Study on Biology, Consumption Rate and Seasonal Abundance of Coccinellids (Coccinellidae) under Greenhouse and Field Conditions

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Abstract

The biology and seasonal abundance of coccinellids and their consumption rate on wheat aphids was studied from 1996 to 1999 at Ambo Plant Protection Research center (PPRC). The dominant species of coccinellids were *Adonia* spp.and *Cheilomenes lunata* F. The most widely recorded species of aphids in the experimental site were green bug, *Schizaphis graminium* (Rondant); the Russian wheat aphid, *Diuraphis noxia* (Mordvilko); Oat aphids *Rhopalosiphum padi* (L) and English grain aphid, *Macrosiphum maidis* (Fetch). Under greenhouse trials predator (*Ch.lunata* F) and aphid (*D. noxia*) were included. Eggs of *Cheilomenes lunata* F were laid in bunch, each containing 4-52 egg mass, on leaves close to aphids. The development of eggs lasted 3.0-10 days. The larvae required 12-18 days to develop into pupae. Pupation took up to12 days under greenhouse conditions. Eggs were orange-yellow and measured 1.0-1.5 mm in diameter. Larvae were 2.0 -10.48 mm long and were brownish grey or light grey to blackish with yellow or white spots depending upon the species. Adult beetles that were brightly colored and 3.0-5.5 mm long could live up to 117 days. Both the larvae and adults are aphid predators. It was estimated that a single larva could consume from 11.9–23.8 aphids per day while adults consumed 17.9-52.5 aphids per day. The highest population of aphids recorded was from the end of September upto mid-October whereas coccinellids attained a peak population in mid-October. Both growth stages (larvae and adults) could feed an average of 52.26 aphids per day and they might consume about 2668.31 aphids throughout their life. Studying the biology and seasonal abundance of these predatory insects is essential for better understanding of wheat aphid population dynamics and is useful when developing control programs within the context of IPM.

Introduction

The major wheat production constraints in Ethiopia are technical and socioeconomic. The technical constraints include a high incidence of insect pests, diseases, weeds and low soil fertility. The socioeconomic constraints are lack of improved inputs and control technologies of major insect pests (Hailu *et al* 1991). Different wheat aphids, leafhoppers and other insect pests attack wheat. About 41 different insect pests have been recorded on wheat in Ethiopian. Some are of minor importance, some are sporadic and a few are very important (Abdurahman and Adugna 1991.) Aphids possess piercing and sucking mouthparts, which are used to extract juices from the wheat plant. In addition to direct injury resulting from their feeding aphids may transmit barley yellow dwarf viruses. One of the aphid species commonly attacking wheat is Russian wheat aphid (*Diuraphis noxia*) which causes considerable damage. In some cases, farmers in the country have recorded total crop failure due to high infestations of aphids. *Schizaphis graminum* and *D. noxia* are generally considered important pests in highland areas, under moisture stress conditions and on young plants suffer more than mature ones.

Research on wheat aphid control in Ethiopia has focused on using different sowing dates, resistant varieties, insecticides and their frequency of applications. Chemical means of controlling wheat aphids are expensive and environmentally hazardous. Alternative control measures such as integrating host plant resistance and biological control have been repeatedly reported to give satisfactory control of *D. noxia* in South Africa.

Recent wheat aphid research in Ethiopia has focused on the regulatory power of natural enemies, particularly predators and parasitoids (Mulugeta *et al.*, 1999). In this study, aphid predators, *Adonia Variegata* (Goeze) spp., *tredecinsignata* (Muls) and *Cheilomenes lunata* (F.) (Coleoptera: Coccinellidae), comprised the dominant species recorded at Ambo Plant Protection Research Center and have a significant role in reducing the population of wheat aphids. The center is located in West Shoa Administrative zone, 130km west of Addis Ababa at 08°57'Nand 038°51'E at an altitude of 2225meter above sea level.

Adugna H.and Tesema M. (1987) reported that several types of predators and parasitoids attack aphids on barley. They have indicated that the coccinellid beetles, *Adonia variegata (Goeze)* is the most important one and appeared in large numbers when the populations of the aphids were high. The other important coccinellids recorded were *Lioadolia* and *Cheilomenes sp.* But, the populations of these predators were rather low and they were found late in the season at the heading stages of the crop. The population of these natural enemies increased only with the rise in the population of the aphids. This happens mostly at the time of heading of the crop. Earlier at the seedling stage, when the plant is more vulnerable to aphids attack, the population of the natural enemies was generally too low to be effective in checking the population of aphids (Adugna *et al.*, 1987).

Our understanding of predator-prey interactions is limited and to synchronize the population of both aphids and their natural enemies, rearing those effective species of natural enemies and releasing them at the time when the wheat plant is more vulnerable and the aphid population is high is very important. Thus, studying the biology, behavior and seasonal abundance of the coccinellids is essential to better understand wheat aphid population dynamics. Such knowledge is useful when developing control programs and IPM. The objectives of this study were to monitor the seasonal abundance of coccinellid predators and evaluate their impact as mortality factors in the population dynamics of wheat aphids at Ambo and to study some aspects of the biology of prevalent predator (coccinellid) species under greenhouse conditions.

Materials and Methods

Field trials

The experiments were done at Ambo Plant Protection Research Center. The seasonal abundance of wheat aphids and their natural enemies were monitored in field samples of naturally infested wheat plants at field trails. Wheat variety Enkoy was planted in 10x7m-plot size. The plot divided into four blocks, each having a size of 10x1m area and separated by 1m spacing between each block. The predation impacts of the predators were checked by direct observation or exclusion methods. Predation impacts of the predators were determined by counting the number of aphids and predators/plant on 20 randomly selected shoots in each of the four wheat blocks. Counts were made every week until crop maturity in order to determine the potential of predators and different gradient of aphid population buildups. Three types of treatments were considered (inclusion, closed, open-sided) each having 1m x 1m x 1.5m and an uncaged control. The cages used consist of rectangular metal frame covered with fine close mesh. A total of four closed, four open-sided and four uncaged plots were used for the study. In all cases, the open-sided cages were made to have circular or rectangular openings in two opposite sides to allow free access of the wheat aphids and their natural enemies. The cages were randomly placed on different plots within a wheat field at about 2-3-leaf stage of wheat plants and when aphids appeared on the plants. Aphid density was determined by counting on randomly selected shoots in all types of cages. At the same time, aphid predators were also recorded and the peak population of aphids and predators in the different treatments were determined and related to changes in the density of predators using t-test procedures using MSTAT-C statistical program.

Greenhouse trials

To study coccinellids biology, a known number (1 adult & 1 larva + 60 aphids) of predators and aphids were introduced into petri dishes and observations were made for their growth stages and daily consumption rates of both adults and larvae under greenhouse conditions. The species *Cheilomenes lunata* F. was considered. Newly laid eggs were placed on filter paper in petri dishes and kept separately. The filter paper was moistened daily and follow up of the eggs was made daily until eclosion. When the eggs hatched, the larvae were kept in petri dishes individually and provided with 60 aphids/day. To estimate the growth stage and duration of each larval instars, body length measurements were taken at 2-days intervals after hatched. A total of 44 newly hatched larvae was collected and was placed separately in petri dishes and supplied with a known number of aphids up to the end of their life and observation was made on their growth stages and daily consumption rates. A total of 39 newly emerged adult beetles of *Cheilomenes lunata* F was also kept in a separate petri dishes and provided with 60 laboratory reared Russian wheat aphids (*Diuraphis noxia*) were used as host insect. To determine the feeding efficiency or daily consumption rates of each stages of considered predators the total number of aphids introduced, total number of live aphids counted after 24 hrs exposure is computed.

Results

More aphids were observed in the inclusion and closed cages than the other treatments though differences were not significant (Fig.1). Relatively higher numbers of predators were recorded in inclusion cage than in open-sided cages. In the 1997/98-crop season, aphid populations were also higher in both inclusion (103-268 aphids) and closed cages (109.8-507.3 aphids) whereas in open sided cages and outside the cages 91.5-266.3 and 134.5-171.1 aphids were recorded, respectively. However, the t-test analysis showed that non-significant difference between all treatments. In both seasons (1996/97 and 1997/98), the peak aphid populations were recorded in mid-late October. The population of predators varied among cage types. The peak population of aphids and predators in different cage types (inclusion, closed, open-sided) and year at Ambo conditions were recorded from end of September to mid-October.

As shown in figure 1 and 2 wheat aphids were observed in early September and the population remained very low throughout the month. But from the end of September up to the end of October the populations reached its peak and it started to decline in early of November. In 1996/97, the aphid population was found generally to be low and the highest peak recorded in two types of cages (inclusion and closed). But there was no significant difference in mean number of aphids recorded between these two cages (t (0.01) (10) = 0. 1492). The rate of decline of the aphid population as the result of the impact of the natural enemies varied from year to year, location to locations and due to other different factors. For example in 1995, the association between the populations of aphid and their natural enemies in open-sided cages was positive and significant ($r = 0.823$, $p>0.01$), indicating density-dependent nature of the predators and parasitoids.The population of predators and other natural enemies found high in mid-October and onwards when aphid populations started to decline in all cages. The natural enemies that were recorded in different cage types were coccinellids (*Cheilomenes spp.* and *Adonia Variegata* (Goeze) spp. Relatively higher numbers of predators were recorded in inclusion cages and gradually increasing in their population than in closed cages while aphid number decreased in inclusion cages when compared with closed cages. However, these predators were too few to regulate the higher aphid population. However, they showed a potential to reduce the number of aphids to some extent.

Cheilomenes lunata F eggs were laid in small batches containing 4 - 52 (20.2 ± 14.8) (n = 12) egg mass on leaves close to aphids (Table 1). Eggs are 1.0 - 1.5 mm long, orange-yellow in color. The number of days that are required for egg development varied from 3.0 -10.0 (4.70 ± 2.05) days in average (n = 27) (Table 1). The body length of larvae ranged from 2.0 - 10.48 mm long. The maximum body length of larvae was recorded between 8th and 14th days after eclosions and 12th and 14th days after eclosion. The body length began to decrease as the larvae began to shrink indicating that they are ready to be changed to pupal stage (Table 2). The body color at this stage was brownish grey, light grey to blackish with yellow or white spots depending up on the type of Coccinellid groups. The larval developmental period ranged from 12-18 days with an average of 14.30 ± 1.35 days (n = 58). The duration for pupal development ranged from 5.0 up to 12.0 days with an average of 7.32 ± 1.37 days (n = 50). Adults are brightly colored with a body length ranging from 3.0 to 5.5 mm. The adult beetle's longevity varied and the highest was 117 days, with an average of 63.67 ± 35.09 days (n =39) (Table 1).

The mean number of aphids that can be consumed by one larvae and adult *Cheilomenes lunata* F was also considered. The number of aphids consumed by one coccinelid larva were estimated to be between 11.9 and 23.8 or 18.20 ± 2.38 aphids/day, while adult beetles consumed from 17.9 up to 52.5 or 38.06 ± 11.89 aphids/day. Under greenhouse conditions both stages can feed on an average of 52.26 aphids per day on average. They may consume about 2668.31 aphids throughout their life span (larva + adult stages) (Table 3). Consumption of *Cheilomenes* spp and *Adonia Variegata* (Goeze) spp varied depending on the predator species. Based on the greenhouse trial observations, it can be assumed that they may consume more aphids under field conditions where conditions are relatively favorable. . Therefore, the consumption rate study under greenhouse conditions also showed the great potential of these predators to check the population of wheat aphids. Both the host aphids and predators can easily be reared under green house conditions.

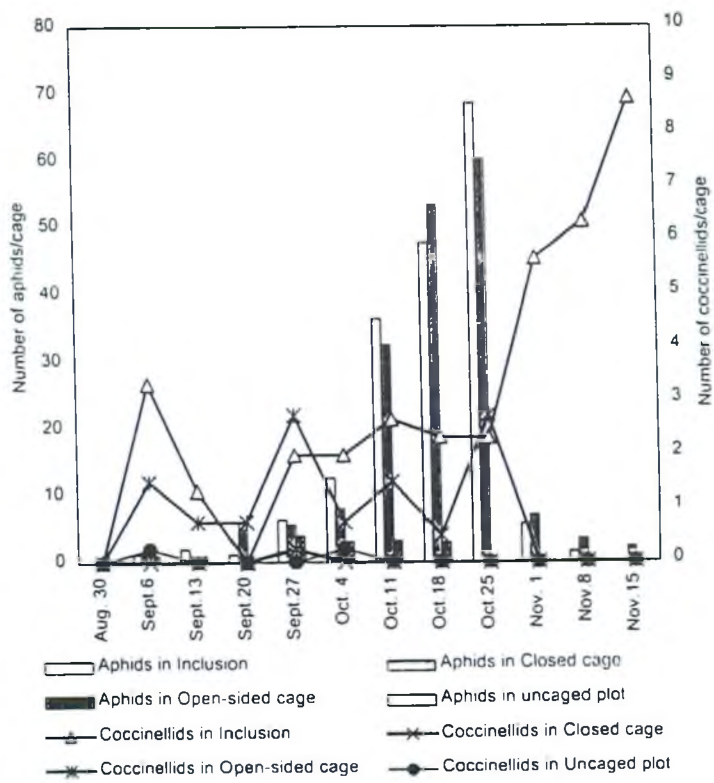

Fig. 1 Number of aphids and coccinellids in inclusion, closed, open sided cages and uncaged plots in 1996/97 (n=4 cages and 20 shhots/cage

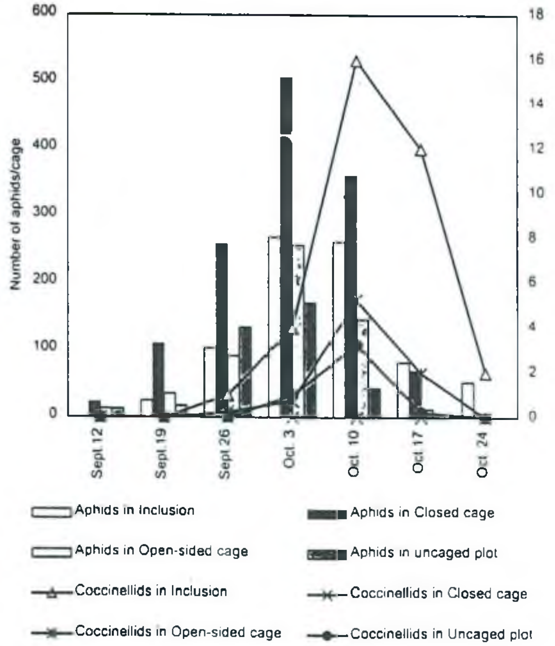

Fig. 2 Number of aphids and coccinellids in inclusion, closed, open sided cages and uncaged plots in 1997/98 (n=4 cages and 20 shhots/cage

Table 1. Developmental periods of the different stages of laboratory reared Coccinellid spp. under green house conditions at Ambo, PPRC

Coccinellids growth stage	Time (days)		
	Range	Mean + S. E (±)	No. observed
Eggs	3---10	4.70 ± 2.05	27
No. of eggs/mass or butches	4---52	20.2 ± 14.8	12
Larvae	12–18	14.30 ± 1.35	58
Pupae	5---12	7.32 ± 1.37	50
Adult beetles	117	63.67 ± 35.09	39

Table 2: Growth stage of Coccinellid larvae as indicated by body length measurements at two days intervals at Ambo, PPRC.

Days after eclosion	Body length (mm) at two days intervals	No. Observed
0	2.0 ± 0.0	9
2	3.28 ± 0.36	9
4	5.2 ± 0.2	9
6	6.25 ± 0.34	9
8	8.28 ± 0.81	9
10	10.48 ± 0.33	9
12	8.5 ± 1.33	9
14	8.45 ± 1.14	9

Table 3. Daily consumption rates of larval and adult stages of Coccinellids on wheat aphids under greenhouse condition at Ambo, PPRC

Stage	Range	Mean + S.E (±)	No. Observed	Average age in days	Average consumption rate/day	Total
Larvae	11.9—23.8	18.20 ± 2.38	44	14.30	18.20	260.26
Adult beetles	17.9—52.5	38.06 ± 11.89	39	63.27	38.06	2408.05
Total	-	-	83	77.57	56.26	2668.31

Discussion

Ethiopian farmers (small and large scale) strive to maximize wheat yields, often by applying insecticides as routine insurance treatments. Such indiscriminate use of insecticides can result in the development of pest resistance. Environmental studies have revealed that the use of synthetic organic insecticides in crop pest control programs around the world has resulted in disturbing the environment, pest resurgence, pest resistance to insecticides and lethal effects on non-targeted organisms. Furthermore, these pesticides are beyond the reach of small-scale farmers particularly in developing countries (Morallo, *et al.*, 1987). This is also true in Ethiopia and elsewhere in Africa,

Babenkov (1980) reported that border treatment of wheat against aphids gave considerable control resulting in congregation of natural enemies which supplemented pest control. Batyrov, *et al.* (1979) studied some integrated methods to control aphids with an attempt to the occurrence of natural enemies. In their experiment they found that the predators annihilated the aphids, so that chemical control was largely unnecessary and aphids remained at a low level while predators increased. Biological control of aphids in West Asia and North Africa (WANA) using coccinellids was reported in annual reports of International Center for Agricultural Research in the Dry Areas (1997). In this report it was indicated that aphids were devastating insect pest of several ICARDA crops. In 1996/97, the role of a new coccinellid (*Harmonia axyridis*) in controlling aphids was studied in Syria. The study was conducted on the performance of this new predator, in comparison with the already established *predator Coccinella septempuctata,* in the laboratory on two aphid species, Russian wheat aphid (RWA, *Diuraphis noxia*) and black bean aphid (BBA, *Aphis fabae*). Results showed *that H. axyridis* had significantly higher fecundity than *C. septempunctat* when reared on BBA and RWA, *H. axyridis* laid a total of 1536 and 843 eggs/female, respectively. *Coccinella septempunctata*, on the other hand, laid only 1164 and 218 eggs/female, respectively. The other biological parameters (oviposition period, adult longevity, percent eggs hatched) were similar for the two predators. These data indicate that *H. axyridis* could be a potential predator of aphids in WANA.

Kemal A. (1999) also studied population dynamics of pea aphids and its natural enemies at two localities (Danbi and Kulumsa) of Ethiopia. He has reported that pea aphids first appeared in late July or early August and the population increased in September in all years coinciding with flowering and pod growth stages. In general he has emphasized that aphid populations reached a peak in the latter half of September and showed a sharp decline in October. The natural enemies that were recorded on pea aphids were also similar with that of wheat aphids. The parasitoids caused up to 42% mortality of aphids at Kulumsa in 1995 indicating their importance as biological control agents. He has also reported that the appearance of these natural enemies was late and lagged behind the aphid population. The trend is the same, except slight differences in seasonal abundance of wheat aphids at Ambo.

Lamb, (1980) considered the rise and decline of a local population of the aphids-*Aphis barberae* (Homoptera: Aphididae). His conclusion indicated that the infestation of aphids appeared to arise from a single central colony and spread when alate or rapturous aphids traveled short distances to adjacent plants. The growth patterns indicated that each infestation represented a single clone. Both infestation declined rapidly, due largely to predation by syrphids, coccinellids and chrysopids and become locally extinct early in the summer. In Nigeria, the predators belong mainly to the families of coccinellidae and syrphidae were also reported.

Laboratory studies (Ofuya T. 1986; Akingbungbe and Ofuya T. 1988; Ofuya T. 1990; 1995a) have shown the coccinellids in the genus *chielomenes* as promising for biological control of the cowpea aphids (Ofuya 1995).

From our experiment it is also possible to understand that wheat aphids are subject to predation by adult and larvae of ladybirds (coccinellids). Larvae of Syrphids and parasitized dead aphid bodies (mummies) can often be found in large numbers on the host crops both in the field and greenhouse condition at Ambo. The experiment showed that the natural regulation of wheat aphids could be possible through the activities of natural enemies, especially by predators existing in the area.

Although a large number of research programs were conducted, especially in wheat the action of natural enemies remains to be poorly quantified. This is true at the field level (interactions with pests and crop plants) and at the agroecosystem level (interactions with alternate crops and adjacent non-crop habitats). In spite of the interest and commitment to biological control using natural enemies, the possibilities for integrating this strategy have not been fully explored for the control of wheat aphids. However, natural enemies such as predators from coccinellidae family and other parasitoids have been identified.

Knowledge on their biology and rearing techniques are very important. Based on this information, we suggest that it would be possible to design the use of this predatory insect as one of the components of integrated wheat aphid management.

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