Exploitation of a new agricultural technology including genetically as well as chemical advances has hampered the natural conditions in developing countries like India largely due to a single limiting factor like chemical fertilizers. Exorbitant and ever increasing cost of chemical fertilizer, particularly of the nitrogen and widening gap between the supply and demand together with a poor purchasing capacity of Indian farmers have placed them to a further hardship in making proper investments to raise the successful crops. It is, therefore, relevant and of immediate need that some alternate resources must be explored to meet a part of nitrogen requirements and to reduce the pressure of chemical fertilizer (Roy, 1982). It is therefore important to find out economic ways of trapping atmospheric nitrogen and bringing it to the cultivated lands as energy is becoming a key limiting factor in both agricultural and industrial production. Global interests in biological nitrogen fixation are a direct consequence of this input constraint (Nakul, 1990).

Biofarming is a process of agriculture in which the main objective is to protect microorganism present in the soil so that the health and quality of the soil is maintained. Vermicomposed is a biochemical process which is earthworm eating organic material to cow dung in a suitable condition and converting it into organic manure. The uses of vermicompost on one hand make a change in the physical composition of soil and in the other all nutritional in gradient are made a available to the plants (Pramanik et al., 2007). Vermicompost is literally the best nutrient rich, organic fertilizer and soil conditions. The process of producing vermincompost is called vermicomposting (Roberts et al., 2007).
The use of bio-organic fertilizer can increase the output and improve the quality of crops. It is responsible for maintaining the agriculture environment. Nowadays, it has been widely used with excellent results in all kinds of crops and plants in several countries.

Pulses are a better alternative source of proteins, the base of the daily diet of an average Indian with a very high biological value. But unfortunately the pulses which are grown by our farmers are not sufficient. One of the most challenging problems faced by our scientists that are to be attained the self sufficiency and increased agricultural production to meet out the need of a fast growing population. The deficiency of protein in diet is much more dangerous to human health than any other components. Protein deficiency is more apparent in South – East Asia including India. The legume is only the source of proteins for vegetarian population in India.

In India nearly 11 million hectares comes under pulses. However the quality of yield is very poor. The average yields are reported 500 kilograms per hectare. This is probably because of the great difference in characteristics of the soil, low moisture availability and the paucity of efficient *Rhizobium* strains in many of these soils. The establishment and ability of the leguminous crops to fix atmospheric nitrogen depend on the establishment of the successful symbiotic relationship between the host legume and the nodule forming rhizobia, though *Rhizobium* is a common inhabitant of soil. The production is level quite low and the proliferation is conditioned by various factors such as physical and chemical properties of the composition and antagonism from other.
Pigeon pea [Cajanus cajan (L). Millsp.] is a late maturing, tall growing, wide spaced crop with a deep root system which makes it suitable for intercropping system (Rathod et al., 2004). Pigeon pea is one of the major pulse crops of the tropics and sub-tropics. It is the second most important pulse crop in India after grams.

Although pigeon pea is globally grown on 5.2 million of hectares land in about 50 countries, its 77% area is grown in India (FAO, 2008). In India, pigeon pea is important in the states of Maharashtra (1.1 million hectare), Karnataka (0.58 million hectare), Andhra Pradesh (0.51 million hectare), Uttar Pradesh (0.41 million hectare), Madhya Pradesh (0.32 million hectare), and Gujarat (0.35 million hectare). These six states account for over 70% of the total pigeon pea area in India. The cultivation area and yield of pigeon pea have recorded a steady positive growth in the past 50 years, but the average national productivity has remained unchanged it is around 700 kilo grams per hectare. This is a matter of concern since the domestic demand of pigeon pea is rapidly increasing and the Indian government has resorted to import about 0.5 to 0.6 million tons of pigeon pea mainly from Myanmar and Southern-Eastern African countries. Madhya Pradesh is also an important pigeon pea growing state, It has about 3.50 lakh hectares of acreage and 2.17 lakh tons produced with the productivity about 620 kilo gram per hectare.(Saxena and Nadarajan, 2010).

Pigeon pea is a rich source of carbohydrates, minerals and vitamins. The seeds contain a range of 51.4–58.8% carbohydrates (Faris and Singh, 1990), 1.2–8.1% crude fibre and 0.6–3.8% lipids (Sinha, 1977). It is a good source of dietary minerals such as calcium (Ca), phosphorus (P), magnesium
(Mg), iron (Fe), sulphur (S) and potassium (K) (Sinha, 1977) and water soluble vitamins especially thiamine, riboflavin and niacin (Salunkhe et al., 1986). Pigeon pea contains more minerals, ten times more fat, five times more vitamin A and three times more vitamin C than ordinary peas (Foodnet, 2002) and (Odeny, 2007).

Pigeon pea also known as red gram or Arhar / Tooar assumes special importance among the pulse crops grown in India, as it forms a part of the daily diet of the majority of the Indian people. Pigeon pea is an annual or a perennial shrub cultivated throughout India and it’s normally grown in the rainy season as rainfed crop. India is deficit both in pulses and oilseeds production. Intercropping of these crops is one of the ways to increase pulse and oilseed production, as intercropping is more advantageous than sole cropping of both pulses and oil seeds (Lourduraj et al., 1998).

The pigeon pea (Cajanus cajan, syn. Cajanus indicus) is a member of the family Fabaceae, other Common names are arhar, red gram, toovar / toor (Hindi / Gujarati / Marathi / Punjabi), togari (kannada) kandi (Telugu), gandul, guandul, congo pea, gunga pea, and no-eye pea etc.

All the evidences gathered till date point to peninsular India as the place where pigeon pea originated. But the name ‘Pigeon pea’ probably given is by the Americans, where it reached same time in the 15th century because the seeds were found to be favored by pigeons. It is now widely grown in the India subcontinents which accounts for almost 90% of the world’s crop. Other regions where pigeon pea is grown are South East Asia, Africa, and the Americas. There is substantial area of pigeon pea in Kenya, Uganda and
Malawi. In Eastern Africa and in most other countries pigeon pea is grown in small areas.

Pigeon pea is an important food crop (dried Peas, flour, or green vegetable peas) and a forage / cover crop. The dried peas may be sprouted briefly, and then cooked, for a flavor it is different from the green or dried peas. Sprouting also enhance the digestibility of dried pigeon peas via the reduction of indigestible sugars that would otherwise remain in the cooked dried peas.

In India, split pigeon peas (tuvar dal) are one of the most popular pulses along with chick peas (chana), urad and moong. It is also called "tuvara parippu" in Kerala. In south India a popular dish sambhar is made with this. Dal is also made with pigeon peas.

Pigeon peas are nutritionally important, as it contains high level of protein and the important amino acids like methiounine, lysine, and tryptophan. In combination with cereals, pigeon peas make a well balanced human food. In some places, such as Dominican Republic and Hawaii, pigeon peas are grown for canning. In Caribbean Island of Puerto Rico, rice and green pigeon peas are together considered the main traditional food, serves as a representative of Puerto Rican cuisine in many food festivals around the world, for example it provides great reviews in the Taste of Chicago 2007, an annual food festival.

The woody stems of pigeon peas are used as firewood, fencing and thatch. In Thailand, pigeon peas are grown as a host for scale insects which
produces lac. Pigeon pea is used as an important crop for green manure in some areas. As, it can provide up to 40 kilograms nitrogen per hectare.

It is a useful medicine used in the controlling swelling of internal organs. Some herbal practitioners/ researchers are of the opinion that it diminishes the swelling of internal organs like stomach, liver, intestine etc. In case of wound or cancer of these organs it is helpful in reducing them. It is, there for recommended for various usage like;

Green leaves of pigeon peas around 10 grams along with 7 black peppers should be finely ground and mixed in water and then taken as a drink. Green leaves of pigeon peas, ground and added to half boiled water. It should be applied externally to the affected body part. Pigeon peas should always be cooked in water and its super netted water is given to patient for recovery from weakness.

In most areas pigeon peas are grown in association with other raw crops such as sorghum, pearl millet or maize. Pigeon peas can be of a perennial type, in which the crop can last 3 – 5 years or an annual type more suitable for grain production.

The crop is cultivated on marginal land by both rich and poor farmers, who commonly grow traditional medium and long duration landraces. Short duration pigeon peas suitable for multiple cropping have recently been developed. Traditionally, the use of such input as fertilizers, weeding, irrigation, and pesticides are minimal, so present yield levels are low. Greater attention is now being given to managing the crop because it is in high demand at remuneration prices. Pigeon peas are found very drought resistant
and can be grown in the areas with less than 650 mm annual rainfalls. World production of pigeon peas is estimated at 46,000/ square kilometer. This is about 82% of the total is grown in India only.

Pigeon pea (*Cajanus cajan* L.) can be used to mitigate the situation to a large extent. Hence, there is a great urgency to increase the pulse production particularly pigeon pea production. There are two sources open to achieve the self sufficiency, one to increase the area under the plough which is rather bleak and the other to increase the production per unit area per unit time by adopting modern technology that includes an optimum supply of nutrients through the cheap and most efficient sources i.e. biofertilizers.

The low yield of crops in India as in many other countries following traditional methods of farming a largely due to poor fertility of the soil caused by the progressive depletion of the plant nutrients through crop growing.

Pigeon pea is used in more diverse ways than others. Besides its main uses as dal crushed dry seeds, as animals feed green leaves as fodder, stem as fuel wood and to make hut, baskets etc. and the plants are also used to culture the lac-producing insect. Its seeds contain 20.9% protein.

Pigeon pea is known to provide several benefits to the soil in which it is grown. Being a legume, it fixes atmospheric nitrogen into the soil though *Rhizobium* bacteria. Over a hectare of the land 80,000 tons of nitrogen are found. The richness of nitrogen in the atmosphere is of no significance unless it is converted in the form of ammonium or nitrate and fixed into the soil. The leaves fall at maturity not only adds the organic matter to the soil, but also provides additional nitrogen. Pigeon pea is growing in the depth and spread
laterally to its root system, which incidentally enable it to tolerate draught. Its root system is reported to break the plough pans thus improves soil structure.

Vermicomposting is a method of preparing enriched compost with the use of earthworms. It is one of the easiest methods to recycle agricultural wastes and to produce quality compost. Earthworms consume biomass and excrete it in digested form called worm casts. Worm casts are popularly called as “Black Gold”. The casts are rich in nutrients, growth promoting substances, beneficial soil microflora and having properties of inhibiting pathogenic microbes.

Vermicompost is stable, fine granular organic manure, which enriches soil quality by improving its physicochemical and biological properties. It is highly useful in raising seedlings and for crop production. Vermicompost is becoming popular as a major component of organic farming system.

Decomposable organic wastes such as animal excreta, kitchen waste, farm residues and forest litter are commonly used as composting materials. In general, animal dung mostly” cow dung and dried chopped crop residues are the key raw materials. A mixture of leguminous and non-leguminous crop residues enriches the quality of the vermicompost.

There are different species of earthworms’ viz. *Eisenia foetida* (Red earthworm), *Eudrilus eugeniae* (night crawler), *Perionyx excavatus* etc. Red earthworm is preferred because of its high multiplication rate and there by converts the organic matter into vermicompost within 45-50 days. Since it is a surface feeder it converts organic materials into vermicompost from the top.

**Important characteristics of red earthworm (Eisenia foetida)**
### Characters

<table>
<thead>
<tr>
<th>Character</th>
<th><em>Eisenia foetida</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Body length</td>
<td>3-10 centimeter</td>
</tr>
<tr>
<td>Body weight</td>
<td>0.4-0.6 gram</td>
</tr>
<tr>
<td>Maturity</td>
<td>50-55 days</td>
</tr>
<tr>
<td>Conversion rate</td>
<td>2.0 q /1500 worms/2 months</td>
</tr>
<tr>
<td>Cocoon production</td>
<td>1 in every 3 days</td>
</tr>
<tr>
<td>Incubation of cocoon</td>
<td>20-23 days</td>
</tr>
</tbody>
</table>

The types of vermicomposting depend upon the amount of production and composting structures. Small scale vermicomposting is done to meet the personal requirement and farmer can harvest 5-10 tones of vermicompost annually. While large scale vermicomposting is done at commercial scale by recycling large quantity of organic waste with the production of more than 50 tones to 100 tons annually.

In recent years, vermicomposting has emerged as an efficient technology for recycling of organic wastes into good quality compost with the help of epigamic group of earthworms. The rapid breakdown of organic wastes by earthworms produces vermicompost having high amount of total and available nitrogen, phosphorous, potassium, (N,P,K) micro nutrients, microorganisms and enzyme activators and growth regulators (Parthasarathi *et al.*, 2008) and (Chaoui *et al.*, 2003).

Vermicompost is nothing but the excreta of earthworms, which is rich in humus and nutrients. We can rear earthworms artificially in a brick tank or near the stem / trunk of trees (especially horticultural trees). By feeding these earthworms with biomass and watching properly the food (bio-mass) of earthworms, we can produce the required quantity of vermicompost.
Advantages of vermicompost

1. Vermicompost is rich in all essential plant nutrients.

2. Provides excellent effect on overall plant growth and enhance the growth of new shoots / leaves and improves the quality and shelf life of the produce.

3. Vermicompost is free flowing, easy to handle, apply and store and does not produce any bad odor.

4. It improves the soil structure, texture, aeration and water holding capacity and prevents soil from erosion.

5. Vermicompost is rich in beneficial micro flora such as fixers, P-solubilizers, cellulose decomposing micro-flora etc in addition to improve soil environment.

6. Vermicompost contains earthworm cocoons and increases the population and activity of earthworm in the soil.

7. It also controls soil as well as environmental pollution.

8. It prevents nutrient losses and increases the utilizing efficiency of chemical fertilizers.

9. Vermicompost is free from pathogens, toxic elements, weed seeds etc.

10. Vermicompost minimizes the incidence of pest and diseases.

11. It enhances the decomposition of organic matter in soil.
12. It contains valuable vitamins, enzymes and hormones like auxins, gibberellins etc. Nutrient content of vermicompost.

**Nutrient Composition of Vermicompost**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>1.5 – 2.5 %</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.9 – 1.7 %</td>
</tr>
<tr>
<td>Potash</td>
<td>1.5 – 2.4 %</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.5 – 1.0 %</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.2 – 0.3 %</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.2 – 0.3 %</td>
</tr>
</tbody>
</table>

*Table 1.1*

Higher soil fertility is the key of crop production, which supplies different nutrients to the plants of crops for their growth and for good yield, but soil fertility is still being depleted by continuously growing crops of some type so it becomes necessary to supply different nutrients by external sources. Chemical fertilizers were abundantly applied, but in recent years the cost of fertilizer has considerable increased resulting into low net return. Fertilizers enrich soil, but do not support the life of microbial fauna and hence there is less humus and less release of nutrients. Soil health gets depleted and even become prone to erosion by wind and rains. Chemical fertilizers are made up of only a few minerals and impede the uptake of other nutrients and thus imbalance the whole mineral pattern of soil. Environmentalists are of the opinions that fertilizers and other agro-chemical used are rather spoiling our environment and agro-ecosystem. For avoiding these disadvantages of chemical fertilizers, organic farming should be adopted. These are other
factors enumerated to intensity research upon various micro organisms for their utilization as biofertilizers.

Biologically active product, more appropriately called "Microbial inoculants" containing active strength of selective micro-organism like bacteria, algae, fungi alone or in combination which may help in increasing crop productivity by way of helping the fixation of biological nitrogen.

Biofertilizer is a natural organic fertilizer known that helps to provide all the nutrients required by the plants and helps to increase the quality of the soil environment with the help of natural microorganisms.

Biofertilizer is one of the best modern tool for agriculture. It is a gift of our modern agricultural science. Biofertilizers are applied in the agricultural field as a replacement to our conventional fertilizers. Conventional fertilizers contain compost, household wastes and green manure. Those are not as effective as chemical fertilizers. So, farmers often try to use chemical fertilizers in the field for crop development. But obviously the chemical fertilizers are not environment friendly. They are responsible for water, air and soil pollution and can spread cancer causing agents. Moreover, they may destroy the fertility of the soil in a long run. Scientists have developed biofertilizers to prevent pollution and to make this world healthy for everybody in a natural way. Biofertilizer contains microorganisms which promote the adequate supply of nutrients to the host plants and ensure their proper development of growth and regulation in their physiology. Living microorganisms are used in the preparation of biofertilizers. Only those microorganisms are used which have specific junctions to enhance plant growth and reproduction. There are different types of microorganisms which
are used in the biofertilizers. Biofertilizer being essential components of organic farming play vital role in maintaining long term soil fertility and sustainability (Mishra et al., 2013).

In many soils the nodules containing bacteria are found absent or not adequate in either number or quality to meet the nitrogen requirement of legumes. It is necessary to inoculate the seed with highly effective rhizobia (bacteria) cultures, nodules bacteria are cultured in the laboratory and mixed with a suitable carrier material such as peat or lignite to make inoculants. The process of adding these inoculants to seed is called inoculation. Different legumes require different rhizobia in order to produce an effective symbiosis.

Rhizobia are soil bacteria which can infect the roots of legumes to form effective nitrogen fixing nodules. In many soils, rhizobia already in the soil are not sufficient in number or quality, or are not compatible with the farmers’ legume crops to from effective symbiosis. In those soils, it is necessary to inoculants legume with rhizobia to increase the amount of nitrogen fixed by the crop and increases the farmer’s yield by proper inoculation with rhizobia, the farmer can introduce large number of effective rhizobia which are superior in their ability.

Legume inoculants are liquid or solid substances that contain live rhizobia. Inoculation is simply bringing rhizobia in contact with the seed or legume root.

The farmer coats his seed with inoculants (Biofertilizer) before a planting so that a high number of superior rhizobia will be present when the
legume roots emerge. These inoculants rhizobia can then quickly infect the root and start the process of nodulation.

Seed bacterialization with nitrogen fixing microorganism for increased production of agricultural crops gain popularity. *Rhizobium* legumes symbiosis is well understood and *Rhizobium* inoculation is widely practice in many countries.

It is well known that protein deficiency is serious malnutrition condition in India as well as in many other developing countries. In India great majority of the population being vegetarian, they depend mainly on vegetable source such as legumes, for their protein requirements. Besides providing the much needed protein, the cultivation of legumes will help in this regards. In maintaining the soil fertility, because of their ability to fix atmospheric nitrogen in their root in association with nodule bacteria of rhizobia and this also helps in diverting the nitrogenous fertilizers to other cereals. The beneficial effects of legumes in increasing the soil nitrogen are well known for this the cultivation of leguminous crops and their introduction in crop rotation is an ancient practice.

Application of *Rhizobium* culture is an established fact to increase the pulse production. The response of inoculation depends upon many factors like climate, variety and soil type, pH, nutrient availability etc. during the growth and presence of effective strains of *Rhizobium* which is important for nodulation, nitrogen fixation and yield. Increased yield response of crop plants have been observed in following seed inoculation with *Rhizobium* with vermicompost and recommended dose of Nitrogen, Phosphorus and Potassium (NPK) are compatible to these organisms, colonize the rhizosphere
and enhance plant growth by providing it with nitrogen fertilizers (Gupta and Namdeo, 2000). But in soils of Indore district, nitrogen fixation is the problem due to many factors; high pH (7.8 - 8.1) is one of them. At Indore, inoculation response is very poor due to many reasons which cause low yield and depletion in nitrogen status after legume crops. However, very little work have been done on the effect of *Rhizobium* inoculants with Nitrogen, phosphorus and potassium fertilizer and organic matter on soil nutrient status, uptake of nutrients by crop, bacterial population, quality and yield of pigeon pea grown in Malwa region of Madhya Pradesh.

**Object of work**

Pigeon pea (*Cajanus cajan*) is the major leguminous crop grown in different agro climatic zones of the country. Pigeon pea tops in the world production of both oil seeds and edible oil and major protein source in the present food habit of Indians. Biological nitrogen fixation by *Rhizobium* is known to enhance the overall vegetative growth and health of crop. But the artificial inoculation of rhizobial culture has never reached beyond laboratory stage.

In view of this the present studies are aimed to find out most suitable rhizobial culture as bio fertilizer for pigeon pea crop with special reference to

- Isolation of *Rhizobium sp.* from root nodules of pigeon pea.
- Studies of biochemical and physiological characteristics of pigeon pea rhizobia.
- Authentication test of pigeon pea root nodules bacteria.
Selection of test strain of *Rhizobium sp.* with and without Nitrogen, Phosphorus and Potassium (NPK) – Recommended Dose of Fertilizer (RDF) and vermicompost for better yield production.