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Pesticide differentially affects natural predators causing pest build up: a case study in brinjal.

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Abstract

Pesticide application aimed at pest regulation in agricultural field can have unintended differential and negative impacts on non-target species.Therefore, its continuous and uncontrolled usage can disturb the balance of agricultural ecosystem. The objective of the present study was to assessrelative impacts ofpesticideson pest and predator populations in an agricultural ecosystem. We chose brinjal farm as our focal system as it is an economically important crop that has high pest vulnerability and therefore requires heavy pesticide usage. Whitefly is a major pest of brinjal.Spiders are important natural predators that is known to control pests by active predation. We explored the impacts of pesticide on whitefly and spider populations in brinjal farming system. Thirty farms were selected in the coastal agro-climatic zone in southern West Bengal. Whitefly abundance increased significantly with increasing usage intensity of pesticides used by farmers. Spider abundance decreased as pesticide intensity increased. Decreasing spider density resulted in increased whitefly population. These results show how non-target impact of pesticide impedes natural pest regulation.

Keywords: Pesticide, Pest, Natural predator, Whitefly, Spider, Non target impact

Introduction

Chemical pesticides are important part of modern agriculture, and they have significantly aided in controlling pests that increased crop yields(Cooper and Dobson 2007). However, careless pesticide application can have unintended and negative consequences for non-target speciessuch as pollinators and natural predators(Theiling and Croft 1988;Vanbergen *et al.* 2013)that provide valuable ecosystem servicesin agricultural systems. Unrestrained use of pesticides can therefore disrupt the balance of agricultural ecosystems. Natural predators are important component of agroecosystemsthat can keep the pest populations at check. Increased pesticide intensity can lower predator population and their pest controlling capacity (Sánchez-Bayo 2021) which in turn may lead to an increase in pest population demanding more pesticide input. Pesticide application therefore triggers a vicious cycle which ultimately leads to both yield loss as well as loss of farm profit due to increase in production cost (Bommarco*et al.* 2011). Despite the risks, the use of pesticides continues to increase globally (Sharma *et al.* 2019). Thus, it is crucial to investigate the understudied relationship between pesticide intensity, pests and predator populations in agricultural ecosystems.

Brinjal is among the most significant three vegetables in many South Asian countries, including India, Bangladesh, Nepal, and Sri Lanka(Alam*et al.* 2003).Whitefly (*Bemiciatabaci*Gennadius) is an important sucking pest that causes significant damage to brinjal plants (Mandal*et al.* 2010.).Whitefly belongs to the Hemiptera order. They harm brinjal plants in both direct and indirect ways.Both nymphs and adults suck sap from the lower leaf surfaces using their piercing and sucking mouthparts.Furthermore, they disrupt

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transport in conducting vessels and appear to introduce a toxin that reduces photosynthesis (Sharma and Chander 1998). Yellow spots appear on the leaves when several insects suck the sap from the same leaf, which causes crinkling, curling, bronzing, and drying. In severe conditions, when most leaves on the plant are affected, photosynthesis is reduced, and yield drops significantly. They are also potential virus vectors; more over honeydew secreted by them attracts black sooty mould another photosynthesis inhibitor further contributing to yield loss. Spiders (order Araneae)are one of the major groups of generalist natural predators and they have been reported to be an important pest regulator (Nyffeler and Benz1987).A healthy spider population is a vital component ofany ecologically efficient, sustainable, low-input agricultural system (Ekschmitt*et al.* 1997). We explored the impacts of pesticideson whitefly and spider abundance in brinjal agricultural systems.

Materials and methods

Study area:

The study was conducted in the southern part of West Bengal, India. Thirty brinjal farms from three administrative districts (Kultali, Swarupnagar, and Nandigram II) in the "coastal saline agroecological Zone" with a similar agro-climatic regime were chosen for the study. The overall climate in this region is tropical humid, with rainfall ranging from 1600 to 1800 mm and air temperatures can range from22.7°C to 37°C. (Adhikari*et al.* 2010). The study areastretched across 130 kilometres from East (22°0'5.95"N, 87°49'50.30"E) to West (22°51'41.69"N, 88°53'43.73"E). The farms were chosen to be located at least 2 kilometres apart from one another. The same variety of brinjal (*Tarini* variety) was grown on all farms. The farms were selected to represent a pesticide use gradient based on a Pesticide Intensity Index (PII).

Pesticide Intensity Index:

Pesticide intensity index(PII) of an individual farm was estimated from the quantity of chemical pesticides consumed, frequency of use and toxicity levels of the used pesticides. Pesticide input amount is the total amount of chemical pesticides divided by the area of that particular farm (ml/meter2). Pesticide input frequency is the total no of applications of chemical pesticides (no of spray/month). All the pesticides were categorized into four toxicity ranks according to their toxicity levels rank 1= slightly toxic, rank 2= moderately toxic, rank 3= highly toxic, and rank 4= extremely toxic (Sawant*et al.* 2022). Pesticide toxicity rank of individual farm was calculated by the following formula.

Toxicity rank= $\sum_{i=1}^{n} pfi * pti$ (where pf_i is the pesticide use frequency of the i_{th} pesticide and pt_i is the toxicity rank for the same. n is the number of pesticides used).

Pesticide amount, frequency, and toxicity were normalized, averaged, and added following Flohre *et al.* 2011.

$$PI = \frac{\sum_{i-1}^{n}(p_i - p_{\min})(p_{\max} - p_{\min})}{n} \times 100$$

where PII is the Pesticide use Intensity Index, p_i is the observed value (Total amount of pesticide applications or frequency of pesticide applications or toxicity rank of the farm), p_{min} is the minimum observed value in all farms, p_{max} is the maximum observed value in all farms, n is the number of individual indicators (here n=3), and i is the identifier for the three indicators.

Field sampling:

Fieldwork was performed in the pre-monsoon season of 2019 (from March to June 2019). All thirty fields were sampled once in a similar crop stage. All the sampling was done on days with sunny clear weather (no rain).

Spider sampling:

Four random quadrats of 0.5 meter × 0.5 meter were sampled in each field. Vacuum-sampling was done for 2 minutes in each quadrat at 0800, 1000, 1200 and 1400 hrs. In a quadrat, entire plants were sampled (Green 1999). A vacuum machine (model: STIHL SH 86 C-E) powered by a two-stroke petrol engine was used for sampling. A net sleeve was placed inside the muzzle to sample spiders. Spiders were vacuum sampled, then put into ethyl acetate-killing jars before being transferred to marked vials of 70% ethyl alcohol for taxonomic identification. All the spider samples were identified up to the family level (Sebastian *et al.* 2009) and then up to morphospecies.

Whitefly sampling:

We estimated whitefly population of each field following a presence-absence sampling procedure. This technique requires visual observation of the whitefly adults on the leaves (Palumbo *et al.* 1994).We counted the number of leaves that had one or more whitefly adults, that is, whether they were present or not (absent).Four random quadrats were chosen for the observation and fifty random leaves from each quadrat were observed (50 leaves x 4 quadrat=200 leaves). Whitefly population was estimated as a ratio of whitefly affected leaves (number of leaves present with whitefly/200) and all observed leaves.

Statistical analysis:

All the analyses were performed in R statistical software (version 4.2.1) for Windows (Team, R.C., 2015). Normality and heteroscedasticityof data were checked using normal Q–Q plots and standardized residuals versus fitted value plots (Crawley 2007). Our data did not fit in a normal distribution. To explore the relationshipbetween pesticide intensity (PII), whitefly and spider we fitted our data in generalized linear models (GLMs) using 'glm' and 'glm.nb' functions. To assess the effect of pesticide intensity on the whitefly populationwe assumed binomial error distribution with a 'logit' link.The relationship of spider abundance with pesticide intensity was assessed with another GLM where we assumed a negative binomial error distribution with a 'log' link function. We summed the abundance of spiders of all four quadrats in each field and used them in the analysis. The relationship of whitefly with spider abundance was also explored with a GLM where we assumed a Gamma error distribution with an 'inverse' link. All models were selected based on their lowest Akaike's information criterion (AIC) value (Burnham and Anderson 2002). For the analysis, we used 'readxl','MASS' and 'ggplot2' packages in R.

Results and discussion

We found a gradient of pesticide intensity across our thirty field sites with the PII value ranging from 0 (no chemical pesticide input) to 92.98 (highest level of chemical pesticide input) (Figure 1). We collected a total of 328 spider specimens from the fields belonging to seven families. Oxyopidae is the most dominant family (66.8%) in our brinjal fields followed by Salticidae (20.4%), Araneidae (6.4%), Theridiidae (3.05%), Tetragnathidae (1.83%), Thomisidae (0.91%) and Lycosidae (0.61%)(Figure 2).

We found whiteflypopulation is increasing with pesticide intensity (GLM binomial $p < 0.05$, df =29, $R^2 = 0.48$) (Figure 3). This means increased use of pesticides does not guarantee whitefly control. This phenomenon can be caused by pesticide resistance development in whitefly. Whitefly resistance to pesticides is reported in various locationsinIndia (Naveen *et al.* 2017). Spider abundance was negatively affected by pesticide intensity in brinjal farms (GLM negative binomial $p < 0.001$, df =29, $R^2 = 00.36$) (Figure 4). Our finding corroborates previous studies that have shown pesticides have a negative influence on spiders and other natural predators in agricultural fields (Nash *et al.* 2008). When we looked at how whitefly responds to spider abundance, we found whitefly is negatively related to spider abundance in our farms (GLM Gamma $p < 0.01$, df =29, $R^2 = 0.35$)(figure5). Farms that have lower pesticide intensity have more spiders and that leads to decreased whitefly density due to predation. On the contrary, farms that use more pesticides experience a rise in the whitefly populationsince there aren't enough spiders to control them, and whiteflies have developed resistance to the pesticides.

The repeated application of compounds containing the same active ingredients, as well as the use of excessive pesticide doses during a cropping season, has resulted in the development of resistance in whitefly to organophosphates, pyrethroids, and carbamate (Kranthi *et al.* 2002) in crops like cotton. Our study reveals possible pesticide resistance of whitefly in brinjal farms and requires further study. Moreover, in high pesticide intensity farms we found a decline in spider abundance. This indicates that spiders are vulnerable to pesticide application.Negative effects on nontarget natural predators, in combination with pesticide resistance in whitefly, could explain the observed higher pest level, and lower spider abundances in high pesticide intensity fields. Some studies have found that natural enemies are commonly more sensitive to pesticides and develop pesticide resistance slower than their prey (Hill and Foster 2000, Xu*et al.* 2001).Generalist natural predators have been shown to be effective at pest control in managed ecosystems (Murdoch *et al.* 1985, Symondson*et al.* 2002).The decrease in spider abundance observed in the current study coupled with a possible pesticide resistancemay have boosted whitefly populations in pesticide-intensive farms. The actual role and effectiveness of spiders in controlling whitefly population is not well documented but our findings clearly suggest that the role of spiders as biological control agents in brinjal deserves more attention.

Figures:

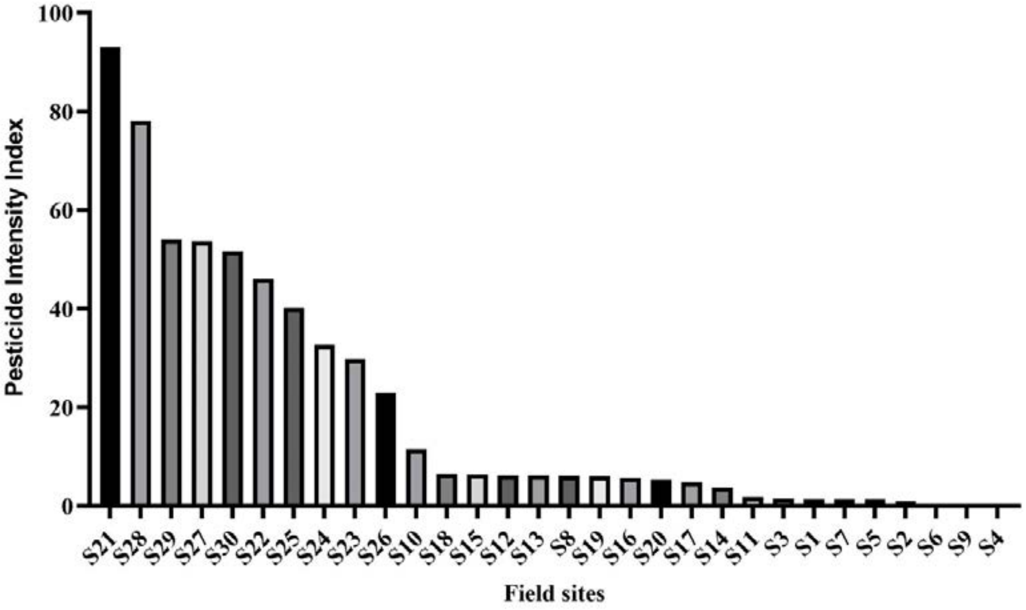

Figure 1: Pesticide intensity index values of our field sites arranged in descending order. S1-S30 are field sites.

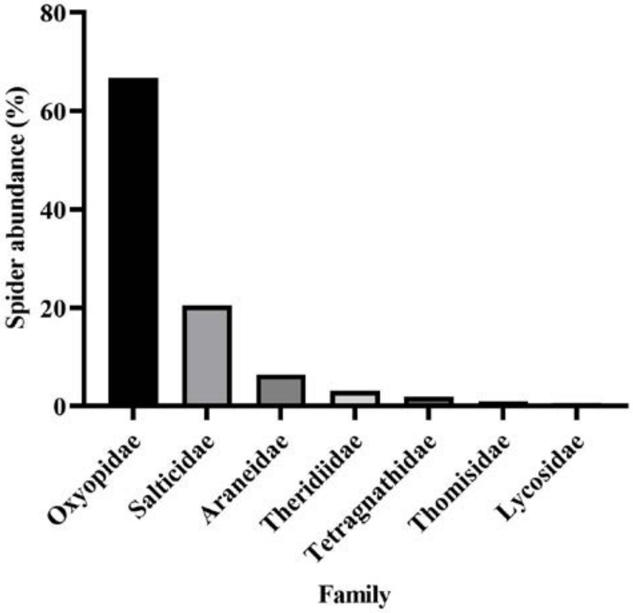

figure 2: Relative abundance of spider families in brinjal farms.In x axis observed spider families and in y axis realtive abundance of spiders(percentage)

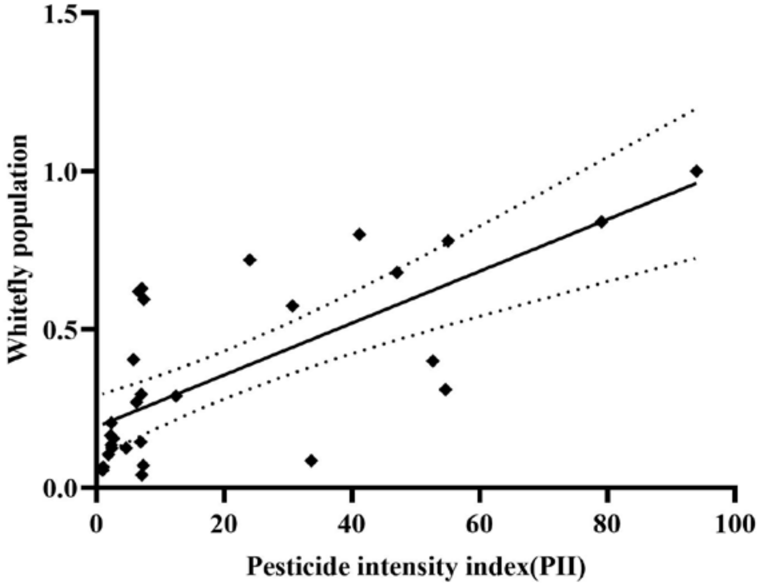

Figure 3 : Relationship of whitefly with pesticide intensification. in x axis pesticide intensification index values and in y axis whitefly population(infected leaves ratio) .p <0.05, df =29,method =GLM, $R^2 = 0.48$

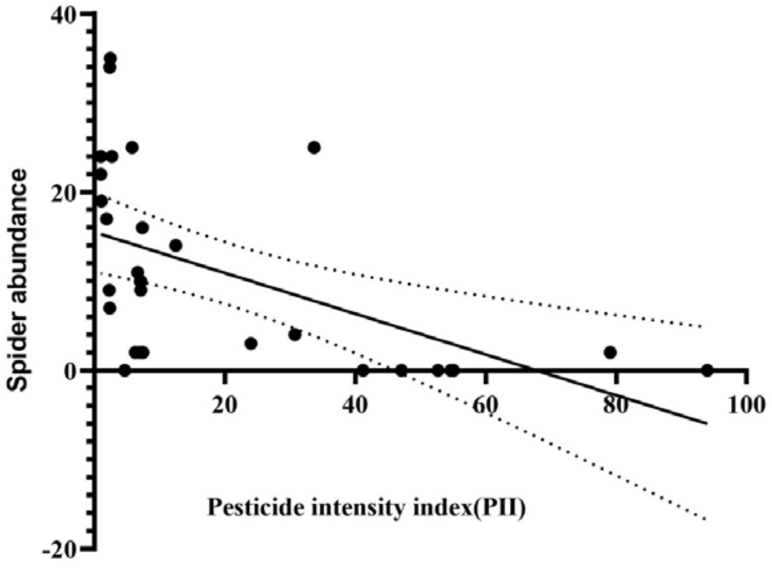

Figure 4: Relatioship of spider abundance with pesticide intensification. in x axis pesticide intensification index values and in y axis spider abundance (total no spider) .p <0.001, df =29, method=GLM, $R^2 = 0.36$.

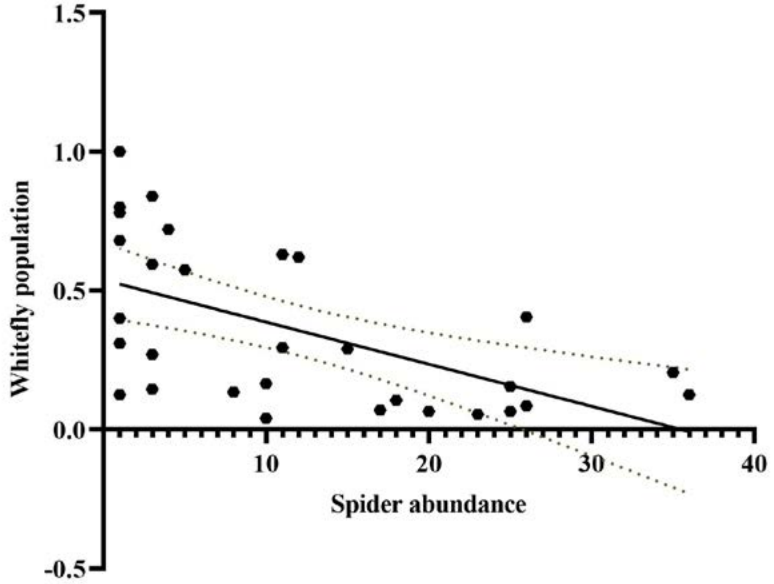

Figure 5: Relatioship of whitefly with spider abundance. In x axis spider abundance (total no spider) and in y axis whitefly population (affected leaves ratio). $p < 0.01$, df =29, method=GLM,$R^2 = 0.35$.

Table 1: List of pesticides used in the study sites. Pesticide application and quantity range is in the table.

Pesticide chemical composition	Toxicity	Frequency (application per month)	Quantity (ml/10 litre)
Monocrotophos (36%)	Extremely toxic	1 to 4	10 to 20
Acephate (20%SP)	Highly toxic	10 to 15	10 to 20
Acephate (50%)+Imidacloprid (1.8%SG)	Highly toxic	3	20
Acetamiprid (20%SP)	Highly toxic	3	20
Chloropyriphos (50%) +Cypermethrin (5%)	Highly toxic	1 to 2	10 to 15
Cypermethrin (10%)	Highly toxic	1 to 4	6 to26
Cypermethrin (25%)	Highly toxic	15	10
Cypermethrin (3%)+ Quinalphos (20%)	Highly toxic	4 to 15	16 to 20
Deltamethrin (1%) + Triazophos (35%)	Highly toxic	2	15
Enamectin Benxoate (5%)	Highly toxic	4	15
Enamectin Benzoate (1.9%)	Highly toxic	7 to 15	20
Imidacloprid (70%)	Highly toxic	1	2
Lambda-Cyhalothrin (5%)	Highly toxic	15	20

Pesticide chemical composition	Toxicity	Frequency (application per month)	Quantity (ml/10 litre)
Profenofos (40%) + Cypermethrin (4%)	Highly toxic	1 to 3	10 to 15
Propargite (57% EC)	Highly toxic	1	10
Pyriproxyfen (5%)+ Fenpropathrin (15%)	Highly toxic	4 to 15	10 to 20
Quinalphos (25%)	Highly toxic	15	20
Biological plant insecticide	Moderately toxic	1	5
Diafenthiuron (50%)	Moderately toxic	1	6
Flonicamid (50%)	Moderately toxic	2	5
Pyriproxyfen (10%)	Moderately toxic	10	13
Spinosad (45%)	Moderately toxic	4	6 to 10
Thiamethoxam (25 %)	Moderately toxic	1	5
Thiamethoxam (30 %)	Moderately toxic	15	20
Spinetoram (11.7%)	Slightly toxic	1 to 4	7 to 12
Chlorantraniliprole (18.5%)	Slightly toxic	1	5
Neem based insecticide	Slightly toxic	10	20
Neem based Azadirachtin (1%)	Slightly toxic	2	10
Organic protectant	Slightly toxic	1	10
Plant Extract	Slightly toxic	3	20
Biological Insecticide	Slightly toxic	1	10

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References

Adhikari, B., Bag, M.K., Bhowmick, M.K. and Kundu, C., 2011. Status paper on rice in West Bengal.*Rice knowledge management portal*, 27.

Alam, S.N., Rashid, M.A., Rouf, F.M.A., Jhala, R.C., Patel, J.R., Satpathy, S., Shivalingaswamy, T.M., Rai, S., Wahundeniya, I., Cork, A. and Ammaranan, C., 2003. *Development of an integrated pest management strategy for eggplant fruit and shoot borer in South Asia.*AVRDC-WorldVegetableCenter.

Bommarco, R., Miranda, F., Bylund, H. and Björkman, C., 2011. Insecticides suppress natural enemies and increase pest damage in cabbage. *Journal of Economic Entomology*, **104**(3), pp.782-791.

Cooper, J. and Dobson, H., 2007. The benefits of pesticides to mankind and the environment.*Crop Protection*, **26**(9), pp.1337-1348.

Ekschmitt, K., Weber, M. and Wolters, V., 1997. Spiders, carabids, and staphylinids: the ecological potential of predatory macroarthropods. *Fauna in soil ecosystems* (pp. 321-376).CRC Press.

Flohre, A., Fischer, C., Aavik, T., Bengtsson, J., Berendse, F., Bommarco, R., Ceryngier, P., Clement, L.W., Dennis, C., Eggers, S. and Emmerson, M., 2011.Agricultural intensification and biodiversity partitioning in European landscapes comparing plants, carabids, and birds.*Ecological Applications*, **21**(5), pp.1772-1781.

Green, J., 1999. Sampling method and time determines composition of spider collections. *Journal of Arachnology*, pp.176-182.

Hill, T.A. and Foster, R.E., 2000. Effect of insecticides on the diamondback moth (Lepidoptera: Plutellidae) and its parasitoidDiadegmainsulare (Hymenoptera: Ichneumonidae). *Journal of Economic Entomology*, **93**(3), pp.763-768.

Kranthi, K.R., Jadhav, D.R., Kranthi, S., Wanjari, R.R., Ali, S.S. and Russell, D.A., 2002. Insecticide resistance in five major insect pests of cotton in India.*Crop protection*, **21**(6), pp.449-460.

Mandal, S., Singh, N.J. and Konar, A., 2010.Efficacy of synthetic and botanical insecticide against whitefly (Bemiciatabaci) and shoot and fruit borer (Leucinodesorbonalis) on brinjal (Solanummelongena L.).*Journal of Crop and Weed*, **6**(1), pp.49-51.

Murdoch, W.W., Chesson, J. and Chesson, P.L., 1985. Biological control in theory and practice.*The American Naturalist*, **125**(3), pp.344-366.

Nash, M.A., Thomson, L.J. and Hoffmann, A.A., 2008. Effect of remnant vegetation, pesticides, and farm management on abundance of the beneficial predator Notonomus gravis (Chaudoir)(Coleoptera: Carabidae). *Biological Control*, **46**(2), pp.83-93.

Naveen, N.C., Chaubey, R., Kumar, D., Rebijith, K.B., Rajagopal, R., Subrahmanyam, B. and Subramanian, S., 2017. Insecticide resistance status in the whitefly, Bemisiatabaci genetic groups Asia-I, Asia-II-1 and Asia-II-7 on the Indian subcontinent. *Scientific reports*, **7**(1), pp.1-15.

Nyffeler, M. and Benz, G., 1987. Spiders in natural pest control: a review 1. *Journal of Applied Entomology,***103**(1-5), pp.321-339.

Palumbo, J.C., TonhascaJr, A. and Byrne, D.N., 1994. Sampling plans and action thresholds for whiteflies on spring melons. Online. Coop. Ext. IPM Series, (1).

R development core team 2013. R: A language and environment for statistical computing. http://www. R-project.org.

Sánchez-Bayo, F., 2021.Indirect effect of pesticides on insects and other arthropods.*Toxics,***9**(8), p.177.

Sawant, C.G., Sharma, L.D. and Sadhukhan, R.,2022. Label Claim and Labeling of Pesticides. Pesticide Residues, Published by Jaya publishing house, Delhi, p.112.

Sebastian, P.A. and Peter, K.V. eds., 2009.*Spiders of India*.Published by Universities press, Hyderabad.

Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G.P.S., Handa, N., Kohli, S.K., Yadav, P., Bali, A.S., Parihar, R.D. and Dar, O.I., 2019.Worldwide pesticide usage and its impacts on ecosystem.*SN Applied Sciences*, **1**, pp.1-16.

Sharma, K. and Chander, S., 1998. Spatial distribution of jassidAmrascabiguttulabiguttula (Ishida) on cotton.*Indian Journal of Entomology*, **60**(4), pp.326-328.

Symondson, W.O.C., Sunderland, K.D. and Greenstone, M.H., 2002. Can generalist predators be effective biocontrol agents?. *Annual review of entomology*, **47**(1), pp.561-594.

Tabashnik, B.E., 1989. Managing resistance with multiple pesticide tactics: theory, evidence, and recommendations. *Journal of Economic Entomology*, **82**(5), pp.1263-1269.

Theiling, K.M. and Croft, B.A., 1988. Pesticide side-effects on arthropod natural enemies: a database summary. *Agriculture, Ecosystems & Environment*, **21**(3-4), pp.191-218.

Vanbergen, A.J. and Initiative, T.I.P., 2013. Threats to an ecosystem service: pressures on pollinators. *Frontiers in Ecology and the Environment*, **11**(5), pp.251-259.

Xu, J., Shelton, A.M. and Cheng, X., 2001. Variation in susceptibility of Diadegmainsulare (Hymenoptera: Ichneumonidae) to permethrin. *Journal of Economic Entomology*, **94**(2), pp.541-546.