Uganda Journal of Agricultural Sciences, 2003, 8 : 67 - 74 ISSN 1026-0919
Printed in Uganda
© 2003 National Agricultural Research Organisation

Effects of cotton inter-cropping systems on establishment and biological control efficacy of the Lepisiota spp predator ant on major insect pests

Ogwal,S. Epieru, G. Bwarogeza,M and V. Acom
Serere Agricultural and Animal Production Research Institute (SAARI)
P.O Private Mail Bag, Soroti, Uganda
Telephone: 077611774/077702553
Fax: 077250553, E-mail: saaridir@infocom.co.ug

Abstract

Studies were conducted along Otwal-Amuria transect and at Serere Agricultural and Animal Production Research Institute (SAARI) to establish choice and preference, host association and ecological conditions necessary for establishment and biological insect pest management by the predatory ants *Lepisiota* spp on major cotton insect pests. Survey results showed that this particular species of ants was only present in Otwal subcounty in Apac district, Aromo and *Ogur* sub-counties in Lira district numbering 128.3, 70.9 and 68.8 ants per trap catch respectively. The survey showed that the ants prefer particular environmental conditions for their survival and insect pest management effectiveness. This restricted occurrence could also be a result of restrictions on the use of agricultural chemicals like insecticides in the study areas through Lango Organic Promotion. Inter-cropping results showed that ant response to artificial food bait was highest in plots with sole cotton, sorghum, hibiscus and maize inter-crops. Ant trap catches were negatively correlated with aphid infestation level. This indicated that for good early establishment, rapid population build-up and effectiveness a food bait for aphids like legumes should be inter-cropped with cotton. No-choice tests showed that these ants feed on all stages of bollworms, Lygus and stainer bugs with a preference to younger stages. Choice tests showed that the ants preferred bollworms. Yield results showed that although pest management by these predators were good on legume inter-crops, the low yields realized from cowpea, maize and sorghum inter-crops were mostly due to their suppressive effects on cotton.

Key words: *Lepisiota spp*, inter-cropping, predator ant, biological control, stainer bugs, bollworms, cotton, aphids, pest management, Lygus

Introduction

Cotton is a major fiber export crop for Uganda, grown in 33 districts. A major constraint in its production is the four mid-late season insect pests namely the American bollworm *Helicovepa armigera,* the Pink bollworm *Pectinophora gossypiella,* and the Spiny bollworm *Earias insulana* and Stainer bugs *Dersidercus* spp. These insect pests of cotton cause varying quantitative and qualitative losses depending on time of planting, soil fertility status and the ecological environment. Control of these pests in Uganda and worldwide has depended on the use of chemical insecticides. The use of insecticides contributes greatly to the cost of production at the farm level, thus making cotton production un economic at the farm level. To be able to make profit from world market price of cotton lint, there is a need to cut down the cost of production by adopting insect pest management techniques that can minimize the use of chemical insecticides. One of the approaches adopted is the use of the predatory black ants of the *Lepisiota spp* in the Lango Farming System through Lango Organic Farming Promotion. The presence and abundance of these ants have been associated with good yields of cotton during the production season although without knowledge on their role in cotton production. With this indegineous knowledge in mind, there was a need to investigate the roles of these ants and the ecological requirements for their establishment and biological effectiveness.

Inter cropping cotton with food crops such as bush beans, groundnuts, and soya beans is a normal and recommended practice in the Lango Farming system.. Among the advantages cited for intercropping in general are providing the farmer with both food and cash, saving on land and labour, reducing risks and uncertainties due to biotic and abiotic factors, improvement of soil fertility with nitrogen fixing legumes, and reduction in soil loss by providing ground cover.

In many agroecosystems, landscape structural diversity has been greatly simplified and insect communities are dominated by pest species (Marino and Landis, 1996). Studies have shown that increasing structural diversity in agroecosystems results in a greater diversity of both pests and beneficial insects and often less damage by pests. This is true with inter-cropping, under-cropping field crops with ground cover, promoting a weedy background,) and having a larger between-field scale.

The increase in insect diversity with increasing structural diversity appears to result from two correlated factors: increased plant species diversity and increased plant architectural complexity (Marino and Landis, 1996).

The objectives of this study were:

a) To survey and map out areas of occurrence and abundance of the *Lepisiota* spp ant species
b) To determine and come-up with a catalogue of cotton and other crop pests managed by the ants
c)To investigate the effects of different cotton inter-cropping systems on establishment of the ants their and biological effectiveness in pest management.

Although work was carried out in Otwal-Amuria transect and at Serere Agricultural and Animal Production Research Institute (SAARI), this paper gives the progress of the work along the transect.

Materials and methods

This study that was initiated in May, 1999 and is being conducted in three phases.

Phase 1 Survey on occurrence and abundance of the predator.

This survey was conducted along a transect cutting across Lango and Teso Farming systems having contrasting cropping systems, climate, soils and vegetation. The transect runs from Otwal in Apac through Aromo – Ogur – Apala – Aloi – Omoro – Obalanga up-to Kuju in Amuria, Katakwi district with a total distance of about 150 km. Ten sites were selected at almost equal distances, 15 km apart. At each site, one farmer was selected as a replicate with fields that are representative of the area.

Around each of the selected fields for other ecological studies, 10 baits of fish meal in 40 mm diameter test tubes were placed round the fields at equal distances with improvised maize cob lids with circular holes (3mm diameter) in the middle small enough to allow access to surface moving ants and to exclude other large predators. The test tubes were put in made holes and the ground around the glass vials were slightly compacted and smoothed so that the rim was not protruding. For 24 hours, these baits were picked and place individually in polythene bugs. The trapped insects were demobilized by placing the vials in a deep freezer for 12 hours. Black ants of that species in each vial were separated and counted and the numbers recorded against each vial and site.

Phase 2 Choice and no choice feeding tests

To assess and draw a catalogue of insect pests of cotton which are preys to these ants, a no choice feeding test was conducted using field collected ants from the transect and fed artificially on fish, meat and chicken meals prior to the tests in the laboratory. Assessment was done by placing the ants on petri-dishes with covers and water supplied to them by absorbent cotton wool. The ants in petri dishes were starved for 12 hours but supplied with water. To ascertain whether or not these ants feed on the bollworms (Helicoverpa armigera, Pectinophora gossypiella and Earias *insulana)*, *Lygus bug (Taylorilygus vosseleri)* and Stainer bugs *(Desydercus spp)*, field captured insect pests above were fed to them in four replicates. Choice and preference studies were conducted as above but putting all the major pests in one petri dish and taking counts from above the transparent petri dish cover.

Phase 3 Cotton Inter-cropping studies.

This study was designed to evaluate the predatory black ant in augmentative release against major cotton insect pests. The trials were conducted along the selected Otwal – Omoro transect and at SAARI using inoculation with field trapped ants, which later spread naturally. At both SAARI and along the transect, treatments included sole cotton spaced at 75 x 15 cm; cotton at a spacing of 75 cm by 15 cm and inter-cropped separately with beans, cowpeas, and groundnuts and at a spacing of 300 x 100 cm intercropped separately with maize, sorghum and *Hibiscus*. These treatments were replicated four times at SAARI and the ten sites along the transect formed the replicates. Plot size was 30 by 22.5 m. Weeding was done as required and insecticide application was prohibited. Record taking was started 45 days after cotton planting for aphids *Aphis gossypiella* and 60 days for Lygus and bollworms.

Aphid counts were made from 30 randomly selected plants per plot by observing and counting nymphs and adults from the first 5 open leaves and number recorded against that plant number. Bollworm scouts were made on the leaves, squares, flowers and bolls of 100 randomly selected plants per plot. The species and number of bollworms were recorded. Lygus infestation was monitored by the use of a sweep net. A total of 50 sweeps

per treatment were made each time records were taken. The trapped insects were put in the polyethylene bugs and demobilized by putting them in a deep freezer for 12 hours before counting. All the harvested cotton was weighed and yield determined.

Results and discussion

The survey showed that black ants of the Lepisiota spp was only present in Otwal subcounty in Apac district, Aromo and Ogur sub-counties in Lira district, numbering 128.3,70.9 and 68.9 ants per trap respectively.

Table 1a: Mean Black ant Lepisiota spp trap catches over time under different cotton inter-cropping systems for 1999/2000 season

Cropping system	Weeks after planting cotton								
	6	7	8	9	10	11	12	13	14
Cotton x Beans	19.50	12.25	16.00	15.25	30.75	25.25	18.25	16.50	26.50
Cotton x Hibiscus	26.75	15.25	12.75	23.75	32.75	19.75	15.25	17.50	29.50
Cotton x G'nuts	29.50	17.00	25.50	18.50	31.00	15.00	11.25	18.75	40.50
Cotton x Sorghum	23.50	14.75	13.50	28.00	22.50	14.50	9.25	20.75	28.50
Cotton x Cowpea	18.25	16.50	9.75	16.00	14.25	13.25	10.50	20.00	47.50
Cotton x Maize	13.75	11.25	8.00	12.75	19.50	10.25	9.00	19.75	20.75
Sole cotton(control)	20.25	18.50	15.75	30.75	19.50	18.50	13.50	28.00	43.25
Weekly means	**18.94**	**13.19**	**12.66**	**18.13**	**21.28**	**14.56**	**10.88**	**17.66**	**29.56**

Table 1b: Mean Black ant Lepisiota spp trap catches over time under different cotton inter-cropping systems for the 2000/1 season.

Cropping system	Weeks after planting cotton							
	6	7	8	9	10	11	12	13
Cotton xBeans	6.75	5.00	3.25	3.75	2.50	5.00	11.75	10.25
Cotton x Hibiscus	13.50	7.25	4.00	6.25	2.25	4.25	17.00	9.25
Cotton x G'nuts	11.00	7.25	4.25	5.25	2.75	3.50	11.75	12.25
Cotton x Sorghum	6.00	3.75	2.50	3.50	1.75	3.50	9.25	8.25
Cotton x Cowpea	1.75	3.50	2.75	3.50	1.50	6.25	31.00	12.75
Cotton x Maize	4.50	5.25	0.25	6.50	1.25	2.75	4.25	10.50
Sole Cotton (control)	6.50	8.00	8.75	9.50	3.00	4.75	14.75	9.50
Weekly means	**6.25**	**5.00**	**3.22**	**4.78**	**1.88**	**3.75**	**12.47**	**9.09**

Table 2a: Mean Aphis gossypii count per 5 top open leaves over time under different cotton inter-cropping systems for the 1999/2000 season

Cropping system	Weeks after planting cotton								
	6	7	8	9	10	11	12	13	14
Cotton x Beans	3.62	4.73	2.30	2.43	2.83	4.90	1.74	4.09	4.68
Cotton x Hibiscus	3.65	4.00	1.43	1.56	1.19	3.58	1.70	3.13	3.05
Cotton x G'nuts	5.87	6.91	2.32	1.96	0.89	5.72	1.05	3.14	4.31
Cotton x Sorghum	1.32	6.00	0.80	2.23	0.77	3.58	1.29	2.88	3.46
Cotton x Cowpea	*6.58*	*3.92*	*1.03*	*1.62*	*1.28*	*2.78*	*1.50*	*3.49*	*3.45*
Cotton x Maize	*6.62*	*4.53*	*1.29*	*1.36*	*1.00*	*3.38*	*1.08*	*2.46*	*3.05*
Sole cotton (control)	5.70	5.18	1.53	1.25	1.61	4.11	1.95	2.95	3.75
Weekly means	**4.17**	**4.41**	**1.34**	**1.55**	**1.20**	**3.51**	**1.29**	**2.77**	**3.22**

Table 2b: Mean Aphis gossypii count per 5 top open leaves over time under different cotton cropping systems for the 2000/1 season

Cropping system	Weeks after planting cotton								
	6	7	8	9	10	11	12	13	14
Cotton x Beans	0.64	1.03	0.68	1.30	1.04	1.68	2.12	1.04	1.35
Cotton x Hibiscus	1.91	0.42	0.39	1.22	1.13	1.55	1.18	0.87	1.84
Cotton x G'nuts	1.40	0.82	0.18	1.12	0.88	0.79	1.71	0.83	1.29
Cotton x Sorghum	0.94	0.79	0.31	1.07	1.29	1.42	1.71	0.76	0.90
Cotton x Cowpea	1.58	0.93	0.38	1.54	1.37	2.04	2.20	1.57	2.34
Cotton x Maize	0.83	0.99	0.63	2.13	0.94	1.22	1.63	0.96	0.78
Sole cotton (control)	1.02	0.83	0.30	1.33	0.78	1.58	2.03	1.37	1.54
Weekly means	**1.04**	**0.73**	**0.36**	**1.21**	**0.93**	**1.29**	**1.57**	**0.93**	**1.26**

Table 3a: Mean bollworm counts from 100 plants over time under different cotton cropping systems for the 1999/2000 season

Cropping system	Weeks after planting cotton								
	9	10	11	12	13	14	15	16	17
Cotton x Beans	0.00	0.25	0.00	0.50	1.00	1.50	0.50	0.75	8.00
Cotton x Hibiscus	0.00	0.00	0.00	1.00	0.75	0.25	1.00	0.25	6.25
Cotton x G'nuts	0.00	0.00	0.50	0.00	1.00	0.50	0.00	0.00	1.50
Cotton x Sorghum	0.00	0.25	0.50	0.75	1.50	1.00	0.50	0.25	9.00
Cotton x Cowpea	0.00	0.50	0.25	0.75	0.50	1.00	0.25	0.25	5.00
Cotton x Maize	0.25	0.00	0.00	0.75	0.75	1.00	1.25	0.50	5.25
Cotton control	0.00	0.00	0.00	0.75	1.25	0.75	1.00	0.25	3.50
Weekly means	**0.03**	**0.13**	**0.16**	**0.56**	**0.84**	**0.75**	**0.56**	**0.28**	**4.81**
ETL	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**

Table 3b: Mean bollworm counts from 100 plants over time under different cotton cropping systems for the 2000/1 season

Cropping system	Weeks after planting cotton								
	9	10	11	12	13	14	15	16	17
Cotton x Beans	0.25	0.75	2.00	2.50	4.00	2.00	3.75	3.50	3.50
Cotton x Hibiscus	0.00	0.75	3.25	1.25	2.25	1.25	1.75	4.50	4.00
Cotton x G'nuts	0.25	0.50	1.00	2.33	0.0.50	2.75	3.50	6.50	5.00
Cotton x Sorghum	0.25	0.75	3.75	3.50	2.00	2.00	4.00	5.50	3.50
Cotton x Cowpea	0.50	1.25	2.50	3.50	0.50	0.75	3.25	4.00	3.00
Cotton x Maize	1.75	0.25	1.50	2.25	1.25	1.50	3.25	3.50	3.50
Cotton control	0.25	1.00	1.25	4.25	2.00	2.00	3.50	7.75	6.25
Weekly means	**0.41**	**0.66**	**1.91**	**2.45**	**1.56**	**1.53**	**2.88**	**4.41**	**3.59**
ETL	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**

Choice feeding tests showed that the ants feed on all stages of bollworms, Lygus and stainers with preference towards younger stages. Choice tests showed among the major insect pests of cotton tested, the ants prefer bollworms. This behavior can be seen from Table 4b where Lygus sweep net catches in sole cotton (control), maize, sorghum, hibiscus went beyond economic threshold level ETL of 15 Lygus /50 sweeps particularly in the last four weeks of assessment, due to low population of ants. These results also showed that these ants were not very effective in managing Lygus probably due to their high mobility. This could mean that these ants generally are poor bio-control candidates for flying insects as compared with bollworms Tables 3a and 3b

Cotton yield results in Table 5 show that although there was good insect pest management in legume inter-crops, the low yields released from cowpea, maize and sorghum inter-crops were most likely due to the intercrop suppressive effects on the cotton.

Field-testing is an important step in evaluating natural enemies for biological insect pest management. To establish the potential of any candidate, convincing empirical demonstrations are essential. They are needed to determine ecological conditions for effectiveness, confirm climatic adaptability and establish compatibility with all conditions imposed by the particular situation, especially when plant productivity requires multiple phyto-protection measures as in most agricultural systems.

Table 4a: Mean Lygus counts from 50 sweeps over time under different cotton cropping systems for the 1999-2000 season

Cropping system	Weeks after planting cotton							
	9	10	11	12	13	14	15	16
Cotton x Beans	0.00	0.00	0.00	5.75	6.50	6.25	2.75	2.00
Cotton x Hibiscus	0.00	0.00	0.00	6.75	6.50	5.00	1.25	3.75
Cotton x G'nuts	0.00	0.00	0.00	5.25	5.00	4.00	1.00	2.25
Cotton x Sorghum	0.00	0.25	0.00	6.75	6.25	3.75	0.50	1.75
Cotton x Cowpea	*0.00*	*0.00*	*0.00*	*4.25*	*6.75*	*3.00*	*1.75*	*2.50*
Cotton x Maize	*0.00*	*0.00*	*0.00*	*7.25*	*5.50*	*4.75*	*0.75*	*2.00*
Cotton control	0.00	0.00	0.00	4.25	4.50	5.00	0.75	2.75
Weekly means	**0.00**	**0.03**	**0.00**	**5.03**	**5.13**	**3.97**	**1.09**	**2.13**
ETL	**15.00**	**15.00**	**15.00**	**15.00**	**15.00**	**15.00**	**15.00**	**15.00**

Table 4b: Mean Lygus counts from 50 sweeps of over time under different cotton cropping systems for the 2000/1 season

Cropping system	Weeks after planting cotton								
	9	10	11	12	13	14	15	16	17
Cotton x Beans	5.25	3.00	5.00	14.00	11.75	16.00	22.50	15.50	11.75
Cotton x Hibiscus	7.00	6.25	8.25	16.75	11.25	20.00	20.25	16.50	13.50
Cotton x G'nuts	13.50	9.00	8.25	15.67	9.25	20.75	25.50	22.75	22.75
Cotton x Sorghum	7.00	7.25	5.50	11.75	10.50	11.25	20.00	15.25	14.00
Cotton x Cowpea	4.25	3.50	4.50	13.75	10.50	9.25	12.00	13.50	12.25
Cotton x Maize	4.50	8.00	3.50	15.75	6.00	16.75	19.50	18.00	14.25
Sole cotton (control)	7.75	8.00	4.75	12.50	10.00	17.00	27.25	24.75	24.50
Weekly means	**6.16**	**5.63**	**4.97**	**12.52**	**8.66**	**13.88**	**18.38**	**15.78**	**14.13**
ETL	**15.00**	**15.00**	**15.00**	**15.00**	**15.00**	**15.00**	**15.00**	**15.00**	**15.00**

Table 5: Mean seed cotton yields under different cotton cropping systems

Cropping system	Seed cotton yield (kg/ha)
Cotton x Hibiscus	1400 b
Cotton x Ground nuts	1460 b
Cotton x Cowpea	989 c
Sole cotton (Control)	1789 a
Cotton x Sorghum	1075 c
Cotton x Maize	1083 c
Cotton x Beans	1504 b
Grand mean	**1328.57**

Figures in the same column with the same letter are not significantly different from one SED = 91.5
another

(P = 0.05)
C.V (%) rep = 5.0
C.V (%) rep x units = 9.7
Prob. = 0.001

This survey showed that these ants prefer particular conditions for occurrence and biological insect pest management effectiveness. This restricted occurrence could also be a result of the restriction on the use of chemicals on all crops by Lango Organic promotion using their deployed staff at parish level.

These findings indicated that to use Lepisiota spp ants as biological control agents against cotton insect pests, the above legumes which are a bait for aphids should be inter-cropped with cotton to encourage early field establishment and population increase. In a similar study, Weseloh (1995) experimentally manipulated ant numbers in a forest where Gypsy moths were scarce and found that moth larvae numbers were inversely related to ant numbers. In an attempt to induce ants to climb trees he used sugar sprays to attract them, similar to honeydew (presence of aphids) in this experiment.

Ants forage on trees mainly to obtain honeydew and other simple carbohydrates by concentrating around. Several studies showing that ant tending Homoptea benefit plants by interfering with herbivores (Mahdi and Whittaker, 1993)

In recent years, there has been great concern about the loss of bio-diversity in managed forests and agricultural ecosystems (Esseen and Renhorn, 1996). This has resulted in a growing need to develop management techniques that can maintain a large fraction of the original bio–diversity while sustaining a continued supply of commercially valuable forest and agricultural products. One method with large potential to learn from is the patterns and processes that regulate species occurrence and behavior in natural forests. Beneficial insects are sensitive to environmental disturbances and habitat destruction. Due to their sensitivity to disturbance, natural enemies have proved to be useful as indicators of agricultural community in both tropical and temperate areas.

Results and discussion

The survey showed that black ants of the Lepisiota spp was only present in Otwal subcounty in Apac district, Aromo and Ogur sub-counties in Lira district, numbering 128.3,70.9 and 68.9 ants per trap respectively.

Ant trap catches from legume inter-crops increased later in the season. This increase could have been a result of aphid migration as the legume inter-crop matures leaving ants with no alternative food source other than the bait. The increase in number of black ants in relation to artificial food bait was highest in plots planted with sole cotton, or cotton intercropped with sorghum, Hibiscus and maize (Tables 1 and 1b). This high response was associated with low aphid counts in these treatments.(Tables 2a and 2b). Low response to the food bait especially on cowpea, groundnut and beans inter-crop was due to the heavy infestation of these legumes by aphids, as these ants feed on aphid honey dew as an alternative food source.

Tables 2a and 2b showed that there were more aphids on cotton in 1999/2000 season than in the 2000/1 season. These differences could have been due to rainfall intensity as aphids suffer from rain wash. There were more aphids on sole cotton and sorghum inter-crop as compared with inter-crops with legumes. This abundance was shown to correlate negatively with ant response to artificial food bait.

Choice feeding tests showed that the ants feed on all stages of bollworms, Lygus and stainers with preference towards younger stages. Choice tests showed among the major insect pests of cotton tested, the ants prefer bollworms. This behavior can be seen from Table 4b where Lygus sweep net catches in sole cotton (control), maize, sorghum, hibiscus went beyond economic threshold level ETL of 15 Lygus /50 sweeps particularly in the last four weeks of assessment, due to low population of ants. These results also showed that these ants were not very effective in managing Lygus probably due to their high mobility. This could mean that these ants generally are poor bio-control candidates for flying insects as compared with bollworms Tables 3a and 3b.

Cotton yield results in Table 5 show that although there was good insect pest management in legume inter-crops, the low yields released from cowpea, maize and sorghum inter-crops were most likely due to the intercrop suppressive effects on the cotton.

Field-testing is an important step in evaluating natural enemies for biological insect pest management. To establish the potential of any candidate, convincing

empirical demonstrations are essential. They are needed to determine ecological conditions for effectiveness, confirm climatic adaptability and establish compatibility with all conditions imposed by the particular situation, especially when plant productivity requires multiple phyto-protection measures as in most agricultural systems.

This survey showed that these ants prefer particular conditions for occurrence and biological insect pest management effectiveness. This restricted occurrence could also be a result of the restriction on the use of chemicals on all crops by Lango Organic promotion using their deployed staff at parish level.

These findings indicated that to use Lepisiota spp ants as biological control agents against cotton insect pests, the above legumes which are a bait for aphids should be inter-cropped with cotton to encourage early field establishment and population increase. In a similar study, Weseloh (1995) experimentally manipulated ant numbers in a forest where Gypsy moths were scarce and found that moth larvae numbers were inversely related to ant numbers. In an attempt to induce ants to climb trees he used sugar sprays to attract them, similar to honeydew (presence of aphids) in this experiment.

Ants forage on trees mainly to obtain honeydew and other simple carbohydrates by concentrating around. Several studies showing that ant tending Homoptea benefit plants by interfering with herbivores (Mahdi and Whittaker, 1993)

In recent years, there has been great concern about the loss of bio-diversity in managed forests and agricultural ecosystems (Esseen and Renhorn, 1996). This has resulted in a growing need to develop management techniques that can maintain a large fraction of the original bio–diversity while sustaining a continued supply of commercially valuable forest and agricultural products. One method with large potential to learn from is the patterns and processes that regulate species occurrence and behavior in natural forests. Beneficial insects are sensitive to environmental disturbances and habitat destruction. Due to their sensitivity to disturbance, natural enemies have proved to be useful as indicators of agricultural community in both tropical and temperate areas.

Conclusion

This study showed that the predatory ants can be used beneficially to manage mostly Lepidopteran insect pests. Inter-cropping cotton with legumes like beans, cowpeas, and groundnuts boost ant population with good pest management. This has made cotton farmers get premium cotton price together with food increase profit margin as chemical pest control is forfeited.

References

Esseen, P and Renhorn, K 1996. Epiphytic Lichen biomass in managed and old –growth boreal forests: Effect of branch quality. *Ecological applications*, Vol. 6 (1): 228-232.

Mahdi, T. and J. B. Whittaker, J.B 1993. Do birch trees (Bell) grow better if foraged by wood ants ? *Journal of annual ecology*, Vol. 62: 101 –116.

Marino, P.C. and Douglas A. Landis, D.A. 1996. Effect of landscape structure on parasitoid diversity and parasitism in agroecosystems. *Ecological applications*, Vol. 6 (1): 276-284.

Weseloh, R M 1995. Ant traffic on different tree species in Connecticut. *The Canadian Entomologist*, .Vol. 127 (4): 569-575.