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Biological Control of Plant Pests, Disease and Weeds

While pursuing research on control of pests, diseases and weeds of economically important crops steady efforts have been made to develop cost-effective, eco-friendly, commercially viable mass production technologies of various biocontrol agents and improved formulations for use under the Integrated pest management (IPM) in the country. It has been envisaged to investigate the use of biopesticides/ natural enemies along with other components of IPM and integrated nutritive management (INM). During the year, a network programme on pheromones, and one for the management of *Parthenium* weed have been initiated.

Integrated pest and nutrition management:

This programme being implemented at 14 centers in 12 states viz. Uttar Pradesh (IIPR, BHU), Uttaranchal (GBPUAT), Kerala (IISR), Jammu and Kashmir (RRL), Tamil Nadu (TNAU), Assam (AAU), Gujarat (GAU), Karnataka (UAS), Andhra Pradesh (RARS and CTRI), Maharashtra (PDKV), Orissa (OUAT) and Andaman & Nicobar (CARI) is to be concluded this year. The salient achievements are given below.

At UAS, Dharwad, bioefficacy of *Nomuraea rileyi* was evaluated against *Spodoptera litura* and *Helicoverpa armigera* on groundnut in the coastal agro-ecosystem of Karnataka. It was also evaluated on soybean in farmer's fields over 150 acres in four villages against *S. litura* and *Thysanoplosia orichalcea*. Results showed that insecticide treatment compared with *N. rileyi* is highly effective in reducing the pest population, foliage damage, pod damage besides increasing the yield. *N. rileyi* is found to be cost promotive. *N. rileyi* was highly effective in managing *Spodoptera litura* on capsicum under net house conditions. Bioassays against *S. litura* revealed that formulations based on sunflower, groundnut, sesame, soybean and castor oils were better than aqueous formulations.

INM/IPM practices were demonstrated on 100 ha farms in two villages of Krishna district by CTRI, Rajamundhri. In IPM villages, the major insect pests viz., *S. litura* and *Heliothis armigera* populations were found to be notably less than in non-IPM (chemical control) villages. Natural enemies like apanteles, coccinellids and spider populations were more on groundnut in INM/IPM villages. The cost-benefit ratio was also higher (1:2.36) in IPM villages as compared to non-IPM villages (1:1.70).

At RRL, Jammu, about 1000 kg of the lignite-based formulations of bio-fertilizers, plant growth promoting rhizobacteria (PGPRs) (*Rhizobium*, *Azotobacter*, *Azospirillum*, *Pseudomonas*) and bio-control agents (*Trichoderma viride* and *T. virens*) were prepared by fermentation and supplied to SKUAST Jammu, SKUAST Srinagar and other agriculture agencies for field /frontline demonstrations. More than 125 ha area was covered under frontline demonstration crops such as beans, tomato, chillies, brinjal, knol-khol, onion, bhindi, cucurbits, pea, chickpea, and saffron in different agroclimatic zones of J&K state. The average increase in the yield of the crop was in the range of 2-47% and disease reduction in the range of 3.2-20%. Studies showed that the shelf life of the formulations in liquid state at +40C is 4-5 months. A microprocessor-controlled 75 litre fermentor with *in situ* autoclaving facilities was installed at SKUAST, Srinagar for the production of microbial biofertilizers and biocontrol agents in the state.

A study at IISR, Calicut on compatibility, stability and potential of biocontrol consortium on suppression of *Phytophthora* footrot of black pepper, 25 efficient strains of bacterial biocontrol agents were characterized based on carbon utilization, antibiotic sensitivity and utilization of succinic acid. Studies on temperature tolerance of the fungal biocontrol agent, *Trichoderma harzianum* indicated that its viable population significantly reduced after 40oC. Siderophore-mediated antagonism was found to be the prominent mechanism of antagonism in the biocontrol agent *Pseudomonas fluorescens* strains (IISR-6, IISR-11 and IISR-13) against *Phytophthora capsici*. Strains IISR-6 and IISR-51 were found to enhance root emergence and root proliferation in black pepper cuttings, which could be adopted for nursery disease management.

A directory of pathogens of tea pests has been made by AAU, Assam from the tea gardens of North East. From the different insect pests of tea, several entomopathogenic fungi (*Beauveria bassiana*, *Helopeltis thevora*, *Astycus chrysoclorus*, *Penicillium*) and actinomycetes (*Paecilomyces carneus*, *Glyclotalpa africana*, *Verticillium lecanii*, *Oligonychus coffeae* and *Toxoptera aurantii*) have been isolated. Besides, NPVs were also collected from bunch caterpillar (AbNPV), looper caterpillar (BsNPV) and lymantrid caterpillar. Mass production of *B. bassiana* and *V. lecanii* was standardized and attempts were made to utilize locally available industrial wastes like rice hull, saw dust and rice bran. *B. bassiana* can be used effectively for suppressing the tea mosquito bug. Field efficacy data revealed that use of a formulation by combining *B. bassiana* + *V. lecanii* performed significantly better not only in suppressing the pest population, but also in enhancing the yield by 56% over the control. Furthermore, the microbials were found to be compatible with botanicals (azadirachtin). Studies conducted on storage and shelf life showed that in RH: SD: RB medium, the *B. bassiana* remains virulent up to one month of storage at room temperature (25 - 27°C). In order to improve shelf life of the mass-produced mycoinsecticides, the medium was modified by supplementing it with chitin of different arthropods. Addition of crab and prawn chitin induced viability substantially. A regular survey and surveillance programme is underway at the center.

At IIPR, Kanpur, studies were conducted and biological control of gram pod borer *Helicoverpa armigera* was demonstrated in chickpea, pigeonpea and sunflower. Field demonstration of *HaNPV* of chickpea revealed that average pod damage due to *H. armigera* in treated chickpea was 2.4% against 10.7% of untreated plants. Five isolates of *HaNPV* were screened and Kanpur isolate was found to be efficient. It was observed that different adjuvants of *H. armigera* (Kanpur isolate) act differently on increasing its efficacy and bringing about mortality of the insect.

An effective IPM package has been developed for the management of pests and diseases of tomato, chillies, cauliflower and cabbage of eastern Uttar Pradesh at IIVR, Varanasi. NPV of *Helicoverpa armigera* and *Spodoptera litura*, *T. harzianum*, *T. viride*, *T. virens*, *Aspergillus niger*-V isolates and *Bacillus subtilis* were isolated and characterized. Among the different SLNPV cultures, Cuddalore was the best on the basis of LD50 with 2.5 x 102 POB count/ml. Performance of *T. viride* was better than other bioagents in relation to damping off. The most effective and economic substrate for mass multiplication of *Trichoderma* is rice husk and rice bran mixed with sorghum in 1:1 ratio. Maintenance of 5 to 6.5 pH and temperature 25oC is best for prolonged storage of NPV solution. Integration of NPV and endosulfan has been found more effective against *H. armigera*.

At AU, Tamil Nadu, strains of *Trichogramma chilonis Ishii*, tolerant to high temperature (320 C and 340 C) were developed and compared with normal strains for parasitic qualities. The temperature-tolerant strains were on par with normal strains and did not lose any one of the parasitic qualities studied. Three new fungal pathogens viz. *Fusarium solani*, *Penicillium janthinellum* and *Mucor prayagensis* were recorded on the rice leaf folder caterpillars, *C. naphalocrocis medinalis guen*. Talc-based dry preparations containing spores were prepared as biopesticides. Similarly, oil formulations against RLF were found to be effective in field evaluation.

National biocontrol network programme:

The salient achievements of R&D projects are as follows:

Molecular studies on biocontrol agents

With a view to developing an authentic data base of agriculturally and industrially important strains of fungi and bacteria, a programme on molecular characterization of selected strains is underway at RRL, Jammu. Primers have been designed for the ribosomal typing of fungal isolates collected from various centers. RAPD and RFLP studies of various fungal and bacterial isolates have been carried out. Chemical markers are being developed for different fungi using techniques like MALDI-TOF and LCMS.

Molecular characterization of *Macrophomina phaseolina* has been initiated at BHU, Varanasi and a mini-prep method of direct isolation of genomic DNA from the culture plates has been developed and PCR technique has been optimized using rDNA spacer regions i.e. internal transcribed spacers (ITS) and intergenic spacers (IGS). No polymorphic pattern among the isolates was found by using ITS. Uncut IGS primers produced sufficient level of discrimination within the isolates of *M.*

phaseolina. More than 80 RAPD primers were tried using different strains of *M. phaseolina*. RAPD-PCR generated very distinct multiple products showing considerable variability among the isolates. The number of amplified bands were variable, depending on the primers or the isolates used. Good polymorphic results obtained with 4 RAPD primers i.e. OPAO1, OPAO3, OPAO4 and OPAO9. The data obtained by these primers could be used for generating RAPD-SCAR probes.

At UAS, Dharwad, studies are in progress on genomic flux and molecular analysis of insecticide resistance in cotton bollworm, *Helicoverpa armigera*. A cotton cultivation map of south India and schedules for insecticide usage pattern, phenotyping and weather parameters were prepared. Sampling locations were identified, based on the map and insecticide usage. Cotton bollworm sampling was carried out from all the marked locations as and when the incidence prevailed. Technical grade insecticides were used in identified locations to monitor insecticide bioassay in field population. Cry 1Ac protein from hyper expression vector Pk223-3 in *E. coli* IM103 was purified and used for bioassay. Genomic DNA was isolated from *Helicoverpa armigera* and genetic diversity analysis was carried out using RAPD. Insecticide bioassay for field population were carried out and insecticide resistance folds for all the insecticides were determined. Geographically proximal population of *H. armigera* shared greater nucleotide similarity, whereas Dharwad population was found to be genetically distinct. Genetic similarity coefficient within each population varied between 0.24 and 0.49. DNA fingerprinting of geographical populations of cotton bollworm and molecular analysis of insecticide resistance are under progress.

Large number of bacterial isolates (from rhizosphere soil) were screened at the University of Madras, Chennai for antifungal activity against *Fusarium moniliforme* and *Curvularia lunata* to find out a candidate organism for cloning the chitinase gene. An isolate showing very high activity was selected and characterized using biochemical characterization and rRNA sequencing and taxonomically identified as *Bacillus subtilis*. 25 kD protein has been purified to homogeneity using a chitin column and the protein is being used to raise polyclonal antiserum so that it can be used to screen bacteria for presence of similar proteins.

Studies on biological control of bacterial blight of rice caused by *Xanthomonas oryzae* pv. *oryzae* have been undertaken using bacterial antagonists by traditional and molecular approaches. Out of a total of 1,175 plant-associated bacteria collected, 637 were fluorescent bacteria, while the remaining were nonfluorescent *Bacillus* spp strains. Forty-two *Bacillus* strains and 278 fluorescent strains of bacteria inhibited the growth of *Xanthomonas oryzae* pv. *Oryzae* *in vitro*. A PCR-based screening method was developed for the production of DAPG by the fluorescent bacteria. PCR primers, Phl2a and Phl2b were used to detect and amplify 745-bp fragment characteristic of DAPG. The role of DAPG for suppression of rice bacterial blight is being evaluated in the net-house and field experiments. Five efficient *Bacillus* strains (*Bacillus lentus*, *B. cereus*, *B. circulans*, *B. sp-1* and *B. sp-2*) were characterized. When used for treatment of rice plants of cultivars, IR24 and Jyothi, these bacteria afforded a maximum of 50-55% bacterial blight suppression in the field. Additionally, treatments with *Bacillus* spp enhanced rice growth, tiller numbers (3-fold) and grain yield (203-fold).

Studies are underway on molecular analysis of antifungal activities of antagonistic bacteria at Pondicherry University. Fluorescent pseudomonad bacteria exhibiting broad-spectrum antifungal activities were isolated. The metabolites were purified and identified as dimer of phenazine-1-carboxylic acid based on mass spectrometric as well as high-resolution NMR analyses. Characterization of another new antifungal metabolite is under progress.

At KFRI, Kerala, studies have been undertaken on tracing the origin and spread of teak defoliator outbreaks through a molecular approach. Data on spatial and temporal pattern of teak defoliator (*Hyblaea puera*) infestation was gathered. Larval samples from endemic, epicenter and epidemic populations were collected, preserved, and used for molecular studies. Standardized techniques were used for molecular characterization and estimation of parentage in *Hyblaea puera*. About 100 RAPD primers were screened for insect specificity and 10 most polymorphic primers were identified for genetic variation studies. Using the selected markers the relationship between endemic and epicenter populations (inter populations), within endemic populations (intra populations) and between populations (inter individual) was estimated.

Studies on engineering sheath blight resistance in rice has been carried out by employing *Trichoderma* chitinase genes at TNAU, Coimbatore. Two chitinases (42 kDa and 30 kDa) were detected in the culture filtrates of *Trichoderma viride* MNT7 by western blotting using an anti-barley chitinase antiserum. Purification of the *Trichoderma viride* MNT7 42 kDa/30 kDa chitinases was achieved. MNT7 42 kDa /30 kDa chitinases were characterized using substrate inducibility, glucose repressibility and antifungal activity against the target pathogen, *R. solani*.

At IIHP, Palampur, an ELISA-based diagnostic kit has been developed against *bean yellow mosaic potyvirus* (BYMV). Different varieties of gladiolus were screened for the presence of BYMV using this diagnostic kit. This kit has been found comparable with the reference kit. Being based on polyclonal antibodies, this kit also detects other strains of BYMV infecting other crops and would be cost effective.

Microbial pesticides and other natural enemies

A virulent isolate of NPV of *Amsacta albistriga* has been identified at the University of Madras, Chennai from Dharwad, Karnataka for the management of groundnut red hairy caterpillar, which is found to be 5.6 - 8.4 fold more effective than existing isolates. *Calotropis* is identified as suitable host plant for mass multiplication of NPV of *A. albistriga* under laboratory condition through which the *in vivo* yield of NPV has been enhanced by 1.08 - 2.35 fold when compared to other plant hosts. Administration of NPV along with 10% aqueous extract of *Tribulus terrestris* was able to increase the *in vivo* yield of NPV significantly from 1.34 - 1.55 fold. The adjuvant mix, NPV+ urea 0.5% + Ranipal BVN 0.1% and crude sugar 0.5% is found to be effective in enhancing the virulence, resulting in 96.7, 93.3 and 81.7 per cent mortality to II, III and IV instars larvae, respectively.

Large-scale demonstration of the product formulation of NPV of *Hyblaea puera* (HpNPV) was conducted for the management of teak defoliator by the scientists of KFRI, Trichur. A new insect rearing tube has been designed and fabricated for larval rearing and retrieval, dispensing of diet and inoculum. Seven storable formulations of HpNPV have been developed and bioassayed for their efficacy under laboratory conditions. Field testing of formulated freeze-dried wettable powder form of HpNPV were carried out and compared with the unformulated product. A high pressure mechanized spraying system was developed and evaluated for field application of virus in teak plantation.

Studies on the biological control of mono- and multi-pathogenic diseases of chickpea and pigeonpea (caused by fungi and nematodes) have been undertaken at AMU, Aligarh. Root-knot disease was significantly controlled due to application of *P. fluorescens*. Its application decreased the severity of galling by 9-11% and increased the yield by 14%. The combination of *P. fluorescens* and *T. harzianum* was found highly effective in controlling the wilt of chickpea in the presence or absence of root-knot nematode leading to 31-57% increase in the yield.

Isolation of virulent strains of baculovirus is being carried out for the management of rainfed groundnut red-hairy caterpillar at TNAU, Madurai. Biological activity of four geographic isolates of NPV of *Albistriga* under laboratory condition revealed that the isolate from Dharwad was more effective against II, III and IV instar of *A. albistriga*. Two rounds of application of Dharwad isolate of NPV formulation (with other constituents) have been found very effective in reducing the population of *A. albistriga* in groundnut crop.

At UAS, Bangalore, attempts have been made towards integrated management of root-knot nematode in tomato and burrowing nematode in banana by utilizing indigenous types of mycorrhizal bioagent viz. *Glomus fasciculatum*. Fifty seven isolates were found from the rhizosphere of plantation crops, fruit crops, vegetable crops, oil seeds, pulses, cereals, flower crops and others in different districts of Karnataka. Selected 13 isolates from Southern Karnataka were screened against burrowing nematode (*Rotylenchulus similis*) on banana and root-knot nematode, (*Meloidogyne incognita*) on tomato. Udupi areca isolate was found to be effective in improving the host parameters and decreasing the nematode population of *R. similis* on banana, while Shimoga banana isolate was better in improving the host parameters and decreasing the nematode population against *M. incognita* on tomato.

Mass multiplication of phytoseiid mite predators (*Amblyseius longispinosus*, *A. tetranychivorus* and *Typhlodromus rickeri*) have been standardized. The predators were released in selected poly-houses growing roses and carnation around Bangalore, Hosur and Pune for management of spider mites.

A survey by ACRI, Tiruchirappalli, of major betelvine growing districts (Tiruchy, Karur, Salem and Coimbatore) revealed the association of *M. incognita* in pathogenic level showing a gall index of 3-5 scale. Talc-based formulations were prepared with the three indigenous strains of *Pseudomonas fluorescens* (Pfbv-2, Pfbv-5 and Pfbv-9) and tested on seed virus. Seedvines were treated and planted. Two strains (Pfbv-2 and Pfbv-5) showed enhanced growth and all the three strains were found to show inhibitory effect against *Phytophthora* under *in vitro* conditions. All the three strains were also found effective against *Meloidogyne incognita*.

At RRL, Jorhat, crop enhancement and development of induced disease resistance have been established in chick pea and pigeon pea against fusarial wilt pathogens through combined use of PGPR and rhizobial strains. Also, bacterization with RRLJ 134 enhanced the rooting percentage, emergence of leaves and chlorophyll content of the new leaves of the tea cuttings grown in *F. lamoensis* infested and pathogen free soils. Reduction of the brown rot disease in tea cutting grown pathogen infested soils was also observed.

Novel insecticidal toxins have been isolated, at PDBC, Bangalore, purified and characterized from *Photobacterium* and *Xenorhabdus* spp. (enterobacteria) from bacterial cells and cell-free culture filtrates of *Photobacterium* and *Xenorhabdus* spp. They were examined for their toxicity against the larvae of *Helicoverpa armigera*, *Phthorimaea operculella*, *Plutella xylostella* and *Spodoptera litura*. Larval mortality of the insects under study was higher in cell-free culture filtrates than

in bacterial cell treated condition. Both the cells and cell-free culture filtrates of *Photorhabdus* recorded higher larval mortality compared to that of *Xenorhabdus*. The larvae of *P. xylostella* and *P. operculella* recorded hundred percent mortality in 48 h of exposure to the cell-free culture filtrates, while those of *H. armigera* and *Spodoptera litura* recorded a maximum larval mortality of 58 and 49 percent, respectively. Late instar (3rd) larvae of *H. armigera* and *S. litura* recorded lower mortality compared to their early instars (2nd) when exposed to cell-free culture filtrates of the bacteria.

Botanical pesticides

At SPIC Science Foundation, Chennai, botanical antifungal formulation was field evaluated against leaf spot disease of black gram, green gram and red gram at Vamban. Dosage of antifungal formulation for different crops was determined and its effects on the control of predators and beneficial insects were observed. Large scale production of the formulation and its field demonstration were conducted for paddy, groundnut, grapes, tea and coffee at different locations. Extraction, enrichment and isolation of limonoids from selected Indian Meliaceae plants (*Chukrasia tabulata* and *Xylocarpus mekongensis*) have been carried out. Groundnut rust disease on detached leaves was applied as the antifungal bioassay system for extract fractions and pure compounds of *Chukrasia tabulata*. Methanol extract showed antifungal activity against *Chukrasia lindemuthianum* at 40mg. *Spodoptera febrifuga* extracts inhibited *Phylloscripta* sp., *C. lindemuthianum* and *Pestalotiopsis mangiferae* at 20mg. Neem oil and neem leaf extracts did not show inhibition even at 100mg, where as neem bark extract showed inhibition against *C. lindemuthianum*, *Alternaria alternata* and *Phylloscripta* sp. at 20mg.

Extracts of *Linostoma decandrum*, *Clerodendron inerme* and *Aegle marmelos* have been tested for tea pest management at AAU, Assam. Toxicity of the aqueous extracts was tested against the red spider mite, *Oligonychus coffeae* and the result revealed that the root extract was more toxic than that of leaves. In a multicomponent defense study for insect control at IBRC, Jalandhar, it has been established for the first time that non-azadirachtin type of limonoids are synergistic in specific combinations vis-à-vis the structural chemistry of the compounds. Attempts are being made towards developing useful multi-component formulations where synergistic non-azadirachtin type of limonoids would be quantified as is done in case of azadirachtin. This center has also isolated toosendanin from *Melia dubia* species (which is known to occur in Chinese *Melia toosendan*) and have been found as feeding deterrent for *Helicoverpa armigera* larvae. Efficacy of toosendanin in combination with other allelochemicals of this plant is under investigation.

At IARI, New Delhi characterisation of potential biopesticide molecules from fungal biocontrol agents (*Trichoderma harzianum*) is being done. Secondary metabolites have been isolated and identified by spectroscopic (IR, NMR and Mass) techniques from cultural filtrate of *T. harzianum*. Among the secondary metabolites identified, the 6-pentyl-alpha-pyrone has been found most effective against *Sclerotium rolfsii* (ED50 = 188.32 ppm) and *Rhizoctonia solani* (ED50 = 99.55 ppm). The powdered dried mycelium of *T. harzianum* retained its viability and antagonistic activity against a number of pathogenic fungi even after one year. Secondary metabolites such as palmitic acid; 3-methyl heptadecanol; ketotriol; ergosterol and 6-[3, 6-dihydroxy-7-(2-furano)]-a-pyrone have been isolated and identified from dried hyphae of *T. harzianum*. A method has been standardized for the synthesis of 6-Pentyl-alpha-pyrone.

Studies on the management of three major diseases viz. fruit rot, anthracnose and fruit fly diseases of guava have been undertaken using bioactive compounds from natural plant resources at Bioved, Allahabad. Physico-chemical composition of fruit and fruit yield of seven guava varieties were analysed. Between 30 and 40% losses were recorded by fungal infection due to *Rhizopus stolonifer*, *Gloeosporium psidii*, *Colletotrichum psidii*, *Pestalotia psidii*, *Phomopsis psidii*, *Penicillium notatum*, *Aspergillus flavus*, *Aspergillus niger*, *Alternaria* sp., *Mucor* sp., *Cladosporium* sp. and fruit fly-*Dacus dorsalis* etc. Apple colour variety of guava is more resistant as compared to other varieties. Latex of three plants viz. *Argemone mexicana*, *Carica papaya* and *Croton bonplandianum* at 100% concentration showed the highest inhibition at 94.3%, 93.17% and 89.90% respectively in mycelial growth of *Rhizopus stolonifer*, and at 92.04%, 90% and 88.76% in *Gloeosporium psidii*. *Citrus sinensis*, *Eucalyptus globules*, *Tagetes erecta* and *Ocimum sanctum* oil were found as a repellent botanical insecticide for the control of fruit fly- *Dacus dorsalis* at the concentration range of 0.1% to 0.5%.

Pheromones and semiochemicals

At IICT, Hyderabad, studies on the synthesis and field evaluation of pheromone system is underway for the monitoring /mass trapping of brinjal shoot and fruit borer (*Leucinodes orbonilis*) as a component of IPM. A variable synthetic route for the synthesis of two-pheromone components of brinjal shoot and fruit borer on 5 gm batch size has been developed. Quality assessment of the pheromone components were conducted by capillary gas chromatography followed by field experiments during the Kharif season of 2002.

In a collaborative project at NCL, Pune and MPKV, Rahuri, tritrophic relationship between the host crop and insect pest-natural enemy complex in cotton and chickpea has been established. Two types of olfactometers were fabricated indigenously to study orientation of parasites at NCL, Pune. Colonies of *Helicoverpa armigera* and *Chrysoperla carneae* were established in the laboratory. Bioassays were standardized to study orientation of parasites with the help of Y shaped olfactometer and four volatiles were tested. A filter paper bioassay was standardized to study parasitization and 29 volatiles and plant oils and their combinations were studied for their effect on parasitization. Different parameters such as light intensity, temperature and color were studied to get optimum value for maximum parasitization. Method was also standardized to study EAG responses of both *Trichogramma chilonis* females and *Chrysoperla carnea* females and larvae and EAG responses of total 32 volatiles and green leaf extracts were examined.

Patents:

Patent is being filed by DBT for the position of the proton of a dimer- of phenazine-1-carboxylic acid of a compound from fluorescent *Pseudomonas* exhibiting broad spectrum antifungal activities. Patents have also been filed for the photostability process of neem constituents and also for the development of two effective bioformulations of *Beauveria bassiana*. Patents for the mass production technologies of *Nomuraea rileyi*, *Trichoderma viride*, *Trichoderma virens*, *Beauveria bassiana*, *Verticillium lecanii*, *Myrothecium verrucaria* and for the two effective bioformulation of *bassiana* have been filed.

Popularization of biopesticide technology:

Several extension activities have been organised at the instance of DBT for creating awareness among the farmers on the large scale use of biocontrol agents under IPM. Biopesticide product formulations developed at different centres were distributed among the farmers as a free incentive for use in various regional crops. The extension activities included regional workshops, agroclinics, agrifair, farmers ghosthi, krishi melas and farmers field etc. Besides, training programmes were also organized for farmers and extension functionaries, scientists and progressive entrepreneur on the production and management strategies of biocontrol agents. About 58,000 farmers benefited and around 1700 handouts in various regional languages were published and widely distributed among the agricultural scientists and the end users. DBT has also brought out several technical brochures highlighting the achievements of various projects and giving the details of the technologies developed.

Technology transfer:

Mass production technologies of biocontrol agents/biopesticides have been transferred during the year. Fermentation-based technologies of three biocontrol agents (*Trichoderma viride*, *T. virens*, *Bacillus* spp.) and three biofertilisers (*Rhizobium* spp, *Azotobacter* spp., and *Azospirillum* spp.) have been developed at RRL Jammu and transferred as an integrated package for biopesticides (*T. viride* & *T. virens*). *Rhizobium* Biofertilizers have been transferred to three industries viz., M/s Pratishta Industries Ltd., Secunderabad, M/s Javeri Agro-industries & Investment Co. Ltd., Amrawati and M/s Pragati Biotech, Gurgaon. Mass production technology of *Aspergillus niger* (AN27) has also been transferred to M/s Cadila Pharma, Ahmedabad. Other technologies for *T. harzianum*, *T. chilonis*, *Chrysoperla carnea*, HaNPV and SiNPV and pheromone technology for the management of internode borer of sugarcane and rice yellow stem borer of rice have been standardized and validated.

Since the registration has become a prerequisite for the commercialization of biopesticides, the department has taken suitable measures/ action to facilitate the registration and regulatory procedures. At the initiative of the department, the guidelines for registration have been simplified and streamlined. Department has gone one step further in this direction and decided to evolve an action plan for registration of potential biopesticide technologies which have been developed and validated through R&D efforts. The Dept. is providing support for the generation of toxicological data for registration purpose for identified microbials in a phased manner. In the first phase, toxicological data for about nine microorganisms and their formulations are being generated at two identified CSIR centers.