INFLUENCE OF NITROGENOUS FERTILIZER ON INCIDENCE OF PEST AND OTHER ARTHROPODS OF QUINOA

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INFLUENCE OF NITROGENOUS FERTILIZER ON INCIDENCE OF PEST AND OTHER ARTHROPODS OF QUINOA

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CERTIFICATE

This is to certify that thesis entitled **"INFLUENCE OF NITROGENOUS FERTILIZER ON INCIDENCE OF PEST AND OTHER ARTHROPODS OF QUINOA"** *submitted to the* ***Faculty of Agriculture,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) IN E[NTOMOLOGY****, embodies the result of a piece of bona fide research work carried out by* ***KANIZ FATEMA, Registration No. 13-05275*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June 2020
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DEDICATED
TO
MY BELOVED
PARENTS &
HUSBAND

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2018 to March, 2019 to evaluate the influence of nitrogen fertilizer on insect pest complex of quinoa. The experiment was laid out in Randomize Complete Block Design replicated with three times. For this study treatments were, T_1: 50 kg nitrogen fertilizer dose; T_2: 100 kg nitrogen fertilizer dose; T_3: 150 kg nitrogen fertilizer dose; T_4: 200 kg nitrogen fertilizer dose; T_5: 250 kg nitrogen fertilizer dose; T_6: untreated control. The lowest aphid, whitefly and jassid, stink bug, flea beetle, grasshopper, spider, housefly infestation (3.71, 2.70 and 3.36, 2.78, 3.78, 1.78, 1.55, 3.44 respectively) on quinoa was recorded in $T_{1.}$ The lowest percent leaf infestation and percent plant infestation (24.31% and 36.23%, respectively) by insect pests on quinoa was recorded in $T_{1.}$ The highest incidence of lady bird beetle per five tagged plants (3.34) on quinoa was recorded in T_5. Number of *Apis mellifera* per m^2 per minute at different day times was recorded highest in T_5 which comprised with 250 kg nitrogen fertilizer dose and low in T_1. Number of *Apis florea* per m^2 per minute at different day times was aslo recorded highest in T_5 which comprised with 250 kg nitrogen fertilizer dose and low in T_1. So, from this study it was concluded that, the higher amount of nitrogen fertilizer treated field was more susceptible for different insect pest. The highest plant height, panicle length, panicle diameter and 1000 seed weight (54.79 cm, 28.13 cm, 12.52 cm and 2.89 gm respectively) of quinoa was recorded in $T_{3.}$ The highest yield per hectare (1.11 ton/ha) of quinoa was recorded in $T_{3.}$ As a result, the order of efficacy of different fertilizer doses in terms of yield is $T_3>T_4>T_5>T_2>T_1>T_{6.}$ It can be concluded that T_3 may be the best dose for decreasing insect pests and increasing yield.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCPC	British Crop Production Council
CV	Coefficient of variation
$_{o}$C	Degree Celsius
d.f.	Degrees of freedom
et al.	And others
EC	Emulsifiable Concentrate
FAO	Food and Agriculture Organization
G	Gram
Ha	Hectare
IPM	Integrated Pest Management
CRSP	Collaborative Research Support Project
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
Mg	Milligram
Ml	Milliliter
MP	Muriate of Potash
%	Percent
RCBD	Randomize Complete Block Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
WP	Wettable Powder

CHAPTER I

INTRODUCTION

Quinoa, a super food which is one of the world's popular nutritive cereal crop. This is the common name for *Chenopodium quinoa* Willd, a flowering plant and its family is Amaranthaceae (Speher 1998). For Bangladesh, Quinoa is an emerging new agronomic crop which have huge possibilities of research in food sustainability as well as nutritive aspect. Recently, this crop has been released as a new variety called "SAU Quinoa 1" by Parimal Kanti Biswas, a Professor and researcher of the Department of Agronomy of Sher-e-Bangla Agricultural University. This massive success has already registered by the name of SAU Quinoa 1 under the unregistered crop variety registration procedure of national seed board (NSB). The registration number is 05 (46). The professor was the first researcher to introduce the Quinoa species experimentally in Bangladesh and also stated that it must be possible to cultivate this crop in Rabi season all over the country including saline and dry areas of coastal region.

Chenopodium quinoa is a whole grain which is dicotyledonous, about 1-2 m (3.3-6.6 ft) in height (Vaughn and Geissler 2000). This grain crop grown primarily for its edible seeds known as pseudo cereal rather than a true cereal and basically a taproot system crop which penetrating as deep as 1.5 m below the surface, thus protect against drought conditions with broad leaved. In inflorescence, its inflorescence size is 15 -70 cm in length and rising from the top of the plant and axils of lower leaves, usually standing about 1-2 m. Quinoa crop is mainly an achene (a seed-similar to fruit with a firm fur) with diversified colours of white or pale yellow to orange, red, brown and black. The seeds are small in diameter about 1-2.5 mm (Shams and Bhargava 2006).

Quinoa grains are rich in different nutrient content along with eight essential amino acid in higher concentration of lycine, isoleucine, methionine, histidine, cystine and glycine where the main protein content ranges from 7.47 to 22.08% and also contains about 6.3% fat and 64% carbohydrate. It"s protein digest ability is more than 80% (Repo-Carrasco Valencia *et. al.*, 2010). The immune function is enhancing by the exceptionally high levels of amino acids in quinoa aiding in the formation of antibodies, assisting in cell repair, calcium absorption and transport, involvement in the metabolism of fatty acids (Schlick and Bubenheim 1996) and even preventing cancer metastasis. This crop is a great source of phosphorus, potassium, B vitamins, flavonoids, riboflabins and folic acid as well compared to other grains like wheat or barly (Greg and David 1993). All these essential components are beneficial for human health as wall growth and development recently, a recognition was achieved by the FAO as a nutritious and resilient crop due to quinoa's potentiality. Later on, this immense success which was declared 2013 as the International Year of Quinoa (FAO 2013). Generally, these edible seeds are cooked as like as rice and can be used in a wide range of dishes. Plant leaves are also used as spinach. So for these extra ordinary criteria it acts as a complete meal for those who do not eat animal product. The main thing of quinoa is gluten free and is easy to digest. Naturally quinoa is high in anti-inflamatory phytonutrients with high in dietary fiber, having small amount of heart healthy omega-3 fatty acids which make it potentially beneficial for human health in the prevention and treatment of diseases (USDA nutrient database). Analyzing all these superior statements, the Food and Agriculture Organization of the United Nations (FAO) has considered quinoa to be the "grain of the future".

This edible starchy seed crop, Quinoa is originated from the Andean highlands of South America. Evidence shows that quinoa cultivation dates back to 5500 BC (Dillehay *et. al.*, 2007), and its center of origin is considered to be around Lake Titicaca. For this one of its variety known as "Titicaca‟ which named after it. For several years, it was treated as the main food of ancient cultures of the Andes. In Indo-Asia, a similar crop is quite popular and in Indian subcontinent the *Chenopodium album* species is called "bathua" and known as a weed species.

Though this crop have unique plant protection criteria in it, quinoa is attacked by several insect pest and diseases in many South American countries (Danielsen *et. al*., 2003). This is more susceptible to soil borne pathogens in comparison with other species specially seen in Columbia in the north through Ecuador, Peru and Bolivia to Chile in the south. During all stages of growth these pests and diseases attack all plant parts (Drimalkova and Veverka 2004).

For the research aspect, there are little subsequent experimental data was available to understand the quinoa responses to different fertilizers application specially various doses of nitrogen fertilizer application in the rate on its growth and yield as well as impact of fertilizer application on insect pest population. However, no research has done on its insect attack and yield reduction due to insect pest infestation like cutworm (noctuidae), whitefly, jassid, aphid, house fly,stink bug,flea beetle,grasshopper,spider,ant, arthropods, etc.

On the other hand, different doses of fertilizer effect on insect population attack, rodent attack in vegetative plus ripening phase and predation efficiency of ladybird beetle on aphid in this crop is not well known. Hence, the research objectives were based upon the criteria which as:

- To observe the pest species attacking of the quinoa variety.
- To determine the effect of nitrogenous fertilizer dose on insect infestation of quinoa.

CHAPTER II

REVIEW OF LITERATURE

2.1. QUINOA (*Chenopodium quinoa* Willd)

The genus *Chenopodium* (family Chenopodiaceae) comprises about 250 species (Giusti, 1970), which is almost covered Iherbaceous, suffrutescent and arborescent perennials, although most species are colonizing annuals (Wilson 1990). The *Chenopodium* spp. have been cultured for centuries as a leafy vegetable (*Chenopodium album*) as well as an important subsidiary grain crop (*Chenopodium quinoa* and *C. album*) for human and animal foodstuff due to high-protein and a balanced amino-acid spectrum (Bhargava *et. al*., 2003; Prakash and Pal 1998). *C. quinoa* Willd. is a native member of the subsection Cellulata of the genus *Chenopodium* (Bhargava 2007). This crop belongs to the group known as pseudocereals (Koziol 1993; Cusack, 1984) that includes other domesticated chenopods, amaranths and buckwheat. There are also revealed some remarkable agronomic characteristics in quinoa. It is highly tolerant to drought and soil salinity (Razzaghi, 2011). Additionally, some varieties can tolerate temperatures as low as -8°C for short periods (Jacobsen *et. al*., 2003). It can tolerate a wide range of soil conditions, subsisting off poor soil fertility and can withstand pH values ranging from 4.8 to 8.5 (Risi and Galwey 1984;Shams 2011;shams 2012).

2.2. History and current status

Quinoa crop was called „the mother grain‟ by the Incas and it was given a sacred status, a gift from their Gods. The Inca (ruling class) people since 5,000 B.C. was cultivated and worn the crop. The edible grain crop quinoa is revealed as a strength rations by North Americans and Europeans in the 1970‟s (Darwinkel 1997). In traditional range of cultivation stated as far north to Columbia and as far south to southern Chile. Because of its wide distribution, this crop is adapted to a wide range of environment, weather and forms a diverse range of ecotypes (Risi and Galwey 1984). For all these extreme advantages this super food can be considered as the most promising crop especially in poor new reclaimed rural area. With the time of Spanish arrival in the early 16th century, quinoa had reached its maximum range, played a crucial role in Incan agriculture. After the arrival of the Spaniards, its use, consumption and cultivation was almost eliminated and only remained in the farmers traditions. Following Spanish conquest, suppression of its growth happened and quinoa cultivation declined. Though in early days this crop production faces some problem due to socio economic aspect, its reputation is dramatically increased in recent years because it is gluten-free (helpful for diabetic patients) and high in protein. In South America, Bolivia is the largest manufacturer of quinoa in the world with 46 per cent of world manufacture. Peru is followed by in production aspect with 42 per cent and United States of America with 6.3 per cent (FAOSTAT 2013).Also this super food is cultivated in the USA (Colorado and California), South America, China, Europe, Canada, and India. Experimentally It is also cultivated in Finland and the UK. Meanwhile, it is an important crop by indigenous peoples, particularly in areas of marginal ground (Cusack 1984).). Due to its extensive range of cultivation in South America, *C. quinoa* as a species contains the genetic diversity needed to grow in a wide range of environments outside South America (Jacobsen 1999). International interest in quinoa began to rise in the late 1970s and 1980s when the first breeding programs were begun outside of South America. In Europe, programs were established in the UK, Denmark, and the Netherlands (Jacobsen 1994). In North America, efforts were begun in 1983 to grow quinoa in high altitude locations of Colorado through a partnership between Colorado State University and Sierra Blanca Associates (Johnson and Croissant, 1990). Additionally, private efforts to test and grow quinoa varieties in North America were begun by John Marcille in northern Washington state and Emigdio Ballon in northern New Mexico (Wilson and Manhart 1993; Ballon and Emigdio 1990).

Quinoa production expanded outside Colorado to Wyoming and Northern New Mexico (Ward, 2001). By the late 1980s, commercial efforts are taken to grow quinoa in Canada were underway (Small 1999; Tewari and Boyetchko 1990). Large scale production of quinoa in North America is currently centered in Saskatchewan throughout the Northern Quinoa Corporation and in the San Luis Valley of Colorado. However, in the face of efforts to cultivate quinoa in North America and other parts of the world, the majority of worldwide quinoa cultivation takes place in South America. In current years, there has been a large gap between supply of quinoa and growing demand for it. That’s leading to much high prices and negative social and environmental consequences in the principal quinoa producing countries (Jacobsen, 2011; Romero and Shahriari 2011). To ameliorate the current issues, cultivation of quinoa outside of South America could help in a great way which associated with rising production and exports of quinoa from its native range and increasing in Indo-asia region. In order to adapt and grow quinoa in various parts of the world various efforts are increasing day by day (Jacobsen 2003).

2.3. Effect of nitrogen fertilizer in quinoa

Nitrogen fertilizer that's an essential mineral nutrient required by plants for its development (Weisany, 1990). Generally, the effect of nitrogen fertilization on plant morphology and physiology is well documented (Gastal and Lemaire 2002). It is known that quinoa yield and metabolism respond strongly to nitrogen fertilization (Almadini *et. al.*, 2019; Bascuñan-Godoy *et. al*., 2018; Kakabouki *et. al*., 2014; Basra *et. al.*, 2014; Bilalis *et. al*., 2012; Schulte 2005; Berti *et. al*., 2000). However, little attention has been placed on the relationship between quinoa nitrogen fertilization and the production of saponin in the crop (Thanapornpoonpong 2004; Ionna, 2013; Gomaa, 2003; Geren, 2015). Meanwhile, nirogen fertilizer is an important element for quinoa because quinoa is high in protein content (Jacobsen and Christiansen, 2016). Basically, quinoa seed yields increase with an increasing nitrogen rate (Eisa and Abdel Ati, 2014; Schulte *et. al*., 2005) optimal nitrogen application rate reported by authors and locations varies widely. Like as: 120 kg ha^{-1} in Germany (Schulte *et. al*., 2005), 180 kg ha^{-1} in Denmark (Jacobsen and Christiansen 2016) and 310 kg ha^{-1} in Egypt (Eisa and Abdel Ati 2014). These state of being more or less can be understood by the large variations in soil fertility, varieties, and crop needs, as affected by water, nutrition supply, plant density, and other environmental constraints (Badr *et. al*., 2016; Van Gaelen *et. al*., 2015; Finck 1982; Erley *et al.,* 2005).

2.4. Insect pest and disease of quinoa (worldwide)

In Indian prespective, diseases and pests of quinoa has vast diversification. A variety of pathogens, which cause several diseases like mildews, damping off, blight, mosaic, etc. are occasionally seen in quinoa crop. It is known that the plant are infected by viruses, but reports of significant damage are absent. The most severe pathogen on quinoa is downy mildew and is known to cause yield reduction of 33–58%, even in the most resistant cultivars (Danielsen *et. al.*, 2000). To measure downy mildew severity on quinoa, Danielsen and Munk tested (2004) through seven disease-assessment methods and found the three-leaf model as the best to predict yield loss. Studies (Kumar *et. al.*, unpublished results) showed that the two-point assessment method (Jeger and ViljanenRollinson, 2001) was most suited for predicting yield loss in Indian conditions. In North-Indian conditions, quinoa showed high level of resistance towards downy mildew. In quinoa, insect pests attacking and causing damage ranging from 8 to 40% (Ortiz and Zanabria, 1979).Quinoa is also attacked by birds, primarily in the inflorescence stage. These state causes minor damage, as quinoa is conferred with a chemical defense in the form of saponins that confer.

Through the few past years, quinoa was introduced to Egypt. To detect and identify diseases, and insects attack quinoa in five different Egyptian governorates (Giza, Fayium, Ismailia, Beheira and Monufia). By examine different location, such detection was carried out in every 15 days and determine occurrence of diseases or pest (Azarpour *et al.*, 2014).In all previously mentioned governorates, data obtained showed that *Rhizoctonia solani* and *Macrophomena phaseolina* appeared as aggressive causal organism for root rot and damping off disease for young quinoa seedling. In all locations, *Peronospora farinosa f.sp. chenopodii* was detected and *Fusarium solani* was isolated only from samples were collected from Giza location (Fawy, 2015).During vegetative growth stage and before flowering or just after flowering, this disease are seen.

Insect‟s survey was also carried out in this locality. For obtaining the data, attacked plants were collected and transferred in ice box to laboratory for further identification. Two aphid species (*Myzus persicae* and *Aphis gossypii*, Hemiptera) were detected in all location showed by obtained data. In Ismailia governorate, two pests belong also to order Hemiptera were detected during vegetative growth and flowering stages. These two pests were identified as (*Nysius cymoids*) whereas the other was (*Creontiades pallidus*). Cotton mealy bug (*Phenacoccus solenopsis*), another hemiptera pest was detected only in Giza on individual plants at seed formation stage (Abou-Elhagag, 1998). A weevil belongs to Coleoptera (*Sitophilus granaries*) was detected during late flowering and grain formation stages (April- May), on few individual plants. *Atherigona theodori* which is a shoots feeder belongs to Diptera, was found in

Ismailia and Faiyum (Alfieri, 1976).By penetrate plant stem, this pest feed on inner stem content eventually causing wilt and collapse for infected plants. A Lepidopteran insect known as *Tuta absoluta* was also detected in Giza, Faiyum and Ismailia (Tawfik *et. al.,* 2015).This pest mainly attacks fresh green leaves. *Spodoptera exigua* which is Cotton leaf worm was detected in Faiyum on very few plants during early stages of growth (October).

Several insect pests have been reported for quinoa in its native range in South America. Here the most damaging of these pests is the quinoa moth *(Eurysacca melanocampta, E. quinoae*; Rasmussen *et. al*., 2003).

As quinoa continues to be grown in North America, it is likely that native pest will extend their host range in quinoa as well (Lavini *et al.,* 2014). In Europe, where two pests that normally feed on *C. album, Scrobipalpa atriplicella* and *Cassida nebulosa*, have begun to attack quinoa (Sigsgaard *et. al*., 2008; Oelke *et. al*., 1992) reports that insect pressure was not determined to be a significant factor for Colorado grown quinoa.

A wide range of insect pests are found on quinoa in Colorado found several years after the introduction of quinoa (Rojas *et al.*, 2003; Spehar,1998). A study pf pest pressure reported the major seedling infecting insects were found to be *Melanotrichus coagulatus* (Uhler) and the false cinch bug, *Nysius raphanus* Howard. Beet armyworm, *Spodoptera exigua* caused large scale defoliation. Another problematic foliar feeder was the boat gall aphid *Hayhurstia atriplicis* (L.). *Lygus* spp. were noted as problematic seed feeding pests and sugarbeet root aphid (*Pemphigus populivenae* Fitch) caused yield declines (Oelke *et. al*., 1992).A significant quinoa pest noted as flea beetles and aphids were found on quinoa grown in Minnesota (Darwinkel Stølen,1997).

Its noted that some overlap seen in the pests of beets and quinoa in Europe. Beet flea beetles (*Chaetocnema concinna* and *C. tibialis*) and beet carion beetles (*Aclypea opaca*) were found to feed on quinoa grown in sandy soil additionally, black bean beetle (*Aphis fabae*) was also reported as a pest likely causing decreases in yield. The major pest in Washington state is aphids and *Lygus* sp. have been tested in plots throughout the state since trials began in 2010. Aphid infested plants results in hardened honeydew particles which prove considerably difficult to clean from harvested quinoa seed. Moreover, *Lygus* sp. have been observed to take shelter in more compact inflorescences (unpublished data). Studying the potential of *Chenopodium* spp. weeds as alternate hosts of various insect as quinoa and other *Chenopodium* species share common pests.

In this research period, the following insects are mostly seen in research field. Those are:

2.5. Aphid:

Aphid**,** (family Aphididae), also called plant louse, greenfly etc. A group of sap-sucking, soft-bodied insects (order Homoptera) that are about the size of a pinhead, most species of which have a pair of tube ike projections (cornicles) on the abdomen. These are serious plant pests and may stunt plant growth, produce plant galls, transmit plant virus diseases and cause the deformation of leaves, buds, and flowers. Moreover, individuals within a species can vary widely in colour.

A. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Aphididae

Genus: *Aphis*

Specis: *A. fabae*

B. Origin and distribution

Aphids are distributed worldwide, but are most common in temperate zones. In contrast to many taxa, aphid species diversity is much lower in the tropics than in the temperate zones (Zyla *et. al*., 2017). They can migrate great distances, mainly through passive dispersal by riding on winds. For example, the currant lettuce aphid, *Nasonovia ribisnigri*, is believed to have spread from New Zealand to Tasmania in this way (Pip Courtney, 2005). Aphids have also been spread by human transportation of infested plant materials, making some species nearly cosmopolitan in their distribution (John *et. al*., 2009).

Winged aphids may also rise up in the day as high as 600m where they are transported by strong winds (Berry and Taylor, 1968; Isard *et. al*., 1990). For example, the currant-lettuce aphid, *Nasonovia ribisnigri*, is believed to have spread from New Zealand to Tasmania through easterly winds (Hill, 2012).

The black bean aphid may have originated in Europe and Asia, but it is now one of the most widely distributed species of aphids. It is found throughout temperate areas of Western Europe, Asia and North America and in the cooler parts of Africa, the Middle East, and South America (AphID, 2012). In the warmer parts of its range, apterous individuals can survive the winter and they may continue to reproduce asexually all year round (HYPP, 2013). It is known to be migratory (Johnson, 1963).

C. Host range

Aphid can feed on a wide variety of host plants. Its primary hosts on which the eggs overwinter are shrubs such as the spindle tree (*Euonymus europaeus*), *Viburnum* species, or the mock-orange (*Philadelphus* species). Its secondary hosts, on which it spends the summer, include a number of crops including sugar beets, cereal crops, spinach, beans, runner beans, celery, potatoes, sunflowers, carrots, artichokes, tobacco, and tomatoes. It colonize more than 200 different species of cultivated and wild plants. Among the latter, it shows a preference for poppies (*Papaver* species), burdock (*Arctium tomentonum*), fat-hen (*Chenopodium album*), saltbush (*Atriplex rosea*), chamomile (*Matricaria chamomilla*), thistles (*Cirsium arvense*) (Berim, 2009), and docks (*Rumex spp.*)

Two conflicting factors are involved in host preferences, the species and the age of the leaf. They are distributed spindle and beet leaves on growing plants throughout the year, winged aphids moved from one to the other depending on the active growth state of each and the senescence of each host plant. In late summer and autumn, the leaves were old and unattractive to the aphids in comparison with the leaves of the spindle, whereas in spring, the young unfolding leaves of the beet were more attractive than those of the spindle (Kennedy and Booth, 1951).

D. Life cycle

Aphid has both sexual and asexual generations in its life cycle. It also alternates hosts at different times of year. The primary host plants are woody shrubs and eggs are laid on these by winged females in the autumn. The adults then die and the eggs overwinter. The aphids that hatch from these eggs in the spring are wingless females known as stem mothers. These are able to reproduce asexually, giving birth to live offspring, nymphs, through parthenogenesis (Chinery and Michael, 1993). The lifespan of a parthenogenetic female is about 50 days and during this period, each can produce as many as 30 young (Berim, 2009). The offspring are also females and able to reproduce without mating, but further generations are usually winged forms. These migrate to their secondary host plants, completely different species that are typically herbaceous plants with soft, young growth (HYPP, 2013; Chinery and Michael, 1993; Berim, 2009).

Further parthenogenesis takes place on these new hosts on the undersides of leaves and on the growing tips. All the offspring are female at this time of year and large populations of aphids develop rapidly with both winged and wingless forms produced throughout the summer. Winged individuals develop as a response to overcrowding and they disperse to new host plants and other crops. By midsummer, the number of predators and parasites has built up and aphid populations cease to expand (RIR, 2013). As autumn approaches, the winged forms migrate back to the primary host plants. Here, both males and sexual females are produced parthogenetically, mating takes place and these females lay eggs in crevices and under lichens to complete the lifecycle. Each female can lay six to ten eggs which can survive temperatures as low as −32°C (−26°F) (HYPP, 2013; Chinery and Michael, 1993; Berim, 2009). More than 40% of the eggs probably survive the winter, but some are eaten by birds or flower bugs, and others fail to hatch in the spring (Way and Banks, 1964).

E. Nature of damage

Aphid is a major pest of sugar beet, bean and cereal crops, with large numbers of aphids cause stunting of the plants. Beans suffer damage to flowers and pods which may not develop properly. Early-sown crops may avoid significant damage if they have already flowered before the number of aphids builds up in the spring (RIR, 2013). Celery can be heavily infested. The plants are stunted by the removal of sap, the stems are distorted, harmful viruses are transmitted, and aphid residues may contaminate the crop (Godfrey and Trumble, 2009). As a result of infestation by this aphid, leaves of sugar beet become swollen, roll and cease developing. The roots grow poorly and the sugar content is reduced. In some other plants, the leaves do not become distorted, but growth is affected and flowers abort due to the action of the toxic saliva injected by the aphid to improve the flow of sap. (HYPP, 2013)

To obtain enough protein, aphids need to suck large volumes of sap. The excess sugary fluid, honeydew, is secreted by the aphids. It adheres to plants, where it promotes growth of sooty molds. These are unsightly, reduce the surface area of the plant available for photosynthesis and may reduce the value of the crop. These aphids are also the vectors of about 30 plant viruses, mostly of the non-persistent variety. The aphids may not be the original source of infection, but are instrumental in spreading the virus through the crop (RIR, 2013). Various chemical treatments are available to kill the aphids and organic growers can use a solution of soft soap (Godfrey and Trumble, 2009).

2.6. Whitefly

The whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) is a very complex species consists of at least 24 biotypes in tropical and sub-tropical region around the world (Ahmed *et. al*., 2009). *Bemisia tabaci* is a genetically different groups of insect that morphologically indistinguishable (Boykin *et. al*., 2007). Two predominantly aggressive biotypes, known as B and Q, are distributed everywhere around the world (Martinez-Carrillo and Brown, 2007) whereas, in Bangladesh yet B or Q biotype are absent but indigenous biotype BW_1 and BW_2 recorded recently (Jahan, 2012; Maruthi *et al.,* 2005; Rahman *et al.,* 2006). The *B. tabaci* is not genetically consistent. Based on mitochondrial DNA markers, the *B. tabaci* complex can be placed into five major groups according to their geographical origin: (1) New World (US, Mexico, Puerto Rico), (2) Southeast Asia (Thailand, Malaysia), (3) Mediterranean basin (Southwest Europe, North Africa, Middle East), (4) Indian subcontinent (Bangladesh, India, Myanmar, Nepal and Pakistan), (5) Equatorial Africa (Cameroon, Mozambique, Uganda, and Zambia) (Frohlich *et. al*.,1999).

a. Scientific classification:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Aleyrodoidea

Genus: *Bemisia*

Species*: B. tabaci*

b. Origin and distribution

Bemisia tabaci was described over 100 years ago and has since become one of the most important pests worldwide in subtropical and tropical agriculture as well as in greenhouse production systems. It adapts easily to new host plants and geographical regions and has now been reported from all global continents except the Antarctica. In 4.0 ha last decade, international transport of plant material and people have contributed to geographical spread of this pests. *Bemisia tabaci* has been recorded from more than 600 plant species (Oliveira *et. al*, 2001).

c. Host range

Bemisia tabaci is highly polyphagous. Although the genus *Bemisia* has a wide range of host plants (more than 500 species from 74 plant families), not all of them support large populations of whiteflies. Plants that do support large numbers of B biotype whiteflies include cotton, cabbage, different cereal crop, cucumber, squash, melon, watermelon, tomato, eggplant, sesame, soybean, okra, bean, peanut, and many ornamentals, including poinsettia, hibiscus, lantana, verbena, garden mum and gerber daisies, to name a few (Lapidot and Friedmann, 2002).

d. Life history

Egg: Adult whitefly females usually lay between 200 and 400 eggs. Eggs are pyriform or ovoid and possess a pedicel that is a peglike extension of the chorion.

Nymph: The eggs hatch, and the young whiteflies gradually increase in size through four nymphal stages called instars. The first nymphal stage (crawler) is rarely visible even with a hand lens. The crawler move around for several hours before settling to begin feeding. Later nymphal stages are immobile, oval, and flattened, with greatly reduced legs and antennae, like small scale insects.

Adult: Adult whiteflies are about 1/10 to 1/16 inch long and have four broad, delicate wings and are covered with a white powdery wax. The wings of *Bemisia tabaci* are held tent-like above the body and slightly apart, so that the yellow tinged body is more apparent. Adult females tend to lay eggs randomly, either singly or in scattered groups, usually on the under-surface of leaves, whereas the glasshouse whitefly usually lays its eggs in a semi-circle.

e. Nature of damage

Whiteflies suck phloem sap and large populations can cause leaves to yellow, appear dry, or to fall off of plants. Due to the excretion of honeydew plant leaves can become 5 sticky and covered with a black sooty mould. The honeydew attracts ants, which interfere with the activities of natural enemies that may control whiteflies and other pests. Feeding by the immature whiteflies can cause plant distortion, silvering of leaves and possibly serious losses in some vegetable crops. This devastating global insect pest caused damage directly by sucking the plant sap from phloem, indirectly by excreting honeydews that produce sooty mould, and by spreading 111 plant virus diseases.

f. Seasonal abundance

Bemisia tabaci appeared during first week of November with peak between February to March in Indian subcontinent. Its population reached the highest in the February to March (Rishikesh, 2015). Many researchers reported adult longevity, fecundity, and pre-imaginal developmental and survival rates. Finally, pre-imaginal survival of *Bemisia tabaci* varies inversely with relative humidity; it may be 2-80% in the range of 31-90% relative humidity.

2.7. Jassid

The insects belong to the family Cicadellidae are commonly known as leafhopper. These minute insects, collectively known as hoppers, are plant feeders that suck plant sap from grass, plants, shrubs, or trees. Their hind legs are modified for jumping and are covered with hairs that facilitate the spreading of a secretion over their bodies that acts as a water repellent and carrier of pheromones. They undergo a partial mand have various host associations. Some species have a cosmopolitan distribution, or occur throughout the temperate and tropical regions. Some are pests or vectors of plant viruses and phytoplasmas. The family is distributed all over the world, and constitutes the second-largest hemipteran family, with at least 20,000 described species**.**

a. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Subphylum: Hexapoda

Class: Insecta

Order: Hemiptera

Suborder: Auchenorrhyncha

Family: Cicadellidae

Genus: *Amrasca*

Species: *A. biguttula*

Other scientific name:

Austroasca lybica

Chlorita lybica

Chlorita signata

Empoasca benedettoi

Empoasca lybica

Empoasca signata

Jacobiasca signata

b. Origin and Distribution

Jassid is a versatile and widely distributed insect. It has been recorded in India, China, Pakistan, Iran, Bangladesh, Syria, Greece, Spain, Argentina, Brazil and USA. It is distributed widely throughout Africa. This pest is also common in Australia (Ghauri, 1963).

c. Host range

Apart from feeding criteria, jassids have a very wide range of host plants, including herbaceous cultivated plants and weeds, chiefly amongst the Malvaceae, Leguminosae and Solanaceae.

d. Seasonal abundance

Jassid is found in various cultivated plants grown in both rabi and kharif season. Jassid population remained below the economic threshold level up to 35 days of plant age in rabi crops. Highest number of jassids were found in 35 to 75 days old plants in kharif and 65 to 135 days old plants in the rabi season. Plants that grown in the kharif season was more vulnerable to insect attack than grown in the rabi season (Ali and Karim, 1991).

e. Life cycle

Egg: Curved, greenish-yellow eggs (0.7-0.9×0.15-0.2 mm) are laid deeply embedded in the midrib or a large vein on either surface of the leaf or in a petiole or young stem, but never in the leaf lamina. Depending on species, 29-60 eggs can be laid singly and they hatch in 4-11 days.

Nymph: Nymphs are pale green, wedge-shaped, 0.5-2.0 mm long, have a characteristic crab-like, sideways movement when disturbed. They are confined to the under surface of leaves during the daytime, but can be found anywhere on the leaves at night (Evans, 1965). The nymphal period can vary from 7 to 21 days depending on food supplies and temperature.

Adult: Adults are small, elongated, wedge-shaped, about 2.5 mm long, body pale green with semi-transparent, shimmering wings, very active, having a sideways walk like the nymphs, but quick to hop and fly when disturbed. They have a life span of up to 2 months.

f. Nature of damage

In Bangladesh concern, among all cotton jassid, *A. biguttula* is one of the key insect pests of cotton and is the major factor limiting cotton yield (El-Tom, 1987). This pest causes more than 50 percent reduction of seed cotton yield in some cotton genotypes (Bhat *et. al.*, 1984). Both nymphs and adults of this pest can attack leaves at all stages of development. Jassids, particularly the older nymphs, feeding on the small veins appear to affect the functioning of the vascular system so that the leaf edge changes color from dark to pale green, yellow and then red and brown. The whole leaf of susceptible varieties can desiccate and shed. The edges of leaves curl downwards if attacked leaves have not fully expanded. Growth of young plants may be completely stopped. They also introduce a toxin that impairs photosynthesis of cotton plants. In some monsoonal zones, jassids can also be a problem at the end of the season when older plants affected by jassids.

2.8. Stink bugs:

Stink bugs (Hemiptera: Pentatomidae) are one of the major economic pests of many agricultural crops .Meanwhile, frequently they are one of the most difficult pests to control in crops such as soybean,cotton tomato and many fruit crops.Among all green stink bug, mostly common which is native to North America .Others like brown stink bug,marmorated ,stink bug, onespotted stink bug, red household stink bug etc are also seen in agricultural field. Most of the tink bug is about 1.3–2.0 cm long and 0.8 cm wide.Usually bright green and may have a yellow border around the margin of the abdomen, head, and thorax (Underhill 1934). Adults of green stink bug can be indentified by black bands on the antenna and a pointed abdominal spine with a rounded abdominal spine (Miner 1966, McPherson and McPherson 2000).

a. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Pentatomidae

Genus: *Halyomorpha*

Specie: **:** *Halyomorpha halys*

b. Origin and distribution

At first,the green stink bug was described by Thomas Say as *Pentatoma hilaris* in 1832 (Say 1832). Due to frequent evaluations,its scientific name was changed several times and eventually it was changed to its current name, *Halyomorpha halys* (Parshley 1915 .The species of stink bugs that live in arid environments belongs to .genus *Acrosternum* The Entomological Society of America has published some historical evoluation of this insect (ESA 2012).The brown marmorated stink bug is an insect in the family Pentatomidae, native to China, Japan, and other Asian regions.

c. Host range

Stink bugs are polyphagous in nature and feeds on a variety of plants preferring woody plant tissue. For completing the life cycle and proper development, stink bugs typically requires a series of plants with overlapping periods of seed and fruit production (Underhill 1934).Woody hosts including basswood, *Tilia americana* L.; mulberry, *Morus* spp.; pear, *Pyrus* spp.; maple, *Acer* spp; American elder, *Sambucus canadensis* L.; and black locust, *Robinia pseudoacia* L.; yet it is a common pest of vegetable and field crops such as lima beans, *Phaseolus lunatus* L.; green beans, *Phaseolus vulgaris* L.; soybean, *Glycine max* (L.) ,tomato, *Solanum lycopersicum* L.; cotton, *Gossypium hirsutum* L.; eggplant, *Solanum melongena* L.; and cucumber, *Cucumis sativus* L. (Capinera 2001). They are also feeding on the herbaceous weeds goldenrod, *Solidago* spp.; ironweed, *Vernonia* spp.; horseweed, *Conyza* spp. and jimsonweed, *Datura stramonium* L.

d. Life cycle

After overwintering the stink bug appear as an adult. They mainly preferring to do so in leaf litter and deciduous woodlands (Underhill 1934).After emerging from diapause, adults are most active when temperatures exceed 24°C and are more prone to flight when temperatures exceed 27°C. Meanwhile, the adult females are not reproductively mature.Before reproductive state require a preovipositional period to develop (Nielsen and Hamilton 2009). Populations of first generation egg masses are found near the woods where adults have overwintered and continues to feed on weedy hosts . It is reported that the second generation remains in the cropping system throughout its life stages (Miner 1966). Females begin copulating after 22 days and lay their first egg masses about 3 week later and lay eggs in cluster. These eggs are barrel-shaped, changed from light green to yellow before hatching.After hatching, they undergo five instars before becoming adults (Underhill 1934, Miner 1966).

e. Nature of damage

Stink bug reveals as a serious pest of many fruit and fruiting vegetable crops.They are reported to feed on over 100 host plants, including tree fruit, vegetables, shade trees and leguminous crops in Asian countries (Simmons and Yeargan 1988). Due to this bug infestation, the crops most affected are apple, pear, peach, nectarine, lima bean, snap pea, pepper, sweet corn, tomato, field corn, and soybean.Besides these other identified crop hosts include raspberry, blueberry, grape, hazelnut, pecan, cucumber, and pole and bush bean. In its fourth and fifth inster stage they become vorasious feeder and also feed on fruit or seed pods of ornamental tree, shrub species, especially tree-of-heaven (*Ailanthus altissima*), princess tree (*Paulownia tomentosa*), Catalpa (*Catalpa* spp.), English holly (*Ilex aquifolium*), Southern magnolia (*Magnolia grandiflora*), redbud (*Cercis* spp.), and Chinese pistache (*Pistacia chinensis*).

f. Seasonal abundance

The seasonal abundance of stink bug, mostly common in the neotropical area, in overwintering sites in northern state is monitored from September to August.The breaking of dormancy (oligopause) condition is depending on the feeding activity and reproduction of adult bugs(Underhill 1934). Many researcher reported that no stink bugs were found in overwintering sites during the summer (December to February) and during early autumn (March). From mid-autumn to winter (April – August) the population of stink bug captured in these sites increased gradually and decreasing with the start of spring in September. Dormant and non-dormant bugs has fluctuating relative humidity (Simmons and Yeargan 1988) which is 65 ± 5% maintained at 25 ± 1 °C for their optimum survival rate.

2.9. House Fly:

Housefly is a medium size common insect, solitary creatures which is light to dark gray in color. They are about 5-7mm long.The females are usually larger than the male.the insect head has reddish-eyes and sponging mouthparts and thorax bears 4 narrow black stripes.In female, the abdomen is gray or yellowish with dark midline and irregular dark markings on the sides. There is a sharp upward bend in the fourth longitudinal wing vein. On the other hand, underside of the male is yellowish. Both sexes can be readily separated by noting but the space between the eyes, which in females is almost twice as broad as in male(Connor, 2006).

The body is divided into three parts:

Head: In head, a pair of compound eyes, a pair of antenna and a retractile proboscis present, which is adapted for sucking liquid food Female eyes are set apart widely while male eyes are closer together.

Thorax: Having 2-4 well developed dark longitudinal stripes, pair of wings and three pair of legs in thorax.With many short and stiff hair, legs and body are covered called tenent hairs which secretes a sticky substance.

Abdomen: It is 4 segmented and shows light and dark marking. When the fly lays her eggs. a tube like structure is extended from the abdomen in female.

Housefly habits make it suitable for the spread of disease. Mainly breeds in fresh horse manure, human excreta, garbage, decaying fruit and vegetables and attracted to food by its sense of smell. It cannot eat solid food, vomits on solid food to make a solution and then suck it in a liquid state. Thus it deposits countless bacteria on exposed food.

a. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Diptera

Family: Muscidae

Genus: *Musca*

Specie: *Musca domistica*

b. Origin and distribution

Probably the insect housefly having the widest distribution in the world. This common fly(Connor, 2006) originated on the steppes of central Asia.Now a days , their abundance occurs on all inhabited continents, in all climates from tropical to temperate and in a variety of environments ranging from rural to urban.They commonly associated with animal feces, but has adapted well to feeding on garbage, so it is abundant almost anywhere people live in (Gullan, 2010). In Arctic, as well as in the tropics, it is present in all populated parts of Europe, Asia, Africa, Australasia, and the Americas. Their reactions to light, temperature, humidity, and surface colour and texture is greatly influenced their distribution . Most of the houseflies spend the time outdoors or in covered areas near the open air.

c. Host range

Musca domestica, the common housefly, lives in close association with people all over the world as well as feed on human foodstuffs, wastes.For tis, they transport various disease agents.. In warmer climates, flies havig particular interest and considered important in the spread of eye infections (Gullan, 2010). Feeding on human foods, during which process they soften the food with saliva and deposit their feces, beed on it , creating a health hazard. Meanwhile, house fly attacks on dairy cows also (Lockwood, 2012).

d. Life cycle

The life cycle of housefly closely mirrors that of most insects. It begins with a cycle of an egg, then develops through a larva phase, a pupa phase, and finally into an adult (Connor, 2006). After a male housefly chases down and fertilizes a female counterpart, it's ready to lay her eggs.

Egg: The female housefly deposits her eggs in the crevices and corners of the same kinds of decaying organic matter adults feed on. The female lays about 120-150 eggs in one siting. Eggs are laid in horse manure and other decaying materials. They are creamy white in color and are about 1-2 mm in length. The fly lays from 600-900 eggs during her life time. The eggs hatch in 8-24 hours

Larva: At the anterior and posterior end of the body , there is a pair of spiracles are present. Larva is 12 segmented, white in color and about 1-2 mm in length and feed on decaying organic matters. The larval period about 2-7 days. After emerging from the eggs, they also known as maggots. These worm-like creatures are sectionless tubes with hooked mouth parts used for feeding. The maggots grow rapidly and will molt twice more, emerging larger and more developed each time.

Pupa: In their third molting, larvae skins will darken and harden as they enter the pupa stage.The pupal stage lasts from 3-6 days but in winter it may be prolonged.

Adult: Inside pupa protective shell , the larva will fully develop in body segments and appendages of an adult housefly. During summer, complete life cycle from egg to adult may take 5-6 days.

e. Nature of damage

Housefly,*Musca domestica* control is vital to human health and comfort in many areas of the world. The annoyance and the indirect damage produced by the potential transmission of pathogens (viruses, bacteria, fungi, protozoa, and nematodes) associated with this fly which is serious (Minnett *et. al.* 2007).They commonly develop in large numbers in poultry manure and this is a serious problem requiring control. Meanwhile pathogenic organisms are picked up by flies from garbage, sewage and other sources of filth, and then transferred on their mouthparts, through their vomitus, feces and contaminated external body parts to human and animal food . The movement of flies from animal or human feces to food that will be eaten uncooked by humans. At the meantime, when consumed by flies, some pathogens can be harbored in the mouthparts or alimentary canal for several days, and then be transmitted when flies defecate or regurgitate (Gullan *et. al.* 2010). In such situations, serious health problems can develop, especially if there are outdoor food markets, hospitals, or slaughter houses nearby (Service, M. 2008). Pathogens that commonly transmitted by house flies are *Salmonella, Shigella, Campylobacter, Escherichia, Enterococcus, Chlamydia*, and many other species that cause illness .These flies are most commonly linked to outbreaks of diarrhea and shigellosis, but also are implicated in transmission of food poisoning, typhoid fever, dysentery, tuberculosis, anthrax, ophthalmia, and parasitic worms.

f. Seasonal abundance

House flies mostly active from May to October in all years and showed population peaks in August and September (Hewitt, 2011). The abundance of house flies recoreded in southern Alberta, Canada from May to October..Their population abundance much lower than other flies populations and showed peaks in June, July, and September. Weekly changes in house fly abundance were not influenced by temperature and only weakly influenced by above 10 degrees C . House fly attacks on dairy cows occurred mainly from July through October. The weekly rate of changes were associated with emergence of an initial, overwintering generation followed by four generations produced throughout the summer.

2.10. Grasshopper

Grasshoppers (Orthoptera: Caelifera, Acridoidea) are an essential component of healthy and disturbed grassland ecosystems. These insects are abundant in natural and anthropogenic area. Th**ere** are Two Types of Grasshoppers:

a. Long-Horned Grasshoppers - having antennae about the same length as the body.

b. Short-Horned Grasshoppers - having Antennae less than half the length of the body. Often they called Locusts, particularly when migrates. They are the one's cause huge crop damage when they migrate in huge swarms in search of food, devouring virtually every green plant in their path.

Depending on the species, grasshoppers are medium to large insects and adult length is 1-7 cm.They have chewing mouthparts, two pairs of wings, one narrow and tough, the other wide and flexible and long hind legs for jumping. Usually they have large eyes In some species the males have bright colours on their wings that they use to attract females. This insect hears by means of a tympanal organ situated in the first segment of the abdomen, which is attached to the thorax. Most of the grasshoppers stridulate, which simply means that they rub their hind legs against their forewings to produce their trademark tunes.

a. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Orthoptera

Family: Acrididae

b. Origin and distribution

Grasshopper is probably the most ancient living group of chewing herbivorous insects, dating back to the early Triassic around 250 million years ago.The grasshoppers are found on all the continents except Antarctica. Around 12,500 species found worldwide, among them 1080 are found in North America. The findings about grasshopper evolution says in the family Acrididae points to an origin in South America, not Africa (Capinera, *et. al.* 2006). In North America the eastern lubber grasshopper are found is about 5–7 cm long and has large red wings bordered in black (Koli, 2010). The western lubber grasshopper which also called the buffalo grasshopper because of its size, has much smaller, pinkish wings. The slender grasshopper is found in the southern United States has clear wings. Most common and destructive grasshoppers of North America is *Melanoplus,* the largest short-horned grasshopper genus. These also include the Rocky Mountain grasshopper or locust, the migratory grasshopper the two-striped grasshopper and the red-legged grasshopper. *The* common grasshopper typically lives in moderately wet regions around Europe except north of the Arctic Circle, and it is distributed widely over Britain. Its range extends east as far as Siberia and Mongolia. Their preferred habitat consists of areas with longer grass.

c. Host range

Most grasshoppers are polyphagous and eating vegetation from multiple plant sources.Meanwhile, some are omnivorous and also eat animal tissue and animal faeces. But their preference is for grasses, including many cereals grown as crops. Migratory grasshoppers has destroyed areas of range grass and hay almost entirely.

d. Life cycle

By incomplete metamorphosis, grasshoppers develop which is a process that the larvae resembles the adults. There are three distinct stages: the egg, nymph, and the adult stage, or imago (Capinera, *et. al.* 2006).

Egg – Grasshopper life cycle starts from the egg stage. Female grasshoppers lays the fertilized eggs in the form of Egg Pods in mid summer. Each Egg Pod consists of about 10-300 eggs likely rice shaped and eggs remain dormant in autumn and winter seasons. By spring or early summer, the eggs hatch into Nymphs (offspring).

Nymph - The miniature versions of Adult grasshoppers is nymph. After hatching, the young nymphs start feeding on soft and succulent plant foliages. And undergo 5-6 moults, changing their form and structure, before becoming adults. Such moulting process is known as 'Incomplete Metamorphosis'. The nymphal Stage may last for 5-

10 days, based on the Species .When the nymphs moult, their size increases and wing pads progressively develop.

Adult - Wings are developed completely in thorax after 25-30 days and the nymphs mature into adults.

e. Nature of damage

After an early hatch, the grasshoppers may completely destroy newly germinated seedlings. This occurrence happens when the grasshoppers invade the crop from heavily infested stubble. When the crop is seeded in infested stubble, Grasshoppers may also hatch within the field of growing plants (Grzimek, 2004).For this situation, gradual defoliation occur through the growing season reduces yield and quality by depressing weight of the kernels. Defoliated plants become susceptible to head clipping by grasshoppers, further decreasing yield. Grasshoppers feed on green areas of the stem close to the head, causing the head to fall to the ground (Koli, 2010).The damage appears as round to ragged holes in the leaves due to their attack.. They consume the young plants to ground level. Feeding usually starts at field edges and migratory grasshopper or locust swarms devastate crops, causes major agricultural damage, which can lead to famine and starvation.

f. Seasonal abundance

During the day time, grasshoppers are most active but also feed at night. Most of the grasshoppers hatching from eggs in the spring and early summer. Many of them does not reach their full size until late summer or early fall. As eggs of different grasshopper species hatch out at different times (Kumar, *et. al.* 2015) so young grasshoppers can be seen throughout the spring and early summer. It is stated by many researcher that a single season of drought is not normally sufficient to stimulate a major population increase, but several successive dry seasons can do so.

2.11. Spider:

Almost all spiders are air-breathing arthropods, mainly they are arachnids, having eight legs, chelicerae with fangs generally able to inject venom and spinnerets that extrude silk. The largest order of arachnids is spider and rank seventh in total species diversity among all orders of organisms. More than 45,000 known species of spiders, found in habitats all over the world. A spider having a butt and can jump on demand. Cannibal spiders that look like pelicans. They ranges in size from the tiny Samoan moss spider, which is .011 inch long, to the massive Goliath bird eater, a tarantula with a leg span of almost a foot. As all spiders are predators, feeding almost entirely on other arthropods, especially insects. Some are active hunters that chase and overpower their prey. Having a well-developed sense of touch or sight to capture prey. To trap flying insects, webs are instinctively constructed and effectively many spiders inject venom into their prey to kill it quickly, whereas others first use silk wrappings.

a. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Arachnida

Order: Araneae; Clerck, 1757

Family: Pisauridae

Genus: *Achaearanea*

Specie**:** *Achaearanea tepidariorum*

b. Origin and distribution

About 400 million years ago spiders probably evolved fsrom thick-waisted arachnid ancestors that were not long emerged from life in water.(Banerji, *et. al.* 1993). Thin-waisted arachnids with abdominal segmentation and silk producing spinnerets, are known as first spider from plants.fossils like *Attercopus fimbriungus*. During the Devonian Period this spider lived 380 million years ago which was more than 150 million years before the dinosaurs. Common spiders are more or less seen in South America, but they're now recorded across most of southern Canada and almost around the world (Duffey, 1962). A few species of spider live on or near water and some mites are aquatic. Some small little arachnid are found only in well-protected habitats or niches.

c. Host range

In general,spider feed on small insects such as flies, mosquitoes, ants and wasps.Mostof the spider can randomly attack grasshoppers, butterflies, cockroaches or other spiders depending on their size. when the prey is too agile, the spider will try shooting web at it from a distance before pulling the thread toward itself (Hurd, *et. al.* 1992). Three spider species usually prey upon the host: the pirate spider genus *Mimetus* as well as two jumping spider species– *Phidippus variegatus* and *Metacyrba undata*. Assassin bug become prey of the adult spider.Most of the female eating green leafhopper.

d. Life cycle

From the tiniest jumping spider to the largest tarantula, have the same general life cycle. They mature in three stages: egg, spiderling, and adult (Tikader, 1987).

Egg, the Embryonic Stage:

Female spiders store sperm after mating until they are ready to produce eggs. First the mother spider constructs an egg sac and deposits her eggs inside it. Depending on the species a single egg sac may contain just a few eggs, or several hundred . Generally it takes a few weeks to hatch. In some species, the mother guards the egg sac from predators until the young hatch.

Spiderling, the Immature Stage:

The immature spiders, called spiderlings, which are resemble their parents but are considerably smaller when they first hatch from the egg sac. Immediately after hatching they disperse, some by walking and others by a behavior called ballooning.

The disperse spiderlings by ballooning will climb onto a twig or other projecting object and raise their abdomens and release threads of silk from their spinnerets, letting the silk catch the wind and carry them away. Until the new exoskeleton forms completely they will molt repeatedly as they grow larger. Most species reach adulthood after five to 10 molts.

Adult, the Sexually Mature Stage:

Adter the spider reaches in adulthood, become ready to mate and begins the life cycle all over again. In general case study, female spiders live longer than males; males often die after mating. Most of the spiders usually live just one to two years, though its vary by species.

e. Nature of damage

In general, common spiders has no major negative effect on humans. It is simply an annoyance in that its webs tend to collect dust and are unclean (Tanaka, 1989). They rarely bite people and even when they do, venom most species causes only moderate and short-lived effects. this incidence true for the vast majority of house spiders which have no incentive to bite anything they can't eat unless they think it's a matter of life or death.

f. Seasonal abundance

A sharp decrease in abundance of web-building spiders mainly seen in the dry season This aspect continuing into early wet season and population peaks in the late wet to early dry season and in mid wet season . On the other hand, there was a smaller increase in total numbers after the first rains at the end of the dry season (April), followed by a decrease at the beginning of the wet season (Tikader, 1987)

2.12. Flea Beetle

The flea beetle synonym is 'Leaf beetle' belongs to the Coleoptera: Chrysomelidae family. They are named for their ability to jump quickly when disturbed.

The adults are very small to moderate insect . They are similar to other leaf beetles but characteristically have the hind leg femora greatly enlarged. Such enlarged femora allows the springing action of these insects in disturbence. They can also walk normally and many of them are attractively colored; dark, shiny and often metallic colors predominate. Most of the adults feed externally on plants, eating the surface of the leaves, stems and petals.

a. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Chrysomelidae

Subfamily: Galerucinae Tribe: Alticini

Genus*: Phyllotreta*

Species: *P. striolata*

b. Origin and distribution

It has been thought that flea beetles to have been introduced from Eurasia and native to South America. In the United States crucifer flea beetle was first reported in 1923 (Bonnemaison, 1965) and in Aggasiz, BC in the early 1920's while the striped flea beetle is thought to have been introduced into the United States in the 1700s.

Now this insec is commonly found throughout the tropical and subtropical parts of the world.The richest flea beetle communities often associated with rivers or lakes . They introduce in open spaces near forests or scrublands and in various kinds of meadows and prairies. The striped flea beetle was reported from Carolina‖ in 1801 and is now widespread across Canada, United States, Mexico, and South America. In Hungary it is common in basswood and maple canopies (Van and Visser, 2007). Reseachers are stated that the flea beetles are widely distributed to Holarctic region, India, Nepal, Thailand, Cambodia, Vietnam, China, Taiwan, Indonesia, Japan, Korea etc.

a. Host range

Brassicaceae and Resedaceae are flea beetles mainly preferable plants which are grown in cultivated areas, roadsides, orchards and shrubs (Furth, 1979 and Nielsen 1988). In moist habitats the low density of Brassicaceae may be the reason for limited habitat occurrence of flea beetles.All of the plant families that produce mustard oil which is known as aggregation pheromone of the crucifer,flea beetle mostlty prefer them. The genus *Brassica* (Cruciferae), which include the major agricultural host attacked by flea beetle is the most preferred hosts. Mustard and crambe are also susceptible to flea beetle attack.

These beetles will also attack in the garden setting are cabbage, turnip, cauliflower, kale, Brussel sprouts, horseradish, and radish. Along with this host some weeds attacked in the cruciferous group are flixweed, field pennycress, peppergrass, and wild mustard (Nielsen 1988).

Flea beetles host ranges from many species of cultivated Brassicaceae, such as the radish ,edible rape , pak-choi or ching-geen mustard and cabbage.

b. Seasonal abundance

At the end of June to beginning of July, the emergence of the beetles of the new generation started and the most numerous catches were observed in July.where as at the end of August a remarkable reduction in the number of the *Phyllotreta sp.*, is seen due to the heavy rainfalls at the end of August. In Europe and North America, the majority of *Phyllotreta* usually have one generation in a year (Bonnemaison, 1965). The second generations of *Phyllotreta sp.* have been reported for Manitoba and Ontario, Canada and Massachusetts, Northeastern United States (Andersen *et al.*, 2005) in the end of the November.

It is reported by the researchers that the patterns of abundance of overwintering and summer generations of *Phyllotreta sp.* very similar, with summer generations being more numerous than overwintering ones. Such differences in the abundance of overwintering and summer generation flea beetles are seen mainly to several reasons. During emergence in the spring unfavourable weather conditions can influence the population size of the overwintering generation.it is a multivoltine cool season pest that occurs in vegetable fields from October to May.

CHAPTER III

MATERIAL AND METHODS

The experiment was conducted in the research field, Sher-e-Bangla Agricultural University, during rabi season, 1st week of November, 2018 to March, 2019 for the collection of diversified insect pest population as well to observe activity & efficiency of different pest species in quinoa crop. To know the incidence of different species of insect pest complexity under field condition, several data was collected in the performance of Quinoa on different fertilizer levels. The materials and methods those were used and followed for conducting the experiment mainly comprises a short description of the location of experimental site, soil and climatic condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure. The materials and methods and its detail report for this experiment have been presented below under the following headings:

3.1. Experimental period

The experiment was carried out during Rabi season .To study the field crop, it was cultivated at 1st week of November, 2018 to last week of Mach, 2019.

3.2. Experimental location

The experiment was conducted at the Central Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka and it was located in 23°77' N latitude and 90º26' E longitudes. According to the Bangladesh Meteorological Department, Agargaon, Dhaka-1207 the altitude of the location was 8 m from the sea level. In Appendix I the location has been shown.

Plate 1. Quinoa crop in SAU research filed

3.3. Climate condition

The climate of experimental site was under subtropical climate and characterized by three distinct seasons, the Rabi from November to February. The monthly average temperature, relative humidity and rainfall during the crop growing period were together from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix III.

3.4. Soil characteristics

For the experimental field, the soil type was Deep Red Brown Terrace soil and the soil belongs to the Tejgaon series under the Agro-ecological Zone, Madhupur Tract (AEZ-28). Before beginning of the experiment, combined sample of the experimental field was made by collecting soil from several spots of the field at a depth of 0-15 cm. The composition of soil was air-dried, grind and passed through 2 mm sieve and to evolve some important physical and chemical properties it was analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka. The soil was depreciating a texture of silty clay with pH 5.6 and organic matter 0.78%. The results of soil test submitted that the soil composed of 26% sand, 45% silt and 29% clay; details have been presented in Appendix II.

3.5. Materials used for experiment

Planting material used as Quinoa seed. Here one of the variety of quinoa name Titicaca is used as planting material for this study. The seed of Titicaca was collected by the supervisor personally.

3.6. Experimental design and layout

The experiment was conducted in consideration of **six** treatments and laid out in a Randomized Complete Block design. Each of the treatment was replicated three times. Field trials of the research were conducted during the winter season in the research field of Sher-e-Bangla Agricultural University Campus. The experimental area was 12.8 m x 17.5 m. The distance between plots and blocks were 0.5 m and 1.0 m respectively. Area of each plot was 1.4 m x 2.5 m (3.5 m^2)**.** The field for this experiment was divided into 3 blocks aiming to reduce the heterogeneity of the land, each block were sub divided into 6 plots.

3.7. Land preparation

On 6th November, 2018 the experimental field was first opened with the help of a power tiller and land preparation ended by three successive ploughings and crossploughings. To achieve a desirable fine tilth each plough was followed by laddering. At the meantime, visible larger clods were hammered to break into small pieces. All feasible types of weeds, stubbles and residues of previous crop were removed from the field. Immediately after final land preparation, quinoa seed was sowing in the main field according to design. Research plots were cleaned and finally leveled with the help of wooden plank.

Plate 2. Main field of the study

3.8. Fertilizes and manure application

Urea, Triple super phosphate (TSP) and Muriate of potash (MoP) were used in the experimental soil as a source of nitrogen (N), phosphorous (P) and potassium (K), respectively. TSP was applied at the rate of 50 kg ha^{-1}. MoP was applied at the rate of 50 kg ha^{-1}. All of the fertilizers of TSP and MoP along with one third urea were applied in final land preparation.

3.9. Sowing of seeds in the field

The seeds of Titicaca variety of quinoa were sown on 1st week of November 2018 on in solid rows in the furrows having a depth of 2-3 cm and row to row distance was 40 cm.

3.10. Treatments of the experiment

Treatments of the experiment comprised with the following fertilizers levels:

T_1= 50 kg urea ha^{-1}

T_2= 100 kg urea ha^{-1}

T_3= 150 kg urea ha^{-1}

T_4= 200 kg urea ha^{-1}

T_5= 250 kg urea ha^{-1}

T_6= Untreated control

3.11. Intercultural operations

Proper cultivation method was followed for the establishment of the quinoa research which started by seed sowing. After seedling initiation, all intercultural operations such as thinning, weeding, irrigation were accomplished as and when necessary for better growth and development of the crop.

3.11.1. Mulching

In 11 days after sowing, a natural mulching was done with breaking down the top soil on 14 November, 2018.

3.11.2. Thinning

To maintain the uniform population of quinoa for all plots thinning was done in a good manner.

3.11.3. Irrigation, drainage and weeding

Here plots were prepared with well-arranged drainage facilities. For the all experimental plots irrigation was equally applied before 10 and 30 DAS for optimizing the vegetative growth of Quinoa. But additionally supplementary irrigation was delivered just once before flower initiation. Adequate number of drain are also made for draining out excess irrigation water from the experimental plot. Weeding was done properly in the research field to keep the plots free from weeds. By hand weeding, the field was weeded at 10 DAS, 20 DAS and 35 DAS regularly. Meanwhile newly emerged weeds were uprooted carefully at flowering stage by mechanical means.

Plate 3. Watering the field

3.11.4. Crop sampling

Five plants were randomly selected from each treatment as well as marked with sample card. For correct sampling process, here Number of insect pests per five plants, number of leaves per five plants, number of infested leaves per five plants, plant height of five tagged plants, length of inflorescence per five plants, diameter of inflorescence per five plants, thousand seed weight and yield per plot were recorded at different stage of quinoa.

3.12. Insect pest complexity

A wide range of quinoa pests are known all over the world. Many insect pests have been reported for quinoa in its native range. As this is a new crop for Bangladesh, most of the quinoa pest and its insect population are remain unknown. Our research aims at to investigate the feasible insect pest of quinoa and observe their activity in crop vegetation.

Plate 4. Some insect pests in the field

3.12. Data collection

Data were recorded on the following parameters:

Insect pest:

- Total number of leaves per 5 tagged plants
- Number of infested leaves per 5 tagged plants
- Number of aphid per 5 tagged plants
- Number of whitefly per 5 tagged plants
- Number of jassid per 5 tagged plants

Other arthropods:

- Number of lady bird beetle per 5 tagged plants
- Number of honey bee per square meter per minute
- Number of flea beetle per 5 tagged plants
- Number of stink bug per 5 tagged plants

- Number of grasshopper per 5 tagged plants
- Number of spider per 5 tagged plants
- Number of housefly per 5 tagged plants
- Weight of 1000 seeds (g) per plot
- Total yield (kg)

Plate 5. Some beneficiary arthropod in the field-1

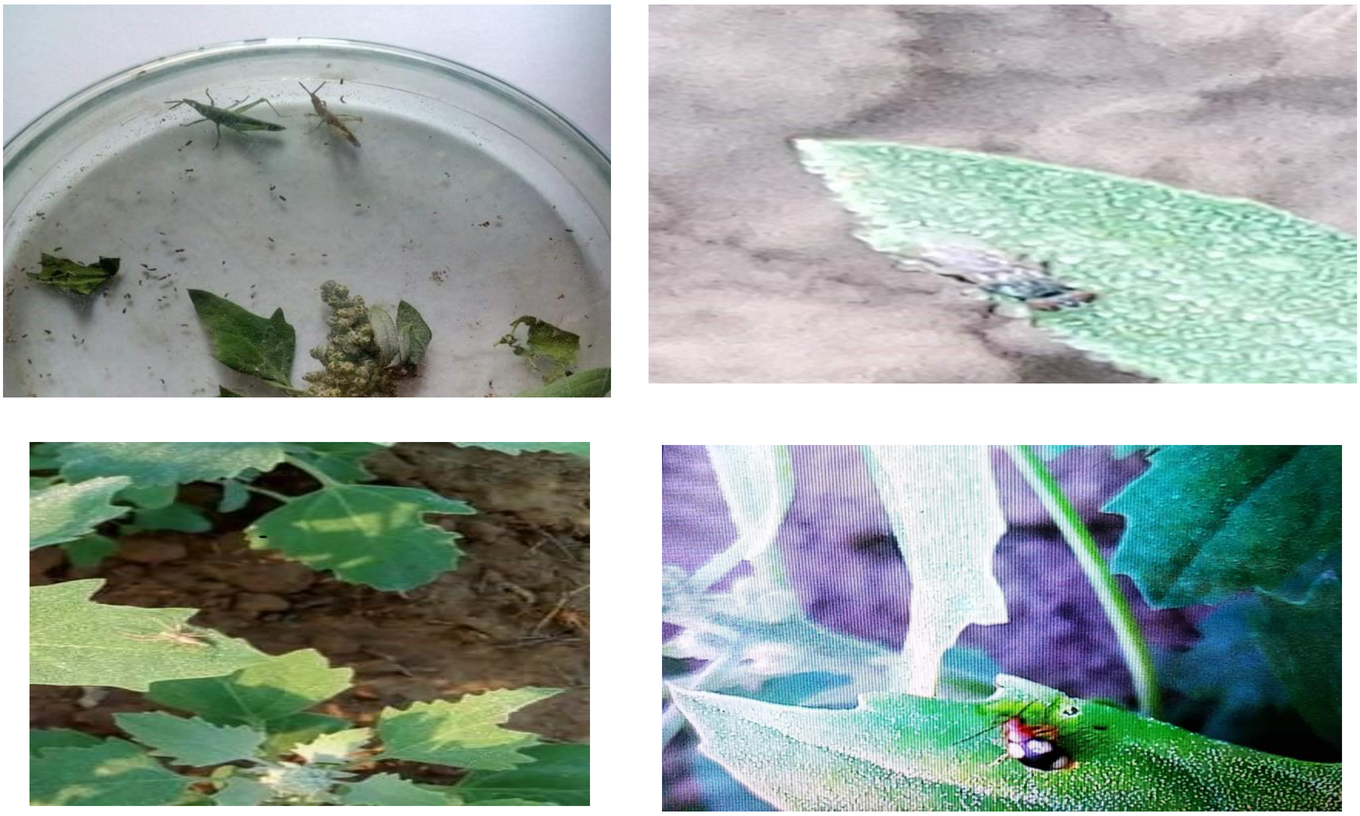

Plate 6. Some beneficiary arthropod in the field-2

3.13. Procedure of data collection

3.13.1. Number of leaves

During the maturity stage of quinoa plant total numbers of leaves from five tagged plants from each plot were recorded at 7 days interval in each treatment.

3.13.2. Number of infested leaves

During the maturity stage of quinoa plant total numbers of infested leaves from five tagged plants from each plot were recorded at 7 days interval in each treatment.

Plate 7. Infested leaf

3.13.3. Number of aphid

During the vegetative, flowering and fruiting stage of quinoa plant number of aphid from five tagged plants from each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.4. Number of whitefly

During the vegetative, flowering and fruiting stage of quinoa plant number of whitefly from five tagged plants from each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.5. Number of jassid

During the vegetative, flowering and fruiting stage of quinoa plant number of jassid from five tagged plants from each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.6. Number of lady bird beetle

During the vegetative, flowering and fruiting stage of quinoa plant number of lady bird beetle from five tagged plants from each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.7. Number of honey bee

During the vegetative, flowering and fruiting stage of quinoa plant number of honey bee from each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.8. Number of Flea beetle

During the vegetative, flowering and fruiting stage of quinoa plant number of flea beetle from each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.9. Number of stink bug

During the vegetative, flowering and fruiting stage of quinoa plant number of stick bug from each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.10. Number of Grasshopper

During the vegetative, flowering and fruiting stage of quinoa plant number grasshopper each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.11. Number of spider

During the vegetative, flowering and fruiting stage of quinoa plant number of spider from each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.12. Number of housefly

During the vegetative, flowering and fruiting stage of quinoa plant number of housefly from each plot were recorded through visual count at 7 days interval in each treatment. And data were recorded separately for analysis.

3.13.14. Weight of 1000 seed

From each plot seeds were harvested and packed separately with indicator. After that from each packet 1000 seed were counted and measured them by using digital balance and recorded the data.

3.13.15. Yield

For the estimation of yield per plot total seeds were collected and weight recorded, from each plot, at each time of data collection.

Plate 8. Harvested crop

3.14. Data calculation

3.14.1. Percent of leaf infestation

Percent of leaf infestation by number was calculated using the following formula:

$$\text{\% leaf infestation} = \frac{\text{No. of infested leaves}}{\text{Total no. of leaves}} \times 100$$

3.14.2. Percent of plant infestation

Percent of plant infestation by number was calculated using the following formula:

$$\text{\% plant infestation} = \frac{\text{No. of infested plants}}{\text{Total no. of observed plants}} \times 100$$

3.14.3. Percent reduction of flower bud infestation

Percent reduction/increase over control was calculated using the following formula:

$$\text{\% Reduction/increase over control} = \frac{x_2 - x_1}{x_2} \times 100$$

Where, x_1 = the mean value of the treated plot

x_2 = the mean value of the untreated plot

3.15. Statistical analysis of data

Analysis of variance was done with the help of computer package MSTAT program (Gomez and Gomez, 1976). The data recorded on different parameters were subjected to analysis of variance (ANOVA) and the means were compared according to Least Significant Difference (LSD) at 0.05% level of significance.

CHAPTER IV
RESULTS AND DISCUSSION

This chapter comprises the presentation and explanation of the results obtained from the experiment on the incidence of insect pests in quinoa. The data have been presented and discussed and possible interpretations are made under the following sub-headings:

4.1. Number of insect pests

4.1.1. Aphid

The effect of nitrogen fertilizer doses on incidence of aphid on quinoa has been shown in Table 1. Significant variations were observed among the nitrogen fertilizer doses in terms of number of aphid on quinoa. The highest number (6.24) of aphid per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (5.35) and T_4 (4.96). On the other hand, the lowest number (3.69) of aphid per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (3.94) and T_3 (4.37). More or less similar results were found in flowering stage and fruiting stage (Table 1).

In case of average number of aphid per five tagged plants, the highest number (6.35) of aphid per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (5.53) and T_4 (5.17). On the other hand, the lowest number (3.71) of aphid per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (4.22) and T_3 (4.38) (Table 1).

Considering the reduction of incidence of aphid per five tagged plants, the highest reduction (32.91%) of aphid incidence over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (23.69%), T_3 (20.80%) and T_4 (06.51%). whereas, the lowest value i.e. increase (14.83%) of aphid incidence over control was observed in $T_{5,}$ which was comprised of 250 kg nitrogen fertilizer dose (Table 1).

Table 1: Effect of different nitrogen fertilizer doses on the number of aphid per five tagged plants

Treatments	Number of aphid per five tagged plants				% decrease over control
	Vegetative stage	Flowering stage	Fruiting stage	Average	
T_1	3.69 f	3.74 e	3.69 d	3.71 e	32.91
T_2	3.94 e	4.36 d	4.36 c	4.22 d	23.69
T_3	4.37 d	4.39 d	4.37 c	4.38 d	20.80
T_4	4.96 c	5.27 c	5.28 b	5.17 c	06.51
T_5	6.24 a	6.59 a	6.24 a	6.35 a	-14.83
T_6	5.35 b	5.68 b	5.58 b	5.53 b	0
CV (%)	0.52	4.32	4.28	2.54	-
LSD (0.05)	0.05	0.37	0.36	0.21	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, $T_{2=}$ 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that the lowest aphid infestation (3.71) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of aphid incidence over control was 32.91%. As a result, the order of efficacy of different fertilizer doses in terms of aphid incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

4.1.2. Whitefly

The effect of nitrogen fertilizer doses on incidence of whitefly on quinoa has been shown in Table 2. Significant variations were observed among the nitrogen fertilizer doses in terms of number of whitefly on quinoa. The highest number (4.60) of whitefly per five tagged plants was recorded in T_5, which was statistically similar with T_6 (4.36) and followed by T_4 (3.67), T_3 (3.51) and T_2 (3.47). On the other hand, the lowest number (2.70) of whitefly per five tagged plants was recorded in T_1, which was significantly different from others. More or less similar results were found in flowering stage and fruiting stage of quinoa (Table 2).

In case of average number of whitefly per five tagged plants, the highest number (4.61) of whitefly per five tagged plants was recorded in T_5, which was statistically similar with T_6 (4.36) and followed by T_4 (3.70), T_3 (3.58) and T_2 (3.37). On the other hand, the lowest number (2.70) of whitefly per five tagged plants was recorded in T_1, which was significantly different from others (Table 2).

Considering the reduction of incidence of whitefly per five tagged plants, the highest reduction (38.07%) of whitefly incidence over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (26.90%), T_3 (17.89%) and T_4 (15.14%). whereas, the lowest value i.e. increase (5.73%) of whitefly incidence over control was observed in $T_{5,}$ which was comprised of 250 kg nitrogen fertilizer dose (Table 2).

Table 2: Effect of different nitrogen fertilizer doses on the number of whitefly per five tagged plants

Treatments	**Number of whitefly per five tagged plants**				**% decrease over control**
	Vegetative stage	**Flowering stage**	**Fruiting stage**	**Average**	
$\mathbf{T_1}$	2.70 c	2.66 c	2.74 d	2.70 c	38.07
$\mathbf{T_2}$	3.47 b	3.46 b	3.19 c	3.37 b	26.90
$\mathbf{T_3}$	3.51 b	3.69 b	3.55 bc	3.58 b	17.89
$\mathbf{T_4}$	3.67 b	3.70 b	3.73 b	3.70 b	15.14
$\mathbf{T_5}$	4.60 a	4.65 a	4.59 a	4.61 a	-05.73
$\mathbf{T_6}$	4.36 a	4.37 a	4.35 a	4.36 a	0
CV (%)	6.22	6.03	6.27	5.88	-
LSD (0.05)	0.40	0.39	0.40	0.37	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, $T_{2=}$ 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that the lowest infestation (2.70) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field. Where the highest reduction of whitefly per five tagged plants over control was 38.07%. As a result, the order of efficacy of different fertilizer doses in terms of whitefly incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

4.1.3. Jassid

The effect of nitrogen fertilizer doses on incidence of jassid on quinoa has been shown in Table 3. Significant variations were observed among the nitrogen fertilizer doses in terms of number of jassid on quinoa. The highest number (5.33) of jassid per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (4.52) and T_4 (4.48). On the other hand, the lowest number (3.37) of jassid per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (3.54) and

T_3 (3.67). More or less similar results were found in flowering stage and fruiting stage of quinoa (Table 3).

In case of average number of jassid per five tagged plants, the highest number (5.47) of jassid per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (4.64) and T_4 (4.47). On the other hand, the lowest number (3.36) of jassid per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (3.67) and T_3 (3.93) (Table 3). Considering the reduction of incidence of jassid per five tagged plants, the highest reduction (27.59%) of jassid incidence over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (20.91%), T_3 (15.30%) and T_4 (03.66%). Whereas, the lowest value i.e. increasing (17.89%) of jassid incidence over control was observed in T_5, which was comprised of 250 kg nitrogen fertilizer dose (Table 3).

Table 3: Effect of different nitrogen fertilizer doses on the number of jassid per five tagged plants

Treatments	**Number of jassid per five tagged plants**				**% decrease over control**
	Vegetative stage	**Flowering stage**	**Fruiting stage**	**Average**	
T_1	3.37 c	3.40 d	3.32 d	3.36 d	27.59
T_2	3.54 c	3.77 d	3.71 cd	3.67 c	20.91
T_3	3.67 c	4.31 c	3.79 c	3.93 c	15.30
T_4	4.48 b	4.42 bc	4.47 b	4.47 b	03.66
T_5	5.33 a	5.65 a	5.43 a	5.47 a	-17.89
T_6	4.52 b	4.74 b	4.71 b	4.64 b	0
CV (%)	5.75	5.34	5.63	4.15	-
LSD (0.05)	0.41	0.40	0.41	0.30	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, $T_{2=}$ 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that, the lowest infestation (3.36) of jassid per five tagged plants on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field. Where the highest reduction of jassid per five tagged plants over control was 27.59%. As a result, the order of efficacy of different fertilizer doses in terms of jassid incidence is $T_5 > T_6 > T_4 > T_3 > T_2 > T_1$.

4.1.4. Stink bug

The effect of nitrogen fertilizer doses on incidence of stink bug on quinoa has been shown in Table 4. Significant variations were observed among the nitrogen fertilizer doses in terms of number of stink bug on quinoa. The highest number (5.20) of sting bug per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (4.40) and T_4 (4.23). On the other hand, the lowest number (2.48) of sting bug per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (2.98) and T_3 (3.50). More or less similar results were found in flowering stage and fruiting stage (Table 4).

In case of average number of stink bug per five tagged plants, the highest number (5.38) of stink bug per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (4.45) and T_4 (4.36). On the other hand, the lowest number (2.78) of stink bug per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (3.08) and T_3 (3.61) (Table 4).

Considering the reduction of incidence of stink bug per five tagged plants, the highest reduction (37.60%) of stink bug incidence over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (30.76%), T_3 (18.80%) and T_4 (2.00%). whereas, the lowest value i.e. increase (-21.00%) of sting bug incidence over control was observed in T_5, which was comprised of 250 kg nitrogen fertilizer dose (Table 4).

Table 4. Effect of different nitrogen fertilizer doses on the number of stink bug per five tagged plants

Treatments	**Number of sting bug per five tagged plants**				% decrease over control
	Vegetative stage	Flowering stage	Fruiting stage	Average	
T_1	2.48 e	2.95 e	2.90 e	2.78	37.60
T_2	2.98d	3.16 d	3.10 d	3.08	30.76
T_3	3.50 c	3.69 c	3.64 c	3.61	18.80
T_4	4.23 b	4.44 b	4.40 b	4.36	2.00
T_5	5.20 a	5.50 a	5.45 a	5.38	-21.00
T_6	4.41 b	4.48 b	4.46 b	4.45	0.00
CV (%)	4.35	2.19	2.14	--	--
$LSD_{(0.05)}$	0.30	0.16	0.155	--	--

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, T_2= 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that the lowest stink bug infestation (2.78) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of stink bug incidence over control was 37.60%. As a result, the order of efficacy of different fertilizer doses in terms of stink bug incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

4.1.5. Flea beetle

The effect of nitrogen fertilizer doses on incidence of flea beetle on quinoa has been shown in Table 5. Significant variations were observed among the nitrogen fertilizer doses in terms of number of flea beetle on quinoa. The highest number (6.50) of flea beetle per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (5.48) and T_4 (5.44). On the other hand, the lowest number (3.94) of flea beetle per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (4.15) and T_3 (4.69). More or less similar results were found in flowering stage and fruiting stage (Table 5).

In case of average number of flea beetle per five tagged plants, the highest number (6.38) of flea beetle per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (5.45) and T_4 (5.36). On the other hand, the lowest number (3.78) of flea beetle per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (4.08) and T_3 (4.61) (Table 5).

Considering the reduction of incidence of flea beetle per five tagged plants, the highest reduction (30.64%) of flee beetle incidence over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (25.12%), T_3 (15.35%) and T_4 (1.63%). whereas, the lowest value i.e. increase (-17.15%) of flea beetle incidence over control was observed in T_5, which was comprised of 250 kg nitrogen fertilizer dose (Table 5).

Table 5. Effect of different nitrogen fertilizer doses on the number of flea beetle per five tagged plants

Treatments	**Number of flee beetle per five tagged plants**				% decrease over control
	Vegetative stage	Flowering stage	Fruiting stage	Average	
T_1	3.48 e	3.94 e	3.90 e	3.78	15.35
T_2	3.98 d	4.15 d	4.10 d	4.08	25.12
T_3	4.50 c	4.69 c	4.64 c	4.61	15.35
T_4	5.23 b	5.44 b	5.40 b	5.36	1.63
T_5	6.20 a	6.50 a	6.44 a	6.38	-17.15
T_6	5.41 b	5.48 b	5.46 b	5.45	0.00
CV (%)	3.45	1.76	1.71	--	--
$LSD_{(0.05)}$	0.30	0.16	0.16	--	--

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, T_2= 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that the lowest flea beetle infestation (3.78) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of flea beetle incidence over control was 30.64%. As a result, the order of efficacy of different fertilizer doses in terms of flea beetle incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

4.1.6. Grasshopper

The effect of nitrogen fertilizer doses on incidence of grasshopper on quinoa has been shown in Table 6. Significant variations were observed among the nitrogen fertilizer doses in terms of number of grasshopper on quinoa. The highest number (4.20) of grasshopper per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (3.40) and T_4 (3.23). On the other hand, the lowest number (1.48) of grasshopper per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (1.98) and T_3 (2.50). More or less similar results were found in flowering stage and fruiting stage (Table 6).

In case of average number of grasshopper per five tagged plants, the highest number (4.39) of grass hopper per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (3.41) and T_4 (3.36). On the other hand, the lowest number (1.78) of grasshopper per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (2.08) and T_3 (2.61) (Table 6). Considering the reduction of incidence of grasshopper per five tagged plants, the highest reduction (47.83%) of grasshopper incidence over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (38.89%), T_3 (23.26%) and T_4 (1.31%). whereas, the lowest value i.e. increase (-28.78%) of grass hopper incidence over control was observed in T_5, which was comprised of 250 kg nitrogen fertilizer dose (Table 6).

Table 6. Effect of different nitrogen fertilizer doses on the number of grasshopper per five tagged plants

Treatments	**Number of grasshopper per five tagged plants**				% decrease over control
	Vegetative stage	Flowering stage	Fruiting stage	Average	
T_1	1.48 e	1.97 e	1.90 e	1.78	47.83
T_2	1.98 d	2.15 d	2.10 d	2.08	38.89
T_3	2.50 c	2.69 c	2.66 c	2.61	23.26
T_4	3.23 b	3.44 b	3.41 b	3.36	1.31
T_5	4.20 a	4.51 a	4.47 a	4.39	-28.78
T_6	3.40 b	3.35 b	3.46 b	3.41	0.00
CV (%)	5.91	3.19	2.85	--	--
LSD $_{(0.05)}$	0.30	0.18	0.16	--	--

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, T_2= 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that the lowest grasshopper infestation (1.78) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of grasshopper incidence over control was 47.83%. As a result, the order of efficacy of different fertilizer doses in terms of grasshopper incidence is T_5>T_6>T_4>T_3>T_2>T_1.

4.1.7. Spider

The effect of nitrogen fertilizer doses on incidence of spider on quinoa has been shown in Table 7. Significant variations were observed among the nitrogen fertilizer doses in terms of number of spider on quinoa. The highest number (4.11) of spider per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (3.30) and T_4 (3.14). On the other hand, the lowest number (1.27) of spider per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (1.79) and T_3 (2.29). More or less similar results were found in flowering stage and fruiting stage (Table 7).

In case of average number of spider per five tagged plants, the highest number (4.25) of spider per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (3.39) and T_4 (3.26). On the other hand, the lowest number (1.55) of spider per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (1.96) and T_3 (2.48) (Table 7).

Considering the reduction of incidence of spider per five tagged plants, the highest reduction (54.21%) of spider incidence over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (42.22%), T_3 (26.81%) and T_4 (3.83%). whereas, the lowest value i.e. increase (-25.47%) of spider incidence over control was observed in T_5, which was comprised of 250 kg nitrogen fertilizer dose (Table 7).

Table 7. Effect of different nitrogen fertilizer doses on the number of spider per five tagged plants

Treatments	**Number of spider per five tagged plants**				% decrease over control
	Vegetative stage	Flowering stage	Fruiting stage	Average	
T_1	1.27 e	1.48 e	1.90 e	1.55	54.21
T_2	1.79 d	1.98 d	2.10 d	1.96	42.22
T_3	2.29 c	2.50 c	2.67 c	2.48	26.81
T_4	3.14 b	3.23 b	3.47 b	3.26	3.83
T_5	4.11 a	4.20 a	4.47 a	4.25	-25.47
T_6	3.30 b	3.40 b	3.46 b	3.39	0.00
CV (%)	5.69	5.91	2.85	--	--
$LSD_{(0.05)}$	0.27	0.30	0.16	--	--

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, T_2= 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that the lowest spider infestation (1.55) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of spider incidence over control was 54.21%. As a result, the order of efficacy of different fertilizer doses in terms of spider incidence is T_5>T_6>T_4>T_3>T_2>T_1.

4.1.8. House fly

The effect of nitrogen fertilizer doses on incidence of house fly on quinoa has been shown in Table 8. Significant variations were observed among the nitrogen fertilizer doses in terms of number of house fly on quinoa. The highest number (5.20) of house fly per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (4.47) and T_4 (4.23). On the other hand, the lowest number (2.48) of house fly per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (2.98) and T_3 (3.50). More or less similar results were found in flowering stage and fruiting stage (Table 8).

In case of average number of house fly per five tagged plants, the highest number (6.05) of house fly per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (5.12) and T_4 (5.03). On the other hand, the lowest number (3.44) of house fly per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (3.75) and T_3 (4.28) (Table 8). Considering the reduction of incidence of house fly per five tagged plants, the highest reduction (32.70%) of house fly incidence over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (26.75%), T_3 (16.35%) and T_4 (1.74%). whereas, the lowest value i.e. increase (-18/.26%) of house fly incidence over control was observed in T_5, which was comprised of 250 kg nitrogen fertilizer dose (Table 8).

Table 8. Effect of different nitrogen fertilizer doses on the number of house fly per five tagged plants

Treatments	Number of house fly per five tagged plants				% decrease over control
	Vegetative stage	Flowering stage	Fruiting stage	Average	
T_1	2.48 e	3.97 e	3.90 e	3.44	32.70
T_2	2.98 d	4.17 d	4.10 d	3.75	26.75
T_3	3.50 c	4.69 c	4.67 c	4.28	16.35
T_4	4.23 b	5.44 b	5.47 b	5.03	1.74
T_5	5.20 a	6.57 a	6.47 a	6.05	-18.26
T_6	4.47 b	5.48 b	5.46 b	5.12	0.00
CV (%)	4.35	1.76	1.71	--	--
LSD $_{(0.05)}$	0.30	0.16	0.16	--	--

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, T_2= 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that the lowest house fly infestation (3.44) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of house fly incidence over control was 32.70%. As a result, the order of efficacy of different fertilizer doses in terms of house fly incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

4.1.9. Leaf infestation by insect pests

The effect of nitrogen fertilizer doses on the number of total leaves of quinoa has been shown in Table 11. Significant variations were observed among the nitrogen fertilizer doses in terms of total number of leaves of quinoa. The highest number (56.66) of leaves per plant was recorded in T_5, which was significantly different from others and followed by T_4 (53.45) and T_3 (52.32). On the other hand, the lowest number (42.78) of leaves per plant was recorded in T_6, which was significantly different from others and followed by T_1 (48.37) and T_2 (50.34) (Table 11).

The effect of nitrogen fertilizer doses on the number of infested leaves of quinoa has been shown in Table 11. Significant variations were observed among the nitrogen fertilizer doses in terms of infested number of leaves of quinoa. The highest number (27.82) of leaves per plant was recorded in T_5, which was significantly different from others and followed by T_6 (21.65), T_4 (20.66) and T_3 (20.47). On the other hand, the lowest number (11.76) of leaves per plant was recorded in T_1, which was significantly different from others and followed by T_2 (17.77) and T_3 (20.47) (Table 4).

In case of percent leaf infestation, the highest leaf infestation (50.61%) was found in $T_{6,}$ which was statistically similar with T_5 (49.10%) and followed by T_4 (38.65%) and T_3 (39.13%). On the other hand, the lowest leaf infestation (24.31%) was found in $T_{1,}$ which was significantly different from others and followed by T_2 (35.30%) (Table 11). Considering the reduction of leaf infestation by insect pests of quinoa per plant, the highest reduction (51.97%) of leaf infestation over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (30.25%), T_3 (23.63%) and T_4 (22.68%). Whereas, the lowest reduction (02.98%) of leaf infestation over control was observed in $T_{5,}$ which was comprised of 250 kg nitrogen fertilizer dose (Table 11).

Table 9: Effect of different nitrogen fertilizer doses on the leaf infestation by insect pests of quinoa per plant

Treatments	Total leaf number	Infested leaf number	% leaf infestation	% decrease over control
T_1	48.37 e	11.76 e	24.31 d	51.97
T_2	50.34 d	17.77 d	35.30 c	30.25
T_3	52.32 c	20.47 c	39.13 b	22.68
T_4	53.45 b	20.66 c	38.65 b	23.63
T_5	56.66 a	27.82 a	49.10 a	02.98
T_6	42.78 f	21.65 b	50.61 a	0
CV (%)	0.49	1.47	1.59	-
LSD (0.05)	0.43	0.48	1.05	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, $T_{2=}$ 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that, the lowest percent leaf infestation (24.31%) by insect pests per plant on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field. Whereas, the highest leaf infestation (50.61%) by insect pests per plant on quinoa was recorded in T_6 which was comprised of untreated control. As a result, the order of efficacy of different fertilizer doses in terms of percent leaf infestation by insect pests of quinoa per plant is T_6>T_5>T_4>T_3>T_2>T_1.

4.1.10. Plant infestation by insect pests

There was no statistically variance among the observed plant number of quinoa. The effect of nitrogen fertilizer doses on the number of infested plants of quinoa has been shown in Table 12. Significant variations were observed among the nitrogen fertilizer doses in terms of infested plant number of quinoa. The highest number (8.25) of plants per ten observed plants was recorded in T_6, which was significantly different from others and followed by T_5 (6.75) and T_4 (6.13). On the other hand, the lowest number (3.62) of plants per ten observed plants was recorded in T_1, which was significantly different from others and followed by T_2 (4.99) and T_3 (5.68) (Table 12).

In case of percent plant infestation, the highest plant infestation (82.46%) was found in $T_{6,}$ which was significantly different from others and followed by T_5 (67.45%) and T_4 (61.28%). On the other hand, the lowest plant infestation (36.23%) was found in $T_{1,}$ which was significantly different from others and followed by T_2 (49.87%) and T_3 (56.76%) (Table 12).

Considering the reduction of plant infestation by insect pests of quinoa per ten plants, the highest reduction (56.06%) of plant infestation over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (39.52%), T_3 (31.17%) and T_4 (25.69%). Whereas, the lowest reduction (18.20%) of plant infestation over control was observed in $T_{5,}$ which was comprised of 250 kg nitrogen fertilizer dose (Table 12).

Table 10: Effect of different nitrogen fertilizer doses on the plant infestation by insect pests of quinoa per ten plants

Treatments	**Number of plant observed**	**Infested plant number**	**% plant infestation**	**% decrease over control**
T_1	10	3.62 e	36.23 f	56.06
T_2	10	4.99 d	49.87 e	39.52
T_3	10	5.68 c	56.76 d	31.17
T_4	10	6.13 b	61.28 c	25.69
T_5	10	6.75 b	67.45 b	18.20
T_6	10	8.25 a	82.46 a	0.00
CV (%)	-	1.17	1.72	-
LSD (0.05)	-	0.32	0.45	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, $T_{2=}$ 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that, the lowest percent plant infestation (36.23%) by insect pests per ten plants on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field. Whereas, the highest plant infestation (82.46%) by insect pests per plant on quinoa was recorded in T_6 which was comprised of untreated control. As a result, the order of efficacy of different fertilizer doses in terms of percent plant infestation by insect pests of quinoa per plant is $T_6>T_5>T_4>T_3>T_2>T_1$

4.2. Number of beneficial insects

4.2.1. Lady bird beetle

The effect of nitrogen fertilizer doses on incidence of lady bird beetle on quinoa has been shown in Table 13. Significant variations were observed among the nitrogen fertilizer doses in terms of number of lady bird beetle on quinoa. In case of vegetative stage, the highest number (3.24) of lady bird beetle per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (2.72) and T_4 (2.64). On the other hand, the lowest number (1.50) of lady bird beetle per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (8.81) and T_3 (2.24). More or less similar results were found in flowering stage and fruiting stage of quinoa (Table 13).

In case of average number of lady bird beetle per five tagged plants, the highest number (3.34) of lady bird beetle per five tagged plants was recorded in T_5, which was significantly different from others and followed by T_6 (2.92) and T_4 (2.67). On the other hand, the lowest number (1.61) of lady bird beetle per five tagged plants was recorded in T_1, which was significantly different from others and followed by T_2 (2.00) and T_3 (2.50) (Table 13).

Considering the reduction of incidence of lady bird beetle per five tagged plants, the highest reduction (44.86%) of lady bird beetle over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (31.51%), T_3 (14.38%) and T_4 (08.56%). Whereas, the lowest value i.e. increasing (14.38%) of lady bird beetle over control was observed in $T_{5,}$ which was comprised of 250 kg nitrogen fertilizer dose (Table 13).

Table 11: Effect of different nitrogen fertilizer doses on the number of lady bird beetle per five tagged plants

Treatments	Number of lady bird beetle per five tagged plants				% decrease over control
	Vegetative stage	Flowering stage	Fruiting stage	Average	
T_1	1.50 e	1.66 c	1.69 c	1.61 e	44.86
T_2	1.81 de	1.96 c	2.25 b	2.00 d	31.51
T_3	2.24 cd	2.56 b	2.69 b	2.50 c	14.38
T_4	2.64 bc	2.59 b	2.72 b	2.67 c	08.56
T_5	3.24 a	3.43 a	3.37 a	3.34 a	-14.38

T_6	2.72 b	2.81 b	3.30 a	2.92 b	0
CV (%)	11.06	8.89	10.49	4.17	-
LSD (0.05)	0.45	0.38	0.48	0.18	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, T_2= 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that, the highest incidence (3.34) of lady bird beetle per five tagged plants on quinoa was recorded in T_5 which was comprised of 250 kg nitrogen fertilizer dose in the field. Where the lowest incidence of lady bird beetle per five tagged plants was 1.61 in T_1. As a result, the order of efficacy of different fertilizer doses in terms of lady bird beetle incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

honey bee per five tagged plants, the highest reduction (45.59%) of honey bee over control was observed in T_1 which was comprised of 50 kg nitrogen fertilizer dose, followed by T_2 (32.84%), T_3 (30.39%) and T_4 (24.02%). Whereas, the lowest value i.e. increasing (1.96%) of honey bee over control was observed in T_5, which was comprised of 250 kg nitrogen fertilizer dose (Table 14).

4.2.1. Honey bee

4.2.1.1. *Apis mellifera*

At 9.30 AM, the effect of nitrogen fertilizer doses on incidence of *Apis mellifera* on quinoa has been shown in Table 9. Significant variations were observed among the nitrogen fertilizer doses in terms of number of *Apis mellifera* on quinoa. The highest number (3.82) of *Apis mellifera* per m^2 per minute was recorded in T_5, which was significantly different from others and followed by T_6 (3.30) and T_4 (3.14). On the other hand, the lowest number (1.47) of *Apis mellifera per* m^2 per minute was recorded in T_1, which was significantly different from others and followed by T_2 (1.79) and T_3 (2.29). More or less similar trend results were found in 10.30 AM, 11.30 AM, 12.30 PM, 1.30 PM, 2.30 PM, 3.30 PM (Table 9).

At 4.30 PM ,The highest number (1.43) of *Apis mellifera* per m^2 per minute was recorded in T_5, which was significantly different from others and followed by T_6 (1.37) and T_4 (1.32). On the other hand, the lowest number (1.08) of *Apis mellifera per* m^2 per minute was recorded in T_1, which was significantly different from others and followed by T_2 (1.21) and T_3 (1.23).

Table 12. Number of *Apis mellifera* per m^2 per minute at different day times

Treatments	***Apis mellifera* per m^2 per minute**							
	9.30 AM	10.30 AM	11.30 AM	12.30 PM	1.30 PM	2.30 PM	3.30 PM	4.30 PM
T_1	1.27 e	1.48 e	1.90 e	2.94 e	2.90 e	1.27 e	1.48 e	1.08 c
T_2	1.79 d	1.98 d	2.13 d	3.17 d	3.13 d	1.79 d	1.98 d	1.21 b
T_3	2.29 c	2.50 c	2.67 c	3.69 c	3.67 c	2.29 c	2.50 c	1.23 b
T_4	3.14 b	3.23 b	3.47 b	4.44 b	4.47 b	3.14 b	3.23 b	1.32 ab
T_5	3.82 a	3.92 a	3.95 a	4.95 a	4.87 a	3.82 a	3.92 a	1.43 a
T_6	3.30 b	3.40 b	3.46 b	4.48 b	4.46 b	3.33 b	3.41 b	1.37 a
CV (%)	6.38	6.03	2.84	2.47	2.15	6.38	6.03	4.83
$LSD_{(0.05)}$	0.31	0.35	0.15	0.18	0.16	0.33	0.32	0.11

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, T_2= 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

4.2.1.2. *Apis florea*

At 9.30 AM, the effect of nitrogen fertilizer doses on incidence of *Apis florea* on quinoa has been shown in Table 10. Significant variations were observed among the nitrogen fertilizer doses in terms of number of *Apis florea* on quinoa. The highest number (10.33) of *Apis florea* per m^2 per minute was recorded in T_5, which was significantly different from others and followed by T_6 (9.59) and T_4 (9.50). On the other hand, the lowest number (8.27) of *Apis florea per* m^2 per minute was recorded in T_1, which was significantly different from others and followed by T_2 (8.79) and T_3 (9.29). More or less similar trend results were found in 10.30 AM, 11.30 AM, 12.30 PM, 1.30 PM, 2.30 PM, 3.30 PM (Table 10).

At 4.30 PM ,The highest number (3.17) of *Apis florea* per m^2 per minute was recorded in T_5, which was significantly different from others and followed by T_6 (2.98) and T_4 (2.96). On the other hand, the lowest number (2.58) of *Apis florea per* m^2 per minute was recorded in T_1, which was significantly different from others and followed by T_2 (2.77) and T_3 (2.8

Table 13. Number of *Apis florea* per m^2 per minute at different day times

Treatments	*Apis florea* per m^2 per minute							
	9.30 AM	10.30 AM	11.30 AM	12.30 PM	1.30 PM	2.30 PM	3.30 PM	4.30 PM
T_1	8.27 d	11.33 b	13.33 b	14.33 b	19.33 b	16.33 b	15.33 b	2.58 c
T_2	8.79 cd	11.50 b	13.50 h	14.50 b	19.50 ab	16.50 ab	15.50 ab	2.77 bc
T_3	9.29 bc	11.88 ab	13.88 ab	14.88 ab	19.55 ab	16.55 ab	15.55 ab	2.86 a-c
T_4	9.50 b	11.95 ab	13.95 ab	14.95 ab	19.95 ab	16.95 ab	15.96 ab	2.96 ab
T_5	10.33 a	12.33 a	14.33 a	15.33 a	20.33 a	17.33 a	16.50 a	3.17 a
T_6	9.59 b	11.99 ab	13.99 ab	14.99 ab	19.99 ab	16.98 ab	15.99 ab	2.98 ab
CV (%)	3.43	3.48	2.98	2.78	2.42	2.86	3.50	7.17
LSD $_{(0.05)}$	0.58	0.75	0.77	0.83	0.87	0.89	1.00	0.38

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, $T_{2=}$ 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control

4.3. Effect of treatments on yield attributing characteristics and yield

4.3.1. Yield attributing characteristics

Plant height: The effect of nitrogen fertilizer doses on the plant height of quinoa has been shown in Table 8. Significant variations were observed among the nitrogen fertilizer doses in terms of plant height of quinoa. The highest plant height (54.79 cm) was recorded in T_3, which was similar to T_4 (54.30 cm), T_5 (53.90 cm) and T_1 (48.07 cm). On the other hand, the lowest plant height (43.11 cm) was recorded in T_6, which was statistically similar to T_2 (45.67 cm) (Table 8).

Inflorescence length: The effect of nitrogen fertilizer doses on the length of quinoa inflorescence has been shown in Table 8. Significant variations were observed among the nitrogen fertilizer doses in terms of length of quinoa inflorescence. The highest length (28.13 cm) was recorded in T_3, which was statistically similar to T_4 (27.63 cm) and T_2 (21.27 cm). On the other hand, the lowest length (17.50 cm) was recorded in T_6, which was similar to T_1 (21.10 cm) and T_5 (21.10 cm) (Table 8).

Inflorescence diameter: The effect of nitrogen fertilizer doses on the inflorescence diameter of quinoa has been shown in Table 8. Significant variations were observed among the nitrogen fertilizer doses in terms of diameter of quinoa inflorescence. The highest inflorescence diameter (12.52 cm) was recorded in T_3, which was significantly different from others and followed by T_4 (11.62 cm) and T_5 (10.56 cm). On the other hand, the lowest inflorescence diameter (8.38 cm) was recorded in T_6, which was significantly different from others and followed by T_2 (8.73 cm) and T_1 (9.75 cm) (Table 8).

1000 seed weight: The effect of nitrogen fertilizer doses on the 1000 seed weight of quinoa has been shown in Table 8. Significant variations were observed among the nitrogen fertilizer doses in terms of 1000 seed weight of quinoa. The highest weight (2.89 gm) was recorded in T_3, which was significantly different from others and followed by T_4 (2.73 gm) and T_5 (2.62 gm). On the other hand, the lowest weight (2.19 gm) was recorded in T_6, which was significantly different from others and followed by T_2 (2.28 gm) and T_1 (2.45 gm) (Table 8).

Table 14: Effect of different nitrogen fertilizer doses on plant height, inflorescence length, inflorescence diameter and 1000 seed weight of quinoa

Treatments	Plant height (cm)	Inflorescence length (cm)	Inflorescence diameter (cm)	1000 seed weight (gm)
T_1	48.07 ab	21.10 bc	9.75 d	2.45 d
T_2	45.67 b	21.27 abc	8.73 e	2.28 e
T_3	54.79 a	28.13 a	12.52 a	2.89 a
T_4	54.30 a	27.63 ab	11.,62 b	2.73 d
T_5	53.90 a	21.10 bc	10.56 c	2.62 c
T_6	43.11 b	17.50 c	8.38 f	2.15 f
CV (%)	0.35	1.11	1.93	1.90
LSD (0.05)	0.35	0.41	0.34	0.08

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, $T_{2=}$ 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that, the highest plant height, inflorescence length, inflorescence diameter and 1000 seed weight (54.79 cm, 28.13 cm, 12.52 cm and 2.89 gm, respectively) of quinoa was recorded in T_3 which was comprised of 150 kg urea fertilizer dose in the field. Where the lowest plant height, inflorescence length, inflorescence diameter and 1000 seed weight (43.11 cm, 17.50 cm, 8.38 cm and 2.15 gm, respectively) was found in $T_{6,}$ which was comprised with untreated control. As a result, the order of efficacy of different fertilizer doses in terms of plant height, inflorescence length, inflorescence diameter and 1000 seed weight is $T_3 > T_4 > T_5 > T_1 > T_2 > T_6$.

4.3.2. Yield

Yield per hectare: The effect of urea fertilizer doses on the yield of quinoa per hectare has been shown in Table 9. Significant variations were observed among the urea fertilizer doses in terms of yield of quinoa per hectare. The highest yield (1.11 ton/ha) was recorded in T_3, which was statistically similar with T_4 (1.03 ton/ha) and followed by T_5 (0.89 ton/ha). On the other hand, the lowest yield (0.68 ton/ha) was recorded in T_6, which was significantly different from others and followed by T_2 (0.94 ton/ha) and T_1 (0.84 ton/ha) (Table 9).

Considering the increase of yield over control, the highest increased yield (63.24%) per hectare over control was observed in T_3 which was comprised of 150 kg urea fertilizer dose, followed by T_4 (51.47%), T_2 (38.24%) and T_1 (30.88%). Whereas, the lowest increased yield (23.53%) per hectare over control was observed in $T_{1,}$ which was comprised of 50 kg nitrogen fertilizer dose (Table 9).

Table 14: Effect of different nitrogen fertilizer doses on yield of quinoa

Treatments	Yield/ha (ton)	% increase over control
T_1	0.84 c	23.53
T_2	0.94 bc	38.24
T_3	1.11 a	63.24
T_4	1.03 ab	51.47
T_5	0.89 bc	30.88
T_6	0.68 d	0
CV (%)	3.53	-
LSD (0.005)	0.22	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= 50 kg nitrogen fertilizer dose, $T_{2=}$ 100 kg nitrogen fertilizer dose, T_3= 150 kg nitrogen fertilizer dose, T_4= 200 kg nitrogen fertilizer dose, T_5= 250 kg nitrogen fertilizer dose, T_6= Untreated control]

From the above findings it was revealed that, the highest yield per hectare (1.11 ton/ha) of quinoa was recorded in T_3 which was comprised of 150 kg urea fertilizer dose in the field. Where the lowest yield per hectare (0.68 ton/ha) was found in $T_{6,}$ which was comprised with untreated control. As a result, the order of efficacy of different fertilizer doses in terms of yield per hectare is $T_3>T_4>T_5>T_2>T_1>T_6$.

4.4. Relationship between plant height and yield of quinoa

Correlation study was done to establish the relationship between the plant height and yield of quinoa. From the study it was revealed that significant correlation was observed between the plant height and yield of quinoa (Figure 3). It was evident from the Figure 3 that the regression equation y = 0.0236x – 0.2641 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.6217) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between plant height and yield of quinoa, i.e., the yield increased with the increase of the plant height of quinoa.

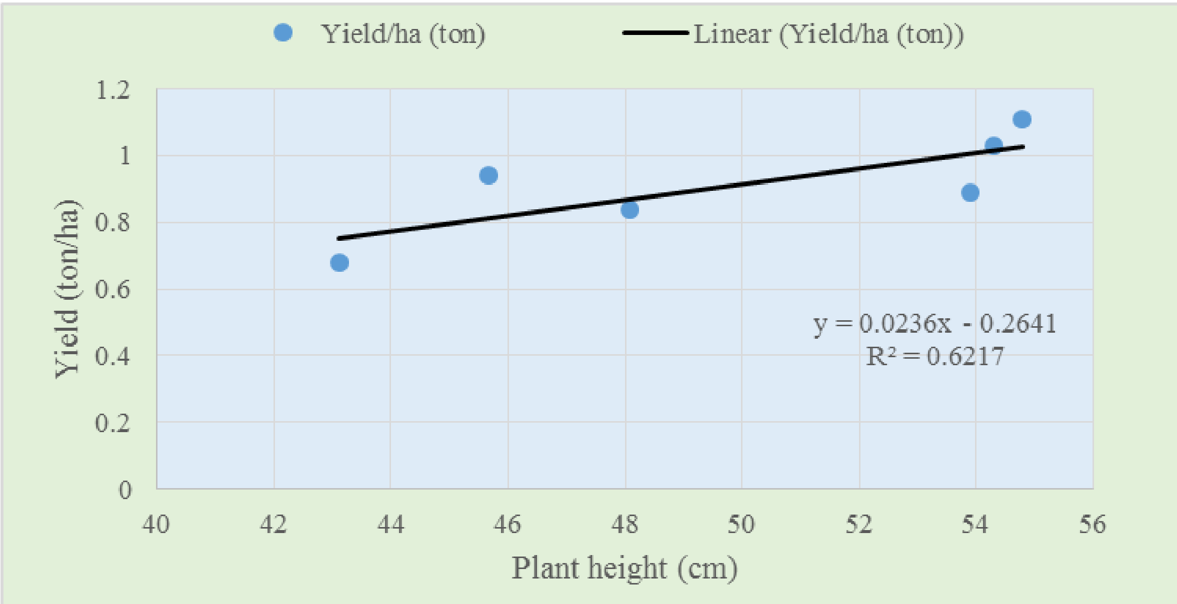

Figure 1. Relationship between plant height and yield of quinoa

4.5. Relationship between inflorescence length and yield of quinoa

Correlation study was done to establish the relationship between the inflorescence length and yield of quinoa. From the study it was revealed that significant correlation was observed between the inflorescence length and yield of quinoa (Figure 4). It was evident from the Figure 4 that the regression equation y = 0.0338x + 0.1449 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8861) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between inflorescence length and yield of quinoa, i.e., the yield increased with the increase of the inflorescence length of quinoa.

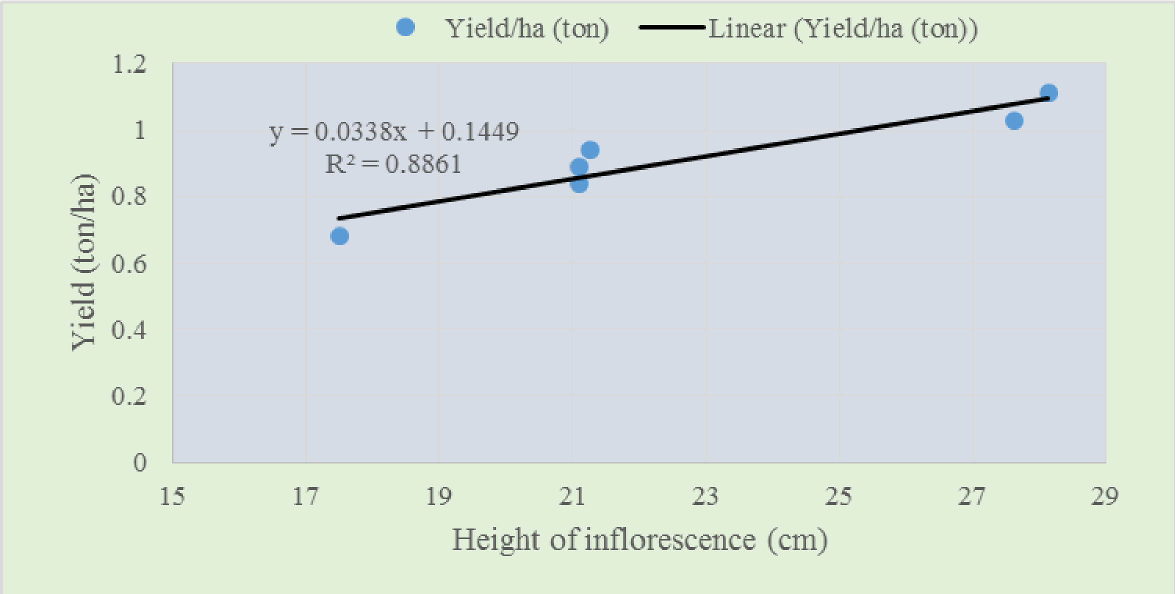

Figure 2. Relationship between inflorescence height and yield of quinoa

4.6. Relationship between inflorescence diameter and yield of quinoa

Correlation study was done to establish the relationship between the inflorescence diameter and yield of quinoa. From the study it was revealed that significant correlation was observed between the inflorescence diameter and yield of quinoa (Figure 5). It was evident from the Figure 5 that the regression equation y = 0.0782x + 0.1123 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.7119) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between inflorescence diameter and yield of quinoa, i.e., the yield increased with the increase of the inflorescence diameter of quinoa.

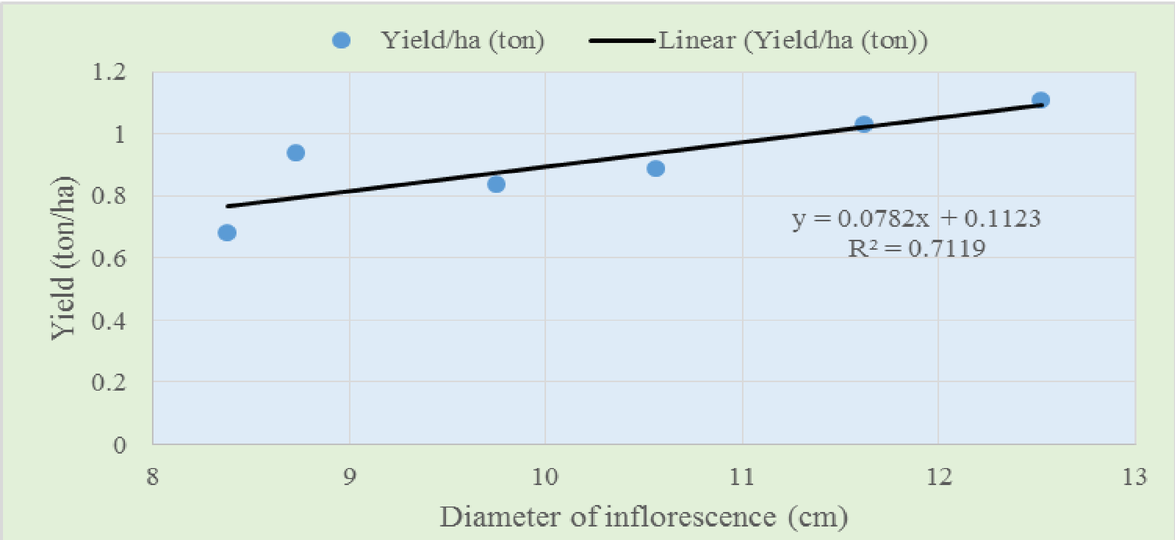

Figure 3. Relationship between the diameter of inflorescence and yield of quinoa

4.7. Relationship between 1000 seed weight and yield of quinoa

Correlation study was done to establish the relationship between 1000 seed weight and yield of quinoa. From the study it was revealed that significant correlation was observed between the 1000 seed weight and yield of quinoa (Figure 6). It was evident from the Figure 6 that the regression equation y = 0.4611x – 0.2469 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.7322) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between 1000 seed weight and yield of quinoa, i.e., the yield increased with the increase of 1000 seed weight of quinoa.

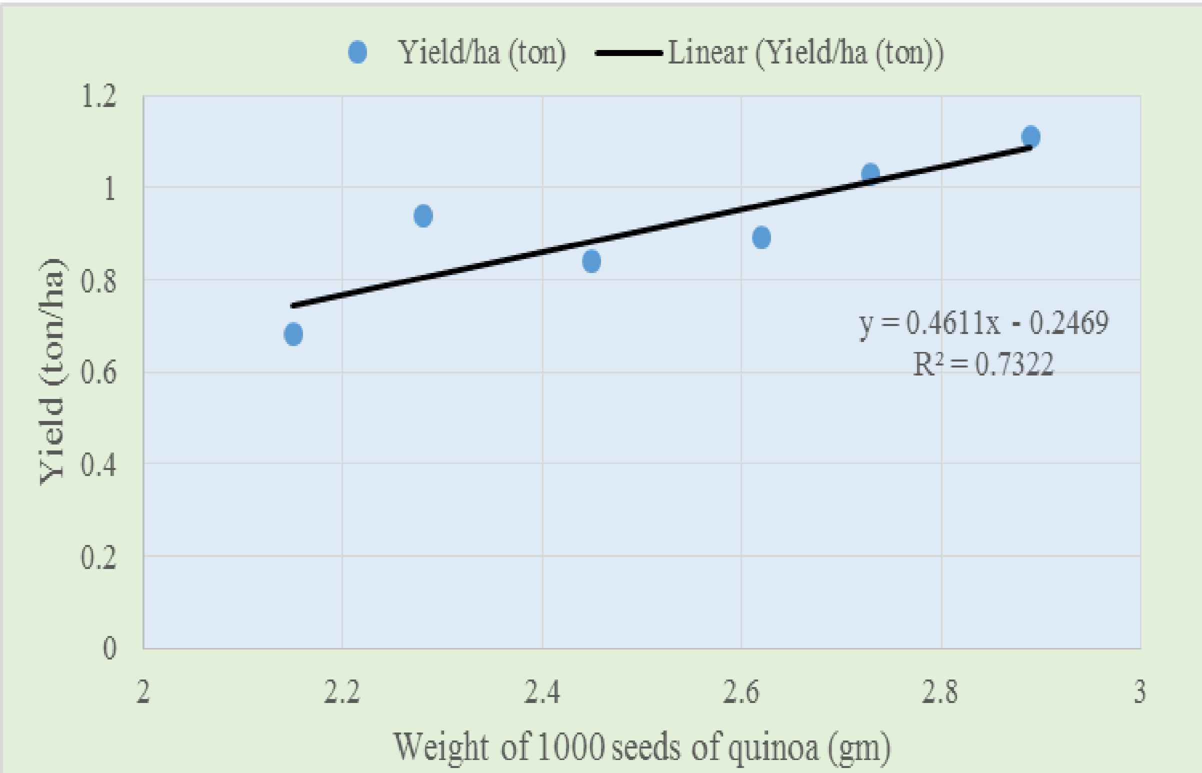

Figure 4. Relationship between 1000 seed weight and yield of quinoa

CHAPTER V

SUMMARY AND CONCLUSION

Influence of nitrogen fertilizer on insect pest complex of quinoa was investigated at the field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2018 to March, 2019. The treatments were T_1 comprised of 50 kg nitrogen fertilizer dose; T_2 comprised of 100 kg nitrogen fertilizer dose; T_3 comprised of 150 kg nitrogen fertilizer dose; T_4 comprised of 200 kg nitrogen fertilizer dose; T_5 comprised of 250 kg nitrogen fertilizer dose; T_6 comprised of untreated control. Data on number of insect pest incidence and their infestation, beneficiary insect incidence, plant height, inflorescence length, inflorescence diameter, 1000 seed and total yield were recorded from different treatments applied to the field.

Considering the incidence of aphid, the lowest aphid infestation (3.71) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of aphid incidence over control was 32.91%. As a result, the order of efficacy of different fertilizer doses in terms of aphid incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

Considering the incidence of whitefly, the lowest infestation (2.70) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field. Where the highest reduction of whitefly per five tagged plants over control was 38.07%. As a result, the order of efficacy of different fertilizer doses in terms of whitefly incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

Considering the incidence of jassid, the lowest infestation (3.36) of jassid per five tagged plants on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field. Where the highest reduction of jassid per five tagged plants over control was 27.59%. As a result, the order of efficacy of different fertilizer doses in terms of jassid incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

Considering the incidence of stink bug, the lowest infestation (2.78) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of stink bug incidence over control was 37.60%. As a result, the order of efficacy of different fertilizer doses in terms of stink bug incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

Considering the incidence of flea beetle, the lowest infestation (3.78) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of flea beetle incidence over control was 30.64%. As a result, the order of efficacy of different fertilizer doses in terms of flea beetle incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

Considering the incidence of grasshopper, the lowest infestation (1.78) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of grasshopper incidence over control was 47.83%. As a result, the order of efficacy of different fertilizer doses in terms of grasshopper incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

Considering the incidence of spider, the lowest infestation (1.55) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of spider incidence over control was 54.21%. As a result, the order of efficacy of different fertilizer doses in terms of spider incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

Considering the incidence of house fly, the lowest infestation (3.44) on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field, where the highest reduction of house fly incidence over control was 32.70%. As a result, the order of efficacy of different fertilizer doses in terms of house fly incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

In case of percent leaf infestation by insect pests, the lowest percent leaf infestation (24.31%) by insect pests per plant on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field. Whereas, the highest leaf infestation (50.61%) by insect pests per plant on quinoa was recorded in T_6 which was comprised of untreated control. As a result, the order of efficacy of different fertilizer doses in terms of percent leaf infestation by insect pests of quinoa per plant is $T_6>T_5>T_4>T_3>T_2>T_1$.

In case of plant infestation, the lowest percent plant infestation (36.23%) by insect pests per ten plants on quinoa was recorded in T_1 which was comprised of 50 kg nitrogen fertilizer dose in the field. Whereas, the highest plant infestation (82.46%) by insect pests per plant on quinoa was recorded in T_6 which was comprised of untreated control. As a result, the order of efficacy of different fertilizer doses in terms of percent plant infestation by insect pests of quinoa per plant is $T_6>T_5>T_4>T_3>T_2>T_1$.

Considering the incidence of lady bird beetle, the highest incidence (3.34) of lady bird beetle per five tagged plants on quinoa was recorded in T_5 which was comprised of 250 kg nitrogen fertilizer dose in the field. Where the lowest incidence of lady bird beetle per five tagged plants was 1.61 in T_1. As a result, the order of efficacy of different fertilizer doses in terms of lady bird beetle incidence is $T_5>T_6>T_4>T_3>T_2>T_1$.

Considering the incidence of honey bee (Apis florea and Apis mellifera), was recorded in T5, ,the highest incidence (3.17 and 3.82) of honey bee per m2 per minute on quinoa was recorded in T5 which was comprised of 250 kg nitrogen fertilizer dose in the field.

Where the lowest incidence of honey bee per five tagged plants was 2.58 and 1.47 in T1. As a result, the order of efficacy of different fertilizer doses in terms of honey bee incidence is T5>T6>T4>T3>T2>T1.

The highest plant height, inflorescence length, inflorescence diameter and 1000 seed weight (54.79 cm, 28.13 cm, 12.52 cm and 2.89 gm, respectively) of quinoa was recorded in T_3 which was comprised of 150 kg urea fertilizer dose in the field. Where the lowest plant height, inflorescence length, inflorescence diameter and 1000 seed weight (45.68 cm, 17.60 cm, 8.38 cm and 2.15 gm, respectively) was found in $T_{6,}$ which was comprised with untreated control. As a result, the order of efficacy of different fertilizer doses in terms of plant height, inflorescence length, inflorescence diameter and 1000 seed weight is $T_3>T_4>T_5>T_2>T_1>T_6$.

The highest yield per hectare (1.11 ton/ha) of quinoa was recorded in T_3 which was comprised of 150 kg urea fertilizer dose in the field. Where the lowest yield per hectare (0.68 ton/ha) was found in $T_{6,}$ which was comprised with untreated control. As a result, the order of efficacy of different fertilizer doses in terms of yield per hectare is $T_3>T_4>T_5>T_2>T_1>T_6$.

Conclusion

From the present study, it may be concluded that incidence of insect pests and infestation by them was significantly varied among the treatments. The overall study revealed that, high amount of nitrogen fertilizer attracts the insect pests of quinoa. From this study, T_5 comprised of 250 kg nitrogen fertilizer dose performed as a susceptible for the insect pest incidence and infestation by them. Considering overall results of this present study, it can be concluded that T_3 comprised of 150 kg nitrogen fertilizer per hectare dose may be the best dose for decreasing insect pests and increasing yield.

Considering the findings of the study the following recommendations can be drawn:

i. To determine the perfect dose of nitrogen fertilizer such study should be performed repeatedly.

ii. It should be adopted in large scale production and determine the insect pests of quinoa.

iii. Further study of this experiment is needed in different locations of Bangladesh for accuracy of the results obtained from the present experiment.

CHAPTER VI

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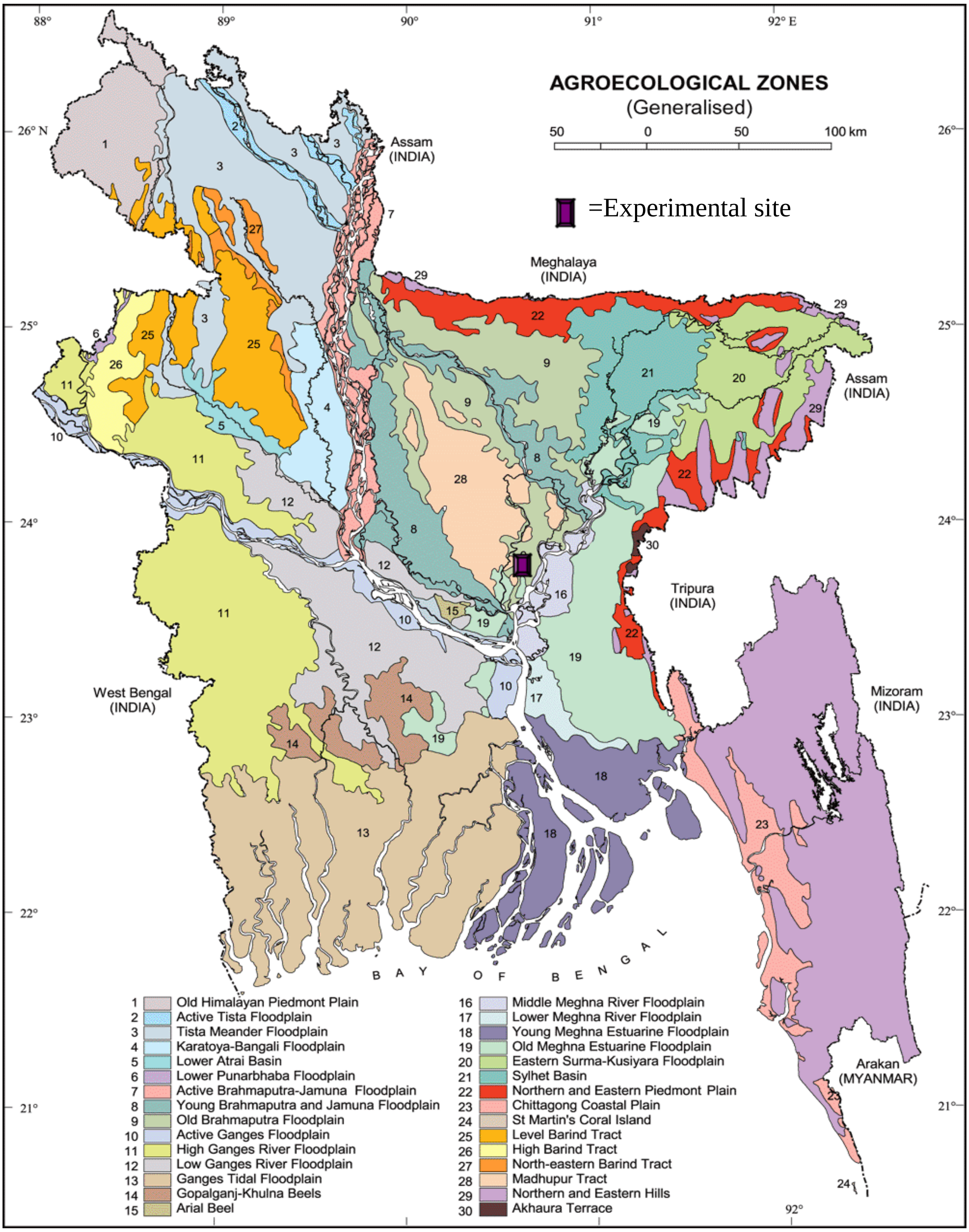
CHAPTER VII

APPENDIXES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	**Value**
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix III: Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from November 2018 to March 2019

Date/Week	Temperature		Relative humidity (%)	Rainfall (mm) (Total)
	Maximum	Minimum		
November	30	16	78	2.08
December	29	14	71	0
January	26	12	67	3.50
February	28.1	22.3	52.2	4.53
March	32.5	20.4	38	5.8

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka- 1207

Appendix IV. ANOVA for number of aphid at vegetative stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.003	0.001	2.1869	0.163
Doses of nitrogen fertilizer	5	13.586	2.717	4438.132	0.000
Error	10	0.006	0.001		

Appendix V. ANOVA for number of aphid at flowering stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.064	0.032	0.6891	
Doses of nitrogen fertilizer	5	16.257	3.251	69.4971	0.000
Error	10	0.468	0.047		

Appendix VI. ANOVA for number of aphid at fruiting stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.06	0.03	0.6814	
Doses of nitrogen fertilizer	5	13.328	2.666	60.266	0.000
Error	10	0.442	0.044		

Appendix VII. ANOVA for average number of aphid

Source	DF	SS	MS	F	Prob.
Replication	2	0.019	0.009	0.6035	
Doses of nitrogen fertilizer	5	14.258	2.852	184.7265	0.000
Error	10	0.154	0.015		

Appendix VIII. ANOVA for number of whitefly at vegetative stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.055	0.027	0.5093	
Doses of nitrogen fertilizer	5	7.014	1.403	26.2005	0.000
Error	10	0.535	0.054		

Appendix IX. ANOVA for number of whitefly at flowering stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.105	0.052	1.0171	0.3962
Doses of nitrogen fertilizer	5	7.418	1.484	28.8419	0.000
Error	10	0.514	0.051		

Appendix X. ANOVA for number of whitefly at fruiting stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.116	0.058	1.0805	0.376
Doses of nitrogen fertilizer	5	7.24	1.448	27.0705	0.000
Error	10	0.535	0.053		

Appendix XI. ANOVA for average number of whitefly

Source	DF	SS	MS	F	Prob.
Replication	2	0.078	0.039	0.8146	
Doses of nitrogen fertilizer	5	7.169	1.434	29.9812	0.000
Error	10	0.478	0.048		

Appendix XII. ANOVA for number of jassid at vegetative stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.105	0.052	0.9204	
Doses of nitrogen fertilizer	5	8.508	1.702	29.8832	0.000
Error	10	0.569	0.057		

Appendix XIII. ANOVA for number of jassid at flowering stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.071	0.035	0.645	
Doses of nitrogen fertilizer	5	9.238	1.848	33.742	0.000
Error	10	0.548	0.055		

Appendix XIV. ANOVA for number of jassid at fruiting stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.304	0.152	2.6713	0.1176
Doses of nitrogen fertilizer	5	9.045	1.809	31.7574	0.000
Error	10	0.57	0.057		

Appendix XV. ANOVA for average number of jassid

Source	DF	SS	MS	F	Prob.
Replication	2	0.088	0.044	1.4157	0.2875
Doses of nitrogen fertilizer	5	8.743	1.749	56.0006	0.000
Error	10	0.312	0.031		

Appendix XVI. ANOVA for number of total leaves

Source	DF	SS	MS	F	Prob.
Replication	2	0.043	0.022	0.3534	
Doses of nitrogen fertilizer	5	341.997	68.399	1123.8987	0.000
Error	10	0.609	0.061		

Appendix XVII. ANOVA for number of infested leaves

Source	DF	SS	MS	F	Prob.
Replication	2	0.253	0.126	1.6114	0.2474
Doses of nitrogen fertilizer	5	221.482	44.296	564.966	0.000
Error	10	0.784	0.078		

Appendix XVIII. ANOVA for percent leaf infestation

Source	DF	SS	MS	F	Prob.
Replication	2	0.744	0.372	1.0027	0.401
Doses of nitrogen fertilizer	5	1618.403	323.681	872.9987	0.000
Error	10	3.708	0.371		

Appendix XIX. ANOVA for number of lady bird beetle at vegetative stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.066	0.033	0.4852	
Doses of nitrogen fertilizer	5	6.116	1.223	18.0095	0.0001
Error	10	0.679	0.068		

Appendix XX. ANOVA for number of lady bird beetle at flowering stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.134	0.067	1.3609	0.3001
Doses of nitrogen fertilizer	5	5.95	1.19	24.0932	0.000
Error	10	0.494	0.049		

Appendix XXI. ANOVA for number of lady bird beetle at fruiting stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.004	0.002	0.027	
Doses of nitrogen fertilizer	5	6.106	1.221	15.5932	0.0002
Error	10	0.783	0.078		

Appendix XXII. ANOVA for average number of lady bird beetle

Source	DF	SS	MS	F	Prob.
Replication	2	0.013	0.006	0.5741	
Doses of nitrogen fertilizer	5	5.835	1.167	106.8195	0.000
Error	10	0.109	0.011		

Appendix XXIII. ANOVA for number of honey bee at vegetative stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.575	0.288	28.326	0.0001
Doses of nitrogen fertilizer	5	1.163	0.233	22.9118	0.000
Error	10	0.102	0.01		

Appendix XXIV. ANOVA for number of honey bee at flowering stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.404	0.202	7.9751	0.0085
Doses of nitrogen fertilizer	5	4.506	0.901	35.5595	0.000
Error	10	0.253	0.025		

Appendix XXV. ANOVA for number of honey bee at fruiting stage

Source	DF	SS	MS	F	Prob.
Replication	2	0.082	0.041	1.3651	0.2991
Doses of nitrogen fertilizer	5	1.969	0.394	13.0789	0.0004
Error	10	0.301	0.03		

Appendix XXVI. ANOVA for average number of honey bee

Source	DF	SS	MS	F	Prob.
Replication	2	0.099	0.049	8.8425	0.0061
Doses of nitrogen fertilizer	5	2.244	0.449	80.541	0.000
Error	10	0.056	0.006		

Appendix XXVII. ANOVA for plant height

Source	DF	SS	MS	F	Prob.
Replication	2	0.005	0.003	0.0641	
Doses of nitrogen fertilizer	5	1667.376	333.475	7952.1273	0.000
Error	10	0.419	0.042		

Appendix XXVIII. ANOVA for inflorescence length

Source	DF	SS	MS	F	Prob.
Replication	2	0.014	0.007	0.1269	
Doses of nitrogen fertilizer	5	112.996	22.599	405.4971	0.000
Error	10	0.557	0.056		

Appendix XXIX. ANOVA for inflorescence diameter

Source	DF	SS	MS	F	Prob.
Replication	2	0.199	0.100	2.5358	0.1286
Doses of nitrogen fertilizer	5	39.576	7.915	201.2855	0.000
Error	10	0.393	0.039		

Appendix XXX. ANOVA for 1000 seed weight

Source	DF	SS	MS	F	Prob.
Replication	2	0.003	0.001	0.5518	
Doses of nitrogen fertilizer	5	1.167	0.233	101.2607	0.000
Error	10	0.023	0.002		

Appendix XXXI. ANOVA for yield per hectare

Source	DF	SS	MS	F	Prob.
Replication	2	0.016	0.008	0.4922	
Doses of nitrogen fertilizer	5	16.995	3.399	211.3318	0.000
Error	10	0.161	0.016		