Sustainable management of ladybird beetle (Coleoptera: Coccinellidae) and future effect of climate change

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Abstract

Objective: The study in management of ladybird beetles and effect of future climate change have not been carried out in Chitwan district. Thus, an experiment leading to understanding the sustainable management of ladybird beetle (seven-spotted) *Coccinella septempunctata* (Coccinelidae: Coleoptera) and consequences of future changing climate was conducted.

Methods: The study was conducted in split plot design at Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan, Nepal during the period of November 2014 to March 2015. Four plots with each two conventional (with systematic inputs including spray of insecticide or abamectin) and agroecological (without any inputs and insecticide spray) prepared to determine effect in population of ladybird beetle *C. septempunctata* (Coccinelidae: Coleoptera), while other two with each prepared to determine the interrelationship of drought stress on population of ladybird beetle. Laboratory study was carried out to understand the effect of variable temperature in effectiveness of ladybird (C. *septempunctata*) mass over aphid population. Mustard crop was selected for the study.

Results: The average numbers of ladybird beetles were maximum in agroecological plots in comparison with conventional plots. In irrigated plots the population of ladybird beetles were more than that of dry or drought plot sites. At 14-23^{0}c the peak numbers of aphids consumed by an individual ladybird beetle in a day was 50, and after the maximum temperature gradually the consumption frequency of beetles decreased.

Conclusion: Therefore, an agroecological farming system was found to be an appropriate and sustainable option for the management of ladybird beetles with negative consequences of future climate change (both increased temperature and drought conditions) in the population of ladybird beetles in the district.

Keywords: agroecological, beetles, conventional, drought, temperature

1. Introduction

Insects are considered as an important part of biodiversity in most ecosystems. They deliver various services critical to food production, control of pests, including pollination and nutrient cycling (Ameixa *et al*., 2018) [1], and also they play vital role as a source of food for vertebrates in our environment. The family of insect called Coccinellidae have beetles (Coleoptera), referred to as ladybirds (also ladybugs or ladybird beetles), form a group that plays diverse and important roles in ecosystems.

The family Coccinellidae have about 6000−7000 recognized species (Tomaszewska *et al*., 2021) [42]. The aphid predators are often considered to play a significant role as pest control agents (Michaud, 2012) [32], and a very small number of them have gained particular attention as invasive alien species (Evans *et al*., 2011; Roy *et al*., 2016) [14, 36]. Many soft bodied insects are controlled by ladybird beetle (7-spotted ladybird beetle), *Coccinella septempunctata* (Coccinelidae: Coleoptera) specially aphids that plays significant role as biological control agent. Ladybird beetles are widely distributed insects, most of which feed on aphids, mealy bugs, scale insects, white flies, thrips, leafhoppers, mites, or other small soft bodied insects (Gautam, 1989; Omkar & Pervez, 2000) [16, 34]. Such biological control of insect is regarded as best option to control aphids at the deleterious effect of insecticide in environment, crop and other components (Bellows, 2001) [7]. The close relationship showing behavior of *C. septempunctata* with aphids have increased the curiosity for many researchers to study their interaction. They reproduce so quickly when the prey species are multiplying their population and become inactive when the prey population is also reducing (Kenneth and Hagen, 1970) [24]. For the purpose to investigate aphid control through mass rearing and other processes the Coccinellids have been extensively applied (Saharia, 1982) [37]. Predaceous lady bird beetle feeds on an extended range of soft bodied insects such as aphids, mealy bugs, scale insects, leaf hoppers and mites (Omkar Bind, 1996; Joshi & Sharma, 2008) [34, 23]. The loss of crops and disease vectoring damage are easily controlled by releasing the mass of ladybird beetle in crop field.

The loss of agricultural lands, landscape simplification, and urbanization affect assemblages of ladybirds, especially those restricted to native habitats (Honek *et al*., 2017; Egerer *et al*., 2018; Grez *et al*., 2013, 2021; Gardiner *et al*., 2021) [21, 13, 17, 18, 15]. Largely the natural habitats of lady bird beetles are degrading. Farmers usually spray insecticides in the field of crop to manage aphids and the population of ladybird beetle are affected at the same time. Loss of biodiversity has been observed due to some conventional farming in rural communities (Marini *et al*., 2011; Tscharntke *et al*., 2021) [31]. This means that such farming method contain standardizing and expansion of lands creating loss of natural habitats. The conventional farming method applies extensive agrochemicals and that have direct impact in the population of insects like lady bird beetle (Brühl *et al*., 2021) [9].

Directly or indirectly the population of aphidophagous ladybirds are impacted by the changing climate. The most absolute direct effect is the gradual global increase in temperature (IPCC, 2014) [22]; but, the variation in atmospheric carbon dioxide (CO_2) or climate-sensitive pollutants such as ozone (O_3) (Seinfeld & Pandis, 2016) [38] can also have an impact. The effects of climate change not only warm our environment but also fluctuates the extreme weather condition with its associated events, including precipitation, heatwaves, excessive rainfall and droughts (IPCC, 2014; WMO, 2020) [22, 43]. All the causes mentioned can potentially affect ladybirds directly, the most obvious example being temperature via ectothermy and thermal tolerance.

The activities through agroecological practices are increasingly seen as an effective solution to lower the negative consequences of conventional farming on insect communities (Deguine *et al*., 2021) [10]. Interventions such as sustainable farming, crop diversification, reduced chemical inputs, agroforestry, integrated farming, cover cropping, etc. falls under agroecological practices. Such strategies promote the population of insect's including predators which are effective in controlling pest in the crop field. It is imperative to analyze how such insect's respond to different farming practices in fluctuating environment and climatic condition. Different perspective and results have been noticed in the past, such as certain studies have reflected that some insect's falling in groups of natural enemies (predators or parasitoids) improve their population with the changing agroecological conditions (Martin *et al*., 2011), while other studies have revealed checked population of such insects at variable agroecological sites (Liu *et al*., 2018) [27]. Such effects have been well investigated insects like ladybird beetle at different ecological zones. Thus, an investigation to determine most effective agroecological method to manage ladybird population (*C. septempunctata*) in mustard field at fluctuating climatic condition was carried in Chitwan district of Nepal.

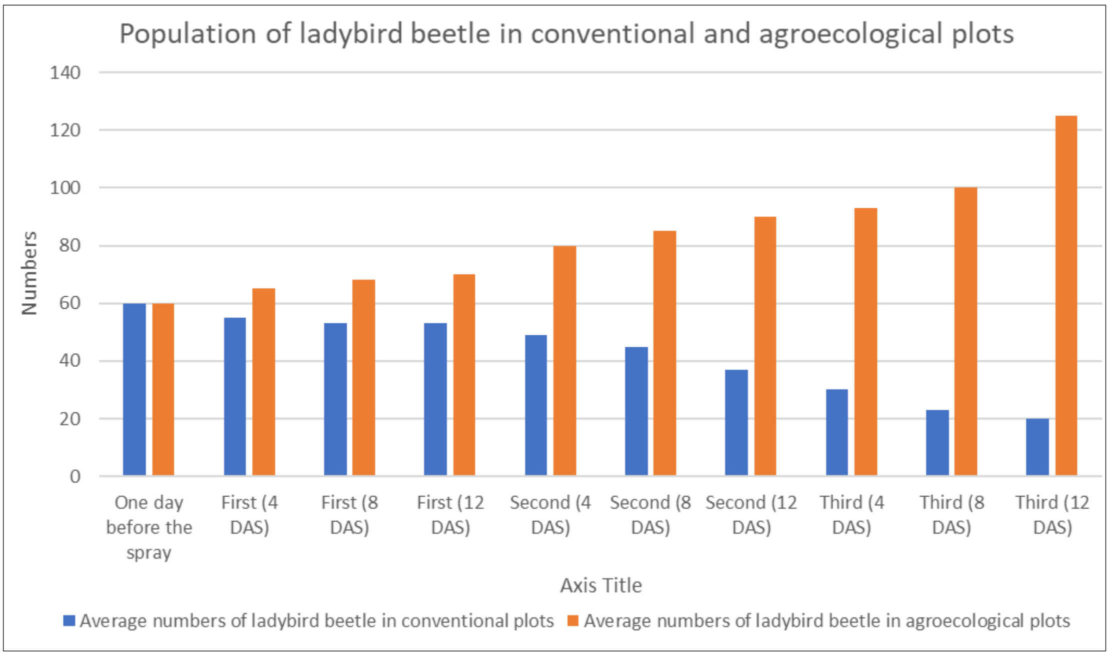
2. Materials and methods

Six plots (each with size 5*5-meter square) were prepared in agronomy farm of Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan, Nepal during the period of November 2014 to March 2015. Split plot design method was applied to conduct the research. Two plots with conventional method (with systematic inputs including insecticide) of farming and other two with agroecological farming (without systematic inputs and insecticide) were prepared. Out of remaining two, one plot was irrigated while the other was non-irrigated to measure the effect of drought in ladybird beetle *C. septempunctata* (Coccinelidae: Coleoptera) population. Simultaneously laboratory study was carried to understand the effect of variable temperature in effectiveness of ladybird (C. *septempunctata*) mass over aphid population. Mustard crop was selected for the study, and sample of plant twigs, aphids, and beetles were reared in the laboratory maintained at Entomology department of Agriculture and Animal Science (IAAS), Rampur, Chitwan. Insecticide abamectin was sprayed to control aphid population. Timely the data were recorded from the field.

The recorded data were all tabulated and systematically arranged treatment wise under three replications using MS-Excel which were subjected to Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT-0.05 level) for mean separations using Gen stat software.

3. Results and discussions

3.1 Numbers of ladybird beetle in conventional and agroecological plots



Note DAS: Days after spray

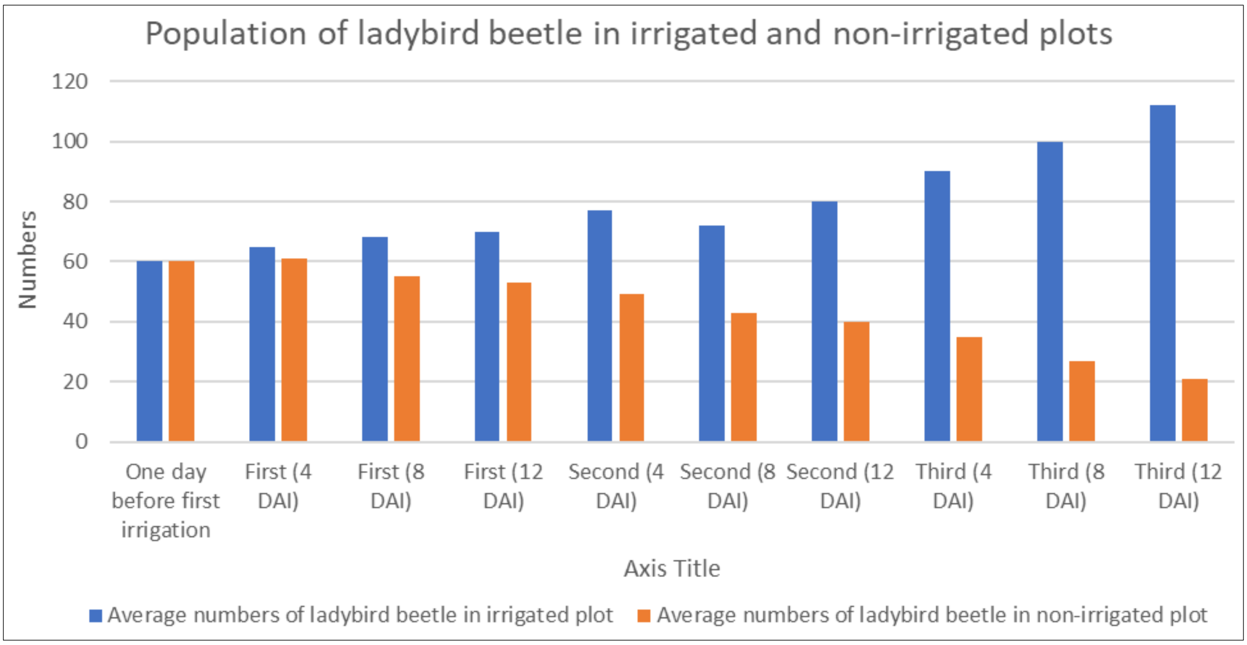
Fig 1: Numbers of ladybird beetle in conventional and agroecological plots

It was found that number of ladybird beetle were 60 before the first spray of insecticide (abamectin). The average numbers of ladybird beetle were found to be 55 and 65 in conventional and agroecological plots after first spray in 4 days, while 53 and 68 in 8 days and 53 and 70 in 12 days respectively. The average numbers of ladybird beetle were recorded to be 49 and 80 in conventional and agroecological plots after second spray of 4 days, 45 and 85 in 8 days and 37 and 90 in 12 days respectively. Finally, the average numbers of ladybird beetle found to be 30 and 93 in conventional and agroecological plots after third spray of 4 days, 23 and 100 of 8 days and 20 and 125 of 12 days respectively (Figure 1).

Various factors such as management, elevation and season are responsible for the increase or decrease in population of many insects including ladybird beetle (Hodgson *et al*., 2011; Baldacchino *et al*., 2014; Habel *et al*., 2019; Makwela *et al*., 2019) [20, 2, 19].

Some studies have reflected that in agroecological farming field of cotton crops population of ladybird beetles are more common compared with conventional cotton fields (Bengtson *et al*., 2005; Lu *et al*. 2015; Liere *et al*., 2017) [28, 26]. This may be due to the negative effect of abamectin in the ladybird beetle population. The disturbance created while managing the crop field in conventional plots may disturb the mass of beetles.

3.2 Effect of drought stress in ladybird population



Note DAI: Days after irrigation

Fig 2: Effect of drought condition in ladybird beetle

It was recorded that there were 60 average numbers of ladybird beetle in both irrigated and non-irrigated (dry) plots before the irrigation. The average numbers of ladybird beetle were observed to be 65 and 61, 68 and 55, 70 and 53 at 4, 8 and 12 days after first irrigation in irrigated and non-irrigated plots respectively. Similarly, the average numbers of ladybird beetle counted to be 90 and 35, 100 and 27, and 112 and 21 at 4, 8, 12 days after third irrigation in irrigated and non-irrigated plots respectively (Figure 2).

Insect turnover was due to abundant food and the favorable microclimate in conventional farming practices, as Bhati *et al*. (2016) [8] reported. Changes to abiotic conditions associated with climate change, such as drought stress have negative effect in the population of phytophagous insects such as ladybird beetle (Koricheva *et al*., 1998; Pritchard *et al*., 2007; Banfield-Zanin & Leather, 2015; Leather *et al*., 2014, 2015) [25, 35, 3-5]. Future climate will not only warm the environment but also fluctuates precipitation and with excessive rainfall or drought condition causing negative consequences in insects like ladybird beetle (IPCC, 2014; WMO, 2020) [22, 43].

3.3 Effect of temperature in ladybird beetle consuming aphid population

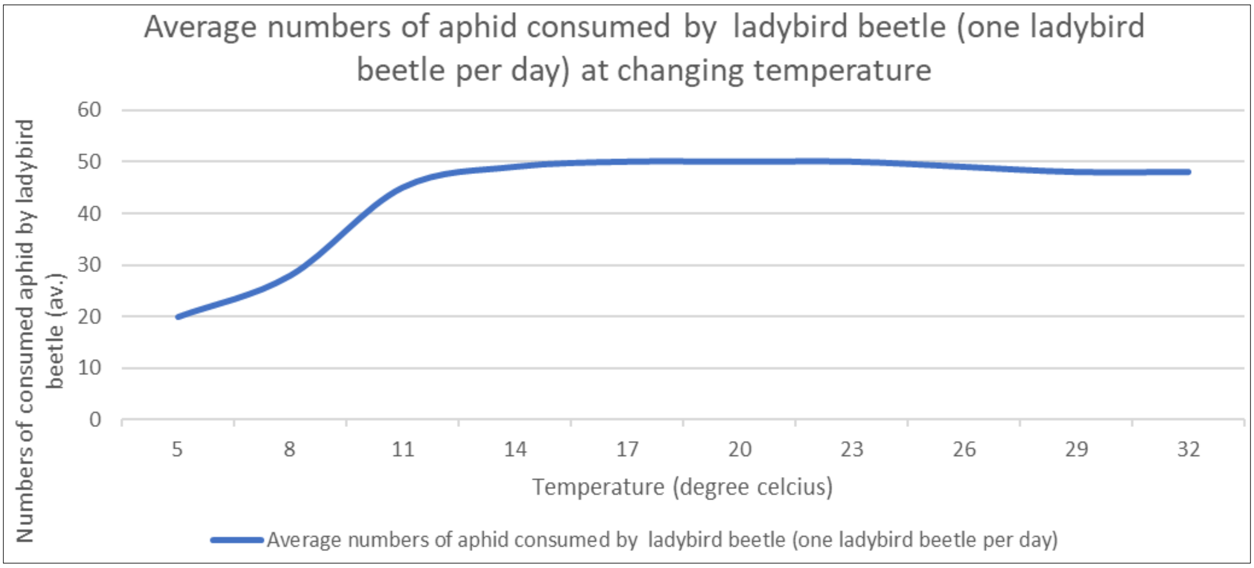


Fig 3: Average numbers of aphids consumed by lady bird beetle in different temperature

It was noticed that at the temperature of 5, 8, 11, 14, 17, 20, 23, 26, 29 and 32^{0}c the average numbers of aphids consumed by single ladybird beetle in a day were 20, 28, 45, 49, 50, 50, 50, 49, 48 and 48 respectively (Figure 3).

The consumption rate of aphids by an individual ladybird beetle increases with increase in temperature. Maximum numbers of aphids were consumed at above 11^{o}c up to 23^{0}c. Elevated temperatures have numerous influences over life history, behavioral, and physiological parameters of natural enemies, such as ladybugs (Lumbierres *et al*., 2020) [29] and thus creates biological control to varying (and often unpredictable) extents. Elevated temperatures can produce antioxidant defenses in order to reduce free radicals and protect the insect from thermal stress (Marcelo & Tania, 2002; Yao *et al*., 2007) [30, 44]. These antioxidant defenses are species-specific and regulated by a suite of temperature-dependent enzymes.

The system of ladybird beetle life is governed by temperature (Dixon *et al*., 2005) [12]. Metabolic, developmental, and feeding rates have hump-shaped temperature dependences; optimum, upper, and lower thresholds change within species (Dixon *et al*., 2009) [11]. With rise in warming or temperature the Intraguild predation among aphidophagous predators may be enhanced (Soares *et al*., 2003; Sentis *et al*., 2014) [41, 39], which can drive local extinctions of intraguild prey. In general, warming surges the ladybird feeding aphid frequency and capacity up to a thermal maximum, above which feeding rate gradually decreases (Sentis *et al*., 2012) [40].

4. Conclusion

The study was conducted in split plot design at Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan, Nepal during the period of November 2014 to March 2015. Four plots with each two conventional and agroecological prepared to determine population of ladybird beetle *C. septempunctata* (Coccinelidae: Coleoptera), while other two with each prepared to determine the interrelationship of drought stress on population of ladybird beetle. Laboratory study was carried out to understand the effect of variable temperature in effectiveness of ladybird (C. *septempunctata*) mass over aphid population. Mustard crop was selected for the study. The average numbers of ladybird beetles found maximum in agroecological plots in comparison with conventional plots. In irrigated plots the population of ladybird beetles were found more than that of dry or drought plot sites. With increase in temperature the rate of aphid consumption by ladybird beetles increased and gradually decreased after a certain range of temperature. Thus, conventional, and non-irrigated (drought) plots including temperature have non-significant relation on the population and capacity of ladybird beetles.

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