P K Shukla[1]*, T Damodaran[1], Govind Kumar[2] and Gundappa[3]

Bio-formulations for sustainable fruit production through bio-intensive management

The decline in populations of beneficial organisms, threats to human health, and environmental hazards caused by the excessive use of chemicals in crop production have prompted the search for safer alternatives. India ranks 12th in the world and 3rd in Asia in terms of pesticide consumption. Growing health consciousness has encouraged the adoption of bio-intensive organic farming. Microbes play a vital role in maintaining soil health, enhancing nutrient availability to plants, and managing crop pests. ICAR-CISH has developed and promoted products such as ICAR-FUSICONT, CISH-Bio-enhancer, CISH-Bio-zapper, and CISH-*Beauveria bassiana* for plant health promotion and pest management.

Keywords: *Beauveria bassiana*, CISH-Bio-enhancer, CISH-Bio-zapper, ICAR-FUSICONT, Subtropical fruit crops

THE non-pathogenic microorganisms impact soil health, nutrient cycling, pathogen and insect pest suppression, and enhance plant growth and productivity. Soil microbes are an integral part of the agricultural ecosystem, and their richness improves soil fertility and functioning. Many species of bacteria and fungi inhabit soil, but not all are equally beneficial. Therefore, after isolation and efficacy testing, selected microbes have been utilized to address important issues faced by farmers. Recently, the Institute has developed and promoted products such as ICAR-FUSICONT for wilt disease management in banana, mango, etc.; CISH-Bio-enhancer for promoting soil nutrient use efficiency in different horticultural crops; CISH-Bio-zapper for environmental detoxification; and CISH-*Beauveria bassiana* for the management of several important pests of mango and guava.

ICAR-FUSICONT

ICAR-FUSICONT is a 9(3) registered bio-pesticide developed using the CSR-T-3 strain of *Trichoderma reesei* through joint efforts of the ICAR-Central Institute for Subtropical Horticulture, Lucknow, and ICAR-Central Soil Salinity Research Institute, Regional Research Station, Lucknow, for the management of the dreadful pathogen *Fusarium oxysporum* f. sp. *cubense* Tropical Race-4 and Race 1 in banana using beneficial microbes. Extensive incidence and damage to banana were noticed in Maharajganj, Gorakhpur, Sant Kabir Nagar, and Ayodhya districts of Uttar Pradesh and in Baghalpur, Katihar, and Purnia districts of Bihar, and no control measure seemed competent to save the crop. After initial success of ICAR-FUSICONT in Sohawal block of Ayodhya district during 2019 and 2020, an extensive wilt management program was conducted in all hotspot districts of Uttar Pradesh and Bihar during 2021 to 2023, achieving a 92–95 percent success rate. The technology was commercialized to three firms for global and domestic production. It was also found effective in managing Race 1 strain of *Fusarium* in banana cultivars Elaki, Malbhog, and Sabri. ICAR-FUSICONT technology was granted a non-exclusive license to M/s Innotera Pvt. Ltd., Ahmedabad, for both global and domestic marketing; M/s Khandelwal Biofertilizers, Karnataka, with label claims for both banana and cumin wilt management; and M/s Zytex Biotech, Mumbai. These firms are commercially producing it to make it available in the market. The technology managed the disease in about 35% of the affected area, contributing a net income of Rs. 301 crores annually by saving the crop and increasing yield by about 28% in hotspot regions of the country.

Recently, *T. reesei* was evaluated against the mango wilt pathogen, *Ceratocystis fimbriata*, in the laboratory and ICAR-FUSICONT was applied in mango wilt-affected orchards in several hotspot districts of Uttar Pradesh. Results were highly encouraging, with over 80% recovery of infected mango trees.

Application protocol

- Apply 3% solution of ICAR-FUSICONT @ 0.5 litre per plant at the time of transplanting, followed by @ 1.0 litre per plant 2nd, 5th, 7th, 10th and 12th month after transplanting as soil drench treatment in banana.
- Apply 3% solution of ICAR-FUSICONT @ 3.0 to 5.0 litre per tree with irrigation water in the basin of 2.5 to 4.0 m radius at quarterly interval during the first year and later at 6 months interval in wilt affected orchards of mango.

CISH-Bio-enhancer

This product is a microbial consortium derived from indigenous cow-based natural farming products such as *Panchgavya*, *Beejamrita*, *Amritpani*, *Vermiwash*, and cultivated land. The formulation integrates traditional agricultural wisdom with modern microbiological research, aiming to enhance soil health and plant productivity in a sustainable and cost-effective manner.

The bio-enhancer contains selected beneficial bacteria exhibiting high solubilization of essential nutrients such as phosphorus, potassium, and zinc. These microbes also produce plant growth regulators, such as indole acetic acid and siderophores, which aid iron acquisition and suppress harmful and pathogenic soil microbes. CISH-Bio-enhancer facilitates improved nutrient uptake and activates native soil microbial populations through synergistic interactions in the rhizosphere, restoring ecological balance and soil fertility. The total soil microbe population in treated plots was higher at crop termination compared to control. The result is robust plant growth across a wide range of crops with 30% fertilizer savings.

CISH-Bio-enhancer: Efficiency evaluation

Parameter	Control	Biozapper	Efficiency (% increase)
Capsicum Yield	350 g/plant	650 g/plant	85
Brinjal Yield	1,250 g/plant	1,500 g/plant	20
Tomato Yield	1,550 g/plant	2,300 g/plant	48
Brahmi Yield	8.5 q/ha	10 q/ha	18
Brinjal cv. *Navkiran* (F1)	387 q/ha	405 q/ha	4.6
Maize	65.8 q/ha	69.5 q/ha	5.6

Recommended rate of application of CISH-Bio enhancer

- 8–12 g powder formulation OR 10–20 ml liquid formulation per kg seed
- 100–200 ml liquid formulation (10 CFU/ml) per litre of water for dipping 100 seedlings
- 250–500 ml formulation diluted in 5–10 L water per 100 saplings
- 2–5 L liquid or 2–5 kg powder formulation per ton of compost/FYM
- 2–5 L liquid or 2–5 kg powder formulation per acre, mixed with 100 kg FYM/compost
- 250–500 ml liquid formulation per acre in 150–200 L water
- 500 ml–1 L liquid formulation per tree per year (split in 2–3 doses)

CISH-Bio-zapper

This eco-friendly microbial formulation is developed to tackle agricultural pesticide residues and enhance plant growth. It represents an innovative approach to environmental detoxification and sustainable crop management.

CISH-Bio-zapper is a blend of selected microbes with documented abilities to degrade persistent pesticides such as imidacloprid, carbosulfan, chlorpyrifos, and growth regulators like paclobutrazol. Over 90% of these compounds are degraded in cultivated soil within 30 days. Additional beneficial properties include production of IAA, ammonia, and hydrogen cyanide (HCN); solubilization of phosphorus, potassium, and zinc; and suppression of pathogens such as *Fusarium oxysporum*, *Pythium aphanidermatum*, *Ceratocystis fimbriata*, and *Colletotrichum gloeosporioides*. Each bacterium included in the product was individually evaluated for pesticide biodegradation using GCMS and HPLC. Media optimization for large-scale production ensured compatibility of consortia and growth requirements. Multi-stage pilot and field testing included on-farm validation at research stations and farmers' fields.

Field applications showed CISH-Bio-zapper enhanced brinjal yields to 11 t/ha compared to 4.4 t/ha in controls. It improved plant health metrics and soil enzyme activities (dehydrogenase, FDA) in mango and legume fields.

Application protocol

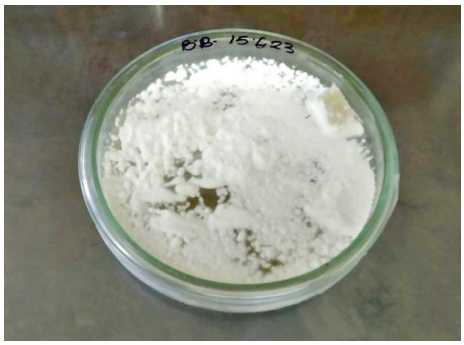
- **Seed treatment**: Mix bio-zapper with water (1:3 ratio) to make a slurry; dip seeds for 2–5 hr. Shade dry and sow immediately.
- **Seedling root dip**: Mix bio-zapper in water; dip roots of seedlings for 2–5 hr.
- **Soil treatment**: Mix 7 kg bio-zapper in 200 kg compost/FYM and incubate for 15–20 days before application.

CISH-Beauveria bassiana

The fungus *Beauveria bassiana* has long been used as a commercial product for insect pest management. *B. bassiana* is a contact insecticide; spores must physically contact the insect cuticle to be effective. Thorough and

CISH-Bio-zapper: Efficiency evaluation

Parameters	Biozapper	Control	Efficiency
Brinjal yield	>11 t/ha	4.4 t/ha	+149% increase
Pesticide degradation	>95% in 30 days	1-2%	Drastic reduction in soil residues
Pathogen inhibition	>95% within 5 days	-	Strong bio-control of soil pathogens
Plant growth promoting (IAA, etc.)	Present	-	Enhanced growth/stress resistance
Fertilizer use	Reduced by 35%	-	Substantial input cost savings
Soil enzyme activity (Dehydrogenase, FDA)	Significant improvement	-	Soil health restored and sustained
Groundwater pollution	Reduced risk	-	Environmental protection



B. bassiana on PDA medium

B. bassiana on rice grains

B. bassiana on insect larvae

even coverage during application is essential. Fungal spores adhere to the insect, penetrate the body cavity, and produce secondary metabolites, including the toxin beauvericin and the antibiotic oosporein, which weaken the host's immune system and outcompete intestinal bacteria. As a generalist feeder, *B. bassiana* controls all life stages of leaf-feeding insects, including aphids, thrips, whiteflies, mealybugs, caterpillars, beetles, and others. Immature stages are generally more susceptible than adults.

A commercial suspension of *B. bassiana* spores has a shelf life of one year when stored at room temperature and longer when stored in the refrigerator at 1–5 °C. Spray mixes should be applied as soon as possible after mixing. Spores remain viable for a longer time when applied to leaf undersides or in the evening due to reduced sunlight exposure. Bio-control of insect pests in crops is necessary for eco-friendly management. Local isolates are better adapted to conditions and play an important role in pest management. A local isolate of *B. bassiana* was found efficient through efficacy tests, and a suitable medium was developed for its economically viable commercial production.

An isolate of *B. bassiana* was developed from guava bark-eating caterpillar larvae. Its survival was recorded from 1 to 44 °C and growth from 9 to 34 °C. It was tested against mango mealy bug under field conditions in January and found effective. A cost-efficient medium was developed for mass multiplication. It was later tested against several mango (midge, mealybug, hopper, thrips, leaf webber, semiloopers) and guava (bark-eating caterpillar) insect pests using standard protocols and found highly effective @ 5 g/l containing 10^8 spores/g. Reduced rates (10^3–10^5 spores/ml) were also effective under favorable conditions. Recommended application is 1 ml or g of formulation containing 10^8 spores per litre of water for spray. Foliar spray should be avoided under hot, dry conditions.

CONCLUSION

The use of ICAR-FUSICONT for wilt disease management; CISH-Bio-enhancer for promoting soil nutrient use efficiency; CISH-Bio-zapper for detoxification of pesticide residues; and CISH-*Beauveria bassiana* for pest management indicates that these products are highly suitable for integrated crop management. Since subtropical fruit crops are mostly perennial, chemical interventions are limited during the year, creating significant scope for biological products to be applied at specific phenological stages for crop growth promotion and pest management.

For further information, please write to:
[1]ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow 226 101; [2]ICAR-Directorate of Medicinal and Aromatic Plants Research, Boriavi 387 310; and [3]ICAR-National Bureau of Agricultural Insect Resources, Bengaluru 560 024; *Corresponding email: pksmush@gmail.com