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A QUALITATIVE STUDY OF FOOD CONSUMPTION, GROWTH AND FECUNDITY OF A REDUVIID PREDATOR IN RELATION TO PREY DENSITY

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Nymphal instars and adults of a reduviid, *Neohaematorrhophus therasii* Ambrose and Livingstone were fed with caterpillars of *Corcyra cephalonica* Stainton in four prey densities (one, two, four and eight caterpillars/day/predator). Developmental period, predatory rate, percentage of survival and adult longevity of predators were negatively affected by prey scarcity. Low prey densities increased the preoviposition period. Fecundity and hatchability were increased as a function of prey density. The total prey consumption rate of both the nymphal instars and adults were minimum and maximum in one and eight prey densities respectively.
Heteroptera, Reduviidae, reduviids, predators, natural enemies, *Corcyra* larvae, biology, bionomics, predatory rate.

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Stadiji nimfe i odrasli grabežljive stjenice *Neohaematorrhophus therasii* Ambrose and Livingstone hranjene su s gusjenicama *Corcyra cephalonica* Stainton u četiri stupnja raspoložive hrane (jedna, dvije, četiri i osam gusjenica po danu i predatoru). Smanjenje broja gusjenica negativno utječe na trajanje razvoja, brojnost, postotak preživljavanja i dužinu života imaga predatora. Niska gustoća raspoložive hrane produljuje trajanje sazrijevanja jaja. Plodnost i izlijeganje bili su u porastu s gustoćom raspoložive hrane. Ukupna ishrana nimfi i imaga bila je najmanja kod jedne gusjenice, odnosno najveća kod gustoće osam gusjenica.
Heteroptera, Reduviidae, grabežljive stjenice, predatori, prirodni neprijatelji, gusjenice *Corcyra*, biologija, bionomija, gustoća populacije.

Introduction

Reduviids constitute a prominent group of predators due to their amenability to mass production (SAHAYARAJ, 1998) and potential for use in pest management (SAHAYARAJ, 1999).

One of the potential factors that need to be taken into account to understand field situation is the effect of prey scarcity or rarity. Some results indicate that prey density or prey scarcity positively affect the predator development, growth rate and fecundity (DUNBAR and BACON, 1972; BOZER *et al.*, 1996; DRUMMOND *et al.*, 1984; KUMARASWAMI, 1991). Prey scarcity caused predatory stinkbugs to compromise reproductive output for metabolic maintenance until sufficient prey was available to provide the necessary energy for reproduction (WIEDENMANN and O'NEIL, 1990). Reduviids individually required more food and consumed more preys than other predators (EVANS, 1962; SCHAEFER, 1988; AMBROSE and KUMARASWAMI, 1993, AMBROSE and CLAVER, 1997).

Pest suppression efficacy of reduviids on various crop pests is extensively studied throughout the world (SCHAEFER, 1988; COHEN, 1990; JAMES, 1994; SAHAYARAJ, 1995; SAHAYARAJ and AMBROSE, 1997; AMBROSE, 1997). Biology, ecology, pest preference, pest stage preference and functional response of *Neohaematorrhophus therasii* Ambrose and Livingstone were studied (SAHAYARAJ, 1991). Different prey type on the laboratory rearing of *N. therasii* (SAHAYARAJ and AMBROSE, 1994) suggested that its development and fecundity were enhanced by *C. cephalonica* larvae and the need for further studies on the effect of prey density on the development and fecundity of this biocontrol agent. However, information on survival and predatory potential vis-a-vis the required number of host larvae for this reduviid is lacking and hence studies were undertaken.

Materials and methods

Reduviid Predator

Adults of *N. therasii* were collected from Sivathipatti scrub jungle bordering agro-ecosystem (70°47E and 8°30N) Tirunelveli district, Tamil Nadu, India. They were maintained under laboratory conditions (30-32°C; 11-13h photoperiod and 75-80% relative humidity) in plastic vials (6 x 6 cm) on larvae of rice moth *Corcyra cephalonica* Stainton (Lepidoptera, Colleridae). SAHAYARAJ (1998) recommended this prey for the laboratory rearing of reduviids. First nymphal instars hatched from the laboratory laid eggs were chosen for these experimental studies. They were reared on four different prey density categories such as one prey category (OPC), two preys category (TPC), four preys category (FPC) and eight preys category (EPC) per predator per day. Sixty newly hatched nymph of *N. therasii* were taken individually in each plastic vial (6 x 6 cm) for every treatment.

Insect Prey

C. cephalonica eggs were purchased from Tamil Nadu Agricultural University (TNAU), Coimbatore and the larvae were reared on the diet containing wheat flour (2.5 kg), rice bran (500 g), crushed groundnut kernel (50 g), yeast granules (50 g), multi-vitamin tablet (500 mg) and streptomycin powder (1.0 g) in plastic troughs (5 L). Newly emerged fourth and fifth instar larvae of *C. cephalonica* from the laboratory stock culture were chosen as prey for this study. Since *C. cephalonica* larvae spun webs

and remained hidden under them, the reduviid predator often failed to attack and often got entangled in the webs and died. So the reduviid bugs were supplied with *C. cephalonica* larvae, whose heads were crushed gently to avoid webbing. KOPEC (1922) observed the necessity of brain for the inception of insect metamorphosis by making ligatures around the body of the caterpillars. Care was taken to crush the head of larvae, in order to avoid the hemolymph oozing. The head crushed larvae were found to be alive for about 30 days without feeding and remained fresh in appearance. The larvae fed upon by reduviids turned brownish black that facilitated to record the number of prey eaten by the predator.

Biological studies

Appropriate number of fourth and fifth instar larvae of *C. cephalonica* were provided to *N. therasii*. On every next day, the number of *Corcyra* larvae either consumed or killed was counted and was replaced daily with fresh larva. In such a way that the number of prey in each category was kept constant throughout the experiment. In this way predation was monitored throughout the lifetime of the predator. The data on the number of larvae consumed by different nymphal instars and adults of *N. therasii* were converted into predatory rate by using EVANS (1962) formula. Predatory rate = Number of prey consumed during an instar/Duration of the instar. Developmental duration of each stadium and total developmental period of the immature stages and survival rate of *N. therasii* at all the prey densities were recorded. The laboratory emerged adults from each category was grouped as one pair separately in plastic containers (6 x 6 cm) and totally 20 replications were maintained in each category. Adult longevity and fecundity per female over the lifetime was recorded in each prey density categories. The age at which adult females commence oviposition (pre-oviposition period), number of eggs, numbers of batches of eggs laid by a female predator and their hatchability were also recorded. An oviposition index was calculated as the percentage of egg laying days in the adult life span (SAHAYARAJ, 1991).

Statistical analysis

Analysis of variance (ANOVA) was used to determine the difference between prey density categories and fecundity, hatchability, stadial period, adult longevity and predatory rate. Duncan's multiple Range Test (DMRT) was used to separate treatment means (DANIEL, 1987). Significance was analysed at 5 per cent level. Sex ratio was statistically analysed by Chi square test.

Results

Stadial period and survival

The data (Table 1) revealed significant differences among the treatments and their stadium duration was influenced by prey density or scarcity. Decreasing prey density prolonged fourth and fifth stadium of *N. therasii*. Similarly prey density shortened the total nymphal period from one prey level (73.00 ± 1.96 days) to eight prey's level (68.25 ± 1.42) days respectively. Statistical analyses among prey levels were significant (P < 0.05). However, the comparison between two to four and eight and four to eight were statistically insignificant. Among the five stadia, the longest average stadial period was recorded in the fifth stadium in all the prey categories except the eight-prey density category. An opposite trend was observed in the second stadium except in the four and eight prey density levels. The survival rate of eight-prey density category was longer (88.00) followed by four, two and one respectively. Except between 4 and 8 prey categories, all other comparisons were statistically significant (P < 0.05) by DMRT.

Table 1. Effect of prey density on the stadial period (in days), sex ratio and percentage survival of *N. therasii* on *C. cephalonica*

Prey Number	Stadial Period (in days)			
	I	II	III	IV
One	15.22±0.36[a]	10.55±0.55[a]	15.66±0.66[a]	15.22±1.40[a]
Two	14.91±0.62[ab]	10.18±0.99[ab]	12.63±1.12[b]	11.82±0.52[b]
Four	14.61±1.19[abc]	12.38±0.58[ac]	14.69±1.74[ac]	11.38±0.70[bc]
Eight	17.38±1.23[a]	13.58±1.23[ac]	12.41±0.75[b]	10.83±3.13[bc]

Prey Number	Stadial Period (in days)		Sex ratio Male : Female	Survival (in %)
	V	I-Adult		
One	18.38±0.64[a]	73.00±1.96[a]	0.51 : 1.0	60.00[a]
Two	18.18±1.49[ab]	69.77±3.19[b]	0.57 : 1.0	73.33[b]
Four	16.16±1.08[c]	68.80±2.13[c]	0.63 : 1.0	86.66[c]
Eight	15.25±0.74[c]	68.25±1.42[c]	0.50 : 1.0	88.00[c]

Means followed by different letters with in a column are significantly different Using Duncan's multiple Range Tesr (DMRT)

Adult longevity and sex ratio

The longevity of the females was uniformly longer than that of the males (Fig. 1). The longest and shortest adult longevity of both male and female *N. therasii* was observed in the predators reared in eight and one prey density levels respectively. The statistical comparisons between different prey densities were insignificant for male adult longevity. However, the female adult longevity was significant (P < 0.05) except between two and four categories comparison. Irrespective of the prey densities tested, the sex ratio was female - biased in all categories and it was statistically significant by Chi square test (Table 1).

Fecundity and hatchability

Table 2 indicates the details of oviposition and hatchability of *N. therasii* in relation to different densities of *C. cephalonica.* Data show that *C. cephalonica* densities influences the fecundity and hatchability of the test insects. Number of eggs laid by the predator increased with increasing prey density. Highest fecundity was observed at eight-prey level, which had the longest adult longevity (Table 2). So, the predator with longer adult life span began to oviposit earlier (8.16 ± 2.98 days) and also retained lower number of oviposition days (16.43 ± 1.94 days). As observed in fecundity the number of nymphs hatched and hatching percentage was also the highest at the eight-prey density level. The difference in the total number of eggs laid by a female between the predators reared at different densities of *C. cephalonica* larvae was statistically significant (P < 0.05). The frequency of 0 per cent and 100 per cent hatching are minimum and maximum respectively in eight-prey density (Table 2).

Prey consumption and predatory rate

In the present work the food requirement of *N. therasii* has been assessed in terms of predatory value and it was taken as index for the laboratory rearing of the predator. As the age of the predator increases, the total prey consumption was also increased in all the prey density categories (Fig. 2). Nymphal instars and adults of *N. therasii* consumed both the fourth and fifth nymphal instar larvae of *C. cephalonica.* In the treatment having daily one host larvae per predator, the maximum consumption of larvae was observed (10.4 ± 0.65 larvae/day) by *N. therasii* immature stage as compared to other treatments (18.9 ± 0.93, 28.7 ± 1.21 and 38.8 ± 1.66 for TPC, FPC and EPC respectively) and are statistically significant (P < 0.05). Similar trend was also observed on the predatory rate of immature stages (0.14, 0.27, 0.42 and 0.57 prey/predator for OPC, TPC, FPC and EPC respectively). The mean total consumption of an adult was 107.11 ± 3.77, 117.07 ± 5.32, 121.11 ± 6.75 and 136.28 ± 4.89 *C. cephalonica* larvae at the rate of 2.44, 2.21, 2.17 and 2.07 larvae for OPC, TPC, FPC and EPC respectively.

Table 2 - *C. cephalonica* density on the fecundity and hatchability of *N. therasii*

Parameters	Prey density			
	One	Two	Four	Eight
Preoviposition period (in days)	15.66 ± 2.02[a]	12.33 ± 1.80[b]	9.5 ± 0.99[c]	8.16 ± 2.98[c]
Number of eggs laid/female	40.66 ± 7.85[a]	59.00 ± 10.39[d]	62.00 ± 4.73[c]	68.33 ± 10.31[d]
Index on oviposition days	20.13 ± 1.58[a]	19.81 ± 4.74[ab]	19.54 ± 1.89[abc]	16.43 ± 1.94[bc]
Hatching percentage	75.72 ± 3.18[a]	86.30 ± 15.37[b]	90.71 ± 2.28[bc]	93.19 ± 1.09[c]
Frequency of 0% hatching	1.00 ± 1.00[a]	1.50 ± 0.95[ab]	0.66 ± 0.42[ac]	0.33 ± 0.21[c]
Frequency of 100% hatching	8.33 ± 3.33[a]	9.66 ± 2.47[ab]	11.16 ± 1.10[bc]	12.33 ± 1.80[c]

Means followed by different letters within a column are significantly different using Duncan's Multiple Range Test

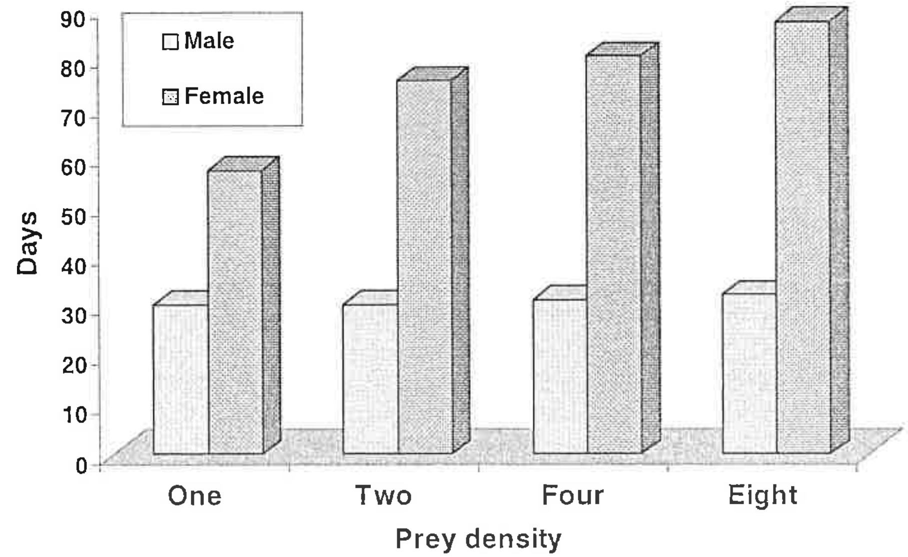

Fig. 1. Impact of prey density on the adult longevity of *N. therasii*

Discussion

The shortest stadial period was observed in the nymphal instars of *N.therasii* fed with *C. cephalonica* (67.59 days) followed by *Dysdercus cingulatus* Fab. (69.33 days) and *Odontotermes obesus* Rambur (101.30 days) (SAHAYARAJ and AMBROSE, 1994) while provided the prey at *ad libitum*. EVELEIGH and CHANT (1981) and AMBROSE and CLAVER (1997) suggested that low prey density minimises the stadial period with regard to the higher prey density. Generally predators that attack prey more frequently develop faster than predators which attack the prey less frequently (BAUMGAERTNER *et al.*, 1981; LENSKI, 1984). BOZER *et al.* (1996) pointed out that when the prey was scarce, allelochemicals in the diet of prey had a greater negative impact on the sting bug growth rate than when the prey was plenty. LAKKUNDI (1989); VENNISON (1989); SAHAYARAJ (1995) and AMBROSE (1997) reported that the fifth and the second stadia were the longest and the shortest respectively in most of the reduviids studied.

There was a positive relationship between the percentage of *N. therasii* survival and prey density. Only few predators died prior to the moult and the time of moulting on different prey density feeding experiments (WIEDENMANN and O'NEIL, 1990). However, EVELEIGH and CHANT (1981) stated that there was additional mortality from the low prey density category due to cannibalism and other factors. Since we have reared the predators individually, cannibalism had no role in mortality.

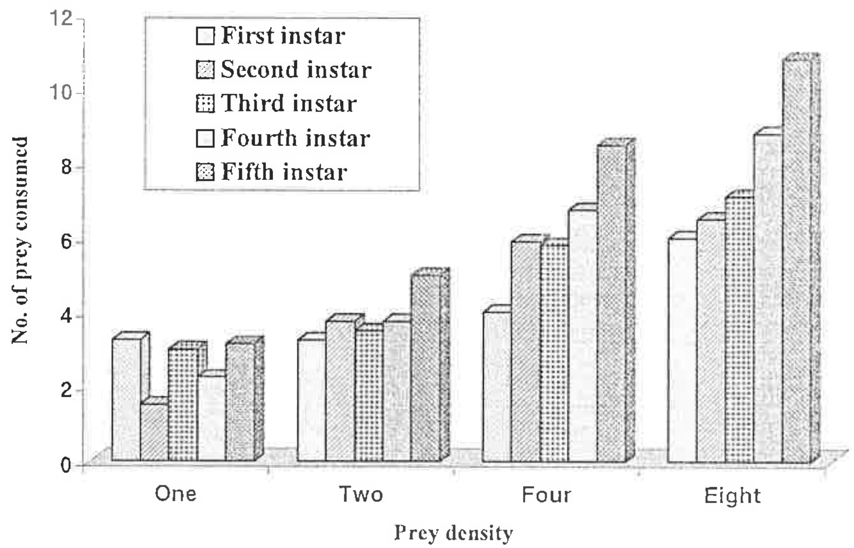

Fig. 2. Effect of prey density on predatory rate of N. therasii

Low prey inputs didn't increase the longevity in other predators such as pentatomid (MUKERJEE and LE ROUX, 1969), chrysopid (GANEV, 1977), mantis (MATSURA and MOROOKA, 1983), orb-weaving spider (WISE, 1975), carabid beetles (BAARS and VANDUK, 1984), predatory stink bug (LAGASPIS and O'NEIL, 1993), green lacewing (SARODE and SONALKAR, 1998) and mirid (TORRENO, 1994) and also in other reduviid (AMBROSE and CLAVER, 1997). Predators which emerged as adults earlier can live more days than the predators which attain adult stage slowly. Prey density did not affect the sex ratio and it was statistically significant in all the prey densities tested. The female-biased sex ratio in *N. therasii* was already observed by AMBROSE and LIVINGSTONE (1991); SAHAYARAJ (1991) and SAHAYARAJ and AMBROSE (1994). They reported that *N. therasii* is a polyphagous reduviid and their population was regulated by the prey population. They further observed the female biased population in the natural habitat and also in the laboratory. The highly female- biased sex ratio is advantageous in maintaining a mass culture of this reduviid.

The preoviposition period was greatly reduced in *Rhynocoris fuscipes* F. when the prey density was higher. However, the predators fed with excess prey showed delayed preoviposition in *Anthocoris confusus* (Reuter) (EVANS, 1976), and *Podisus maculiventris* (Say) (WIEDENMANN and O'NEIL, 1990). The number of eggs laid per female was in direct correlation with prey density and female adult longevity. CRAWLEY (1975) stated that predators that attack more prey lay more eggs than the predators which attacking less prey. A higher level of survival coupled with decreased egg production suggests a trade off between metabolic demands for these two processes (QUIRING and MC NEIL, 1984). SLANSKY (1980) attributed that the number of eggs laid by an insect shows a close relationship with the amount of food consumed and the adult female may cause a delay in the onset of egg-production due to lack of food. Similarly, the total number of eggs produced by a female decreased with low prey input in *Cyrtorhinus lividipennis* Reuter (CHUA and MIKIL, 1989), *P. maculiventris* (WIEDENMANN and O'NEIL, 1990), *Delphastus pusillus* Le Conte (HEINZ *et al.*, 1994), *C. tenis* (TORRENO, 1994), *R. fuscipes* (AMBROSE and CLAVER, 1997). Predatory beetle *Calosoma sycophanta* L. (WESELOH, 1993) and pentatomide *P. maculiventris* (LEGASPI and O'NEIL, 1993) reproduced only when prey numbers was high and scarce. AMBROSE and CLAVER (1997) stated that, if food becomes more available, the amount of energy that could be used for reproduction would be increased resulting in greater egg production.

As observed in fecundity, the number of nymphs hatched and hatching percentage were also high at eight-prey density level, and, under limited prey conditions, predators oviposited infertile eggs. Other reduviids viz., *Rhynocoris marginatus* Fab. (AMBROSE *et al.*, 1990) and *Rhynocoris kumarii* Ambrose and Livingstone (AMBROSE and SAHAYARAJ, 1991) the hatchability was high when the predator had the lowest (80) and the highest (100) frequency of hatching. Further more, AMBROSE and CLAVER (1997) stated that percentage of the viability of egg decreased when the prey density decreased.

Both for the nymphal instars and for adults, the total food consumption increased as the prey supply was increased. In general, the number of prey consumed at the beginning of each stage was always higher than at the end. BAUMGAERTNER *et al.* (1981) stated that the weight gain or number of prey consumed by the predator could be described as a function of age. It is interesting to note here that the total prey consumption of *N. therasii* increased from the first instar to the fifth instar and it was declined in the adults. Predatory rate or rate of feeding per predator per day was lower in the immature stages than in the adults of reduviids. An opposite trend was observed by LAKKUNDI (1989), EVANS (1962), AMBROSE and KUMARASWAMI (1993) and AMBROSE and CLAVER (1997) in other reduviids. EVANS (1962) considered the predatory value as a general guide to measure the potential value of the predator. Among the nymphal instars, fifth nymphal instar consumed/killed maximum number of *Corcyra* larvae, and hence nymphal instars can be employed for quicker control of pest under field condition than the adult of *N. therasii.* Reduviids either consumed or killed more prey than need to satiate themselves (AMBROSE, 1999). However, similar kinds of studies are necessary on field crop pests with this predator. The data clearly indicate that the number of prey eaten by the predator was a function of the number of prey provided. These findings differ from those of TERNBULL (1962), who observed that spiders consume virtually the same amount of food irrespective of food supply.

The lower the developmental period, and the preoviposition period, the higher adult longevity and survival rate, fecundity and hatchability were obtained in the treatment with eight larvae/predator/day, it can be considered as the optimum prey density for rearing *N. therasii* in the laboratory for small scale production.

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SOVICE (LEPIDOPTERA, NOCTUIDAE) U PODRUČJU VRANSKOG JEZERA KRAJ BIOGRADA, HRVATSKA

Ante SAVKOVIĆ *

Primljeno: 21. 2. 2001. – Prihvaćeno: 11. 7. 2001.

Od 1964. do 1970. god. autor je skupljao leptire sovica svjetlosnim mamkom u području oko Vranskog jezera u sjevernoj Dalmaciji. Uhvaćeno je 26.619 primjeraka leptira iz 13 potporodica, 88 rodova i 142 vrste. Među njima je 6 vrsta novih za faunu Hrvatske. Razmatrana je povezanost nekih vrsta potporodice Plusiinae s ekološkim čimbenicima, a naročito vrste *Autographa gamma*, koja je bila prisutna u više od 1/5 svih primjeraka, kao i njena štetnost i mogućnost prognoze.

Lepidoptera, Noctuidae, motrenje, istraživanje faune, popisi faune, populacije štetnika, prognoze, ekologija, *Autographa gamma*

SAVKOVIĆ, A., Noctuids fauna (Lepidoptera, Noctuidae) in area of Vransko lake near Biograd, Croatia. – Entomol. Croat. 2001, Vol. 5. Num. 1-2: 31 - 50.

In the period from 1964 to 1970 the author collected noctuids by the light trap in the area of Vransko lake. There were trapped 26.619 specimens from 13 subfamilies, 88 genera and 142 species. Among them there are 6 new species in the Croatian fauna. Relations between some species of subfamily Plusiinae and ecological factors are discussed, specially species *Autographa gamma*, which was present in one fifth of all specimens, regarding its noxiousness and prediction possibility.

Lepidoptera, Noctuidae, monitoring, faunistic surveys, checklists, pest populations, predictions, ecology, *Autographa gamma*.

Uvod

Istraživanja su provedena u području oko Vranskog jezera kraj Biograda na moru u sjevernoj Dalmaciji. To je područje udaljeno svega 2 - 4 km od mora, a leži na nadmorskoj visini od 1 do 19 metara. Područje se proteže u smjeru sjeverozapad - jugoistok, tj. u smjeru najčešćih i najjačih vjetrova koji tu pušu, bure i juga. Klima je submediteranska, ponekad sa značajnim utjecajem planinskih elemenata. Ljeta su vruća i često vrlo suha, a zime nekad vrlo oštre. Tlo je vrlo plodno, većinom je to crnica, vrlo bogata humusom, od 6,4 do 10 %, i slabo bazične reakcije, pH od 7,7 do 7,9. Podzemna je voda visoka, tako da ni u najsušnijem razdoblju vegetacija nije ugrožena. Šire područje zauzima oko 10.000 ha obradiva tla.

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Rad su obradili Paula Durbešić i Mladen Kučinić. Popis vrsta sa sistemom Nowacki & Fibiger (1996) uskladio, dio o novim vrstama u Hrvatskoj napisao i rukopis završno uredio Branko Britvec.