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Major insect pest impact on cash crops in the semi-arid zone of Rajasthan: A review

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Abstract
The semi-arid zone of Rajasthan is a significant producer of cash crops, including cotton, Bajara, and mustard. However, insect pests pose a substantial threat to the productivity and profitability of these crops. This review aims to synthesizes the existing literature on the impact of insect pests on cash crop yields in the semi-arid zone of Rajasthan. The review highlights the major insect pests affecting cash crops, including aphids, whiteflies, and Caterpillars. The impact of these pests on crop yields, quality, and economic losses is discussed. The review also examines the factors contributing to the severity of insect pest infestations, including climate change, poor crop management practices, and inadequate pest control measures. Furthermore, the review discusses the integrated pest management strategies that have been successfully implemented in the region to minimize yield losses and improve crop productivity. The findings of this review highlight the need for sustained research and extension efforts to develop and promote cultural, biological controls and chemical controls. IPM strategies that are tailored to the specific needs of farmers in the semi-arid zone of Rajasthan. This review endeavors to piece together all known information about the insect pest that attack on crops.

Keywords: Insect pests, cash crop Yields, semi-arid zone, Rajasthan, integrated pest management.

Introduction

The northern arid regions in India comprise largely of the desert of Rajasthan, and water is scarce in these regions; therefore, it is a dry zone that extends from the Indus in the west to Jamuna in the east, and from the southern Punjab plains in the North to the Rann of Cutch in the south. The Aravalli hills are divided into two portions of Rajasthan, about three-fifths of Rajasthan lying to the North and West, and two fifths to the east. This desert known Thar Desert and 25 mm rain line divided in to two part-arid zone and semi-arid zone. Shekhawati region is the northern and semi-arid region of Rajasthan. Districts of Churu, Jhunjhunu and Sikar form this region. (Many wealthy merchants and bankers in India built havelis here during the British Raj). Barmer, Jalore, Jodhpur, Nagaur and Hanumangarh districts are part of the Bshw climatic region, which is semi-arid and has dry winters and insufficient rainfall in summers. The groundwater is low, rainfall is low, and water runoff is high. The annual rainfall is between 100 and 400 mm or 400 and 800 mm. These regions are completely dependent on groundwater such as ground tanks, ponds, and other traditional water stores. Semi-arid regions are characterized by sandy soils, low annual rainfall, and a rainy season that is short and resistant. The region is also known for its traditional biodiversity, which includes desert trees, shrubs, shrubs, and crops. Fruits (Ber, date palm, anola, pomegranate, lasoda, karonda, custard apple, guava, oranges, kinnow, and sweet lime), forage crops (pearl millet, sorghum, maize, cowpea, cluster bean, oats, barley, lucerne, and berseem), and other crops (Chari (fodder), pulses, rapeseed, mustard, coriander, cumin, fenugreek, moth bean, and sesame etc) were grown in the semi-arid zone of Rajasthan.

The major crops pearl Millet (*Pennisetum glaucum*), Maize *(Zea mays*), Chickpea (*Cicer arietinum*), Mustard (*Brassica nigra*), Cluster bean *(Cyamopsis tetragonoloba*), are grown in the semi-arid zone of Rajasthan. Here some insect pest like Aphids, Leafhoppers, Moth, Weevils, Beetles, Termites, Scale insects are the main sources of biotic stress on crop and these cause serious damage on crops and resulting its reason of loss of agricultural production.

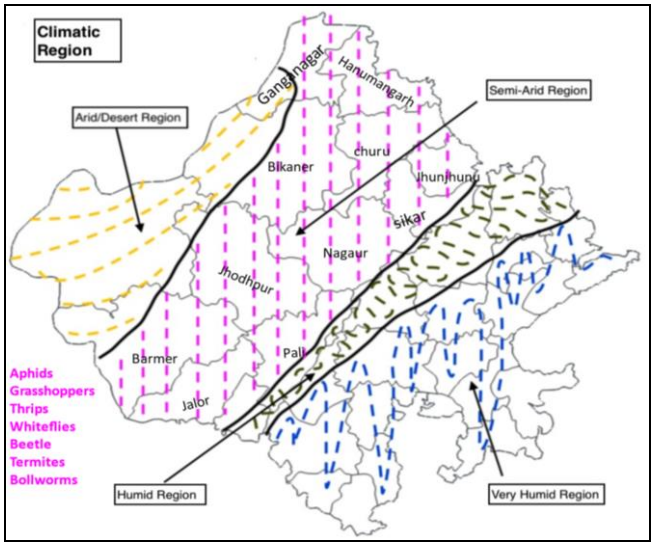

Fig 1: Major Insect Pest in Semi-arid Region of Rajasthan

Economic backbone of any country is agriculture and it contributes significant improvement in growth of the country and people's life is standard and financial growth. There insect pest is crucial role play in ecosystem on earth and its impact both types positive and negative. In the agriculture sector, the pest attacks on crops are a serious issue and resulting in crop quality degrade. The most common pests, germs and weeds are serious damage on crops and resulting low market value of the agricultural products. The detection and classification of insects is essential for making reactive decision with the recovery of crops and bring a potential profit in the agricultural sector.

Traditional or manual methods are time consuming and dependent on the experts but artificial intelligence techniques have best pest detection and classification with minimum time and maximum accuracy. [42] Insect pests is the primary cause of reduced of crop production. There is an enthusiasm among farmers to take crop protection measures. Pest and insect control is one of the unique ways to prevent diseases and chemical control methods such as antifeedants, chemo sterilant, and irradiation techniques are generally used. The types of crop pests, major crops and pests, pest status, scientific classification and biology of the pest are important for known any type of infection on crops, prevention and Control. Mechanical, chemical, and biological control are use there for prevent the crop by pest [25]. Rajasthan state is diversified in the ecological and climatic conditions and among all the ecogeographic regions of the state. Its ecological Regions shows the high richness and insects' faunal diversity by Thar Desert, Eastern plain and Southeastern plateau. In the geographical scenario, the highest number of species of insect, 398 insect's species of recorded from the Aravalli range, 283 species from the Thar Desert, 225 species from the Eastern plain and 86 species from the Southeastern plateau [35]. The present review could help farmers align the crops production with the changing conditions and demand of time.

Table 1: Major Cash Crops and related Insect Pest

Common Crop	Speciality	Insect pests
Wheat-*(Triticum)*	It is the most widely grown cereal crop in Rajasthan and the state ranks fourth in production.	Aphids, Cereal Leaf beetle, Surface grasshopper, Ghujia weevil, Termites, Armyworm, Pod Borer, Browen mite, pink stem borer, Brown stink bug, White grubs, Wireworm.
Bajara (Millet)-*Pennisetum glaucum*	Rajasthan has the highest production of millet in the country. About 41.7% of the total millet production in India.	Stemborers; armyworms, leaf beetle, leaf folder, flea beetle, leaf roller, surface grasshopper, and ants.
Maize- *Zea mays*	Maize is used as food and in the form of green corn cobs.	Stem borer, pink stem borer, Cornworm, Armyworm, Aphids, Shoofly, shoot bug, Web worm, Grasshopper, Leafhopper, Ash weevil, Climbing cut worm
Guar (Cluster bean)-*Cyamopsis tetragonoloba*	About 84% of the total production of India.	Fusarium wilt, root rot, chickpea stunt, grey mould, pod-borer
Cotton-*Gossypium*	Cotton is the most expensive crop and called white gold in Rajasthan	American Bollworm, Pink bollworm, Spotted bollworm, red cotton bug, Tobacco caterpillar, Jassid, cotton aphid, Thrips, White fly, Mealy bug, Wooly mites
Gram (Chickpea)- *Cicer arietinum*	Rajasthan ranks third in producing gram in India.	Gram pod borer, Spotted pod borer, Aphids, Whitefly, Thrips
Sesame- *Sesamum indicum*	Sesame seed with a unique fragrance and many health benefits.	Leaf Webber, Capsule borer, Gall fly, Whitefly, Jassid
Barley- *Hordeum vulgare*	It is mostly cultivated in North India	Aphids, Armyworms, Wireworms, Khapra beetle, cutworms, black point, smuts
Mustard- *Brassica nigra*	Rajasthan is the largest producer of mustard and its share in total mustard production in India is 46.06%.	Aphid, mustard sawfly, painted bug, leaf miner, Green Peach Aphid, Pea Leaf-miner, Hairy Caterpillar, Cabbage butterfly, Diamond back moth
Arhar (Pigeon Pea)-*Cajanus cajan*		Foliage beetles, whitefly, Leafhopper, Scale insects, Termites, leaf damaging weevils, pod borers, blister beetle, blue butterfly
Groundnut- *Arachis hypogaea*	Second largest state in the production of groundnut in India.	White grubs Termites Leaf minor, Jassids, Thrips, Aphids, Hairy Caterpillars, Tobacco Caterpillar, Gram caterpillar
Green Gram (Moong)-*Vigna radiata*	12 lakh tonnes of moong is produced from Rajasthan.	whitefly, leaf hopper, black aphid, Bihar hairy caterpillar, beetle, stem fly, spotted caterpillar
Soybean- *Glycine max*	Third ranks are soybean production in Rajasthan	Stem fly, tobacco caterpillar, Bihar hairy caterpillar, green semilooper, pod borer, leaf miner, whitefly, aphids, stinkbug and girdle beetle

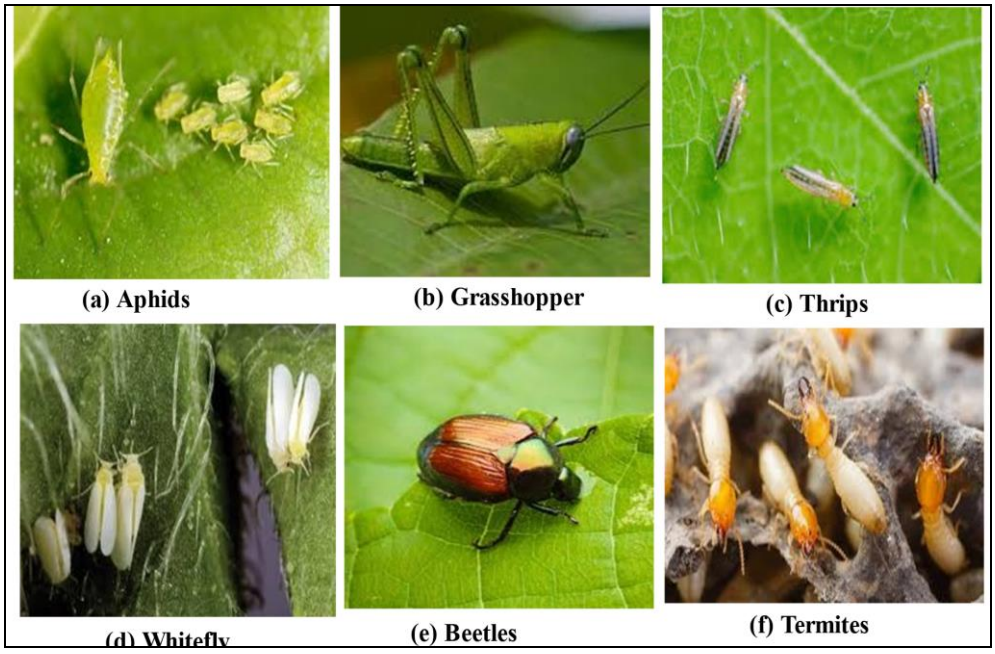

Fig 3: Major pest on crops in semi-arid Rajasthan (a) Aphids, (b) Grasshopper, (c) Thrips, (d) Whitefly, (e) Beetles, (f) Termites

Major type of pest with classification and status in this area

In the semi-arid zone of Rajasthan, insect pests are a significant concern in this zone, here some of the major types of pests that affect crops are Aphids, Grasshoppers, Thrips, Whiteflies, Beetle, Termites, Bollworms, Caterpillars.

Aphids

Superfamily: *Aphididea*
Scientific name: *Myzus persicae*
Common name: Greenfly, Blackfly
Host: wheat, barley, and mustard crops

The aphids are soft-bodied small insects, size is < 7 mm and feed by sucking plant sap. They usually live in colonies on the under sides of leaves or terminal shoots and they excrete liquid substance honeydew which cause sooty mould usually turns them black and it is food for ants, bees and some parasitic wasps. Aphids are directly and indirectly both type of damage on crops. They damage the crops directly by sucking their nutrients and photosynthesis and respiration by the growth of sooty moulds on the honeydew deposited there on and aphids also damage the crop indirectly by transmitting hundreds of plant viruses. Out of globally 5110 species of aphids described, about 250 species are mainly agricultural and horticultural pests [40]. The wheat crop is generally infected with aphids during the growth stages when both the adults and nymphs take a heavy toll by sucking cell sap which reduces the vitality of the wheat plants. Firstly, aphids were observed on the wheat crop on 11th of January at this time, the population was 0.18 aphid/ plant, after a gradual increase in the population was observed that reached to its peak in the mid of March (51.55 aphid/plant). After mid of March, the population started declining and 1.56 aphid/plant were observed in the mid of April and gradually no aphids were seen in the wheat fields. The aphid infestation was scattered on leaves, spikes and in mid of March also observed on stem [16]. The cowpea aphid majorly infects legume crops such as cowpea, groundnuts, faba bean, chickpea, pigeon pea, lentil, mung bean, lucerne but they can infest common beans especially in low altitude areas, the host range of aphid is wide in the leguminous family including weeds and some ornamental plants. In the third week of August, aphis gossypii Glover appeared and increased with the increasing relative humidity. The aphid population reached maximum (40.2/plant) in the fourth week of September and declined thereafter [32]. The mustard aphid passed through four nymphal instars before attaining the adult stage and the average length of first is 0.74 ± 0.07, second is 0.89 ± 0.06, third is 1.14 ± 0.14 and fourth is 1.31 ± 0.13 mm instar nymph [19]. This aphid has the ability to adapt rapidly to various unfavourable environments including water-deficit stress [9]. *Aphis craccivora Koch* (Homoptera, Aphididae) feeds on phloem and cause damage to susceptible cultivars directly by modifying the metabolism and by extracting plant nutrients and, indirectly, by transmitting phytopathogenic viruses. Cowpea aphids damage by direct feeding and injecting toxic saliva into phloem, block the growth or death of the plant. These are released honeydew honeydew and block plant respiration, stimulate development of black mold, and reducing photosynthesis. Some viral diseases such as cowpea aphid-borne mosaic virus are spreading by cowpea aphids [1]. Cowpea aphid also feeds other legumes crops, such as Medicago truncatula, alfalfa, chickpea, lentil, lupin, peanut and many pasture legume species [11]. Biological control is not adequate because natural enemies often appear when CPA infestation is already high and causing serious damage. Pesticides applying early in the season prevents CPA infection and colonization but beneficial insects can be destroyed and leading to outbreaks of other insect pests. [41]. Improving cultivars by adding in resistance through breeding promises a sustainable strategy for aphid control not only in single cowpea but also in many other crop species. Constant and variable/increasing are two different densities of cow pea aphids and three measured symptoms of cowpea aphid density is chlorosis, pseudo galling, and stunted growth. These symptoms first became apparent at the end of week 1 and increased in severity by the end of week 2. These Damage symptoms were also seen in the constant cowpea aphid density and with most of the damage symptoms observed categorized as pseudo galling. The variable cowpea aphid density, where every plant exhibited at least one of the expected symptoms and only half of the constant cowpea aphid density plants.

Grasshopper

Order: *Orthoptera*
Suborder: *Caelifera*
Infraorder: *Acrididae*
Scientific name: *Schistocerca Americana*
Host- wheat, millet, maize

Grasshoppers are plant-eaters, with a few species at times becoming serious pests of cereals, vegetables and pasture, especially when they swarm in the millions as locusts and destroy crops over wide areas. Grasshoppers can damage a variety of crops, including pearl millet, seasonal crops, and vegetables. Grasshoppers' pest causing damage to crops and grazing lands in Rajasthan. The insects called desert locusts. Rajasthan has been exposed to locust attacks in the past and in 2020, desert locusts affected 3.6 lakh hectares of crops across ten districts in Rajasthan. The worst affected district is Sri Ganganagar, where damages to standing crop go up to 75%. Parts of Barmer, Bikaner, Churu, Sikar, Hanumangarh, Jaisalmer, Jalore, Jodhpur, Nagaur and Sirohi are also highly affected. Most common grasshopper species in Rajasthan are Hieroglyphus banian, Spathosternum praciniferaum, and Acrida turrita. In pearl millet fields, seasonal crops and vegetables, Severe infestation was observed and where grasshopper species (H. banian) caused 91% infestation. Locusts and grasshoppers are qualitatively different from other pests: Their populations can quickly grow to catastrophic levels and some species have dense bands and swarms that can cause a fastly damage in a very short time period. They swarms can migrate hundreds of kilometers per day and covering millions of square kilometers, resulting in major economic, social, and environmental impacts [13]. Highest densities ranging from 5 to 17.5 per m2 in 2021 in Rajasthan, while grasshopper densities dropped in the year 2022 from 4 to 14.5 per m2. Majority there were found during the first rainy season (12.5 members per square metre), which was significantly lower during the second rainy season (10.125 members per square metre). The second-year pest population drop can be attributed to lower rainfall in 2022 compared to 2021.Increasing rainfall and temperature that happen steadily in the transition from the end of summer (June) to the start of the winter season (November) coincide

with the production of flowers and leaves of crops [46]. locusts can commonly migrate hundreds of kilometres, rapidly damaging pastures and crops in the areas, which can be harmful for the food security and livelihoods of the rural populations and they leading to major economic, social, and environmental impacts. The speedily increase and sudden change it means extremely difficult for landholders to protect their crops, so government intervention is generally necessary. Only needs to be local intervention and national intervention but international intervention in many instances, particularly with locusts, whose migrations commonly are from one country to another country as a transboundary threat [27]

Global warming and other anthropogenic activities change ecosystems and these increase the potential probability of locust to outbreaks in the region, outbreaks of some local species could also be a serious problem. Generally, Pest species of the locust and grasshopper mainly belong to Caelifera near East and some to Ensifera. Global warming and some agricultural activities can increase the potential for outbreaks of local species and provide favourable conditions for desert locust invasions. In review provide a historical background for locust invasions/outbreaks in the Near East, assess the potential for outbreaking of local species and define a perspective for future actions for global changes [12]. Locust and Grasshopper destroy the food sources of humans, animals, and wildlife, and these affecting food security and biodiversity. Due to losses these pests are not limited to damage to green vegetation; the resulting loss of vegetation cover results in increased runoff and soil erosion. Many varieties of natural enemies of Locust and Grasshopper exist in nature, which create the complexity of the ecological relationships with the ecosystems. Both are cause agricultural losses and environmental damage, and Intricate networks of pathogens, parasites, and predators keep their populations below a certain level. Natural enemies are not only biocontrol agents but it's also help maintain ecological balance, by preserving their natural habitats and providing favourable conditions [7].

Locusts are a group of grasshoppers that called locust phase polyphenism. These density-dependent phenotypic plasticity situation where cryptic and solitarious individuals can form dense migrating swarms by transforming into conspicuous gregarious individuals. This transformation is not only in color and behaviour but also in morphology, reproductive physiology and biochemistry and resulted two phases, the solitarious (greenish individuals) and the gregarious (yellowish and reddish-orange individuals). there are seventeen species have been identified as expressing locust phase polyphenism and considered true locust species. They belong to six Acrididae subfamilies: *Cyrtacanthacridinae*, *Oedipodinae*, *Calliptaminae*, *Gomphocerinae*, *Acridinae* and *Melanoplinae* [45]. Grasshopper identified according to host preferences classified as graminivorous, forbivorous and ambivorous or mixed feeders. Grasshopper can damage rice in all stage of crop growth, Nymphs and adults can feed on leaves by cutting the edges of leaves [6]. Six months period, a study on grasshopper diversity was conducted across three distinct sites in the Kannur district of Kerala: Kavvayi Island, Brennen College Campus, and Poovatharkund Waterfalls in Tholambra, and in the study identified a total of 22 grasshopper species spanning 19 genera and four families. *Acrididae* family was the most represented with 14 species, followed by Pyrgomorphidae with 4 species, *Tettigoniidae* with 3 species, and *Tetrigidae* with 1 species. [38]

Thrips

Order -*Thysanoptera*

Host- chilli pepper, mustard, onion, garlic, cotton, and vegetable crops

Thrips are a most significant pest in the semi-arid region of Rajasthan, India. Here, Chilli thrips (*Scirtothrips dorsalis*) affects chilli peppers, Cotton thrips (*Thrips tabaci*) affects cotton crops, vegetable thrips (*Thrips palmi*) affects tomatoes, cucumbers, and squash.

Thrips are small size insects and live cryptic habits. Many invasive thrips are notorious for causing extensive crop damage, vectoring viral diseases. Thrips are small hemimetabolic insects and their size from 0.5 to 14 mm (0.02 to 0.55 in) in length for the larger predatory thrips, but most thrips are about 1 mm in length. Flight-capable thrips have two similar and have strap-like pairs of wings with a fringe of bristles. The wings are folded back over the body at rest and their legs usually end in two tarsal segments with a bladder-like structure known as an "arolium" at the pretarsus. Thrips are present in this area functionally diverse group; many of the known species are fungivorous. Commercially important crops affected by the small proportion of the species are serious pest. Some of these serve as vectors for over 20 viruses that cause plant disease (Tospovirus). Many flower-dwelling thrips species bring benefits as pollinators, with some predatory thrips feeding on small insects or mites.

These are shown some Damaging symptoms as Yellowing or bronzing of leaves, Distorted or stunted plant growth, Reduced fruiting and flowering, Presence of thrips on leaves and stems. *Thrips palmi* Karny (*Thysanoptera, Thripidae*), the melon thrips, is a polyphagous pest of *Cucurbitaceae* and *Solanaceae* (Walker, 1994) [43]. Thrips palmi Karny is the melon thrips, has spread widely and rapidly in tropical and subtropical regions, but despite a number of all successfully eradicated outbreaks and regular interceptions, Considerable experience of managing this pest has been gained in different countries as it has spread around the world [2]. During a Rabi season, this pest arises in last week away from February including reached its peak during a 14th Standard Meteorological Week. Within the Kharif season, it began within the beginning based on October including gradually increased until it reached its peak during a 39th Standard Meteorological Week. Males arise very uncommon in parthenogenesis and female T. tabaci populations can be found within some parts based on the world. Females can deliver around 79 eggs. this reproductive aspect exists very important. Nine onion cultivars treated evaluated during three years based on field studies from 2014 to 2017 to determine their susceptibility to onion thrips including whether leaf color exist related to thrips fondness [39]. A sprite including grown-up away from onion thrips feed leaves by puncturing with scratching about leaf tissues including causes longwise, shimmering texturing either blotching on like onion leaves, bringing about a deficiency based above chlorophyll with diminished photosynthetic effectiveness. On garlic crops the thrips pest commenced in the first week of February and reached its peak in the second week of March. The predator, Coccinella septumpunctata Linn. was commenced in the second week of February and reached the maximum in the second week

of March. It is well fact that the incidence of insect pests depends upon climatic conditions, crop growth stages, and natural enemies of a pest at a particular time. The weather parameters *viz.*, temperature, relative humidity, rainfall, mean bright sunshine hours, etc. play an important role in the incidence of thrips in garlic crop. T. tabaci was reported as a regular and major pest in Rajasthan and other parts of the country. Thrips cause both quantitative and qualitative losses to the tune of 34-43 percent. Thrips puncture the tender leaves and suck the exuding sap. As a result of continuous feeding by such a large population the plant leaves become curl, wrinkle and gradually dry up, resulting in shriveled bulb and seed formation [17]. Study the Seasonal Incidence of Thrips, Thrips tabaci on Onion at Horticulture farm, Department of Entomology and Laboratory during December to May (Rabi) of 2008-09 [22].

Whitefly

Order: Hemiptera

Family: *Aleyrodidae*

Host- cotton, vegetable, and fruit crops

Whiteflies pests are a significant pest in agricultural regions of the semi-arid zone of Rajasthan, India. Here are some whiteflies as Bemisia tabaci (Cotton whitefly) affect the cotton, vegetables, fruits and Trialeurodes vaporariorum (Greenhouse whitefly) affects vegetables, fruits, ornamental plants widely. Whiteflies are typically active in during the warmer months (March to October), with peak populations occurring during the summer (June to August) in semi-arid region of Rajasthan. Whiteflies can cause significant economic losses particularly in cotton and vegetable crops in Rajasthan. In warm or tropical climates and especially in greenhouses, whiteflies present major problems in crop protection. Some damage Symptoms are showing as yellowing or curling of leaves, reduced plant growth and yields, presence of whitefly eggs, nymphs, and adults on leaves, honeydew droplets on leaves, promoting sooty mold growth. Incidence of whitefly on cotton, Maximum adult population of whitefly recorded in August month, these are negatively correlated with rainfall, morning and evening relative humidity, positively correlated maximum temperature and minimum temperature, moreover bright sunshine shows positive correlation [15]. Whitefly is a polyphagous pest and cause both direct and indirect damage to cotton plant, the direct damage is caused by sucking the sap after feeding resulted leaf yellowing, leaf wilting, leaf drop and overall decline in seed cotton yield and indirect damage results from excretion of sugary liquid called 'honeydew' on which sooty mould (black fungi) grows [20].

During kharif season, divulged the initiation of white fly infestation was recorded in 2nd week of August and reached a peak level 10.8/5 leaves in 2nd week of September when the temperature ranged between 20.6–29.9°C and RH 70–99%. White fly incidence of correlation coefficient values showed that maximum and minimum RH besides minimum temperature had positive correlation but maximum temperature and rainfall showed negatively correlation with white fly population. [18]. Nature of these insects are polyphagous and feed on wide range of leguminous and non-leguminous crops. According to Lal (1985) about 64 species of insects are known to attack this crop. Whitefly, *Bemisia tabaci* (Hemiptera: *Aleyrodidae*) is sucking type pest and both nymphs and adults of whitefly suck the cell sap, direct injury it also damages the crop indirectly as a vector transmitting a viral disease known as mung bean yellow mosaic virus (MYMV).[34]. The yellow mosaic virus disease of mung bean caused 30-70% yield loss, an annual loss of US $ 300 million, the virus affected plants have yellow and green specks or patches on the leaves of mungbean, black gram, soybean which finally turn entire yellow resulting affected plants bear fewer flowers and pods containing smaller and shrunken seeds thus affecting yields qualitatively and quantitatively. Reduction in number of pods/plants, seeds/pod and seed weight are the main contributing factors for yield reduction [33].

Whiteflies are small hemipterans pest in number more than 1,550 described species and about 50 are agricultural pests. Adults are free-living, first to fourth instars are sessile on the plant, whitefly species known parasitoids belong to Hymenoptera; two genera, *Encarsia* and *Eretmocerus*, occur worldwide. All parasitoid eggs are laid in—or in *Eretmocerus*, under—the host. They develop within whitefly nymphs and emerge from the fourth instar, and in *Cales*, from either the third or fourth instar. [23]. Geminiviruses are transmitted by the whitefly *Bemisia tabaci*, comprise a large and diverse family of viruses that infect a wide range of important monocotyledonous and dicotyledonous crop species and cause significant yield losses. They are belonging to the family Geminiviridae is divided into three genera (one of which is Begomovirus) and circulative manner and infect dicotyledonous plants. In review considers the most severe viral diseases of four major crops (tomato, bean, cassava and cotton), these viral diseases should provide a perspective of the issues involved in breeding for begomovirus resistance in crop plants. They are polyphagous and effectively feed on phloem sap using mouthparts modified into long, flexible stylets and whitefly attack by activating defense genes leading to production of toxic compounds on crop plants. Toxic substance reaches plant phloem and survive on host plants, whiteflies secret effectors in the saliva to regulate plant responses and activate detoxification system to with plant defenses. Whitefly transmitted viruses may exert substantial effects on host plants and the performance of whiteflies on host. Whiteflies choose a suitable host for colonization, pierce the plant cuticle and weave between mesophyll cells to find the phloem. These cause cellular damage, as they initiate a small number of probes into mesophyll cells only when in close proximity to the phloem. The plant cellwalls and plasma membranes, the disturbance of extracellular macromolecular structures while traveling toward the phloem, and the delivery of gelling and watery saliva and along the stylets' path introduce chemical signals called molecular patterns that trigger the basal plant defense its response known as pattern-triggered immunity (PTI) [29]. Two main whitefly pests in the Tropics are *B. tabaci*, *T. vaporariorum*. And other whitefly species investigated by the TWFP included *B. afer* and *Aleurotrachelus socialis. B. tabaci* is the main vector of plant viruses inducing African cassava mosaic disease, sweet potato virus disease, bean golden mosaic disease, and many other diseases of horticultural crops, mainly tomato, hot and sweet peppers, squash, melon, and several other cucurbits. Whitefly/virus epidemics were shown to be pesticide abuse the contributing most important factors and the use of virus-infected planting materials. Biological control is only effective on cropping pattern with minimal or rational use of insecticides and should be considered only as a complementary IPM strategy.

Beetles

Order: *Coleoptera*

Host- Wheat, Barley, Gram, Cotton, Vegetables (e.g., tomatoes, cucumbers, squash), Fruits (e.g., citrus, grapes)

Beetles are a diverse group of insect pests, found in various habitats, including agricultural fields in the semi-arid zone of Rajasthan, India, it can be significant pests of various crops. Stem borers (*Cerambycidae*) damage crops like wheat, barley, and gram by boring into their stems, Leaf beetles (*Chrysomelidae*) feed on leaves of crops like cotton, vegetables, and fruits, Seed beetles (*Bruchidae*) affacts seeds of crops like gram, wheat, and barley, Root beetles (*Curculionidae*) feed on roots of crops like cotton, vegetables, and fruits. Beetles front pair of wings are hardened into wing-cases, elytra. The *Coleoptera*, with about 400,000 described species, is the largest of all orders, constituting almost 40% of described insects and 25% of all known animal species. Dung beetles are important role in nitrogen cycling, enhancing plant development, secondary seed distribution, bioturbation and parasite control, The crucial coprophagous beetles belonging to *Scarabaeinae* subfamily that support ecosystems by consuming animal faeces both as adults and larvae. The *Coleoptera* order is the biggest group of organisms coleoptera includes around 3,50,000 out of 8,00,000 insect species that have been classified into four sub-orders and 177 families [44]. Dung beetle species under *Aphodiinae* and *Scarabaeidae* family and also known as dung chafers or tumble bugs. They use their heads and paddle shaped antennae to mould waste into a ball. Grazing animal type, pasture continuity, habitat type (forest or open pasture), soil type, and humidity all have an impact on dung beetle groups. Adults' species of dung beetle length from 0.3 to 4cm and are typically dark in colour, while some have a metallic colour. Dung beetles typically have spherical bodies and short wing covers (elytra) that show the end of the abdomen. The larval shape is cylindrical or C-shaped. The most species of the subfamilies *Melolothinae*, *Rutelinae*, *Cetoniinae*, and *Dynastinae* (Rhinoceros beetle) feed on plant products and agricultural pests of many cash crop. Many species eat manure or decaying plant matter, while others eat developing roots or leaves and a few fungi. The scarab species destroy turf grasses when they are in the larval stage; Milky grubs of larvae that eat root and damage artificial turf grasses [37]. Chafers (phytophagous beetles) are major pest of crop, plant and forest vegetation. The *Laparosticti* (agro dung beetles), play a decisive function in cleaning the faeces of mammals and cattle. The scarab family can either be helpful or dangerous in nature10 [3]. They are biological scavengers, cleaning away the soil climate from the excrement of large and medium-sized grazing animals by burying masses of faeces in the soil. The phytophagous scarab beetles usually serve as pests during their larval as well as their adult stage and their role in the ecosystem as well as their feeding behaviour in serving as pests to different crops, plants and fruits [47] The survey on pearl millet (*Pennisetum typhoides* [*P. glaucum*]) in 2002 abd 2003, chafer beetle (*R. indica*) undertaken in Sikar, Nagaur, Jhunjhunu and Churu districts of Rajasthan, India, during kharif on farmers field, infestation and the population of beetles varied from 1 to 10 per ear head. Johnsongrass (*Sorghum halepense*), maize, sorghum (*Sorghum bicolor*) and foxtail (*Cenchrus ciliaris*) were recorded as alternate hosts. The beetles were finding to feed on the flowers of saccharum (*Saccharum munja*) and tigergrass (*Saccharum spontaneum*) in October in the off season. Ground beetle (*Anthia sexguttata*), horse spider, small spider, web forming spider, owl (*Podargus strigoides*), lizard (*Lacerta viridis*), frog (*Rana tigrina*) and flying fox (*Pteropus edwardsii*) were natural enemies of the chafer beetle.[28] Beetles are morphometric intra specific variation and it arise on watermelon in bloom during April-May, 2019 with a mean population range of 1.5 to 10.0 beetles per plant.[26].

Rajasthan. Rajasthan state is very diverse due to its topography, Here Tal Chhapar Wildlife Sanctuary, Churu, is situated in the Thar desert region of Rajasthan. The diversity of any area is affected by the flora and fauna of that area. A most diversified class is Coleoptera which was collected there, and during the research period from January 2022 to October 2023, the Season of winter, summer, monsoon, and post-monsoon by Quadrat sampling method. Found total number of species Scarabaeidae was the supreme family (6 species) followed by *Cerambycidae* (3 species), *Carabidae*, (2 species), *Tenebrionidae*, *Coccinellidae*, *Elateridae*, and *Meloidae* with one species respectively. *Scarabaeidae* Family was found most dominant family, as it recorded 40% species followed by *Cerambycidae* with 20%, *Carabidae* with 13.4%, and remaining with 6.6% species each.[14]. Beetles across the globe, in numerous freshwater and terrestrial habitats, the Order Coleoptera is incredibly diverse in terms of species. Beetles have 3,50,000 described species, with around 15,088 species recorded from India.

Termites

Order- *Blattodea*

Infraorder- *Isoptera*

Family- *Termitoidae*

Host- Wheat, Barley, Gram, Cotton, Vegetables (e.g., tomatoes, cucumbers, squash), Fruits (e.g., citrus, grapes)

Termites are social insects that can be significant pests in the semi-arid zone of Rajasthan, India. Termites are a group of detritophagous eusocial insets which consume a variety of decaying plant material, generally in the form of wood, leaf litter and soil humus. Soft-bodied and often unpigmented worker caste commonly called "white ants''. About 2,972 extant species are currently described, 2,105 of which are members of the family Termitidae. Termites are the most dominant pest decomposers in the tropical forest's plants and tree, show high diversity and abundance. In tropical ecosystems, they play a key role in modifying the biotic and abiotic environment. The distribution of termites in India higher altitudes and extreme temperatures have restricted. In the north-eastern regions the termite's species are rich, compared to rest of India. About 35 species have been reported damaging agricultural crops and buildings out of the 337 species. *Odontotermes* is the major mound-builder, whereas *Coptotermes*, *Heterotermes*, *Microtermes*, *Microcerotermes* and *Trinervitermes* are the major subterranean genera occurring in India. The losses caused amount to several hundred million of rupees per year. Termites damage crops from sowing till harvest, and it is difficult to detect damage in the field. Usually, it is too late when the symptoms are noticed. In general, termite damage is seen more (20–25%) in rain-fed crops than irrigated ones (10%). Perennial crops are usually attacked during dry seasons and annual crops towards harvest time. Termite infestations have been reported in fruit crops, sugarcane,

cotton, paddy, maize, pearl millet, pulses, citrus, vegetables, spices, groundnut and potato in arid zones of India.

Odontotermes obesus (Rambur) and Microtermes obesi Holmgren damage crops in Rajasthan, India, and both vegetative and reproductive stages damage especially wheat, maize, barley, pulses, oilseeds, vegetables, fruits, plantations, sugarcane, cotton crops etc. The damage can lead to almost 100% yield losses, especially if it occurs in early stages of crop growth. Management if termites Over the past 60 years, many insecticides from several chemical groups have been used in crop yields [36]. Termites built most complex nesting systems. They change the ecosystems by their activities, and at the same time, they are dreaded pests on agriculture and man-made wooden structures. Due to their cryptic life, it is very difficult to manage them, use chemical insecticides on termites, their method of application is challenging but killing few thousand termite workers does not mean killing the colony; primary and secondary reproductive are alive and active deep inside the termite mounds, the termite problem scarely [4].

Swarming of termites is the most important sign of termite infestation in and around buildings/structures and termite damage in various buildings, public places, dams and dykes, agri-horticultural constructions and timber-in-service are presented. Indian Standards, Insecticide Act (1968) and United Nation Environment Program for management of termites in pre- and post-construction stages of various buildings and other structures are recorded with relevance of application and dose are recognized and recommended, use of termiticides. Here use the termite management technologies like use of borate, bait and barrier are briefed, with pest control industry, invented device such as a termatrac [24]. They are polymorphic eusocial and live in varied sized distinct colonies, various unique biological phenomena, like division of labour, nest architecture, caste system, swarming and colony formation, foraging behaviour and symbiosis with and specific microbes for digestion of lignin and cellulose in food. They are active pests with both positive and negative effects on the environment and management of termites have been approached with different strategies, such as cultural, mechanical, biological and chemical control measures. In NCBI GenBank, 21 species were identified; these included 5 species each from Odontotermes and Microcerotermes, 4 species from Coptotermes, 2 species each from Microtermes and Eremotermes, and one species each from Amitermes, Angulitermes, and Neotermes. External phenotype and related to reference sequences 16S rRNA gene sequences were utilized to made phylogenetic trees to explore the relatedness among identified species [30]. Termites to feed on hardly degradable polymers such as lignocellulose, the degradation of lignocelluose in the oxygen-limited hindgut paunch occurs in three steps: first a hydrolytic, second an oxidative/fermentative and, third, a methanogenic/acetogenic step. Cellulose and hemicellulose are degraded by bacteria, yeasts, and some members of flagellates. Higher termites degrade cellulose by own enzymes, because of the absence of symbiotic prostists and hemicellulose, they show considerable variation in their feeding behaviour, which is not limited to xylophagy [21].

Twelve termite species were present, with *Microtermes* sp. constituting 35% of the identified termite species. Termite feeding land-use types, wood-feeding termites were the most abundant while soil-feeders were rare in the agricultural field. The termite species richness and relative abundance between agricultural field and primary woodland, the pattern observed across may be potential support for the IDH suggesting that intermediate levels of physical disturbance intensity influence the structure and functioning of termite assemblages in semi-arid region [31]. Termites are among the most important agents of soil building, particularly termites like the fungus cultivating Macrotermes that build large mounds. Termites are keystone species in natural ecosystems and their role in the C cycle is potentially substantial, the pest, organic and inorganic C fractions, C stocks, and their correlation with each other, depth, and biogenic features in mounds, mound soils had significantly higher soil organic carbon (SOC) and inorganic carbon (SIC) than surrounding soils, there was no consistent relationship between SOC and SIC distributions throughout the mounds, which is likely related to solubility-linked translocations of carbonates. SOC was highest in top soils with a second clear peak in subsoils (>1 m) that was associated with biogenic features, termite channels and burrows [8]. Termites are also causing serious damages to pastureland in the semi-arid areas, threatening livestock production, by damaging crops, termites cause food insecurity and by damaging natural vegetation they cause denudation, accelerated erosion, and loss of biodiversity [10].

Conclusions

This review has made an effort to collect all the data currently available information on the status, abundance, and ecology of the major insects and provided valuable information for future investigation of semiarid region of Rajasthan. Insects appear to be crucial in maintaining ecological integrity in natural system, particularly through secondary seed dispersal and nutrient cycling. It is possible to effectively regulate the environmental correlations to success or failure potential and relate these parameters to ecological performance using trait-based attitudes. The studies primarily focus on insect abundance and diversity in semi-arid regions. In semi-arid areas, insect abundance and activity are strongly associated with climatic variables, particularly rainfall and humidity. The most abundant insects are Aphids, Grasshoppers, Thrips, Whiteflies, Beetle, Termites, Bollworms, Caterpillars, with most orders showing peak abundance during the favourable season such as winter, summer, rainy, autumn. This suggests that different insect groups may have varying responses to environmental conditions in semi-arid regions. In terms of functional groups, predators and phytophages tend to be the most abundant in semi-arid ecosystems, followed by saprophages, polyphages, and coprophages [5]. Farmer education and technical assistance are considered the most critical steps toward the implementation of sustainable and economically viable IPM strategies in tropical countries affected. Further research focused on Rajasthan's semi-arid zones would be necessary to draw more precise conclusions about the major insects in this specific area.

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