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In addition, PGP microbes have useful traits for tolerating abiotic stresses like extreme temperatures, pH, salinity and drought, as well as heavy metal and pesticide pollution. The application of PGP microbes in the field is expected to enhance crop growth and yield even when the plants are under a combination of stresses. It is therefore essential to generate comprehensive knowledge on potential strategies for screening, characterizing and formulating beneficial PGP microbes, while gaining insight into the molecular mechanisms underlying their action and evaluation at field levels. Identifying such potential rhizobial and other PGP microbes and developing a robust technology could be useful for integrated pest management (IPM) and integrated nutrition management (INM) programs, while also reducing the need for external inputs such as synthetic fertilizers and pesticides. ICRISAT research is focused on the effects of such PGP bacteria on nitrogen fixation, P-solubilization, growth promotion and against various biotic (including insect pests and diseases) stresses on our mandate crops, including chickpea, pigeonpea, groundnut and sorghum, which are staples in the semiarid tropics. ICRISAT has demonstrated **the usefulness of 16 PGP *Streptomyces* strains for their growth promotion and yield enhancement traits under rice, sorghum, chickpea and pigeonpea crop field conditions. Further, three secondary metabolites have been purified from these strains, including two against pod borers and one against charcoal rot disease in sorghum. Whole genome sequences of these strains have also documented and published.**

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Plant extracts as an alternative to insecticide treatments in sub-Saharan Africa

In sub-Saharan African countries, as in most countries worldwide, ethnopharmacology relates to the use of plants in traditional medicine. Some plants are also used in the form of aqueous extracts or essential oils for the protection of crops against pests and diseases both in the field and granaries. This provides a partial alternative to synthetic insecticide treatments, or even a total alternative in organic farming conditions. Ready-made formulations are seldom available and are mainly based on natural pyrethrum extracts from *Tanacetum cinerariifolium* (Asteraceae) or neem (*Azadirachta indica*, Meliaceae). The challenge is to identify new plant species based on plant diversity studies and traditional/academic knowledge, and then to disseminate this knowledge to end users, i.e. farmers, NGOs, consultants and researchers.

Plant extract uses under experimental conditions or in common practice have been inventoried in the Knomana knowledge base*. This knowledge base was built from publications compiled by members of an informal network of researchers from 13 French-speaking African countries**. Following an extension of the research to encompass other geographical areas, as well as animal and human health fields, **Knomana now includes 44,300 usage descriptions (January 2021). This includes a broad range of information, such as scientific names of plants and active ingredients of extracts used, scientific names of target organisms and protected crops. Overall, 2,543 plant species are listed as having been tested against 720 target pest species.** The focus is currently on plant usage toxicity risks to humans and other non-target organisms. Assessment of these risks—which may generate further insight to supplement Knomana—is a crucial goal with regard to the EcoHealth approach.

* Knowledge management on pesticidal plants in Africa: https://ur-aida.cirad.fr/nos-recherches/projets-et-expertises/knomana

** Benin, Burkina Faso, Cameroon, Central African Republic, Côte d'Ivoire, Democratic Republic of the Congo, Gabon, Madagascar, Mali, Mauritania, Niger, Senegal and Togo.

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▼ *Preparation of an aqueous plant-based extract in Senegal.* © M. Dione

▶ *Plant extracts used in cotton crop fields in Paraguay.* © P. Silvie