Jpn. J. Ent., **60** (3): 551–557. September 25, 1992

Stage Duration, Size and Coloration of Two Praying Mantises, *Tenodera aridifolia* (STOLL) and *Tenodera angustipennis* SAUSSURE (Mantodea, Mantidae)

Taku IWASAKI

Entomological Laboratory, College of Agriculture,
University of Osaka Prefecture, Sakai, Osaka, 593 Japan

Abstract Two praying mantises, *Tenodera aridifolia* and *T. angustipennis*, were reared under quasi-natural conditions in Kyoto to compare stage durations, body lengths and body colors. In both species, most individuals grew to adults through 7 nymphal instars (7-instar type), while a few males (15.0% in *T. aridifolia*; 11.1% in *T. angustipennis*) through 6 instars (6-instar type). In the 7-instar type, adults of *T. aridifolia* were larger (78.4 and 83.5 mm in male and female mean body lengths) than those of *T. angustipennis* (75.0 and 78.4 mm). Nymphs hatched between April 26 and June 11 in *T. aridifolia* and between June 8 and 15 in *T. angustipennis*, and total nymphal durations of *T. aridifolia* were longer (96.4 and 94.5 days in males and females) than those of *T. angustipennis* (76.8 and 72.8 days) in the 7-instar type. In both species, males of 6-instar type were larger than those of 7-instar type in the 6th instar, but the size relation was reversed in the adult. Adults of the green type were more common than those of the brown type in both species; the rate of green type was larger in *T. angustipennis* (91.0%) than in *T. aridifolia* (65.4%). Ratios of green to brown type were also larger in *T. angustipennis* than in *T. aridifolia* in the fields of Kyoto and Osaka. Some individuals changed the body color from green to brown after the 3rd instar stage when the green or brown coloration became distinct.

Key words: Molting type; stage duration; size; coloration; *Tenodera*; mantis; rearing.

Introduction

Two praying mantises, *Tenodera aridifolia* and *T. angustipennis*, are both common in grasslands of central Japan. *T. aridifolia* mainly inhabits forest edges, where grasses such as kudzu (*Pueraria lobata*), goldenrod (*Solidago altissima*), pampas grass (*Miscanthus sinensis*) and sasa grass (*Pleioblastus variegatus*) are abundant, while *T. angustipennis* is found in paddy fields or fallowed fields predominated by the goldenrod. Habitats of the two species are roughly segregated from each other (ISHIHARA 1976; MATSURA 1984). Although *T. angustipennis* has been studied on the subject of life history (MATSURA *et al.* 1975: MATSURA 1979; MATSURA *et al.* 1984), predation (MATSURA 1981; MATSURA & NAKAMURA 1981; INOUE & MATSURA 1983) and oviposition (MATSURA & MOROOKA 1983), there are few comparative studies with the congener *T. aridifolia*. Thus the rearing of both *T. aridi-*

folia and *T. angustipennis* was conducted under quasi-natural conditions in order to clarify the life history of both species and to understand their ecological relationships.

Materials and Methods

Six and three egg cases of *Tenodera aridifolia* and *T. angustipennis* collected in Kyoto city in March, 1988, were kept outdoors being sheltered from the direct sunlight in the campus of Kyoto University. After eggs hatched out, 20 or 10 nymphs from each egg case were reared individually in order to prevent cannibalism. Rearing containers were changed according to the nymphal development; 200 ml and 450 ml plastic cups for 1st–4th and 5th–6th instar nymphs, respectively, and 1350 ml rectangular plastic containers for 7th instar nymphs and adults. Each container was equipped with a small net as the scaffold in ecdyses. A cricket, *Gryllus bimaculatus* (DE GEER), of about one fifth of the mantis in body length was fed the nymphs almost every morning except for the day of ecdyses, while adults were fed ad libitum. Nymphs were provided with water 2 or 3 times in each instar including the day of ecdysis. The body length and body coloration were measured and observed on the next day of each ecdysis.

The coloration of adults was investigated also in the natural fields of Kyoto and Osaka prefectures in 1988–1990.

Results

Number of molts and stage duration

The number of individuals surviving to the adult stage is shown in Table 1. Although most individuals of both species grew to adults through 7 nymphal instars ("7-instar type"), 3 males (15.0% of total males) of *Tenodera aridifolia* and 1 male (11.1%) of *T. angustipennis* became adults after 6 molts ("6-instar type"). Most nymphal deaths were due to the failure in ecdysis in both species.

Table 2 shows the duration of each stage. In 1988, nymphs hatched between April 26 and June 11 in *T. aridifolia* and between June 8 and 15 in *T. angustipennis*, and adults emerged between July 27 and September 10 in *T. aridifolia* and between

Table 1. The number of the adults of 6- and 7-instar types obtained from the present rearing of *T. aridifolia* and *T. angustipennis*.

Species	No. hatch	No. emergence	Survival rate (%)	male		female
				6-instar type	7-instar type	7-instar type
T. aridifolia	110	52	47.3	3	17	32
T. angustipennis	60	22	36.7	1	8	13

Table 2. Mean durations of each stage of *T. aridifolia* and *T. angustipennis* in days. Standard deviations are shown in parentheses. P: the significance by t-test between males and females of 7-instar type (NS: P>0.05, *: P<0.05).

Sex	Molting type	N	Stage 1	2	3	4	5	6	7	Total	Adult
T. aridifolia											
male	6-instar	3	15.7	12.3	11.0	10.5	13.0	22.3	—	85.0	71.0
	type		(5.8)	(2.9)	(1.0)	(1.0)	(0.0)	(1.2)	—	(8.7)	(11.5)
male	7-instar	17	18.5	13.2	10.8	9.1	10.7	11.9	22.1	96.4	48.6
	type		(3.5)	(2.6)	(1.1)	(1.3)	(0.8)	(3.1)	(3.2)	(4.8)	(33.0)
	P		NS	NS	NS	NS	NS	NS	NS	NS	*
female	7-instar	32	18.8	12.8	10.8	9.1	10.5	11.6	21.0	94.5	73.0
	type		(3.1)	(1.9)	(1.0)	(1.1)	(0.9)	(1.1)	(2.4)	(5.1)	(31.7)
T. angustipennis											
male	6-instar	1	14.0	8.0	8.0	9.0	10.0	23.0	—	72.0	66.0
	type		—	—	—	—	—	—	—	—	—
male	7-instar	8	10.8	8.1	8.0	8.3	9.7	16.2	16.3	76.8	56.0
	type		(2.3)	(1.2)	(1.1)	(0.9)	(0.9)	(7.5)	(2.2)	(6.8)	(24.2)
	P		NS	NS	NS	NS	NS	NS	NS	NS	NS
female	7-instar	13	9.5	8.4	8.5	8.2	9.4	11.2	17.8	72.8	63.0
	type		(1.5)	(1.0)	(1.5)	(1.3)	(1.7)	(3.2)	(2.9)	(4.3)	(14.6)

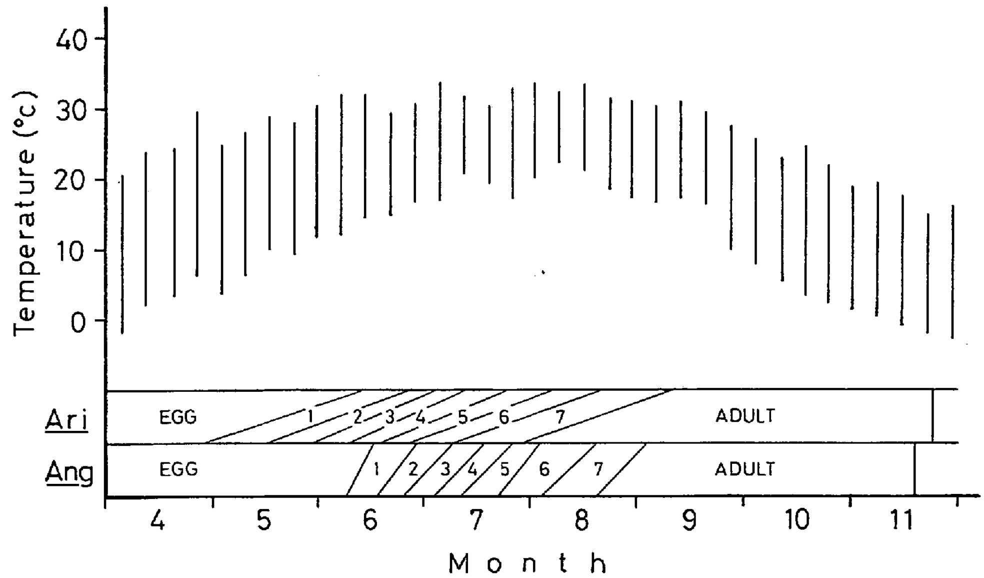

Fig. 1. Weekly maximum and minimum temperatures in the campus of Kyoto University and the generalized developmental schedule drawn from the present rearing of *T. aridifolia* and *T. angustipennis*. Each oblique line is combined between the first and the last recruitment to each stage in each species.

Table 3. Mean body length (mm) in each stage of *T. aridifolia* and *T. angustipennis*. Standard deviations are shown in parentheses. There are significant differences between underlined figures in two species of the corresponding molting type ($P<0.05$ by t-test). P_1 and P_2 are significances by t-test between males of 6- and 7-instar types, and between males and females of 7-instar types, respectively (NS: $P>0.05$; *: $P<0.05$; **: $P<0.01$).

Sex	Molting type	N	Stage 1	2	3	4	5	6	7	Adult
T. aridifolia										
male	6-instar type	3	10.3	16.3	22.3	31.0	41.7	57.0	—	73.3
			(1.2)	(0.6)	(0.6)	(1.0)	(2.1)	(2.0)	—	(3.8)
	P_1		NS	NS	NS	NS	**	*	—	**
male	7-instar type	17	10.8	15.8	22.1	30.3	40.3	53.3	67.6	78.4
			(0.4)	(0.7)	(1.0)	(1.5)	(1.2)	(2.4)	(3.5)	(4.2)
	P_2		NS	*	NS	NS	*	NS	**	**
female	7-instar type	32	11.0	16.2	22.6	30.8	41.1	54.4	70.7	83.5
			(0.4)	(0.6)	(0.8)	(1.2)	(1.2)	(1.6)	(2.2)	(3.5)
T. angustipennis										
male	6-instar type	1	9.0	15.0	22.0	30.0	38.0	54.0	—	66.0
			—	—	—	—	—	—	—	—
	P_1		NS	NS	NS	NS	NS	*	—	**
male	7-instar type	8	9.8	15.0	20.9	29.3	39.0	50.7	61.7	75.0
			(0.6)	(0.9)	(0.8)	(0.7)	(1.0)	(1.2)	(1.8)	(2.4)
	P_2		NS	NS	NS	NS	NS	NS	NS	*
female	7-instar type	13	10.1	15.2	21.6	29.7	39.8	51.6	62.3	78.4
			(0.3)	(0.6)	(0.7)	(0.9)	(1.1)	(1.6)	(2.3)	(2.7)

August 19 and September 3 in *T. angustipennis*. The mean duration of the total nymphal stages of *T. aridifolia* was significantly longer (96.4 and 94.5 days in males and females) than that of *T. angustipennis* (76.8 and 72.8 days) in the 7-instar type ($P<0.01$ by t-test). The mean duration of each stage did not differ between sexes in the 7-instar type of either species ($P>0.05$), except for the adult stage of *T. aridifolia*. The mean 6th instar stage of 6-instar type was significantly longer than that of 7-instar type in *T. aridifolia* ($P<0.01$). The mean 1st instar stage of *T. aridifolia* was much longer than that of *T. angustipennis* ($P<0.01$), which is probably because the former species hatched about a month earlier and experienced lower temperatures than the latter (Fig. 1).

Body length

Table 3 shows the mean body length of each stage in *T. aridifolia* and *T. angustipennis*. In both species, 6th instar males of 6-instar type were larger than those of 7-instar type in the mean body length ($P<0.05$ by t-test), although adult males of 6-instar type were smaller than those of 7-instar type ($P<0.01$). Females tended to be larger than males. This tendency was already clear in nymphal stages in *T. aridifolia*, but in the 7-instar type of *T. angustipennis* it was not until the adult

Table 4. Body coloration of the adults of *T. aridifolia* and *T. angustipennis*, and the change of body coloration once after the green or brown types are distinct (see text). The rates of green or brown type in the adults of both species are shown in parentheses.

Species	Adult coloration		Change of body coloration	
	Green	Brown	Green to Brown	No change
T. aridifolia	34 (65.4%)	18 (34.6%)	10	42
T. angustipennis	20 (91.0%)	2 (9.0%)	1	21

Table 5. The rates of green type adults of *T. aridifolia* and *T. angustipennis* in the fields.

Species	Localities	Year	Rate of green type	
T. aridifolia				
	Kyoto city	1988	73.9%	(68/ 92)*
	Izumi city, Osaka	1989	66.2%	(157/237)
	Izumi city, Osaka	1990	70.3%	(78/111)
	Total		68.9%	(303/440)
T. angustipennis				
	Kyoto city	1988	94.5%	(52/ 55)
	Sakai city, Osaka	1989	79.3%	(153/193)
	Total		82.7%	(205/248)

* No. green type/No. sampled.

stage that the sexual difference in body length became evident. It should be noted that *T. aridifolia* was larger than *T. angustipennis* in most stages of 7-instar type in both sexes.

Body coloration

Table 4 shows the adult body coloration and the change of body coloration after the 3rd instar. In both species nymphs of early stages had light brown bodies until the 3rd or 4th instar stage, when their body color turned either distinct green or brown. Green-type individuals were more common than brown-type in both species, though the rate of green to brown type was smaller in *T. aridifolia* than in *T. angustipennis* ($P<0.05$ by FISHER's exact probability test). Similar tendency was also observed in the fields in Kyoto and Osaka (Table 5). The average rate of green to brown type in *T. aridifolia* was smaller than that in *T. angustipennis* (303/440 vs 205/248, $\chi^2=15.6$, $P<0.01$). The change of body coloration from green to brown occurred during nymphal stages in some individuals of both species (Table 4).

Discussion

MATSURA *et al.* (1984) reared *Tenodera angustipennis*, and revealed the relationships among the molting type, stage duration, size, food consumption and food assimilation efficiency in each stage. They reported that the 6-instar type occurred in both sexes (only in males in the present study), but more frequently in males than in females. The dimorphism for the molting type may be maintained by the trade-off between growing to bigger adults (7-instar type) and growing to adults earlier (6-instar type). To grow into bigger adults is considered more important in females than in males, since females of 6-instar type will produce smaller oothecae containing fewer eggs than those of 7-instar type (MATSURA & MOROOKA 1983). In contrast, males of 6-instar type will gain the same fitness as those of 7-instar type if they copulate with the females of the same size. There are some species which have a similar molting-type polymorphism in the genus *Tenodera*. For instance, *T. aridifolia sinensis* has 7- and 8-instar types (HURD 1988). An African species, *T. superstitiosa* (FABRICIUS), is also known to have 7- and 8-instar types, and even a 9-instar type rarely occurs (KUMAR 1973).

The two congeneric praying mantises, *T. aridifolia* and *T. angustipennis*, segregate their habitats from each other in the field in Kyoto and Osaka (ISHIHARA 1976, MATSURA 1984). In the present study, *T. aridifolia* hatched in spring about a month earlier on the average than *T. angustipennis* with a widely scattered hatching pattern. However, since the total nymphal stage was longer in *T. aridifolia* than in *T. angustipennis* by a month, probably because of lower temperatures experienced by the younger nymphs of the former species, the adults of both species emerged almost simultaneously in late summer. The early hatching and development of *T. aridifolia*, which is larger than *T. angustipennis* in each stage, amplify the size difference between the two species. The trait may relate to the habitat segregation of the two species, because their demands for prey size or strength of scaffold (some parts of plants) for ambushing and moving are considered to depend on the body size of the predators.

RAU and RAU (1913) investigated the change of body color of the mantis *Stagmomantis carolina* (JOHANNSON). This species also has two color types: green and brown (or gray). Although the green nymphs have the ability to turn dark gray or brown as well as to remain green, the gray type nymphs do not change their body color under any environmental conditions (RAU & RAU 1913). These are similar to the results of the present study with *T. aridifolia* and *T. angustipennis*. However, it is still unclear whether they have the capability of changing the body color from brown to green. The rate of green to brown type was lower in *T. aridifolia* than in *T. angustipennis* in the fields in Kyoto and Osaka. It is possible that the rate of green or brown type is affected by the nature of habitats; green living plants are more prevalent in paddy fields, the main habitats of *T. angustipennis*, than in the habitats of *T. aridifolia*, since withered plants are always removed from paddy field artificially.

Acknowledgement

I express my thanks to Dr. M. ISHII of University of Osaka Prefecture for his useful advice and reading the manuscript. I also thank Dr. T. MATSURA of Kyoto Kyouiku University, Dr. H. OHTA of Kyoto University and Prof. Dr. T. YASUDA of University of Osaka Prefecture for their valuable advices. I am indebted to Prof. Dr. T. HIDAKA of Kyoto University for giving the opportunity to carry out this study.

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(Received February 25, 1992; Accepted May 15, 1992)