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Popular Article

# Biological alternative: A eco-friendly approach for soil productivity and plant protection

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Biological alternative, put simply, is a product that identifies a plant's natural resistance to an environmental stressor and amplifies that quality to create an exceptionally successful version of it. The introduction of such products offers an effective and more environmentally friendly substitute for synthetic chemicals, which we now know to be toxic to the environment (and sometimes to humans as well). Synthetic chemicals can negatively impact on soil health. Unhealthy soil makes it difficult for a diverse plants population to grow, which diminishes food sources for pollinators and other insects. When insect populations suffer so do the birds that eat those insects, and so on up the food chain. Poor soil is bad for biodiversity. In the past, synthetic pesticides and fungicides have been necessary to ensure sufficient crop yield to meet the demand of population. The threat of harmful insects, bacteria, and fungi is growing with globalization and climate change. All biological agents are appropriate for their use in organic farming production.

Bio-fertilizers are microorganisms that have the capability of increasing the soil fertility by fixing atmospheric nitrogen and through phosphate solubilization. Bio-fertilizers have biological nitrogen fixing organism which help them in promoting the growth of plants and trees by increasing the supply of essential nutrients, enhance biomass production and grain yields. Biofertilizers comprises living organisms viz: *Rhizobium, Azotobacter, Azospirillum,* PSB and *Pseudomonas,* phosphorus solublizing bacteria, mycorrhizal fungi, blue-green algae, and bacteria etc. have been found to be very effective tools of soil fertility management and biological nutrient mobilization. Recently customized consortia of such bio-fertilizer organisms, better adapted to

local climatic conditions have also been developed and are available commercially. Efficiency of such microbial formulations is much higher under no-chemical use situations; therefore, application of such inputs needs to be ensured under all cropping situations. There are some important and widely used bio-fertilizers.

**Symbiotic nitrogen-fixation:**

*Rhizobium, Frankia* and *Anabaena azollae* bacteria in association with legumes, fixes atmospheric nitrogen in root nodules of leguminous. The legumes and their symbiotic association with the rhizobium bacterium result in the formation of root nodules that fix atmospheric nitrogen. These are widely used bio-fertilizer which can fix around 100-300 kg nitrogen $ha^{-1}$ in one crop season.

**Asymbiotic/ Associative symbiotic nitrogen-fixation:**

Blue Green Algae, *Azolla, Azotobacter, Azospirillium, Beijerinkia, Clostridium, Klebsiella, Anabaena* and *Nostoc,* grow on decomposing soil organic matter and fixes atmospheric nitrogen in suitable soil medium. *Azotobactor* has beneficial effect on vegetables, millets, cereals, sugarcane and cotton. Organism is capable of producing nitrogen as well as antifungal, antibacterial compounds, siderophores and harmones. *Azospirillium* has beneficial effect on oats, barley, maize, sorghum, forage crop and pearl millet. It fixes nitrogen by colonising root zones.

**Phosphorus solubilizing bacteria (PSB):**

Phosphorus solubilizing bacteria are commonly used plant probiotics that promote plant development by converting insoluble Phosphorus into soluble phosphorus that is easily absorbed plant by roots. *Bacillus megaterium* var. *phosphaticum, Bacillus subtilis, Bacillus circulans* and *Pseudomonas striata,* are beneficial bacteria capable of solubilizing inorganic phosphorus from insoluble compounds. Phosphorus solubilization ability of rhizosphere microorganisms is considered to be one of the most important in plant phosphate nutrition.

**Phosphorus solubilizing fungi (PSF):**

The group of beneficial microorganisms capable of hydrolyzing organic and inorganic insoluble phosphorus compounds to soluble phosphorus form that can easily be assimilated by plants.

phosphorus solubilizing activity of fungal microorganisms such as *Penicillium, Aspergillus,* and *Trichoderma* strains can be used to solubilize phosphorus bearing materials in fermentation systems and substitute for chemical processing. *Penicillium sp, Aspergillus awamori*



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and *Fusarium* play a noteworthy role in increasing the bioavailability of soil phosphates for plant nutrition.

**Phosphorus solubilizing microorganisms (PSM):**

Soil microorganisms are capable of solubilizing/mineralizing insoluble soil phosphate to release soluble phosphorus and making it available to plants. These microorganisms improve the growth and yield of a wide variety of crops. Arbuscular mycorrhiza-Glomus sp.,Gigasporasp., Acaulospora sp., Scutellospora sp. and Sclerocystis sp.; Ericoid mycorrhizae-Pezizellaericae; Ectomycorrhiza-Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp. and Orchid mycorrhiza-Rhizoctonia solani. phosphate solubilizing microorganisms (PSM) could play an important role in phosphorus nutrition in many natural and agro-ecosystems.

**Potassium solubilizing bacteria (KSB):**

Potassium soluble bacteria is a bio-fertilizer that plays an important role in the formation of mono acids and proteins, these are produced by ammonium ions, which are then absorbed by the root from the soil. It also helps plants to take up other elements that activate several enzymes. It helps in raising potash in all soil types and increases the crop yield by 15-20% and increases crop resistance against different weather conditions. This biofertilizer also helps in photosynthesis properly and improves fruit and grain size and quality of crops. Potassium solubilization is carried out by a large number of bacteria such as ***Bacillus*** mucilaginosus, ***Bacillus megaterium,*** ***Bacillus*** edaphicus, ***Bacillus*** circulans, *Pseudomonas, Burkholderia, Acidithiobacillus ferrooxidans,* and *Paenibacillus spp*. The Potassium Releasing Microorganisms (KRMs) present in the soil are capable of converting the fixed form of potassium into an available form of K for the plants to uptake. Potassium solubilizing microbes also produce hormones that help plants withstand both biotic and abiotic stresses.

**Bio-fertilizers for micro nutrients:**

Bio-fertilizers help in maintaining the micronutrients in soil and making them available to plants. Micronutrients like boron, iron, manganese, zinc, and copper, although required in small quantities, are essential for plant health and growth to plants. Silicate and zinc solubilizers-*Bacillus* sp. micro nutrient and bio-fertilizers along with recommended dose of major nutrients increases the availability of the essential nutrients in the rhizosphere zone. Several zinc-solubilizing bacteria, such as *Bacillus amyloliquefaciens, Bacillus endoradicis, Bacillus oryzicola, Chitinophaga oryziterrae* sp.,*Pseudomonas protegens, Bacillus megaterium*, and *Bacillus*



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*altitudinis* have been recognized as plant growth-promoting bacteria due to the production of plant hormones and growth factors. *Pseudomonas, Bacillus, Leptothrix, Citrobacter, Acidobacteria, Firmicutes, Nitrospira, Chromobacterium, Actinomyces, Azotobacter* and *Azospirillum* are widely known for molybdanum solubilization and enhancing plant availability.

**Plant growth promoting Rhizobacteria:**

Plant growth-promoting rhizobacteria are microbes associated with plant roots that promote plant growth are referred to as promoting rhizobacteria are the soil bacteria inhabiting around/on the root surface and secretion of various regulatory chemicals in the vicinity of rhizosphere. Generally, plant growth promoting rhizobacteria facilitate the plant growth directly by either assisting in resource acquisition (nitrogen, phosphorus and essential minerals) or modulating plant hormone levels, or indirectly by decreasing the inhibitory effects of various pathogens on plant growth and development in the forms of biocontrol agents. Pseudomonas-*Pseudomonas fluorescens* are known to enhance plant growth promotion and reduce severity of various diseases. The efficacy of bacterial antagonists in controlling fungal diseases was often better as alone, and sometimes in combination with fungicides.

**Blue green algae (BGA):**

Blue-green algae reduce soil alkalinity and it is good for rice cultivation and bio-reclamation of land. Blue-Green Algae are a type of photosynthetic bacteria consisting either of single cells or colonies which is also known as the Cyanobacteria. Cyanobacteria contain only one type of chlorophyll, Chlorophyll a, a green pigment. In addition, they also contain pigments such as carotenoids, phycobilin proteins, chlorophyll, xanthophylls along with c-phycoerythrin and c-phycocyanin. Some of the blue green algae can fix nitrogen as it contains nitrogenase – an oxygen-sensitive enzyme. When they fix carbon from carbon dioxide, some blue green algae fix dinitrogen from the atmosphere. They are called nitrogen-fixing blue green algae and are inclusive of symbiotic and free living forms.

**Azolla:**

Azolla is a heterosporous aquatic ferns that are green in colour in the family Salviniaceae. They are extremely reduced in form and specialized, looking nothing like other typical ferns but more resembling duckweed or some mosses, freely floating on the water surface. It can be used in animal and poultry feed as a protein source. Small floating fern, *Azolla harbours, blue-green algae,*



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*anabaena*, commonly seen in shallow fresh water bodies and in low land fields. They fix nitrogen in association.

**Mycorrhizae**:

*Mycorrhizae* is symbiotic association of fungi with roots of vascular plants. The fungi which commonly form mycorrhizal relationships with plants are ubiquitous in the soil. Certain plants require an association with mycorrhizae. For example, mycorrhizae are necessary for the germination and establishment of *Pinus* seeds. When two organisms form a mycorrhizal relationship, the fungus colonises the host plant's root tissues either intra cellularly like in arbuscular mycorrhizal fungi (AMF or AM), or extracellularly like in ectomycorrhizal fungi. Mycorrhizae may associate parasitically with host plants depending on the species or the environment. This helps in increasing phosphorous uptake and improves the growth of plants.

**N.P.K.Consortia:**

Bio-fertilizer is a blend of microbes capable of fixing nitrogen, solubilizing phosphate, and mobilizing potash to provide well-balanced nutrition to crops. It significantly reduces the need for chemical nutrient additives, resulting in healthy plants, abundant crops, and lower input costs. NPK Bio-Fertilizer is a consortium of *Rhizobium, Azotobacter* and *Acetobacter, Phospho* Bacteria-*Psuedomonus* and Potassium Solution-Baciles bacteria which are atmospheric nitrogen and phosphorus fixing organisms. NPK consortia has higher efficiency in Nitrogen, Phosphorous, and potassium fixing and has the ability to drive atmospheric Nitrogen and provide it to plants. It converts complex nutrients present in non-available forms into simple forms absorbed by crops. Improves soil organic carbon, soil useful bacteria population, biomass carbon, biomass nitrogen, and soil respiration. Consortia is a unique microbial formulation of multiple bacteria which are able to synthesize macro nutrients - atmospheric nitrogen, solubilize phosphorus and mobilize potassium into available form, thereby supplementing balanced nutrition to the crops. It helps to increase the crop yield and improves the soil health and increases plant drought tolerance under stress condition. NPK bio fertilizer increases the availability of micronutrients (such as Mn, Mg, Fe, Mo, B, Zn, and Cu) from the soil to the plant, resulting in faster root growth, and nutrients uptake, and increased resistance/tolerance to diseases/drought. It is boosts nitrogen uptake while also producing plant growth hormones and vitamins. These aids the crop's germination, early emergence, and root development.



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**Application of Bio-fertilizers:**

These are some of the most important Bio-fertilizers types that are widely used in crops. So, Bio fertilizers are the need of the hour. They are stable reliable and environment-friendly also.

**Soil Treatment:** Bio-fertilizers can be used to treat soil since they restore the soil's original fertility. For soil treatment, we mixed bio fertilizers with compost fertiliser and, we kept mixture for a night. Then we spread this mixture into soil where seed is to be sown.

**Seed Treatment:** We can also use organic fertilizers to treat the seeds. For seed treatment process, seeds are soaked in a mixture of nitrogen and phosphorus fertilizers. After that, the seeds dry out and harden as quickly as possible.

**Recommended liquid Bio-fertilizers:**

| Crops | Recommended Bio-fertilizer | Application method | Quantity to be used |
|---|---|---|---|
| **Field crops**<br>**Pulses:** Chickpea, pea, groundnut, soybean, beans, lentil, lucern, berseem, green gram, black gram, cowpea and pigeon pea. | *Rhizobium* | Seed treatment | 200ml/acre |
| **Cereals:** Wheat, oat, barley, rice, maize, sorghum. | *Azotobacter/ Azospirillum* | Seed treatment | 200ml/acre |
| **Oil seeds**: Mustard, seasum, linseeds, sunflower, castor. | *Azotobacter* | Seed treatment | 200ml/acre |
| **Millets**: Pearl millets, finger millets, kodo millet | *Azotobacter* | Seed treatment | 200ml/acre |
| **Forage crops and Grasses:** Bermuda grass, sudan grass, napier grass , paragrass, star grass etc. | *Azotobacter* | Seed treatment | 200ml/acre |
| **Other Misc**. Plantation Crops, Tobacco. | *Azotobacter* | Seedling treatment | 500ml/acre |
| Tea, Coffee | *Azotobacter* | Soil treatment | 400ml/acre |
| Rubber, Coconuts | *Azotobacter* | Soil treatment | 2-3 ml/plant |
| **Agro-Forestry/Fruit Plants:** All fruit/agro-forestry (herb,shrubs, annuals and perennial) plants for fuel wood fodder, fruits, gum, spice, leaves,flowers,nuts and seeds puppose | *Azotobacter* | Soil treatment | 2-3 ml/plant at nursery |
| Leguminous plants/ trees | *Rhizobium* | Soil treatment | 1-2 ml/plant |



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**Recommended Bio-fertilizers:**

| Crops | Recommended Bio-fertilizer | Recommended / Doses |
|---|---|---|
| **Field Crops**<br>**Pulses :** Chickpea, pea, groundnut, soybean, beans, lentil, lucern, berseem, green gram, black gram, cowpea and pigeon pea. | *Rhizobium* | **1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker<br>**2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated |
| All Crops | Phosphate Solubilizing Bacteria (PSB) | **1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker<br>**2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field.<br>**3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted. |
| All Cereals, Oilseeds, Vegetables and Cash crops | *Azotobactor* | **1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker<br>**2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field.<br>**3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted. |
| All Cereals, Oilseeds, Vegetables and Cash crops | *Azospirillum* | **1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker<br>**2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field.<br>**3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted. |
| All Crops | Potassium Mobilizing Bacteria(KMB) | **1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker |



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| | | |
|---|---|---|
| | | **2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field.<br>**3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted. |
| All Crops | NPK Consortia | **1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker<br>**2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field.<br>**3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted. |
| Rice | Blue Green Algae | 4 kg BGA Culture apply for 1 acre area after 1 week of transplanting or biasi. |

**Bio-pesticide:**

Bio-pesticides are of plant origin and include plant products like alkaloids, phenolics, terpenoids and some secondary chemicals. They are biologically active against insects, fungi, nematodes affecting their behavior and physiology. Commonly known insecticides are Pyrethrum, Nicotine, Neem, Margosa, Rotenone etc. *Trichoderma virideae* or *Trichoderma harazianum* or *Pseudomonas fluorescence* formulation @ 4 gm $kg^{-1}$ seed either alone or in combination, manage most of the seed borne and soil borne diseases. There is other formulations viz. *Beauvaria bassiana*, *Metarizium anisopliae*, *Numeri arileyi*, *Verticillium* sp, which are available in the market and can manage their specific host pest. *Bacillus thurengensis stenebrionis and Bacillus thurengensis sandigo* are effective against coleopterans as well as some other insect species. *Bacillus thuringiensis* has been used in the management of diamond back moth on crucifers and vegetables @ 0.5-1.0 kg $ha^{-1}$. Viral biopesticides of baculovirus group viz. granulosis viruses (GV) and nuclearpolyhedrosis viruses provided a great scope in plant protection field. Spray of nuclear polyhedrosis viruses (NPV) of *Helicoverpa armigera* (H) or *Spodoptera litura* (S) @ 250 larval equivalents are very effective tools to manage the *Helicoverpa* sp. or *Spodoptera* sp. respectively.



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***Verticillium lecanii*** -As powder ($10^7$cfu/gram) 2.5 kg should be dissolved in 500 liter of water for per hectare and should be sprayed. As liquid ($10^{10}$-$10^{12}$ cfu $ml^{-1}$) its 1000-1250 ml should be dissolved in 500 liter of water for per hectare and then sprayed for the management of mites and insects like green hopper, leaf miner, thrips, whitefly, brown hopper and other insects.

***Beauveria bassiana***-As powder ($1x10^8$ cfu $gram^{-1}$) 2.5 kg should be dissolved in 500 liter of water for per hectare and should be sprayed. As liquid ($1x10^{10}$-$1x10^{12}$ cfu $ml^{-1}$) its 1000-1250 ml should be dissolved in 500 liter of water for per hectare and then sprayed. For the areas affected by white grubs mainly for the crop the citrus, mango and coconuts etc. 5 ml of *Beauveria bassiana* per liter water to be applied. *Beauveria bassiana* @ 2 kg should be mixed with 200 liter of water dispensed through the drip or drench system to control the grubs. It can be applied on the crops like banana, soybean, paddy, oilseeds, tomato, chilli, potato, maize, sugarcane, turmeric, citrus crop, onion, garlic, floriculture and horticulture crops.

Pest predators and pathogens has also proved to be effective method of keeping pest problem below ETL. In undative release of *Trichogramma sp*. @ 40,000 to 50,000 eggs $ha^{-1}$, *Chelonus blackburni* @ 15,000 to 20, 000 $ha^{-1}$, *Apanteles* sp.@15,000 to 20,000 $ha^{-1}$ and *Chrysoperla sp*.@ 5,000 $ha^{-1}$, after 15 days of sowing and others parasites and predators after 30 days of sowing, can also effectively control pest problem in organic farming.

**Recommended Biological agents:**

| Crops | Major pests | Eco-friendly management through biological agents |
|---|---|---|
| Chickpea/ Pigeon pea/ Pea/Lathyrus /Moong/ Urad | *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) | • Application of *Bacillus thuringiensis* Kurstaki 8L @ 1.6 kg $ha^{-1}$. and *Bacillus thuringiensis* Kurstaki ES @ 1.5 lt $ha^{-1}$, respectively, at early stages of crop infestation ($1^{st}$, $2^{nd}$ and $3^{rd}$ instar larval infestation) with at least 2 applications at 7 days interval.<br>• HaNPV $6x10^9$ POB/ml @ 250 lt $ha^{-1}$. |
| Mustard/ Safflower/ | Aphids (*Lipaphis erysimi*). | • *Cheilomenes sexmaculata* Fabricius 5000 larvae or 500 adults $ha^{-1}$,<br>• *Coccinella septempunctata* Linnaeus 5000 larvae or 500 adults $ha^{-1}$,<br>Two releases; first release to coincide with the appearance of aphids |
| Sunflower | Aphid (*Lipaphis erysimi*). | • *Chrysoperla carnea* (Stephens) 10,000 first instar larvae $ha^{-1}$. |
| Brinjal | Fruit and shoot borer (*Leucinodes orbonalis)* | • *Bacillus thuringiensis* 500 g ai $ha^{-1}$ (10 days interval).<br>• 3- 4 releases of egg parasite, *T. chilonis* @1.0 lakh $ha^{-1}$ |



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| Cucurbitaceous | • Fruitfly (*Bactrocera cucurbitae*)<br>• Aphids (*Lipaphis erysimi*). | **Poison bait-** Mix Ethyl Alcohol-60 ml + Methyl eugenol-40 ml + Malathion/ DDVP (Pesticide)- 20 ml (*i.e.* in the ratio of 6 :4:2). Use in Mango, Guava, Papaya, Citrus and other fruit crop.<br>• *Cheilomenes sexmaculata* Fabricius 5000 larvae or 500 adults $ha^{-1}$, |
| Okra | • Shoot and fruit borer (*Earias vittella*)<br>• Fruit borer (*H. armigera*) | • *Trichogramma brassiliensis* 2,50,000 parasitized eggs $ha^{-1}$ (Inundative release)<br>• 50,000 parasitized eggs $ha^{-1}$ (Weekly inoculative release)<br>• *Bacillus thuringiensis* 500 g ai $ha^{-1}$ (10 days interval) |
| | • Okra aphid | • *Chrysoperla zastrowi arabica* 50,000 first instar larvae/ha (weekly release) |
| Tomato | Fruit borer *(Helicoverpa armigera*) | • *Trichogramma brassiliensis* 2,50,000 parasitized eggs $ha^{-1}$ (Inundative release)<br>• 50,000 parasitized eggs $ha^{-1}$ (Weekly inoculative release)<br>• *Bacillus thuringiensis* 500 g ai $ha^{-1}$ (10 days interval)<br>• HaNPV @ 250 lt $ha^{-1}$ (10 days interval) |
| Onion | Thrips | • *Xylocoris*<br>• *Blaptostethus* |
| Potato | Potato tuber moth *Phthorimaea operculella* | • *Chelonus blackburnii* 50000 adults $ha^{-1}$ in the field, Two releases at weekly intervals.<br>• 2 adults per kg of potatoes in godowns. |
| Colocasia | Armyworm *Spodopteralitura* (Fabricius) | • *Trichogramma spp.* |
| Cabbage | DBM (*Plutella xylostella*) | • *Bacillus thuringiensis* 500 g ai $ha^{-1}$ (10 days interval). |
| | Cabbage aphid | • *Chrysoperla zastrowi arabica* 50,000 first instar larvae/ha (weekly release). |
| Weeds | Congress grass weed *(Parthenium hysterophorus L.)* | • *Zygogramma bicolorata* Pallister, one adult was found to bring defoliation of a single parthenium plant in 6-8 weeks. Therefore, if releases are to be carried out at this rate, about 0.4. to 0.7 million insects will be required per hectare, as the weed density varies between 40 to 70 plants per square metre. In practice, it is neither possible nor necessary to release so many insects as they are capable of multiplying rapidly. Releases of about 500-1000 beetles can bring about establishment and eventual control. |



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**Recommended Bio-pesticide:**

| Bio-pesticide | Eco-friendly management against major insect / disease |
|---|---|
| *Trichoderma viride / harzianum*<br>*Pseudomonas florescence*<br>Alone or in combination | • Seed treatment for seed born disease @10 gm $kg^{-1}$<br>• Soil treatment for soil born disease @ 5 kg $qt^{-1}$ of FYM $ha^{-1}$ |
| *Trichoderma viride / harzianum* | • Soil borne pathogens i.e. wilt, dry root rot, collar rot etc of chickpea, vegetables, oilseeds and fruit crops @ 5 lt $ha^{-1}$<br>• Blast disease in rice @ 5 lt ha-$^{1}$<br>• Sheath blight, brown spot and sheath rot of rice @ 5 lt ha-$^{1}$ |
| *Pseudomonas florescence* | • Soil borne pathogens i.e. wilt, dry root rot, collar rot etc of chickpea, vegetables, oilseeds and fruit crops @ 5 lt $ha^{-1}$<br>• Sheath blight and sheath rot of rice @ 5 lt ha-$^{1}$ |
| *Bacillus subtilis* | • Soil borne pathogens i.e. wilt, dry root rot, collar rot etc of chickpea, vegetables, oilseeds and fruit crops @ 5 lt $ha^{-1}$<br>• Early and late blight in tomato, rice blast in rice, foliar blight in beans/soybean @ 5 lt $ha^{-1}$ |
| *Metarhizium anisopliae* | • Brown plant hopper in rice @ 5 lt $ha^{-1}$<br>• Early shoot and top shoot borer @ 5 lt $ha^{-1}$<br>• Sugarcan pyrilla @ 5 lt $ha^{-1}$<br>• Groundnut cut worm @ 5 lt $ha^{-1}$<br>• Rhinoceros beetle @ 5 lt $ha^{-1}$<br>• Diamond back moth of cabbage, Lepidoptera caterpillars and other sucking insects (white flies, aphids, thrips) of crops@ 5 lt $ha^{-1}$ |
| *Beauveria bassiana* | • Stem borer and leaf folder in rice @ 5 lt $ha^{-1}$<br>• White grub of groundnut @ 5 lt $ha^{-1}$<br>• Diamond back moth of cabbage, Lepidoptera caterpillars of crops@ 5 lt $ha^{-1}$ |
| *Bacillus Thuringiensis* | • Diamond back moth of cabbage @ 5 lt $ha^{-1}$<br>• Leaf eating caterpillars (soybean, groundnut, chickpea, vegetables spodoptera sp.) @ 5 lt $ha^{-1}$<br>• Beetles of different crops @ 5 lt $ha^{-1}$ |
| *Lecanicelium lecanii* | • White flies, aphids, thrips in vegetables and fruits, scale insects, mealy bug, and other sucking insects @ 5 lt $ha^{-1}$ |
| *Paceliomyces lilacinus* | • Nematodes in vegetables, white flies, aphids, thrips in different crops @ 5 lt $ha^{-1}$ |

**Other alternative:** Use of disease free seed or stock and resistant varieties are best preventive practice in organic pest management. Maintenance of biodiversity, effective crop rotation, multiple cropping, habitat manipulation and use of trap crops are also effective practices which can keep the population of pests below economical threshold limit (ETL). In the border of the main crop



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different natural enemies attracting crops like marigold/other yellow colored flower ornamental crops planting should be done which should be synchronized with the main crop. The crop like coriander in gram, mustard, can also be planted in order to promote and conserve the natural enemies. Proper plant spacing and alley planting of the crops should be done with a proper gap between row to row and plant to plant. After every 2-3 meter plantings of the main crop a gap of 0.75-1.00 meter should be practiced.

Removal of affected plants and plant parts, collection and destruction of egg masses and larvae, installation of bird perches, light traps, sticky coloured plates and pheromone traps are most effective mechanical methods of pest control.

**Light trap-** General for all nocturnal flying insects- 1 trap/ha (60 watt CFL).

**Sticky trap yellow**–For the monitoring of aphid, jassid, like insects. 1 trap/100 $m^2$ area.

**Sticky trap blue -** For the monitoring of thrips like insects. 1 trap/100 $m^2$ area.

**Votta T trap-** Brinjal shoot and fruit borer, pin moth (*Tutaabsoluta*) for the monitoring 10 traps/ha and for the management 25 traps/ha.

**Pheromone trap--** This is a general tool which is mostly used for lepidopteran insects it causes damage at larval stages. For the management of adult stage of different species of Lepidoptera insects sex pheromones available in the market/company/dealers which can be used as the case is there.

| Insect | Lure name | Crop | Time of installation |
|---|---|---|---|
| 1. Rice stem borer | Scirpo lure | Rice | • One week after transplanting.<br>• End of tillering stage |
| 2. *Helicoverpa armigera* | Helli lure | Gram and differe crop | • 25 days after sowing.<br>• At flower initiation. |
| 3. *Spodoptera litura* | Spodo lure | Different crops | • One week after transplanting.<br>• Three weeks after sowing. |
| 4. Spotted bollworm | Earvit lure | Okra and Cucurbitaceous | • One week after transplanting.<br>• One week prior to flowering. |
| 5. Diamond back moth | DBM lure | Cole crops | • One week after transplanting. |
| 6. Brinjal Shoot and fruit borer | Leucine lure | Brinjal | • One week after transplanting.<br>• One week prior to flowering. |
| 7. Fruit fly | Bedor lure | Mango,Guava, Litchi | • Prior to flowering. |
| 8. Melon fly | Baku lure | Cucurbitaceous crop | • One week prior to flowering. |



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