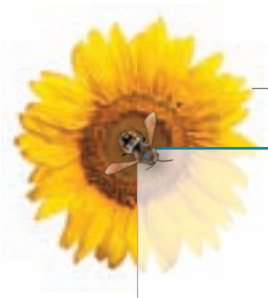


SECTION 7
PRODUCTION DEPENDENT VARIABLES AND SAMPLING UNITS

Many variables have been used to assess the impact of pollination level on crop output. These include variables related to pistil characteristics (e.g. number of conspecific pollen grains per stigma, number of pollen tubes per style, and the proportion of fertilized ovules), to the initiation of fruits (e.g. fruit set and seed set), to agronomic yield expressed in weight or number of produce per unit area, and economic yield expressed as gross or net return per unit area in local currency.

7.A. AGRONOMIC YIELD

Yield variables are usually not available until a long lag time after flowering and many factors not related to the pollination level during flowering can interfere with the production output and thereby confound the effects of the pollinator treatment. Also yield data are not always easy to record. In particular, plants with indeterminate flowering may require repeated harvesting of the marketable produce over the whole production season (e.g. vegetables such as green bean *Phaseolus vulgaris* var. *vulgaris* L., eggplant *Solanum melongena* L., pepper Capsicum annuum var. annuum L.), tomato *Lycopersicon esculentum* var. *esculentum* Mill. and zucchini *Cucurbita pepo* L., and also some fruits such as mango *Mangifera indica* L. and strawberry *Fragaria ananassa* Duchesne ex Rozier). Also, for perennial crops, the harvest should be measured over two seasons to avoid the confounding effect of alternate bearing on different trees and orchards. Nonetheless, because the protocol is aimed at gathering data meaningful for farmers, despite their shortcomings yield variables will be the only ones considered here.

As indicated previously (Section 2), crop plants can compensate for pollen limitation with longer flowering periods and greater flower production. In addition, fruit set and seed set can be resource-limited, and thereby the results obtained by increasing pollination levels on a subset of

flowers on a plant may result in larger fruit and more seeds from those flowers, but not greater overall production on a plant basis (Knight *et al*. 2005). As a consequence of these two important mechanisms, **it is essential when considering agricultural output that the whole plant be used as the smallest sampling unit rather than individual flowers or a sample of flowers regardless how large**. Therefore, the proposed yield measurements are based on the whole plant as smallest sampling unit, that is the yield will be calculated on the basis of a sample of individual plants, a set of plots or the whole field. For each, the pros and cons are examined below. Those applying the protocol can select the best sampling units for their focal crop and study fields to measure the agronomic yield and the quality of the output, the only requirement being that the same sampling units be used in all study fields inasmuch as possible.

7.A.1 Individual plants

Pros and cons

→ Natural yield unit from a farmer's standpoint (especially for trees).
→ Biological unit, reflecting an integrated response to the treatment.
→ Applicable in mixed cropping systems.
→ Provides intrafield variability (usable with gradient within field).

← Needs plant density at harvest to calculate yield.
← Does not control for resource allocation between years unless recorded over several years.
← Not possible for some crops when plants are highly intermingled at harvest (buckwheat, rape).
← Variability among plants often very large.
← Mechanical harvest usually not possible except for some tree crops.

7.A.2 Recording plot (unit length of row or unit area of study field)

Pros and cons

→ Useful when individual plants are too intermingled (buckwheat, rape).
→ By recording plot size, result are directly expressed in yield units meaningful for farmers.
→ Amenable to mechanical harvest.
→ Provides intrafield variability (usable with gradient within field).

← May require more work than individual plants for harvesting.
← Not applicable in mixed cropping systems.

7.A.3 Whole study field

Pros and cons

- → Data can often be obtained directly from farmer.
- → Direct measurement of commercial yield over the whole study field.
- → Meaningful for farmers and the public.

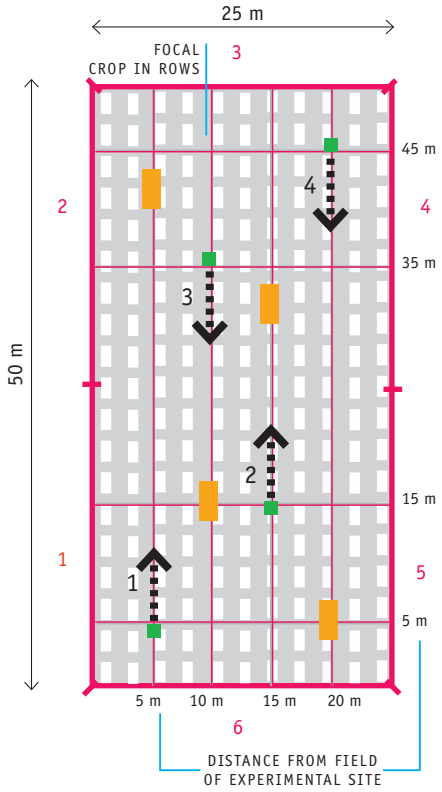
- ← Farmers may be reluctant to provide data.
- ← No measurement of intrafield variability (not usable for gradient within field).
- ← Between field variability can easily confound the link to pollination level (water availability; fertilizer; pest control).

From a practical standpoint, whenever possible, it is best to obtain the yield data from individual plants or from plots that are a given length of row (e.g. Aras *et al*. 1996, Vaissière *et al*. 1984). For instance, in a melon *Cucumis melo* L. field where it is difficult to distinguish plants, the yield plot could be taken as 2 meters of a row. The layout for such sampling units is presented in Figures 7.1, 7.2 and 7.3 and some examples of data sheets to record such data are provided in Annexes 11 to 14. When individual plants are harvested as in mixed planting systems, it is best to harvest adjacent plants that are located in the same general area as the proposed plots (Figures 7.1 and 7.2). In general, it is best to harvest a minimum of 2 plants per plot (e.g. trees for orchard crops) and up to 10 plants or more per plots for herbaceous determinate crops. Produce should be harvested when fully mature and right before commercial harvest.

Once a produce is harvested, it may be possible to measure quality characteristics of all or a sample of the production units if time, budget and available technology permits. No special protocol will be provided here for these measurements as they will clearly vary from one crop to another, be a function of the analytical tools available locally for these analyses, and may also be context specific, that is dependent upon the requirements of a specific market. For example in Kenya, the pods of export-grade runner beans (*Phaseolus coccineus* L.) must be straight shaped and measure between 24 and 27 cm in length and anything smaller or beyond this range is considered a reject. Poor pollination leads to missing seeds resulting in sickle-shaped beans that are no longer acceptable for the export market.

Figure 7.1

LAYOUT OF YIELD PLOTS IN FIELD PLANTED WITH ROW CROP



Yield plot (length of 1 to 5 m of row, or 5 to 10 adjacent plants)

LOCATION OF PREVIOUS SAMPLES, FROM FIGURE 6.1:

i Scan sampling to measure pollinator density (Plot No. i with 100 to 500 flowers depending on crop)

j Net captures to measure pollinator diversity (Subunit No. j of a standardized transect consisting of six 25-m long subunits for insects capture over a 2-m width for 5 minutes)

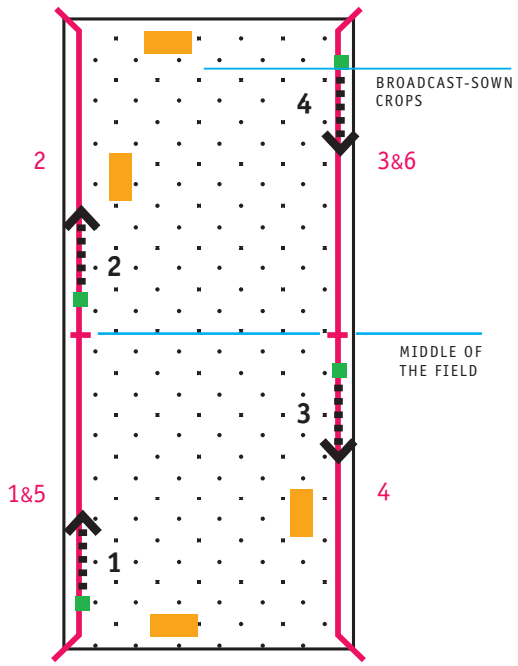
[Plot to assess floral mass]

Sampling should be carried out under good weather conditions for pollinator foraging: Sunny if possible, low wind, vegetation dry, and daily maximum temperature > 15°C

[covariable recordings in brackets]

Figure 7.2

LAYOUT OF YIELD PLOTS IN SMALL FIELD WITH A BROADCAST-SOWN CROP (E.G. MUSTARD/RAPE OR BUCKWHEAT)



Yield plot (l1 m^2 area, or 5 to 10 adjacent plants) located at least 2 m from edge of field inasmuch as possible

LOCATION OF PREVIOUS SAMPLES, FROM FIGURE 6.2:

i Scan sampling to measure pollinator density

j Net captures to measure pollinator diversity

[Plot to assess floral mass}

[optional recordings in brackets]

Examples of data on quality than can be recorded are:

- For fruit and vegetable crops: average size (e.g. diameter, circonference, shape, weight; Figures 1.4, 1.8, 7.4 and 7.5), number of filled seeds (e.g. apple; cucurbits), quality of the flesh consumed (sweetness, flavor; e.g. with tomato Hogendoorn *et al*. 2010).
- For nut crops: average size (e.g. diameter, circonference, weight).
- For oilseed crops: seed size, oil content, quality parameters of the oil (Barbier *et al*. 1967).
- For seed crops for planting: germination rate, quality parameters for seed industry (Kevan and Eisikowitch 1990).

7.B ECONOMIC YIELD

If the price paid to the producer per production unit is known, it may also be possible to assess the yield of each harvesting unit (plant, plot or field) in economic terms, that is expressed in local currency or an international standard.

Pros and cons

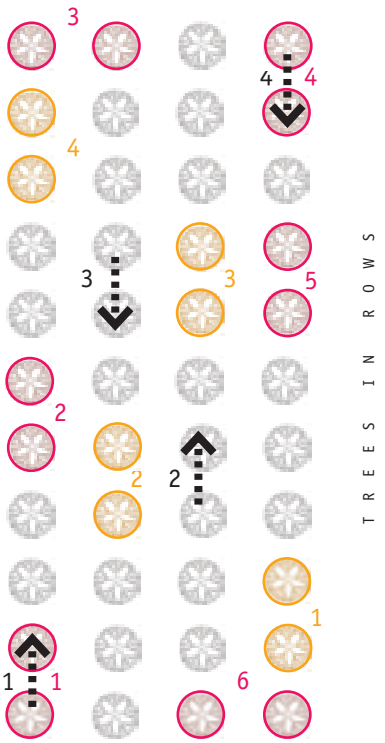
→ Meaningful variable for farmers and consumers.
→ Meaningful for government and policy makers.
→ May assist farmers to record proper documentation.
→ May also include non-market values, e.g. nutritional valu.

← Farmers may be unwilling to share the price at which they sold their crop.
← Very context specific.
← Can be very volatile from one season to the next.
← Lack of accepted methodology (interdisciplinary).
← Link to pollination deficit may be tenuous and difficult to establish.
← Usually beyond the control of individual farmers.

If at all possible, the producer price should be obtained for the production of each study field so as to provide some input data for the economic analyses of the impact of adopting pollinator-friendly practices.

Figure 7.3

LAYOUT OF YIELD PLOTS IN AN ORCHARD WITHOUT POLLENIZER TREES



k — Yield plot (2 adjacent trees of the production variety), located at least 1 row away from the edge of the orchard inasmuch as possible

LOCATION OF PREVIOUS SAMPLES, FROM FIGURE 8:

i — Scan sampling to measure pollinator density (Plot No. i with 100 to 500 owers or panicles depending on crop)

j — Net captures to measure pollinator diversity: Subunit No. j of a standardized transect consisting of six 25-m long subunits for insects capture over a 2-m width for 5 min

Figure 7.4

IMPACT OF POLLINATION LEVEL ON STRAWBERRY QUALITY

© Kristine Kreweka Agroecology, Göttingen, Germany

Strawberries after open insect-pollination (left), passive self-pollination (center), and passive self-pollination plus 75 percent of the incident airborne pollen flow (right). Pollination can have a strong impact on agronomic yields and produce quality.

Figure 7.5

IMPACT OF POLLINATION ON MARKET VALUE

Because adequate pollination has a direct and positive effect on fruit size, symmetry and overall appearance, it is especially important for small farmers who sell their produce at a road stand as here nearby Nairobi in Kenya.

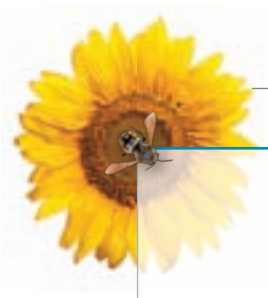
SECTION 8
STATISTICAL ANALYSES

With a completely randomized design with one factor with two levels (e.g. Figure 3.2), control sites without introduced pollinators will have a factor value set at 0 while fields with introduced pollinators using a fixed stocking rate will have a factor value set at 1. The values of the dependent variables for the two groups will then be easily contrasted using usual one-way ANOVA procedures. When pairs or blocks of fields are used, similar methods can be used using adapted ANOVA procedures. When a factorial design is used for a combination of two treatments (e.g. Figure 3.3), a two-way ANOVA should be used so as to be able to test the effect of interaction between the two factors.

This will probably not be so with the distance to the closest patch of natural habitat or the proportion of natural habitat in a 2 km radius around each study field as those values are continuous and will probably vary from field to field along a gradient so that regression analyses may be more appropriate to analyze the results of the landscape treatments.

For large fields with a gradient of distances from the pollinator front, ANOVA with contrasts or regression methods should be used depending on the number of distances set from the pollinator front.

In all cases, it will also be of interest to look at the correlation between forager density and diversity on one hand and the yield variables on the other, as in Hoehn *et al.* (2008). This will be especially important in drawing appropriate management conclusions from the studies conducted using the proposed protocol.



SECTION 9
GENERAL CONCLUSIONS

The present protocol was developed for use by the seven countries 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 by no means meant to be restricted to these countries. Indeed, this protocol has been developed so as to encompass the largest array of crops and situations possible. It is anticipated that it can be used over a wide range of crops and in many countries so that it becomes possible to better document the pollination situation for as many animal-pollinated crops as possible on a worldwide basis. It is therefore hoped that many people will find this protocol useful and will adopt it and share their experience with it in return and provide feedback so as to improve it. This protocol can be downloaded for free on the web site at

http://www.internationalpollinatorsinitiative.org/jsp/documents/documents.jsp;

a discussion forum on the use of this protocol is available at

http://www.fao.org/agriculture/crops/core-themes/theme/spi/gppp/gppp-home/en.

Finally, it should be stressed that this protocol is aimed to address pollination as a production factor at the farm scale level. As such, one should always remember that, as a production factor in its own right, pollination management needs to be fully integrated into the overall farm management system to optimize production in a holistic and sustainable way.

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POLLINATION DEFICIT ASSESSMENT STUDY – FIELD CHARACTERISTICS

COUNTRY: _____ **SITE :** _____ **YEAR :** _____

FIELD NUMBER _____ **COMMON NAME OF FOCAL CROP** _____

FIELD LOCATION & SURROUNDINGS

(GPS COORDINATES) LONGITUDE _____ LATITUDE _____ ALTITUDE (M) _____

TOPOGRAPHICAL SITUATION (HILL TOP, ON SLOPE, VALLEY BOTTOM, PLATEAU,…)

TYPE OF HOLDING (SMALL FARMER OR LARGE FARM) _____ SOIL TYPE _____

SOIL PREPARATION

HEDGE SUROUNDING THE FIELD YES / NO

MAIN PLANT SPECIES IN THE HEDGE

DISTANCE OF FIELD TO CLOSEST PATCH OF NATURAL HABITAT (M ; PATCH ≈ > 0.4 ha = 1 ACRE IN SURFACE)

FIELD SIZE (HA OR ACRE) & APPROXIMATE DIMENSIONS

FOCAL CROP

SPECIES SCIENTIFIC NAME

PRODUCTION VARIETY

VARIETY POLLENIZER IF PRESENT (FRUIT TREES)

ORIGIN OF SEEDS OR SEEDLINGS (GRAFTED ?)

CULTURAL PRACTICES

PLANTING DATE **PLANTING DENSITY** (# PLANTS OF THE FOCAL CROP /UNIT AREA)

TYPE OF PLANTING ROWS / BROADCAST / RANDOM * **TYPE OF STAND** MONOCULTURE / MIXED PLANTING*

RATIO OF POLLENIZER TREE / PRODUCTION TREE (FOR DIOECIOUS CROPS & FRUIT TREES)

DISTANCE BETWEEN ROWS (M)

DISTANCE AMONG PLANTS WITHIN ROWS (M)

** CROSS ITEM THAT DOES NOT APPLY*

SHEET NUMBER____

ANNEX 2:
DATA SHEET TO RECORD POLLINATOR DENSITY ON PLOTS OF AN HERBACEAOUS CROP

Density of insect pollinators in open pollinated flowers (scan sampling)

COUNTRY: **BRAZIL** SITE : **PETROLINA** FOCUS CROP : **CANTALOUPE (*Cucumis melo*)** YEAR :

				RECORDING CONDITIONS					NUMBER OF FLOWER VISITORS				
									HONEY BEES		OTHER BEES	OTHER	
Field number & size (ha)	**TREATMENT**	**Date & observer**	**Recording number**	**Time at start**	**Period**	**Weather conditions**	**Plot number**	**Number flower observed**	***Apis mellifera***	**Bumble bees**	**other wild bees**	**(including drone flies Syrphidae)**	**Remarks**
1 to **10**	Honey bee colony nearby **present / absent***		1, 2, 3, 4	**1000 h, 1200 h, 1400 h, 1600 h**	**Morning or Afternoon**	Sunny, overcast, wind level (instantaneous temperature if available)	**1** or **2** or **3** or **4**		**scan sampling** : the insect(s) must be present at the very time when the inside of the flower is first seen				
			0 ≈ prior to colony introduction *(if applicable)*				1	200					
							2	200					
							3	200					
							4	200					
			1				1	200					
							2	200					
							3	200					
							4	200					
			2				1	200					
							2	200					
							3	200					
							4	200					

* Indicate the number of colonies of *Apis mellifera* nearby the study field & whether these colonies were present or introduced at onset of flowering

SHEET NUMBER____

ANNEX 3:

DATA SHEET TO RECORD POLLINATOR DENSITY ON ORCHARD TREES IN PLOTS LOCATED ALONG A GRADIENT OF DISTANCES TO POLLINATOR FRONT

Density of insect pollinators in open pollinated flowers (scan sampling)

COUNTRY: **GHANA** SITE : _____ FOCUS CROP : **MANGO** (*Mangifera indica)* YEAR : _____

PRODUCTION VARIETY : _____

						RECORDING CONDITIONS					NUMBER OF FLOWER VISITORS					
											HONEY BEES	OTHER BEES		FLIES	OTHER	
Orchard number & size (ha)	**Location**	**TREATMENT**	**MEAN DISTANCE OF TREES IN EXPERIMENTAL PLOT TO POLLINATOR FRONT**	**Date & observer**	**Recording number**	**Time at start**	**Period**	**Weather conditions**	**Plot number** (2 adjacent trees / plot)	**Number of inflorescence with ≥ 1 open flower surveyed**	***Apis mellifera***	**Stingless bees**	**other wild bees** (including carpenter bees)	**FLIES** (Syrphidae & others)	**OTHER** (including wasps)	**Remarks**
1 to 5		Honey bee colonies present or brought or not*	m		0 ≈ Prior to colony introduction (if applicable), 1, 2, 3, 4	0800-1000 h, 1000-1200 h, 1200-1400 h, or 1400-1600 h	Morning or Afternoon	Sunny, overcast, wind level, (intantaneous temperature if	**1** or **2** or **3** or **4**		**scan sampling** : the insect(s) must be present at the very time when the flower is first seen					
* Indicate the number of colonies of *Apis mellifera* nearby the study orchard & whether these colonies were present or introduced at onset of flowering																
			60						1	100						
									2	100						
									3	100						
									4	100						
			210						1	100						
									2	100						
									3	100						
									4	100						
			360						1	100						
									2	100						
									3	100						
									4	100						
			510						1	100						
									2	100						
									3	100						
									4	100						

SHEET NUMBER____

Density of insect pollinators in open pollinated flowers (scan sampling)

COUNTRY: **INDIA** SITE : **MOHAL, KULLU** FOCUS CROP : **APPLE (*Malus x domestica*)** YEAR :

					RECORDING CONDITIONS						NUMBER OF FLOWER VISITORS						
											HONEY BEES		OTHER BEES		DRONE FLIES (Syrphidae)	OTHER	
Orchard number & size (ha)	Location	TREATMENT	Date & observer	Recording number	Time at start	Period	Weather conditions	Tree type*	Plot number (2 adjacent trees / plot**)	Number of open flowers surveyed	*Apis cerana*	*Apis mellifera*	Bumble bees	other wild bees			Remarks
1 to 10		Honey bee colonies brought or present or not*		1, 2, 3, 4	1000–1230 h or 1330–1600 h	Morning or Afternoon	Sunny, overcast, wind level, (intantaneous temperature if available)		**1** or **2** or **3** or **4**		**scan sampling** : the insect(s) must be present at the very time when the flower is first seen						
* Indicate the number of colonies of *Apis cerana* and/or *Apis mellifera* nearby the study orchard & whether these colonies were present or introduced at onset of flowering																	
				0 ≈ prior to colony introduction *(if applicable)*				production	1	250							
								pollenizer	**1**	**250**							
								production	2	250							
								pollenizer	**2**	**250**							
								production	3	250							
								pollenizer	**3**	**250**							
								production	4	250							
								pollenizer	**4**	**250**							
				1				production	1	250							
								pollenizer	**1**	**250**							
								production	2	250							
								pollenizer	**2**	**250**							
								production	3	250							
								pollenizer	**3**	**250**							
								production	4	250							
								pollenizer	**4**	**250**							

SHEET NUMBER____

Density of insect pollinators in open pollinated flowers (scan sampling)

COUNTRY : **NEPAL** SITE : **CHITWAN, TERAI** FOCUS CROP : **SQUASH (*Cucurbita moschata*)** YEAR :

				RECORDING CONDITIONS				NUMBER OF FLOWER VISITORS					
								HONEY BEES		OTHER BEES		OTHER	
House	**Pollinator treatment***	**Date & observer**	**Recording number**	**Time at start**	**Period**	**Weather conditions**	**Number of flowers observed**	***Apis cerana***	***Apis mellifera***	**Bumble bees**	**other wild bees**	**(including drone flies Syrphidae)**	**Remarks**
	House with honey bee colony **present** or **absent***		1, 2, 3, 4	**0800–1000 h or 1000–1200 h**	**Early morning or late morning**	Sunny, overcast, strong wind (instantaneous temperature if available)	(staminate and pistillate flowers observed together)	**scan sampling** : the insect(s) must be present at the very time when the inside of the flower is first seen					
			1				100						
			2				100						
			3				100						
			4				100						
							100						
							100						

* Indicate the number of colonies of *Apis cerana* and/or *Apis mellifera* nearby the study orchard & whether these colonies were present or introduced at onset of flowering

SHEET NUMBER____

ANNEX 6:
DATA SHEET TO RECORD POLLINATOR DIVERSITY IN PLOTS OF AN HERBACEOUS CROP

Diversity of non-*Apis* insect pollinators in open pollinated flowers (sweep net captures)

COUNTRY: **INDIA** SITE : **KOSI KATARMAL** FOCUS CROP : **MUSTARD (*Brassica campestris*)** YEAR :

					RECORDING CONDITIONS				TYPE (SPECIES) & NUMBER OF SPECIMENS PER TYPE				
									BEES OTHER THAN HONEY BEES				
Field number & size (ha)	**Location**	**TREATMENT**	**Date & observer**	**Recording number**	**Time at start**	**Period**	**Weather conditions**	**Transect number in a day**	**Bumble bees (*Bombus* spp.)**	**other wild bees**	**DRONE FLIES (Syrphidae)**	**OTHER**	**Remarks**
	Valley, mid-mountain, hill top	Honey bee colonies nearby **present / absent***		1, 2, 3, 4	1000–1200 h or 1400–1600 h	Morning or Afternoon	Sunny, overcast, strong wind (instantaneous temperature if available)	1, 2, … 6	Flower visiting insects that are likely pollinators caught by sweep net over a 5 minute period along a 25 m transect within or along side the field with a total of 6 transects				
				0 ≈ prior to colony introduction *(if applicable)*				1					
								2					
								3					
								4					
								5					
								6					
				1				1					
								2					
								3					
								4					
								5					
								6					

* Indicate the number of colonies of *Apis cerana* and/or *Apis mellifera* nearby the study field & whether these colonies were present or introduced at onset of flowering

SHEET NUMBER____

ANNEX 7:
DATA SHEET TO RECORD POLLINATOR DIVERSITY ON PLOTS IN AN ORCHARD WITH POLLENIZER PLANTS

Diversity of non-*Apis* insect pollinators in open pollinated flowers (sweep net captures)

COUNTRY: **INDIA** SITE : **MOHAL, KULLU** FOCUS CROP : **APPLE (*Malus x domestica*)** YEAR :

					RECORDING CONDITIONS				TYPE (SPECIES) & NUMBER OF SPECIMENS PER TYPE			
									BEES OTHER THAN HONEY BEES			
Orchard number & size (ha)	**Location**	**TREATMENT**	**Date & observer**	**Recording number**	**Time at start**	**Period**	**Weather conditions**	**Plot number** (2 adjacent trees / plot**)	**Bumble bees**	**other wild bees**	**DRONE FLIES (Syrphidae)**	**OTHER**
1 to 10		Honey bee colonies brought orpresent or not		1, 2, 3, 4	1000–1230 h or 1330–1600 h	Morning or Afternoon	Sunny, overcast, strong wind (Temperature if available)	1, 2, … 6	Flower visiting insects that are likely pollinators caught by sweep net over a 5 minute period on 2 adjacent trees within experimental site or along side for small orchards; **one recording of 5 min should focus on two pollenizer trees (indicated in grey)**			
* Indicate the number of colonies of *Apis cerana* and/or *Apis mellifera* nearby the study orchard & whether these colonies were present or introduced at onset of flowering												
				0 ≈ prior to colony introduction *(if applicable)*				1 2 3 4 5 **6 (pollenizer)**				
				1				1 2 3 4 5 **6 (pollenizer)**				

SHEET NUMBER____

ANNEX 8:
DATA SHEET TO RECORD POLLINATOR DIVERSITY ON ORCHARD TREES IN PLOTS LOCATED ALONG A GRADIENT OF DISTANCES YO POLLINATOR FRONT

Diversity of non-*Apis* insect pollinators in open pollinated flowers (sweep net captures)

COUNTRY: **GHANA** SITE : FOCUS CROP : **MANGO (*Mangifera indica)*** YEAR :

					RECORDING CONDITIONS				TYPE (SPECIES) & NUMBER OF SPECIMENS PER TYPE				
									BEES OTHER THAN HONEY BEES				
Orchard number & size (ha)	**Location**	**TREATMENT**	**MEAN DISTANCE OF TREES IN EXPERIMENTAL PLOT TO POLLINATOR FRONT**	**Date & observer**	**Recording number**	**Time at start**	**Period**	**Weather conditions**	**Plot number** (2 adjacent trees / plot)	**Stingless bees**	**other wild bees**	**Flies (including drone flies Syrphidae)**	**OTHER (including wasps)**	**Remarks**
1 to 5		Honey bee colony brought or present or not*	m		0 = Prior to colony introduction (if applicable), 1, 2, 3, 4	0800-1000 h, 1000-1200 h, 1200-1400 h, or 1400-1600 h	Morning or Afternoon	Sunny, overcast, strong wind (Temperature if available)	1, 2, … 6	Flower visiting insects that are likely pollinators caught by sweep net over a 5 minute periodon two adjacent trees within the experimental site or along orchard for small units				
			60						1					
									2					
									3					
									4					
									5					
									6					
			210						1					
									2					
									3					
									4					
									5					
									6					

* Indicate the number of colonies of *Apis mellifera* nearby the study orchard & whether these colonies were present or introduced at onset of flowering

SHEET NUMBER____

Flower density (number of open flowers per unit area) **& flowering phenology**

COUNTRY: **INDIA** SITE : **KOSI KATARMAL** FOCUS CROP : **BUCKWHEAT (*Fagopyrum esculentum*)** YEAR :

Field number & size (ha)	Location	TREATMENT	Date & observer	Recording number	0.5 m^2 quadrat number	Number of inflorescence with ≥1 open flowers per quadrat	Remarks	Recording number	0.5 m^2 quadrat number	Number of inflorescence with ≥1 open flowers per quadrat	Remarks
1 to 10	Mountain top	Honey bee colony nearby present / absent*		1, 2, 3, 4				1, 2, 3, 4			
				0 ≈ prior to colony introduction *(if applicable)*	1			3	1		
					2				2		
					3				3		
					4				4		
				1	1			4	1		
					2				2		
					3				3		
					4				4		
				2	1				1		
					2				2		
					3				3		
					4				4		

* Indicate the number of colonies of *Apis mellifera* nearby the study field & whether these colonies were present or introduced at onset of flowering

SHEET NUMBER____

ANNEX 10:
DATA SHEET TO RECORD FLOWERING PHENOLOGY IN AN ORCHARD CROP WITH POLLENIZER TREE

Flowering phenology

COUNTRY: **INDIA** SITE : **MOHAL, KULLU** FOCUS CROP : **APPLE (*Malus x domestica*)** YEAR :

Orchard number & size (ha)	Location	TREATMENT	Date & observer	Recording number	Tree type*	Plot number (2 adjacent trees / plot*)	Branch number in each tree**	Total number of flower buds on branch (to be recorded only once at or prior to onset of bloom)	Number of opened flowers on branch	Remarks
1 to 10		Honey bee colony brought or not*		1, 2, 3, 4	**Indicate the variety**	**1** or **2** or **3** or **4**				
				0 ≈ prior to colony introduction (if applicable)	production	1	1			
							2			
					pollenizer	**1**	**1**			
							2			
					production	2	1			
							2			
					pollenizer	**2**	**1**			
							2			
					production	3	1			
							2			
					pollenizer	**3**	**1**			
							2			
					production	4	1			
							2			
					pollenizer	**4**	**1**			
							2			

** For pollenizer trees, use tree closest to the two production trees of the plot surveyed

** Select & tag one representative branch on each opposite side of each tree; each branch should be large like about 2 thumbs at its base & record all buds & opened flowers on each branch at each reading

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ANNEX 11:
DATA SHEET TO RECORD YIELD ON PLOTS OF AN HERBACEOUS CROP PLANTED IN ROWS AND IN MONOCULTURE

Yield data

COUNTRY: **KENYA** SITE : **NANYUKI** FOCUS CROP : FRENCH BEAN (***Phaseolus vulgaris***) YEAR :

					YIELD COMPONENTS			
Field number & size (ha)	**Location**	**TREATMENT**	**Date harvest**	**plot number (length of row in m)**	**Number of plants harvested in the plot**	**Weight of fresh pods**	**Number of fresh pods**	**Remarks**
1 to **10**	(indicate large farms or small holder)	**Close** or **far** from patch of natural habitat				g / plot		
				1				
				2				
				3				
				4				

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ANNEX 12:
DATA SHEET TO RECORD YIELD OF INDIVIDUAL PLANTS OF AN HERBACEOUS CROP ON PLOTS WITH MIXED PLANTING

Yield data

COUNTRY: **INDIA** SITE : **KOSI KATARMAL** FOCUS CROP : **MUSTARD (*Brassica campestris*)** YEAR :

							YIELD COMPONENTS			
Field number & size (ha)	**Location**	**TREATMENT**	**Date harvest**	**plot number (0.5 m² quadrat)**	**Number of plants harvestable in plot**	**Plant number**	**Number of pods per plant**	**Weight of seeds per plant**	**Number of seeds per plant**	**Remarks**
1 to **10**	**Mountain top / Plaine**	Honey bee colony nearby **present / absent***						g / plant		
				1		1				
						2				
						3				
						4				
						5				
				2		1				
						2				
						3				
						4				
						5				
				3		1				
						2				
						3				
						4				
						5				
				4		1				
						2				
						3				
						4				
						5				
						1				
						2				
						3				
						4				
						5				

* Indicate the number of colonies of *Apis cerana* and/or *Apis mellifera* nearby the study orchard & whether these colonies were present or introduced at onset of flowering

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Yield data

OUNTRY: **INDIA** SITE : **MOHAL, KULLU** FOCUS CROP : **APPLE (*Malus x domestica*)** YEAR :

							YIELD COMPONENTS		
Orchard number & size (ha)	**Location**	**TREATMENT**	**Tree type***	**Date harvest & observer**	**Plot number** (2 adjacent trees / plot)	**Tree number**	**Number of fruits per tree**	**Weight of fruits per tree**	**Remarks**
1 to 10		Honey bee colony brought or not*	Indicate the variety		**1** or **2** or **3** or **4**			kg / tree	
			Production variety		**1**	1			
						2			
					2	1			
						2			
					3	1			
						2			
					4	1			
						2			

* Indicate the number of colonies of *Apis cerana* and/or *Apis mellifera* nearby the study field & whether these colonies were present or introduced at onset of flowering

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ANNEX 14:
DATA SHEET TO RECORD YIELD ON ORCHARD TREES IN PLOTS LOCATED ALONG A GRADIENT OF DISTANCES TO POLLINATOR FRONT

Yield data

OUNTRY: **GHANA** SITE : Modest Step farm FOCUS CROP : **MANGO (*Mangifera indica*)** YEAR :

Orchard number & size (ha)	Location	TREATMENT	MEAN DISTANCE OF TREES IN EXPERIMENTAL PLOT TO POLLINATOR FRONT	Tree type*	Date harvest & observer	Plot number (2 adjacent trees / plot)	Tree number	YIELD COMPONENTS: Number of fruits per tree	YIELD COMPONENTS: Weight of fruits per tree	Remarks
1 to 10		Honey bee colony brought or not*	m	Indicate the variety		**1** or **2** or **3** or **4**			kg / tree	
			60	Production variety		**1**	1			
							2			
						2	1			
							2			
						3	1			
							2			
						4	1			
							2			

* Indicate the number of colonies of *Apis cerana* and/or *Apis mellifera* nearby the study field & whether these colonies were present or introduced at onset of flowering

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As a contribution to the International Pollinators Initiative, 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. 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.

GLOBAL ACTION ON POLLINATION SERVICES FOR SUSTAINABLE AGRICULTURE

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