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Seasonal Occurrence of *Campoletis chlorideae* Uchida and Its Control Efficacy on the Oriental Tobacco Budworm, *Helicoverpa assulta* (Guenee), in Tobacco Fields in Suwon

수원지방 담배포장에서의 *Campoletis chlorideae*의 발생소장과 담배나방 방제효율

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ABSTRACT The occurrence of Oriental Tobacco Budworm (OTB), *Helicoverpa assulta* (Guenee), larvae in early and late planted tobacco fields showed two or three distinct peaks. The parasitoid, *Campoletis chlorideae* Uchida, occurred for a short period with one peak following the second peak of OTB in early planted fields. However, in late planted fields, the parasitoid occurred as long as the OTB larvae were abundant. The OTB larval density was higher in late planted fields than in early planted fields. Among four varieties of tobacco, the OTB larval occurrence was relatively high on NC-744 throughout the season. However, more parasitoid cocoons were found in Burley-21 and NC-82. The seasonal occurrence of the larval parasitoid, *C. chlorideae,* assessed by an OTB larval release and recovery method, continued from late June to early September and relatively higher abundance was noticed from early July to late August. In a field cage evaluation of *C. chlorideae* as a biological control agent of OTB larvae, higher rate of *C. chlorideae* release (4 females/2 m^3) resulted in higher larval parasitism (86.1%) and less leaf damage (8.7%) in tobacco. The leaf damage by OTB larvae was significantly high in the untreatment plot (23.2%) and the lowest damage (1.6%) was recorded in the chemical treatment plot.

KEY WORDS *Heicoverpa assulta*. *Campoletis chlorideae*. seasonal occurrence. biological control

초　　록 담배포장에서 담배나방의 발생은 조식 및 만식 재배구 모두에서 2 또는 3개의 뚜렷한 최성기를 보였다. 반면에 *Campoletis chlorideae*는 담배 조식구에서는 담배나방의 두번째 최성기 직후 짧은 기간동안 발생하였으며 만식구에서는 담배나방 유충이 존재하는 한 발생하였다. 만식구에서의 담배나방 발생은 조식구에서보다 많았다. 4가지 담배 품종중 NC-744에서 담배나방 유충의 발생이 비교적 컸다. 그러나, 기생벌의 발생은 Burley-21과 NC-82에서 많았다 담배나방 유충의 포장에서의 인위적인 방사 및 재포획법에 의한 결과는 *C. chlorideae*의 활동은 6월말부터 9월초까지 보였으며 7월초 부터 8월말까지는 비교적 높은 밀도로 발생하였다. *C chlorideae*의 담배나방에 대한 생물적방제 수단으로서의 가치평가를 위한 포장내 소규모 케이지 실험결과 방사밀도가 높을수록(암컷 4마리/2 m^3) 유충기생률이 높고(86.1%) 담배잎의 피해는 감소함을 보였다(8.7%). 무처리구에서의 담배잎의 피해는 상당히 높았으며(23.2%) 살충제처리구에서 피해가 가장 낮았다(1.6%).

검색어 *Heicoverpa assulta, Campoletis chlorideae,* 발생소장, 생물적방제

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The Oriental Tobacco Budworm (OTB), *Helicoverpa assulta* (Guenee), is an important pest of tobacco, *Nicotiana tobaccum L.*, and red pepper, *Capsicum annuum* L. in Korea (Hwang 1987, Han 1993). The OTB larvae feed on tobacco leaves near the terminal bud, occasionally destroying the bud and attack fruits of red pepper. The damaging potential of this pest is very high because of its relatively large body size, fast develpment, and voraceous feeding habit. In red pepper, the OTB larvae are protected from their natural enemies and insecticides since they stay inside the fruits. On the contrary, in tobacco, the OTB larvae are vulnerable to natural enemies since larvae stay on leaves.

The overwintered generation of OTB population mostly infests tobacco in June. Adults from the first generation invade red pepper in July and spend its second generation. Although the possiblity of occurrence of OTB first generation in red pepper can not be excluded, the chance seems to be very low since the phenology of overwintered OTB population do not synchronize the phenology of red pepper. The OTB population density has been very low in tobacco in recent years, thus causing less problems to tobacco (Han 1993). However, the tobacco plants could harbor OTB population which would infest red pepper later in the season. The total annual light trap catches of OTB moths had greater correlaton with trap catches of its first generation moths than those of overwintered generation moths (Han 1993). This indicates that suppression of the first OTB generation would be important in the OTB control.

The information on seasonal occurrence of the OTB larvae and its larval parasitoid is very important for careful timing of control measures to achieve most effective control. The OTB larval parasitism by *Campoletis* sp. was reported to range from 86.3 to 98.8% in tobacco in June in Suwon during 1983-1986 (Hwang 1987). No further studies have been conducted on OTB larval parasitism by *Campoletis* sp. in fields.

In our preliminary study, the OTB larval parsitoid was collected and identified as *Campoletis chlorideae* (Dr. H. Nagaraja, Biological control center for integrated pest management, Bangalore, India; personal communication). This study was conducted to determine the effects of tobacco planting date and tobacco varieties on seasonal occurrence of OTB and *C. chlorideae*. The OTB larval parasitism by *C. chlorideae* was assessed using a larval release and recovery method in tobacco fields. Also, performance of *C. chlorideae* to control OTB larvae in small field cage experiments was evaluated to provide basis for biological control for the OTB using *C. chlorideae*.

MATERIALS AND METHODS

Field studies were conducted in the tobacco fields of Korea Ginseng and Tobacco Research Institute, Suwon Experiment Station, Suwon in 1992 and 1993. To assess the control efficacy of *C. chlorideae*, small field cage study was conducted in the experiment field, College of Agriculture and Life sciences, Seoul National University, Suwon in 1993. Forty to forty five-day-old greenhouse-grown tobacco seedlings were transplanted in rows on 105cm centers, and plants were spaced 45 cm apart within a row in all experiments. All surveyed fields were maintained without using insecticides.

Effect of Tobacco Planting Dates

In 1992, KF-109 tobacco seedlings were transplanted on 30 April (early planting) in 3 plots (15×6.3 m each) and NC-744 tobacco seedlings were transplanted on June 12 (late planting) in 3 plots (15×3.2 m each). The early- and late-transplanted fields were ca. 500 m apart. In 1993, NC-744 was transplanted on 6 May as early planting in 2 plots (15×5.3 m each) because of field limitation. Tobacco plants were left without tipping in 1992, but were tipped in 1993. OTB larvae were collected from 40 randomly selected plants covering all plots at 4~7 day intervals from June to September in both years. Collected larvae were brought to the laboratory and reared on artificial diet in plastic diet cups (30 ml) until parasitoid cocoons formed in an incubator (25 ± 1°C, 16L:8D photoperiod, and 40~60% RH) for assessment of parasitism by *C. chlorideae*.

Effects of Tobacco Varieties

Seedlings of NC-744, NC-82, KF-109, and Burley-21 were transplanted in 3 plots (15×2.1 m each) for each variety on 12 June, 1992. Plants were left without tipping and desuckering. Numbers of OTB larvae and *C. chlorideae* pupae were recorded on 10 randomly selected plants covering 3 plots for each variety at 3~7 day intervals from June to September.

Asessment of Parasitism of OTB Larvae by *C. chlorideae* in a Tobacco Field and in a Small Field Cage Experiment

Seedlings of NC-744 were transplanted in 6 plots (10×6.3 m each) on 3 May and in 6 plots on 4 June in 1993. The assessment of parasitism was conducted at weekly intervals from 21 June to 23 July in plots planted on 3 May and from 27 July through 7 September in plots planted on 4 June. In each trial, three OTB larvae (2~3 day old) were placed on each of randomly selected five tobacco plants per plot. Because of shortage of OTB larvae, total 75 and 80 larvae were placed on 21 June and 19 August, respectively. Individual larva was placed on a tobacco leaf in upper part of the plant. After 4 days, the recovered larvae were brought to the laboratory and reared on artificial diet until *C. chlorideae* pupated. The *C. chlorideae* cocoon was held in the same cup until emergence of the adult parasitoid. In addition, number of larvae parasitized and the sex ratio of the parasitoid were determined.

The small field cage experiment was conducted in early July, 1993. The tobacco variety, NC-82, was transplanted in early May. The randomized block design was used with 4 replications. Four plants were enclosed in a cage (2×1×1 m) and twenty OTB larvae (2 day old) were placed on leaves in the upper part of the plant one by one (5 larvae per plant). Three levels of parasitoid (1-, 2-, and 4- *C. chlorideae* female per cage) were released into the cage. OTB larvae without *C. chlorideae release*, and chemical spray (fenvalerate 5EC; 20 ml/10a) served as control. Observations were made on parasitism and leaf damage in each cage after 10 days. The data were transformed by the arcsine transformation and subjected to analysis of variance (ANOVA) (SAS Institute 1987). Means were separated with Tukey's test (SAS Institute 1987).

RESULTS

Effect of Tobacco Planting Dates

In 1992, three peaks of OTB larval populations were observed in the early planted tobacco while two peaks were found in the late planted tobacco (Fig. 1 a&b). There was larger gaps among larval population peaks on the early planted tobacco compared on the late planted tobacco. Also, seasonal abundances of the OTB larvae were different between tobacco planting dates. Higher number of OTB larvae was observed on late planted tobacco (242 larvae in total) than on early planted tobacco (188 larvae in total). The OTB larval parasitism by *C. chlorideae* increased by middle of July and decreased thereafter in 1992 (Fig. 1a&b). The occurre-

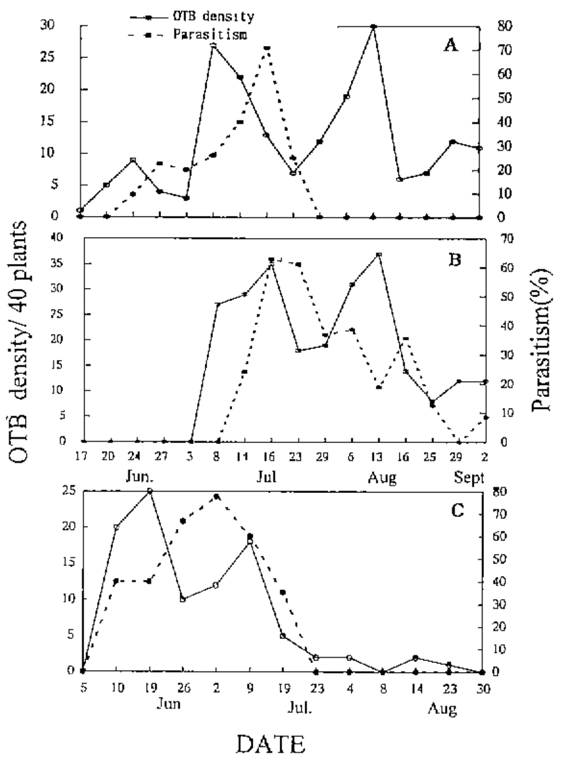

Fig. 1. Parasitism of *C. chlorideae* on OTB in early (A) and late planted tobacco (B) in 1992 and in early planted tobacco (C) in 1993

Table 1. Occurrence of OTB larvae and *C. chlorideae* cocoons (numbers per 10 plants) on different varieties of tobacco, Suwon, 1992

Date	NC-744		NC-82		KF-109		Burley-21	
	OTB	*Campoletis* cocoon	OTB	*Campoletis* cocoon	OTB	*Campoletis* cocoon	OTB	*Campoletis* cocoon
Jun. 24	0	0	0	0	9	0	0	0
27	0	0	0	0	9	0	0	0
Jul. 8	10	0	7	0	3	0	7	0
14	11	2	5	2	5	1	8	2
16	11	9	6	3	6	1	12	9
23	8	3	2	2	0	0	8	6
29	10	1	2	1	0	0	7	5
Aug. 6	13	2	8	5	4	0	6	5
13	17	3	7	1	6	2	7	1
19	10	4	1	1	3	0	0	0
25	6	1	2	0	0	0	0	0
29	8	0	0	0	0	0	4	0
Sept. 2	10	1	2	0	0	0	0	0
Total	115	27	42	15	44	4	59	28

nce patterns of *C. chlorideae* were different between tobacco planting dates; the densities of *C. chlorideae* increased slowly and decreased abruptly after its peak on the early planted tobacco, while those of *C. chlorideae* increased rapidly and decreased gradually through late season on the late planted tobacco.

The seasonal occurrence pattern of OTB larvae in 1993 on early planted tobacco was very different from that in 1992 although the first and second OTB peak occurred in mid-June and early July, respectively, in both years (Fig. 1c). In 1993, the density of the first peak was much higher than that of the second peak while the pattern was reversed in 1992, and the OTB larval density decreased drastically and remained low after late July (Fig. 1c). The activity of *C. chlorideae* in 1993 was similar to that in 1992 with the maximum parasitism by early July. The OTB larval parasitism ranged from 35.0 to 77.8% during the season. The activity of the parasitoid was not observed from late July on early planted tobacco in both years.

The OTB larvae observed on top portion of the plant (suckers, bud, flowerbud, and first & second leaf from the top) contributed to 82.6% of observed total number of larvae.

Effects of Tobacco Varieties

Higher number of OTB larvae occurred on NC-744 than on other varieties (Table 1). Total OTB larval density per 10 plants on NC-744 during the season was 115, which was two times greater than on any other varieties. Weekly larval densities per 10 plants on NC-82, KF-109, and Burley-21 were less than 9 throughout the season with exception of Burley-21 on 16 July, resulting in total densities of 42, 44, and 59 larvae, respectively. Higher number of *Campoletis* cocoons were found from Burley-21 and NC-744 (28 and 27 cocoons, respectively) than from other varieties. Only 4 *Campoletis* cocoons were found from KF-109 during the season. There was no obvious relationship between densities of OTB larvae and *Campoletis* cocoons, but proportions of *Campoletis* cocoon density to OTB larval density in Burley-21 and NC-82 were higher than those in NC-744 and KF-109.

Asessment of Parasitism of OTB Larvae by *C. chlorideae* in a Tobacco Field and in a Small Field Cage Experiment

Results of OTB larval parasitism by *C. chlorideae* by a release and recovery method are presented in Table 2. The OTB larval recovery ranged from

Table 2. Assessment of parasitism of *C. chlorideae* on OTB by a release and recovery method, Suwon, 1993

Date	No. of larvae released	Larval recovery (%) x̄± SD	Parasitism (%) x̄± SD	♀ Emergence (%)	Plant age
Jun. 21	75	62.8± 9.3	8.3± 7.5	50.0	49DAT[a]
30	90	77.8± 20.0	18.4± 5.4	90.9	58
Jul. 6	90	51.1± 11.5	50.0± 15.2	75.0	64
16	90	20.0± 3.1	26.7± 5.2	80.0	74
23	90	27.8± 6.6	25.5± 6.2	50.0	81
27	90	57.8± 19.5	82.0± 22.3	66.7	53
Aug. 8	90	35.5± 7.8	54.7± 16.5	80.0	65
14	90	45.5± 15.6	39.2± 13.6	80.0	71
19	84	37.8± 6.5	48.3± 15.1	57.1	76
25	90	35.5± 12.2	45.5± 14.9	50.0	82
31	90	37.8± 5.0	7.5± 2.7	50.0	88
Sept. 7	90	31.1± 12.2	10.5± 5.0	50.0	95

[a]DAT means days after transplanting.

Table 3. Performance of *C. chlorideae* in the control of OTB in small field cages in the tobacco field

Treatment	Parasitism (%) x̄± SD	Leaf damage (%) x̄± SD	Leaf damage reduction (%) x̄± SD
1 female wasp/2 m^3	59.0± 10.0b	12.1± 3.2b	44.0± 13.2c
2 female wasp/2 m^3	86.2± 6.0a	8.8± 2.2b	62.2± 8.1b
Fenvalerate	0.0c	1.6± 0.7c	90.5± 4.8a
Untreatment	0.0c	23.2± 5.5a	—

Means within columns followed by the same letter are not significantly different (ANOVA procedure, Tukey's test, $p>0.05$, SAS Institute 1987)
A cage size is 2 by 1 by 1 m.

20.0 to 77.8%. The parasitism varied from 7.5 to 82.0% during the experiment. Although the parasitization occurred from late June to early September, relatively high parasitism was observed from early July to late August. Female wasps emergence varied from 50.0 to 90.9% during the study with an average of 65%. Higher proportion of female wasps was observed between 30 July and 14 August.

There were significant differences in OTB larval parasitism among treatments ($F=264.45$; $df=4, 12$; $p=0.0001$). Among three levels of parasitoid releases, 4 female wasps per 2 m^3 (2×1×1 m) showed the highest parasitism (86.1%), but was not statistically different from 2 wasps per 2 m^3 in larval parasitism (Table 3). No larval parasitism was observed in both plots of chemically treated and untreated check. The leaf damage by OTB larvae was highest in untreated (23.2%) and lowest in chemically treated (1.6%) ($F=38.89$; $df=4, 12$; $p=0.0001$). The leaf damage was not statistically different among parasitoid releases although 4 females per 2 m^3 resulted in less damage (8.7%) compared to lower levels of parasitoid release (Table 3).

DISCUSSION

The incidence of OTB larvae was observed from second week of June until harvest of the plant. The higher incidence of OTB was observed on late planted tobaccos (241 larvae per 640 plants) than on early planted tobaccos (188 larvae per 640 plants). This result agreed with the findings of Ahmed *et al.* (1989), who observed the significant effect of sowing date of cotton on the larval density of *H.*

armigera. Similar observations were also made by McPherson *et al.* (1992) who reported higher damage and lower yield by *H. virescens* in late planted tobaccos. The differences in seasonal OTB larval occurrence patterns on early planted tobacco between 1992 and 1993 might be due to tipping and desuckering tobacco plants in 1993, which could make plants less attractive to the OTB. Higher number of larvae were located on the bud (38.4%) followed by suckers (14.5%), flower bud (12.1%), and first leaf (10.4%) when tobacco plants were not tipped. However, when plants were tipped 76.3% of total OTB larvae were found on the top portion of the plant consisting of bud, and first and second leaf from the top. This is a very useful information to develop a sampling plan for the OTB larvae on tobacco plants. Higher numbers of OTB eggs on flower buds during flowering than leaves and suckers demonstrate the plant with flower buds may be used as a trap of OTB eggs. This finding can be explored further for managing of the OTB.

Activity of *C. chlorideae* was observed soon after OTB larvae occurred. OTB larval parasitism was as high as 77.8% during the peak activity of *C. chlorideae*. The *C. chlorideae* activity was greater on tobacco than on red pepper possibly due to differences in the feeding habit of the OTB larvae (personal observation). OTB larvae feed on tobacco leaves, while they feed inside the fruits on red pepper. Pawar *et al.* (1989) reported that parasitism by *C. chlorideae* varied with various host crops of *H. armigera*.

The host and parasitoid relationship observed on four varieties of tobacco showed higher OTB larval density (115 larvae) on NC-744 than on three other varieties, NC-82 (42 larvae), Burley-21 (59 larvae), and KF-109 (44 larvae). The proportion of the host larva and its parasitoid cocoon was relatively greater in Burley-21 and NC-82 compared to other two varieties. Thus, the varieties which are less preferred to OTB and highly favorable to parasitoid (NC-82 and Burley-21) could possibly be used in OTB management program.

Much information is available in literatures on the activity of *C. chlorideae* on *H armigera* under natural conditions (Bilapate *et al.* 1979; Pawar *et al.* 1986a,b; Shivaprakasam *et al.* 1986; Sathe 1987; Yadav & Lal 1988; Ahmed *et al.* 1989; Dai 1990) In our study, the assessment of parasitism was conducted by a periodic release and recovery of OTB larvae on tobaccos in addition to the assessment of parasitism on naturally occurring larvae. The release and recovery method seemed to be very useful to understand the real activity of the parasitoid because of ensured host larvae. Furthermore, reasons for the fluctuation of the parasitoid activity could be understood better. The plant age and weather factors such as temperature, humidity, and wind speed seemed to significantly influence parasitism of OTB larvae by *C. chlorideae* (unpublished data). Wind speed, relative humidity, and rainfall were negatively correlated with larval parasitism. Shivaprakasam *et al.* (1986) reported the positive influence of crop age on the parasitism of *H. armigera* by *C. chlorideae* until the plant maturity. Our results indicate the similar pattern. Among three levels of *C. chlorideae* release in small field cages, four female wasps per 2 m^3 produced good larval parasitism and less leaf damage. Although chemical treatment resulted in the least damage in tobacco, higher release ratio of *C. chlorideae* (>4 females/2 m^3) might produce better result. Also, combination of *C. chlorideae* and insecticides which are less toxic to *C. chlorideae*, if any, could produce better result. Our results indicate that the significant role of *C. chlorideae* could be expected in reducing OTB density and leaf damage in tobacco. Noble & Grahm (1966) reported that *C. perdistinctus* recorded maximum of 82% parasitism against *H. virescens* and significantly reduced *H. virescens* population in cotton. Since our study on *C. chlorideae* is almost new to Korea, the present results would provide significant informations for the development of an OTB management program.

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REFERENCES

Ahmed, K., F. Khalique & M. Afzai. 1989. Effect of agronomic factors on the incidence of *Heliothis armigera* (Hubn.) and its parasite, *Campoletis chlorideae* (U.) in chickpea field. Pakistan *J. Sci. and Indust. Res.* **32**: 694-697.

Bilapate, G. G., A. K. Raodeo & V. M. Pawar. 1979. Population dynamics of *Heliothis armigera* Hubner on sorghum, pigeonpea and chickpea in Marathwada. *India. J. Agri. Sci.* **49**: 560-566.

Choe, B. M. 1968. Studies on the biological control of the Oriental tobacco budworm. Chong Ju Educational College *Res. Rept.* **3**: 45-54.

Dai, X. F. 1990. Biology of *Campoletis chlorideae* (Hym.: Incheumonidae) and its control of cotton bollworm in the field. *Chinese J. Biol. Contol.* **6**: 153-156.

Han, M. W. 1993. Studies on forecasting models of the Oriental tobacco budworm, *Helicoverpa assulta* (Guenee). Ph. D. diss. 98 pp. Seoul Nat'l Univ.

Hwang, C. Y. 1987. Studies on the relationship of tobacco budworm and its parasitoids. Ph.D. diss. 56pp. Chung Nam Nat'l Univ.

McPherson, R. M., K Bondari & M. G. Stephenson. 1992. Influence of transplanting date and tobacco budworm (Lepidoptera: Noctuidae) treatment threshold density on flue-cured tobacco quality and yield and secondary pests. *J. Econ. Entomol.* **85**: 1940-1945.

Mistric, W. J. & W. W. Pittard. 1973. Damage to flue-cured tobacco by tobacco budworm and corn earworm alone and combined at various infestation densities. *Entomon.* **66**: 232-235.

Nagarkatti, S. 1982. The utilization of biological control in *Heliothis* management in *India. Proc. Intern, Wkshp. Heliothis* management. pp. 159-169.

Noble, L. W. & H. M. Graham. 1966. Behavior of *Campoletis perdistinctus* (Viereck) as a parasite of the tobacco budworm. *J. Econ. Entomol.* **59**: 1118-1120.

Pawar, C. S., V. S. Bhatnagar & D. R. Jadhav. 1986a. *Heliothis* spp. and their natural enemies, with their potential for biological control. Proc. *Indian Acad. Sci.* (Anim. Sci.) **95**: 697-703.

Pawar, C. S., V. S. Bhatnagar & D. R. Jadhav. 1986b. Host plants and natural enemies of *Heliothis* spp. in India: A Compendium. Cropping Entomology Progress Report 13, ICRISAT. pp.107.

Pawar, C. S., V. S. Bhatnagar & D. R. Jadhav. 1989. *Capmoletis chlorideae* Uchida (Hym.: Ichneumonidae) as a parasite of *Helicoverpa armigera* (Hub.) (Lep.: Noctuidae) in southwest India. In: Proc. of the Indian Academy Science, *Animal Science.* **98**: 259-265.

SAS Institute. 1987. SAS/STAT user's guide. release 6.03 ed. SAS Institute, Cary, NC.

Sathe, T. V. 1987. New records of natural enemies of *Spodoptera litura* (Fab.) in Kolhapur, *India. Curr. Sci.* **56**: 1083-1084.

Shivaprakasam, N., G. Balasubramanian, S. Venkatesan, V Jeyaraman & A. Narayanan. 1986. Effect of host plants on parasitism by parasitoids of *Heliothis armigera* Hubner. *Madras Agri. J.* **73**: 468-470.

Yadav, C P. & S. S. Lal. 1988. Relationship between certain abiotic and biotic factors and the occurrence of gram podborer, *Heliothis armigera* (Hbn.) on chickpea. *Entomon.* **13**: 269-273.

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