GPP&HFP South Africa
Deliverable September 2014: Final Report on Deficit Work

Activity: (two original activities apply to this deliverable)

- Apply the FAO "Pollination Deficits Protocol" to the target pollinator-dependent crops in the sunflower and apple STEP site, using the procedures outlined in Annex F as far as possible by end of ~~December 2011~~March 2012
- Apply the FAO "Pollination Deficits Protocol" to the target pollinator-dependent crops in the onion STEP site, using the procedures outlined in Annex F as far as possible by end of March 2012.

Deliverable: Information on detection and assessment of pollination deficits in target pollinator-dependent crops in all STEP sites.

NOTE: While it was originally thought that South Africa had delivered the final deficit report in March 2012, the Project Management Unit realised that the report should be updated to include results from Mariette Brand's PhD study.

The pollination deficit work consists of recording the abundance and species richness of insect flower visitors on the crop as well as harvesting the fruit or seeds from the crop, from a specified number of plants, when mature in order to relate levels of pollination to crop yields (Vaissière, Freitas & Gemmil-Herren 2011).

<u>Apples</u>

In **September/October 2008** data was collected on apple pollination (Granny Smith orchards) on 12 farms in the Western Cape. Four "wild" farms did not make use of managed honeybees (or have neighbours with hives within a 2 km radius) for pollination and the orchards sampled bordered on natural vegetation. A set of contrasting four farms did use managed bees but were more than 2 km away from natural vegetation. As a final comparison, four farms made use of honeybees and bordered on natural vegetation. The purpose of the experimental design was to see if there was any difference in apple yield parameters as a result of the various sources of pollination used. Fruit on pre-marked branches were collected during the fruiting period in April 2009 before harvest.

Data were collected at all farms on honeybee abundance per tree, number of fruit per branch, fruit-set per branch, seed-set and fruit quality (combination of size and shape). While counting honeybees, other insect visitors were also recorded. In each orchard one branch on each of 25 trees were closed with a mesh bag and paired with a control open branch of similar position on the same tree. This was done to determine the improvement in yield due to insect pollination.

Results – A total of 583 honeybees were counted during observations, however only seven non-honeybee individuals were recorded visiting flowers. Honeybee abundance was significantly lower at wild farms; however, numbers of fruit and fruit-set was not significantly different between farms, but number of seeds per apple was significantly lower on wild farms and significantly more frequently misshapen. Pollinator exclusion data indicated that numbers of fruits per branch was three times lower, and apples contained half the numbers of seeds when flower visitation was prevented.

Thus, in summary, Granny Smith apples are dependent on insect pollination for crop production, with a deficit in seed-set when managed honeybees were not used for pollination due to lower honeybee abundance on apple trees.

In **October 2011** no deficit work was attempted as the apple site team (established June 2011; consisting of farmers, apple pack-house consultants and beekeepers) advised that virtually all farms producing apples for the major pack-houses make use of managed bees (normally 2 hives per hectare). In addition, there is also significant chemical thinning of blossoms and fruit, as well as hand thinning of developing fruit. This practice makes the detection of a deficit improbable as there is high abundance of managed honeybees and a large percentage of developing fruit is thinned before the crop matures. For all purposes there is thus currently no pollination deficit in apples with the current management practices implemented on the majority of apple farms (and likely other deciduous fruit as well).

The pollinator abundance and composition part of the protocol was however implemented as previous work mentioned above was done before the GPP protocol had been finalised and therefore this component of the protocol had not been undertaken. The purpose of sampling was to identify the composition and abundance of insect flower visitors in apple orchards using the GPP experimental design, although based on the research done in 2008, we expected honeybees to be the dominant insect visitor.

Results – Using the GPP protocol we found <1% non-honeybee visitors on trees when orchards bordered natural vegetation, while the ratio was even lower when farms were isolated from natural vegetation. These findings thus support the previous data that honeybees are indisputably the dominant pollinator of apples in the Western Cape.

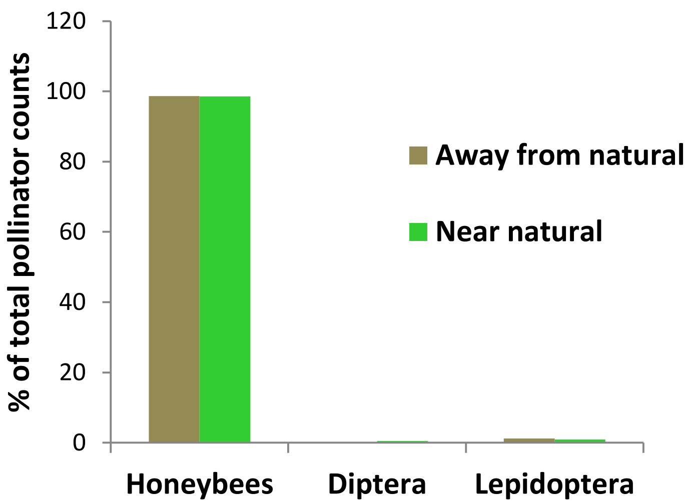

Figure 1: pollinator counts in apple orchards near and far from natural vegetation

Apple farmers do not experience a yield deficit, but actually often over pollinate. Pollination management is thus considered to be near optimal with the use of managed honeybees. This is further supported by the numerical dominance of honeybees observed.

<u>Onion Hybrid Seed</u>

As part of Mariette Brand's PhD thesis, in **October/November 2009** data on onion hybrid seed pollination was collected on 7 farms in the Western Cape, with 11 more farms sampled in **October/November 2010** (some being in the Northern Cape). All farms varied in the number of managed honeybees used and percentage of natural vegetation surrounding the sampled onion fields, thus forming gradients in both variables. Hybrid lines used on the onion field sites were different for each farm sampled.

At each farm data was collected on insect flower visitor abundance, species richness and composition, onion pollen loads on most abundant flower visitors, and the weight of onion seeds collected per umbel. In addition, data was also collected in the between line movement of honeybees (male and female lines), as well as interactions with other insects were noted. Pollinator exclusion experiments were also done by covering the umbels of 20 plants with a mesh bag during the flowering period to prevent insect pollination.

Table 1: Non-honeybee bee species identified from coloured pan traps (PT) and hand-collection (HC) efforts within hybrid onion seed crops in South Africa.

Order	**Family**	**Genus (species)**	**PT**	**HC**
	Colletidae	*Colletes* sp. 1	✓	
		Colletes sp. 2	✓	✓
		Colletes sp. 3	✓	
		Hylaeus sp.	✓	
		Hylaeus braunsi (Alfken)	✓	
		Hylaeus heraldicus (Smith)	✓	
	Halictidae	*Ceylalictus* sp.	✓	✓
		Halictus sp. 1	✓	
		Halictus sp. 2	✓	
		Halictus sp. 3	✓	
		Halictus sp. 4	✓	✓
		Halictus sp. 5	✓	
		Halictus sp. 6	✓	
		Halictus sp. 7		✓
		Lasioglossum sp. 1	✓	
		Lasioglossum sp. 2	✓	
		Lasioglossum sp. 3	✓	
		Lasioglossum sp. 4	✓	
		Lasioglossum sp. 5	✓	
		Lasioglossum sp. 6	✓	
		Lasioglossum sp. 7	✓	
		Lasioglossum sp. 8	✓	
		Lasioglossum sp. 9	✓	
		Lasioglossum sp. 10	✓	
		Lasioglossum sp. 11	✓	
		Lasioglossum sp. 12	✓	
		Lasioglossum sp. 13	✓	
		Lasioglossum sp. 14	✓	
		Lasioglossum sp. 15	✓	
		Lasioglossum sp. 16	✓	
		Lasioglossum sp. 17	✓	
		Lasioglossum sp. 18	✓	
		Lasioglossum sp. 19	✓	
		Lasioglossum sp. 20	✓	
		Lasioglossum sp. 21	✓	
		Lasioglossum sp. 22	✓	
		Lipotriches sp.	✓	
		Nomia sp. 1	✓	
		Nomia sp. 2	✓	
		Nomia sp. 3	✓	
		Nomia sp. 4	✓	✓
		Nomioides sp.		
		Patellapis sp. 1	✓	
		Patellapis sp. 2	✓	
		Patellapis sp. 3	✓	

	Patellapis sp. 4	✓	
	Patellapis sp. 5		✓
	Pseudapis sp. 1		✓
Megachilidae	*Fidelia villosa Brauns*	✓	
	Lithurgus spiniferus Cameron	✓	
	Megachile frontalis Smith	✓	
	Megachile semierma Vachal	✓	
	Megachile venusta Smith	✓	
	Osmiini sp.	✓	
	Othinosmia sp.	✓	
	Pseudoanthidium sp.	✓	
Apidae	*Allodapula monticola (Cockerell)*	✓	✓
	Amegiila kaimosica (Cockerell)	✓	
	Amegiila obscuriceps (Friese)	✓	
	Amegiila niveata (Friese)	✓	
	Anthophora indet.	✓	
	Anthophora labrosa Friese	✓	
	Anthophora praecox Friese	✓	
	Braunsapis ?vitrea (Vachal)	✓	
	Braunsapis sp.	✓	
	Tetraloniella braunsiana (Friese)	✓	
	Tetraloniella nanula (Cockerell)	✓	
	Thyreus vachali (Friese)		✓
	Xylocopa caffra (Linnaeus)		✓

Results

Seed yield dependence on insect pollination

Open-pollinated umbels of all 12 cultivars had an average seed weight of 4.27 ± 2.08 grams per umbel (range: 0.42-14.77, N = 211) while the control umbels had an average seed weight of 0.02 ± 0.08 grams per umbel (range: 0.00-0.87, N = 217) which were statistically significantly different (t = -29.61, df = 211, P < 0.001).

Factors affecting seed yield

Parent line ratio co-correlated with honeybee visitation rates and the two factors were used in separate models to determine their significance in affecting hybrid onion seed yield. Anthophile diversity and non-*Apis* visitation frequency was also co-correlated, so the factor that gave the lowest AIC value, non-*Apis* visitation frequency, was used instead. Hybrid onion seed weight was not significantly affected by the percentage of surrounding natural habitat, non-*Apis* visitation frequency, managed hive density, nor water management practices. However, hybrid onion seed crops in the southern Karoo produced significantly higher yields (4.76 ± 1.87 grams/umbel (N = 82)) than crops grown in the Klein Karoo (3.52 ± 2.20 grams/umbel (N = 128)), while higher honeybee visitation frequency significantly increased seed yield. The ratio of male-fertile to male-sterile rows also significantly affected seed yield, with higher seed yields obtained from crops with higher male-fertile ratios.

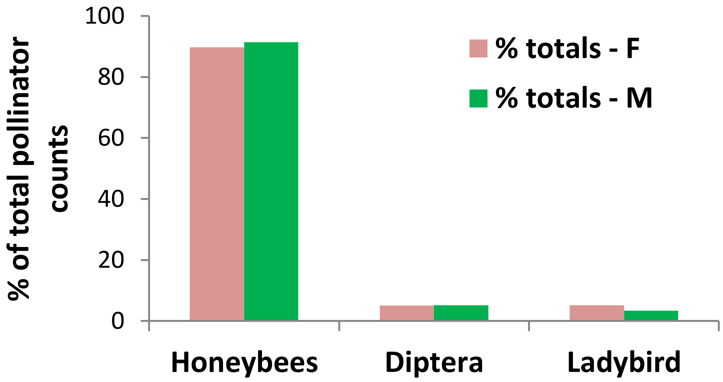

Figure 2: pollinator counts in hybrid onion seed fields in male (m) and female (f) lines

Onion farmers from this region typically do not experience a yield deficit, and thus pollination management is considered to be near optimal with the use of managed honeybees. This is further supported by the numerical dominance of honeybees observed. Mariette Brand's PhD only covered the 2009 and 2010 season when crop yields in the study areas were normal. However, in 2012 there was a large scale crop failure. This sparked the onion seed industry to conduct specialised study on the attractiveness of onion flowers in such crop failure years. Mariette's PhD however shows that both wild and managed honeybees show similar foraging patterns on hybrid onions – when honeybee activity is lower on onion umbels so is other bee species. This indicates the periodic seasonal crop failure every 5 to 10 years is not due to a shortage of pollinators, but rather some failure in onion line crosses (cross-pollination). This could be due to irrigation with brackish (low quality) water reducing the attractiveness of onion lines used for crossing. Alternatively, as eluded too by Mariette's work, changes in timing of regional rainfall through influencing timing of competing natural forage sources causes wild and managed honeybees (the main pollinator) to rather use non-onion crop flower resources when onions require pollination. This work is too agriculturally specialised for SANBI GPP project and falls outside our remit of biodiversity benefits or management. Also, the onion industry is highly competitive and secretive, not providing the information required for designing such trials. The onion seed industry will commission their own experimental research to determine the exact reason for crop failures experienced in a season every 5 to 10 years.

Sunflowers

In **February/March 2009** 33 sunflower plots on 9 farms (at least 2 km apart) were sampled with plots being a minimum of 500 m apart. Plots varied in their distance from natural vegetation and distance from managed hives. For every plot the abundance, species richness and composition of flower visitor were recorded. Pollination exclusion experiments were also conducted at the same time with 9 sunflower heads being covered with a mesh bag before flowering and 9 left open as controls.

Table 2. Species list of bees collected during sunflower deficit work (Carvalheiro et al. 2011).

Family	Insect species	Relative abundance (%)	Importance to crop (%)
Hymenoptera		**79.36**	**85**
Apidae	*Apis mellifera scutellata*	77.12	83.8
Apidae	*Tetraloniella apicalis* cf. (Friese)	0.14	0.1
Apidae	*Xylocopa inconstans* Smith cf.	0.09	0.1

Halictidae	*Lasioglossum* sp.	1.86	0.9
Halictidae	*Lipotriches* sp. cf	<0.01	<0.01
Halictidae	*Systropha* sp1	0.01	<0.01
Megachilidae	*Megachile frontalis* Fab. cf.	0.14	0.1
Diptera		**5.78**	**2.3**
Bombyliidae	Bombyliidae sp1	0.03	-
Bombyliidae	Bombyliidae sp2	0.01	-
Caliophoridae	Caliophoridae sp	0.47	0.2
Caliophoridae	*Rhyncomya* sp.	0.01	<0.01
Conopidae	Conopidae sp1	0.06	-
Empididae	Empididae sp1	0.65	-
Empididae	Empididae sp2	0.02	-
Sarcophagidae	Sarcophagidae sp.	0.77	0.4
Syrphidae	*Betasyrphus adliagatus* Wiend.	0.68	0.2
Syrphidae	*Eumerus obliquus* Fab.	0.48	0.1
Syrphidae	*Senaspis haemorrhoa* Gerst.	0.16	0.2
Syrphidae	*Betasyrphus* sp1	0.33	0.4
Syrphidae	*Eristalinus taeniops* (Wied)	0.17	0.1
Syrphidae	*Ischiodon aegyptius* (Wied)	0.13	-
Syrphidae	*Eristalinus cf. plurivittatus* (Macq	0.01	-
Syrphidae	Syrphidae sp1	0.02	-
Tephritidae	Tephritidae sp	1.37	0.5
NI	Diptera sp1	0.09	-
NI	Diptera sp2	0.32	0.2
Lepidoptera		**2.6**	**2.1**
Arctiidae	*Amata cerbera* L.	0.11	0.1
Arctiidae	*Utetheisa pulchella* L.	0.5	0.5
Hepialidae	*Eudalaca exul* Herrich-Schäffer	<0.01	<0.01
Hesperidae	*Spialia* sp1	0.03	<0.01
Hesperidae	Hesperidae sp1	0.17	<0.01
Hesperidae	*Borbo* sp1	0.09	<0.01
Lycaenidae	*Spindasis victoriae* (Butler)	0.02	-
Nymphalidae	*Acraea horta* L.	0.02	-
Nymphalidae	*Cynthia cardui* L.	<0.01	<0.01
Nymphalidae	*Hypolimnas misippus* L.	1.12	1.2
Nymphalidae	*Junonia hierta* Fab.	<0.01	<0.01
Nymphalidae	*Junonia oenone* L.	<0.01	<0.01
Nymphalidae	*Papilio horta* L.	0.01	-
Pieridae	*Belenois thysa* Hopffer	<0.01	<0.01
Pieridae	*Catopsilia florella* (Fab.)	<0.01	<0.01
Pieridae	Pieridae sp1	0.11	-
Sphingidae	*Macroglossum trochilus*	0.42	0.3

Results – 69 species were found to visit sunflowers, of which 47 were also recorded foraging on flowering weeds found within the crop fields at very low densities. Hymenoptera, chiefly *Apis mellifera*, made up the dominant pollinators on sunflower, with flies and butterflies only contributing 6% and 3% respectively (Table 2). Honeybees represented 84% of all flower visitations on sunflowers. Honeybee abundance was higher closer to hives than far away - this trend was not significant. Honeybees did decline significantly with increasing distance from natural vegetation, with regression models indicating a 39% decrease in abundance at 1000m, while flower visitor species richness decreased by 76%. For all the cultivars sampled, seed mass of a hundred seeds was higher for uncovered sunflower heads than covered heads, although differences were greater or smaller depending on the cultivar (12 to 45% improvement in yield with insect pollination). Flower visitor species richness and cultivar were found to be the best model predictors of seed yield (uncovered heads only).

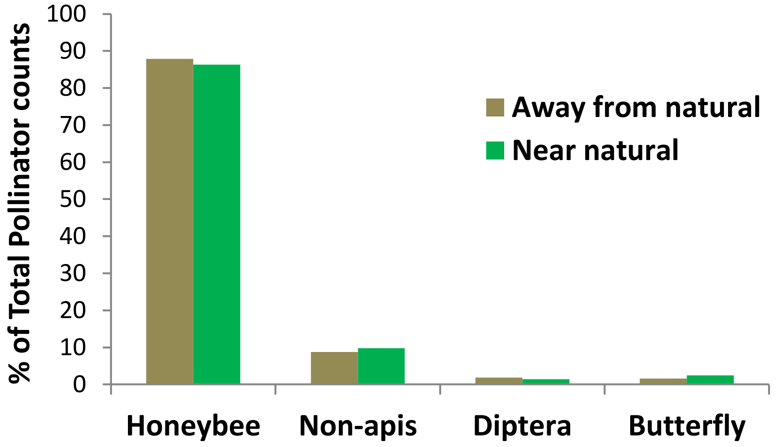

Figure 3: pollinator counts in sunflower fields near and far from natural vegetation

In **March 2011** 10 sunflower crop study fields were sampled to collect deficit data. Five sunflower fields were selected within close proximity to natural vegetation (within 200m of un-disturbed natural vegetation) and five study fields far (at least 1000m) from natural vegetation areas. Numbers of managed honeybee hives and their distance away from the fields were recorded but all fields had managed honeybees nearby. In May 2011, 40 sunflower heads were collected per field and sunflower seeds were weighed. However due to logistical constraints on flowering fields available and their position in the landscape, fields simultaneously differed in proximity to natural vegetation and sunflower cultivar present. This prevents any meaningful between field comparisons of seed yield. There were also no sunflower heads that had erratic seed set.

Table 3. Species list of pollinators collected during sunflower monitoring and deficit for March 2011.

Family	Species
Apidae	*Apis mellifera scutellata*
Apidae	*Ceratina subscintilla*
Apidae	*Pasites jonesi*
Apidae	*Tetraloniella braunsiana*
Apidae	*Thyreus delumbatus*
Halictidae	*Halictus* sp. 1
Halictidae	*Halictus* sp. 2
Halictidae	*Halictus* sp. 4
Halictidae	*Lasioglossum* sp.14
Halictidae	*Lasioglossum* sp.15
Halictidae	*Lasioglossum* sp.6
Halictidae	*Nomia* sp. 1

Halictidae	*Nomia* sp. 2
Halictidae	*Nomia* sp. 3
Halictidae	*Nomioides* sp.
Megachilidae	*Megachile chrysopogon*
Megachilidae	*Megachile discolor*
Megachilidae	*Megachile maxillosa*
Megachilidae	*Megachile nasalis*

Results – About 3-4 species of bees were recorded with honeybees foraging on sunflowers, while about 19 species were collected in the pan traps across all field sites, with honeybees comprising approximately 85% of all visitors on flower heads.

No pollinator shortage was observed in the sunflower production area. Nearly all fields have managed honeybee hives present and all plots are within 1km of hives preventing a proper pollinator deficit experimental design. It is clear that honeybees are the major pollinator of this crop and sunflower fields are an important forage resource used by beekeepers for honey production, colony build up and swarm trapping. The informal mutually beneficial relationship between sunflower growers and beekeepers appears sufficient and stable enough to ensure that no pollination deficit occurs.