Field Pea Production Guideline
Using Rhizobial Bio-fertilizer Technology

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Ethiopian Institute of Agricultural Research
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Introduction

Field pea (*Pisum sativum L.*) one of the most important annual legume crops. Field pea crop plays an important role in the lives of the farmers in the highlands of Ethiopia; it serves as a source of food and feed with a valuable and cheap source of protein. It plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric nitrogen. It is also a good source of income to the farmers and foreign currency to the country. The productivity of field pea in Ethiopia is far below the potential due to several factors including limited improved seeds, varieties, biotic and abiotic stresses, inherent low yielding potential of the indigenous cultivars (Asfaw et al., 1994), declining soil fertility status, poor cultural practices, land management and lack of fertilizer use (Amare and Adamu, 1994).

The history of field pea cultivation dates back to the Neolithic farming villages of the Near East, early as 7000 BC. FAO (1998) stated that East Africa is the first origin of field pea. West Asia is the second in South and East Mediterranean sub regions. The species Pisum sativum is a dominant production system in Ethiopia though wild and primitive forms are also known to exist in the high elevations of the country, especially in the north (Hagedorn, 1984; Amare and Adamu, 1994). In Ethiopia, field pea grows in several regions, at an altitude of 1800-3000 m with annual rainfall of 700-1000 mm. Field pea (*Pisum sativum L.*) has valuable and cheap sources of protein when consumed with cereals, which are deficient in essential amino acids. Pulses play significant roles in soil fertility restoration and in export market; however, production and productivity are far below the potential.

[1]
The legume-rhizobial (symbiotic bacteria) capable of invading and eliciting root or stem nodules on leguminous plants to convert atmospheric nitrogen (N\textsubscript{2}) into ammonia (NH\textsubscript{3}) in plant roots) symbiosis plays a very important role in a productive and sustainable agriculture. While research has indicated many promising avenues for introduction of Nitrogen-fixing strains into cropping systems and for enhancement of the contributions from Nitrogen-fixation, to date few of these technologies for instance Strain FP-2017, FP-2016, FP-2013 EAL-300 and AEAL 302 have on the way of adopting by farmers. At most of the technologies that are likely to lead to improvements of Nitrogen fixation in different cropping systems are well within the reach of research programs in developing countries. The technologies can deliver enormous benefits through judicious use of bio-fertilizers technologies.

Several demonstration works confirmed that leguminous crops show remarkable growth and yield response to rhizobial inoculations in different agro-ecologies of Ethiopia. As a result, the uses of rhizobial bio-fertilizer inoculants have been showing magnificent yield increment and improve condition of soil fertility. Therefore the objective of this guideline is to deliver farmers, extension workers and seed producers with standardized and simplified rhizobial bio-fertilizer users.

**Main Factors for reduction of field pea production**

There are many factors for the reduction of field pea production, incidence of diseases like Ascochyta spp. (Mycosphaerella [2])
pinodes) and powdery mildew \textit{i}Erysiphe polygoni) (Dereje and Tesfaye, 1994) and insect pests like pea aphids (Acyrthosiphon pisum), African ballworm (Helicoverpa armigera), pea bruchid (Bruchus pisorum) in the field and weevil (Callosobruchus chinensis) in the storage (Kemal and Tibebu, 1994). It contributes to grain yield instability and reduces farmers’ confidence in growing field pea. It occurs in major field pea growing areas. This disease causes stem, leaf and pod spot on the mature plant and foot rot on seedlings. Yield loss on field pea due to this disease were reported to be 50-75\% in USA, 45\% in England, 33\% in Canada and 20-53\% in Ethiopia (Dereje Gorfu, 2000). It is stubble and seed born pathogen where inoculums infecting plant parts and adhering on seed surface as dormant mycelia, spores and fruiting bodies of the fungus, could be responsible for disease transmission.

There is no field resistance of field pea cultivars to this disease because it is inherited as a complex polygenic trait (Worth, 1998). However, at Holetta, there are some lines identified as moderately resistant to Ascochyta blight (e.g., IFPI series introduced from Australia) that could be used in the breeding program as source of resistance gene. Seed treatment with fungicides such as carbendazin is one feasible alternative to eradicate the primary inoculums to avoid risk of epidemics (Dereje and Sangchote, 2003). Chlorotalonil (Bravo 500 50\% or Daconyl 2787) at the rate of 2.5 kg active ingredient per ha could be used under field condition.

Powdery mildew on field peas is a widely distributed disease as the crop. It is a troublesome disease when days are warm and dry; nights are cool enough for dew formation. Sever powdery mildew infection is reported to adversely affect plant and
seed weight, number of seed per pod and per plant, plant height and number of nodules per plant. Studies have shown that where severe mildew was present, control of the disease increased yield 100%. Reports from Ethiopia indicated that it causes yield loss up to 37%. This disease is of less effect in high rainfall areas of Ethiopia where its spores are removed from the plant tissue by rain and cannot cause infection. However, late sown and off-season fields were reported to be severely affected by the disease. Areas like Adet, Denbi, Kulumsa, Bako, were considered to be hotspot for powdery mildew in field pea.

Control measures are using early planting, sprinkler irrigation, chemical control with Benomyl 50% WP (Benlate 50% WP) 2 kg active ingredient per ha could be applied starting when 5% attack has been scored on the crop. However, this seems somewhat costly and unaffordable by poor farmers; at least two sprays must be applied at 10 days intervals.

Other factors is biotic and abiotic stress: Biotic stress such as weed and insect pests and abiotic stresses like water logging, soil acidity and low soil fertility are major constraints to field pea production. According to research reports, weed inflicts yield loss up to 15%.

Pests: insect pests that attack field pea in Ethiopia include pea aphids (Acyrthosiphon pisum), pod borer (Helicoverpa armigera) and bean bruchids (Callosobruchus chinensis). In Ethiopia indicate that yield loss on field pea due to pea aphid ranges from 22 to 49% in hotspot areas. Control measures for Insect pests are better with integrated pest management (IPM) involving tolerant varieties, regular monitoring of the crop and judicious use of pesticides. In general, it is dubious whether there is any level of practical gene-driven resistance exists to these insect in field pea for practical use. As best alternative, however, there are
recommended chemicals in Ethiopia for the control of these insect pests pea aphids could be controlled by spraying pirimicarp (Pirimor 50% powder) at the rate of 0.5 kg active ingredient, or pirimipos-methyle (Actelic 50% Ec) 0.5 kg per ha; pod borer could be controlled by single spray with 150g active ingredient of cypermethrin while bean bruchids could be controlled by seed dressing with Pirimipos-methyl (Actelic 2% powder) at the rate of 40g for 100 kg of seed.

**Appropriate Agro-ecology**

**Altitude, rainfall, soil type and temperature**

- Field pea widely produced at an altitude of between 1800 and 3000m.a.s.l. around Degan and woinedega of the country. If an altitude is below 1800m asl, it could be affected by drought and disease, if it is above 3000m asl, it could be affected by chilling injury and decrease the yield potential. Field pea need 800mm-1100mm at highland areas and 700-900 mm at mid altitude of rainfall per annual averegically which is conducive rainfall. As an optional, using irrigation as source of moisture place where there are shortage of rainfall can give high yield.

- Field pea has to be planted in warm soils (minimum temperatures preferably above 12°C). Sandy loam; sandy clay loam or clay loam with a clay content of between 15 and 35% is suitable. Also will not grow well in soils that are compacted, too alkaline or poorly drained. With sandy soils, problems of low fertility or nematode damage may occur.

- The minimum and maximum mean temperature requirements are 10°C and 27 ºC respectively. The maximum temperature
during flowering should not exceed 30°C. High temperatures during the flowering stage lead to abscission of flowers and a low pod set, resulting in yield loss. Day temperatures below 10°C will delay maturity and cause empty mature pods to develop.

- Field pea can grow on clay, silt or heavy deep, fertile and well-drained soils with adequate reserve of organic matter and a pH range of 5.5-6.5. Soil temperature starting from germination to maturity stage should be averegically between 15-20 °C and also at low level between 10-15 °C is also conduncive. Place where there are water logging problem using drainage system broad bed makers is very important one. Moreover, post plant can cause disease problem (e.g powdery mildew) specially at flowering stage and maturity stage. This cause high yield decrement as indicated by different research outputs.

**Field pea Variety Released by Research**

The history of field pea cultivation dates back to the Neolithic farming villages of the Near East, early as 7000 BC. FAO (1998) stated that East Africa is the first origin of field pea. West Asia is the second in South and East Mediterranean sub regions. The species Pisum sativum is a dominant production system in Ethiopia though wild and primitive forms are also known to exist in the high elevations of the country, especially in the north (Hagedorn, 1984; Amare and Adamu, 1994). In Ethiopia, field pea grows in several regions,
at an altitude of 1800-3000 m with annual rainfall of 700-1000mm.

Among pulses crops field pea (*Pisium sativum* L.) play significant roles in soil fertility restoration and in export market. In Ethiopia research started for many years and at now, there are different varieties released for different agro ecology. From those more are in the hands of the farmers and the recently released one still on the shelf in small amount. Especially variety which can adapt to water logged area and recently released one are described on the table below with their respective morphological characteristics.
Table 1: List of National level Research Released Field pea Varieties

<table>
<thead>
<tr>
<th>Name of Variety</th>
<th>Year of release</th>
<th>Days to maturity</th>
<th>Suitable agro-ecology</th>
<th>1000 seed weight (gm)</th>
<th>Flower Color</th>
<th>Seed color</th>
<th>Yield (q/ha) On station</th>
<th>Yield (q/ha) On farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP-D.ZD*</td>
<td>1979</td>
<td>130-160</td>
<td>1800-2300</td>
<td>800-1100</td>
<td>156</td>
<td>white</td>
<td>blond</td>
<td>20-30</td>
</tr>
<tr>
<td>NC-95 Hayik*</td>
<td>1981</td>
<td>120-150</td>
<td>2300-3000</td>
<td>800-1100</td>
<td>163</td>
<td>purple</td>
<td>Gray</td>
<td>20-30</td>
</tr>
<tr>
<td>Milky</td>
<td>1995</td>
<td>120-150</td>
<td>2300-3000</td>
<td>800-1100</td>
<td>157</td>
<td>white</td>
<td>blond</td>
<td>25-35</td>
</tr>
<tr>
<td>Holeta 90</td>
<td>1996</td>
<td>120-150</td>
<td>2300-3000</td>
<td>800-1100</td>
<td>143</td>
<td>purple</td>
<td>Gray</td>
<td>25-40</td>
</tr>
<tr>
<td>Megeri*</td>
<td>2006</td>
<td>95-150</td>
<td>2300-3000</td>
<td>700-1000</td>
<td>136</td>
<td>purple</td>
<td>Light green</td>
<td>21-41</td>
</tr>
<tr>
<td>Gume*</td>
<td>2006</td>
<td>100-149</td>
<td>1800-2400</td>
<td>700-1000</td>
<td>201</td>
<td>white</td>
<td>Red brown with black spot</td>
<td>20-41</td>
</tr>
<tr>
<td>Burkitu *</td>
<td>2009</td>
<td>110-160</td>
<td>1800-3000</td>
<td>700-1000</td>
<td>208</td>
<td>white</td>
<td>blond</td>
<td>35-50</td>
</tr>
</tbody>
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For mid altitude

<table>
<thead>
<tr>
<th>Name of Variety</th>
<th>Year of release</th>
<th>Days to maturity</th>
<th>Suitable agro-ecology</th>
<th>1000 seed weight (gm)</th>
<th>Flower Color</th>
<th>Seed color</th>
<th>Yield (q/ha) On station</th>
<th>Yield (q/ha) On farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mohandefer</td>
<td>1979</td>
<td>130-160</td>
<td>1800-3000</td>
<td>700-900</td>
<td>223</td>
<td>white</td>
<td>blond</td>
<td>20-30</td>
</tr>
<tr>
<td>FP-EX-DZ</td>
<td>---</td>
<td>130-160</td>
<td>1800-3000</td>
<td>700-900</td>
<td>223</td>
<td>white</td>
<td>blond</td>
<td>20-35</td>
</tr>
<tr>
<td>Markos</td>
<td>1995</td>
<td>120-130</td>
<td>1800-2300</td>
<td>700-900</td>
<td>188</td>
<td>white</td>
<td>Cream with black spot</td>
<td>25-35</td>
</tr>
<tr>
<td>Bilalo</td>
<td>2012</td>
<td>118-170</td>
<td>1900-3000</td>
<td>700-1000</td>
<td>224</td>
<td>purple</td>
<td>Grayish</td>
<td>26-56</td>
</tr>
<tr>
<td>Bursa</td>
<td>2015</td>
<td>134-157</td>
<td>1900-3000</td>
<td>700-1000</td>
<td>189</td>
<td>purple</td>
<td>Dark brown</td>
<td>20-54</td>
</tr>
</tbody>
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* Variety suitable for highland and mid altitude.

Unused of fertilizer will be occurring about 35% of yield reduction, as showed most research evidences.

[8]
Method of Production

Site selection

For field pea soils and climatic conditions should be favorable for good crop production. The accessibility of the seed production field to transport and proximity to seed processing plants is also equally important in site selection for seed production. Also the presence of irrigation water and facilities is very important to avoid risks of moisture shortage at any stage of crop growth.

Field pea crop production requires special cultural management and attention. Proper land management is essential from site selection and planting through harvest and even marketing for maximum profitability. Therefore to obtain high yield from field pea, suitable variety, proper agronomic practices, good land preparation, recommended fertilization, better weed control, crop protection and soil moisture conservations practices are very important.

To produce high field pea yield, using the following site selection criteria is very appropriate.

- Do not select sloppy area which is >5%
- Do not select water logged area, this cause the death of soil microorganisms used for nutrient solublizing.
- The soil temperature which is available for field pea growth is between 20- 25°C and at minimum 10-20 °C.

Field pea performance is increased when established in neutral soil pH from 6-7. Low levels of pH will initiate [9]
stunting of crop growth and yellowing of the leaves throughout the canopy. Applying lime prior to establishment is recommended if pH levels are marginal; where this can be done in the season prior to establishment of the field pea crop the benefit of the lime will be greater.

**Land preparation**

- Field pea is sensitive to compacted soil layers as well as surface compaction. They do not require a fine seedbed as such and hence only 2-3 plowings with the local plow or one disc plowing followed by two disc-harrowing is enough. It is an advantage if land preparation can start early to encourage weed seeds to germinate so that they can be destroyed in subsequent cultivation.

- It is advisable that the land be ploughed as soon as possible after the land has been cleared of the preceding crop. It is also good to incorporate residue in such a way that it can be decomposed before planting of the field pea. As far as subsistence farmers are concerned, land preparation is done by oxen drawn implements. Under such conditions 2 – 3 times plowing before planting is considered adequate.

- The soil should not be so fine enough and after rain cultivating more than two times is adequate. If the site is water logged, drainage system is necessary to avoid excess water on the farm. On the other hand, at drought area tied ridge is important to conserve the soil moisture and
protecting soil moisture vapor. However over cultivation and repeated tillage practice can cause soil nutrient loss and erosion. Normally proper land preparation is important for the following purpose.

- To improve water filtration, aeration and decrease water vapor
- To improve germination, root expansion and growth and weed control
- To decrease soil born disease and pests

In general repeated cultivation of land not only used for crop growth, but also used to improve soil physical condition. In contrast inappropriate time of cultivation can have negative impact on soil physical condition which affects the plant growth through water holding and the soil become wet enough.

- Poor land preparation results in the occurrences of Powdery mildew on field peas is a widely distributed disease as the crop. It is a troublesome disease when days are warm and dry; nights are cool enough for dew formation.

- They can be controlled through solarization of soil and field rotation, e.g. cereals–legumes–fallow. Field pea grows best on alkaline soil. Deep plough to invert the soil followed by two or three harrowing to create a fine tilth and level planting bed is recommendable.
**Sowing time**

To produce attainable yield proper sowing time when soil is wet is important. In our country more of field pea producing area uses at half of the June and early July for proper sowing time. When there is no sufficient soil moisture seed germination could be fail and cause yield reduction. During preparing seed for planting treat seeds with appropriate fungicide and insecticide are necessary to avoid soil born disease. The most suitable planting date is determined by the following factors:

- Correct soil temperature
- Probability of heavy rain which may lead to soil crusting and restrict seedling emergence
- Possibility of high temperatures later in the season which may cause blossom drop
- Length of the growing season (high temperatures during flowering, rain during harvest)
- Crop rotation programs (position of the field pea crop in the total crop setup, i.e. planted after another crop, such as maize).

Time of sowing is very important. Delays in sowing reduce potential yield considerably. For any field pea growing areas, the proper sowing time is when conditions are ideal for germination, emergence, establishment and growth of field pea.

Important factor during sowing is depth of planting. Even if it is not possible to generalize, 2-6 cm is the proper range to use depending on seed size, soil type and climate. Under hot, dry
conditions and when rainfall is unreliable deep sowing give the seed more protection from sun-baking and places the seed in a possible advantage not to be induced to germination by light showers. However, such practice in areas of heavy soil and good rainfall results in poor emergence. Though sowing time usually relies on the rainfall, soil type and adaptive cultural practices of the farmers should be into consideration.

Generally, timely sowing is essential for optimum yields since late sown crops can run into the periods of low moisture and heavy aphid infestation in the mid altitude and frost in the high altitude areas. In the main season sowing mid to third week of June in mid altitude and last week of June to first week of July in the high altitude areas are recommended based on the onset of rainfall.

**Seed rate and sowing method**

The actual seed rate used depends on various factors: seed size (expressed as 100 or 1000 seed weight), row width, intra-row spacing, and others. Spacing (plant) depends on the size of mature plant - both above ground and below ground - and how well the land is used efficiently to the best advantage. The seed can be row planted or broadcasted followed by subsequent ploughing to cover the seeds. Where lodging is suspected, it is advisable to use 10% less fertilizer and slightly less seed rate than the viable recommendation. Seed rates can be calculated by taking into account the size of the seed, germination percentage and expected field loss due to birds, soil born diseases and insects.
Seed Rate (Kg/ha) = \[
\frac{10,000 \times \text{required plants} / \text{m}^2}{\text{Number of seeds/kg}} \times \frac{100}{\text{% germination}} \times \frac{100}{100 - \text{expected field loss}}.
\]

For example, given that 60 plants (assuming a spacing of 40cm between rows and 5cm between plants) of faba bean are required per m², 4500 seeds make a kilo and the seed has a germination of 85% with an expected field loss of 15%, then:

Seed rate = \[
\frac{10000 \times 60}{4500} \times \frac{100}{85} \times \frac{100}{100 - 15}
\]

= 133.33 x 1.18 x 1.25

= 196.66 kg/ha

It should also be noted that the type of the soil influences the seed rate required in that higher germination capacity and vigor are required for good population density in heavy soils.

The seed size of the crop determines the amount of seed needed per hectare. Those which have small seed size need 100-120 kg/ha while those with large size 100-150 kg/hectare. As well the germination percentage should be above 85% and genetic purity is 95%. Proper seed depth and soil moisture content results good germination and finally gives high yield. On behave of this, during we are sowing the field pea we have to use distance between row 20cm, distance between plant 5cm and seed depth 3cm to 5cm depending on seed size. This allows adequate space for mechanical cultivation to control weeds. Seed properly uncovered with soil also decline to germinate and susceptible different pests, if germinate also can’t produce sufficient roots and easily lodged. Likewise, if
the soil covers the seed above the recommended depth, failure to germinate and the crop could be sparsely populated.

**Types of Fertilizer and their Usage**

**What is fertilizer?:** Fertilizer is any material, organic or inorganic, natural or synthetic, that supplies plants with the necessary nutrients for plant growth and optimum yield. Soil fertility problem is one of the field pea production constraints in Ethiopia.

The soils are generally deficient in N and P. Field pea is responsive to fertilizer when soil nutrient levels are inadequate to support expected yield with the existing climatic conditions. Crop response to a nutrient is generally affected by soil moisture, temperature, placement, tillage, crop and so on. Thus, producers should know and give due attention to soil types, climate, and the field pea plant itself. Fertilizer rate can be applied to the soil 50-100Kg/ha DAP are recommended as blanket recommendation depending on fertility status of the soil.

**Inorganic fertilizers:**

- Known as *synthetic or chemical fertilizers* are factory made products which are added in soil to feed plants. These fertilizers are highly concentrated chemical forms of Nitrates (N), Phosphates (P), Potash (K) & other macro/micro nutrients. Inorganic fertilizers are provided in small quantity, these are instant nutrient releasing fertilizers. Di-Ammonium Phosphate, DAP is used at a
blanket recommendations of 100 kg DAP per hectare for all legume crops. Where deficiency of sulphur is detected, NPS (18-23-5) also at 100 kg per hectare is recommended for use on legumes.

- Other nutrient formulations can be beneficial but they should be applied based on soil test based fertilizers recommendations. If overused, there can be harmful effect on both plants as well as soil in short term as well as long term. Humans started using synthetic fertilizers in 20th century, as these fertilizers revolutionized the whole agriculture sector.

**Organic fertilizers:**

- Organic fertilizer is made from plant/crop residue, decomposed of natural substances. Organic fertilizer is provided in bulk quantity, these are slow nutrient releasing fertilizers. There is no immediate or long term harmful effect of organic fertilizers to plants or soil. In fact, organic fertilizers can convert poor soil into superior fertile soil. Humans have been using organic fertilizers for thousands of years in agriculture. Examples of organic fertilizers: Cow dung manure, any other animal dung manure, farmyard manure, bone meal, bio-compost, Vermi-compost, Leaf mould etc.

- Organic fertilizers not only release nutrients needed by the plants, they break down and improve the structure of the soil and increase its ability to hold water and nutrients.
Over time, organic fertilizers will make the soil very fertile.

- Different research revealed that properly decomposed farm yard manure averagically contains 0.5% of nitrogen, 0.2% of phosphorous, and 0.5% of potash. Compost should be apply to the soil at least one month early before planting, and the compost must be incorporate thoroughly with soil is vital.

**Green fertilizer**

- Green fertilizers are natural substances that can be added to the soil to increase its fertility. This includes manure, peat moss, seaweed extracts and bird and bat guano, as well as a variety of other substances. Green fertilizers have lower concentrations of nutrients than chemical fertilizers, so they often give results that are less immediate and impressive. On the other hand, natural fertilizers have many advantages, such as:

  - They feed plants without being harsh, so it can be said that they are generally goof proof. They are also not harsh to other forms of life present in your soil. This is important, since what actually makes your soil rich are all the organisms and micro-organisms that live within it.

  - They have a slower release rate, so they feed your plants more gradually and over a longer period of time, which is good in the long run.
• Green manure is a crop or plants that are grown and then intentionally plow under to improve the underlying soil and alternatively called cover crops. But green manure is a cover crops specifically meant to tilled back to the soil.

• A well known cover crops used for green manure is pulse crops like soybean, faba bean, alfalfa, chickpea, common bean, clover vetch and lupine are some of them. Those cover crops used as green manure mostly improve Nitrogen level in the soil and will pull nutrients from the depth up to the surface to benefit the next season’s crop.

**What is Rhizobial Bio-fertilizer?**

**Rhizobial bio-fertilizer:** is a substance which contains living microorganisms, when applied to seeds, plant surfaces, or soil, colonize the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Bio-fertilizers add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances.

Bio-fertilizers can be expected to reduce the use of chemical fertilizers and pesticides. The microorganisms in bio-fertilizers restore the soil's natural nutrient cycle and build soil organic matter. Through the use of bio-fertilizers, healthy plants can be grown, while enhancing the sustainability and the health of the soil. Since they play several roles, a preferred scientific term for such beneficial bacteria is "plant-growth promoting rhizobacteria" (PGPR). Therefore, they are
extremely advantageous in enriching soil fertility and fulfilling plant nutrient requirements by supplying the organic nutrients through microorganism and their byproducts. Hence, bio-fertilizers do not contain any chemicals which are harmful to the living soil.

- Rhizobial inoculants are selected strains of beneficial soil microorganisms cultured in lab and packed in a carrier/without carrier. They are host specific, low cost and environmentally-friendly source of N\textsubscript{2}. Carrier-based rhizobial inoculants are coated on legume seeds before planting to enhance growth and yield of legume crops and provide N\textsubscript{2} and organic carbon for subsequent or associated crops. Incorporating legume crop residues will make this effect even more significant. Seeds coated with rhizobial inoculants should not come into contact with chemical N\textsubscript{2} fertilizer. The coated seeds must be planted in moist soil as soon as possible. Phosphatic fertilizers help the rhizobial inoculants work well with the legume. Rhizobial inoculants can improve and sustain soil fertility and soil health when used as part of a long-term rotation system. These inoculants provide N\textsubscript{2} but other nutrients should be added to crops in line with the recommendations for the area.

- The relationship between a host legume and the rhizobial is symbiotic, providing benefits to both participants. Once the rhizobial have established themselves in the root nodule, the plant provides carbohydrates in the form of malate and succinate, and the rhizobial provide ammonia
for the formation of amino acids. Many legumes are popular agricultural crops specifically because they require very little fertilizer: their rhizobial fix nitrogen for them. Used properly some legumes can even serve as fertilizer for later crops, binding nitrogen in the plant remains in the soil.

**Benefits of Bio-fertilizer:** Rhizobial Bio-fertilizer provides the following benefits:

- By means of fixation nutrients will be available in the soil.
- Since a bio-fertilizer is technically living, it can symbiotically associate with plant roots. Involved microorganisms could readily and safely convert complex organic material into simple compounds, so that they are easily taken up by the plants. Microorganism function is in long duration, causing improvement of the soil fertility. It maintains the natural habitat of the soil.
- It increases crop yield by 20-30%, replaces chemical nitrogen and phosphorus by 30%, and stimulates plant growth. It can also provide protection against drought and some soil-borne diseases.
- Bio-fertilizers are cost-effective relative to chemical fertilizers. They have lower manufacturing costs, especially regarding nitrogen and phosphorus use.
- Maintain soil nitrogen levels through fixation, Improves soil health by promoting the growth of other beneficial soil micro-organisms if the roots of the legumes are left
in the ground.

- Provides increased soil organic matter from root and leaf drops when systematically worked into the soil.

- Improves yield up to 10% (particularly with 100 ka DAP ha$^{-1}$) in any cropping system, Through:
  - Soil health improvement, Boosting plant growth promoting enzymes, hormones and auxins.
  - Increasing yields leads to higher income that leads to greater margins when favorable markets exist for the crop produces.

- Increased number of flowers and pods set per plant and increased number of seeds in each pod, higher biomass and grain yield.

**Source of Rhizobial Microorganisms:**
- Most of those microorganisms found in the soil where organic carbon is available and the soil is fertile. But sometimes it could be exist where there are scarcely nutrient status.

**Handling of Inoculants:** Bio-fertilizer plastic-packet contain microorganism which is microscopic and need a great careful. It have to care from direct contact from sunlight, moisture, cold and even no need of opening until we are ready for use. Although it has no negative impact on human health, no need of trying to test by our mouth and keep out of reach of children. Until using the product we should handle on the following procedure:

[21]
• During transportation at temperature between 10 °C to 28 °C to keep organisms alive. In very hot areas, consider transporting in cold vans/ice box.

• Users/suppliers do not have to expose to direct sunlight or vehicle engine heat.

• Users/suppliers do not have to open unless ready for use.

• Users/suppliers do not have to transport together with chemicals (e.g. pesticides).

**Supplier-level**

• Store at room temperature up to 280°C, and not lower than 10 0°C to keep organisms potent. In very hot areas, consider storing in an earthen pot partially buried in the soil or in cold rooms for bulk storage.

• Do not expose to direct sunlight or other heat sources.

• Do not store close to chemicals (e.g. pesticides). They may kill the N-fixing bacteria.

• Do not stock longer than the expiry date.

**Farmer-level**

• Store at room temperature up to 28 0°C, and not lower than 10 0°C to keep organisms potent, in very hot areas, consider storing in an earthen pot partially buried in the soil.

• Do not expose to direct sunlight or store in the kitchen or near fires.

• Do not open unless ready for use.
• Do not store close to chemicals (e.g. pesticides). They may kill the N-fixing bacteria.

• Use before the expiry date.

• Use immediately after opening the package.

**Storing of Inoculants:** Always remember that bio-fertilizer plastic-packet contain living microorganism. They should be treated with care. Most important, they must be kept away from direct sunlight and heat. When ordering inoculants, it may be helpful to inform the producer of the climatic conditions in your area so that adequate protection during shipping can be arranged.

• Exposing an inoculants to sun or heat for even a few hours, for instance on the shipping dock, in a hot shed, or in a hot car will severely reduce the number of live rhizobial and thus reduce the effectiveness of the inoculants.

• Generally, rhizobial survive in cool temperatures. Farmers, extension agents, and local distributors should store inoculants in a refrigerator if at all possible, but never in a freezer since freezing will kill the rhizobial.

• The ideal temperature is between 4° and 26°C. If refrigeration is not available, the inoculants can be kept for a short time in a cool, shady spot indoors; an underground cellar or cool cave is suitable for longer-term storage.

• Inoculants can also be stored for up to six months in a well-sealed ceramic jar and buried in a shady spot
underground. The jar should be covered with a thick wooden lid to serve as protection as well as insulation from heat.

- Even high-quality inoculants will lose its effectiveness if most of the rhizobial die due to improper storage. Heat is the most serious threat. Distributors should take care to refrigerate their inoculants or otherwise keep them cool.

**Important Points on Label of Inoculants Before Deliver to Users**

The extension agent needs to read the label on the inoculants package carefully before deliver the bio-fertilizer inoculants to farmers, seed producers and similar stakeholders. On the label must written vital information as follows:

- It should be list the name and address of the inoculants manufacturer.
- The label should list the host legume species the inoculants is effective.
- Extension agents who familiar with the use of inoculants can select products from manufacturers with good status and high standards of quality control.
- The label should provide information on the species of rhizobial in the inoculants and may also list the strain or strains used for which soil conditions.
- The label must give directions for use and rate of application.
• The label should also give information on how to store the inoculants.
• Even if inoculants is used before the expiration date, it will not be effective if it has been improperly stored.

Finally, the label should give the net weight of the inoculants. By comparing the recommended application rate and the extension agent should be able to calculate the correct amount of inoculants a farmer will need for the amount of seed to be planted.

**Avoid Precoated Seed**

In some countries, manufacturers distribute seed that has already been coated with inoculants. We do not recommend purchasing pre-inoculated seed. Their quality is often poor because rhizobial do not survive well on seeds. Farmers should inoculate their seed just during planting.

**Handling Inoculants in the Field**

For best results, inoculants should be carried to the field in insulated coolers containing ice. If coolers are not available, the inoculants should be wrapped in moist towels and carried in a basket covered with a wet towel. In the field, the inoculants container should be kept in the shade of a tree or umbrella.

**Steps of Seed Inoculation Method at Planting**

There are many product types on the market. Some are
powdered and others are liquid and usually come with instructions on how to use them. Users should follow the manufacturers’ instructions for the best results. The following are generic steps on how to use the powdered type to inoculate your seed just during planting. Note there may be some differences from the manufacturers’ instructions. So the required materials /facilities to inoculate the seeds as follows:

- If the soil is highly acidic it should be treated with lime before planting, but soil with high heavy metals content are unsuitable for the bacteria to thrive.
- Waterlogged soils should be drained before applying rhizobial inoculants.
- Rhizobial inoculants should be applied earlier than the date of expiry.
- It will be crucial to use the right inoculants for the right legume crop-host specificity.
- Be ready sufficient pure container (bowl, bucket etc.) to mix the seed by inoculants.
- Shaded area, tree canopy or umbrella should be available to keep inoculated seeds away from direct UV rays of sun light.
- During planting moistured soil condition is very important, if not too wet and dry conditions at planting retard germination process and hence slows colonization of the roots by the bacteria in the inoculants
- Seeds pre-treated against pathogens need not be inoculated with rhizobial. If you must have to use such seeds, drop tiny moulds (balls) of the inoculants product in the seed hole
without direct contact. High concentration of antibiotics or presence of pathogens is also not suitable.

- Inspect the inner transparent bag for any fungal growth (shagata); once you check no more foreign growth, mix the entire content very well.

- Open the inoculants sachet under shade, pour the equivalent amount onto the moistened seeds found on plastic bowl or bucket and Mix seed and inoculants by slowly shaking until all the seeds are uniformly coated.

- Be careful not to split the seeds or peel the outer coat by using excessive force.

- Cover or put inoculated seed under the shade, do not expose coated seeds to direct sunlight for a long time else the N-fixing bacteria will die before planting.

- Plant seeds immediately after inoculation

- Users should inoculate only the amount of seed that can be planted within a day.

- After planting inoculated seeds, immediate covering with soil is wise to protect lethal effect of UV rays/sun light.

Seeds should be inoculated in a cool shady place on the day of planting. The inoculated seeds should be planted in moist soil and covered immediately so the rhizobial are not exposed to the sun. If possible, the field should be irrigated immediately after planting. Nodulation will be best if the seeds germinate right away and the roots come quickly into contact the inoculants.
If there is any unused inoculant, the package can be sealed with tape and stored in a cool place. If for some reason it is not possible to plant the seeds immediately after inoculation, they should be stored in a cool place and planted as soon as possible. Storing precoated seeds for more than a day or two is not recommended because the rhizobial do not survive long on the seed.
Pictorial Description of Bio-fertilizer Inoculants

Before sowing we should have to put seeds in a pure plate or plastic bucket then all seed should moisten by adding a drop of liquid sticker solution and add powder of bio-fertilizer in to plastic bucket then properly mix all seeds are coated by bio-fertilizer until the original seed color changed to black. Then we can start plant the seed by row as shown on the picture.

Do not expose coated seeds to direct sunlight for a long time else the N-fixing bacteria will die before planting.

Inoculated Seed with Rhizobial Bio-fertilizer gives vigorous growth, Provide available nutrients and enabling to have better yield.

After germinated the Inoculated seed, we should give due attention to monitor and crop management fallow up.
Crop rotation

Environment which is potential for wheat and barley production also the agro ecology could be fit for faba bean and field pea production. Crop rotation has advantages for soil fertility; improve yield, decrease disease, control weed and insects. If we grow cereal crops annually, disease severity become increase from time to time. Residual effects of faba bean straw could increase wheat yield by 77% for the first year and 33% of yield for the second year. It also decreases the nitrogen consumption of the next crop.

Weeding

Field pea does not compete well with weeds, particularly at their early stages. Also weeding field pea late in the season critically affects field pea yields due to mechanical damage. Weeding at appropriate time, critical period of competition is very crucial. Weeding is especially easily done for row planted field peas. In the rift valley areas, weeding at least once during early growing season (15 days after emergence), is reported to give reasonable yield compared to weeding twice – early (10 – 15) and mid season (25 – 30 days), But it should be noted that it is not advisable to weed the field pea crop during and after flowering to avoid abortion, disease incidence and mechanical damage.
Weed control Field pea can easily affected by broad leaf and grass weeds continuous management is needed. Unless the yield could be decreased up to 15%. After germination 3-4 weeks frequently weeding is necessary. Moreover, before seed maturation the late emerging weed should be rogue out if possible. Grass species weed could be controlled by herbicides (Fuzilade 250g/l E.C, by 0.25 kg per ha and (Fluazifobuthyl 250g E.C per liter active ingredient per ha could be applied. This herbicide application for grass species weed will be after the crop emerge 3-4 leaves to flowering stage. To sum up, Cultivate between rows twice during early stages of plant growth using a mechanical cultivator, weed by hand at later stages if required and eliminate off-types and plants growing outside the row by hand.

Harvesting, Handling, Threshing and Storage

Harvesting

When the crop is meant for dry seed, it is harvested when fully mature, and when grown for consumption as a vegetable, it is harvested green. The most common harvesting system is to pull and thresh the crop by hand. Field pea can mature from 110-150 and 100–126 days at highland and mid altitude areas after planting based on agro ecology. In either case, the crop should not be cut until the lower pods are matured and the upper ones fully developed. "If harvest is delayed until the upper pods are
ripe, there can be great losses from shattering. The crop should be cut on cloudy days and may be cut at night.

Late harvesting may result in shedding and rotting of pods if untimely rain is encountered and in shattering of the seeds. Therefore, harvesting should be done at the appropriate stages when the leaves and the pods dry out and when the grain moisture content is significantly reduced. Under our condition where time of harvesting more or less exactly coincides with the start of the dry season, it is easily possible to achieve low moisture contents while the crop is in the field.

The crops are not as such suitable for combine harvesting and simultaneous threshing and harvesting is may be economically performed using manual labor where labor is available and cheap. The crops should be protected from rain after harvesting while in the field with the use of canvases and polythene sheets. Field pea is indeterminate in growth habit that the lower pods mature earlier when the upper ones are still green. Therefore, the freshly cut crops should be left on the ground and after well-dried (may be three to four weeks after) the crops should be fed to a stationary thresher to get clean seeds.

Early harvesting usually results in shriveled and poor quality seeds. Such seeds do have low market prices as well as consumer preferences.

**Threshing**

Threshing is a skilled art, whether done by machine or done by
hand. Seed which has been subject to improper threshing may appear intact and normal, but may have small cracks or internal damage that produces seedlings with developmental disorders that ultimately lead to seedling death or stunted growth. Properly cured seed will be seed that has moisture content high enough to prevent small cracks upon threshing, but low enough to prevent internal damage to the embryo. The method of choice is related to the volume of seeds to thresh and the equipment available.

**Hand threshing method:** Threshing by hand is a good method for processing small amounts of seed. The pods can be either split by hand or placed in a plastic tub and wrung through your hands, in which case you’ll want to wear gloves.

**Seed Storage**

Seeds should be stored in a dry and cool place free of pests and somehow be protected from absorbing moisture from the floor. Seeds should be treated with proper chemicals for storage pests but care must be taken that the treatment of the seed with improper chemicals may impair the ability of the seed to germinate.

**Storage methods**

Grain storage is carried out for three purposes.

- To retain a supply of food
- To service a trading system
- To retain seed for planting for the following season

Farmers store nearly all their grains in various ways. Systems and storage facilities vary from culture to culture according to local resources. The chemical treatment of the seed immediately after
harvest and the fumigation of the store before storage are advisable to keep the quality of the seed in storage.

References


Ethiopian Institute of Agricultural Research, Holetta Agricultural Research Center.