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PROTOCOL TO DETECT AND ASSESS POLLINATION DEFICITS IN CROPS: A HANDBOOK FOR ITS USE

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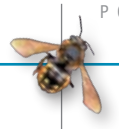

PROTOCOL TO DETECT AND ASSESS POLLINATION DEFICITS IN CROPS: A HANDBOOK FOR ITS USE

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PREFACE

In agro-ecosystems, pollinators are essential for orchard, oilseed crop, horticultural and forage production, as well as the production of seed for many root and fibre crops. Pollinators such as bees, birds and bats affect 35 percent of the world's crop production, increasing outputs of 87 of the leading food crops worldwide, plus many plant-derived medicines in the world's pharmacies.

Just as the agricultural community is taking stock of the contribution of pollination to crop production, populations of managed pollinators (the Western honey bee *Apis mellifera*, the Eastern honey bee *Apis cerana*, and their Asian relatives) are experiencing new and poorly understood threats. Wild pollinators in agricultural landscapes can provide important pollination services and serve also as a critical form of insurance against the risks of pests and diseases amongst managed pollinators.

Within the context of its lead role in the implementation of the Initiative for the Conservation and Sustainable Use of Pollinators (also known as the International Pollinators Initiative-IPI) of the United Nations Convention on Biological Diversity adopted in 2000 (COP decision V/5, Section II), FAO has established a "Global Action on Pollination Services for Sustainable Agriculture". FAO has also developed a global project, supported by the Global Environment Facility (GEF) through the United Nations Environment Programme (UNEP) entitled "Conservation and management of pollinators for sustainable agriculture, through an ecosystem approach". Seven countries (Brazil, Ghana, India, Kenya, Nepal, Pakistan and South Africa) have worked together with FAO to identify and carry out targeted activities that can address threats to pollinators in agricultural landscapes. The outcomes of the global project are expected to expand global understanding, capacity and awareness of the conservation and sustainable use of pollinators for agriculture.

As a contribution to the IPI, FAO and its partners have collaborated with INRA (Institut National de la Recherche Agronomique, a public research body of the French government) to develop a protocol for assessing and detecting if a crop production system is suffering a pollination deficit. Field testing and adaptation of the protocol for the variable cropping systems in different countries was made possible through a grant from the International Fund for Agricultural Development (IFAD) on the "Development of Tools and Methods for Conservation and Management of Pollination Services for Sustainable Agriculture", in 2009 and 2010. This document thus presents a handbook for the application of the protocol, outlining the underlying concepts, the hypothesis to be tested, and the modification and application of the protocol to a variety of circumstances in developing countries, such as small fields, home gardens, and high environmental variability. As the protocol is applied, FAO and its partners will be able to provide information on the results of detecting and assessing levels of pollination deficit in crops important for nutrition and food security around the world.

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INTRODUCTION

The following describes a protocol to be applied to focal crops at the farm scale level to (i) detect and assess pollination deficits in field situations in a standard and statistically testable way; and (ii) draw management conclusions from the proposed experiment for possible action to eliminate or at least reduce these deficits. It can also be used simply to assess pollinator density and diversity on a focal crop for comparison purposes among different sites.

Pollination is the transfer of pollen from the producing anthers to the receptive stigma and it is an essential preliminary step for the sexual reproduction of flowering plants. Pollination level can be precisely measured as the number of compatible and viable pollen grains that reach a stigma during the effective pollination period, and it is therefore directly related to yield for all crops in which the output is a product of sexual reproduction. Indeed, pollination management should be regarded as a production factor in its own right for all these crops as it can affect the agronomic yield and its many components such as fruit set and seed set, fruit quality (e.g. size, aspect, sugar content, flavor and nutritional content), seed quality (e.g. germination rate, oil content), and other characteristics such as earliness and uniformity of output (e.g. rape *Brassica napus* L.: Lerin 1982, Sabbahi *et al*. 2006), market value and profitability, and finally the environmental and societal impacts of a crop (McGregor 1976; Free 1993).

FAO facilitates and coordinates the International Initiative for the Conservation and Sustainable Use of Pollinators (IPI: http://www.internationalpollinatorsinitiative.org/), which was established in 2000 by the Fifth Conference of Parties of the Convention on Biological Diversity. One of the objectives of the IPI is to promote the conservation and the restoration and sustainable use of pollinator diversity in agriculture and related ecosystems based upon the four elements of the IPI Plan of Action: assessment, adaptive management, capacity building, and mainstreaming. It is in this context that FAO commissioned in 2008 a literature review on

the topic of detecting and assessing pollination deficit in crops. This review study then served as background for an expert workshop to identify methods for detection and assessment of pollination deficit in crops and develop a practical yet efficient protocol to assess such deficits. This FAO-sponsored workshop was held on 3-5 April 2008 nearby Avignon, France, under the auspices of INRA (Institut National de la Recherche Agronomique) with 13 participants from around the world (Figure 1.1).

The workshop considered two perspectives that establish the context for a focus on pollination deficits and human livelihoods: (i) from a pollinator perspective, pollination crises appear increasingly likely, as evidence of pollinator declines become more and more apparent in numerous locations; and (ii) from a plant perspective, there are many potential drivers of increasing pollination deficits such as lack of compatible pollen for self-incompatible and dioecious species, and reduced pollen production and/or poor pollen quality due to genotype and its interaction with nutrient status, water deficits or other aspects of growing conditions. Climate change may be contributing to pollination deficit by affecting the phenology of both the plant and its pollinators in different ways so as to lead to asynchrony, or reducing the durations of pollinator activity and plant flowering.

The workshop then examined the definitions, concepts and theory of pollination deficits and pollen limitation in broad terms. The context of 'optimal pollination' from a plant perspective (fitness) is clearly different from that of a farmer's perspective (agronomic or economic yield), and also from the perspective of sustainable development (which may be more oriented toward long-term sustainability and reliability depending on the area ; Figure 1.2). With this background, the workshop participants agreed on the following definition: **Crop pollination deficit refers to inadequate pollen receipt that limits agricultural output**. The review of the methods used to assess pollination deficit in crops was based on 67 papers. The synthesis of this large array of case studies was conducted along 3 axes: (i) the dependent variable(s) used to assess pollination deficit (e.g. number of pollen tubes per style or pollen grains per stigma, fruit set, seed set, fruit characteristics, or seeds characteristics); (ii) the experimental unit used in the assay (a sample of flowers, of branches, a whole plant, a plot or a whole field or larger area); and (iii) the demand of the crop, that is the intrinsic pollination need for optimal field productivity based upon the sexual reproductive biology and physiology of the crop, the temporal scale of the demand (duration of flowering: determinate versus undeterminate species), the spatial scale of the demand (field size and landscape pattern), and the production strategy (e.g. off-season production of covered crops). The main methodological problems and possible improvements

Figure 1.1

PARTICIPANTS IN THE FAO-SPONSORED EXPERT WORKSHOP ON *ASSESSING POLLINATION DEFICITS IN CROPS*

From left to right: Jim Cane (USDA, Logan, Utah, USA), Resham Bahadur Thapa (Institute for Agriculture and Animal Sciences, Chitwan, Nepal), Paulo Eugênio Oliveira (Universidade Federal de Uberlândia, Brazil), Jérôme Vandame (INRA Avignon, France), Wanja Kinuthia (National Museums of Kenya, Nairobi, Kenya), Barbara Gemmill-Herren (FAO Rome, Italy), Simon Potts (University of Reading, UK), Bernard Vaissière (INRA Avignon, France), Linda Collette (FAO Rome, Italy), Ruan Veldtman (South African Biodiversity Institute, Cape Town, South Africa), Breno Freitas (Universidade Federal do Ceará, Fortaleza, Brazil), Natacha Chacoff (Centro Regional de Investigaciones Cientificas y Tecnológicas, Mendoza, Argentina).

Figure 1.2

OPTIMAL POLLINATION LEVELS - WITHIN THE RESOURCE ALLOCATION PATTERNS OF THE CROP

Cocoa (*Theobroma cacao* L.) flowers, and the subsequent pods, are borne on the trunk of the cocoa tree. On average, only about 5 percent of flowers on a cocoa tree will give rise to a mature pod (Free 1994). In a study where all the flowers on a cocoa tree were hand-pollinated, the yield of the tree exceeded the yields of all other cocoa trees; but the tree died the next year (Falque *et al.* 1996)! It is most often the case that optimal yields are considerably less than 100 percent fruit or seed set, and a certain percentage of flowers abort.

in assessing pollination deficits were then reviewed with the clear goal to develop a practical ready-to-use protocol that could be readily implemented to detect and assess pollination deficits for the major crops in the seven countries that are taking part in the GEF/UNEP/FAO project on the "Conservation and Management of Pollinators for Sustainable Agriculture through an Ecosystem Approach" (Brazil, Ghana, India, Kenya, Nepal, Pakistan and South Africa). It is this protocol that has been refined, detailed and improved in concert with stakeholders and end-users that is presented here.