

Bees in space: the atmospheric requirements of bumblebees, *Bombus impatiens*, to be used as pollinators in a greenhouse on Mars

Erika Nardone, Peter Kevan, Michael Dixon and Michael Stasiak, University of Guelph

INTRODUCTION

- The total atmospheric pressure on Mars is about 0.7kPa (Levine *et al.* 2008)
- **Pressurized environments would be required to sustain human life an exploration, and associated life support systems (Levine *et al.* 2008), and this may include crop plants and associated pollinators**
- Maintaining these environments at atmospheric pressures lower than 101kPa (sea level on Earth) would be much more cost-effective (Levine *et al.* 2008)
- Various plants studied under reduced atmospheric pressure have been found to be able to grow under pressures of 25kPa and even 10kPa (Massimino and Andre 1999; Goto *et al.* 2002)
- It is likely that in the plant-pollinator relationship, pollinators will be the limiting factor under conditions of reduced atmospheric pressure

OBJECTIVE

To measure the foraging and flight capabilities, and the behaviour of bumblebees, *Bombus impatiens*, in environments with reduced total atmospheric pressure (hypobaria)

METHODS

- In a hypobaric chamber (Fig. 1a), a hive of bumblebees was connected via a tube to a flight cage (Fig. 1b), which contained an array of artificial flowers with a 30% sucrose solution
- The bumblebees could travel freely between the hive and the flight cage, and were exposed to seven different atmospheric treatments daily for three days: 97 (ambient), 80, 70, 60, 50, 40, and 30kPa
- Atmospheric composition of gases was maintained equivalent to that of ambient pressure
- The treatments were video-recorded and were administered in a random order each day; exposure to each treatment lasted for 30 minutes
- Each video segment (Fig. 1c) was viewed and a number of different variables were scored and recorded: the total number of visits to the flight cage, the percentage of time bees spent foraging, flying, walking and remaining stationary, and the level of control exhibited by bees in their take-offs and landings
- The results for each treatment were averaged over the three days

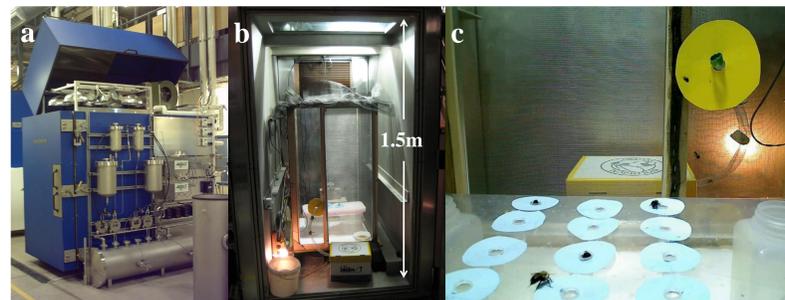


Figure 1. (a) View of exterior of hypobaric chamber (b) view of interior of hypobaric chamber with flight cage and bumblebee hive (c) screen shot of video clip of the interior of the flight cage with the entrance to the flight cage and the foraging array

RESULTS

- For treatments with an atmospheric pressure of 50kPa or higher, the average number of bee visits to the flight cage was between 74 and 112 per hour, whereas the treatments with the lower pressures averaged fewer than 26 bee visits per hour (Fig. 2)
- The average percentage of time spent by bees foraging, flying, walking and remaining stationary was similar for treatments of 50kPa or higher, whereas when exposed to lower pressures, the bees spent much more time walking and remaining stationary and less time foraging and flying (Fig. 3)
- Similarly, the take-offs and landings of bees were much more controlled and efficient during the treatments of 50kPa or higher, and less controlled during the lower pressure treatments (Fig. 4)

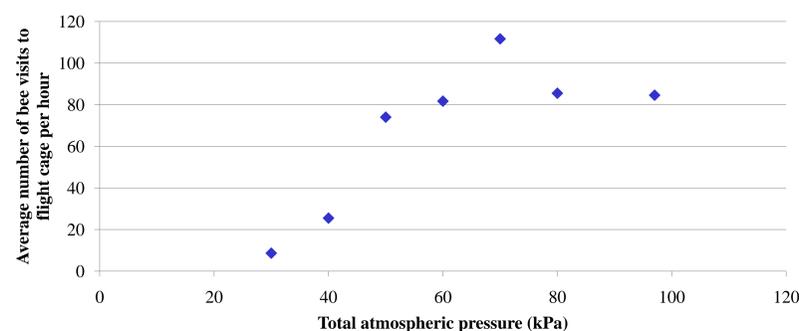


Figure 2. The average number of bee visits to the flight cage per hour for each atmospheric pressure treatment. Values displayed are the average of three replicates.

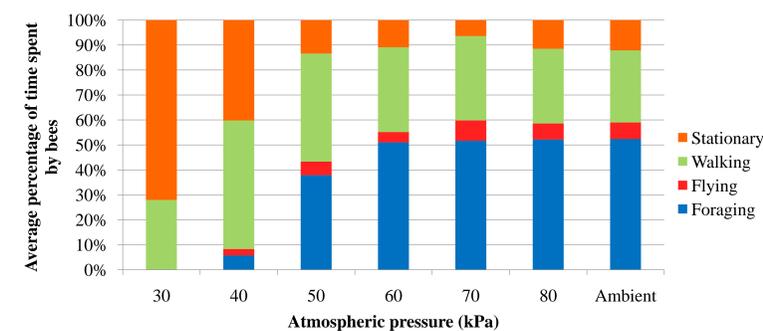


Figure 3. Average percentage of time spent by bees foraging, flying, walking, and stationary during each atmospheric pressure treatment. Values displayed are the average of three replicates.

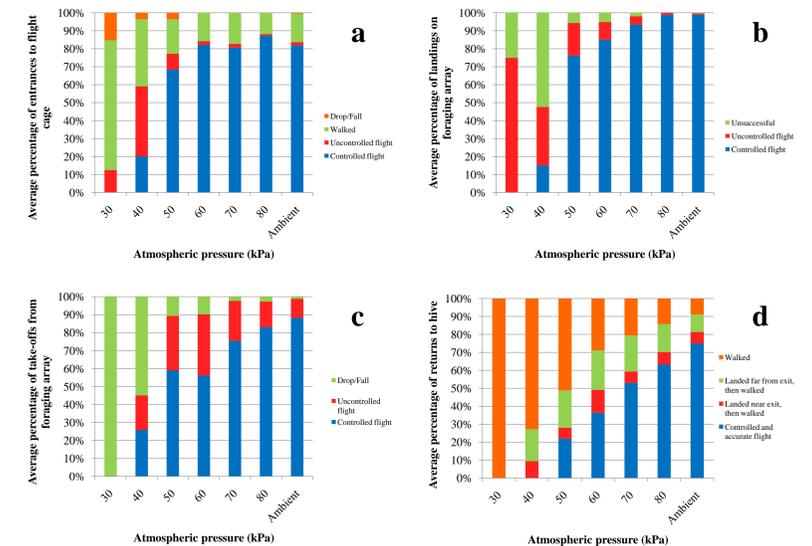


Figure 4. The average percentages of levels of control exhibited by bees in (a) take-offs from the entrance to the flight cage, (b) landings on the foraging array, (c) take-offs from the foraging array, and (d) returns to the hive. Values displayed are the average of three replicates.

DISCUSSION

- The results indicate that at atmospheric pressures of 50kPa and above the bumblebees were flying and foraging at a rate and level of control similar to that exhibited during ambient atmosphere
- The results also indicate that the bumblebee activity and how they spent their time during each atmospheric pressure treatment was due to both physiological limitations and behavioural choices; more work may have to be done to determine the extent to which each of these factors play a role in their activity
- Steps have already been undertaken to determine the next part of the equation: how altering the partial pressure of oxygen while maintaining a constant total pressure will impact the bees' flying and foraging ability and behaviour

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