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PP-202 [Beekeeping Technology and Quality]

IoT-Based Hive Monitoring for Assessing Colony Strength and Honeybee Pollination Efficiency

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Objectives

- Assess honeybee colony strength using **smart hives** during agricultural pollination.
- Evaluate pollination based on **real-time weight/activity data**.
- Generate high-quality data for **AI-based predictions**.
- Integrate IoT monitoring into **precision agriculture**.

Introduction

- **Pollination efficiency** is key to crop yield, especially in sunflower production.
- Traditional evaluation of colony strength and pollination efficiency is often **invasive and subjective**.
- The absence of **objective daily assessment** of forager bee activity limits development of global pollination services.
- This study **uses IoT-based smart hives** (AmoHive) to non-invasively monitor colony activity via **hourly weight tracking.**

Materials and Methods

Six **AmoHive** hives were used:

- 4 deployed to **sunflower fields** (2 with attractant, 2 without).
- 2 remained at a stationary site (~15 km away).
- Each hive transmitted **hourly data**: weight, internal/external temperature, internal/external humidity, GPS and solar panel voltage (a proxy for solar irradiance), and more.
- On July 10, an **eco-attractant** was sprayed via XAG P100 Pro **drone**.
- Colony strength and pollination effort were assessed by daily *'Breakfast Canyon*' depth — the weight loss due to morning forager departure.

Innovation

- Eco-attractants applied by drone stimulate nectar foraging.
- **Real-time hive data** enables **transparent pollination** service **assessment**.
- Individual colony contribution becomes measurable and controllable.
- **Data-driven pollination** improves precision and yield.
- AmoHive's solar-based power management enables long-term autonomous operation **with minimal energy use**, synchronized with environmental conditions and bee behavior.
- Adaptive sleep/wake cycles significantly **reduce** the frequency of data transmission**, minimizing** cumulative **electromagnetic exposure** and its potential **negative effects** on **bee health and behavior**.

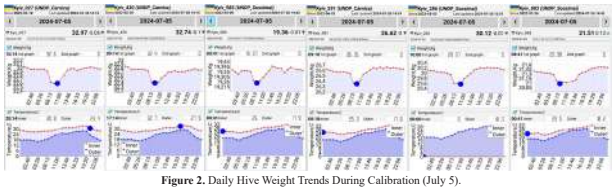

Figure 2. Daily Hive Weight Trends During Calibration (July 5).

This figure shows 24-hour weight and temperature data from all six smart hives on the day before the pollination experiment began (July 5). Each graph reflects a typical daily weight curve with a distinct morning drop — the *'Breakfast Canyon*' — followed by a gradual weight gain throughout the day. The depth of the *'Breakfast Canyon*' was comparable across all colonies, indicating similar forager populations and colony strength under identical environmental conditions. These **calibration** measurements were used as the reference **baseline** for interpreting colony-specific responses during the pollination experiment.

Figure 1. AmoHive smart hives and smartphone application. Online monitoring of hive weight, temperature, humidity, and solar activity.

Figure 3. GPS locations of smart hives in the sunflower field.

Figure 4. An agricultural drone spraying an environmentally friendly attractant over a sunflower field.

Further details on the construction and capabilities of the smart hive are available in the scientific article : Kurdin, I.; Kurdina, A. Internet of Things Smart Beehive Network: Homogeneous Data, Modeling, and Forecasting the Honey Robbing Phenomenon. Inventions 2025, 10(2), 23. https://doi.org/10.3390/inventions10020023

Figure 5. Visualization of the uniform spraying process.

Results

- Colonies near the attractant area showed **higher** nectar collection.
- Hive 027 peaked **at +4.91 kg/day**; total gain **34.8 kg** vs. 14.5 kg (Hive 591, no attractant).
- Attractant-treated area showed **+250 kg/ha yield increase**.
- Online hive data captured the impact of **invasive inspection** (July 14), with **a drop** in pollination activity and nectar intake.
- Pollination Ability Estimation via '*Breakfast Canyon*' Metrics

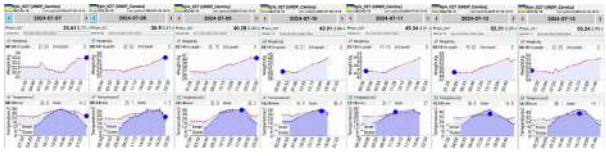

Figure 6. Daily Weight Dynamics of AmoHive-027

Detailed hourly weight and temperature data for Hive 027 from July 7 to 13 illustrate a clear pattern: sharp morning drops (*'Breakfast Canyon*') followed by steady daily weight gains. A notable increase in **foraging activity** and **nectar collection** occurred after **attractant spray**ing on July 10. This supports the hypothesis of attractant-induced enhancement in foraging behavior.

Figure 2 confirms that all colonies had similar forager strength prior to the experiment. **Table 1** and **Figure 6** demonstrate that colonies near the **attractant-treated area** (Hives 027 and 430) collected significantly **more nectar than the others**, with Hive 027 peaking at 4.91 kg/day. A sharp decline in activity on July 14 across all hives, visible in the **weight dynamics**, reflects the impact of beekeeper intervention.

№ Hive	Name of Honey Bees	Initial depth of 'Breakfast Canyon'	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
027	carnica	430gr	0.77	3.31	3.49	4.15	4.91	3.29	2.95	-6.3	1.25	3.25	2.2	0.7	1.77	0.86	0.46	0.4	0	34.77 kg
430	carnica	440gr	0.51	2.77	2.72	3.24	4.08	2.73	2.66	-4.0	2.43	4.05	2.15	1.28	1.71	1.03	0.6	0.07	-0.1	33.30 kg
985	carnica	120gr	0	0	0	0.05	0.2	0.17	0.19	0.35	0.2	0.4	0.32	0.09	0.22	0.05	0.06	0	0	2.0 kg
591	carnica	270gr	0.16	1.07	1.4	1.78	1.9	1.85	1.85	-2.8	1.64	2.03	1.29	0.45	1.11	0.5	0.4	0.13	0.03	14.50 kg
286	carnica	570gr	0.04	0.88	0.26	0.61	0.91	1.25	1	0.95	1.26	1.41	1.73	-0.6	0.42	0.24	0.34	0.38	0.06	11.10 kg
883	carnica	410gr	-0/2	0.71	0.24	0.43	0.37	0.49	0.5	0.39	0.8	0.8	1.47	-0.4	0.18	0.23	0.21	0.25	0.04	6.82 kg

Table 1. Hive Weight Changes, July 7-23, 2024

This table summarizes **daily weight gains** (kg) across six hives during the 17-day pollination period. Hives 027 and 430 near the attractant-treated field showed significantly higher gains — peaking at 4.91 kg/day (Hive 027) — compared to untreated and control hives. The disruption on July 14 (highlighted blue) followed emergency beekeeper intervention. The final column shows cumulative nectar collection. These values were used to assess colony performance and pollination engagement.

Conclusions

- **IoT-based hive monitoring**, combined with analysis of the **depth and dynamics** of the *'Breakfast Canyon*' (maximum morning hive weight drop due to forager departure), enables **real-time, non-invasive assessment** of colony **strength** and **pollination engagement** — both individually and in comparison with other colonies within the smart apiary.
- Drone-sprayed eco-attractants can boost **nectar collection** and enhance colony performance.
- **Minimizing colony stress** (e.g., avoiding mid-pollination period inspections) improves pollination efficiency.
- **Real-time data** supports **transparent service evaluation** between beekeepers and farmers.
- This work demonstrates the successful integration of **precision beekeeping** and **agriculture** for **sustainable, data-driven crop management**.

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The use of Internet of Things (IoT)-based monitoring systems is becoming increasingly important for assessing the strength of honeybee colonies and their role in pollinating agricultural crops. Intensive pollination by bees significantly contributes to increased crop yields.

However, establishing the relationship between crop yield increase influenced by bee pollination, the assessment of individual colony strength involved in pollination, and the evaluation of their pollination efficiency is a complex and time-dependent process, as results become evident only after flowering or, ultimately, during harvest.

Here, we demonstrate that homogeneous experimental data on hive weight, internal temperature, and humidity, transmitted hourly from IoT sensors in smart hives, enable the assessment of colony strength before and during pollination. This approach allows comparisons of colony strength and their specific impact on pollination efficiency.

The pollination ability of a bee colony can be determined by the daily weight assessment of the bee population that has left the hive, while its dynamics can be evaluated by comparing daily weight changes of bees that have left the hive.

Precision and uniform dispersal of environmentally friendly attractants over flowering agricultural plants using agricultural drones may enhance pollination efficiency by bees.

The evaluation of colony strength and its pollination ability based on daily weight assessments of foraging bees can be applied in both precision agriculture and precision beekeeping.

The obtained homogeneous experimental data may be suitable for applying machine learning methods to develop predictive models of bee colony behavior during the pollination of various agricultural crops across different geographical locations under changing climatic conditions.