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Ecological Studies on Cabbage Pests

Embaby, E. S. M.[1*] and Lotfy, D. E. S.[2]

[1]Plant Pathology Dept., National Research Centre, Cairo, Egypt; [2]Plant Protection Research Institute, Agriculture Research Centre, Cairo, Egypt.

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Abstract A weekly survey of pests present on cabbage crop was undertaken from October 2014 to January 2015. Data show that, several insect pests were found to attack cabbage crops which were identified under three families and two orders. These are the imported Cabbageworm, (*Pieris rapae L*., Pieridae, Lepidoptera), Cabbage aphid (*Brevicoryne brassicae* L., Aphididae, Homoptera), Diamondback moth (*Plutella xylostella* L., plutellidae, Lepidoptera) and Beet armyworm (*Spodoptera exigua* L.), Noctuidae, Lepidoptera). The most common brassica pests, are *Pieris rapae* (17.9 %) followed by Cabbage aphid (*Brevicoryne brassicae* L., (7.59 %) and *Plutella xylostella* (diamondback moth) was (1.38 %) while Beet army worm (*Spodoptera exigua* L). which occurred as secondry insect pests on cabbage crop record (0.27 %). Both Diamondback moth (*Plutella xylostella* L.) and Beet army worm (*Spodoptera exigua* L) were less collected. Effects of weather factors on population dynamics of the most common cabbage pests were found to decrease if temperature decreased as result of cooler climate as well as increasing the relative humidity R.H. (%) in addition at El-Dair region was higher fungal count spread which caused higher mortality of cabbage pests. Fungi are probably reported as natural enemies more frequently than other pathogen groups such as bacteria. Naturally occurring entomopathogenic fungi have also been shown to occasionally cause high mortality of pest larvae or pupa. During this survey, the incidences of identified entomopathogenic fungi were found to be higher i. e. *Metarhizium anisopliae* while the bacterium *Bacillus thuringiensis* was low. Some deaths may have been caused by secondary infections as *Aspergillus niger*, *A. flavus*, *A. parasiticus*, *Fusarium* sp., *Mucor* sp. and *Rhizopus* sp.

Keywords: Cabbage pests, ecology, temperature, humid conditions and natural enemies' entomopathogenic.

Introduction

The Cruciferae/Brassicaceae or Mustard Family is a large natural family of major economic importance containing a diverse variety of crop plants grown for salads, vegetables, condiments, and ornamental plants. These include cabbage, cauliflower, broccoli, brussel sprouts, radish and field crops such as turnip, mustard and rape. Crucifer crops differ is their susceptibility to attack by

*Corresponding author: Embaby, E. S. M.; **Email**: embaby.elsayed@yahoo.com

several insects such as imported cabbageworm, diamondback moth, aphids, Beet armyworm, flea beetle and heart caterpillar. In some parts of the world losses due to insect and mite pests has been estimated as high as 20%. The majority of groves region are unsprayed and this is probably due to isolation, lack of use of insecticides in the past, and a natural ecological balance. Reduced levels of pesticides provide a more stable environment and reduces fluctuations within pest populations the reduction in crop yields and costs of preventing damage attributable to insects are notoriously difficult to obtain. Studies of the major crops conducted in the USA indicate that without insecticides, 50% or more of the major crops could be lost to insects (Mason, 2013).

The Imported Cabbageworm, *Pieris rapae* (Linnaeus) (Lepidoptera: Pieridae), occurs in temperate regions around the world. *Pieris rapae* is easily confused with other common cabbage. Host plants are generally members of the family Brassicaceae (e.g. cabbage, cauliflower, brussel sprouts, mustard, canola), although they may also be garden plants from other families, such as nasturtium, mignonette, and stock. Cabbageworms feed on foliage, and if left unchecked often will reduce mature plants to stems and large veins. Larvae produce copious quantities of fecal material which also contaminate and stain produce. *P. rapae* larvae eat ragged holes in the leaves of the host plant. When attack is heavy, only the veins are left, resulting in considerable losses to commercial growers. Less heavily infested plants become stunted and fouled with dark green faecal pellets (Van Driesche, 2008 and Capinera, 2014).

Cabbage (*Brassica Oleracea* var. capitata L.) is an extensively grown vegetable in the world, it is among the most popular food crops; it grows well in many parts of the country (Legwaila *et al.*, 2014). The diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), is a widespread pest of cultivated and wild Brassicaceae. Its abundance throughout the world wherever crucifers are grown. These include cabbage, cauliflower, broccoli, brussel sprouts, radish and field crops such as turnip, mustard and rape. It is also known from garden plants, including alyssum, candytuft, stock and wallflower (Waterhouse and Sands 2001). The performance of the Diamondback moth, *Plutella xylostella* L.,on Ethiopian cultivated and wild crucifers was studied in the laboratory for two generations. Head cabbage, *Brassica oleracea* var. *Capitata* L., was the most suitable host with the shortest developmental period and the highest reproductive potential (Ayalew *et al.*, 2006).

The cabbage aphid, *Brevicoryne brassicae* L. (Homoptera: Aphididae), is a specialist on Brassicaceae, it is negatively affected, particularly the genus

Brassica**.** Aphids penetrate leaves and stems, and feed on plant phloem sap. They can cause generalized stunted plant growth and are important virus vectors. Cabbage aphid may reduce plant growth by 35%, the number of side branches by 43%, and the oil content by over 10%. Aphids may cause 85% yield loss and may induce the increase in glucosinolate content in rapeseed (Strauss *et al*., 2002). Cabbage aphid infestations vary widely between growing seasons depending on the occurrence of natural enemies and climate conditions. A dry and hot microenvironment is favourable for the aphids. (Jönsson and Stephansson, 2002). The first signs of aphid attack are little pale spots, but on severe outbreaks the entire leaf yellows, curls up and distorts and later shows a purplish discolouration. Outbreaks will be sparse in the beginning but rapidly spread. The growth is stunted by the aphid feeding and high infestations in young plants could lead to wilt. In larger plants a reduction in quality is seen which leads to yield losses. The aphid in addition could transmit several viruses, which are important in some growing areas (Alford, 1999; Jönsson and Stephansson, 2002). According to the authors, the indirect effect mediated by a fungal entomopathogen in this case may be strongly affected by weather conditions, thus making the experimental results of the trials inconclusive (Pope *et al*., 2002).

Beet armyworm, *Spodoptera exigua* Hübner (Lepidoptera: Noctuidae), is a widely distributed polyphagous pest of numerous cultivated crops, including cotton, tomato, celery, lettuce, cabbage, and alfalfa (Metcalf and Flint 1962). It is generally considered a secondary pest. Populations generally build after natural enemy populations have been reduced through application of broad spectrum insecticides (Ruberson *et al*., 1994; Graham *et al*., 1995). The beet armyworm is a serious and persistent agricultural pest worldwide and is a polyphagous insect pest with a worldwide spread, and is considered a serious pest of vegetables, field, and flower crops. The beet armyworm is a cosmopolitan species that attacks over 90 plant species in at least 18 families, many of which are crop plants (Saaed *et al*., 2010). This insect pest has no diapauses and can overwinter in the pupal stage such as in California (Zheng *et al*., 2013).

Ecological effects on cabbage pests

Temperatures and humid conditions: The lepidopteran insects cause leaf feeding damage. Populations decrease with higher as well as lower temperatures. A narrow host range is desirable from the ecological point of view. Therefore, the specific action of entomophthorales is highly valuable from the point of selective reduction of host insects, which implies that non-target species are not affected; this can be of special interest in the presence of other natural enemies. Entomophthorales need humid conditions to sporulate and to germinate. Many species have developed the ability to induce the infection and death of the host in the evening. Thus, they can profit from the presence of dew which induces sporulation and favours infections of new hosts (Siegfried Keller, 2007). A biotic and biotic condition strongly influences key components of fungal activity and fitness including transmission efficiency and persistence within and outside the host. Humidity in excess of 90% in the microenvironment surrounding fungi is required for germination, infection, and sporulation (e.g. Inglis *et al*., 2001) and is considered to be the most critical environmental factor influencing the development of epizootics. Ambient temperatures affect speed of germination, growth and kill. There is an inverse relationship between speed of kill and temperature although overall mortality may not be affected (Thomas and Blanford, 2003). Solar radiation is detrimental to persistence, particularly on the phylloplane where fungi can be rapidly deactivated. The fungi are very virulent and specific in their choice of host. To be effective the fungi needs a moderate temperature, a prolonged period of humidity and a quit large insect population to ensure a rapid spread (Kuusk & Sandskär, 2004 and Juliane *et al*., 2006).

a-Temperature: Ambient temperatures can affect fungal entomopathogen field efficacy. optimal germination and growth rates of fungal entomopathogens range between 23 ^{o}C and 28 ^{o}C, growth.In general, rapidly slows above 30^{o}C, and ceases for most isolates at 34–37^{o}C. Similarly, conidial germination is adversely affected by temperatures above 30^{o}C. Temperatures below 16^{o}C increasingly slow germination and growth rates for most of the fungal entomopathogens, and thus affect efficacy in terms of a longer survival of the target population (Inglis *et al*., 1999; Ihara *et al*., 2008 and Roy *et al*., 2010). This can have important bearing on mycopesticide field efficacy in northern climates and also on temperate rangeland where night time insect body temperatures can be 10^{o}C for more than 6 h day-1. Night time ground temperatures even reached 5–6^{o}C, in South and North Dakota during the Summer of 2003 during a grasshopper field trial (Jaronski unpublished data) (Roy *et al*., 2010).

b-Humidity: There is a requirement for high humidity for spore germination in vitro (Lazzarini *et al*., 2006), insects can become infected at much lower humidity. It is generally thought that infection is independent of ambient relative humidity (Lord, 2005 and Roy *et al*., 2010). In considering environmental effects on a mycoinsecticide, one must differentiate the ambient environment, within canopy habitat, and, especially, leaf surface microhabitat, especially for small target insects such as whitefly nymphs, aphids, thrips, and mites. Ambient temperature and humidity measurements, taken above the crop canopy can have little relationship to conditions within the canopy. For example, Shipp *et al.* (2003) observed that ambient humidity had little effect on *B. bassiana* activity against aphids, thrips and whiteflies on cucumber leaves under greenhouse conditions. In cabbage (*Brassica oleracea* Linne) leaves, the ambient relative humidity (RH) of 70% increased to 90% 1 cm above both upper and lower leaf surfaces, and increased from 56% RH to 70% within 5 mm of waterlily (*Nymphaea* spp.) leaf. Within the immediate proximity of leaf stomata, RH could be 95–99% at 1 mm above leaf surface. RH of 40% at 1 mm above the leaf surface of dock (*Rumex* spp.) vs. 10% ambient RH, and 95% vs. 50% ambient with a tulip (*Tulipa* sp.) leaf. A study by (Boulard *et al*., 2002 and Roy *et al*., 2010.) is the most detailed and potentially relevant to the use of entomopathogenic fungi. They observed a 20–30% increase above ambient RH at 5 mm above tomato leaf surface in the morning, 7–10% at the end of the day (Roy *et al*., 2010).

This study aimed to identify all the cabbage crop pests present that are likely to cause problems in the future, the effect of different ecological factors as temperature and humidity on the occurance of the different pests and their natural organisms that attack pests are studied.

Materials and methods

Survey: The major of Cruciferae/Brassicaceae were surved (Cultivation, area, yield and product) in both old land and new land in Egypt during 2014/2015 season and data were obtained from Ministry of Agriculture, Egypt.

Collections: A weekly survey of cabbage pests present was carried out under taken from October 2014 to January 2015. Three different plots at El-Dair region, Qalubia Governorate, Egypt, were visited to collect all pests and to observe any disease present on them. All available (724) plants were examined for the presence of cabbage pests from untreated cabbage plants in the field and transpored to the laboratory. The experiment was performed under controlled conditions and placed into rearing tubes to record the identification of these insects after collecting, and were placed individually in sterile half-pint containers.

Ecological studies

a-Environmental conditions: Monthly the average of temperature degree and Relative humidity R.H. [%] which affecting cabbage pests and population density in Qalyoubia region were estimated during the experimental season 2041/2015 by Central laboratory for Agricultural Climate.

b- Natural enemies: Natural organisms affecting cabbage pests were collected and identified in Plant Pathology Dept., National Research Centre, Egypt acording to (Raper and Funel, 1965) for *Aspergillus* genus(Booth, 1977) and (Nelson *et al.*, 1983) for *Fusarium*, and (Barent and Hunter, 1977) for Metarhizium and the genera of imperfect fungi (Kulwant *et al*., 1991) for either *Aspergillus, Fusarium* and *Penicillium.* Also, using a colour Atlas of pathogenic fungi (Frey *et al*., 1979) and (Webster and Weber, 2007). Population density of cabbage pests were calculated during the experimental season 2014/2015.

Results and Discussion

1-Survey: Surveys of important Cruciferae/Brassicaceae planted crops in Egypt were recorded in Table (1). Data in this table show that, cabbage crop was the major Cruciferae/Brassicaceae planted in Egypt followed by Cauliflower, Turnip and Radish. The total cultivated area of cabbage crop was 6284 Feddan, (belonging 223 and 6061 Feddan, in both new and old land respectively. The total production 59361 Ton belonging 2954 and 56407 Ton in both new and old land respectively.

Table 1. A survey of important Cruciferae/Brassicaceae (area, yield and production) planted in Egypt

Cruciferae Crop's	**Old land**			**New land**			**Total**		
	Area *	**Yield**	**Product**	**Area ***	**Yield**	**Product**	**Area ***	**Yield**	**Product**
Cabbage	6061	9.307	56407	223	13.247	2954	6284	9.446	59361
Cauliflower	849	7.855	6669	221	16.000	3536	1070	9.537	10205
Turnip	162	8.648	1401	-	-	-	162	8.648	1401
Radish	152	4.816	732	22	3.909	86	174	4.701	818
Total	7224	30.626	65209	466	33.156	6576	7690	32.332	71785

Area*/ Feddan Hectare = 2.2 Feddan

Figure 1. Healthy and infected cabbage plants by cabbage pest's complex infection

Figure 2. Larvae and pupa of the imported cabbageworm (*Pieris rapae* L.)

Figure 3. Infected pupae of diamondback moth (*Plutella xylostella* L.)
H=Healthy pupae **I**=Infected pupae, which covered by mycelium

3-Ecological studies

Effect of weather factors: Effect of weather factors (i. e. temperature [^{o}C] and relative humidity R.H [%]) on population dynamics of the cabbage pest's complex occurred during 2014/2015 season were recorded in **Table (3).** Data show that, there is a perfect negative relationship between relative humidity R.H [%] and temperature [^{o}C] on insect population dynamics. Relative humidity R.H [%] in Qalyoubia region was higher and ranged between 71% in October 2014 to 85% in December 2014. On the other hand, the average temperature [^{o}C] in Qalyoubia region was lethal. It was ranged between 23.6 ^{o}C in October 2014 to 12 ^{o}C in December 2014. So that, all cabbage pests (complex infection) were found to be decreased were the population dynamics of the pests decreased as result of cooler climate as well as increasing the relative humidity R.H [%]. In addition this region was susceptible to higher fungal count spread which caused higher mortality of cabbage pests. The population density of Cabbage worm (*Pieris rapae* L.) decreased from 70 to 50, 10 and zero after decreasing the average temperature [^{o}C] from 23.6, 17.3, 12.0 and 13.3 in October, November, December and January 2015 respectively. The population density of cabbage aphid (*Brevicoryne brassicae* L.) decreaed from 35 to 20 and zero under the same conditions. The population density of diamondback moth (*Plutella xylostella* L.), was found to be decreased from 8 to 2 and zero and *(Spodoptera exigua* L.*)* decreased in the same manner from 2 to 0 and zero under the same conditons.

Table 3. Effects of weather factors on population dynamics of the cabbage pests during 2014/2015 season

Month 2014/2015		2014			2015
		Oct.	Nov.	Dec.	Jan.
Temperature [^{o}C]		23.6	17.3	12	13.3
Relative humidity [R.H%]		71	82	85	81
Common Name	Scientific Name				
Cabbageworm	*Pieris rapae* L.	70	50	10	0
Cabbage aphid	*Brevicoryne brassicae* L.	35	20	0	0
Diamondback moth	*Plutella xylostella* L.	8	2	0	0
Beet armyworm	*Spodoptera exigua* L.	2	0	0	0

Satar *et al*., (2005) reported that temperature has the major effect on the biology and life cycle of aphids. Optimum temperature for the development of the cabbage aphid was 25/30 ^{o}C. High mortality rates also occurred at 15^{o}C (26.7%). *B. brassicae* populations in the East Mediterranean region of Turkey are well adapted to temperatures between 20 and 27.5 ^{o}C, showing a high capita growth rate within this temperature range. Temperatures below or above this range (between 20 and 27.5^{o}C) result in drastically reduced population growth, and temperatures over 30 ^{o}C are lethal to nymphs of the cabbage aphid. (Hemmati *et al*., 2001b), (Baverstock *et al*., 2005a) and (Siegfried Keller, 2007) stated that infected aphids die when conditions are humid, cool and free from ultra-violet radiation. The time to kill is dependent on temperature; in *Aphid pisum*, infection did not occur at 0 ^{0}C or at 30 ^{0}C and the time to kill varied from 5 to 16 days at 20 and 10 ^{0}C, respectively.

A number of a biotic and biotic mortality factors interacting together that affect the natural intergeneration population dynamics of *P. xylostella*. Climatic conditions were cited as major factors which regulate the population dynamics of *P. xylostella* (Shelton, 2001). The present finding also showed that maximum humidity adversely affected the population of *P. xylostella*. It was confirmed by (Talekar and Shelton, 1993)\. Ahmad, and Ansari, (2010) reported that density of *P. xylostella* decreased down slowly. (Bahar *et al*., 2012) and (Munir *et al*., 2015) stated that the development of *P. xylostella* was very slow at lowest constant (7 ℃) and fluctuating temperatures (0-14 ℃) while fast development of *P. xylostella* was recorded at highest constant (30 ℃) and fluctuating temperatures (23-30 ℃)**.**

Survey of natural enemies (natural microorganisms) affecting population density of cabbage pests

Natural organisms which affecting cabbage pests and population density were collected and identified during the experimental season 2014/2015. Many of the fungi and one of bacterium that were infecting the larvae and/or pupa were also unable to be isolated and identified. Data in Table (4) showed that, all pest species are attacked by various entomopathogenic fungi, which can affect their pest status to varying degrees. Naturally occurring entomopathogenic fungi have also been shown to occasionally cause high mortality of pest larvae or pupa. Six fungal genera belonging to eight fungal species and one bacterium were isolated and identified which are considered epizootic to brassica pests, *Pieris rapae* (white butterfly), *Brevicoryne brassicae* L. (cabbage aphid) , *Plutella xylostella* (diamondback moth) and *Spodoptera exigua* (Beet army worm) Fig. (4). These are *Aspergillus niger* which record (0.89%), *A. flavus* record (0.89%), *A. parasiticus* record (0.29%), *Beauveria bassiana* record (1.58%), *Fusarium* sp. record (0.69%), *Metarhizium anisopliae* record (72.0%), *Mucor* sp. record (0.99%) and *Rhizopus* sp. record (19.8%) in addition the bacterium *Bacillus thuringiensis* which record (2.77%). During this survey, the incidences of identified entomopathogenic fungi were found to be high i. e. *Metarhizium anisopliae* while the incidence bacterium *Bacillus thuringiensis* was low. Also, this survey show some deaths may have been caused by secondary infections as *Aspergillus niger, A. flavus, A. parasiticus, Fusarium* sp., *Mucor* sp. and *Rhizopus* sp. High humidity and high host populations are important prerequisites for the occurrence of naturally occurring epizootics of the specialist brassica pests, *Pieris rapae* (white butterfly), *Brevicoryne brassicae* L. (cabbage aphid) and *Plutella xylostella* (diamondback moth), *Spodoptera exigua* (Beet army worm).

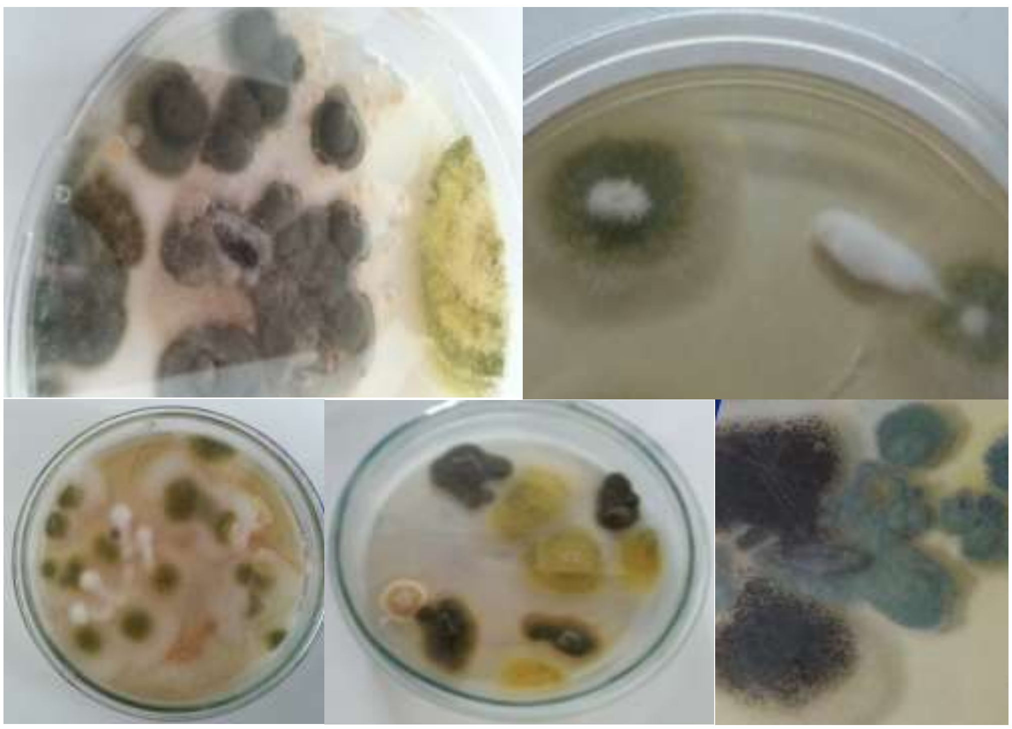

Figure 4. Naturally occurring entomopathogenic fungi which occasionally cause high mortality of pest larvae or pupa of *P. xylostella*.

Table 4. Percentage of natural microorganisms affecting the population density of cabbage pests.

Microbial isolates		Type of insect												Total
		Aphid *Brevicoryne Brassicae L.*			**Cabbage worm** *Pieris rapae* L.			**Diamondback moth** *Plutella Xylostella* L.			**Beet army worm** *Spodoptera exigua L.*			
		A	L	P	A	L	P	A	L	P	A	L	P	
Aspergillus niger	Tc	2	NF	NF	NF	NF	NF	NF	3	4	NF	NF	NF	9
	%	0.19	0.0	0.0	0.0	0.0	0.0	0.0	0.29	0.39	0.0	0.0	0.0	0.89
A. flavus	Tc	NF	NF	NF	NF	NF	NF	NF	NF	3	NF	NF	6	9
	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.29	0.0	0.0	0.59	0.89
A. parasiticus	Tc	NF	NF	NF	NF	NF	NF	NF	NF	3	NF	NF	NF	3
	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.29	0.0	0.0	0.0	0.29
Beauveria bassiana	Tc	NF	NF	NF	NF	3	NF	NF	NF	13	NF	NF	NF	16
	%	0.0	0.0	0.0	0.0	0.29	0.0	0.0	0.0	1.28	0.0	0.0	0.0	1.58
Fusarium spp.	Tc	NF	NF	NF	NF	1	NF	NF	NF	6	NF	NF	NF	7
	%	0.0	0.0	0.0	0.0	0.09	0.0	0.0	0.0	0.59	0.0	0.0	0.0	0.69
Metarhizium anisopliae	Tc	500	NF	NF	NF	32	NF	NF	4	190	NF	NF	NF	726
	%	49.6	0.0	0.0	0.0	3.17	0.0	0.0	0.39	18.8	0.0	0.0	0.0	72.0
Mucor sp.	Tc	10	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	10
	%	0.99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.99
Rhizopus sp.	Tc	30	NF	NF	NF	110	NF	NF	60	NF	NF	NF	NF	200
	%	2.97	0.0	0.0	0.0	10.9	0.0	0.0	5.95	0.0	0.0	0.0	0.0	19.8
Bacillus thurigensis	Tc	NF	NF	NF	NF	NF	NF	NF	NF	28	NF	NF	NF	28
	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.77	0.0	0.0	0.0	2.77
Total	Tc	542	NF	NF	NF	146	NF	NF	67	247	0	0	6	1008
	%	53.76	0.0	0.0	0.0	14.48	0.0	0.0	6.64	24.5	0	0	0.59	100

TC= Total colonies NF = Not found
A = Adult L = Larvae P = Pupae

Tomiyama, and Aoki (1982) stated that the ecology of DBM, including the effects of natural enemies. Most references are related to infection by fungi of the family Entomophthoraceae and one of infection by the bacterium *Bacillus thuringiensis*. The larvae and less frequently the pupae of *Plutella xylostella* (L) are sometimes attacked naturally by pathogens, particularly two fungi of the family Entomophthoraceae, *Erwynia blunckii* and *Zoophthora radicans*. Other pathogens recorded include one other entomophthoraceous fungus, and *Bacillus thuringiensis* var kurstaki. (Hall and Papierok, 1982) and (Tomiyama, and Aoki, 1982) reported that some fungi are highly infective for DBM and cause an important natural mortality. *Zoophthora radicans* (Brefeld) (=Entomophthora sphaerosperma) (Phycomycetes: Entomophthoraceae) infects insects from several orders and is a widespread pathogen of DBM attacking usually the larvae but also sometimes the pupae**.** Larvae killed by this fungus are attached to the substrate by strong rhizoids emerging along the ventral surface of the abdomen**.**

Conclusion

All the microbial insecticides can be intensively used without any possibility of development of resistance. In view of their specificity and safety, there will be at least environmental, ecological and health hazards. Microbial pesticide would offer a new method to control insecticide resistant pest population could prevent the rise of secondary pest problems, extend of chemical insecticides, while protected the efforts and investment of the farmers and help in organic – production of vegetables, fruits and pulses etc. for domestic consumption and export**.** Also, microbial pesticides are safe to mankind and animals, do not pollute the environment, do not kill beneficial parasites and predators and generally pests do not develop resistance to these microbes. In microbial management pathogens are utilized which may be virus, bacteria, fungi, protozoans and nematodes. Use of these pathogens may vary considerably between crops and locations depending upon climate, symptomatology and economic threshold of crop damage. Entomophthoralean fungi are very important natural mortality factors in arthropod populations that interact with other natural enemies in positive and negative ways**.**

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