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MICROCLIMATE AND THE ACTIVITY OF PARAGYMNOMERUS SPIRICORNIS (SPINOLA) (HYMENOPTERA: EUMENIDAE)

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It was found during the contiguous observation since 1939 of the wasp *Paragymnomerus spiricornis* (SPIN.) that the specimens were active preponderantly between 11 a.m. — 5 p.m., in the months June—July, on the loess wall below the Csúcshegy of the Tihany Peninsula. The intensity of their activity is closely related to the microclimate. Data concerning the vegetation of the loess wall as well as some orienting information on temperature fluctuations in front of and on the loess wall were already mentioned in earlier surveys (MÓCZÁR, 1960). To analyse more thoroughly the connection between microclimate and the activity of the wasps, opportunities arose between 21 June—16 July, 1971, when contiguous daily observations could be made (28 June—7 July) by registrating with appropriate instruments — and the help of Mrs. B. HAJÁSZ and Miss M. KÁLMÁN — the microclimatic conditions and by marking 109 wasp nests and 53 wasp individuals with the combinations of variously colored symbols (MÓCZÁR, 1972), and thus have their activity followed in minute details.

The climate of the Tihany peninsula shows warm temperate continental features. The main temperature of the warmest month is 21.5 °C, that of the coldest –1.5 °C. The peninsula belongs to that part of the Balaton Plateau where the number of clear (sunny) hours is about 1900–2000 per year.

Concerning the annual distribution of the period of sunshine, the minimum (60–70 hours) is in January, the maximum (290–300 hours) in July; its temporal distribution is closely connected with the clouded or unclouded state of the sky and not with geographical latitude. Clear conditions are encountered especially in July–August (30–40% clouded sky), a situation equal with the most sunny areas of the Great Hungarian Plain. In the areal situation of sunshine and solar energy, the physiogeographical configuration and exposition are important factors; is was established in our earlier investigations (ANDÓ, 1959) that especially the southern, southeastern, and southwestern inclinations receive a considerable amount of light and energy.

In the formation of the local climate, the immediate environment and a rich physiogeographical facies are determining features. With regard to the distribution of temperature and precipitation, the mountains are generally colder and richer in precipitation than the intramontane basins. The multiannual mean temperature value of the closed basin of the peninsula is about 10–10.5 °C, whereas that of the foothills fluctuates between 9.5–10 °C. The temporal distribution of precipitation evolves also in accordance with the typically warm continental character of the climate. Together with the early summer maximum (60–70 mm), the peninsula receives only an annual 600–650 mm of precipitation. The main winds carrying rain have a NW to W course. As to the multiannual average, this is the dominant wind direction in the area, though winds from the west to southwest prevail by the autumnal months. This latter phenomenon also evinces Mediterranean effects. In anticyclonal situations a local aerial circulation develops between the water surface and the dry land, a phenomenon considerably influencing the evolvement of local climate and microclimate.

The observable activity of the wasps extends to only a part of the summer period, hence we conducted our investigations in the period mentioned above and according to the following points of view:

1. The lieu and exposition of the loess wall as habitat;
2. the connections of the habitat and the solar factors:
   a. the duration of insolation of the loess wall;
3. the temperature conditions of the habitat and its environment:
   a. temperature of the loess substrate at depths of 2 and 5 cm;
   b. the changes of atmospheric temperature, maxima and minima;
   c. connections between activity observed per quarter hours and temperature;
   d. qualitative distribution of the daily activity;
   e. mean period (duration) of daily activity;
4. Aerial humidity, precipitation and wind conditions concerning the habitat its environment;
5. Summary.

1. The position and exposition of the loess wall as habitat

The nesting colony of the wasps is the steeply inclined, caved – in loess wall. The average inclination of the surface is between 20–30°. In certain cases (as also in that of the habitat), very steep declivities, up to a value of 90 ° or even more, originated by tectonic movements. The surface erosion of the loess wall is not significant owing to its protection againts wind by the considerable forest stands of the immediate neighbourhood. The exposition of the habitat slope was in all cases southern to soutwestern: on western slopes few and on nortwestern ones no nests were to be found. This is explainable by the considerably different light-climate exposition of the slopes, of which the S–SW exposition received the greatest amount of insolation. In the case of a 20 °C declivity for instance, light energy and the angle of inclination of sunshine are twice as much on a southern to southwestern slope at noon during the summer than on a northern slope (ANDÓ, 1959).

The environment of the S–SW loess wall inhabited by the wasps consists, phytocoenologically, of steppe swards and karst shrubs (*Festucetum sulcatae* and *Cotino-Quercetum*); it is owing to this fact (MÓCZÁR, 1960) that the wasp settled and breeds on the loess wall, as reported several times in the past 34 years (MÓCZÁR, 1939–1972). In Hungary, the wasp nests in one other place only, the corresponding slopes of the Mts. Villány, South Hungary; otherwise the species ranges in the Mediterranean region.

2. Connections of the habitat and solar factors

a. The duration of insolation of the loess wall

The southern and southwestern exposition as well as the angle of inclination of the loess wall assure the obtaining of a considerable amount of light and energy. The hourly sequence of magnitude of insolation angle and energy values for the horizontal level (calculations in Central European Mean time), in the period 26 June–8 July, 1971, was at Tihany as follows:

Table 1. Insolation and energy values per hour

Hour	Insolation angle values	$Cal/cm^2/min^1$
4 h 48″	7° 3′	0.0368
5 h 48″	16° 35′	0.1855
6 h 48″	26° 37″	0.4001
7 h 48″	36° 51′	0.6297
8 h 48″	46° 53′	0.8161
9 h 48″	56° 5′	0.9958
10 h 48″	63° 13′	1.116
11 h 48″	66° 5′	1.156
12 h 48″	63° 13′	1.116
13 h 48″	56° 5′	0.9958
14 h 48″	46° 53′	0.8161
15 h 48″	36° 51′	0.6297
16 h 48″	26° 37′	0.4001
17 h 48″	16° 35′	0.1855
18 h 48″	7° 3′	0.0368

On the loess wall, values double owing to the angle of inclination and exposition. The amount of sunshine falling on the wall is especially high between 11 a.m.–5 p.m. This is the main reason why the activity of the wasps starts relatively late in the forenoon, and continues in essence in the afternoon only so far and only in sites where the wall is insolated. In sunny, clear weather the wasps are active also between 10 a.m.–7 p.m. The earliest and latest activities are illustrated in Table 2.

Table 2. Number of earliest and latest active wasps.

4 July	3 ——	———————— 6
5 July	10 ————	—— 28
6 July	21 ————————	———— 10
7 July	10——30 ————————	———— 39
	10^{33}—10^{30}—11^{00}—11^{30}—12^{00}—13^{30}—14^{00}	17^{30}—18^{00}—18^{30}—19^{00}

It is worthy of note that, according to TSUNEKI (1969), *Odynerus frauenfeldi* SAUSSURE flies out as the earliest between 7^{01}–7^{30} and at the latest between 15^{00}-16^{30}, being active occasionally until 17^{00}–17^{30}.

3. Temperature conditions of the habitat and its environment

a. Temperature of the loess substrate at depths of 2 and 5 cm

On clear and sunny days (5–6 July), the warming-up of the loess wall presented a peculiar picture. The rate of warming-up is illustrated by the graphs of Figs. 6–8. It is rather conspicuous that the surface and the air layer immediately above it heat up rapidly, while the heat diffuses rather slowly

Fig. 1. A part of the western slope of the loess wall at Tihany.

Fig. 2. The cup anemometer and the Assmann psychrometer in front of the Paragymnomerus nests.

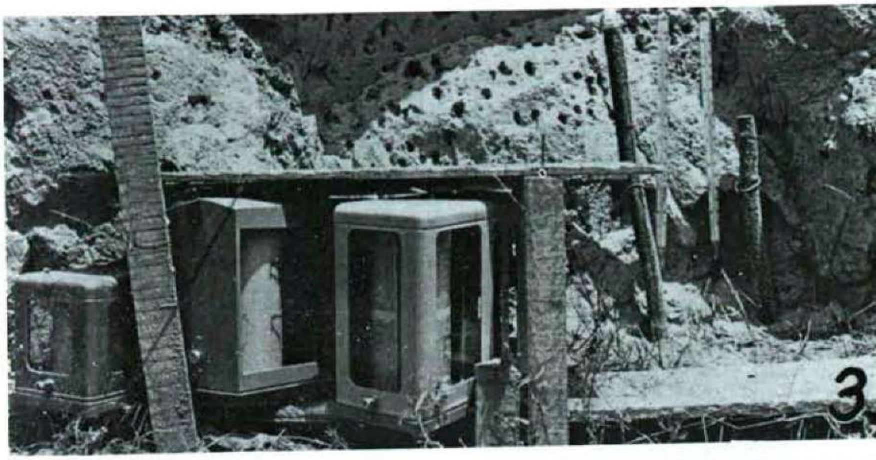
within the loess substrate. Two cm below the surface, the magnitude value of the temperature during the forenoon warming-up phase lags, as related to that of the air 10 cm above the surface, 2 hours, and at a depth of five cm 4 hours. An isoplete illustration (Fig. 9) displays the distribution of warming-up, with reference to the amount of heat received and the heat regime, of the surface, the atmosphere and the loess substrate. The immediate surface layer to a depth of 0.5 cm can be considered a definitely warm layer, the same as the air layer directly above it.

The value of the correlation coefficient between the temperature values observed at a depth of 2 cm and the activity of the wasps is still positive and comparatively great (0.8608 ± 0.0722). A close stochastic relationship exists

Fig. 3. Temperature recording instruments (barograph, termohygrograph, psychrograph), with the soil thermometers at 2 and 5 cm depths (right side).

Fig. 4. Minimum thermometer on the slope near the loess wall.

Fig. 5. Hygrograph (left), soil thermometer and thermograph placed at the Balaton level.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between the two variables. In the investigated temperature and activity interval, the approaching regression function of the connection is linear (Fig. 10).

The value of the correlational coefficient between the temperature values measured at a depth of 5 cm and the activity of the wasps is low (0.2444 ± ± 0.297), hence it cannot be brought into relationship with the activity of the wasps on the surface of the loess wall (Fig. 11). Temperature changes within the wall influence rather the development of the larvae reposing in the excavated brood chambers.

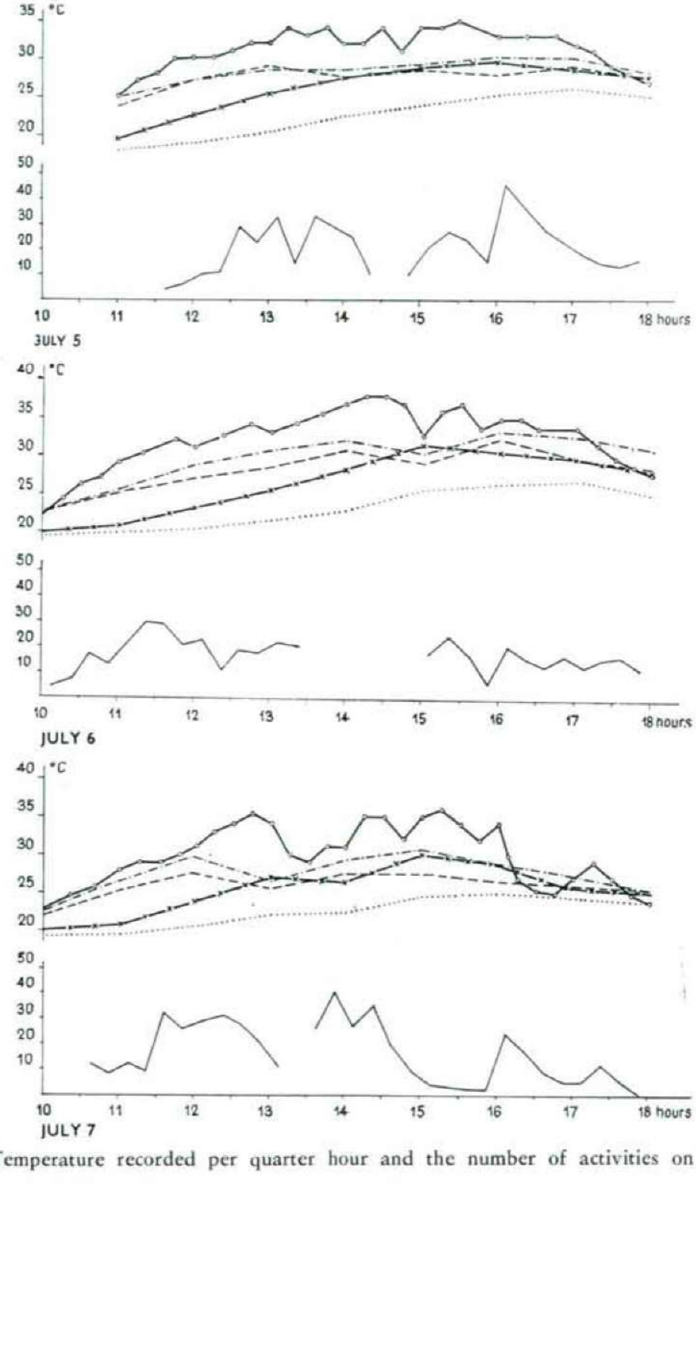

Fig. 6—8. Temperature recorded per quarter hour and the number of activities on 5, 6, 7 July.

b. Changes of atmospheric temperature, minima and maxima

In the investigated period, atmospheric temperature was not invariably favourable, but rather separable into three macrosynoptic situations:

cloudy, rather warm weather with showers,
variably overcast sky, very cold weather,
wind-free, clear, warm weather.

This latter was experienced between 5–7 July and on some subsequent days; prior to this, the prevailing weather was extraordinarily cold (1–2 July). The daily temperature mean fluctuated between 13–15 °C, less by 5–7 °C than the mean calculated for the previous hundred years. In clear, warm, dry, windless weather the daily temperature mean exceeded 20 °C, indeed, it was + 1.3 °C higher on 6 July than again the daily mean calculated for hundred years.

The daily temperature data of the loess wall and its environment are given in Figs. 6–8. The changes of the atmospheric temperature were composed from a series of data. The termograph was continuously operating near the nesting site of the wasps on the loess wall (Fig. 3, left). We took readings every hour by an Asmann psychrometer, first on the site of the loess wall preferred by the Sceliphrons, then in a cavity then at a height of 1 m immediately in front of the wall (Fig. 2). Of these, the first and the third data gave more reliable data in view of the nests of the wasps. The termograph ran invariably in the same place, therefore it gave even more reliable data than the values measured by the manual instrument read every hour.

The minimum and maximum values measured on the days under discussion are submitted in Fig. 12. on 5 July, we measured the 35 °C maximum at 15^{30} (Fig. 6), but the maximum activity was between 16^{00}–16^{15}. The 36 °C maximum on 6 July was at 14^{30} (Fig. 7), while the maximum activity fell between 13^{45}–14^{00}. It should be added that on the same day we measured 35 °C at 12^{45}, on the basis of a continuous warming-up, therefore a maximum temperature was present already then. After an also uninterrupted warming-up, on 7 July, the maximum 38 °C was read at 14^{30} (Fig. 8), while the maximum activity occurred between 11^{15}–11^{30} (the possible source of error might lie in the fact that we observed only a part of the loess wall between 14^{00}–15^{00}).

It appears therefore that the maximum activity follows the onset of the temperature maximum.

c. Activity observed per quarter hours and temperature

For the evaluation of the relationship between activity and atmospheric temperature, the days 5–7 July were the most suitable. Activity numbers recorded at the points of time of observation and the corresponding temperature values per quarter hour are given in detail in Figs. 6–8. Owing to the causes given above, we record here the thermograph data.

On 5 July, temperature started with 25 °C at 11^{00}, reaching after a largely gradual increase 34 °C by 13^{15}. Also activity increased gradually, from 4 to 33 per quarter hour, falling back to 23 only between 12^{45}–13^{00} – in a period when temperature remained unchanged (31.9 °C) but when the sun was obstruction by a cloud and to this the wasps reacted sensitively. When temperature fell by 1 °C (33 °C) at 13^{30}, also activity dropped consideably (to 15). This phenomenon repeated itself between 13^{15}–14^{30}. At 14^{45} temperature fell by 3 °C (to 31 °C), with a corresponding decrease also in activity. Between 14^{45}–15^{30} temperature again reached by 4 °C the daily maximum (35 °C), so that the number of active wasps increased again, therefore after the smaller relapse owing to the clouded sky activity maximum again rose to 46 in the wake of the temperature maximum. After 16^{00}–16^{14} both temperature and activity decreased gradually together.

On 6 July, temperature was 23 °C at 10^{00}, with the maximum 35 °C reached at 12^{45}. Activity, with some smaller fluctuations, reached its first maxima (32 and 31, respectively) between 11^{30}–11^{45} and 12^{15}–12^{30}. Subsequently, temperature fell 6 °C till 14^{15} (29 °C), markedly observable also on the activity of the wasps. Besides the two smaller drops in temperature (3 °C on both occasions), a greater decrease (10 °C, resulting in 25 °C) happened only at 16^{45}; before the evening cold, this was followed yet by a smaller warming up period (29 °C at 17^{15}). Owing to these latter fluctuations in temperature, activity

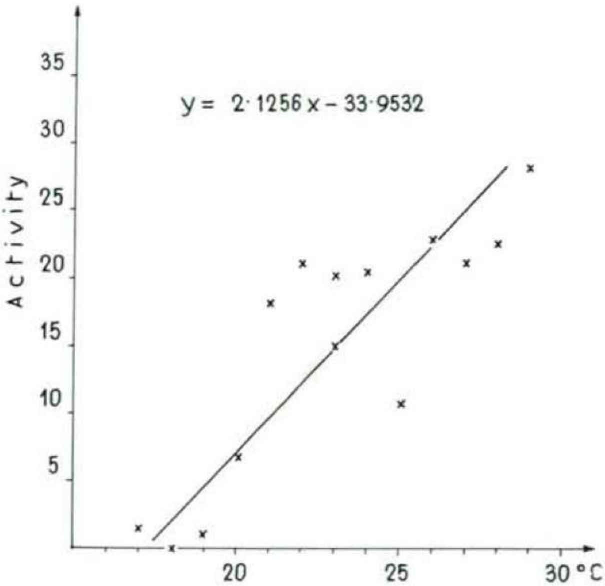

Fig. 10. Regression of connection between temperature of loess wall measured at a depth of 2 cm and the activity of the wasps.

also seemed to decrease considerably, and the number of active wasps increased significantly only after the temperature maximum mentioned above.

On 7 July, temperature rose from 22 °C at 10^{00} to 38 °C by 14^{30}, therefore by 16 °C. Subsequently, it fell back considerably at 15^{00} and 15^{45}, decreasing gradually to 28 °C by 18^{00}. The course of activity is less unequivocal. Most active wasps (30) were observed between 11^{15}–11^{30}, and though temperature continued to rise – even if occasionally dropping somewhat owing to the

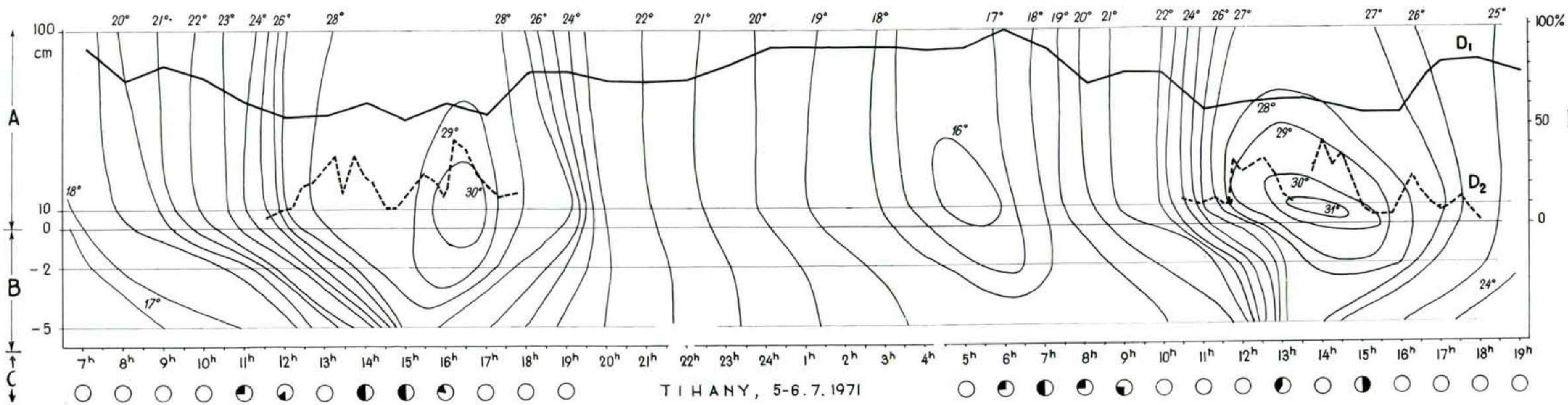

Fig. 9. Temperature distribution in the isoplete system. A = atmospheric temperature; B = soil temperature; C = values in hours of sunshine duration and temporal line; D = per cent scale; D/1 = atmospheric humidity in per cent; D/2 = activity in per cent.

passing of clouds – it failed to increase activity. The falls in temperature at 15^{00} and 15^{45} had significantly decreased also activity.

By a statistical analysis of the atmospheric temperature and the activity of the wasps it can be established that the correlational connection of activity is the closest with the temperature measured by the thermograph ($c = 0.986 \pm \pm 0.0065$). This result completely agrees also with the data of Figs. 6–8. The regressional connexion of atmospheric temperature and activity is linear in the investigated interval, similarly to that of the temperature of the loess wall measured at a depth of 2 cm (Fig. 13). A less close stochastic relationship could be observed with the temperature measured by the Assmann psychrometer at a height of 1 m ($c = 0.9119 \pm 0.0415$) or in the cavity of the loess wall ($c = 0.719 \pm 0.145$). The cause lies in all probability in the measuring technique discussed above. Our newest, 1972 observations seem to substantiate the assumption that the activity of the wasps still increases to a temperature about 40 °C, reaching its maximum there, and then it conspicuously falls back.

d. The qualitative distribution of the daily activity

Of the various activities of the wasp, a prolonged observations is mainly possible of the building of the nest (that is, the digging of the pupal chamber, the construction of the turret or the discarding of the excavated earthen pills) and the transportation of the sawfly larvae. According to our observations, the wasps were busy constructing, between 10 a.m.–6 p.m., in the following number (= amount, and not numbered!) of turrets or carrying sawfly larvae for food (the amount of this latter given in brackets):

Table 3. Qualitative distribution of daily activity. Numbers refer to the amount of nests under construction, those in brackets designating the total of nests into which sawfly larvae were transported.

5 July	— —	— —	7 (2)	20 (6)	21 (4)	23 (3)	24 (4)	14 (7)	4 (1)
6 July	— —	13 (3)	9 (6)	22 (2)	24 (9)	22 (2)	15 (7)	5 (2)	1 (1)
7 July	1 (4)	15 (6)	16 (12)	20 (6)	21 (4)	22 (2)	21 (5)	11 (8)	— (3)
Total	1 (4)	28 (9)	32 (20)	64 (14)	66 (17)	67 (7)	60 (16)	30 (17)	5 (5)
	10	11	12	13	14	15	16	18	hours

Accordingly, most wasps were constructing nests between 12^{00}–16^{00} hours, and most were carrying sawfly larvae between 11^{00}–14^{00} and 15^{00}–17^{00} hours.

If the numbers of constructing or larva-transporting wasps are compared with the daily mean temperature data (Figs. 6–8), we find the following picture:

The greatest number of wasps were constructing their nests on 5 July in the hours of the temperature maximum (14^{00}–16^{00}); on 6 July in the hours between the temperature maxima (12^{00}–15^{00}); on 7 July in the hours of the temperature maximum (14^{00}–15^{00}) and in the two hours preceding it (12^{00}–14^{00}). As far as the transportation of sawfly larvae for food was concerned, the wasps were carrying the larvae also during the hour after the maximum (15^{00}–16^{00}) on 5 July; in the hour following the first or the forenoon maximum (13^{00}–14^{00}) (at the time when temperature had conspicuously decreased) on 6 July; and in the forenoon hour (11^{00}–12^{00}) of the still warming up temperature, as well as following the maximum (16^{00}–17^{00}) on 7 July.

e. Mean period (duration) of daily activity

If observations running merely to one or two days are disregarded and only those extending over at least 3 days are taken into account, the following periods, with respect to the daily activity of the individual wasps, are obtained (Table 4):

Table 4. Period totals of the daily activity.

Serial number of wasp	Daily activity/hour on July					Daily mean of work
	3rd	4th	5th	6th	7th	
15			4.50	2.37	6.29	4.47
18	0.32		5.34	4.25	6.31	4.16
19	0.52	2.58	5.31	6.36	5.09	4.12
23	4.57		0.17	4.42	2.37	3.00
28	3.38	3.39	0.57	6.49	7.38	5.43
29			5.19	5.44	6.32	5.52.
30		4.15	5.47	6.22	5.19	5.26
31		3.11		2.06	6.34	4.33
33			6.00	4.52	5.04	5.19
34			4.28	3.25	1.57	3.17
35	0.44		2.03	5.59	5.00	3.29
36			2.22	6.40	7.39	5.34
37			4.33	2.40	5.02	4.05
38			5.08	6.40	6.04	5.58
39	6.15	4.46	2.04	3.53	4.55	4.46
46	1.19	0.40		5.08	6.20	3.22
47		5.02	1.53	4.37	6.08	4.25
48			4.50	6.53	4.45	6.09
50			4.00	5.18	5.03	4.47
56			4.24	0.04	2.55	2.27
57		3.57	2.25	6.54	6.20	4.54
59		0.13	5.45	4.46	0.31	2.48
61			4.58	5.34	7.11	5.54
64			4.57	4.03	7.38	5.32
65			5.22	7.16	7.31	6.42
66			4.24	7.18	6.17	5.59
68			4.16	5.17	0.04	3.07
72			4.27	2.45	6.19	4.30
75			2.57	8.24	5.28	3.48
81			1.16	6.28	4.11	3.56
85			5.12	3.01	0.31	2.55
86			2.08	6.06	1.55	3.23
87			2.11	6.42	7.22	3.15
89			3.10	1.01	5.49	3.20
90			0.08	1.56	2.02	1.22
93			1.27	5.11	6.42	4.26
94			0.49	5.15	7.01	4.22
102				4,34	4.03	4.21
						158.01

According to the above data, the daily activity of the wasps fluctuate between rather wide limits. Even on the day of the most favourable temperature (7 July), Wasp No. 68 spent no more than 4 minutes in its nest, whereas Wasp No. 36 was active for 7 hours and 39 minutes on the loess wall. The totalling of the data shows that during the above observation days the 38 wasps were active for an average of 4.158 hours on the surface of the loess wall held under observation.

4. Atmospheric humidity, precipitation and wind conditions of the habitat and its environment

The per cent distribution of the annual wind direction in the region discussed is as follows:

NW	18%	S	5%
N	10%	SW	12%
NE	8%	W	19%
E	12%	Wind free	10%
SE	6%		

The area is on the lee side, but the vegetation gives complete shelter against winds for the nesting site of the wasps. Though aerial movements measurable with an anemometer (Fig. 2) could be observed in the case of a stormy wind force, even this movement was so slight at the loess wall that

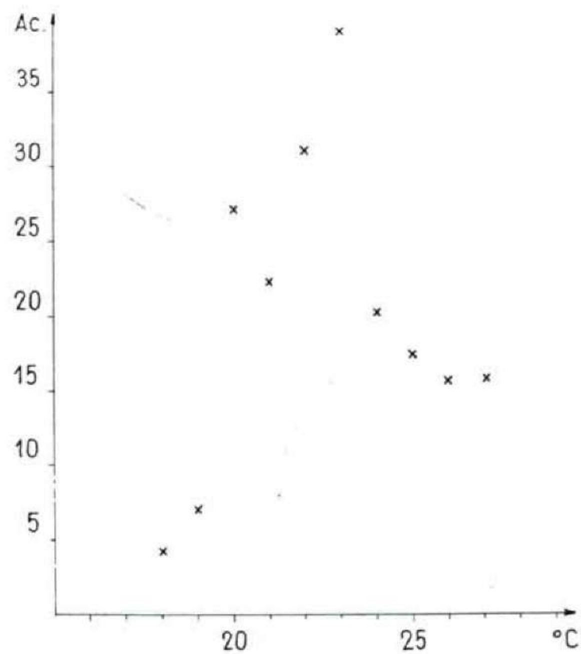

Fig. 11. Connection between the temperature of the loess wall measured at a depth of 5 cm and the activity of the wasps.

it had not influenced the activity of the wasps in the least. Atmospheric humidity conditions, on the other hand, affected the wasp to a considerably greater extent.

Paragymnomerus spiricornis has a Mediterranean range, and on the basis of its stenök eremophilous character one may presume that an increase in the

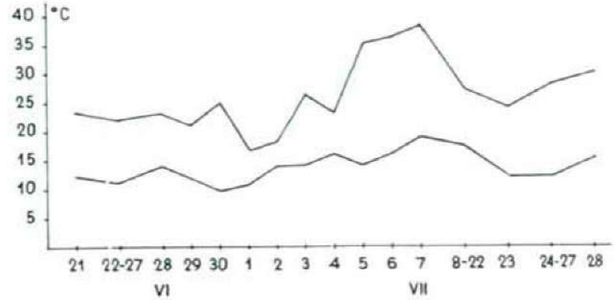

Fig. 12. Minimum—maximum data of the loess wall and its environment.

atmospheric humidity will influence the activity of the wasps rather to disadvantage. Instrumentated observations in this year have shown that the activity of the wasps is inversely proportional with the relative humidity content, and this was corroborated also by the correlational analysis ($C = -0.9728 \pm \pm 0.0112$).

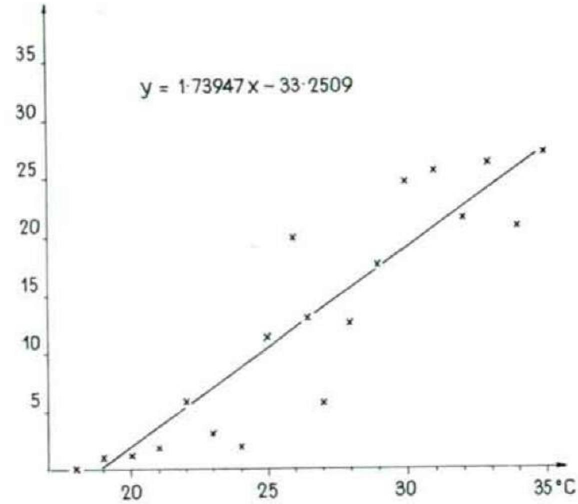

Fig. 13. Regression connection between atmospheric temperature in front of the loess wall and the activity of the wasps.

Since atmospheric humidity during the daytime is higher in the forenoon hours than in the afternoon, also this factor – in close connection with temperature – must have considerably influenced the activity of the wasps.

5. Summary

The Tihany Peninsula has a warm climate of a continental character. It receives as much sunshine as the most insolated part of the Great Hungarian Plains. The region has most characteristic local and microclimate conditions; especially the exposed hillsides show climatic features which determine the several life communities. Thus the position of the loess wall and the *Festucetum sulcatae* and *Cotino-Quercetum* environment afford nearly uniquely suitable conditions for the gregarious colonization of the site by *Paragymnomerus spiricornis* (SPINOLA). The exposition of the loess wall and the sheltering effect of the surrounding vegetation render the site free of aerial movements, a slight breeze occurring there only in stormy and tempestuous weather in the neighbourhood. The SW exposition of the slope, inclined nearly 90°, is directly insolated from about 10–11 a.m., so that, owing to the steep inclination, the considerable amount of energy causes a rapid upward increase of temperature, inciting – between 11 a.m. and 7 p.m. – the activity of the wasps.

The value of the correlational coefficient between the subsurface temperature of the wall (measured at a depth of 2 cm) and the activity of the wasps is positive and great, the regressional function of the relationship is linear. Temperature values measured at a depth of 5 cm influence rather the development of the larvae in the pupal chambers. Aerial humidity content is inversely proportionate with the activity of the wasps, the value of the correlational coefficient is -0.9728 ± 0.112. The activity of the wasps is mostly influenced by the atmospheric temperature in front of the loess wall (the correlational coefficient is 0.986 ± 0.0065). Maximum activity sets in after the temperature maxima. Activity figures, totalled per quarter hour, correspondingly followed the changes in temperature observed by a thermograph on 5 and 6 July. On 7 July, the two failed to exhibit this close connexion, though still in agreement. Drops in temperature or even the passing of a larger cloud causes a decrease in activity. Concerning the qualitative distribution of activity, the greatest number of wasps was observably occupied in constructing nests between 12^{00}–16^{00} in the suitable warmth and carrying sawfly larves for food between 11^{00}–14^{00} and 15^{00}–17^{00}. Nest constructing occurred mainly during the hours of the temperature maximum, while the transportation of the sawfly larvae in the preceding or the subsequent hours. The period of daily activity of the wasps fluctuates between 4 minutes and 7 hours 39 minutes. Thirty-eight numbered (marked) wasps were active on the loess wall for a mean period of 4 hours and 15 minutes per individual during 5 days of observation.

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