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## Assessment of the effects of ionizing radiation in bees – BEERAD

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Human activities linked to nuclear industry generate ionizing radiation (IR). The risk assessment linked to the radiocontamination of the environment after a nuclear accident is a major ecological issue but is still surrounded by controversial results and conclusions on the real impact of such events on flora and fauna inhabiting the targeted zones. Moreover, the potential underlying mechanisms of the action of IR are poorly known. Therefore, it is important to acquire data on the potential effects of IR on ecosystems both in experimental and realistic conditions.

The BEERAD project (ANR-21-CE34-0002, 2022-2025) proposes using the honeybees as a model to study the effects of IR on major physiological functions, and also at individual and population levels. Honeybees are insects of economic, agro-environmental, societal and scientific importance.

The objective of this project is to increase the knowledge of effects and mechanisms of action of IR on physiology and populations of honeybees in the context of chronic exposure (i.e., exposure of a significant period of time relative to the lifespan of exposed organisms) and at low dose rates (sublethal ecotoxicity) in realistic conditions, i.e., on the field and in the laboratory.

The main objectives are:

- To define the exposure conditions both in laboratory and field experiments (in order to compare results obtained via these two approaches) and measure external (micro-dosimeters) and internal dose rates, to give a more precise estimate of the total dose rates absorbed by the bees
- To measure the physiological and toxico-pathological effects induced by IR at sub-individual levels (molecule, cell and tissue), particularly with response to an infectious agent
- To measure the effects induced by IR at individual and populational levels through the effects on reproduction/development and cognitive process
- To compare both types of exposure (laboratory/field), integrate the responses and extrapolate to other living organisms (other bee species, other pollinating insects) through modelling in order to conclude on the level of effects of IR on bees and other pollinating insects

A double approach of experiments conducted in field and in laboratory is realized.

In the laboratory, we use large and small scale irradiation facilities. The delivered dose rates via this irradiation facility are precisely known and will be monitored using micro-dosimeters.

In the field experiments, we work in the difficult-to-return zone around the Fukushima Daiichi Nuclear Power Plant. Six sites were selected according to their levels of radioactive contamination in order to implement beehives.

The project is being conducted by using skills of INRAE (expertise of the biological model, analyses of and individual biomarkers, physiological disturbances and of population indicators) IRSN (expertise in the radiological exposure, measurement of exposure to radionuclide and calculation of the total dose, tools for irradiating animals at increasing dose rates of gamma irradiation) and IER (Institute of Environmental Radioactivity) in Fukushima (knowledge of the zones, authorizations to conduct experiments, monitoring beehives).

In both laboratory and field experiments, the effects of IR on honeybees are studied by combined approaches at molecular, cellular and tissue levels. We aim to determine the impacts of radiation on great physiological functions that conditioned key events for the survival of individuals and the colony (colony behavior, reproduction, development, cognitive performances). We consider not only the direct physiological impacts in bees submitted to an irradiation stress but also the resilience of the bees and bee colonies after an irradiation period. We also evaluate the effects of IR on sensitivity of bees to pathogens. For all experiments, all measured effects (physiological, population, etc.) will be analyzed in relation to the total dose rate absorbed by bees.

Finally, we intend to conduct modelling studies with two different objectives: (i) to predict early adverse events that could occur in colonies exposed to radiation and (ii) to extrapolate the results obtained with the bees to other species.

The presentation will give an overview of the first two years of the project, main results and achievements, and the perspectives for 2025.

**Keywords:** ionizing radiation, honeybee *Apis mellifera*, physiology, biomarkers, Fukushima Daiichi NPP

