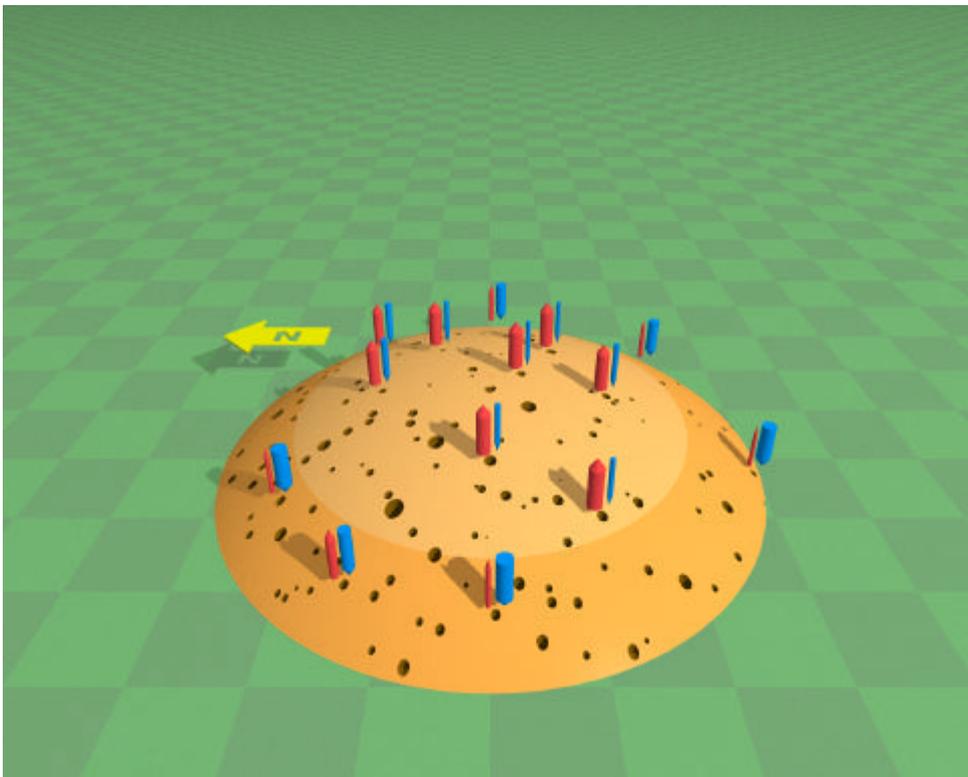


II. NEST VENTILATION MECHANISMS OF THE LEAF-CUTTING ANT *ATTA VOLLENWEIDERI*



Schematic drawing of a nest mound of *Atta vollenweideri*.
The arrows indicate the probability of inflow (blue) and outflow (red).

Introduction

As shown in chapter one, in the subterranean nests of *Atta vollenweideri* both fungus and ants consume large amounts of oxygen and produce large amounts of CO₂. Diffusion alone is not sufficient for gas exchange with the environment. Thus, for oxygen supply as well as for disposal of CO₂ nest ventilation is necessary. Although leaf-cutting ants and their nesting habits have been thoroughly investigated, the ventilation system of their nests is not well understood. Unlike honey bees, the wingless leaf-cutting ant workers cannot actively ventilate their nests by fanning (Lindauer 1961; Seeley 1974). However, the ants can control passive nest ventilation by continuously modifying the nest architecture, e.g. by changing the number of channel openings following an annual pattern (Jonkman 1980).

In principle, there are two main mechanisms for passive nest ventilation: Thermal convection and wind-induced ventilation. Thermal convection requires heating of the nest above ambient temperature. This can be achieved by production of metabolic heat or absorption of sunlight. Termites for instance produce metabolic heat inside their nests and thereby induce air circulation (Lüscher 1961). Thermal convection has also been discussed for ant species living in temperate zones (Kirchner 1998).

The other possible driving force for nest ventilation is external wind. For leaf-cutting ants it has been shown that surface wind changes the internal concentration of CO₂, thus influencing the nest microclimate (Kleineidam and Roces 1999). However, the importance of wind for nest ventilation in social insects has not been quantified .

Wind-induced nest ventilation requires pressure differences in the channel system. Such pressure differences can arise from lower pressure at the outflow site or higher pressure at the inflow site. Both conditions might be wind-induced and are illustrated in Fig.2.1. Wind might pump air into the openings at the upwind side (A) and/or suck out air through channel openings perpendicular to wind direction (B). Although the resulting flow through the nest can be the same, the underlying principles of nest ventilation can differ.

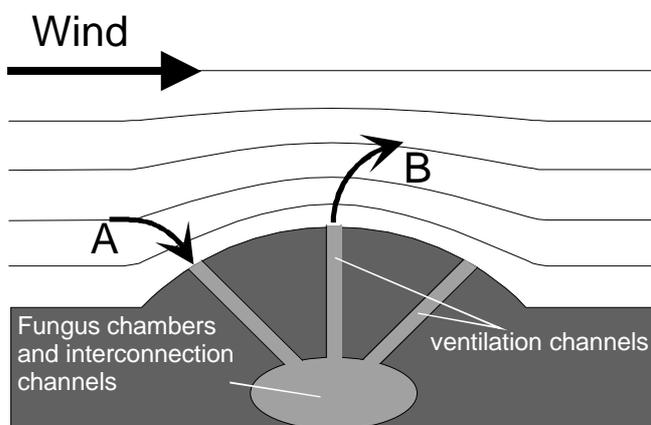


Fig.2.1 Schematic cross section through a nest of *Atta vollenweideri* with indication of possible ventilation mechanisms. Wind might pump air into channels on the upwind side (A) and/or might suck out air through central channels (B).

If wind pumps air into the upwind facing channel openings of the mound the nest ventilation mechanism can be compared with a *Pitot Tube* (Fig.2.1, arrow A). So far the use of a *Pitot Tube* has been demonstrated only in aquatic animals (Wallace and Merritt 1980; Young and Braithwaite 1980).

If wind sucks air out at the outflow site the nest ventilation mechanism can be compared with a *Venturi Tube* or with a physical principle termed *Viscous Entrainment*. The idea of a *Venturi Tube* transferred to the nest mound of *Atta vollenweideri* would mean that wind blowing over the nest mound results in outflow through the central channel (Fig.2.1, arrow B). *Viscous Entrainment* results from local pressure differences by a moving fluid passing a stagnant fluid. Wind passing the stagnant air volume at a channel opening (Fig.2.1, arrow B) might drag and thus suck air out of the channel. For *Viscous Entrainment* the shapes of the channel openings have a decisive impact. Both, *Venturi Tube* effect and *Viscous Entrainment* have been shown to be important in the ventilation of the burrows of prairie dogs (Vogel *et al.* 1973).

The proposed ventilation mechanisms do not exclude each other and might even act simultaneously. However, the ants should adjust the mound architecture of their nests according to the ventilation mechanism predominantly used. Thus, in order to understand the adaptive value of the nest architecture it is essential to understand the ventilation mechanism used by the ants.

This chapter focuses on wind-induced ventilation of a field nest of *Atta vollenweideri*. The flow conditions in the channels are described and a nest ventilation mechanism used by the ants is proposed. The findings are discussed particularly in the context of the technical constructions mentioned above (*Venturi Tube*, *Pitot Tube*).

Methods

Field experiments were done in the National Park Río Pilcomayo, Formosa Province, Argentina (58°W; 25°S). The annual average temperature in this region is 23°C and the mean precipitation is 1200 mm (mean relative humidity 79%). Precipitation surpasses evaporation in all months of the year except in August (Pujalte *et al.* 1995).

A mature nest with a mound volume of 16 m³ was investigated. The mound was dome-shaped with a circular base, thus its volume was estimated using the following formula for spherical caps: $V = \pi h(3r^2 + h^2)/6$. In this formula r represents the radius of the nest mound and h the height of the mound over ground level. 169 visible channels were counted at the beginning and observed only very little changes in the number of nest openings during the investigation period of two month (Dec. 97 - Jan. 98). The cross-sectional area of the channels was measured at the narrowest part of the first 10 cm from the openings.

According to the size of the mound the nest was older than four years indicating that the growth phase was completed. Once clearly established a nest of the leaf-cutting ant reaches an average age of about ten years (Jonkman 1978).

Measuring devices and data acquisition

Airflow velocity in the channels was measured with specially designed thermal anemometers. The sensors had a bi-directional characteristic with a measuring range of $\pm 20 \text{ cm s}^{-1}$ and an average sensitivity of 100 mV cm^{-1} . The time constant of the sensors was 2.4 s allowing to capture fast transients of airflow. The sensors were mounted at the center of a small tube of 16 mm diameter and 55 mm length. The tubes had coarse wire grids on both openings to prevent ants from entering. Surface wind was measured with a conventional unidirectional air flow sensor (Siemens Matsushita Typ C1011 A80). All sensors were calibrated individually to compensate for tolerances.

The anemometer tubes were placed in the channels at a depth of 10 cm and were fixed with a wire. All anemometers were oriented in such a way that a negative sign of the sensor output voltage indicated outflow and a positive sign inflow of air into the nest mound. The diameters of the channels selected for measurements were at least 3 cm. Worker ants attacked the anemometers for up to 30 min after insertion. Therefore the measurements were started one hour later after all ants had withdrawn from the devices.

All sensor signals were recorded with a data logger based on a commercial programmable microcontroller module (Wilke Technology, BasicTiger AXN-1/1 V1.06n). The sampling rate was 30 min^{-1} with an A/D resolution of 10 bit.

In order to investigate the function of the channels in dependency of the location of openings on the mound the air flow velocity in groups of five or six channels was recorded simultaneously on three different days. Recording duration ranged from 113 to 156 min and the surface wind directions were different on all days of the measurements (N/E; S/W; E/SE). Air flow velocity and direction were measured in a total of 17 channels that were homogeneously distributed over the nest surface. From the flow velocity recordings of the channels the rates of inflow (F_{IN}) and outflow (F_{OUT}) were calculated as $F_{\text{IN}} = (T_{\text{IN}} / T) \cdot 100\%$ and $F_{\text{OUT}} = 100\% - F_{\text{IN}}$, where T was the total measuring time and T_{IN} was the sum of times of inflow.

In order to investigate the dynamics of nest ventilation one recording was used during which the wind velocity decreased continuously. Wind direction was Northeast and the total recording time was 156 min. Three independent periods of 20 min duration were selected, each representing a category of surface wind velocity as shown in Fig.2.2. Mean wind velocity in the three categories was 6.6 ms^{-1} (A), 2.2 ms^{-1} (B) and 0.70 ms^{-1} (C). Wind velocity in category A was normally distributed, whereas in category B and C low wind velocities dominated.

The dependency of airflow velocity in the channels on surface wind velocity was evaluated with pearsons correlations. Where necessary, the data were transformed prior to the correlations with $f(x) = x^{1/3}$ to obtain normally distributed values (Sachs 1988).

The temporal relation of air velocity fluctuations in the channels provide information about the mechanism by which wind drives nest ventilation (sucking out air and/or pumping in air). If one of the two possibilities, sucking or pumping, predominates, specific delays between inflow and outflow have to be expected (e.g. due to inertia and compressibility of air). The temporal relations between flow transients in different channels were analyzed by cross-correlations. This analysis was based on the irregular pattern of the fast fluctuations which were superimposed to the slowly changing baseline level of airflow. Therefore the first

derivative dv/dt of the flow velocity was calculated to reduce the interfering influence of the baseline level. The dv/dt time traces of all channels were then cross-correlated with each other comprising time lags from 0 to 24 s (corresponding 0 to 12 samples).

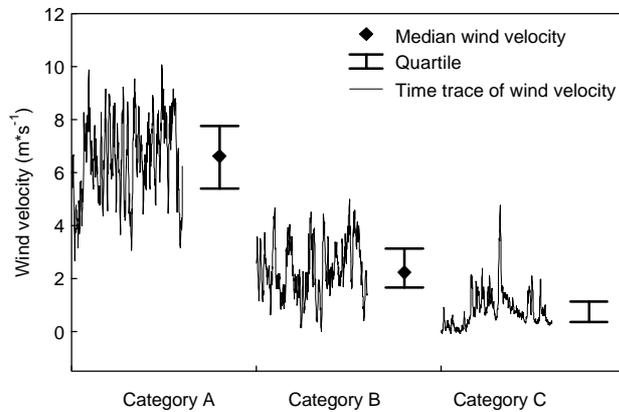


Fig.2.2 Decreasing wind velocity during one long-term recording was used to assign three different wind categories which were used to analyze the dynamics of nest ventilation.

Results

Visual inspection of the nest revealed that only very few of the channel openings were used as entrances by foraging workers. Foraging trails could be found at 18 of 169 openings at the investigated nest suggesting that most of the channels were serving other purposes. The openings differed in shape and their number changed over time (Fig.2.3). Rim structures formed a collar around many openings of the channels. Other openings had no conspicuous structures. Often following rain, the ants built impressive turrets with a lot of holes above the openings (Fig.2.4). Many workers were involved in this building activity, but the turrets could be maintained by the colony only for a while. Subsequent rain usually washed them away. The height of the turrets exceeded 20-fold the body length of a worker, they were reinforced with twigs between the clay crumbs and had several holes with thickened rims.



Fig.2.3 Mature nest of leaf-cutting ants in the palm savanna of Gran Chaco (Argentina). The mound has a diameter of 6 m and a volume of about 16 m³. 169 openings give access to the nest interior which houses several million of colony members and their symbiotic fungus.



Fig.2.4 Turret, built by workers of the leaf-cutting ant *Atta vollenweideri*. This kind of structure at the nest openings possibly enhances nest ventilation.

Functions of nest channels and positions of channel openings

First it was investigated how airflow in the channels was distributed over time and whether the channels might have specific functions depending on the position of their openings on the nest.

Surprisingly, the histogram of the distribution of F_{IN} shows two distinctly separated peaks (Fig.2.5, right). This two-peaked distribution indicates that individual channels served predominantly either as inflow channels ($F_{IN} > 50\%$) or as outflow channels ($F_{IN} < 50\%$). The mean inflow rate was $F_{IN} = 80.9\% \pm 4.0\%$ ($n = 8$) for inflow channels and $F_{IN} = 18.7\% \pm 3.3\%$ (corresponding to $F_{OUT} = 81.3\% \pm 3.3\%$; $n = 9$) for outflow channels and the two categories were significantly different from each other ($U = 0$, $p < 0.001$). Since the channels could be clearly classified regarding flow direction, the distribution pattern of inflow and outflow openings on the mound were investigated. Fig.2.5 (left) shows the

plot of the distance of the channel openings from the center (d_c) vs. F_{IN} . The plot reveals a sharp separation between a central outflow region and a peripheral inflow region. The position of the border between the two regions were calculated by a non-linear regression using a sigmoidal model as $d_c = 217\text{cm} \pm 2.3\text{cm}$ ($R = 0.95$, $p < 0.001$). Due to the spherical shape of the nest mound an increase in distance of an opening to the center implies a lower elevation above ground level. Thus the decisive parameter determining the function of a channel (inflow or outflow) could also be the height of its opening above ground.

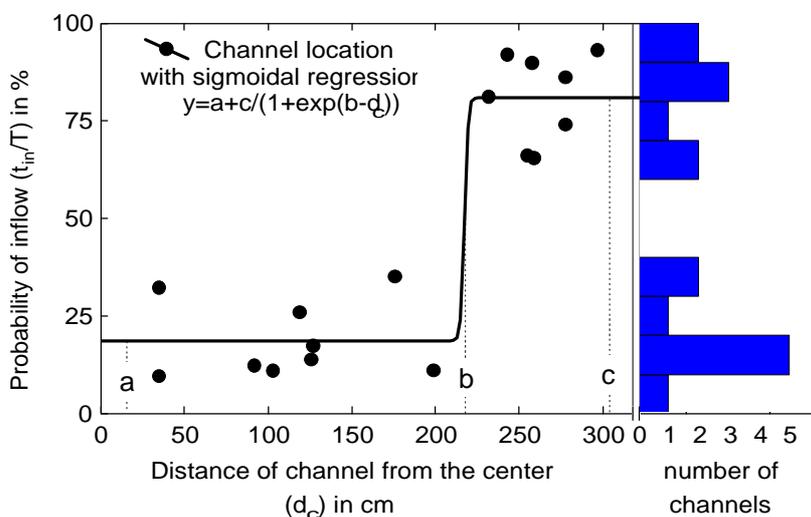


Fig.2.5 Inflow probability as a function of distance from the center of the nest (left). A sigmoidal regression describes more than 90% of the variance and the inflection point marks the border between inflow-channels at the periphery and outflow-channels in the center. Number of channels with respect to their inflow probability (right). Two distinct groups resembling inflow- and outflow-channels can be discriminated statistically.

Whether a channel functions as inflow or as outflow channel might also depend on the position of its opening regarding wind direction. Therefore the channels were sorted into two groups. One group contained all channel openings oriented upwind with respect to the center of the mound ($n = 8$) and the other group contained the openings oriented downwind ($n = 9$). However, F_{IN} values of the two groups were not significantly different from each other ($U = 30$, $p = 0.61$), indicating that the function of the channels does not depend on wind direction.

Quantitative relation between channel airflow and wind

The influence of surface wind on air velocity in the channels is illustrated in Fig.2.6. With increasing wind velocity air velocity in inflow and outflow channels increased. Surface wind was gusty on all days of experiments and air flow in the channels showed conspicuously strong fluctuations.

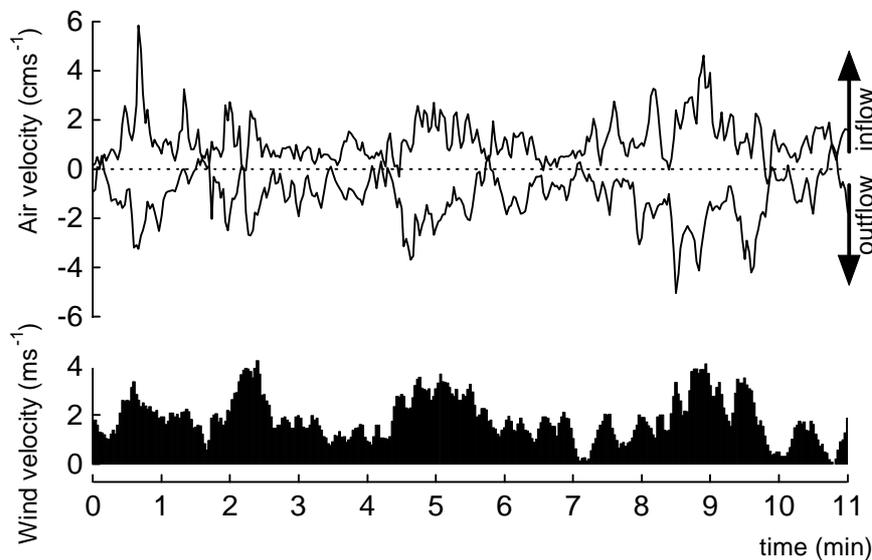


Fig.2.6 Example for simultaneous recordings of surface wind velocity 1m above the mound (lower trace) and air velocity in two different channels (middle and upper trace) during a period of 16 min.

In order to analyze the influence of wind on air flow in the channels the temporal relations of these fluctuations have to be taken into account. Thus, for further analysis the time traces of the airflow recordings were aligned based on the delays between inflow and outflow (see chapter below). Outflow transients were not delayed to external wind transients. Wind velocity v_s was correlated with the airflow velocities v_c in the inflow channels and the outflow channels. Note that the absolute values of the v_c data were used and transformed to obtain normally distributed values (see Methods). Fig.2.7 shows the scatterplot of v_c vs. v_s and the linear regression for wind category A. The correlation between v_s and v_c of outflow channels ($R = 0.60$, $p < 0.001$) was stronger than the correlation between v_s and v_c of inflow channels ($R = 0.38$, $p < 0.001$). The difference between the two correlation coefficients was statistically significant (T-test, $p < 0.01$). The higher correlation coefficient R obtained from the outflow channels indicates that outflow depends stronger on surface wind than inflow.

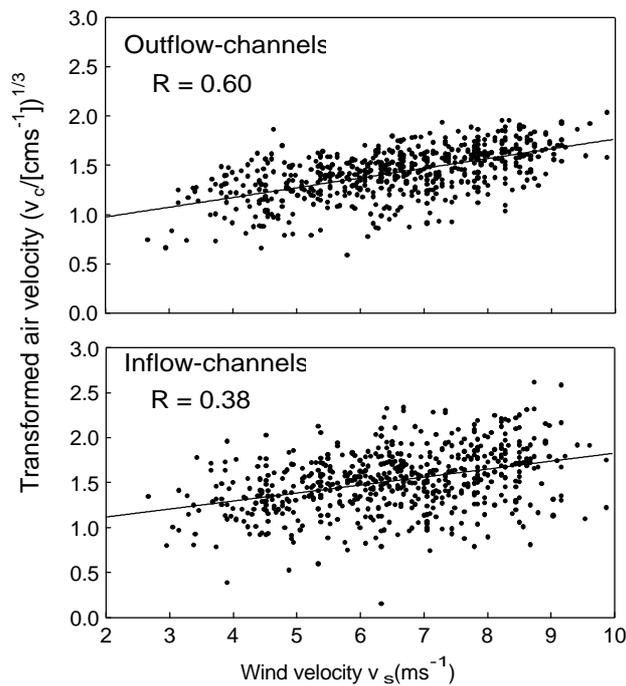


Fig.2.7 Correlation between surface wind velocity and air velocity (transformed values) in two outflow-channels (upper, pooled) and three inflow-channels (lower, pooled). The slopes of both regressions are not significantly different. Note the higher correlation of outflow-channels to surface wind.

Efficiency estimation of wind-induced nest ventilation

Based on the airflow rates in different channels the effectiveness of wind-induced nest ventilation were estimated. The exchanged air volume were calculated by the mean flow velocities and the channel diameters. Table 2.1 shows the values for five different channels of the same recording period. Even at low surface wind velocities the estimated outflow through the most central channel was more than $1.5 \text{ m}^3\text{h}^{-1}$.

		surface wind categories					
		A ($\bar{v} = 6.6\text{ms}^{-1}$)		B ($\bar{v} = 2.2\text{ms}^{-1}$)		C ($\bar{v} = 0.7\text{ms}^{-1}$)	
channel	area [cm^2]	$v_c[\text{cms}^{-1}]$	$V[\text{m}^3\text{h}^{-1}]$	$v_c[\text{cms}^{-1}]$	$V[\text{m}^3\text{h}^{-1}]$	$v_c[\text{cms}^{-1}]$	$V[\text{m}^3\text{h}^{-1}]$
a (periph.)	50	1.54	2.78	0.56	1.01	0.48	0.87
b (periph.)	13	4.99	2.26	3.05	1.38	0.93	0.42
c (periph.)	20	5.43	3.84	2.49	1.76	0.57	0.40
d (central)	20	-1.55	-1.10	-0.88	-0.62	-0.59	-0.42
e (central)	50	-4.70	-8.50	-1.93	-3.49	-0.92	-1.67

Table 2.1 Volume flow rates (V) through exemplary channels estimated by the mean air velocity (v_c) and the diameter of the respective channels over a period of 20 min each for three different wind categories (\bar{v} : median surface wind velocity). Positive numbers denote inflow and a negative sign outflow. The criterion for the classification of the channels as peripheral or central was their position with respect to the inflection point of the sigmoidal regression presented in Fig.2.6.

Non wind-induced air flow velocity in the channels were extrapolated with the regression obtained in the previous section (Fig.2.7). The regression of outflow vs. surface wind were used because of the higher correlation coefficient. Without wind an air flow of only 0.48 cms^{-1} can be expected in outflow channels (which is below the sensitivity of our devices), whereas air velocity was 1.25 , 2.58 and 4.62 cms^{-1} at wind velocity of 3 , 6 and 9 ms^{-1} respectively.

The results show that large air volumes flow through the nest and that without wind the air flow is markedly reduced.

Temporal dependencies between wind and airflow in the channels

Temporal analysis showed that air is sucked out of the nest. The air flow transients (first derivatives of air flow velocities, see Methods) of each of the three identified inflow channels were cross correlated with each of the two outflow channels. Fig.2.8 shows the mean cross correlation coefficients for the three wind categories with lags ranging from -12 to 12 samples. A clear temporal relation between flow transients in outflow channels vs. inflow channels were found.

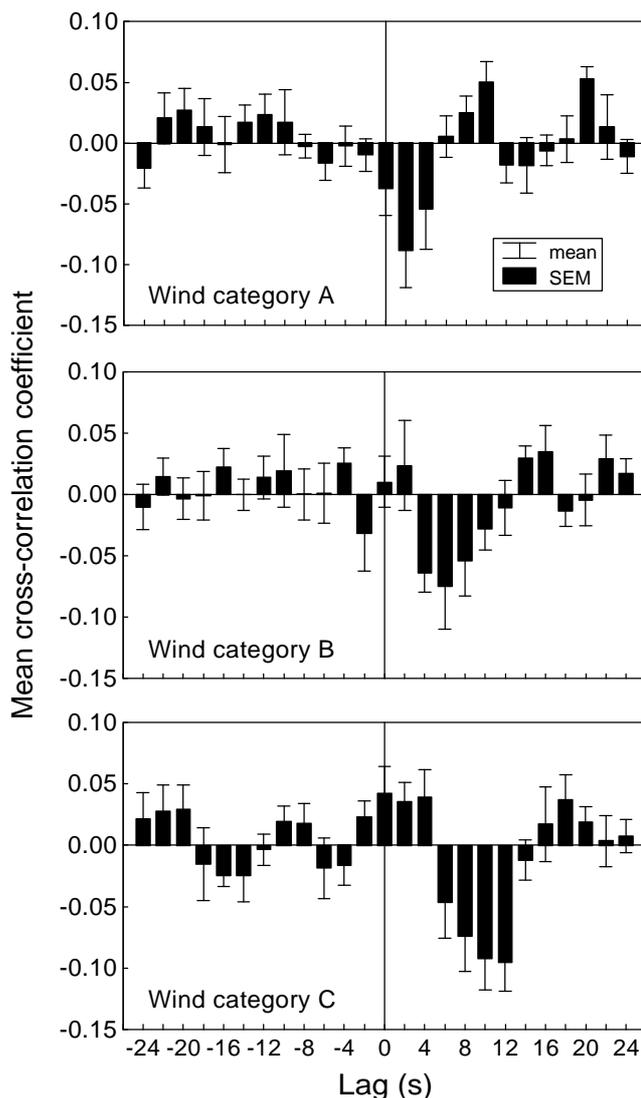


Fig.2.8 Phase relation of inflow channels to outflow channels at the three different wind categories. For cross-correlation the first derivatives of the air velocities were used. Each data set of the two outflow-channels was cross-correlated with each data set of the three inflow channels.

The analysis revealed two main results. First, outflow transients precede inflow transients. Second, the average delay between outflow and inflow transients depend on mean air velocity. The average delay is 2 s at high wind velocities (wind category A) and 12 s at low wind velocities (wind category C).

The correlation coefficients of air velocities between inflow and outflow ranged from $R = 0.50$ to $R = 0.58$ for all wind categories and were statistically indistinguishable. Without correction for the delay the correlation coefficients were considerably lower for wind category B and C (Table 2.2).

wind category	max. coeff. at lag (s)	R of raw data	R with delay corrected	p-value in row
A	1 (2)	0.4503	0.5011	0.27
B	3 (6)	0.3900	0.5078	0.01
C	6 (12)	0.3463	0.5778	<0.001

Table 2.2 Correlation coefficients of air velocity (data pooled and then transformed) between inflow- and outflow-channels before and after correction for the phase relation. Note that there was no significant difference between the correlation coefficient in all wind categories after phase correction (T-test, $p > 0.05$; column: delay corrected).

Interactions between inflow channels

Since the channels inside the nest are interconnected, mutual influences of the flow among inflow channels were expected. Therefore, the phase relations (of the transients) between three inflow channels were analyzed with cross-correlations. The channel openings were separated at least 2 m from each other. However, no consistent phase relations could be found between inflow channels. Fig.2.9 shows an example of air velocity in two of the inflow channels over time.

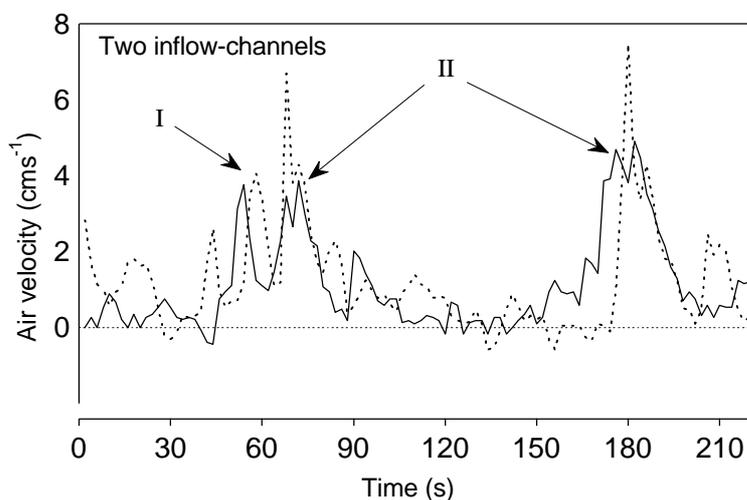


Fig.2.9 Example of air velocity in two different inflow-channels during a period of 210 s. Inflow does not occur simultaneously in two different inflow-channels and no consistent phase relation between these two channels exists during the three analyzed time sections of 20 min. As in Fig.2.6, positive values denote inflow.

The transients of wind velocity occurred not always simultaneously (I) and no strong phase relation exists. The short drop of inflow velocity in one channel at the maximum inflow velocity in the other inflow channel gave some support to the hypothesis (II). However, the data did not provide enough material to support the idea of mutual influence between flow in inflow channels.

Discussion

The nest ventilation mechanism for the giant nests of the genus *Atta* proposed in the literature is thermal convection (Weber 1972; Hölldobler and Wilson 1990). However, several findings challenge this hypothesis.

Wilson and Sheehy were the first to study the nest ventilation mechanism of *Atta sexdens* and *A. cephalotes* (cited in Stahel and Geijskes 1939). They described that some nest openings suck in air. Stahel and Geijskes (1939) further investigated this phenomenon using small puffs of smoke. Their results did not confirm the hypothesis of thermal convection as driving force for nest ventilation since the expected dependency on ambient temperature (day/night) was not found. A further result contradicting the thermal convection hypothesis is the fact that the symbiotic fungus of *Atta* suffers severe damage at temperatures above 30°C (Quinlan and Cherrett 1978; Powell and Stradling 1986). In several studies no temperatures above 30°C were found in the nest areas where the fungus is located (Eidmann 1935; Weber 1972). Therefore, in subtropical habitats the nest can hardly be heated up to temperatures that would induce convective air movements. If at all, thermal convection may play a role in nest ventilation only during cold periods, e.g. in winter.

This study shows that nest ventilation in *Atta vollenweideri* relies mainly on wind-induced airflow. The main results can be summarized as follows:

1. There are two channel categories, outflow channels and inflow channels. The openings of outflow channels are located in the central region on the top of the mound. Openings of inflow channels are located at the peripheral region close to the bottom of the mound.
2. Nest ventilation depends on wind velocity. Higher surface wind velocities result in higher air flow velocities in the channels.
3. Outflow through outflow channels driven by external wind occurs first, followed by inflow through inflow channels.
4. (1), (2) and (3) together provide evidence for a mechanism in which wind is the driving force for nest ventilation: air is sucked out of the nest through the openings of the central channels at the top of the mound.
5. The findings indicate that besides the wind driven mechanism (4) other mechanisms contribute only very little to nest ventilation.

Inflow and outflow do not occur arbitrarily in the channels. The channels are obviously functionally determined for inflow or outflow to a high degree (80%). The remarkable separation of inflow openings at the outer mound region and the outflow openings at the central region suggests a highly ordered nest architecture below the surface. Unfortunately, nest excavations in the past allowed only incomplete reconstructions of the channel system (Eidmann 1935; Stahel and Geijskes 1939; Jonkman 1980). However, some authors described a circular channel around the center of the nest of *Atta sexdens* to which the downward leading channels from the mound periphery connect. This construction has been discussed as a prerequisite for dispersion of collected leaf material by foragers into the different fungus chambers (Daguerre 1945; Jacoby *et al.* 1953). Additionally, it might serve the distribution of inflowing fresh air. Our measurements failed to show the expected mutual interaction of air flow between different inflow channels. This might be due to the large distance between the measured channels and remains to be investigated.

The first reaction to surface wind is an outflow of air. All outflow openings are located on top of the mound. Therefore, nest ventilation is caused by different wind conditions at the bottom and the top of the mound. The assumption that wind velocity at the top of the mound is higher than at the base which is sheltered by the surrounding grass vegetation is not far fetched. It is tempting to compare this situation with the functional principles of technical devices such as the *Pitot Tube* or the *Venturi Tube* (for detailed descriptions of the *Pitot Tube* and the *Venturi Tube* in general see e.g. (Vogel 1994)). Both devices rely on *Bernoulli's law* which describes the relation between flow velocities and pressure differences. Man took advantage of *Bernoulli's law* long before it was described, as is demonstrated by the climatization mechanism of Iranian houses 900 AC (Bahadori 1978). One should, however, be aware that this law is strictly valid only if volume flow and fluid density is constant.

The idea behind the *Pitot Tube*, which is used e.g. for aircraft speedometers, is to exploit the difference between kinetic pressure and static pressure of moving air. For this purpose the *Pitot Tube* has two openings. One opening faces into the stream of air and the other opening is perpendicular to flow direction. The pressure at the opening facing the wind is composed of the kinetic pressure plus the static pressure. At the other opening only static pressure occurs, thus air is pumped into the tube.

At first glance this is exactly the situation at the nest mound (Fig.2.1, arrow A). Some openings are facing into the wind and the openings of the central channels on the top of the mound are perpendicular to the direction of the wind blowing over the nest. So, air should be pumped through the inflow openings and leave the mound through the outflow openings at the top. However, the findings do not support this hypothesis.

If air would be pumped into the inflow openings wind transients should first occur there and then at the outflow openings. But the situation found is just the reverse. Obviously, wind is not pumped into the nest mound but rather sucked out. Furthermore, wind direction did not influence inflow probability. Wind velocity is probably very low at the bottom where the inflow openings are located but the inlet of a *Pitot Tube* should be positioned where the highest wind velocities occur. Therefore, the mechanism of a *Pitot Tube* cannot account for ventilation in the investigated nest.

The functioning principle of the other device mentioned above, the *Venturi Tube* is used in pumps or in pipelines. Here the decisive constructional detail is a constriction (often called a nozzle) in the middle of a pipe. According to *Bernoulli's* equation the velocity of flow is increased and pressure decreased at such a nozzle. The reduced pressure can be used to suck liquids or gases through an inlet at the nozzle into the pipe systems, e.g. in a carburetor (secondary flow). Other than with the *Pitot Tube* a similarity between the *Atta* nest architecture and the *Venturi Tube* is not immediately obvious, and it is necessary to emphasize that there is only a superficial similarity. Since the wind is blowing more or less in parallel with the ground, the nest mound may be considered as a constriction for the wind flow like a 'half nozzle' in a *Venturi Tube* (Fig.2.1). If wind velocity is increased and pressure decreased at the 'constriction' (top of the mound) then the findings suggest that the ants with their nest mound use the same effects like man with the *Venturi Tube*.

Local pressure differences resulting in *Viscous Entrainment* at the channel openings might be an alternative explanation for the finding that outflow induces nest ventilation. *Viscous Entrainment* (viscous sucking) depends on the resistance of real fluids to rapid shear rates with the consequence of attraction of stagnant fluid to rapidly moving fluid. Thus, by *Viscous Entrainment* wind might suck out air through channels at the top of the mound. *Viscous Entrainment* and *Venturi Tube* effects might work together in reducing the pressure at the outflow site. The data do not allow to discriminate between *Viscous Entrainment* and *Venturi Tube* effect. *Viscous Entrainment* is enhanced by sharp rim structures which has been shown for the burrows of prairie dogs (Vogel *et al.* 1973). Also small openings favor *Viscous Entrainment*, but the largest channel openings were found on the very top of the mound and during the experiments these openings had no sharp rim structures.

As already mentioned, workers can shape the openings as it is shown in Fig.2.4. The building of turrets in *Atta vollenweideri* is pronounced after rainfall and in another leaf-cutting ant species (*Acromyrmex landolti*) the turrets are discussed in terms of flooding prevention of the nest (Navarro and Jaffe 1985). Since these turrets are built in the central region of the nest which is exposed to surface wind they may also be important for the control of nest ventilation. Moreover, they show characters which would enhance ventilation by *Viscous Entrainment*, since the openings in the turrets are small and with sharp rims. The contribution of turrets and rim structures at the openings to nest ventilation remain to be investigated.

This study shows that as soon as a slight breeze blows over the nest mound, wind-induced ventilation is the predominant ventilation mechanism of the nests of *Atta vollenweideri*. Nest ventilation is attained by wind sucking air out of the central channels at the top of the mound. Two physical principles can account for the mechanism, *Bernoulli's* law like in a *Venturi Tubes* and *Viscous Entrainment*. The shape of the mound and of the openings suggest that both principles are used by the leaf-cutting ants *Atta vollenweideri*.