

JOURNAL OF APPLIED ZOOLOGICAL RESEARCHES



Vol. 31 No.1
JUNE 2020

ABSTRACTING IN BIOLOGICAL ABSTRACTS (USA), CAB ABSTRACTS (U.K.),
BIOSIS PREVIEWS (USA, CAB HEALTH (U.K.), INSDOC/NISCAIR (INDIA)

website : www.azra-india.com

APPLIED ZOOLOGISTS RESEARCH ASSOCIATION (AZRA)

Regd. Office: K-9B/285 Bhagabanpur, Patrapada,
Bhubaneswar-751 019, Odisha, India

Executive Council (2020-2025)**President**

Dr. B. Vasantharaj David (Chennai)

Vice Presidents

Dr. (Mrs.) Jagadiswari Rao (H.Q.)

Dr. J. K. Sundaray (Bhubaneswar)

Prof. Digvir S. Jayas (Canada)

Prof. A. G. Sreenivas (Raichur)

Prof. R.W. Alexander Jesudasan (Chennai)

Dr. A. Sujatha (Venkataramana Gudem)

General Secretary

Dr. Anand Prakash (H.Q.)

Secretary Foreign Affairs

Er. Biswa Prakash (Maine, USA)

Editor-in-Chief

Prof. Damodar Satapathy (Berhampur)

Joint Secretaries

Prof. L. K. Rath (Bhubaneswar)

Dr. Lakshman Sahoo (Bhubaneswar)

Treasurer

Dr. K. S. Behera (Cuttack)

Councillors

Prof. S.K. Shrivastava (Durg)

Dr. K. Revathi (Chennai)

Prof. B. Bharatha Lakshmi (Visakhapatnam)

Dr. S. S. Mishra (Lucknow)

Prof. R.N. Ganguli (Raipur)

Dr. Mohd. Arif (Allahabad)

Prof. P. Nagaraja Rao (Hyderabad)

Dr. Santosh K. Srivastava (Bhubaneswar)

Prof. C. S. K. Mishra (Bhubaneswar)

Dr. Arup Mukherjee (Cuttack)

Miss Jayashree Prakash (H.Q.)

Dr. M. K. Bag (Cuttack)

Mr. G. Krishna Rao (Bhubaneswar)

Dr. Tribikram Samal (Bhubaneswar)

Dr. P. N. Anantha (Khordha)

Dr. Rajasekhara Rao Korada (Bhubaneswar)

Dr. Murmu Khuntia (Bhubaneswar)

Dr. Gayatri Biswal (Bhubaneswar)

Dr. Satyanayayana Sethi (Bhubaneswar)

Dr. Srikanta Lenka (Cuttack)

Dr. Suresh Chand (Kolkata)

Dr. Sushil Kumar (Navasari)

AZRA is constituted to provide more opportunities to advance and integrate researches in the field of applied zoology. AZRA publishes a biannual **Journal of Applied Zoological Researches** since 1990. The membership is open to all active workers in the field of applied zoology to any nationality. Besides the amount of Rs 50/- (US\$ 5/-) as an entrance fee, individual annual membership is Rs 500/- (India) and US \$ 30/- (abroad). Annual Institutional Membership is Rs 1000/- (India) & US \$ 50/- (abroad). Individual Life Membership in India is Rs. 5000/- & US \$ 700/- (abroad). Remittances may be made through **online money transfer** in account of **Applied Zoologists Research Association, Account No. 10329386022, State Bank of India, Naya Bazar, Cuttack**, Bank Code: 02094; IFS Code: SBIN0002094 (Swift); MICR-753002016. All correspondence on membership subscription, publications etc. are to be made to Dr. Anand Prakash, General Secretary, AZRA, K-9B/285, Bhagabanpur Patrapada, Bhubaneswar-751019, Odisha, India. Email: prakas52@yahoo.com & M-09337110294.



EVOLUTION OF MODERN INSECT CLASSIFICATION: A COMPREHENSIVE ACCOUNT

RAHUL KUMAR¹, SHASHANK, P.R.^{1*} NARESH, M. MESHRAM¹, ANOOJ, S. S.¹ AND KOLLA SREEDEVI²

1= Division of Entomology, ICAR- Indian Agricultural Research Institute, Pusa Campus, New Delhi-110 012, India

2= Division of Germplasm Collection and Characterization, ICAR-National Bureau of Agricultural Insect Resources, Hebbal, Bellary Road, Bengaluru – 560 024, India

*Email ID: spathour@gmail.com (corresponding author)

Received: 18 December, 2019

Accepted: 31 March, 2020

ABSTRACT: Insects are the most numerous and diverse group of animals in the entire animal kingdom. Insect classification has evolved in different phases over a considerable period of time. There are four different phases or eras, viz., the Pre-Linnean Era, the Linnean Era, the Darwinian Era, and the Hennigian Era and other developments. Among all eras the Hennigian Era marks a revolutionary shift in classification of insects with introduction of Phylogenetic Systematics that strictly considers monophyly of different taxa to decide their respective positions within the tree of classification. Modern classification of insects is based on knowledge gained from multiple sources like Anatomy, Paleontology, Molecular Biology, and Embryology leading to a more natural and reliable classification scheme. Modern classification of insects also reflects their phylogeny. With new findings and advent of new technologies there is always a scope of change in the existing framework of insect classification in future.

KEY WORDS: Classification, Insecta, Monophyly, Phylogeny, Systematics

INTRODUCTION

Being the most evolutionary successful animals on the planet Earth and the most diverse ones, insects were never easy to classify. Insect classification has evolved through hundreds of years. With advent of new technologies, use of molecular tools and discovery of new fossil records, insect classification has been revised from time to time. The evolution of modern classification of insects is often studied under four subheadings as given by ENGEL and KRISTENSEN (2013). These subheadings demarcate different stages of progress in insect classification that is based on the timeline of a set of changes and progression, hence are called **eras**. These stages are: the Pre-Linnean Era, the Linnean Era, the Darwinian Era, and the Hennigian Era and other developments (ENGEL and KRISTENSEN, 2013). With transition of one era into another, the misconceptions of previous one were discarded and crude ideas were more refined with more number of evidences, trying to make the classification system as natural as possible minimizing all sorts of artificialities. A list of important literary contributions from past on insect classification is provided in Table-1 in chronological order.

The Pre-Linnean Era

The most primitive evidence on insect classification comes from the writings of Aristotle (384-322 BC), who, in his book *Historia Animalium*, grouped all flying insects with other flying animals like bats and birds which reflects huge artificiality in his classification (WEISS,

1929). Insects were often perceived to arise spontaneously (a conception, often dubbed as “*the theory of spontaneous generation*”, which was later disproved by various workers).

Table-1: Important books on insect classification in past and their authors (based on ENGEL and KRISTENSEN, 2013)

Author	Book Title
Aristotle (384-322 BC)	<i>Historia Animalium</i>
St. Isidore of Seville (ca. 560-636 BC)	<i>Etymologiae</i>
Ulisse Aldrovandi of Bologna (1522-1603)	<i>De Animalibus Insectis Libri VII</i>
Thomas Mouffet (1553-1604)	<i>Insectorum sive Minimorum Animalium Theatrum</i>
John Ray (1627-1705)	<i>Historia Insectorum</i>
Maria Sibylla Merian (1647-1717)	<i>Metamorphosis Insectorum Surinamensium</i>
August Johann Rösel von Rosenhof (1705-1759)	<i>Insecten-Belustigung</i>
Carl Linnaeus (1707-1778)	<i>Systema Naturae, Fauna Svecica</i>
Johan Christian Fabricius (1745-1808)	<i>Philosophia Entomologica, Systema Entomologiae, Genera Insectorum</i>
Pierre André Latreille (1762-1833)	<i>Précis des Caractères Génériques des Insectes</i>
William Sharp MacLeay (1792-1865)	<i>Horae Entomologicae (Essays on the Annulose Animals)</i>
William Kirby (1759-1850) and William Spence (1783-1850)	<i>An Introduction to Entomology</i>
Karl Hermann Konrad Burmeister (1807–1892)	<i>De Insectorum Systemate Naturali, Handbuch der Entomologie</i>
John Obadiah Westwood (1805–1893)	<i>An Introduction to the Modern Classification of Insects</i>
Ernst Heinrich Philipp August Haeckel (1834–1919)	<i>Generelle Morphologie</i>
Alpheus Spring Packard (1839–1905)	<i>Guide to the Study of Insects</i>
Anton Handlirsch (1865–1935)	<i>Die Fossilen Insekten</i>
Frank M. Carpenter (1902–1994)	<i>Brues & Melander's Classification of Insects (2nd ed.), Treatise on Invertebrate Paleontology</i>
August D. Imms (1881–1949)	<i>General Textbook of Entomology</i>
Emil Hans Willi Hennig (1913–1976)	<i>Grundzüge einer Theorie der phylogenetischen Systematik, Die Stammesgeschichte der Insekten</i>

Saint Isidore of Seville (ca. 560-636 BC), in his book *Etymologiae*, recognized two separate groups, *De verminibus* and *De minutis volatibus* (though both these groups were of insects, these were not included formally under a common insect group) (Barney *et al.*, 2006) (Fig. 1).

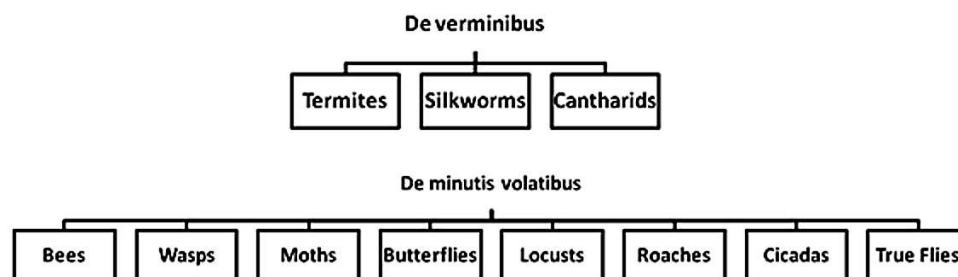


Fig. 1: Two distinct and mutually unrelated groups of “Insects” proposed by Saint Isidore of Seville

Invention of microscope and printing press during 15th century (GUENTHER, 2002) paved way for remarkable revisions of the insect classification. Marcello Malpighi (1628-1694) and Antoine van Leeuwenhoek (1632-1723) studied anatomy of insects using microscope. Inspired by Malpighi study on silkworm, Jan Swammerdam (1637–1680) became pioneer in microscopic study of insect anatomy (SMITH, MITTLER and SMITH, 1973) and has put forward a revolutionary classification of insects in 1669 based on their modes of development, which is in use still today. Ulisse Aldrovandi (1522-1605) of Bologna is credited to write the first specialized text exclusively on the study of insects (OGILVIE, 2008). Aldrovandi in 1602 distinguished insects based on their habitat mainly land and water (terrestrial and aquatic) and attempted classification of insects based on wing and leg morphology. Thomas Mouffet (1553-1604) attempted to classify insects based on their habits in his book *Insectorum sive Minimorum Animalium Thetrum* (KRISTENSEN, 1999). An influential work of this era on classification of insects based on their morphology, biology, ecology and anatomy was produced by John Ray (1627-1705) in his book *Historia Insectorum* (RAVEN, 1942). Maria Sibylla Merian (1647-1717), Furchault de Reaumur (1683-1756) and Rösel von Rosenhof (1705-1759) extensively studied the life histories of insects and along with John Ray, they influenced the research work of Linnaeus (ENGEL and KRISTENSEN, 2013).

The Linnean Era

As the name reflects, this era includes the period when Carl Linnaeus (1707-1778) put forth a systematic classification of insects in 10th edition of his book *Systema Naturae* wherein the binomial nomenclature as the convention of naming the organisms was popularized. He classified insects on the basis of presence or absence and the number of wings present in adult insect. He recognised three “alae” under class Insecta, namely Aptera with no wings, Diptera with 2 wings, Superior alae with 4 wings and Omnes with 4 wings (LINNAEUS, 1758) (Fig. 2). Johan Christian Fabricius (1745-1808) classified insects on the basis of mouth parts and he regarded it as a more natural character than number of wings (Fig. 3). He published his system of classification in his books *Systema Entomologiae* and *Genera Insectorum* (SMITH *et al.*, 1973). Baron Charles De Geer (1720-1778) tried to unite systems of Linnaeus and Fabricius and proposed a new order Dermaptera. Guillaume Antoine Olivier (1756-1814) recognised another new order Orthoptera (earlier included under Neuroptera) (SMITH *et al.*, 1973; ENGEL and KRISTENSEN, 2013).

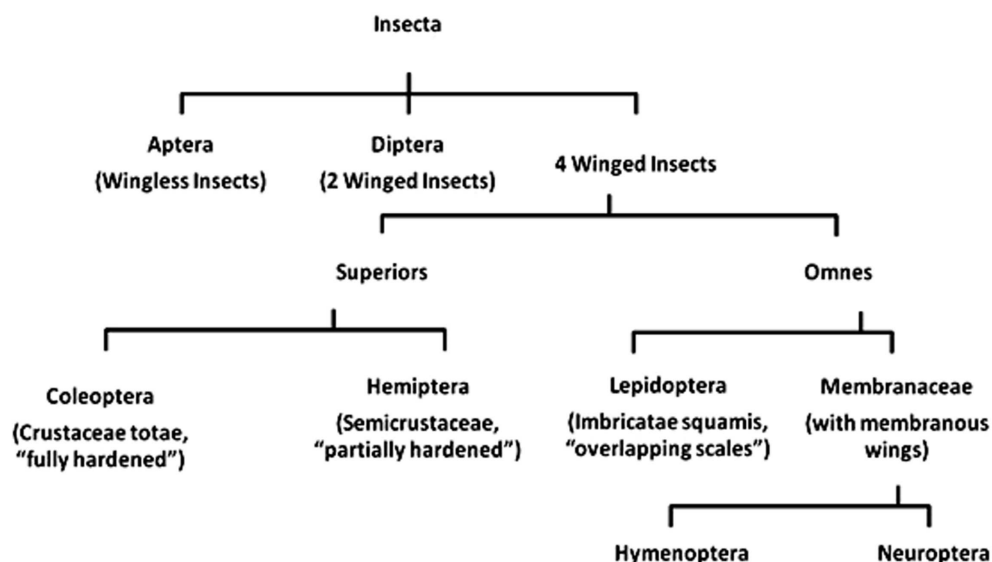


Fig. 2 Classification of insects proposed by Linnaeus

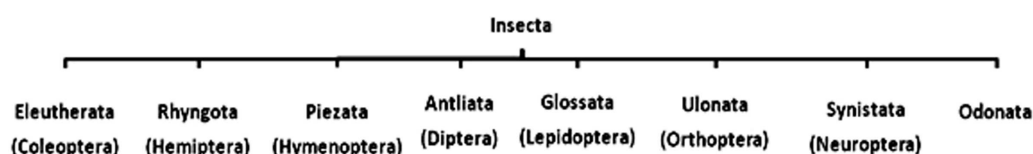


Fig. 3 Classification of insects proposed by Fabricius

Giovanni Antonio Scopoli (1723-1788) stated that classification should be based on whole structure of the insects. Utilising multiple traits, PIERRE ANDRÉ LATREILLE (1762-1833) proposed the classification of insects that is considered first truly natural classification of insects (Fig. 4) (SMITH *et al.*, 1973). His contemporaries, Etienne Geoffroy Saint-Hilaire (1772-1844), Jean Baptiste Lamarck (1744-1829) and Georges Cuvier (1769-1832) are credited of studying comparative anatomy, homology, and evolution of different animal groups including insects' thereby influencing biology as a whole on a wider level (APPEL, 1987; RACINE, 2013). William Sharp MacLeay's (1792-1869) quinary system and Edward Newman's septenary system of classification were based on the philosophy of Lamarck but were quite weird in the sense that these always involved grouping and subgrouping of insects into 5 and 7 taxa (order, families, etc.), respectively (ENGEL and KRISTENSEN, 2013). William Kirby (1759-1850) proposed two new orders i.e. order Strepsiptera and order Trichoptera and along with William Spence (1783-1850), he wrote a book "An Introduction to Entomology". **William Kirby** is considered as the **Father of Entomology** (CLARK, 2009). Karl Hermann Konrad Burmeister (1807-1892) classified insects mainly on the basis of different kinds of metamorphosis and to some extent he also considered other characters like wings and mouthparts (SMITH *et al.*, 1973; ENGEL and KRISTENSEN, 2013) (Fig. 5).

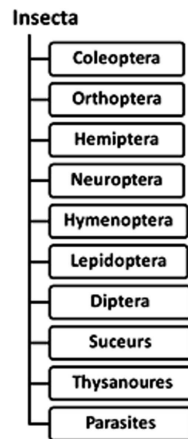


Fig. 4: Latreille's Classification of insects

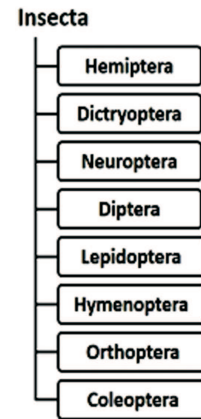


Fig. 5: Burmeister's Classification of insects

Westwood (1805-1893) of Oxford University proposed a classification of "Hexapod metamorphic insects" based mainly on the type of mouth parts. He recognised various series orders and few osculant orders which act as connecting links between two series orders (Fig. 6). Instead of various drawbacks like considering Thysanoptera to be osculant order between order Orthoptera and Neuroptera, by describing consistent patterns of characters and pointing connecting links (WESTWOOD, 1839; WESTWOOD, 1840).

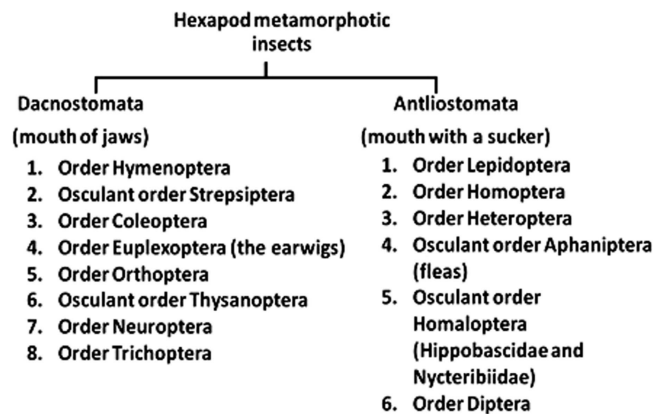


Fig. 6: Westwood's Classification of "Hexapod Metamorphic Insects"

The Darwinian Era

In this era, studies on the classification of insects achieved new horizons as these were initiated to study under the light of evolution after Charles Darwin (1809-1882) proposed his revolutionary "Theory of Natural Selection" of organic evolution in his book "On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life" (FREEMAN, 1977). To establish "natural" relationships among taxa, entomologists started considering new and more characters while classifying insects. James Dwight Dana (1813-1895) put stress upon the degree of cephalization (DANA, 1864),

Gustav Schich (1833-1899) and Franstisek Klap lek (1863-1919) emphasized on the structure of the thorax and mode of locomotion, John Bernhardt Smith (1858-1912) focused on mouth parts and thoracic characters, Benjamin Cooke (1816-1833) emphasized on nature of the pupa, Carlo Emery and Vein Graber (1844-1892) considered development and embryology more important for classifying the insects (WILSON and DONER, 1937).

Ernst Heinrich Philipp August Haeckel (1834-1919) for the first time proposed an explicit phylogeny of the insect orders (termed articulata) in his book *Generelle Morphologie* (WILLMANN, 2003). Paul Mayer (1848-1923) attempted to reconstruct an ancestral insect Protentomon and suggested parallel evolution of wingless hexapods and winged hexapods. Alpheus Hyatt (1838-1902) and Jennie M. Arms (1852-1937) are credited for constructing an explicit evolutionary tree of insects and they considered Ephemeroptera as a distinct order. Friedrich, M. Brauer (1832-1904) was the first to classify insects based on Darwinism (BRAUER, 1869; BRAUER, 1885) (Fig. 7).

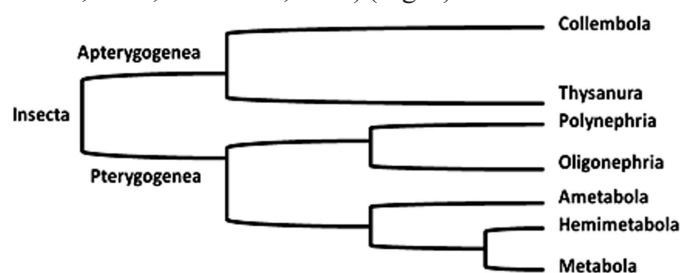


Fig. 7: Brauer's Classification of insects depicted in the form of a tree

In his classification, Brauer put all primarily wingless taxa under Apterygogenea and all secondarily wingless taxa and winged forms under Pterygogenea. He along with Labbock suggested independent evolution of Apterygogenea and Pterygogenea. He recognised 16 orders. Earlier he put termites, bark lice and true lice under Corrodentia and also accepted Erichson's grouping of mayflies, dragonflies, damselflies, stoneflies and Comstock's grouping of corrodentia under Pseudoneuroptera. But later he recognised the artificiality of these groups and classified them as distinct orders, Isoptera, Ephemeroptera (then called as Ephemerida), Odonata, Plecoptera, Mallaphaga and Corrodentia (equivalent to Psocoptera). He also suggested a new order Panorpatae (now known as Mecoptera or Mecaptera) for scorpionflies same time with Packard, and Hyatt and Arms. Alpheus Spring Packard (1839-1905) proposed an evolutionary classification in which hierarchy was generated by creating superorders, orders and suborders. He recognized Eurynchota (modern Paraneoptera) under superorder Phyloptera. He also recognized Orthoptera, Dermaptera, Neuroptera (for Trichoptera and Planipennia) and Pseudoneuroptera (for Odonata, Ephemeroptera and Platyptera) as orders (SMITH *et al.*, 1973; ENGEL and KRISTENSEN, 2013).

The classification system of insects in this era showed a progressive shift in pattern over previous systems as it involved evolution of systems based on diverse characters, analogy-homology distinction and dealing with problems concerned with assigning weightage to conflicting characters, etc. This era witnessed the rise of the field of Palaeoentomology. Scientists started exploring palaeontological evidences to understand

interrelationships of insects. These studies influenced the classification of insects too. Samuel, H. Scudder (1837-1911) published one of the first catalogues of the fossil insects of the world (SCUDDER, 1891). Friederich Goldenberg (1798-1881) & Charles Brongniart (1859-1899) proposed groups such as Palaeodictyoptera, Megasecoptera and Protodonata for fossil insects and regarded them as primordial progenitors of living insect orders (CARPENTER, 1992).

Anton Handirsch (1865-1935) recognized that it is not necessary that all fossil lineages must leave modern counterparts rather some become extinct without leaving any successor. He proposed few extinct orders too. Handlirsch wrote one of the most comprehensive accounts of fossil insects in the form of three volume monolith named *Die Fossilen Insekten* integrating Palaeontology and Neontomology. He proposed evolutionary history of insects based on palaeontological evidence. His accounts also suffered few drawbacks like he wrote that pterygotes arose from a trilobite ancestor which was found to be incorrect (GRIMALDI, 2001).

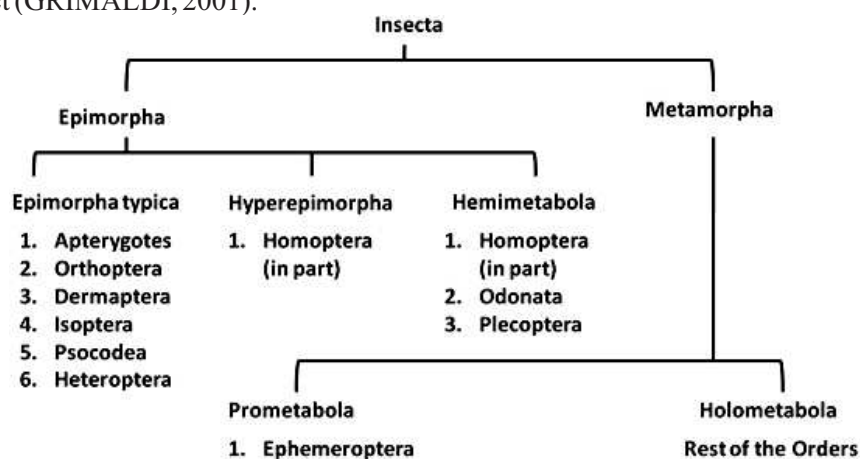


Fig. 8: Classification of insects proposed by Richard Heymons

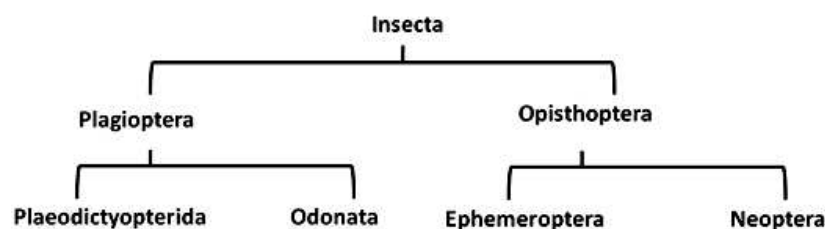


Fig. 9: Division of insects according to Lemche

Crampton (1881-1951) studied *Grylloblatta* and recognised new taxa called Notoptera. Carl, J. B. Börner (1880-1953) recognised the differences between *Zygentoma* (silverfish) and *Archaeognatha* (bristletails), and suggested their separation into different groups. He suggested silverfish to be allied to Pterygota (that was later recognised by Willi Hennig who placed silverfish and pterygotes under a common clade). He also suggested closeness among Odonata and Neoptera based on his studies on mouth parts and proposed a

higher group named Metapterygota to include them. He supported anatomical evidences consisting of more number of characters than fragmentary palaeontological evidences based on few characters (SMITH *et al.*, 1973; ENGEL and KRISTENSEN, 2013). Similarly Heymons (1867-1943) focused more on development of insects, elucidating many finer aspects of insect development. Based on his studies he proposed a classification of insects as depicted in Fig. 8 (HEYMONS, 1909).

Four new extant higher-rank taxa were described in the beginning of 20th century that played a pivotal role in studying insect phylogeny. These are Protura, Zoraptera, Grylloblattodea and nammochoristid scorpion flies. Based on the fundamental structure of insect wings, Martynov proposed division of winged insects (Pterygota) into Palaeoptera and Neoptera (ENGEL and KRISTENSEN, 2013). Most entomologists supported common origin of pterygotes but Lemche suggested a diphyletic origin of winged insects dividing insects into two broad groups, Plagioptera and Opisthoptera, and their further sub-divisions as shown in Fig. 9 (MATSUDA, 1981).

The Hennigian Era and subsequent developments

This era marks the breakthrough in studies pertaining to the classification of insects. The basic framework of classification of insects got established in this era. David Sharp (1840-1922) divided winged insects into Exopterygota and Endopterygota on the basis of external or internal development of wings that was adopted by August D. Imm (1881-1949) too in his influential book "*General Textbook of Entomology*" (RICHARDS and DAVIES, 1957; RICHARDS and DAVIES, 1977). Non-endopterygote insects were never grouped together in past. Crampton objected this classification citing it's non-agreement with the concepts of phylogeny (Crampton, 1938). Hermann Rober Weber (1899-1956) supported non-monophyly of endopterygote insects as earlier suggested by Handlirsch. He was of the opinion that different endopterygotes were independently derived from nonendopterygote ancestors (ENGEL and KRISTENSEN, 2013).

As the name of this era suggests, this period marks the occurrence of Hennigian Revolution (or Cladistic Revolution) that led to the development of the field of Phylogenetic Systematics. Phylogenetic Systematics deals with organising (more precisely systematising) organisms solely on the basis of synapomorphy into taxa where each taxon includes organisms that are strictly monophyletic in nature. This very concept of Phylogenetic Systematics was materialised by Emil Hans Willi Hennig's (1913–1976) in his book *Grundzüge einer Theorie der phylogenetischen Systematik* (ENGEL and KRISTENSEN, 2013). He discarded taxa Apterygota except Thysanura, where the latter included the non-monophyletic taxa Archaeognatha and Zygentoma. He proposed names for putative monophyletic taxa that included Zygentoma and Pterygota as "Dicondyla" and that included Psocoptera, Mallophaga and Anoplura as "Psocodea". He included monophyletic Odonata along with Neoptera within Boner's Metapterygota. He accepted monophyly of Parametabola (Paraneoptera), Saltatoria (Orthoptera) and the clade containing Mantodea along with Blattodea and Isoptera.

Monophyly of Paurometabola (Polyneoptera) was not accepted. The monophyly of Coleoptera, Hymenoptera, Neuroptera and Mecoptera was accepted within endopterygotes but Strepsiptera and Siphonaptera were suggested to be unassociated with other endopterygotes. Parametabolans and Endopterygotes were included under monophyletic Eumetabola. He revised and expanded the account of insect phylogeny in his book '*Die*

Stammesgeschichte der Insekten”. In this book he proposed more resolved and natural order-level phylogeny of insects. He recognized monophyletic nature of Ellipura, Palaeoptera, and Paurometabola (this includes Polyneoptera minus Plecoptera). He proposed relationship among different taxa within monophyletic Paurometabola as represented in Fig. 10 (HENNIG, 1969; 1981).

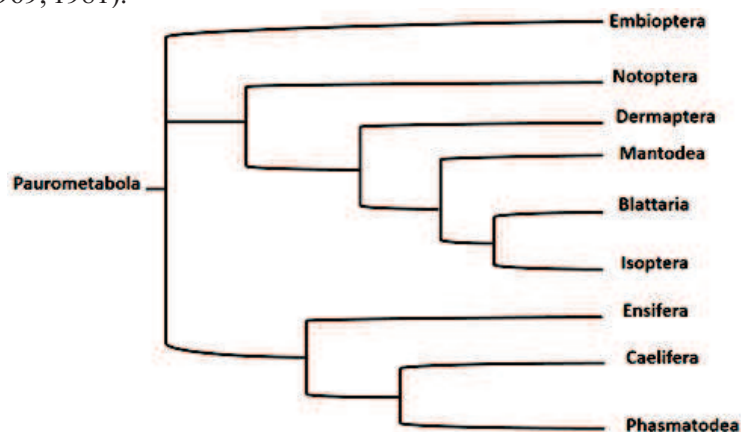


Fig. 10: Tree showing relationship among different Taxa under Monophyletic Clade Paurometabola as proposed by Hennig (branch length not up to scale)

Howard, E. Hinton (1913-1977) provided important information regarding insect phylogeny in a review published in third volume of Annual Review of Entomology. He mentioned about the polyphyletic nature of Myriapoda and Hexapoda, closeness of Symphyla, Entotrophi (Diplura) and Insecta, recognition of Collembola to be a distinct class with respect to the Insecta, recognition of Protura as a distinct class from the Insecta, demarcation of strong differences between Ephemeroptera and other pterygotes; specially; Odonata, removal of the Dictyoptera from the order Orthoptera, recognition of close relationship of Isoptera and Zoraptera with the Dictyoptera; and recognition of close relationship among clades Megaloptera plus Neuroptera and Coleoptera plus Strepsiptera. His findings suffered from few drawbacks too. Zorapteran affinities are obscure and not yet fully resolved but he recognized close relationship of Zoraptera with Isoptera and Dictyoptera. He proposed separate order for micropterigid moths (order Zeugloptera) and boreidmecoapterans (order Neomecoptera) that was incompatible with logic of Phylogenetic-Systematics (SMITH et al., 1973; ENGEL and KRISTENSEN, 2013).

Initiated by Weber and latter carried forward by Gerhard Mickoleit in more extensive manner, a trend of clarifying phylogenetic issues using anatomical data was a remarkable approach for modern classification. Using same approach Mickoleit confirmed the monophyly of Mecopterida and the clade consisting of Diptera plus Mecoptera on the basis of his studies on the pterothorax; the monophyletic status of Neuropterida, the monophyly of clade consisting of Raphidioptera, Megaloptera and Neuroptera/Planipennia and sister group relationship between Neuropterida and Coleoptera on the basis of his studies on endopterygote ovipositors and their derivatives. Rähle suggested sister group relationship between the Embiodea and Phasmatodea that was later confirmed using molecular analyses (ENGEL and KRISTENSEN, 2013). Kristensen cited some drawbacks in Hennig's work like ambiguity of some clades and their contradictory nature, and

insufficient number of evidences or literature cited in favour of many of his findings. In this regard, Hennig ambiguously placed Strepsiptera under Endopterygota that was questioned by Kristensen. Also the unresolved status of assemblage/clade containing Plecoptera plus Paurometabola was brought into picture (KRISTENSEN, 1975).

Later, H. Bruce Boudreux provided a much resolved hexapod tree consisting of both insects and non-insect hexapods. He suggested sister group relationships between Ephemeroptera and Neoptera, between Plecoptera and Embioptera, between Gryllablattodea and clade comprising of Zoraptera and assemblage of Isoptera and Blattodea-Mantodea pair within. Among Holometabolans, he suggested sister group relationship between Neuropterida and Mecopteroida (BOUDREUX, 1979).

In the same era, insect Palaeontology achieved new heights. Works of Aleksander Grigorevich Sharav (1922-1973) and Boris Borisovich Rohdendorf (1904-1977) helped Hennig to establish time of origin of the recognized high-rank clades (GRIMALDI and ENGEL, 2005). KUKALOVÁ-PECK (2008) worked extensively on morphology of fossil insects and studied origin of extant insect taxa based on paleontological evidences. She established monophyly of Palaeoptera, included monophyletic clade Orthoneoptera (consisting of Plecoptera, Embioptera, and Orthoptera) within neoptera, established monophyly of Blatoneoptera (consisting of Dermaptera, Gryllablattodea and Dictyoptera), and recognized sister group relationship among Orthoneoptera, Blatoneoptera and clade consisting of Paraneoptera plus Endopterygota (KUKALOVA-PECK and BRAUCKMANN, 1992 and KUKALOVA-PECK, 2008).

Table-2: List of some important fossil insect taxa (based on GRIMALDI, 2001)

S. No.	Order	Fossil Taxa	Site of Discovery	Period
1.	COLLEMBOLA	<i>Rhyniellapraecursor</i>	Scotland	Devonian
2.	COLLEMBOLA	<i>Permobrya mirabilis</i>	South Africa	Permian
3.	ARCHAEOGNATHA	<i>Monura (Dasyleptus)</i>	Europe	Carboniferous
4.	ARCHAEOGNATHA	<i>Triassomachilis</i>	Europe	Triassic
5.	Lepidothrichidae*	<i>Lepidotrix</i>	Baltic	Eocene amber
6.	EPHEMEROPTERA	<i>Lithoneura</i>	Illinois	Carboniferous
7.	EPHEMEROPTERA	<i>Protoreisma</i>	Kansas, Oklahoma	Permian
8.	Palaeodictyopteroidea**	<i>Thuringopteryx</i>	Germany	Triassic
9.	MANTODEA	<i>Jersimantis</i>	New Jersey	Cretaceous amber
10.	ISOPTERA	<i>Meiatermes</i>	Spain	Cretaceous
11.	ISOPTERA	<i>Valditermes</i>	England	Cretaceous
12.	ISOPTERA	<i>Cretatermes carpenteri</i>	Canada	Cretaceous
13.	ISOPTERA	<i>Carinatermes</i>	New Jersey	Cretaceous amber
14.	EMBIOPTERA	<i>Burmitembia</i>	Burma	Cretaceous amber

*Extinct family. **Extinct super order.

Contemporary discoveries of fossil deposits like Cretaceous Lagerstätte and insect bearing amber deposits led to surge in number of newly described fossil insect species that contributed much to establish more precise and accurate phylogenetic relationships among extant taxa with respect to their ancestral counterparts (GRIMALDI and ENGEL, 2005).

Table-2 shows list of some of the important insect fossils described from these fossil deposits (GRIMALDI, 2001).

Modern Classification of Insects

Modern classification of insects is more natural and accurate than previous classifications. It is based on multiple evidences like Palaeontology, Embryology, Anatomy as well as Molecular Biology. Such an approach based on multiple sources that takes advantage of complementarily among disciplines to characterize, classify and name taxa is known as Integrative Taxonomy (SCHLICK-STEINER *et al.*, 2010). With invention of Electron Microscopy and advanced Molecular Biology tools, it has become easier to establish more accurate phylogenetic relationships among various high rank taxa. DNA sequence data are widely used now-a-days to establish relationships among low rank taxa as well, e.g., identification of species, genus, varieties as well as solving family level conflicts by comparing sequence from different specimens. This approach is called Comparative Genomics (MILLER *et al.*, 2004).

To gain wider and more accurate insights, modern entomologists use sequence data from both Genomic DNA as well as Mitochondrial DNA. Using Mitochondrial DNA sequence has some specific advantages as it is maternal in origin, simple in structural design as it doesn't contain introns and have lost recombination ability, making it a reliable tool to trace point of divergence and extant of accumulation of genetic changes in an organism over time (DESALLE, 2017). For instance, mitochondrial Cyochrome Oxidase-I gene is being used universally to generate DNA Barcode of different species among invertebrates (FOLMER *et al.*, 1994). DNA Barcodes are molecular signatures based on specific DNA sequences that are unique for each individual species. Also, the availability of *in silico* tools and publically accessible data bases containing DNA sequences over internet has revolutionized the area of molecular analyses to establish more reliable phylogenetic relationships among taxa (as well as individual organisms) (WILSON *et al.*, 2017).

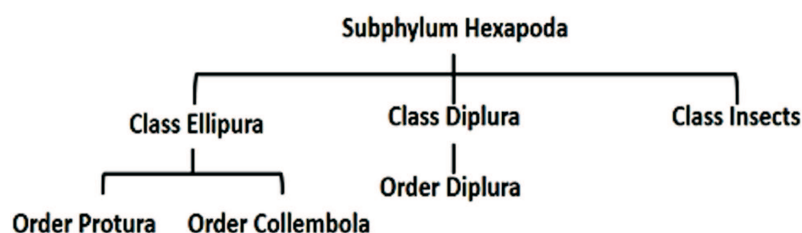


Fig. 11: Outline of the modern classification of Subphylum Hexapoda

In modern classification, non-insect hexapods have been assigned two classes, Ellipura and Diplura, and all true insects have been grouped together under class Insecta. Class Ellipura is further divided into two orders, Protura (coneheads) and Collembola (springtails). Class Diplura consists of only one order Diplura (two-pronged bristletails) (ANDERSON, 2001). Class Insecta is an assemblage of a large number orders assigned under different subclasses and comprises of the largest number of species in animal kingdom. The outline of modern classification of class Insecta up to the rank of orders has been tabulated below (Table-3). This classification has been taken from BARNARD (2011) which as 28 Orders.

This classification has also been accepted and followed by Royal Entomological Society. Many modern zoologists and entomologists like RUPPERT, FOX and BARNES (2004); BRUSCA and BRUSCA (2003); ANDERSON (2001) follow or have proposed somewhat similar classification of insects with minor modifications. This classification takes into account the monophyly of each taxa to avoid coming together of non-monophyletic taxa and to allow closely related taxa to be grouped together. In this regard, monophyletic order Dictyoptera includes three suborders Blattodea, Mantodea and Isoptera that were demoted from the rank of independent orders, the reason that led these suborders to get their names mentioned in Table-3 as well. Name of many orders have kept as it is to avoid confusion and to allow easy comparison with respect to older classifications. For many such reasons, present classification of insects also represents phylogeny of insect taxa. This classification is simple, easy-to-follow yet accurate in comparison to earlier classifications of insects.

Table-3: Modern Classification of Class Insecta (BARNARD, 2011)

Class INSECTA

- Subclass Apterygota
 - Order Archaeognatha or Microcoryphia (Bristletails)
 - Order Zygentoma (Silverfish and firebrats)
- Subclass Palaeoptera
 - Order Ephemeroptera (Mayflies or upwing flies)
 - Order Odonata (Dragonflies and Damselflies)
- Subclass Polyneoptera
 - Order Dermaptera (Earwigs)
 - Order Dictyoptera (Cockroaches, termites and mantids)
 - Suborder Blattodea, Blattaria, or Blattoptera (Cockroaches)
 - Suborder Mantodea (Mantids)
 - Suborder Isoptera (Termites)
 - Order Embioptera (Webspinners)
 - Order Grylloblattaria (Rock crawlers)
 - Order Mantophasmatodea (Heelwalkers)
 - Order Orthoptera (Grasshoppers, crickets and bush-crickets)
 - Order Phasmida (Stick insects)
 - Order Plecoptera (Stoneflies)
 - Order Zoraptera (Zorapterans)
- Subclass Paraneoptera
 - Order Hemiptera (True bugs)
 - Order Phthiraptera (Sucking and biting lice)
 - Order Psocoptera (Booklice and barklice)
 - Order Thysanoptera (Thrips)
- Subclass Endopterygota
 - Order Coleoptera (Beetles)
 - Order Diptera (True flies)
 - Order Hymenoptera (Ants, bees and wasps)
 - Order Lepidoptera (Butterflies and moths)
 - Order Mecoptera (Scorpionflies)
 - Order Megaloptera (Alderflies)
 - Order Neuroptera (Lacewings)
 - Order Raphidioptera (Snakeflies)
 - Order Siphonaptera (Fleas)
 - Order Strepsiptera (Stylops)
 - Order Trichoptera (Caddisflies or sedge flies)

Another recent classification of insects as compiled by Gary Parsons (PARSONS, 2015) has elevated the orders Protura, Collembola and Diplura to the status of class and has included 27 orders under class Insecta. Following Willi Hennig's classification, Thysanura has been referred as order Zygentoma. The orders Grylloblattodea and Mantophasmatodea have been included under order Notoptera and Isoptera into Blattodea in the recent classification.

CONCLUSION: The classification of insects which we follow today is the result of numerous years of hard work by myriad number of keen researchers. Modern classification of insects is based on evidences derived from multiple sources. This makes this classification more reliable and accurate. This doesn't imply that this area of study has achieved a static phase. Insect classification is still evolving. It is a dynamic area that is still under the process of continuous refinement. With accumulation of more evidences, there is always a possibility of new additions, arrangements and subtractions of taxa from existing classification scheme

REFERENCES

- ANDERSON, D. T. 2001. Invertebrate Zoology, 2nd edn. *Oxford University Press, Victoria*, pp 1-476.
- APPEL, T. A. 1987. *The Cuvier-Geoffroy Debate: French Biology in the Decades Before Darwin*. *Oxford Univ. Press, Oxford, U.K.*, pp 1-334.
- BARNARD, P. C. 2011. The Royal Entomological Society Book of British Insects. *Wiley-Blackwell*. pp 1-396.
- BARNEY, S. A., LEWIS, W. J., BEACH, J. A. and BERGHOF, O. 2006. *The Etymologies of Isidore of Seville*. *Cambridge Univ. Press, Cambridge, U.K.*, pp 1-488.
- BOUDREAUX, H. B. 1979. Arthropod Phylogeny with Special Reference to Insects. *Wiley, New York*. pp 1-320.
- BRAUER, F. 1869. *Betrachtungen über die Verwandlung der Insekten im Sinne der Descendenz-Theorie*. *Verhandl. k.-k. Zool. Bot. Ges.*, **19**: 299–318.
- BRAUER, F. 1885. *Systematische-Zoologische Studien*. *Sitzungsber. kais. Akad. Wissen., Math.-Naturwissen. Klass., Abt. 1, Mineral. Bot. Zool. Anat. Geol. Palaontol.*, **91**: 237–414.
- BRUSCA, R. C. and BRUSCA, G. J. 2003. Invertebrates. *Sinauer Associates, Sunderland, Massachusetts*. pp 1-922.
- CARPENTER, F. M. 1992. Superclass Hexapoda. *In Treatise on Invertebrate Paleontology, Part R, Arthropoda 4, Vols. 3–4, ed. Kaesler, R.L. Geol. Soc. Am. Univ. Kans, Lawrence*, pp 1-655.
- CLARK, J. F. M. 2009. Bugs and the Victorians. *Yale University Press*. pp 1-322.
- CRAMPTON, G. C. 1938. The Interrelationships and Lines of Descent of Living Insects. *Psyche*, **45**: 165–181.
- DANA, J. D. 1864. The classification of animals based on the principle of cephalization. No. II. Classification of Insects. *Am. J. Sci. Ser. 2*, **37**: 10–33.
- DESALLE, R., SCHIERWATER, B. and HADRY, H. 2017. MtDNA: The Small Workhorse of Evolutionary Studies. *Frontiers in Bioscience, Landmark*, **22**: 873-887.
- ENGEL, M. S. and KRISTENSEN, N. P. 2013. A history of entomological classification. *Annual Review of Entomology*, **58**: 585-607.
- FOLMER, O., BLACK, M., HOEH, W., LUTZ, R., and VRIJENHOEK, R. 1994. DNA Primers for Amplification of Mitochondrial Cytochrome C Oxidase Subunit I from Diverse Metazoan Invertebrates. *Molecular Marine Biol. & Biotech.* **3**(5): 294-299.

- FREEMAN, R. B. 1977. The Works of Charles Darwin: *An Annotated Bibliographical Handlist*. 2nd edn. Folkstone, Dawson, pp 1-235.
- GRIMALDI, D. 2001. Insect Evolutionary History from Handlirsch to Hennig, and Beyond. *J. Paleont.*, **75**(6): 1152–1160.
- GRIMALDI, D. and ENGEL, M. S. 2005. Evolution of the Insects. *Cambridge Univ. Press, Cambridge, U.K.*, pp 1-760.
- GUENTHER, A. H. 2002. International Trends in Applied Optics. *SPIE Press, Bellingham, WA.*, pp 1-697
- HENNIG, W. 1969. *Die Stammesgeschichte der Insekten*. Kramer, Frankfurt, pp 1-436.
- HENNIG, W. 1981. Insect Phylogeny. *Wiley, New York*, pp 1-514.
- HEYMONS, R. 1909. Die verschiedenen Formen der Insecten-metamorphose und ihre Bedeutung im Vergleich zur Metamorphose anderer Arthropoden. *Ergeb. Fortschr. Zool.*, **1**: 137–188.
- KRISTENSEN, N. P. 1975. The Phylogeny of Hexapod "Orders". A Critical Review of Recent Accounts. *Z. Zool. Syst. Evol.* **13**: 1–44.
- KRISTENSEN, N. P. 1999. Lepidoptera, Moths and Butterflies: Evolution, Systematics and Biogeography. *Handbuch der Zoologie: Eine Naturgeschichte der Stämme des Tierreiches. Arthropoda: Insecta*. Walter de Gruyter, Berlin, **4**(35): 1-5
- KUKALOVA-PECK, J. 2008. Phylogeny of higher taxa in Insecta: finding synapomorphies in the extant fauna and separating them from homoplasies, *Evol. Biol.* **35**: 4–51.
- KUKALOVA-PECK, J. and BRAUCKMANN, C. 1992. Most Paleozoic Protorthoptera are Ancestral Hemipteroids: Major Wing Braces as Clues to a New Phylogeny of Neoptera (Insecta). *Canadian J. Zool.*, **70**: 2452–2473.
- LINNAEUS, C. 1758. *Systema Naturae per Regna Tria Natura, Secundum Classes, Ordines, Genera, Species, cum Characteribus, Differentiis Synonymis, Locis*. Laurentii Salvii, Stockholm. 10th ed., Rev. pp 1-1384.
- MATSUDA, R. 1981. The origin of insect wings (Arthropoda :Insecta). *International Journal of Insect Morphology and Embryology*. **10**(5, 6): 387-398.
- MILLER, W., MAKOVA, K. D., NEKRUTENKO, A. and HARDISON, R. C. 2004. Comparative Genomics. *Annual Review of Genomics and Human Genetics*. **5**: 15-56.
- OGILVIE, B. W. 2008. Nature's Bible: Insects in Seventeenth-Century European Art and Science, *Tidsskrift for kulturforskning*, **7**(3): 5-21.
- PARSONS, G. L. 2015. Recent Classification of Orders of Insects. *Presented at seminar to Entomology Department on 12th October 2015 at Michigan State University*.
- PARSONS, G. L., CASSIS, G., MOLDENKE, A. R., LATTIN, J. D., ANDERSON, N. H., MILLER, J. C., HAMMOND, P., and SCHOWALTER, T. D. 1991. Invertebrates of the H. J. Andrews Experimental Forest, Western Cascade Range, Oregon. V: An annotated list of insects and other arthropods, *U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station*. pp 1-168.
- RACINE, V. 2013. Essay: The Cuvier-Geoffroy Debate. *Embryo Project Encyclopedia*. <http://embryo.asu.edu/pages/essay-cuvier-geoffroy-debate>.
- RAVEN, C. E. 1942. New Light on John Ray. *Proc. Linnean Society London*. **154** (1): 3-10
- RICHARDS, O. W and DAVIES, R. G. 1957. Imms' A General Textbook of Entomology: Including the Anatomy, Physiology, Development and Classification of Insects (9th edn.), *Methuen, London*. pp 1-886.
- RICHARDS, O. W and DAVIES, R. G. 1977. Imms' General Textbook of Entomology: vol. 2: Classification and Biology (10th edn.). *Chapman & Hall, London*. pp 421-1354.
- RUPPERT, E. E., FOX, R. S., and BARNES, R. D. 2004. Invertebrate zoology: A functional evolutionary approach. *Thomson-Brooks/Cole: Belmont, C.A.*, pp 1-963.
- SCHLICK-STEINER, B. C., STEINER, F. M., SEIFERT, B., STAUFFER, C., CHRISTIAN, E. and

- CROZIER, R.H. (2010). Integrative Taxonomy: A Multisource Approach to Exploring Biodiversity. *Annual Review of Entomology*. **55**(1): 421–438.
- SCUDDER, S. H. 1891. Index to the known fossil insects of the world including myriapods and arachnids. *Bull. U.S. Geol. Surv.* **71**: 1–744.
- SMITH, R. F., MITTLER, T. E. and SMITH, C.N. 1973. History of Entomology. *Annual Reviews, Inc., Palo Alto, C.A.*, pp 1-517.
- WEISS, H. B. 1929. The Entomology of Aristotle. *J. New York Entomol. Soc.*, **37**(2): 101-109.
- WESTWOOD, J. O. 1839. Volume 1. An Introduction to the Modern Classification of Insects; Founded on the Natural Habits and Corresponding Organisation of Different Families. *Longman, Orme, Brown, Green and Longmans, London*, pp 1-462.
- WESTWOOD, J. O. 1840. Volume 2. An Introduction to the Modern Classification of Insects; Founded on the Natural Habits and Corresponding Organization of Different Families. *Longman, Orme, Brown, Green and Longmans, London*, pp 1-587.
- WILLMANN, R. 2003. From Haeckel to Hennig: the early development of phylogenetics in German speaking Europe, *Cladistics*. **19**: 449–79.
- WILSON, H. F. and DONER, M. H. 1937. The Historical Development of Insect Classification. *Swift, St. Louis, M.O.*, pp 1-133.
- WILSON, J. J., SING, K. W., FLOYD, R. M., and HEBERT, P. D.N. 2017. Chapter 17- DNA Barcodes and Insect Biodiversity. *In the Insect Biodiversity: Science and Society*. (eds. Footitt, R.G., & Adler, P.H.). *Oxford Univ. Press, Oxford, U.K.*, pp575-592.



NANOINFORMATICS: AN EMERGING BIO-SCIENCE

SHYAMASREE GHOSH¹*, AND RISHAV DASGUPTA²

¹* = School of Biological Sciences, National Institute of Science, Education and Research (NISER), HBNI, Bhubaneswar, Odisha PO- Bhimpur-Padanpur, Via-Jatni, District- Khurda, Odisha – 752050; email; shyamasree_b@yahoo.com, sree.s@niser.ac.in

²= University of Illinois, West Illinois Street, Urbana, IL 61801, USA

Received: 2 February, 2020

Accepted: 31 March, 2020

ABSTRACT: Nanoinformatics is an emerging science developing over the last two decades and finds utmost importance due to the ever expanding field of surface engineering of nanoparticles with desired and improved properties in drug delivery, synthesis of newer nanoparticles, green synthesis of nanoparticles and or their new applications towards human health, development and environment. The term was coined in 2007 and it has found applications in computational design of safer, biocompatible and personalised drugs, nanoparticle formulation, quantitative structure activity relationship (nanoQSAR) and nanoparticle assembly, modelling, simulation, predicting particle effects in infectious disease and malignant diseases like cancer, nanocurration, and environmental risk assessment. With the advancement of DNA and RNA based therapeutics, nanoinformatics has been applied to DNA and RNA computing in diseases. Several machine learning tools and algorithms are having application in Nanoinformatics. In this review, we highlight the importance of nanoinformatics and its application in therapeutics.

Key words: Nanoinformatics, nanoparticles, nanocurration, transcriptomics

INTRODUCTION

Nanoinformatics involves the applications of computation at the nano level (GONZÁLEZ-NILO *et al.*, 2011). The application of nanosciences in medicine is about a decade old. Nanoinformatics involves developing of data repositories and analytical tools by data integration and analysis of data, screening of potential candidates for drug delivery, identifying the toxic components etc (KARCHER *et al.*, 2016). The name "Nanoinformatics", was coined in 2007, by the US National Science Foundation.

With the increasing number of applications of nanoparticles (NPs) in consumer and industry and huge complexity associated with their surface properties, characterization and quantification, reaction with biological surfaces, their biocompatibility, toxicity and safety, formation of protein corona in biological environment, uptake by cells and inflammatory responses have led to the need of their understanding, function and application in the body. While on one hand it is important to understand the physical characteristics and chemical properties of the nanoparticles, it is also important to understand their reaction with the biological surfaces. With the advent and application of genomics and the science of

application of RNA and DNA being more into the therapy against deadly and infectious diseases, nanotechnology finds importance in DNA/ RNA based therapeutics. Thus nanotechnology and its applications in therapy encompasses major domain including information from chemical, physical properties, synthesis and engineering of nanoparticles with advanced and desired delivery and therapeutic properties with minimum or no toxic effects, their biological role, studies from genomics and transcriptomics and understanding and manipulation of DNA/RNA structure and biology (Fig.-1).

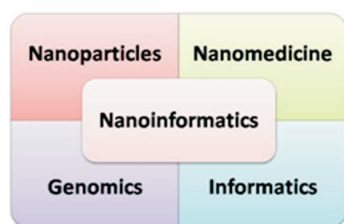


Fig.-1: Nanoinformatics: an emerging Science

The other major challenge encompassing application of nanoparticle in therapy involves their safe use (GHOSH and ANSAR 2014, GHOSH *et al.*, 2015, GHOSH 2018a, GHOSH, 2018b) and regulations. Therefore, nanoinformatics finds application in integrating diverse domains of genomics, nanotechnology, and clinical medicine (Fig.-1).

With nanoinformatics emerging in the USA and Europe to address the molecular-level research to clinical problems (GONZÁLEZ-NILO *et al.*, 2011), an European project named ACTION-Grid was set up in 2008 by European Commission (EC) for collaborative biomedical and nanomedical research among countries of Europe, Latin America, North Africa, Western Balkans, and USA (MAOJO *et al.*, 2010, LOPEZ-ALONSO *et al.*, 2008) and to analyze the challenges and agenda for developing nanoinformatics (CHIESA *et al.*, 2009) aiming at the needs, application domains, and priorities for biomedical Informatics in nano and regenerative medicine.

A predictive model for understanding biological effects of surface-modified gold NPs (AuNPs), based on their physicochemical properties has been designed through the Enalos Cloud Platform (<http://enalos.insilicotox.com/NanoProteinCorona/>) and finds application in regulatory issues related to safe design and screening of nanoparticles (AFANTITIS *et al.*, 2018). Enalos+nodes and Enalos Suite (<http://enalossuite.novamechanics.com/>) designed and developed by NovaMechanics Ltd. for the open-source KNIME platform, enables access to data, use of predictive molecular modeling, data mining, and manipulation of data obtained from chemical databases including PubChem, UniChem, etc. according to OECD principles through the KNIME interface through automated processes and enable QSAR predictive model development with application in drug discovery (VARSOU *et al.*, 2018, MARCHESE *et al.*, 2015).

I. Languages

Data mining and machine learning (ML) algorithms finds importance in the study of biomedical applications of nanoparticles, prediction of their biological fate, physicochemical properties on cellular uptake, cytotoxicity, molecular loading, molecular release nanoparticle size, and polydispersity (MARCHESE *et al.*, 2015, CHEN and SARKAR, 2015).

Natural language processing enabled semi-automation of ENMs categorisation based on their physico-chemical properties, exposure, and biological effects based on information from patent mining, nanomaterial and device characterization, nanomedicine, and environmental risk assessment. Nine natural language processing (NLP) tools including

NanoPort, NanoMapper, TechPerceptor, a Text Mining tool, Nanodevice Analyzer, Document Classifier for data on clinical trials, Nanotoxicity Searcher, NanoSifter, and NEIMiner found application for broadening nanoinformatics (CHEN and SARKAR, 2015). Literature from United States (U.S.) Library of Congress Online Catalog, English Wikipedia, U.S. National Library of Medicine (NLM) Catalog, PubMed, and PubMed Central were extracted for informatics (LIU *et al.*, 2015).

II. Tools and Resources

An integrated simulation tool was developed for assessing the potential release and environmental distribution of nanomaterials based on their life cycle and modelling coupled with mechanistic transport processes of ENMs, impact of geographical and meteorological parameters on Engineered Nanomaterial (ENM) distribution in the environment, comparison of the impact of ENM production and potential releases in different regions, and estimation of source release rates based on monitored ENM concentrations (de la IGLESIA *et al.*, 2013).

Computational methods including data mining, modelling and simulation have enabled effective tools to automate the extraction, management and storage of these vast data volumes (PANNEERSELVAM *et al.*, 2014, JONES *et al.*, 2016). In silico approaches including ISA-TAB-Nano, caNanoLab, and Nanomaterial Registry enable data sharing and developing data standards, with the expansion of nanomaterials data (MASSAWE *et al.*, 2013).

Naoparticles (NPs), their routes of exposure, toxic effects, and targets need to be known from computational approaches. The Nanomaterial Registry is enabling data formatting, and data sharing with the help of authoritative, web-based tool for understanding interaction of environmental and biological interaction studies (MASSAWE *et al.*, 2013).

III. Applications

A. Cancer Therapy

Nanoinformatics enables computational design of safer, biocompatible and effective personalised nanocarrier drugs without toxic effects with information on the quantitative structure-nanoparticle assembly, predicting particle size, characteristics and effects in cancer (SADAN *et al.*, 2018; MELAGRAKI and AFANTITIS, 2018). Nanoinformatics is helping in risk assessment of nanomaterials. Nano (quantitative) structure-activity relationship, nano-(Q)SAR, models finds applications to predict metal oxide (MOx) nanoparticles (NPs) toxicity. M/MOx NPs cytotoxicity has been calculated by using spherical cluster generated from metal (M) or MOx crystal structure and the hydroxyl metal coordination complex and hydroxyl metal coordination complex were used to calculate descriptors and to study properties of the metal cation in an aqueous environment (Shin *et al.*, 2017).

Jaqpot Quattro, an open-source web application for engineered nanomaterials (ENM) modelling is enabling nanoQSAR modelling, validation, predictions, optimal experimental design, and testing of data from laboratories and finds application in the design of safe ENMs (CHROMENIDIS *et al.*, 2017). The FP7 Project MODERN is using computational design to evaluate environmental and health impacts of nanoparticle by generating data management and integration; development of nanodescriptors; determining nanostructure-function correlation, characterising them and assessment of hazards and

application risk to health and environment (BREHM *et al.*, 2017). ISA-TAB-Nano has been designed to build useful datasets from nanotoxicology data for reporting on literature metadata, developed within the NanoPUZZLES EU project with Python code to facilitate parsing and integration of these datasets (DIEB *et al.*, 2015).

NaDev or nanocrystal Device Development is designed to extract information from published literature on nanocrystal devices and their applications using the NaDev corpus and ML techniques (POWERS *et al.*, 2015). Data curation process in nanoinformatics also called as nanocuration has enabled curation of temporal metadata, data completeness, database integration focusing on nanocuration workflow, and data from a data repository (VANCE *et al.*, 2015). Woodrow Wilson International Center for Scholars and the Project on Emerging Nanotechnologies created the Nanotechnology Consumer Products Inventory (CPI) in 2005 with descriptors for consumer products, including information pertaining to the nanomaterials in particular product (HENDRON *et al.*, 2015). The Nanomaterial Data Curation Initiative (NDCI), by the National Cancer Informatics Program Nanotechnology Working Group (NCIP NanoWG), enables data curation to analyse nanomaterial behaviour with data repositories and tools for integrating and interrogating complex nanomaterial datasets (HUANG *et al.*, 2015). Nano-enabled drug delivery (NEDD) has successful applications to modulate drug release and to target particular diseased tissues with applications in brain cancer (LIU *et al.*, 2015).

B. Application in Leishmaniasis

Proteins, RNA, and DNA and nanoengineered one, two, and three dimensional DNA nanostructures, protein RNA-DNA hybrid nano cargoes with targeting scaffolds are being designed for targeted delivery in synthetic biology. Computational tool can design novel nanomaterials from raw sequences from the many databases including GenBank, EMBL, UniProt, RNA Central, PDB and then modifying into desired bionanostructure with defined application. Sequences of *Leishmania species* were released in 2005 and GeneDB and LeishCyc databases were prepared containing information on its genome and metabolic pathways. Nanotechnology finds application in search of proteins, RNA, and DNA targeting leishmanial parasite, nanomaterial characterization, standardizing, experimental reproducibility, sensitivity and accuracy. Targeting of leishmaniasis revolves around resistance exhibited by the infectious pathogen protozoa and nanobased delivery of amphotericin B, has been proved with promising results.

DNA nanostructures have shown promise in treating cancer and holds promise for immunostimulation and vaccine preparation. *Leishmania promastigotes* are susceptible to complement-mediated lysis and aptamers linked to DNA or proteins with polyfunctionalities finds application in targeting of promastigotes (VERMA *et al.*, 2018). Self-assembled nanostructures are able to modify signaling components thereby controlling cell behavior. Strategies of application of coassembled DNA nanostructures with peptides epitopes for cell receptors providing signal for cell differentiation, CpG nanostructures directed to the endosomes to activate innate immune response are being tested. Design of biomimetic material of self-assembling hybrid nanoconjugates and clustered CD20 within lipid raft to induce apoptosis is also being employed in control and targeting of parasites. DNA-RNA based approaches activating proinflammatory response by innate immune signalling and DNA nanotechnology is finding application in vaccine in *Leishmania infection*.

C. Toxicity

Databases of toxic effects include National Institute for Occupational Safety and Health's (NIOSH) (<http://www.cdc.gov/niosh/>), and Oregon Nanoscience and Microtechnologies Institute's (ONAMI) toxicity screen using embryonic zebra fish (<http://www.greennano.org>). In Europe and the United States Advancing Clinico Genomic Trials on Cancer (ACGT) (DIEB *et al.*, 2015) and the cancer Biomedical Informatics Grid (caBIG) (JELIAZKOVA *et al.*, 2015) have enabled sharing of data, modelling, and simulation of drug delivery enabling the direct understanding of role of nanoparticles from the laboratory to clinics.

D. Environment and Toxicity

The impact of ZnO and TiO₂ manufactured nanoparticles (MNPs) on soil bacterial communities for different exposure periods and MNP doses was explored by data visualization techniques and detected by bipartite graphs, enabling fast identification of important soil bacterial taxa that are susceptible to MNPs, thus evaluate the potential for environmental impacts (JELIAZKOVA *et al.*, 2015). The NanoSafety Cluster, funded by the EC uses computation for toxicological data management of ENMs (BATES *et al.*, 2015). The eNanoMapper database solution through its application programming interface (API), and use in visualisation and modelling using ML algorithms have enabled toxicological screening of nanoparticles (JELIAZKOVA *et al.*, 2015) and their quantitative structure-activity relationships (NanoQSAR) modelling. Decision analytic and Bayesian models statistical analysis finds application in nanoinformatics (LEWINSKI *et al.*, 2015). ENMs has major role in environmental remediation and health impacts therefore nanoinformatics is having applications in effects of exposure, surveillance and monitoring, databases, and characteristic effects due to workplace exposure (DE LA IGLESIA *et al.*, 2013). ENMs may spread through the environment and is a threat to the world. In silico ENM toxicity and fate and transport analyses finds importance in environmental impact assessment and their screening by nano-SARs with regulatory applications (MAOJO *et al.*, 2012).

E: Application in Agriculture

Nanoparticles (NPs) has a wide scale application in the field of industry and agriculture and is facilitating the development of genetically modified (GM) crops, precision farming techniques including remote and local sensing, remediation including water treatment plants, pesticide removal from ground water, use of nanosensors, nanoagricultural chemicals and the design of smart delivery systems for nutrients and pesticides (SAMUEL *et al.*, 2016). Although most of these applications are being actively researched globally, it is still at it's infancy. Researchers in the field of nano-agriculture, agriculturists, farmers, manufacturers and regulatory bodies are all involved in the development of this field of Biology together with consumer safety, environmental effects, ethical, legal and social implications. Therefore, it needs integration of knowledge from the different varied domains. Nano-Agriculture Informatics System (NAIS) are being designed to get all the information under one umbrella (ROSE *et al.*, 2011).

DISCUSSION

The Human Genome Project and omics based studies are generating high-throughput data and informatics is helping in its integration, assembly and analysis. (MAOJO *et al.*, 2012). Nanobiotechnology and its human application in therapy are also generating huge

information. To assemble, organise, integrate and analyse the data on applications of nanotechnology in therapy, and medicine, nanoinformatics finds application (DE LA IGLESIA *et al.*, 2011) for fast, cost effective screening probable candidates with less or no toxic effects and targeted delivery. The Bio-Informatics Resource Inventory (BIRI, <http://edelman.dia.fi.upm.es/biri/>), is a web service with applications in as medical nanoinformatics (DE LA IGLESIA *et al.*, 2009). Nanoinformatics and DNA and RNA-based computing is another domain largely expanding (DE LA CALLE *et al.*, 2009). Nanoinformatics in finding applications in detecting and screening of toxic substances automatically (GARCÍA-REMESAL *et al.*, 2013, COHEN *et al.*, 2013). While research is ongoing, in human diseases including both infectious and malignant, it evolving science of nanoinformatics is gaining importance in human applications.

REFERENCES

- AFANTITIS, A., MELAGRAKI, G., TSOUMANIS, A., VALSAMI-JONES, E. and LYNCH, I. 2018. A nanoinformatics decision support tool for the virtual screening of gold nanoparticle cellular association using protein corona fingerprints. *Nanotoxicology*. **12**(10): 1-18.
- BATES, M. E., LARKIN, S., KEISLER, J. M., and LINKOV, I. 2015. How decision analysis can further nanoinformatics. *Beilstein J. Nanotechnol.* **6**: 1594-1600.
- BREHM, M., KAFKA, A., BAMLER, M., KÜHNE, R., SCHÜÜRMAN, G., SIKK, L., BURK, J., BURK, P., TAMM, T., TÄMM, K., POKHREL, S., MÄDLER, L., KAHRU, A., ARUOJA, V., SIHTMÄE, M., SCOTT-FORDSMAND, J., SORENSEN, P. B., ESCORIHUELA, L., ROCA, C. P., FERNÁNDEZ, A., GIRALT, F. and RALLO, R. 2017. An Integrated Data-Driven Strategy for Safe-by-Design Nanoparticles: The FP7 MODERN Project. *Adv. Exp. Med. Biol.* **947**: 257-301.
- CHEN, E. S. and SARKAR, I.N. 2015. Informatics: Identifying and Tracking Informatics Sub-Discipline Terms in the Literature. *Methods Inf. Med.*, **54**(6): 530-539.
- CHIESA, S., DE, L. A., IGLESIA, D., CRESPO, J., MARTIN-SANCHEZ, F., KERN, J., POTAMIAS, G. and MAOJO, V. 2009. European efforts in nanoinformatics research applied to nanomedicine. *Stud. Health Technol. Inform.* **150**: 757-61.
- CHOMENIDIS, C., DRAKAKIS, G., TSILIKI, G., ANAGNOSTOPOULOU, E., VALSAMIS, A., DOGANIS, P., SOPASAKIS, P., SARIMVEIS, H. and QUATTRO, J. 2017. A Novel Computational Web Platform for Modeling and Analysis in Nanoinformatics. *J. Chem. Inf. Model*, **57**(9): 2161-2172.
- COHEN, Y., RALLO, R., LIU, R. and LIU, H. H. 2013. In silico analysis of nanomaterials hazard and risk. *Acc. Chem. Res.*, **46**(3): 802-12.
- DE LA CALLE, G., GARCÍA-REMESAL, M., CHIESA, S., DE LA IGLESIA, D. and MAOJO V. BIRI, 2009. A new approach for automatically discovering and indexing available public bioinformatics resources from the literature. *BMC Bioinformatics*, **10**:320.
- DE LA IGLESIA, D., CACHAU, R. E., GARCÍA-REMESAL, M. and MAOJO, V. 2013. Nanoinformatics knowledge infrastructures: bringing efficient information management to nanomedical research. *Comput. Sci. Discov.* **6**(1): 14011.
- DE LA IGLESIA, D., CHIESA, S., KERN, J., MAOJO, V. and MARTIN-SANCHEZ, F., POTAMIAS, G., MOUSTAKIS, V. and MITCHELL, J. A. 2009. Nanoinformatics: new challenges for biomedical informatics at the nano level. *Stud. Health Technol. Inform.* **150**: 987-991.
- DE LA IGLESIA, D., GARCÍA-REMESAL, M., DE LA CALLE, G., KULIKOWSKI, C., SANZ, F. and MAOJO, V. 2013. The impact of computer science in molecular medicine: enabling high-throughput research. *Curr. Top. Med. Chem.*, **13**(5): 526-75.
- DE LA IGLESIA, D., MAOJO, V., CHIESA, S., MARTIN-SANCHEZ, F., KERN, J., POTAMIAS, G., CRESPO, J., GARCIA-REMESAL, M., KEUCHKERIAN, S., KULIKOWSKI, C. and MITCHELL, J. A. 2011. International efforts in nanoinformatics research applied to

- nanomedicine. *Methods Inf. Med.* **50**(1): 84-95.
- DIEB, T. M., YOSHIOKA, M., HARA, S. and NEWTON, M. C. 2015. Framework for automatic information extraction from research papers on nanocrystal devices. *Beilstein J. Nanotechnol.* **6**: 1872-82.
- GARCÍA-REMESAL, M., GARCÍA-RUIZ, A., PÉREZ-REY, D., DE LA IGLESIA, D. and MAOJO, V. 2013. Using nanoinformatics methods for automatically identifying relevant nanotoxicology entities from the literature. *Biomed Res Int.* 2013:410294. 1-9
- GHOSH, S. and ANSAR, W. 2014. Multidynamic Liposomal Nanomedicine: Technology, Biology, Applications, and Disease Targeting. *Chapter 5: Nanoparticles' Promises and Risks - Characterization, Manipulation, and Potential Hazards to Humanity and the Environment, Springer*, 2014.167-210.
- GHOSH, S. 2018. Green synthesis of nanoparticle and fungal infection, Book chapter-4; *Springer 2018 Green Synthesis, Characterization and Applications of Nanoparticles Edited by Ashutosh Kumar Shukla Siavash Irvani*, 2018: 75-83.
- GHOSH, S. 2018a. Nanomaterials Safety: Toxicity and Health Hazards; *DeGryter: ISBN: 978-3-11-057836-2*
- GHOSH, S., SAHA, S. and SUR, A. 2015. Polymeric Nanoparticles: Application in Cancer Management, *Encyclopedia of Biomedical Polymers and Polymeric Biomaterials, Taylor & Francis*, 1182-1205.
- GONZÁLEZ-NILO, F., PÉREZ-ACLE, T., GUÍNEZ-MOLINOS, S., GERALDO, D. A., SANDOVAL, C., YÉVENES, A., SANTOS, L. S., LAURIE, V. F., MENDOZA H. and CACHAU, R. E. 2011. Nanoinformatics: an emerging area of information technology at the intersection of bioinformatics, computational chemistry and nanobiotechnology. *Biol. Res.* **44**(1): 43-51.
- HENDREN, C. O., POWERS, C. M., HOOVER, M. D., HARPER, S. L. 2015. The Nanomaterial Data Curation Initiative: A collaborative approach to assessing, evaluating, and advancing the state of the field. *Beilstein J. Nanotechnol.*, **6**: 1752-62.
- HUANG, Y., MA, J., PORTER, A. L., KWON, S. and ZHU, D. 2015. Analyzing collaboration networks and developmental patterns of nano-enabled drug delivery (NEDD) for brain cancer. *Beilstein J. Nanotechnol.* **6**:1666-1676.
- JELIAZKOVA, N., CHOMENIDIS, C., DOGANIS, P., and B. FADEEL et al., 2016. The eNanoMapper database for nanomaterial safety information. *Beilstein J. Nanotechnol.* **6**:1609-1634.
- JONES, D. E., GHANDEHARI, H. and FACELLI, J. C. 2016. A review of the applications of data mining and machine learning for the prediction of biomedical properties of nanoparticles. *Comput. Methods Programs Biomed.*, **132**: 93-103.
- KARCHER, S., WILLIGHAGEN, E. L., RUMBLE, J., EHRHART, F., EVELO, C. T., FRITTS, M., GAHEEN, S., HARPER, S. L., HOOVER, M. D., JELIAZKOVA, N., LEWINSKI, N., MARCHESE ROBINSON, R. L., MILLS, K. C., MUSTAD, A. P., THOMAS, D. G., TSILIKI, G. and OGILVIE HENDREN, C. 2018. Integration among databases and data sets to support productive nanotechnology: Challenges and recommendations. *NanoImpact.* **9**: 85-101.
- LEWINSKI, N. A. and MCINNES, B.T. 2015. Using natural language processing techniques to inform research on nanotechnology. *Beilstein J. Nanotechnol.* **6**: 1439-1449.
- LIU, H. H., BILAL, M., LAZAREVA, A., KELLER, A. and COHEN, Y. 2015. Simulation tool for assessing the release and environmental distribution of nanomaterials. *Beilstein J. Nanotechnol.* **6**: 938-51.
- LIU, R., GE, Y., HOLDEN, P. A. and COHEN, Y. 2015. Analysis of soil bacteria susceptibility to manufactured nanoparticles -data visualization. *Beilstein J. Nanotechnol.* **6**: 1635-51.
- LOPEZ-ALONSO, V., HERMOSILLA-GIMENO, I., LOPEZ-CAMPOS, G., MAOJO, V. AND MARTIN-SANCHEZ, F. J. 2008. Action GRID: assessing the impact of Nanotechnology on biomedical informatics. *Ann. Symp. Proc.* 2008 Nov 6:1046.

- MAOJO, V., FRITTS, M., DE, L. A. IGLESIA, D., CACHAU, R. E., GARCIA-REMESAL, M., MITCHELL, J. A. and KULIKOWSKI, C. 2012. Nanoinformatics: a new area of research in nanomedicine. *Int. J. Nanomedicine*. **7**: 3867-90.
- MAOJO, V., FRITTS, M., MARTIN-SANCHEZ, F., DE, L. A. and D. IGLESIA, et al. 2012. Nanoinformatics: developing new computing applications for nanomedicine. *Comput. Sci. Eng.*, **94**(6): 521-539.
- MAOJO, V., MARTIN-SANCHEZ, F., KULIKOWSKI, C., RODRIGUEZ-PATON, A. and FRITTS, M. 2010. Nanoinformatics and DNA-based computing: catalyzing nanomedicine. *Pediatr. Res.* **67**(5):481-9.
- MARCHESE, ROBINSON R. L., CRONIN, M. T., RICHARZ, A. N. and RALLO, R. 2015. An ISA-TAB-Nano based data collection framework to support data-driven modelling of nanotoxicology. *Beilstein J. Nanotechnol.* **6**: 1978-99.
- MASSAWE, E. 2013. Nanomaterials for environmental remediation: investigating the role of nanoinformatics in support of environmental, health, and safety oversight of nanotechnologies at the local level. *J. Environ. Health*. **76**(1): 8-17.
- MELAGRAKI, G. and AFANTITIS, A. 2018. Computational toxicology: From cheminformatics to nanoinformatics. *Food Chem. Toxicol.* **112**: 476-477.
- OSTRAAT, M. L., MILLS, K. C., GUZAN, K. A. and MURRY, D. 2013. The Nanomaterial Registry: facilitating the sharing and analysis of data in the diverse nanomaterial community. *Int. J. Nanomedicine*, **8** Suppl 1: 7-13.
- PANNEERSELVAM, S. and CHOI, S. 2014. Nanoinformatics: emerging databases and available tools. *Int. J. Mol. Sci.* **15**(5): 7158-7182.
- POWERS, C. M., MILLS, K. A., MORRIS, S. A., KLAESSIG, F., GAHEEN, S., LEWINSKI, N. and OGILVIE HENDREN, C. 2015. Nanocuration workflows: Establishing best practices for identifying, inputting, and sharing data to inform decisions on nanomaterials. *Beilstein J. Nanotechnol.* **6**: 1860-71.
- ROSE, P., BHAT, M., VIDHANI K, A., GOLE, A. and GHASIAS, S. 2011. Intelligent informatics platform for nano-agriculture, *11TH IEEE International Conference on Nanotechnology*, Portland, OR, 2011, PP. 916-919. DOI: 10.1109/NANO.2011.6144536
- SADAN, T., CORMODE, D. P. and POPOVTZER, R. 2018. Nanoinformatics Revolutionizes Personalized Cancer Therapy. *Trends Cancer*. **4**(6): 397-399.
- SAMUEL TENNYSON, SUBRAMANIAN ARIVOLI and JOHN WILLIAM, Phytonanopesticides for vector control: A review, *J. Appl. Zool. Res.* **27**(1): 1-12.
- SHIN, H. K., KIM, K. Y., PARK, J. W. and NO, K. T. 2017. Use of metal/metal oxide spherical cluster and hydroxyl metal coordination complex for descriptor calculation in development of nanoparticle cytotoxicity classification model. *SAR QSAR Environ. Res.* **28**(11): 875-888.
- VANCE, M. E., KUIKEN, T., VEJERANO, E. P., MCGINNIS, S. P., HOCELLA, M. F. J. R., REJESKI, D. and HULL, M. S. 2015. Nanotechnology in the real world: Redeveloping the nanomaterial consumer products inventory. *Beilstein J. Nanotechnol.* **6**: 1769-80.
- VARSOU, D. D., NIKOLAKOPOULOS, S., TSOUMANIS, A., MELAGRAKI, G. and AFANTITIS, A. 2018. Enalos+ KNIME Nodes: New Cheminformatics Tools for Drug Discovery. *Methods Mol. Biol.* **24**: 113-138.
- VERMA, S., MANDAL, A., ANSARI, M. Y., KUMAR, A., ABHISHEK, K., GHOSH, A. K., KUMAR, A., KUMAR, V., DAS, S. and DAS, P. 2018. *Leishmania donovani* Inhibitor of Serine Peptidases 2 Mediated Inhibition of Lectin Pathway and Upregulation of C5aR Signaling Promote Parasite Survival inside Host. *Front. Immunol.* **9**: 63.



RESEARCH NEEDS FOR STORED PRODUCT ENTOMOLOGY

DIGVIR, S. JAYAS

University of Manitoba, Winnipeg, MB, Canada R3T 2N2

Email: Digvir.Jayas@UManitoba.Ca

Received: 30 November, 2019

Accepted: 30 March, 2020

Abstract: Stored grain insects (beetles and weevils) cause a considerable damage to stored products. Considerable research has been reported related to understanding of biology and control of insects by entomologists around the world. Studies include understanding life cycles; population dynamics; physical, chemical and biological control of insects. This paper identifies where additional research should be done in the field of stored-products entomology.

Key words: Stored grain insects, beetle, weevils, insect detection, carbon dioxide

INTRODUCTION

Globally, more than 3.1 billion tonnes of grains, pulses and oilseeds (hereinafter collectively referred to as grains) were produced in 2015 (FAOSTAT, 2016) and stored at many points after harvesting, prior to being delivered to processors and domestic and international consumers. Grains are stored in many types of storage systems which can be broadly classified as bag storage or bulk storage systems. Bulk storage systems can be of different sizes and shapes and built using many different types of construction materials. More than 100 types of insects attack grains during storage (SINHA and WATTERS, 1985). Post-harvest losses continue to range from 2% in well-managed systems to 30% in poorly-managed systems. When spoilage occurs in an individual storage bin, 100% of the grain can become unfit for human consumers and sometimes even unfit as animal feed (GUSTAVSSON *et al.*, 2011; JAYAS, 2012; WOLOSHUK and MARTÍNEZ, 2012). These losses are caused by improper storage conditions, causing infestation by species of insects and fungi that thrive on stored grains. Multiplication of insects can result in fungal infection (ARLENE-CHRISTINA *et al.*, 2014).

Losses are measured both in quantitative and qualitative ways. The quantitative losses occur through direct consumption of grains by insects, and quality losses occur from the contamination of grains from insect parts, excreta and fungi. "The fungi reduce the seed viability and market value of grains, impart unacceptable odours, cause grain discolouration, increase free fatty acid value, cause aggregation of grains, result in heat damage, and have the potential to cause allergic reactions in storage facility operators and consumers. In addition, fungi can produce mycotoxins, which are extremely harmful to consumers (SENTHILKUMAR *et al.*, 2017; MAGAN and MEDINA, 2016; MILIĆEVIĆ *et al.*, 2010). Importing countries apply punitive measures to ensure grains do not exceed specified amounts of mycotoxins and chemical residues through widely accepted Codex standards, which are developed and updated on an on-going basis by the World Health Organization (WHO) and the United Nations' Food and Agriculture Organization (FAO).

Not meeting these requirements results in huge financial losses to countries exporting grain. Furthermore, consumers are increasingly placing significance on the

quality of food products that they purchase and consume. High-quality grains are used as raw ingredients in the preparation of healthy, safe and wholesome food products for consumers; high-quality processed food products cannot be developed from poor-quality raw ingredients. Thus, preserving grains requires a multi-disciplinary approach where entomologists, mycologists, chemists, physicists and engineers must work together to develop conditions for safe storage of grains and develop sensors for quality monitoring of grains during storage and processing. This paper only highlights the additional research to be done by entomologists in collaboration with engineers and other researchers. The need in four under-researched areas is highlighted for further research: insect identification, insect detection, population dynamics under sub-optimal conditions, and movement of insects for mathematical modeling. Additional research on topics of interest such as insect biology; resistance of insects to chemicals; and physical, chemical and biological control of insects should be pursued by entomologists for insects of interest in their regions.

Insect identification: Proper identification of insects is critical for their control in stored grain. Most farmers and storage managers now have access to smartphones. These phones can be used to take images of insects, which can be sent for identification to a regional or a central location. The image can be compared with other images of insects stored in a robust database of insect images (LI *et al.*, 2019). The images of insects in the database should be from multiple views obtained by rotating insects along horizontal and vertical axes. Images should be collected using many distances between smartphone and insects as well as using as many types of smartphones as possible. Once such a database is available then deep learning tools can be used to identify insect with reasonable accuracy and result returned to the farmer or storage manager in near real time (SHEN *et al.*, 2018; ZHOU *et al.*, 2019). Development of databases for insects of interest for specific regions must be pursued and deep learning algorithms must be developed for their identification. Importance of correct identification and access to identification site must be popularized among farmers and managers of grain storage facilities.

Insect detection: The problem of detecting insects in grain bins has not been solved efficiently. There are few techniques that can be used to detect insects in samples collected from storage systems, few systems that can detect insects around facilities and only one system (OPI Systems Inc., Calgary, AB, Canada) that can detect insects inside stored bulks (KARUNAKARAN *et al.*, 2004; NEETHIRAJAN *et al.*, 2007; JIAN *et al.*, 2016). There is a need to develop efficient, low cost sensors to detect insects in bulk grains. Insects when present in grain produce carbon dioxide (CO₂), moisture, heat and distinct odours (SINGH (JAYAS) *et al.*, 1983, 1984, 1985; JAYAS 1995; TUMA *et al.*, 1990). Increases in temperature, moisture, CO₂ or odorous compounds can be used to detect insects in grains. Research is needed to detect different volatiles produced by different insect species, so this information can be used to develop nano-scale sensor arrays for deployment inside bins for detecting insects.

Population dynamics under sub-optimal conditions: The lifespan and multiplication rate of the insects are related to temperature, relative humidity (moisture content), food source, mating status, sex ratio and population density (ATHANASSIOU *et al.*, 2017; CHOTIKASATIAN *et al.*, 2017, LANOIX, 2015, SINGH and PRAKASH, 2015; ARTHUR *et al.*, 2014, HAGSTRUM and FLINN, 2012; HAGSTRUM *et al.*, 2012; COX and COLLINS, 2002; FIELDS and WHITE, 1997; WHITE *et al.*, 1995). In most of these studies,

the lifespan and multiplication rates of insects were measured at constant (optimal) temperatures and moisture contents. A grain storage ecosystem is influenced by its ambient environment (JAYAS, 2012; JIAN and JAYAS, 2012); insects infesting grains are exposed to fluctuating temperatures, moisture contents and CO₂ concentrations. Therefore, population dynamics data obtained under constant conditions cannot accurately predict insect populations under actual bin conditions.

Controlled investigations studying insect population dynamics in stored grain bulks under fluctuating storage conditions, characteristic of the different storage climates, are critically needed. My research team has recently determined the population dynamics of rusty grain beetle, *Cryptolestes ferrugineus* (Coleoptera: Laemophloeidae), at increasing and decreasing temperatures and have developed a mathematical model to predict their population under fluctuating conditions (JIAN *et al.*, 2018a, b). As rusty grain beetles and red flour beetle, *Tribolium castaneum* (Herbst.) (Coleoptera: Tenebrionidae), are the two most common insects found in Canadian grains and other insects occur infrequently, similar investigations are being conducted for red flour beetles and experiments are planned for future when these two species occur together. Similar investigations must be conducted for other stored product species under different fluctuating conditions expected to be experienced by stored grains under different climatic regions around the world.

Insect movement and distribution under grain storage conditions: Typically movement and distribution of stored-grain insects have been studied under laboratory conditions using up to 20-25 kg samples and mainly under gradients of temperatures (STEVENSON *et al.*, 2017; ĐUKIĆ *et al.*, 2016; LANOIX, 2015; HAGSTRUM and SUBRAMANYAM, 2006; FLINN and HAGSTRUM, 1998). To develop representative insect movement models, the movement and distribution of commonly found insects in grains needs to be determined under expected grain storage conditions, where gradients of temperature, moisture content and CO₂ occur simultaneously in the same or opposing directions. Furthermore, although limited research has been done on adult rusty grain beetle movement (JIAN and JAYAS, 2009), these cannot be used in the development of comprehensive insect movement model, unless we study the movement of all mobile life stages (larvae and adults) of all common insects. The movement and distribution of insects is also influenced by the size of the grain mass (JIAN *et al.*, 2011a, b; 2012), hence, full-size bin experiments are critical to advance our knowledge of interactions among biotic and abiotic factors within stored grain ecosystems and to develop practical guidelines for managing stored grains.

To study insect movements in one-dimension, one or two meter long properly insulated columns filled with grain can be used and insects introduced at the mid-point and their movement measured in either direction from the point of introduction. After certain duration insect column can be divided into any number of sections by inserting metal plates and samples can be collected for counting insects in each section to quantify insect movement. The movement of insects can be studied at different constant temperatures by conducting experiments in walk-in environmental chambers (Fig.-1; JIAN *et al.*, 2002, 2005a). These one-dimensional columns could be fitted with a water bath or some other mechanism at one end to raise the temperature while other end will be exposed to the temperature of the environmental chamber, thus creating temperature gradients along the column. Using such simple device, many experiments then should be done to study the movement of mobile stages of different insects at constant and different temperature gradients (such as 2.5°C, 5°C, 7.5°C, 10°C per meter).

By filling grains of different moisture contents along the length of the grain columns moisture content gradients can be easily created and insect movement studied at constant temperatures (PARDE *et al.*, 2004). By superimposing temperature gradients on columns with moisture gradients, studies can be conducted on mobile stages of insects when moisture gradients are in the same or opposing directions, i.e., having high moisture grain on one end of the column and high temperature at the other end of the column will create opposing gradients.

By attaching small chambers on either ends of the columns and constantly circulating a known CO₂ concentration gas mixture, CO₂ gradients along the column can be created and insect movement studied under different CO₂ gradients. By superimposing moisture and temperature gradients insect movements can be studied for different combinations of temperature, moisture and CO₂ gradients. For example, how is insect movement affected when all three parameters are high on one end of the column compared to when each parameter is high on one end of the column? Is effect cumulative or synergistic?

Similarly, insect movement should be studied in two dimensions (Figure 2; JIAN *et al.*, 2007) and three dimensions. Two dimensional studies have only been conducted at constant temperatures (JIAN *et al.*, 2007) but by designing heating mechanisms on one or more sides of the chamber, by filling different parts of the chambers with different moisture content grain, and attaching mechanisms for maintaining CO₂ concentrations on different sides of the chamber, studies in two dimensions can be conducted under different gradients of temperature, moisture and CO₂.

For three-dimensional (3-D) studies, dividing a cubical chamber bulk grain into smaller parts is not feasible. A possible approach is to use smaller bags made of a screen that allows free movement of insects across it and assemble a 3-D chamber. After applying required gradients, the chamber can be dis-assembled and insect movement characterized in 3-D.

Once such studies have been conducted and apparent coefficient of insect movement is determined as a function of different gradients, insect movement can be modeled mathematically along with movements of heat, moisture and gases.

Mathematical model of movement of insect in bulk grain

I am hypothesizing that a mathematical formulation using a partial differential equation, along with boundary and initial conditions, given below and solved using a finite element method can model the movement of adult beetles in three dimensions.

$$\frac{\partial u}{\partial t} = D_x \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} - \beta_x \frac{\partial u}{\partial x} - \beta_y \frac{\partial u}{\partial y} - \beta_z \frac{\partial u}{\partial z} + a$$

The boundary condition: $\frac{\partial u}{\partial n} = 0$

The initial condition: $u = N_0(x, y, z) \text{ at } t = 0$

where; $u = u(x, y, z, t)$, the spatial-temporal population density of the insect [adults/m³ at time t];

x, y, z = coordinate of a position [m];

D_x, D_y, D_z = diffusivity or motility [m²/s] in the x, y, and z directions, respectively (determined from experimental data obtained under objective (i));

$\beta_x, \beta_y, \beta_z$ = bias movement velocity (advection rate) in the x, y, and z directions [m/s], respectively (determined from experimental data obtained under objective (i));

α = net insect number change due to insect multiplication and mortality (predicted by population dynamics model under sub-optimal conditions developed from data obtained under objectives (ii & iii)); and

$N_0(x, y, z)$ = initial number introduced at the location (x, y, z) .

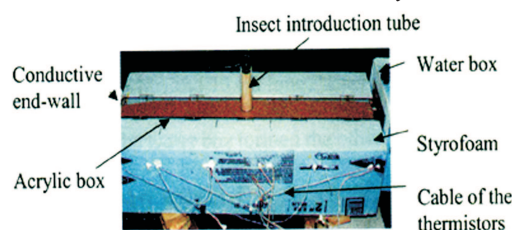


Fig. 1: Set up to study one-dimensional movement of insects under gradients of temperature (Source: JIAN *et al.*, 2005a).

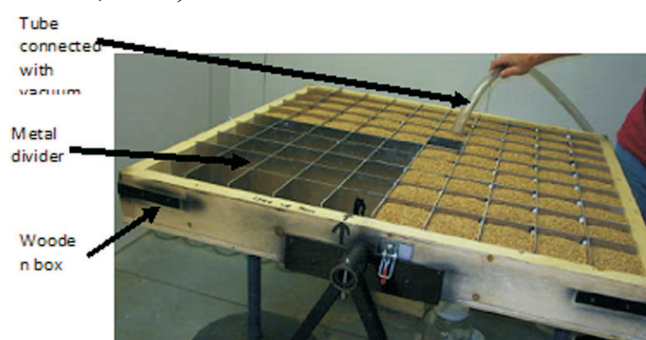


Fig. 2: Set up to study two-dimensional movement of insects under uniform conditions (Source: JIAN *et al.*, 2007).

The D s and β s are functions of space and time but can be assumed to be constants over a short time period (*e.g.*, 1.0 h) and a small area (such as a finite element). We demonstrated this concept under constant conditions of temperatures, moisture contents and gas concentrations in 2-D (JIAN *et al.*, 2007, 2008). This partial differential equation can be simultaneously solved along with the heat; moisture and gas transfer partial differential equations using the finite element method and will lead to a comprehensive ecosystem model. We have already developed a 3-D mathematical model of heat transfer (ALAGUSUNDARAM *et al.*, 1990; JIAN *et al.*, 2005b, 2015a, 2015b) and a 3-D model of movement of CO₂ based on the combined effects of concentration gradients, pressure gradients, and gravity on the transport of gases in the bulk grain and incorporating sorption of CO₂ by grain (XU *et al.*, 2002, SMITH and JAYAS, 2001). We have also developed a 3-D

model of moisture movement through grain (JIAN *et al.*, 2015a) incorporating free convection currents, which occurs in large grain masses due to temperature gradients (JAYAS, 1995, 2012). All of these models when integrated into a single model, we will have a comprehensive model of a stored-grain ecosystem. Running simulations using the comprehensive model with multiple years of weather data from multiple locations around the world and for bins of different sizes and shapes, guidelines with probabilities on insects populations can be developed and shared widely with farmers and storage managers. Such a model will be an exceptional, globally applicable, stored-grain management tool.

REFERENCES

- ARLENE-CHRISTINA, G. D., JAYAS D. S., FIELDS P. G., JIAN F., WHITE N. D. G. and ALAGUSUNDARAM K. 2014. Movement of *Cryptolestes ferrugineus* out of wheat kernels and their mortalities under elevated temperatures. *Journal of Stored Products Research*, **59**: 292-298.
- ARTHUR, F. H., CAMPBELL J. F. and TOEWS M. D. 2014. Distribution, abundance, and seasonal patterns of stored product beetles in a commercial food storage facility. *J. Stored Products Res.*, **56**: 21-32.
- ATHANASSIOU, C. G., KAVALLIERATOS N. G. and CAMPBELL J. F. 2017. Effect of the presence of live or dead insects on subsequent captures of six stored-product beetle species: the relative species matters. *J. Econ. Ent.*, **110**: 770-775.
- CHOTIKASATIAN, C., CHAYAPRASERT W. and PATHAVEERAT S. 2017. A study on the feasibility of quantifying the population density of stored product insects in air-tight grain storage using CO₂ concentration measurements. *J. Stored Products Res.*, **73**: 21-29.
- COX, P. D. and COLLINS J. E. 2002. Factors affecting the behaviour of beetle pests in stored grain, with particular reference to the development of lures. *J. Stored Products Res.*, **38**: 95-115.
- ĐUKIĆ, N., RADONJIĆ A., LEVIĆ J., SPASIĆ R., KLJAJIĆ P. and ANDRIĆ G., 2016. The effects of population densities and diet on *Tribolium castaneum* (Herbst) life parameters. *J. Stored Products Res.*, **69**: 7-13.
- FAOSTAT. 2016. FAO Statistical Yearbook 2016. *Food & Agric. Organization, Rome, Italy*.
- FIELDS, P. G. and WHITE, N. D. G., 1997. Survival and multiplication of stored-product beetles at simulated and actual winter temperatures. *Canadian Entomologist*, **129**: 887-898.
- FLINN, P. W. and HAGSTRUM, D. W. 1998. Distribution of *Cryptolestes ferrugineus* (Coleoptera: Cucujidae) in response to temperature gradients in stored wheat. *Journal of Stored Products Research*, **34**: 107-112.
- GUSTAVSSON, J., CEDERBERG C., SONESSON U., VAN OTTERDIJK R. and MEYBECK A. 2011. Global food losses and food waste: extent causes and prevention. *Rome, Italy: Food and Agriculture Organization (FAO) of the United Nations*.
- HAGSTRUM, D. W. and SUBRAMANYAM B. 2006. Fundamentals of stored-product entomology. *St. Paul, MN: (Am. Assoc Cereal Chemists) AACC International*. 322 p.
- HAGSTRUM, D. W. and FLINN P. W. 2012. Insect pest management for raw commodities during storage. In: *Stored Product Protection, Hagstrum D.W., D.W., Phillips T.M. and Cuperus G. (eds.)*, Kansas State University, Manhattan, KS. Pp. 213-218
- HAGSTRUM, D. W., PHILLIPS T. M. and CUPERUS G. (eds.). 2012. *Stored Product Protection, Kansas State University, Manhattan, KS*.
- JAYAS, D. S. 1995. Mathematical modeling of heat, moisture, and gas transfer in stored-grain ecosystems. In: *Stored-Grain Ecosystems, Jayas D.S., White N.D.G. and Muir W.E. (eds.)*, Marcel Dekker Inc., New York, NY. Pp. 527-567.
- JAYAS, D.S. 2012. Storing grains for food security and sustainability. *Agric. Res.*, **1**(1): 21-24.
- JIAN, F., JAYAS D. S., WHITE N. D. G. and MUIR W. E. 2002. Temperature and geotaxis preference by *Cryptolestes ferrugineus* (Coleoptera: Laemophloeidae) adults in response to 5°C/m temperature gradients at optimum and hot temperatures in stored wheat and their mortality at high temperature. *Environmental Entomology*, **31**(5): 816-826.

- JIAN, F., JAYAS D. S. and WHITE N. D. G. 2005a. Movement and distribution of adult *Cryptolestes ferrugineus* (Coleoptera: Laemophloeidae) in stored wheat in response to temperature gradients, dockage, and moisture differences. *Journal of Stored Products Research*, **41**(4): 401-422.
- JIAN, F., JAYAS D. S., WHITE N. D. G., and ALAGUSUNDARAM K. 2005b. A three-dimensional, asymmetric, and transient model to predict grain temperatures in grain storage bins. *Transactions of the ASAE*, **48**: 263-271.
- JIAN, F., JAYAS D. S., WHITE N. D. G. and SMITH E. A. 2007. Two-dimensional diffusion of *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Laemophloeidae) populations in stored wheat under constant environmental conditions. *Journal of Stored Products Research*, **43**: 342-348.
- JIAN, F., JAYAS D. S., WHITE N. D. G. and SMITH E. A. 2008. Numerical analysis and parameter estimation technique for insect population redistribution models. *Ecological Modelling*, **211**: 47-56.
- JIAN, F. and JAYAS D. S.. 2009. Detecting and responding to resource and stimulus during the movements of *Cryptolestes ferrugineus* adults. *Food & Bioprocess Tech.*, **2**: 45-56.
- Jian, F., Larson R., Jayas D.S. and White N.D.G. 2011a. Three dimensional spatial distribution of adults of *Cryptolestes ferrugineus* (Coleoptera: Laemophloeidae) in stored wheat under different temperatures, moisture contents, and adult densities. *Journal of Stored Products Research*, **47**: 293-305.
- JIAN, F., LARSON R., JAYAS D. S. and WHITE N. D. G.. 2011b. Evaluation of sampling units and sampling plans for adults of *Cryptolestes ferrugineus* (Coleoptera: Laemophloeidae) in stored wheat under different temperatures, moisture contents, and adult densities. *Journal of Stored Products Research*, **47**: 334-340.
- JIAN, F. and JAYAS D. S. 2012. The ecosystem approach to grain storage. *Agricultural Research*, **1**(2): 148-156.
- JIAN, F., LARSON R., JAYAS D. S. and WHITE N. D. G. 2012. Three dimensional temporal and spatial distribution of adults of *Tribolium castaneum* (Coleoptera: Tenebrionidae) in stored wheat under different temperatures and adult densities. *Agricultural Research*, **1**(2): 165-174.
- JIAN, F., CHELLADURAI V., JAYAS D. S. and WHITE N. D. G. 2015a. Three-dimensional transient heat, mass, and momentum transfer model to predict conditions of canola stored inside silo bags under Canadian Prairie conditions: Part I - soil temperature model. *Transactions of the ASABE*, **58**(4): 1127-1134.
- JIAN, F., CHELLADURAI V., JAYAS D. S. and WHITE N. D. G. 2015b. Three-dimensional transient heat, mass, and momentum transfer model to predict conditions of canola stored inside silo bags under Canadian Prairie conditions: Part II model of canola bulk temperature and moisture content. *Transactions of the ASABE*, **58**(4): 1135-1144.
- JIAN, F., DOAK S., JAYAS D. S., FIELDS P. G. and WHITE N. D. G. 2016. Comparison of insect detection efficiency by different detection methods. *Journal of Stored Products Research*, **69**: 138-142.
- JIAN, F., JAYAS D. S., FIELDS P. G., WHITE N. D. G., ZHANG H. and TANG P. 2018A. Demography of rusty grain beetle in stored bulk wheat: Part I, population dynamics at different temperatures and grain bulk sizes. *Environmental Entomology*, **47**(2): 244-255.
- JIAN, F., D. S. JAYAS, P. G. FIELDS and N. D. G. WHITE. 2018B. Demography of rusty grain beetle in stored bulk wheat: Part II. Mathematical modelling to characterize and predict population dynamics. *Environmental Entomology*, **47**(2): 256-263.
- KARUNAKARAN, C., JAYAS D. S. and WHITE N. D. G. 2004. Soft X-rays: a potential insect detection method in the grain handling facilities. *International Quality Grains Conference, Indianapolis, July 19-22, 2004*.
- LANOIX F. 2015. Does interspecific competition between *Tribolium castaneum* and *Tribolium confusum* lead to thermal habitat segregation? *Research Project Report, University of Ottawa, Ottawa, ON*.

- LI, J., ZHOU H., JAYAS D. S. and JIA Q. 2019. Construction of a dataset of stored-grain insects images for intelligent monitoring. *Applied Engineering in Agriculture*, **35**(4): 647-655.
- MAGAN, N. and MEDINA A. 2016. Mycotoxins, food security and climate change: do we know enough? *Microbiology Today*, **43**: 10-13.
- MASON, L.J. and MCDONOUGH M., 2012. Biology, behavior, and ecology of stored grain and legume insects. In: *Stored Product Protection*, Hagstrum D.W., D.W., Phillips T.M. and Cuperus G. (eds.), Kansas State University, Manhattan, KS. Pp. 7-20.
- MILIĆEVIĆ, D.R., ŠKRINJAR M. and BALTIĆ T. 2010. Real and perceived risks for mycotoxin contamination in foods and feeds: challenges for food safety control. *Toxins*, **2**: 572-592.
- NEETHIRAJAN, S., KARUNAKARAN C., JAYAS D. S. and WHITE N. D. G., 2007. Detection techniques for store-product insects in grain. *Food Control*, **18**: 157-162.
- PARDE, S. R., JAYAS D. S. and WHITE N.D.G. 2004. Movement of *Cryptolestes ferrugineus* (Coleoptera: Cucujidae) in grain columns containing pockets of high moisture content wheat and carbon dioxide gradients. *Journal of Stored Products Research*, **40**: 299-316.
- SENTHILKUMAR, T., JAYAS D. S., WHITE N. D. G., FIELDS P. G. and GRÄFENHAN T. 2017. Detection of ochratoxin-A contamination in stored wheat using near-infrared hyperspectral imaging. *Infrared Physics and Technology*, **81**: 228-235.
- SHEN Y., ZHOU H., J. LI, JIAN F. and JAYAS D.S. 2018. Detection of stored-grain insects using deep learning. *Computers and Electronics in Agriculture*, **145**: 319-325.
- SINGH (JAYAS), D., MUIR W. E. and SINHA R.N. 1983. Finite element modelling of carbon dioxide diffusion in stored wheat. *Canadian Agricultural Engineering*, **25**(1): 149-152.
- SINGH (JAYAS), D., MUIR W.E. and SINHA R.N. 1984. Apparent coefficient of diffusion of carbon dioxide through samples of cereals and rapeseed. *Journal of Stored Products Research*, **20**(3): 169-175.
- SINGH (JAYAS), D., MUIR W.E. and SINHA R.N. 1985. Transient method to determine the diffusion coefficient of gases. *Canadian Agricultural Engineering*, **27**(2): 69-72.
- SINGH, S. and PRAKASH S. 2015. Effect of temperature and humidity on the culture of *Tribolium castaneum*, Herbst (Coleoptera: Tenebrionidae) in the laboratory. *International Journal of Scientific and Research Publications*, **5**(7): 1-6.
- SINHA, R. N. and WATTERS F. L. 1985. Insect pests of flour mills, grain elevators and feed mills and their control. *Publication 1776, Agric. & Agri-Food Canada, Ottawa, ON*.
- SMITH, E. A. and JAYAS D. S.. 2001. Modelling the movement of fumigant gas within grain beds. *Transactions of the ASAE*, **44**(3): 661-667.
- STEVENSON, B.J., CAI L., FAUCHER C., MICHIE M. and BERNA A., 2017. Walking responses of *Tribolium castaneum* (Coleoptera: Tenebrionidae) to its aggregation pheromone and odors of wheat infestations. *J. Econ. Ent.*, **110**: 1351-1358.
- TUMA, D., SINHA R. N., MUIR W. E. and ABRAMSON D. 1990. Odour volatiles associated with mite infested bin stored wheat. *Journal of Chemical Ecology* **16**: 713-724.
- WHITE, N. D. G., DEMIANYK C. J., KAWAMOTO H., and SINHA R. N., 1995. Population growth of *Cryptolestes ferrugineus* and *C. pusillus* (Coleoptera: Cucujidae) alone or in competition in stored wheat or maize at different temperatures. *Bulletin of Entomological Research*. **85**: 425-429.
- WOLOSHUK C. and MARTÍNEZ E. M., 2012. Molds and mycotoxins in stored products. Pp. 63-68. In: *Stored Product Protection*, Hagstrum D.W., D.W., Phillips T.M. and Cuperus G. (eds.), Kansas State University, Manhattan, KS.
- XU, S., JAYAS D. S., WHITE N. D. G. and MUIR W. E., 2002. Momentum-diffusive model for gas transfer in granular media. *J. Stored Products Res.*, **38**: 455-462.
- ZHOU, H., MIAO H. , J. LI, JIAN F. and JAYAS D. S. 2019. A low-resolution image restoration classifier network to identify stored-grain insects from images of sticky boards. *Computers and Electronics in Agriculture*, **162**: 593-601.



FIELD EVALUATION OF ECO-FRIENDLY IPM STRATEGIES AGAINST *LEUCINODES ORBONALIS* GUENEE IN BRINJAL ECOSYSTEM

SUNIL KUMAR MANDAL, RAJKUMAR MANDAL AND BARUN

Krishi Vigyan Kendra (Dr. Rajendra Prasad Central Agricultural University) Siwan-841408, Bihar: Email Id- head.kvk.siwan@rpcau.ac.in

Received: 12 February, 2020

Accepted: 30 April, 2020

ABSTRACT: The farmer's field experiment was conducted during Kharif, 2017 in village of Gopalganj district in Bihar to standardize a suitable integrated pest management (IPM) packages against the brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. The trial consisted of eight treatments laid out in Randomized Block Design replicated three times with plant spacing of 75cm x 60cm. All the IPM module treatments were significantly superior over farmer packages and untreated check in minimizing the shoot and fruit borer incidence on the crop. Among different sets of treatments, T₁ and T₂ were more effective in reducing the shoot infestation than the rest the treatments, in which the infestation varied from 5.07 to 13.12% as against in farmers package (16.73%) and untreated check (28.23%). Similarly, fruit infestation data on number and weight basis revealed that the minimum fruit damaged (7.51% and 8.76%, respectively) in T₂. The highest fruit yield (168.25q/ha) and the maximum cost benefit ratio (1:10.12) was also obtained with T₂.

Key words: IPM, brinjal, *Leucinodes orbonalis*, pheromone trap, insecticides

INTRODUCTION

The eggplant (*Solanum melongena* L) is extensively cultivated throughout the year in India. The crop is attacked by dozens of insect pests. Important among them in India is brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (MATHURETAL, 2012; SETHI *et al.*, 2016). The borer causes severe damage to growing shoot tips and fruits to around 23.07% (DAR, 2012; DAR and MIR, 2016) thereby drastically reducing the marketable fruit yield. Large quantities of synthetic insecticides are being used to control the pest resulting in detrimental effect to the environment as well as to human health. The target pest became resistant to the conventional insecticides due to indiscriminate use of pesticides (KABIR *et al.*, 1996). In summer season, it has been reported that for *L. orbonalis* the farmers of Bangladesh are spraying almost daily, whereas, in West Bengal frequency exceed three sprays per week (KABIR *et al.*, 1995).

Concerning the above prospect priority should be given towards sustainable brinjal cultivation in this region under the bio- intensive pest management system that would be more efficacious and at the same time eco-friendly. Such an alternative method is the use of IPM component of brinjal shoot and fruit borer have been identified long back but so far no concentrated efforts have been made to use synthetic chemicals for practical management practices of the target pest in the farmers field. CORK *et al.* (2003) observed that fruit damage reduced 22% & 26.4% in IPM plots of young and mature crop, respectively. With this objective, we conducted an experiment in farmer's field to demonstrate use of IPM package and practices.

MATERIALS AND MEHODS

The field experiment was conducted during kharif season of 2017 on brinjal cultivar 'Pant Rituraj' in the farmers' field in Gopalganj district of Bihar. The trial consisted of eight

treatments, laid out in randomized block design, replicated three times, each plot measuring 5m x 4m and spacing maintained at 50cm x 50cm. All the recommended agronomic practices were followed to raise the crop and formulate a suitable integrated pest management (IPM) package against brinjal shoot borer. The following packages of treatments were evaluated:

- IPM -1 (T_1) - Trapping of sex pheromones and clipping of infested shoots followed by foliar application of Nimbecidine 0.15% @ 4.0 ml per liter of water at 15- days interval.
- IPM -2 (T_2) - Trapping of sex pheromones and clipping of infested shoots with removal of damaged fruits followed by foliar application of Nimbecidine 0.15% @ 4.0 ml per liter of water at 15- days interval.
- IPM -3 (T_3) - Clipping of infested shoots with removal of damaged fruits followed by foliar application of Spinosad 45SC @ 0.5 ml per liter of water at 15- days interval.
- IPM -4 (T_4) - Clipping of infested shoots with removal of damaged fruits followed by foliar application of Emamectin Benzoate 5SG @ 0.25 ml per liter of water at 15- days interval.
- IPM -5 (T_5) - Foliar application of Nimbecidine 0.1% @ 4.0 ml followed by Indoxacarb 14.5 SC @ 1.0 gm/ liter at 15- days interval.
- IPM -6 (T_6) - Soil application of Neem cake @200 kg / ha followed by Cartap hydrochloride 50 SP @ of 1.0 gm/L of water at 15 days interval.
- Check -1 (T_7) - Foliar application of Chlorpyrifos 20EC @ 1.5ml/ L of water as per normal control measures practiced by the farmers (3-4 times per week).
- Check -2 (T_8) - Control plot (Untreated check).

The pheromone traps were placed in the field at 45 days after transplanting. The component of the pheromone was (E)-11-hexa decenyl acetate (E11-16: AC) and E (11)-hexadecen-1-al (E11-16; O11) blended in the ratio of 100:1. Sprays were conducted with the help of a Knapsack sprayer using 500 L of spray fluid per hectare. Three sprays were given at fortnightly interval, commencing 30 days after transplanting. At weekly interval clipping of infested shoots, removal of damaged fruits. Clipping of infested shoots and removal of damage fruits, if any, were undertaken before setting of traps. The observations were made on the total numbers of healthy and infested shoots and the total number of fruits in each picking by counting the number of healthy and infested fruits as well as weight of healthy and infested fruits, from five plants selected at random, in each replication. The infestation data were subjected stastical analysis. The harvest of only healthy fruits was considered for recording the yield from all the pickings.

RESULTS AND DISCUSSION

The results revealed that the all the treatments were superior over untreated check in minimizing the damage by the shoot and fruit borer (Table-1). The data on the infestation of shoots indicated that among the different treatments, the treatment T_2 comprising trapping of sex pheromones and clipping of infested shoots with removable of damage fruits followed by Nimbecidine 0.15% @ 4.0 ml/L of water at 15 days interval were most effective in reducing the shoots infestation (5.07%) than rest of the treatments in which the infestation varied from 6.31 to 16.73% among the treatments as against, in the untreated check, the mean shoot infestation was 28.23%. The average shoot infestation was in order of T_2 (5.07 %) > T_1 (6.31%) > T_6 (9.24%) > T_3 (11.26%) > T_4 (12.17%) > T_5 (13.12%) > T_7 (16.73%) > T_8 (28.23%). The per cent infestation of fruits both on number and weight basis by the borer pest followed the same trend with regard to shoot infestation. The treatment T_2 (7.51% on number basis and 8.76% on weight basis) also proved significantly best treatment over T_7 (Farmers practice) in

Table-1: Effect of IPM packages against brinjal shoot and fruit borer

Treatments	Mean shoot damaged (%)	Mean fruit damaged (%)		Yield (q/ha)	Yield increased (q/ha)	Value of increase yield (Rs./ha)	Cost of treatments (Rs./ha)	Net return (Rs./ha)	C:B ratio
		No. Basis	Wt. Basis						
IPM-1 (T1)	6.31 (14.54)	9.82 (18.24)	10.17 (18.63)	161.93	29.58	35496.00	3567.00	31929.00	1:8.95
IPM-2 (T2)	5.07 (12.92)	7.51 (16.22)	8.76 (17.26)	168.25	35.90	43080.00	3875.00	39205.00	1:10.12
IPM-3 (T3)	11.26 (19.64)	14.08 (21.97)	12.53 (20.70)	162.87	30.52	36624.00	5182.00	31442.00	1:6.07
IPM-4 (T4)	12.17 (20.44)	15.79 (23.42)	13.86 (21.89)	155.41	23.06	27672.00	4216.00	23456.00	1:5.56
IPM-5 (T5)	13.12 (21.22)	17.68 (24.80)	14.75(22.63)	151.65	19.30	23160.00	3754.00	19406.00	1:5.17
IPM-6 (T6)	9.24 (17.66)	12.37 (20.62)	11.54 (19.82)	158.16	25.81	30972.00	5168.00	25804.00	1:4.99
Check-1 (T7)	16.73 (24.12)	33.25 (35.18)	19.62 (26.28)	144.58	12.23	14676.00	5094.00	9582.00	1:1.88
check-2 (T8)	28.23 (32.08)	44.16 (41.67)	38.52 (38.35)	132.35	-	-	-	-	-
S _{Em} (±)	0.957	0.788	1.137	1.753	-	-	-	-	-
CD(P=0.05)	2.874	2.361	3.415	5.264	-	-	-	-	-

Figures in parentheses are arc sine transformed values; Market price of brinjal fruit yield@ Rs.1200/q

all the treatments including T₈ (untreated check). The average fruit damage both on number and weight basis in same order of shoot damage. Earlier, effective control of *L.orbonalis* with trap + shoot clipping + neem based insecticide + removable of damaged fruits during harvesting was reported by MANDAL *et al.* (2008). The reason behind it may be that traps helped in catching the moths and in addition sanitary measures along with neem based insecticide helped in keeping the population of brinjal shoot and fruit borer to a minimum level. The results were also corroborating the finding of CORK *et al.* (2003) recorded that fruit damage was reduced 22% and 26.4% in IPM plots of young and mature crops, respectively.

The yield data revealed significantly higher yield of 168.25 q/ha in T₂ followed by T₃ (162.87 q/ha), T₁ (161.93 q/ha), T₆ (158.16 q/ha) and T₄ (153.41 q/ha), all being on par with each other but significantly more than farmer practice and untreated check. The cost -benefit analysis of different set of treatment revealed that maximum monetary benefit of rupees 43080.00/ha accrued from T₂, the most effective treatment in terms of the larval control as well as yield released on per hectare basis. Yet the highest cost –benefit ratio (1:10.12) was also obtained in T₂. These was followed by T₁ (1:8.95), T₃ (1:6.07), T₄ (1:5.56), T₅ (1:5.17) and rather less efficiently by T₆ (1:4.94) and T₇ (1:1.88) as farmers practice over untreated check. Thus to conclude the results, trapping of sex pheromones and clipping of infested shoots with removable of damaged fruits followed foliar application neem based insecticides (Nimbecidine 0.15% @ 4.0 ml/L of water at 15 days interval) afforded effective control of *L. orbonalis* with higher fruit yield as well as the best cost-benefit ratio.

REFERENCES

- CORK, A. S. N., ALAM, F. M. A. ROUF and TALEKAR N. S., 2003. Female sex pheromone of brinjal fruit and shoot borer, *Liucinodes orbonalis* (Lipidptera: Pyralidae): trap optimization and application of IPM trails. *Bull. Entomol Res.* **93**: 107-113
- DAR, S. A. 2012. Screening of brinjal genotypes/varieties against brinjal shoot and fruit borer (*L. orbonalis* Guenee) *M.Sc. Thesis SKAUST, Srinagar*, pp 35-37.
- DAR, S.A. and MIR S.H., 2016 screening and relative resistance of brinjal collections against *Liucinodes orbonalis* under field conditions of Kashmir (India). *Journal of Experimental Zoology, India* **19**(1): 359-365.
- KABIR, K.H., ROUF F.M.A., BAKASH M. E., MANDAL N.A., HUSSAIN M. A., SATTOR M.A. and ASADUZZAMAN M.S.M. 1995. Insecticides usage pattern on vegetables at farmers level of Jessore region of Bangladesh: a survey report. *Bangladesh Agricultural research Institute, Joydepur Gazipur, Bangladesh. Annual Report. 1993-94*, PP 57-65.
- KABIR, K.H., BAKASH M. E., ROUF F.M.A., KARIM M.A. and AHMED A. 1996. Insecticides usage pattern on vegetables at farmers level of Jessore region of Bangladesh: a survey finding. *Bangladesh J. Agric. Res.* **21**: 241-254.
- MANDAL, D., BRAL K. and TALEKAR N.S. 2008. Integrated Pest Management of brinjal shoot and fruit borer, *Liucinodes orbonalis* Guenee. *J. Appl. Zool. Res.* **19**(1): 42-45.
- MATHUR, A, SINGH N.P. and SINGH S. 2012. Management of brinjal shoot and fruit borer: Dilemma of adopting Bt. Brinjal over Integrated Pest Management Technology. *International Conference on Clean Green Energy IPCBEE.* **27** © (2012) IACSIT press, Singapore.
- SETHI, T., KALIA V., SINGH A. K. and GUJAR G.T., 2016. In vitro rearing of brinjal shoot and fruit borer, *Liucinodes orbonalis* (Guenee) (Lepidoptera : Crambridae) on artificial diet. *Entomon*, **41**(2): 105-114.



IMPACT OF WEATHER PARAMETERS ON INCIDENCES OF CHILLI MITE, *POLYPHAGOTARSONEMUS LATUS* BANKS IN ANDHRA PRADESH.

V. L. PATHIPATI^{*1}, T. VIJAYA LAKSHMI², RAJANI³, C. V. RAMANA⁴
AND L. NARAMNAIDU⁵

1=Associate Professor (Entomology) & Principal, HPC, Dr YSR Horticultural University, Nuzvid, Krishna district, Andhra Pradesh-521201

2=Senior Scientist (Pathology), Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh-521204

3=Scientist (Horticulture), Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh-521204

4= Senior Scientist (Horticulture), Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh-521204

5=Principal Scientist (Horticulture) & Head, Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh-521204

*vijji.edward6@gmail.com, +09490505926

Received: 28 February, 2020

Accepted: 1 April, 2020

ABSTRACT: Chilli (*Capsicum annum* L.) is an important spice & commercial vegetable crop grown all over India. The tarsonemid mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae) is the considered as major sucking pest. Effected leaves show “down ward” resulting in a typical damage known as ‘leaf curl syndrome’. Economic yield loss could be 11-75% quantitatively and 60-80% qualitatively in the event of serious infestation. The prevalence and build up of these insect pests of chilli crop is mostly governed by weather parameters like temperature, relative humidity, rainfall, sunshine hours. Furthermore, the weather parameters vary greatly from place to place and season to season. Field experiments were conducted from 2007-08 to 2012-13 at Horticultural Research Station, Lam Farm, Guntur, to study the seasonal incidence and impact of weather parameters on chilli mite in Andhra Pradesh. The results revealed that the infestation and severity of mite were highly influenced by weather parameters. Mite population reached its peak (7.41/leaf) in the 38th Standard Meteorological Week (SMW) in 2007-08, 21.27 in 2008-09, 221.37 in 2009-10, 17.95 in 2010-11, 19.75 in 2011-12 and 20.88 in 2012-13, respectively. Similar trend was observed both in one and two preceding weeks in every year. The mite population had significant positive correlation with morning relative humidity (0.42 in 2007-08, 0.50 in 2008-09, 0.74 in 2009-10, 0.53 in 2010-11, 0.65 in 2011-12 and 0.50 in 2012-13) and preceding two weeks (0.38 in 2007-08, 0.40 in 2008-09, 0.74 in 2009-10, 0.16 in 2010-11, 0.53 in 2011-12 and 0.50 in 2012-13), respectively. There was significant negative correlation with maximum and minimum temperature, evening relative humidity and non-significant correlation with rain fall in six years of the study. The combined effect of weather parameters on incidence of mites indicated that the variation in the incidence (72 to 79%) was contributed by the weather parameters and major impact was by morning relative humidity on the incidence and severity. Other parameters like temperature and sunshine hours did not show any significant effect. The population levels also vary with year to year because of variations in the

weather parameters. The overall results clearly indicated the peak period of activity of mites species influenced by preceding one and two week weather and significant role of weather parameters on the population dynamics of mites inhabiting the plant parts of chilli crop.

Key words: Chilli, mite, weather parameters, incidences, *Polyphagotarsonemus latus*

INTRODUCTION

Chilli (*Capsicum annuum* Linn.) is an important spice as well as commercial vegetable crop grown all over India. It is an essential ingredient of Indian curry, which is characterized by tempting colour and titillating pungency. In India, Andhra Pradesh occupies a prime place in chilli cultivation accounting for 49% of the total cultivated area under this crop in the country (RAJPUR *et al.*, 2008). Besides the several factors responsible for low productivity and quality deterioration of chilli, the damage caused by insect pests is the most important. So far, 293 insect and mite species were reported on chilli (BUTANI, 1976). The tarsonemid mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae) is the considered as major sucking pest. Effected leaves shows “down ward” resulting in a typical damage known as 'leaf curl syndrome'. Economic yield loss may be 11-75% quantitatively and 60-80% qualitatively in the event of serious infestation. The prevalence and build up of these insect pests of chilli is mostly governed by weather parameters like temperature, relative humidity, rainfall, sunshine hours. Furthermore, the weather parameters vary greatly from place to place and season to season (DHAKA and PAREEK, 2008). For effective pest management, study on the influence of the various factors responsible for population fluctuation on a particular crop might assist in prediction of its occurrence in a given area (SUBHARANI and SINGH, 2007).

Thus the knowledge of the influence of weather parameters of chilli will help to develop a forecasting system and to implement timely plant protection measures. Knowing the peak period of pest infestations one can design pest management tactics more effectively with less incorporation of highly toxic chemical substances in the field. Keeping above aspects in mind, the present investigation was aimed to study on the seasonal incidence of yellow mite in relation to various weather parameters like rainfall, temperature, and relative humidity etc.

MATERIALS AND METHODS

Field experiments were conducted for six years (2007-08 to 2012-13) at Horticultural Research Station, Lam, Guntur, Andhra Pradesh to study seasonal incidence of the test mite on Chilli. The popular and leading chilli variety, LCA-334 was raised in the month of July and transplanted in the month of September in all the years of study. Crop was maintained in an area of 500 m² area. All the recommended agronomical practices were followed from time to time to raise good crop. No plant protection measures were taken throughout the crop season. Observations were made on the incidence of mite (no. per leaf) at weekly interval in the morning hours starting from initial appearance to final disappearance or up to the harvest of the crop from 25 randomly selected and tagged plants. The weather parameters *viz.*, maximum and minimum temperature (°C), relative humidity (%) and total rainfall (mm) in different standard weeks during the crop season were recorded at Meteorological center,

Regional Agricultural Research Station, Lam, Guntur. The relationship between the mite population and weather parameters was worked out by using simple correlation, regression and step down analysis by SPSS software 2007 version

RESULTS AND DISCUSSION

To find out the effect of individual abiotic factor on the population dynamics of mites species infesting chilli leaves, flowers and fruits, the correlation coefficients were analysed between mite population and weather parameters. While working out the correlation coefficients, mite population of each standard week was correlated with preceding one and two weeks weather data which gave better correlation coefficients than with the present week weather data. The incidence of *P. latus* (no. per leaf) in chillies was initiated from 38 STW (0.41 /leaf) and it continued up to the harvest of the crop with a peak activity during 2nd STW (7.41) during 2007-08. Correlation coefficients worked out between mite population and weather parameters of preceding one week indicated that among the various weather parameters significant negative correlation was observed between weather parameters of maximum temperature (-0.37**), minimum temperature (-0.79**), evening relative humidity (-0.45*), rainfall (-0.29) where as significant positive correlation with morning relative humidity (0.42**), with mites population. The correlation studies carried out with preceding two weeks weather data, similar trend was observed in the correlations. Weather parameters of preceding two weeks indicated that among the various weather parameters significant negative correlation was observed between weather parameters of maximum temperature (-0.29**), minimum temperature (-0.78**), evening relative humidity (-0.43*), rainfall (-0.32) where as significant positive correlation with morning relative humidity (0.38**), with mite population (Table-1).

During 2008-09, incidence of *P. latus* (no. per leaf) in chillies was initiated from 42 STW (0.14 /leaf) and it continued up to the harvest of the crop with a peak activity during 52nd STW (21.27). Correlation coefficients worked out between mite population and weather parameters of preceding one week indicated that among the various weather parameters significant negative correlation was observed between weather parameters of maximum temperature (-0.66**), minimum temperature (-0.48**), evening relative humidity (-0.72*), rainfall (-0.02) where as significant positive correlation with morning relative humidity (0.42**), with mites population. The correlation studies carried out with preceding two weeks weather data, showed a similar trend as observed in the correlations. Weather parameters of preceding two weeks indicated that among the various weather parameters significant negative correlation was observed between weather parameters of maximum temperature (-0.86**), minimum temperature (-0.65**), evening relative humidity (-0.50*), rainfall (-0.71) where as significant positive correlation with morning relative humidity (0.50**), with mite population.

During 2009-10, incidence of *P. latus* (no. per leaf) in chillies was initiated from 46th STW (0.17 /leaf) and it continued up to the harvest of the crop with a peak activity during 9th STW (221.77). Correlation coefficients between mite population and weather parameters of preceding one week indicated that among the various weather parameters significant negative correlation was observed between weather parameters of maximum temperature (-

0.33**), minimum temperature (-0.40**), evening relative humidity (-0.10*), rainfall (-0.41) where as significant positive correlation with morning relative humidity (0.74**), with

Table-1: Correlation co-efficient between mite *P. latus* incidence and weather parameters (preceding one and two weeks from 2007 to 2012): PW=Preceding Week

Observatory Weather Parameters	2007-08		2008-09		2009-10		2010-2011		2012-13		2011-2012	
	PW-1	PW-2	PW-1	PW-2	PW-1	PW-2	PW-1	PW-2	PW-1	PW-2	PW-1	PW-2
Maximum Temperature	-0.37**	-0.29**	-0.66**	-0.86**	-0.33**	-0.41**	-0.68**	-0.27**	-0.67**	-0.68**	-0.29**	-0.29**
Minimum Temperature	-0.79**	-0.78**	-0.48**	-0.65**	-0.40**	-0.26**	-0.19**	-0.63**	-0.07**	-0.19**	-0.64**	-0.64**
Morning RH (RH-I %)	0.42**	0.38**	0.42**	0.50**	0.74**	0.74**	0.53**	0.16**	0.65**	0.53**	0.50**	0.50**
Evening RH (RH-II %)	-0.45**	-0.43*	0.72*	-0.50*	0.10*	-0.51*	-0.51*	-0.61*	-0.30*	-0.15*	-0.61*	-0.51*
Rainfall (mm)	-0.29	-0.32	-0.02	-0.71	-0.41	-0.30	-0.41	-0.33	-0.15	-0.06	-0.50	0.24

Table-2: Multiple regression equation developed for *P. latus* incidence on chilli and weather parameters from 2007 to 2012)

Observations	Step down multiple linear equations	Co-efficient of determination (R^2)
2007-08 Preceding 1 week	$Y = 3.30 + 0.49 * T_{\max} - 1.33 T_{\min} + 0.27 * RH-I + 0.02 * RH-II + 0.04 RF$	0.74
2007-08 Preceding 2 week	$Y = 4.33 + 0.4 * T_{\max} + 0.57 * T_{\min} + 1.34 * RH-I - 0.02 + 0.04 RH-II + 0.01 RF$	0.75
2008-09 Preceding 1 week	$Y = 31.67 - 0.75 * T_{\max} - 1.07 T_{\min} * + 0.05 RH-I - 0.27 RH-II - 0.06 RF$	0.73
2008-09 Preceding 2 week	$Y = 30.99 - 0.75 * T_{\max} - 0.13 T_{\min} + 0.09 RH-I - 0.25 RH-II - 0.06 RF$	0.72
2009-10 Preceding 1 week	$Y = 36.24 - 0.90 * T_{\max} - 0.51 T_{\min} + 2.84 + 0.51 * RH-I - 3.60 RH-II - 0.61 RF$	0.78
2009-10 Preceding 2 week	$Y = 18.87 - 0.78 * T_{\max} - 0.93 T_{\min} + 0.06 + 1.95 * RH-I - 0.32 RH-II - 0.16 RF$	0.74
2010-11 Preceding 1 week	$Y = 51.80 - 1.30 * T_{\max} - 0.26 T_{\min} + 0.61 * RH-I + 0.30 RH-II - 0.03 RF$	0.75
2010-11 Preceding 2 week	$Y = 54.22 - 1.49 * T_{\max} - 2.59 T_{\min} + 0.57 * RH-I + 0.20 RH-II - 0.02 RF$	0.75
2011-12 Preceding 1 week	$Y = 52.99 - 1.90 * T_{\max} - 2.77 T_{\min} + 0.24 * RH-I - 0.29 RH-II - 0.12 RF$	0.76
2011-12 Preceding 2 week	$Y = 54.07 - 1.48 * T_{\max} - 2.58 T_{\min} + 0.58 * RH-I - 0.20 RH-II - 0.04 RF$	0.75
2012-13 Preceding 1 week	$Y = 12.98 - 0.46 * T_{\max} + 1.94 T_{\min} + 1.36 * RH-I - 1.33 RH-II - 0.17 RF$	0.73
2012-13 Preceding 2 week	$Y = 11.14 - 0.47 * T_{\max} - 2.02 T_{\min} + 0.35 RH-I - 0.26 * RH-II - 0.01 RF$	0.79

- ASMA, A. and HANUMANTHARAYA, L. 2015. Population dynamics of major insect and mite pests of chilli. *Journal of Experimental Zoology*, **18**(1):173-176.
- BINDU, K. P. and PATEL, J. R. 2001. Population dynamics of different species of thrips on chilli, cotton and pigeonpea. *Indian Journal of Entomology*, **63** (1): 170-175.
- BUTANI, D. K. 1976. Pest and diseases of chillies and their control. *Pesticides*, **10**: 38-41
- CHATTERJEE, M. 2004. Occurrence of yellow mite, *Polyphagotarsonemus latus* Banks Acari: Tarsonemidae and predatory mites in diversified groups of chilli cultivars. *Approved M.Sc. Thesis*. 2004, 86-87.
- DHAKA, S. R and PAREEK, B. L. 2008, Weather factors influencing population dynamics of major insect pests of cotton under semi arid Agro-ecosystem. *Indian Journal of Entomology*, **70**(2): 157-163.
- MEENA, N. K. and KANWAT, P. M. 2010. Studies on seasonal incidence and relative safety of pesticides against Coccinellids in okra ecosystem. *Journal of Biological Control*. **24**(2): 116-122
- PATHIPATI, V. L., VIJAYALAKSHMI T. and NARAM NAIDU L., 2014 Seasonal incidence of major insect pests of chilli in relation to weather parameters in Andhra Pradesh. *Pest Management in Horticultural Ecosystems*, **20**(1): 36-40
- PATIL, R. S. and NANDIHALLI, B. S. 2009. Seasonal incidence of mite pest on brinjal and chilli. *Karnataka Journal of Agricultural Sciences*, **22**(3): 729-731
- SARKAR, P. K., TIMSINA, G. P., VANALDIKI and CHAKRABORTY, S. 2013. Arylpyrroleacaroinsecticide chlorfenapyr-a tool for managing yellow thrips, *Scirtothrips dorsalis* Hood and broad mite *Polyphagotarsonemus latus* Banks of chilli. *Journal of Crop and Weeds*, **9**(1): 188-192.
- SUBHARANI, S. and SINGH, T. K., 2007, Influence of meteorological factors on population dynamics of pod fly *Melanogromyza obtusa* Malloch (Diptera: Agromyzidae) in pigeon pea under agro-climatic conditions of Manipur, *Indian Journal of Entomology*, **69**(1): 78-80.



BIO-EFFICACY OF DIFFERENT PESTICIDES AGAINST MITE (*TETRANYCHUS URTICAE*) ON TOMATO (*LYCOPERSICON ESCULENTUM* MILL)

V. G. SHARMA¹ AND SUSHIL KUMAR²

1=Department of Entomology, N. M. College of Agriculture
Navsari Agricultural University, Navsari, Gujarat, India

2= Department of Plant Protection, ASPEE College of Horticulture and Forestry
Navsari Agricultural University, Navsari, Gujarat, India
Email: saxenasushil2003@gmail.com Mo. 9427108412

Received: 8 March, 2020

Accepted: 19 May, 2020

ABSTRACT: The experiments were conducted during 2015-17 to study the bio-efficacy of different pesticides against mite (*Tetranychus urticae*) on tomato (*Lycopersicon esculentum* Mill). The results revealed that Spiromesifen 22.9 SC 0.028 per cent and Dimethoate 30 EC 0.03 per cent remained most effective treatments against this tomato mite whereas, quinalphos 25 EC 0.05 per cent was proved the least effective.

Keyword : Tomato, insecticides, bio-efficacy, red spider mite, *Tetranychus urticae*

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a profitable vegetable crop cultivated widely in South Gujarat. It is also a popular vegetable at global level, ranked second in importance to potato (MANDAOKAR *et al.*, 2000). In India, the area under tomato cultivation is 7.67 lakh hectares with production of 16385.00 MT and average productivity of 21.40 MT/ha (ANONYMOUS, 2015). Though it is extensively grown all over the country, still the productivity remains low as compared to other countries mainly due to the prevalence of pests. Amongst various insect-pests reported in India, as many as sixteen have been observed feeding on tomato from germination to the harvesting stage which not only reduce its yield but also deteriorate the quality (BUTANI, 1997). The major pests of tomato in India are whitefly (*Bemisia tabaci*), aphid (*Aphis gossypii*), thrips (*Thrips tabaci*), leaf miner (*Liriomyza trifolii*), fruit borer (*Helicoverpa armigera* (Hubner) and red spider mite (*Tetranychus urticae*) (ANONYMOUS, 2012).

Among them, red spider mite (*Tetranychus urticae*) is a major pest under the Order Acari (Family: Tetranychidae). Mites generally feed on underside of leaves, but cover entire leaf surface when high population is observed. They pierce plant cells and withdraw the cell contents. Feeding results in small clumps of dead cell and speckled appearance of infested leaves. Wilting, leaf deformity, desiccation and abscission occur with prolonged high density infestations. Disruption of photosynthesis results in plant stunting and reduction in yield.

Keeping in view the importance of sucking pests on tomato in general and mite in particular, the present study was undertaken to compare effect of novel and modern insecticide cum acaricides for the control of this mite on tomato.

MATERIALS AND METHODS

Field screening of insecticides cum acaricides was carried out against mite (*Tetranychus urticae*) on tomato under field condition in the Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat during *Rabi* seasons of 2015-16 and 2016-17. The site experienced mean annual minimum and maximum temperatures of 15 and 33 °C, respectively.

The field experiments were conducted in *Rabi* tomato during 2015-16 and 2016-17 taking tomato (cv. GT-2) as a test crop. The experiments were laid out in Randomized Block Design (RBD) with 3m x 2m plot size using seven treatments viz., T₁: Indoxacarb 4.5 SC 0.005%; T₂: Dimethoate 30 EC 0.03%; T₃: Lambda-cyhalothrin 5 EC 0.003%; T₄: Spiromesifen 22.9 SC 0.028%; T₅: Quinalphos 25 EC 0.05%; T₆: Thiamethoxam 25 WG 0.008% and T₇: control (no pesticide, only normal water) replicated four times under field conditions. Each plot was separated by a gap of 1m so that drifting of chemicals could be minimized during spraying. The experimental fields were thoroughly prepared by ploughing followed by repeated harrowings. The field was subsequently cleaned by removal of stubbles of the previous crop. Twenty five days old disease free seedlings of tomato were planted at a spacing of 60 × 45 cm. Gap filling was done after 10 days. The application of pesticides was done based on the appearance of the mite. For all the treatments, the crop was given the same dose of NPK as per the state recommendation i.e. 180:60:60 kg N, P₂O₅ and K₂O Kg/ha, respectively. Full amounts of P and K fertilizers were applied at the time of transplanting. However, half doze of nitrogenous fertilizer was applied thirty days after transplanting and the remaining half of N was applied at 15 days after the first application of Nitrogen.

Mite population (adult and nymph) was counted on one leaf each of top, middle and bottom part of the ear marked plant in each replication of the treatment and expressed as total population of plant. The first count was taken one day before the spray and post-treatment counts were taken 1, 7 and 15 days after the spray. The data based on population of nymph and adult mite were statistically analysed at different intervals after spraying in randomized block design and overall population irrespective of post spray interval was assessed. The efficacy of treatments was compared using Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

First year (2015-16)

During first year of experimentation, mite population observed before spray (one day before) were similar (at par) in each experimental plot under investigation however after spray (1, 7 and days after), it was significantly lower in the treated plots than untreated control indicating lowest population in Spiromesifen 22.9 SC 0.028% (0.16/plant) followed by Dimethoate 30 EC 0.03% (0.38) which was significantly different from it. Next in the order of effectiveness was thiamethoxam 25 WG 0.008% (0.60/plant) followed by lambda

Table-1: Efficacy of various insecticides against mite on tomato during 2015-17

Sr. No.	Treatment	Mite : Population/plant* (2015-16)					Mite : Population/plant* (2016-17)					Mite : Population/plant* (2015-17) Overall pooled
		Pre-treat	Post treatment observations at				Pre-treat	Post treatment observations at				Mean over DAS
			1	7	15	DAS		1	7	15	DAS	
1.	Indoxacarb 14.5 SC 0.005%	1.16 (0.85)	1.11 (0.73)	1.06 (0.62)	1.22 (0.99)	1.13 (0.77)	1.14 (0.81)	1.12 (0.75)	1.05 (0.59)	1.16 (0.85)	1.11 (0.74)	1.12 ^{cde} (0.76)
2.	Dimethoate 30 EC 0.03%	1.15 (0.82)	1.02 (0.53)	0.84 (0.21)	0.96 (0.43)	0.94 (0.38)	1.16 (0.85)	0.95 (0.41)	0.90 (0.32)	0.91 (0.33)	0.92 (0.35)	0.93 ^b (0.37)
3.	Lambda cyhalothrin 5 EC 0.003%	1.15 (0.83)	1.08 (0.66)	1.06 (0.61)	1.08 (0.66)	1.07 (0.64)	1.14 (0.80)	1.09 (0.68)	0.96 (0.42)	1.07 (0.64)	1.04 (0.58)	1.06 ^{cd} (0.61)
4.	Spiromesifen 22.9 SC 0.028%	1.16 (0.84)	0.87 (0.25)	0.77 (0.09)	0.79 (0.13)	0.81 (0.16)	1.17 (0.86)	0.82 (0.17)	0.73 (0.03)	0.77 (0.09)	0.77 (0.10)	0.79 ^a (0.13)
5.	Quinalphos 25 EC 0.05%	1.15 (0.81)	1.12 (0.76)	1.12 (0.75)	1.27 (1.12)	1.17 (0.87)	1.11 (0.74)	1.10 (0.71)	1.16 (0.85)	1.13 (0.78)	1.13 (0.78)	1.15 ^d (0.82)
6.	Thiamethoxam 25 WG 0.008%	1.15 (0.83)	1.05 (0.60)	1.01 (0.52)	1.08 (0.67)	1.05 (0.60)	1.12 (0.75)	1.06 (0.63)	0.91 (0.33)	1.11 (0.73)	1.03 (0.55)	1.04 ^c (0.58)
7.	Control	1.15 (0.82)	1.24 (1.03)	1.27 (1.12)	1.43 (1.55)	1.31 (1.22)	1.16 (0.85)	1.23 (1.01)	1.26 (1.09)	1.35 (1.32)	1.28 (1.14)	1.30 ^z (1.18)
SEm+ (T)		0.06	0.05	0.06	0.06	0.03	0.08	0.05	0.06	0.06	0.03	0.03
CD at 5 % (T)		NS	0.16	0.20	0.18	0.09	NS	0.17	0.19	0.18	0.09	0.09
SEm+ (T x D)						0.06					0.06	0.06
CD at 5 % (T x D)						NS					NS	NS
CV (%) (T)		10.98	10.16	13.39	11.01	11.53	14.55	10.94	13.13	11.88	11.98	11.98

*Total of top, middle and bottom leaves/plant

Figures mentioned in parenthesis are re-transformed values and those outside are $\sqrt{x + 0.5}$ values

cyhalothrin 5 EC 0.003 (0.64) which were at par with each other. Next in the order of effectiveness was Indoxacarb 14.5 SC 0.005 (0.77) and Quinalphos 25 EC 0.05% (0.87), the later in turn was found least effective against mite. The control plot recorded highest number of mites as 1.22/plant (Table-1).

Second year (2016-2017)

The trend of mite population in the second year of experimentation, before spray as well as after spray was nearly the same as obtained during the first year trial. Lowest mite population was obtained in Spiromesifen 22.9 SC 0.028% (0.10/plant) followed by Dimethoate 30 EC 0.03% (0.35). Next in the order of effectiveness were Thiamethoxam 25 WG 0.008% (0.55/plant) and Lambda cyhalothrin 5 EC 0.003% (0.58) which was at par with each other followed by Indoxacarb 14.5 SC 0.005% (0.74) and Quinalphos 25 EC 0.05% (0.78) wherein the later was least effective against mite. The control plot had highest number of mites as 1.14/plant (Table-1).

Pooled (2015-17)

Overall effectiveness of various pesticides against mite on tomato was assessed on the basis of two years of field investigation (2015-17) wherein interaction between treatment and year was found non-significant indicating similarity of efficacy order of pesticides during both the years. The mite population before spray (pre spray) was similar (at par) in the experimental plots. While, it was lowest in plots treated by Spiromesifen 22.9 SC 0.028% (0.13/plant) followed by Dimethoate 30 EC 0.03% (0.37). Next in the order of effectiveness were Thiamethoxam 25 WG 0.008% (0.58/plant), Lambda cyhalothrin 5 EC 0.003% (0.61) and Indoxacarb 14.5 SC 0.005% (0.76) which were similar to each other with respect to effectiveness, the later was found at par with quinalphos 25 EC 0.05% (0.82) the least effective treatment against tomato mite. On the other hand, the control plot had the highest mites (1.18/ plant) (Table-1).

KAVITHA *et al.* (2006) reported better and long lasting efficacy of Spiromesifen 240 SC to control chilli mite. Similarly, ALAM *et al.* (2014) also found that Spiromesifen 240 SC @ 150 g a.i./ha significantly reduced red spider mite infestation. DARANDALE and GAIKWAD (2014) revealed that Spiromesifen 240 SC @ 84 g a.i./ ha was more suitable and ecofriendly for the management of mite on brinjal. CHINNIAH *et al.* (2016) revealed that Spiromesifen 22.9 SC @ 500 ml/ha were most effective to control chilli mites.

In the present investigation, lowest mite population was observed in Spiromesifen 22.9 SC 0.028% (0.13 mite/plant) as also reported by the earlier workers thus, it may be concluded that the results obtained in this investigation are in agreement to the earlier reports. Least effective pesticide was Quinalphos 25 EC 0.05% (0.82). Untreated control plot observed highest mite population (1.18 mite/plant) (Table-1). The order of effectiveness of various treatments was: Spiromesifen 22.9 SC 0.028 % > Dimethoate 30EC 0.03% > Thiamethoxam 25 WG 0.008% > Lambda cyhalothrin 5 EC 0.003% > Indoxacarb 14.5 SC 0.005% > Quinalphos 25 EC 0.05% > control.

REFERENCES

- ALAM, F., PATRA, B., CHATTERJEE, M., DEY, P. K., DHAR, P. P., SAMANTA, A. and SOMCHOUDHURY, A. K. 2014. Bioefficacy of spiromesifen 240 SC (w/v) against whitefly and red spider mites *Tetranychus* spp. infesting tomato. *Journal of the Entomological Research Society*, **38**(2): 105-109.
- ANONYMOUS, 2015. National Horticulture Production database.
- ANONYMOUS, 2012. NICRA team of Tomato Pest Surveillance. Manual for Tomato Pest Surveillance. *Jointly published by National Centre for Integrated Pest Management (NCIPM), New Delhi, Central Institute for Dryland Agriculture, Hyderabad, Indian Institute of Horticultural Research, Bengaluru and Indian Institute of Vegetable Research, Varanasi.* 39 p.
- BUTANI, D. K. 1977. Insect pests of vegetables-tomato. *Pesticides*, **11**:33-36.
- CHINNIAH, C., RAVIKUMAR, A., KALYANASUNDARAM, M. and PARTHIBAN, P. 2016. Efficacy of newer acaricide and insecticide molecules against sucking pests of chilli. *Annals of Plant Protection Sciences*, **24**(2): 202-207.
- DARANDALE, S. N. and GAIKWAD, S. E. 2014. Evaluation of acaricides for their safety to the predatory mites. *Trends in Biosciences*, **7**(18): 2708-2712.
- KAVITHA, J., KUTTALAM, S. and CHANDRASEKARAN, S. 2006. Evaluation of spiromesifen 240 SC against chilli mite. *Annals of Plant Protection Sciences*, **14**(1): 52-55.
- MANDAOKAR, A.D., GOYAL, R.K., SHUKLA, A., BISARIA, S., BHALLA, R., REDDY, V.C. 2000. Transgenic tomato plants resistant to fruit borer (*Helicoverpa armigera* Hübner). *Crop Protection*, **19**:307-312.



SEASONAL INCIDENCE OF MANGO LEAF GALL MIDGE, *PROCONTARINIA MATTEIANA* KIEFFER & CECCONI (DIPTERA: CECIDOMYIIDAE)

A.T. PATEL¹ AND SUSHIL KUMAR²

1 = Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

2 = Department of Plant Protection, ASPEE College of Horticulture and Forestry
Navsari Agricultural University, Navsari, Gujarat, India
Email: saxenasushil2003@gmail.com Mo. 9427108412

Received: 23 March, 2020

Accepted: 1 May, 2020

ABSTRACT: Seasonal incidence of mango leaf gall midge, *Procontarinia matteiana* Kieffer and Cecconi was studied on mango cultivars Alphonso and Kesar at Navsari Agricultural University, Navsari, Gujarat. Highest leaf damage (62.51%) and gall intensity (116.56 galls/sq.cm) were observed in Alphonso during 5-6 (29 January-11 February) and 1-2 (1-14 January) standard weeks, respectively while, it was 56.80 per cent leaf damage with 105.69 galls in Kesar during 7-8 (12-25 February) and 1-2 (1-14 January) standard weeks.

Keyword : Mango, leaf gall midge, standard week, galls, *Procontarinia matteiana*

INTRODUCTION

Mango (*Mangifera indica* L.), a member of family Anacardiaceae (MUHAMMAD *et al.*, 2013) is known as king of fruits (SATHE *et al.*, 2014) for its sweetness, excellent flavour, delicious taste and high nutritive value. Mango is a host of about 492 species of insects, 17 species of mites and 26 species of nematodes the world over (BUTANI, 1974). Of these, over 188 species have been reported in India (TANDON and VERGHESE, 1985) and hardly half a dozen are of major importance (TANDON and SRIVASTAVA, 1982). BUTANI (1974) reported mango hopper, mango mealy bug, mango fruit fly, bark eating caterpillar, stem borer and scale insect as major pests, while insect-pests of minor importance were mango stone weevil, leaf weevil, shoot gall, termite, mite and mango bud mite. Insect pests which came into prominence on mango during the last decade are thrips, mango gall midges, fruit borers, shoot borer, mango leaf webber (syn. tent caterpillar) and leaf miner, whereas status of ants is yet to be confirmed as a pest or natural enemy (SRIVASTAVA, 1998).

Among those, the midges (Diptera: Cecidomyiidae) are one of the major insect pests attacking on mango trees. About 22 described and 10 undescribed species of midges have been reported by KOLESIK (2013), some of them are serious pests of mango in India and Pakistan. MARDI (2010) mentioned mango gall midge (*Procontarinia matteiana* Kieffer and Cecconi) (Diptera: Cecidomyiidae) as a new threat to mango industry (ASKARI. and RADJABI, 2003) found mango gall midge, *Procontarinia matteiana* Keiffer and Cocconi

and mango inflorescence midge *Erosomyia mangifera* Felt (Diptera: Cecidomyiidae) among the most important insect pests of mango trees in Iran. UECHI *et al.*, 2002 reported identification of new species, found in Okinawa, Japan. The leaf gall midge was identified as *Procontarinia mangicola* and was placed originally in the genus *Erosomyia* (SANKARAN, and MJENI, 1989) further reported that *Procontarinia matteiana* was considered an important and serious pest of mango in Oman. This species of leaf gall midge has been introduced in India (PATEL *et al.*, 2011; PATEL and SAXENA, 2016).

P. matteiana is still the most unattended pest of mango. This remains active throughout the year showing initiation of gall formation in new flush leading to defoliation of affected leaves and reduction of photosynthesis. Almost all of the *Procontarinia* midges induce galls on leaves, but did not evolve to parasitize other plant organs or taxa. The female gall fly oviposits on new leaves, maggots hatch from the eggs and tunnel into the leaf tissue where the insects develop into mature gall flies. Tumour like growths develop on the host plants as a result of chemical stimuli from the galling insects. These stimuli can be maternal secretions injected during oviposition or stimuli produced by larvae developing within the plant tissue (PASCUAL-ALVARADO *et al.*, 2008; STONE and SCHÖNRÖGGE, 2003). Due to unavailability of any concrete package of practice, the pest is spreading at an alarming rate. Therefore, an attempt has been made to study its bio-ecology on two popular mango cultivars (Alphonso and Kesar).

MATERIALS AND METHODS

The study based on seasonal incidences of mango leaf gall midge, *P. matteiana* was carried out at Regional Horticultural Research Station of Navsari Agricultural University, Navsari, Gujarat during January-December 2017 on Alphonso and Kesar cultivars. For recording observations, ten trees each of Alphonso and Kesar cultivars were selected randomly from one hectare mango orchards of the respective varieties. To know the initiation of damage, the observations were recorded by counting the healthy as well as damaged leaves and expressed as per cent damaged leaves and number of galls per square cm. on damaged leaves as gall intensity on each of the ten terminal twigs from the lower canopy of each tree at fortnightly interval throughout the year. All the experimental trees were kept free from insecticidal spray during the course of investigation.

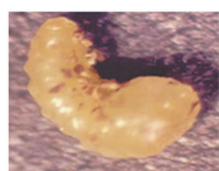
RESULTS AND DISCUSSION

The symptoms of leaf damage caused by mango leaf gall midge appeared throughout the year. In mango cv. Alphonso, lowest leaf damage (40.24%) as well as gall intensity (51.36 galls/sq. cm on infested leaves) was recorded during 35-36th standard weeks in 2017. Highest leaf damage (62.51%) was recorded during 5-6th standard weeks, while, the highest gall intensity (116.56 galls/sq.cm.) was observed during 1st - 2nd standard weeks.

Similarly in mango cv. Kesar, lowest leaf damage (34.56 %) as well as gall intensity (45.50 galls/sq.cm. on infested leaves) was observed during 35-36th standard weeks, while highest leaf damage (56.80 %) was recorded from 7 to 8th standard weeks and highest gall intensity (105.69 galls/sq.cm.) was observed during 1st - 2nd standard weeks (Table-1). As evident from the data presented in Table -1, the overall leaf gall midge damage in both the

mango cultivars i.e. Alphonso and Kesar recorded to reach the maximum during 5-6th and 7-8 standard weeks in Alphonso and Kesar, respectively. Similarly, gall intensity was particularly high during 1st - 2nd standard weeks in both the mango varieties proving that individual varieties did not play any role in attaining the peak intensity of galls, it might be the crop stage (5-8th standard week) i.e. marble sized fruit stage or the floral maturity stage of the crop which played dominant role.

Similarly, lowest leaf damage and gall intensity i.e. initiation of the gall formation was observed during 35-36 standard weeks which happened to be last week of August to first fortnight of September, the period of initiation or emergence of new leaf which was considered most susceptible for egg laying and puncturing on the leaf epidermis by the adult cecid fly in mango.



Larva



Early stage pupa



Late stage pupa



Male adult



Female adult



Galls on mature leaf

Photo plate: Different stages of mango gall midge, *Procontarinia matteiana*

UECH *et al.* (2002) observed galling in mango leaves due to leaf gall midge (*P. mangicola*) resulting into no inflorescence and low yield. PATEL and SAXENA (2016) recorded peak leaf damage by leaf gall midge in mango cv. Kesar during 7th standard week which happened to be the pea cum marble sized fruit stage of the crop however, the damage started at the emergence of new flush (36th SW) (3-9 September) which indicated lowest damage (31.69% in pooled results).

They further reported that when the tree had newest leaves emerged and having thinnest leaf epidermis it became most suitable to oviposition by female midge fly causing puncture in the leaf epidermis, resulting in initiation of swelling symptoms or hyperplasia. As crop passed through various stages and leaf matured, the swelling transformed into wart like appearance which ultimately transformed into gall symptoms. The increase in swelling size may be apparently due to the metamorphic changes in the midge maggots, where later instars

were longer in length and higher in diameter requiring more inner epidermal space leading to the formation of thick galls in mature leaves at pea/marble sized fruit stage (7th SW) (12-18 Feb.). These observations have also been mentioned in the current investigations which conform the present investigation.

Table-1: Seasonal abundance of mango leaf gall midge, *Procontarinia mattheiana*

Standard Week (SW)	Leaf damage (%)		Gall intensity (No. of galls/sq.cm. on damaged leaf)	
	Alphonso	Kesar	Alphonso	Kesar
1-2	57.92	50.61	116.56	105.69
3-4	60.57	51.73	85.39	77.20
5-6	62.51	54.56	84.93	83.46
7-8	60.10	56.80	89.28	87.99
9-10	51.42	47.41	71.42	69.85
11-12	49.88	45.38	68.72	62.11
13-14	47.77	42.17	66.80	61.88
15-16	44.77	40.31	64.50	57.39
17-18	45.67	41.72	59.93	52.54
19-20	47.62	43.53	54.15	48.38
21-22	48.94	44.74	58.69	56.34
23-24	50.58	46.55	67.37	66.16
25-26	48.20	43.89	66.52	62.31
27-28	47.23	42.48	62.05	59.28
29-30	46.67	41.45	60.79	52.83
31-32	45.37	40.58	59.77	51.28
33-34	44.47	39.44	55.72	50.68
35-36	40.24	34.56	51.36	45.50
37-38	41.61	35.11	54.31	47.18
39-40	44.17	37.58	57.01	51.07
41-42	46.63	41.24	62.45	57.05
43-44	50.72	43.18	70.83	59.46
45-46	53.91	44.70	79.60	65.76
47-48	54.96	46.39	85.01	68.71
49-50	55.85	48.58	91.75	74.37
51-52	57.30	49.66	92.91	77.37

REFERENCES

- ASKARI, M. and G. RADJABI, G. 2003. Study on the Biology and population fluctuation of mango *Procontarinia mattiana* Diptera: In Hoormozgan Province. *Applied Entomology and Phytopathology*, **70**(2): 121-135.
- BUTANI, D. K. 1974. Insect pest of fruit crops and their control (Mango), *Pesticides*, **8**(3): 37-41.
- KOLESIK, P. 2013. Gall midges (Diptera: Cecidomyiidae) of mango, paper presented in International symposium on the biology and ecology of gall inducing arthropods and related endophytes'. <http://www.researchgate.net/publication/267099379>. DOI: 10.13140/2.1.4103.42496th.

- MARDI, H. G. 2010. A note on the mango gall midge (*Procontarina matteiana* Kieffer and Cecconi) (Diptera: Cecidomyiidae). A new threat to mango industry in south Kordofan State, Sudan. University of Khartoum *J. Agril. Sci.*, **18**(2): 263- 267.
- MUHAMMAD, W. N. IQBAL, S. SAEED, M. JAVED and MAHMOOD. K. 2013. "Monitoring and Varietal Preference of Mango Midge, *Procontarina mangicola* (Diptera: Cecidomyiidae)". *Pak. J. Zool.*, **45**(5): 1273-1278.
- PASCUAL-ALVARADO, P., CUEVAS-REYES, P., QUESADA, M. and OYAMA, K. 2008. Interactions between galling insects and leaf-feeding insects: The role of plant phenolic compounds and their possible interference with herbivores. *Journal of Tropical Ecology*, **24**: 329–336.
- PATEL, A.T; SUSHIL KUMAR and CHAVAN, S.M. 2011. Screening of mango cultivars against mango leaf gall midge. *Crop Improvement*, **38**(1): 99-101.
- PATEL, K. B. and SAXENA, S. P. 2016. Population dynamics of mango leaf gall midge, *Procontarina matteiana* and its correlation with weather parameters. *Entomon*, **41**(2): 99-104.
- SANKARAN, T. and MJENI, A.M. 1989. "Recent studies on the mango leaf-gall midge *Procontarina matteiana* Kieffer and Cecconi (Dip. Cecidomyiidae) and its parasites in India and on prospects for biological control of the pest in Oman". II *International Symposium on Mango*, **231**: 20-24.
- SATHE, T. V., DESAI, A. S., BHOJE, P. M., and JADHAV, D. K. 2014. Pests of Mango *Mangifera indica* Linn. at Storage and their control. *Indian J. Appl. Res.*, **4**(7): 1-4.
- SRIVASTAVA, R. P. 1998. Pests of mango. In: *mango cultivation* (Eds. R.P. Srivastava). Publisher International Book Distributing Co; Lucknow, pp. 175-187.
- STONE, G. N. and SCHÖNROGGE, K. 2003. The adaptive significance of insect gall morphology. *Trends in Ecology and Evolution*, **18**: 512–522.
- TANDON, P. L. and SRIVASTAVA, R. P. 1982. Notes on new pest of mango in India. *Science and Culture*, **48** (2): 7880.
- TANDON, P. L. and VERGHESE, A. 1985. World list of insect, mite and other parts of mango, *Tech. Doc. No.5, I.I.H.R*; Bangalore.
- UECHI, N., F., KAWAMURA, M., TOKANDA and YUKAWA, J. 2002. A mango pest *Procontarina mangicola* (Shi) Comb. Nov. (Diptera: Cecidomyiidae), recently found in Okinawa, Japan. *Appl. Entomol. Zool.*, **37**(4): 589-593.



EFFECT OF GROWTH AND PRODUCTION ON INDIAN MAJOR CARPS IN FRESH WATER BIOFLOC AQUACULTURE SYSTEM

SAUGATA SASMAL*, ANKIT THAKUR, R. L. SHARMA¹ and GOUTAM ROY

Krishi Vigyan Kendra, Raipur, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

1 = Krishi Vigyan Kendra, Mungeli, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh; *Corresponding author email: drsasmal@gmail.com

Received: 18 April, 2020

Accepted: 30 May, 2020

ABSTRACT: Biofloc technology (BFT) is one of the innovative methodologies for waste management and nutrient retention that offers a solution to solve environmental problems in aquaculture, because it doesn't use water exchange to solve nitrogen compound elimination, but it utilizes microbial assimilation, stimulated for addition of material rich in carbon, to transform those compounds. However, trials of biofloc system in fresh water aquaculture have not been undertaken in India for Indian major carps. Two trials of ten months period each (2017-2019) were performed to investigate the growth and production of Indian major carps in fresh water Biofloc System at Krishi Vigyan Kendra, IGKV, Raipur, Chhattisgarh, India. Three rectangular cemented tanks (30,000 liter capacity) were used in each trial under this purpose. Probiotic (probomix) was used for developing beneficial bacterial colonies and controlling ammonia in confined water system. Healthy fingerlings of Rohu (Avg. weight 57.5 g) & Mrigala (Avg. weight 49.9 g) were stocked @ 1 No/cubic meter of water tank with treatment of potassium permanganate. Floating feed with 28-32% protein level was fed in twice in a day @2% body weight in every trial. Molasses (Biogel) was applied for proper microbial growth. Physico-chemical parameters were studied daily and maintained properly during whole period. Floc volume range was recorded between 17-37 ml/liter water sample, FCO was periodically applied for bacterial growth. The average yield was recorded 271 Kg/tank after a period of 10 months from stocking and FCR was found to be 1.3. Experiments were conducted during 2017-2019, so the variation of temperature was very high. The other important parameters recorded were, average pH value 7.6, dissolved oxygen 5.7 ppm, TDS 684 ppm and C:N ratio 12:1. Probocare & probocure were applied weekly @ 75ml/tank for maintaining floc and water parameters as well. The results obtained in this experiment suggest that the biofloc system in fresh water aquaculture improves growth performances of the Indian major carps in almost zero-water exchange system.

Key words: Biofloc technology (BFT), probiotics, Indian major carps.

INTRODUCTION

Biofloc is comprised of various beneficial microbial communities, but the mechanism of action of some probiotics which leads to increase in biofloc is unknown in aquaculture system. On the other hand, probiotics are single, known live microbial strains and their actions to farm animals and humans are well established. Probiotic is a Greek word derivative of pro and bios; "pro means promoting and bio means life". Probiotics are

considered bio-friendly agents that can be administered in aquatic culture environments to control pathogens and enhance feed utilization, survival, and growth rate of farmed species (MAHAPATRA *et al.*, 2015; DE *et al.*, 2014; HUYNH *et al.*, 2017). The first probiotics discovered is the fermented milk, which contains lactic acid bacteria (LAB). Lactic acid bacteria (LAB) such as some *Lactobacillus* species (e.g., *Lactobacillus plantarum*, *Lactobacillus acidophilus*, *Lactobacillus thermophilus*, *Lactobacillus bulgaricus*, *Lactobacillus casei* etc.) are frequently used as probiotics in fish nutrition (NAYAK, 2010). The use of LAB shown to have the most promising effects on disease resistance, survival, and growth parameters for a wide variety of fish species (MUÑOZ-ATIENZA *et al.*, 2014; RINGØ and DAWOOD *et al.*, 2016; SAHOO *et al.*, 2015). In Biofloc systems, nitrogen compounds transformation is more efficient, because this process is made by facultative heterotrophic bacteria that correspond principally to *Bacillus* and *Pseudomonas* species, which allow increasing their population abundances quickly and oxide-reduction process (MONROY *et al.*, 2015). Therefore, we studied production of India major carp in freshwater biofloc aquaculture system.

MATERIAL AND METHODS

Two trials were conducted in the KVK Raipur Fish Farm during September 2017 to June 2018 and September 2018 to July 2019. Three rectangular cemented tanks (30000 lit) in each trial were brought in use. Proper aeration was provided throughout the culture period and it was made by magnetic air pump (130 Watt & 120 LPM) with air stone (3.0"). Probiotic (probomix) mainly composed of bacillus and lactobacillus groups was used to maintain the floc and molasses (Biogel) for controlling of ammonia in culture tanks. Advanced fingerlings of Rohu (*Labeo rohita*) & Mrigala (*Cirrhinus mrigala*) (avg. weight 53.7 gm) were stocked @ 1 No/cubic meter of water tank treated with potassium permanganate @0.5 ppm. On the stocking day, feeding to the fishes was stopped, next day onwards; floating feed with 28-32% protein level was fed in twice in a day @2% body weight in every trials. Molasses (Biogel) was applied @ 100-300 gm/day (as per C: N ratio) for proper microbial growth through drip system. Physico-chemical parameters were studied through analysis kits daily and maintained properly during whole period. Floc volume range was recorded in imhoff cone (ml/lit of water sample). Growth of fish was randomly recorded on a fortnightly basis.

RESULTS AND DISCUSSION

In each trial, three rectangular tanks (each 30000 liter capacity) were used for ten months culture of IMC and average yield was 271 kg/tank recorded. Stocking density was low only @ 1 No/cubic meter of water; it can be raised upto triple in further studies. Feed conversion ratio (FCR), in its simplest form a comparison of the amount of feed used per unit weight gain of the species being grown, offers a measure of aquaculture production efficiency (WAITE *et al.*, 2014). Typical FCRs were recorded by using commercial feeds under intensive production technology in fish and shrimp culture - 1.0–2.4, respectively (TACON and METIAN, 2008). In conventional method of fish culture, the FCR value which is very high compare to FCR value 1.3 in the present studies.

During whole study period, the water temperature was very much fluctuated, lowest temperature was recorded 7.4 °C in December and 34.2°C in May. The recorded pH range was

6.8-8.6 and average pH value was 7.6. In this experiment, average concentration of Dissolved Oxygen (DO) was 5.7 ppm which was highly satisfactory level because of 24 hours running blowers in the tanks. The recorded average TDS was 684 ppm where as the average C: N ratio was 12: 1 during culture period. Initially the average floc density was 17 ml and the highest density was 37 ml/ liter sample recorded.

Table-1: Growth parameters of fish species in different trials

Parameters	Trial-1	Trial-2	Average
Survival of Rohu (%)	89.00	90.80	89.90
Average weight of Rohu at harvest (g)	850.00	860.00	855.00
Yield of Rohu (Kg) in 3 tanks	423.30	436.88	430.09
Survival of Mrigala (%)	93.00	91.00	92.00
Average weight of Mrigala at harvest (g)	717.00	775.00	746.00
Yield of Mrigala (Kg) in 3 tanks	371.70	394.12	382.91
Total yield (Kg) in three tanks	795.00	831.00	813.00
Productivity (Kg/tank)	265.00	277.00	271.00
Benefit Cost Ratio (B:C)	1.84	1.92	1.88

The each trial was conducted in three cemented tanks with rohu & mrigala species, the average survival rates of Rohu and Mrigala were 89.9% and 92.0%, respectively. The harvestable weight of Rohu was 855 gm whereas 746 gm was recorded in Mrigala. The average benefit cost ratio (B: C) was 1.88 during experimental periods. Biofloc technology application offers benefits in improving aquaculture production that could contribute to the achievement of doubling of farmer's income in short period of time. This technology could result in higher productivity with less impact to the environment. In places where water is scarce or land is expensive and possibility of theft increases vulnerability of profitable aquaculture exists more intensive forms of aquaculture like biofloc technology has been reported to be a cost-effective production system previously as observed by the present trial. This technology needs more investigations with high value fishes under different agro-climatic conditions.

REFERENCES

- DAWOOD, M.A.O., KOSHIO, S., ISHIKAWA, M., YOKOYAMA, S., E L BASUINI, M. F., HOSSAIN, M. S., NHU, T. H., DOSSOU, S. and MOSS, A. S. 2016. Effects of dietary supplementation of *Lactobacillus rhamnosus* or/and *Lactococcus lactis* on the growth, gutmicrobiota and immune responses of red sea bream, *Pagrus major*. *Fish, Shellfish Immunol.* **49**: 275–285.
- DE, C. B., MEENA, D.K., BEHERA, B.K., DAS, P., DASMOHAPATRA, P. K. and SHARMA, A. P. 2014. Probiotics in fish and shellfish culture: Immunomodulatory and ecophysiological responses. *Fish Physiol. Biochem.* **40**: 921–971.

- HUYNH, T. G., SHIU, Y. L., NGUYEN, T.P., TRUONG, Q.P., CHEN, J.C. and LIU, C.H. 2017. Current applications, selection, and possible mechanisms of actions of synbiotics in improving the growth and health status in aquaculture: A review. *Fish, Shellfish Immunol.* **64**: 367–382
- MOHAPATRA, S., CHAKRABORTY, T., KUMAR, V., DE BOECK, G. and MOHANTA, K.N. 2015. Aquaculture and stress management: A review of probiotic intervention. *J. Anim. Physiol. Anim. Nutr.* **97**: 405–430.
- MONROY, M.C., RODRIGUEZ, G., CASTRO J. and BECERRIL, D. 2015. Importance and function of microbial communities in aquaculture systems with no water exchange. *Scientific Journal of Animal Science.* **4**(9): 103–110.
- MUÑOZ-ATIENZA, E., ARAÚJO, C., MAGADÁN, S., HERNÁNDEZ, P.E., HERRANZ, C., SANTOS, Y. and CINTAS, L. M. 2014. In vitro and in vivo evaluation of lactic acid bacteria of aquatic origin as probiotics for turbot (*Scophthalmus maximus* L.) farming. *Fish, Shellfish Immunol.* **41**: 570–580.
- NAYAK, S. K.. 2010. Role of gastrointestinal microbiota in fish. *Aquaculture Res.* **41**: 1553–1573.
- RINGØ, E. and GATESOUE, F. J. 1998. Lactic acid bacteria in fish: A review. *Aquaculture* **160**: 177–203.
- SAHOO, T. K., JENA, P. K., NAGAR, N., PATEL, A. K. and SESHADRI, S. 2015. In vitro evaluation of probiotic properties of lactic acid bacteria from the gut of *Labeo tohita* and *Catla catla*. *Probiotics Antimicrob. Proteins* **7**: 126–136.
- TACON A. G. J. and METIAN. M. 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects *Aquaculture* **285**: 146–58.
- WAITE, R., BEVERIDGE, M., BRUMMETT, R., CASTINE, S., CHAIYAWANNAKARN, N., KAUSHIK, S., MUNGKUNG, R., NAWAPAKPILAI, S. and PHILLIPS, M. 2014. Improving productivity and environmental performance of aquaculture. *Working Paper. Washington, DC, World Resources Institute.* 60 pp



J. Appl. Zool. Res. (2020) **31**(1): 58-61
ISSN 0970-9304

PERFORMANCE OF SORGHUM GENOTYPES AGAINST EAR HEAD BUG AND EAR HEAD WORM

JATIN, K., SHRIVASTAVA, V. K. AND DHEERENDRA MAHOR

Department of Entomology, College of Agriculture, R.V.S.K.V.V., Gwalior (M.P)

Corresponding author email: jatinento36@gmail.com

Received: 31 March, 2020

Accepted: 6 May, 2020

ABSTRACT: Study was conducted to screen the performance of various sorghum genotypes reaction against the panicle pests like ear head bug (*Calocoris angustatus*) and ear head worm (*Cryptoblabes gnidiella*) at Department of Entomology, College of Agriculture, Gwalior during the *kharif* season 2016 with 20 genotypes in a randomized block design with 3 replications to find out the least susceptible genotype for ear head bug and ear head worm. Observations were recorded during the milky stage of the plant. Test genotypes differed significantly with respect to number of ear head bugs. The lowest number of ear head bug population was recorded in genotype ICSSH 88 (4.47 bugs/plant) where as highest was recorded in genotype DHBM4 (7.8 bugs/ plant) which was significantly more than rest of the genotypes. The significant lower number of ear head worms found in genotype ICSSH 86 (5 worms/ear head), while highest attack was on genotype ICSV15006 (10.33 worms/ear head) which was significantly more than other genotypes.

Key words: Sorghum genotype, ear head bug, ear head worm, milky stage.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L) Moench] is valued for its grain, stalks and leaves. It is the fifth most important cereal crop globally and is the dietary staple of more than 500 million people in over 90 countries, primarily in the developing world (REDDY *et al.*, 2007; 2010). Sorghum production is facing a threat from various biotic and abiotic factors; among them, the loss caused by the insect pests has been considered as one of the important factors for lower production. Pest problems in sorghum start at the pre-sowing period and continue till harvest. JOTWANI and YOUNG (1971) recorded over a dozen insect pests on sorghum, the major ones being shoot fly, stem borer, grain midge, and a complex of ear head pests. Nearly 150 insect species have been reported as pests on sorghum in different agro ecosystems (REDDY and DAVIES, 1979). The insects that attack the sorghum panicle may be classed into four groups: grain midges, head bugs, head worms, and head beetles. These losses were probably caused by all panicle pests together were recorded on research stations which usually have higher pest populations than farmers' fields. However, the losses can vary from 5.8 to 84.3% (RANGARAJAN *et al.*, 1973). Ear head bug attacks from head emergence to hard-dough stage of grain development hundreds of adults and nymphs can be observed on a single ear head.

Alternate host plants play an important role in infestations of panicle-feeding bugs in sorghum. Bugs, principally adults, move from alternate hosts to sorghum during grain development. Ear head worms larvae destroy the grain in the head by producing webs of silken thread that remain on and inside the head, heavily infested heads may be covered with

webbing and cause serious loss. Moreover, insecticides are hazardous to many target and non-target species in addition to disturbance in crop eco-system, which led scientists to find out newer, safer, cost effective alternatives. Host plant resistance is the most important component of integrated pest management in sorghum; as it does not involve any extra cost or require application skills in pest control techniques and is compatible with other methods of pest control. The negative effect of resistant genotypes on insect populations is continuous and cumulative over time as the resistant cultivars reduce the cost, and are easy to execute and can fit in the IPM programme. Reduction in pest populations through HPR can also enhance the effectiveness of natural enemies and reduce the need to use pesticides (SHARMA, 1993). This will help to preserve the environment and avoid the risks associated with the use of pesticides. In this study, an attempt has been made to know the performance of host plant (sorghum) against panicle pests like ear head bug and ear head worm.

MATERIALS AND METHODS

Field experiment was laid out in a Randomized block design (RBD) with 20 treatments replicated thrice with a plot size of 5m length of two rows each genotype with a spacing of 45cm between the rows and 12cm between the plants. Sowing was carried during July 2016 at research farm, College of Agriculture, Gwalior by following recommended agronomic practices. Sprinkler irrigation was given in post rainy season when the crop attains reproductive stage to initiate high relative humidity which increases the population build up of ear head pests. Observations on ear head bug (*Calocoris angustatus* Leth.) and ear head worm (*Cryptoblabes gnidiella*) were made on three ear heads of each treatment randomly selected at milky stage of crop. Then the average numbers of ear head worm per three ear head was calculated and subjected to statistical analysis after making suitable transformation. The average population of ear head bug and ear head worm was calculated by using the formula.

$$AP_o = NRP/OP$$

Where: APo = Average population,

NRP = Number of received pests,

OP = Total observed plants.

RESULTS AND DISCUSSION

Insect pests attacking panicles of sorghum are especially damaging as they affect crop development at a late stage and have direct harmful quantitative and qualitative effects on grain yields. At this late stage of crop development, the main production inputs would have already been made, which maximizes economic losses, and there is also little scope for the crop to compensate for damage done so close to harvest. The different sorghum genotypes differed significantly with respect to number of ear head bugs (Table-1). Ear head bug infestation ranged from 4.47 to 7.8 bugs per three plants. Minimum and lowest number of ear head bug population was recorded on genotype ICSSH 88 (4.47 bugs per three plant) which was found promisingly resistant than other genotypes followed by ICSV 25308 (4.98 bugs per three plant). Maximum and highest number of ear head bug was recorded on genotype DHBM4 (7.8 bugs/3 plants) which was susceptible and significantly more than rest of the genotypes except ICSV 25306 (7.47 bugs per three plant) and ICSV 25333 (7.27 bugs/3 plants).

Present findings are in accordance with GAGRE (1990) recorded incidence of ear head bug on sorghum varieties in the range of 5.99 to 34.49/plant where as PARMAR (2012) revealed that incidence of ear head damage varies according to the climatic conditions of the testing station. MOTE AND KADDEM (1978) reported that 24 genotypes were free from ear head damage due to various morphological factors. The findings are also supported by SEKHAR (1997) who found the sorghum ear head bug incidence was high in May-August planted crops.

Table-1: Population of ear head bug and ear head worm on test genotypes

S. No	Genotypes	Ear head bug	Ear head worm
1	ICSV 25335	5.14(2.37)*	9.67(3.18)*
2	ICSSH 87	5.27(2.39)	6.67(2.67)
3	ICSSH 86	6.98(2.72)	5(2.34)
4	ICSV 25306	7.47(2.82)	9.09(3.09)
5	ICSSH 82	5.6(2.46)	7(2.73)
6	ICSSN 79	5.83(2.51)	7.67(2.86)
7	ICSSH 88	4.47(2.22)	8.63(3.02)
8	DHBM 5	5.47(2.44)	8.33(2.97)
9	DHBM 4	7.8(2.88)	9.35(3.13)
10	DHBM 2	6.47(2.63)	9(3.08)
11	ICSV 25308	4.98(2.32)	8.09(2.93)
12	ICSV 25333	7.27(2.78)	7.67(2.85)
13	ICSV 15006	6.21(2.59)	10.33(3.29)
14	SPV 2326	6.32(2.60)	6.67(2.67)
15	SPV 2327	6.14(2.57)	7.78(2.88)
16	SPV 2328	5.3(2.40)	8.33(2.97)
17	DHBM 1	6.32(2.61)	8.09(2.93)
18	DHBM 3	6.9(2.71)	7.33(2.80)
19	SSV 84	5.9(2.53)	8.09(2.93)
20	CSH 22 SS	5.09(2.35)	7.67(2.85)
	SEm±	(0.05)	(0.04)
	CD	(0.16)	(0.12)

On the other hand, ear head worm infestation was ranged from 5 to 10.33 bugs/ 3 cobs. The different sorghum genotypes differed significantly with respect to number of ear head worms. The minimum and significant lower number of worms were recorded on genotype ICSSH 86 (5 worms/ ear head) found resistant and significantly less than other genotypes followed by ICSSH 87(6.67 worms per three ear head). However, the maximum and highest worm attack was recorded on genotype ICSV15006 (10.33 worms/3 ear head) which was susceptible and significantly more than rest of the genotypes except ICSV 25335 (9.67 worms/3 ear head) and ICSV 2306 (9.09 worms/ 3 ear head). The present findings are in accordance to PARMAR (2012), KARIKARI *et al.* (2013). Moreover, they revealed that panicle of loose type are more prone to ear head worm damage than compact and semi-

compact panicles and these findings were also supported by CHOUDHARY and GARG (2004) who found that early and late-flowering cultivars normally escaped head worm damage, while those flowering during midseason are exposed to very high populations.

The negative effect of resistant genotypes on insect populations is continuous and cumulative over time as the resistant cultivars reduce the cost, and are easy to execute and can fit in the IPM programme. Reduction in pest populations through HPR can also enhance the effectiveness of natural enemies and reduce the need to use pesticides. From the above study it is concluded that genotypes resistant to ear head pests and ear head worm are CSH22SS, followed by ICSSH86 and ICSSH87 and these genotypes can be suggested to farmers in areas with more panicle pest problem and also in IPM programmes.

REFERENCES

- CHOUDARY, R.K. and GARG, V. K.. 2004. Incidence of Jowar ear head bug in east Nimar, Madhya Pradesh. *JNKVV Research Journal*. **37** (2): 104-105.
- GAGRE, D.C. (1990). Screening of sweet sorghum varieties against major insect pests. (*Ann. Physiology*)-**2**: 60-65.
- JOTWANI, M. G. and YOUNG W. R. 1971. *Sorghum insect control*: here is what's working in India. *World Farming* **13**(9): 6-8, 10-11.
- KARIKARI, A. S.; ATOKPLE, I.D.K.; BUAH, S.S.; ABUDULAI, A.L.; ETWIRE; P.M. and ASUNGRE, P. 2013. Effect of fertilizer rates on the incidence of insect pests of Sorghum bicolor (L) Moench in the northern region of Ghana. *Fourth Intern. Scientific Symp. "Agrosym 2013", Jahorina, Bosnia and Herzegovina, 3-6 October*; 578-583.
- MOTE, U.N. and KADAM, J.R. (1984). Relative susceptibility of some sorghum entries to ear head bug. *Sorghum Newsl.* **(2)** 7:85.
- PARMAR, MANOJ, 2012. Effect of date of sowing on the abundance of sorghum pests in Malwa region, Indore , Madhya Pradesh, *Presented in 100th India Science Congress Kolkata*. Pp 65-71
- RANGARAJAN, A. V., MAHADEVAN, N. R. and JANGARAJAN, A. 1973. Control of stem borer and ear head bug on sorghum, K4. *Sorghum Newsletter*, **16**: 96-98.
- REDDY, B. V. S., ASHOKKUMAR, A. and SANJANA REDDY, P. 2010. Recent advances in sorghum improvement research at ICRISAT. *Kasetsart Journal (Natural Science)* **44**: 499-506.
- REDDY, B. V. S., KUMAR, A. and RAMESH, S. 2007. Sweet sorghum: A water saving bio-energy crop. *International Conference on Linkages between Energy and Water Management for Agriculture in Developing Countries. January 29-30, 2007. ICRISAT Campus, Hyderabad, India*.
- REDDY, K. V. S. AND DAVIES, T.C., 1979, Attractants for *Atherigona* spp. including sorghum shoot fly, *Asocata Rond*, *ICRISAT Hyderabad*, pp. **16**.
- SEKHAR, P. R. 1997. Some observations on incidence of sorghum ear head bug, *Calocoris angustatus* (Leth.) on sorghum in relation to sowing dates. *J. Insect Sci.*, **10**(1): 78-79.
- SHARMA, H. C. 1993, Host plant resistance to insects in sorghum and its role in integrated pest management. *Crop Protection*. **12**: 11-34.



IMPACT OF BIOCHEMICAL CONSTITUENTS OF HOST PLANTS ON THE RUGOSE SPIRALING WHITEFLY, *ALEURODICUS RUGIOPERCULATUS* MARTIN INFESTATION LEVELS IN ANDHRA PRADESH

S. SUSHMITHA, A. SUJATHA*, N. EMMANUEL

College of Horticulture, Dr. Y. S. R. Horticultural University, Venkataramannagudem - 534101, Andhra Pradesh, India; *Email: - sujathaavvaru1977@gmail.com

Received: 31 March, 2020

Accepted: 6 May, 2020

ABSTRACT: The rugose spiraling whitefly (RSW), *Aleurodicus rugioperculatus* Martin is an invasive pest of polyphagous in nature and attacks a wide range of host plants. RSW has become a consequential pest and identified in the several regions of India, including Godavari districts of Andhra Pradesh. Since, it is a new species, lack of information necessitated immediate attention of scientific community to focus on detailed studies of the pest. In this scenario, a study has been conducted to know the impact of biochemical constituents of host plants in relation to RSW infestation. Results revealed that, a lower level of total phenol content resulted highest RSW infestation in oil palm in which other constituents viz., moisture, chlorophyll, proteins and total sugars were in higher levels among the host plants studied, coconut, guava, banana and cocoa. Lowest RSW infestation was observed in cocoa leaves in which higher level of total phenols and lower levels of moisture, chlorophyll, proteins and total sugars were recorded. The correlation coefficients of RSW infestation were strong and negative with total phenols whereas positive and significant with respect to moisture, chlorophyll, proteins, total sugars; non significant with fiber and lignin.

Key words: Invasive pest, Rugose spiraling whitefly, Biochemical and *Aleurodicus*

INTRODUCTION

Invasive species compete with native species and cause biotic upsets which is the vital reason for crop loss and can adversely affect food security. In past, this type of invasions of exotic pests such as Coffee berry borer (*Hypothenemus hampei*) on coffee (1990 in Wayanad, Kerala), coconut eriophid mite (*Aceria gurreronis*) on coconut (1997 in Ernakulam, Kerala), Papaya mealy bug (*Paracoccus marginatus*) on Papaya (2007 in Coimbatore, Tamil Nadu) (SATHYANARAYANA and SATYAGOPAL, 2013) and South American tomato pinworm, *Tuta absoluta* on tomato (2014 in Pune, Maharashtra) (SINGH and PANCHBHAIYA, 2018) in India affected economy of these crops and caused dreadful situations among the farmers. Recent menace, rugose spiraling whitefly (RSW), *A. rugioperculatus* Martin (Hemiptera: Aleyrodidae) has entered India (KRISHNA RAO and RAO, 2019) and reported on coconut palm (*Cocos nucifera* L.) during August-September months in Pollachi, Tamil Nadu (SUNDARARAJ *et al.*, 2016). However, this pest on coconut was first reported in Andhra Pradesh during the December, 2016 (RAO *et al.*, 2018). Later the pest assumed significance in Andhra Pradesh and within a short period of time has extended over a wide area in other states. RSW is mainly a phloem feeder and excretes large quantities of honeydew causing the growth of sooty mold which disrupts normal leaf physiology (FRANCIS *et al.*, 2016).

The documented information on the effect of host plant biochemical constituents on *A. rugioperculatus* is not available and this was the first study carried out in coastal districts of Andhra Pradesh where horticultural crops including coconut and oil palm cultivation is in large scale. The biochemical constituents present in different quantities to each other in host plants have been reported to exert profound influence on growth, development, survival and reproduction of insects in various ways (PAINTER, 1958). Various biochemical characters of the plants play an important role by providing resistance against number of insect pests (HALDER and SRINIVASAN, 2011). Biochemical composition of the host plants especially coconut, oil palm, guava, banana and cocoa has got a profound influence on the infestation of the pest. Therefore, present study was undertaken to know the role of the biochemical constituents of host plants on infestation of *A. rugioperculatus*.

MATERIALS AND METHODS

The present study was conducted at College of Horticulture, Venkataramannagudem, West Godavari district, Andhra Pradesh, 2018-19. The leaf samples were collected from five major host plants viz., coconut, oil palm, guava, banana and cocoa, and analyzed for biochemical constituents viz., moisture (%), chlorophyll (SPAD units), proteins (g/100 g), phenols (mg/g) and total sugars (%), fiber (%) and lignin (%) contents by following suitable scientific methods.

Moisture content in the fresh leaves of host plants was determined on per cent basis by using Shimadzu MOC63u infrared moisture analyzer. Chlorophyll content in the leaves was estimated by using the instrument SPAD chlorophyll meter.

Protein content of leaves was estimated by Lowry's method (1951). Fresh leaf sample of 0.5 g was extracted in sodium phosphate buffer (pH 6.8) and centrifuged at 5000 rpm for 10 min. An aliquot of 0.2 ml of sample extract was taken in a test tube and the volume was made up to 1.0 ml with distilled water. To the sample, 5 ml of reaction mixture solution C (mixed 50 ml of reagent 'A' with 1 ml of reagent 'B'; reagent 'A' containing 2% sodium carbonate in 0.1N sodium hydroxide, reagent 'B' containing 0.5 per cent copper sulphate in 1% sodium potassium tartrate) was added and incubated at room temperature for 10 min. Finally, 0.5 ml of Folin Ciocalteu's reagent was added, mixed well and incubated in dark chamber for further 30 min at room temperature. The absorbance was measured at 660 nm against blank on spectrophotometer (systronic 117). The amount of protein was calculated using a standard graph prepared from bovine serum albumin ($200 \mu\text{g ml}^{-1}$).

Total phenol content was estimated by using Folin-Ciocalteu reagent method (SADASIVAM and MANICKAM, 2009). Leaf sample of 0.5 to 1.0 g was weighed and it was grounded with a mortar and a pestle with 10 times volume of 80% ethanol, and later it was centrifuged and homogenated at 10,000 rpm for 20 min and the supernatant was saved. The residue was re-extracted for five times with 80% ethanol, in a centrifuge and the supernatants were pooled. The supernatant was evaporated to dryness. The residue was dissolved in a known volume of distilled water (5 ml). Different aliquots (0.2 to 2.0 ml) are pipetted out into test tubes. Volume was made up in each tube to 3ml with water and 0.5 ml of FCR was added.

After 3 minutes, 2 ml of 20% sodium carbonate (Na_2CO_3) solution was added to each test tube, mixed thoroughly and the test tubes were placed in the boiling water exactly for one min. After cooling, it was measured at an absorbance of 650 nm against a reagent blank. A standard curve was prepared by using different concentrations of catechol. The standard curve was found out with a concentration of phenols in the test sample expressed as mg of phenols/100 g material.

The total sugar was determined by using the method given by LANE and EYNON (1923). Ten grams of leaf sample was taken, ground well and transferred to 250 ml volumetric flask. The sample solution was filtered through Whatman filter paper and the residue was discarded. A quantity of 100 ml of filtrate of the above leaf sample was taken into a separate 250 ml conical flask to which 5ml of 50% HCl was added and mixed well. The contents so obtained were kept overnight at room temperature. The acid content in the filtrate was then neutralized with drops of NaOH using a few drops of phenolphthalein as an indicator till the pink colour persisted for at least 15 seconds. Total sugars were then estimated by taking this solution in a burette and titrating against standard Fehling's mixture of A and B (1:1) while it is boiling; till brick red colour end point is obtained.

$$\text{Total sugars (\%)} = \frac{\text{Factor} \times \text{Volume made up}}{\text{Titre value} \times \text{Weight of the sample}} \times 100$$

The crude fiber content of leaves was estimated using the method outlined by the SADASIVAM and MANICKAM (2009). Two grams of dried leaf sample was boiled with 20 ml of sulphuric acid (H_2SO_4) for 30 minutes with bumping chips. The solution was filtered through muslin cloth and residue was washed thoroughly with boiling water until washing was acid free. The residue obtained was boiled with 800 ml sodium hydroxide (NaOH) for 30 minutes. The solution thus obtained was filtered through muslin cloth and the residue was washed with 25 ml of boiling H_2SO_4 , water and 25 ml of alcohol. The residue obtained after clean washing was transferred to a pre weighed washing dish (W1). Then the residue was dried in a dessicator for two hours and weighed (W2). Then it was ignited in muffle furnace for 30 minutes at 600°C . The tray was cooled and weighed (W3).

Loss of weight on ignition = (W2-W1)-(W3-W1)

$$\% \text{ Crude fibre content} = \frac{\text{Loss in weight on ignition}}{\text{Weight of the sample}}$$

Lignin content was estimated through Kappa method given by HUSSAIN *et al.*, 2002. Data based on average of five observations. Leaf sample (0.5 gm) was added in 30 ml distilled water and ground to a fine paste by using a mortar and pestle. The disintegrated sample was transferred to 1000 ml conical flask and distilled water was added to make the total volume to 600 ml. 75 ml of potassium permanganate solution and 75 ml of sulphuric acid solution were mixed together and added immediately to the disintegrated Fiber sample. Thus, the total volume was made to 750 ml. The reaction was allowed to proceed at 250°C temperature exactly for 10 minutes. Then 15 ml of potassium iodide solution was added and the free iodine was titrated with standard sodium thiosulphate solution using starch as an indicator. A blank titration was made using the same volume of water and reagents.

The Kappa Number was then calculated from the following equation:

$$\text{Kappa No.} = \frac{P \times f}{W}$$

Where,

P= 0.1N potassium permanganate (ml)

W= Weight of moisture free sample (g)

f= Factor for correction to 50 per cent permanganate consumption

Lignin content = Kappa No. \times slope obtained from a graph between
Kappa Number and Klason lignin

The results of Kappa Number determination by standard method are corrected to 50 per cent consumption of the permanganate added.

To know the rugose spiraling whitefly infestation per cent, five per cent sample palms or plants/ garden were selected randomly. Three sample leaflets per palm one each from the top, middle and lower whorls of the palm in case of coconut and oil palm whereas in case of guava, banana and cocoa; leaves were randomly selected from three levels of plant canopy from branches oriented in four directions *i.e.*, North, South, East and West. Total number of leaves and infested leaves were recorded and the per cent infestation was worked out.

$$\text{RSW infestation} = \frac{\text{No. of leaves infested with RSW per palm/plant}}{\text{Total no. of leaves per palm/plant}} \times 100$$

RESULTS AND DISCUSSION

The insects are attracted and deterred in one way or the other by the biochemical composition of the plants, which has been documented by findings of many earlier researchers (SINGH, 1983; WAR *et al.*, 2012). Many biochemical factors are known to be associated with insect resistance and it is obvious that the biochemical factors are more important than morphological and physiological factors in conferring non-preference and antibiosis (DAR *et al.*, 2017). Therefore, the estimation of biochemical constituents of host plant leaves is one of the most practical significance and efforts were also made to resolve the influence of biochemical characters on the infestation of RSW. Biochemical based defence is considered to be more effective as it directly affects insect growth and development.

The biochemical constituents from leaves of five crops *viz.*, coconut, oil palm, guava, banana and cocoa, were quantified and the results obtained were correlated with RSW infestation. Observations divulged that, infestation of *A. rugioperculatus* was highest in oil palm crop (83.92%) followed by banana (79.66%), coconut (76.84%), guava crop (72.90%) and low level of infestation were recorded in cocoa crop (24.74 %). The data on moisture content of host plants leaves revealed highly significant and positive correlation ($r= 0.973$) with the infestation of *A. rugioperculatus*. Among the crops studied the oil palm crop with highest moisture content (68.91 %) showed higher infestation (83.92%) whereas decreased infestation levels in other crops *i.e.*, 79.66%, 76.84%, 72.90% and 24.74% in banana,

coconut, guava crop and cocoa, respectively were observed with decrease in moisture content of 62.73, 57.29, 59.35 and 36.08%, respectively (Table-1). Highest moisture content with high pest infestation indicated that moisture content of the leaves played a vital role for host plant preference which provided congenial conditions for pest survival, egg laying, feeding of early stages of pest with short life cycles and build up of population.

The chlorophyll content among host plants leaves showed significant variation which ranged from 28.62 to 64.18 SPAD values. Chlorophyll content in the leaves was found positively and significantly correlated ($r=0.912$) with the infestation of RSW. Chlorophyll content observed in banana, coconut, guava crop and cocoa were 55.48, 51.12, 43.52, and 28.62%, respectively and RSW infestation was 79.66, 76.84, 72.90 and 24.74%, respectively (Table-1) indicating that, higher chlorophyll content favored the pest infestation and this might be a factor for feeding the pest population; higher the food resulting higher the pest sustainability and population buildup. The chlorophyll content in plant leaves is a powerful indicator of foliar nitrogen content which varies among plant tissues, being higher in structures such as flowers, pollen and leaves. Nitrogen content results plants with higher nutritional quality for herbivores, plant structures with high nitrogen levels may attract a greater diversity of insects. Hence the host having highest chlorophyll content *i.e.*, oil palm (64.18 SPAD value) was affected with highest infestation (83.92 %) of RSW.

Total sugar content in the leaves of oil palm, banana, coconut, guava and cocoa was recorded as 5.60, 3.60, 3.40, 3.20 & 0.90%, with infestation of 83.92, 79.66, 76.84, 72.90 and 24.74%, respectively (Table-1). Highest total sugars were found in the leaves of oil palm (5.60 %) showing highest RSW infestation (83.92%). The total sugars was found positively and significantly correlated ($r=0.890$) with infestation of RSW in all the crops studied. Total sugars are major source for insect feeding as well as metabolic activities of the life stages; the present result strongly endorses the above fact.

The total protein content in the leaves of host plants ranged from 2.20 to 12.90 g/100g and the protein content was found significantly positively correlated ($r=0.885$) with *A. rugioperculatus* infestation. Protein content in oil palm, coconut, guava, banana and cocoa leaves recorded as 12.90, 11.80, 9.80, 7.40 & 2.20%, respectively with RSW infestation of 83.92, 76.84, 72.90, 79.66 & 24.74%, respectively (Table-1). Total protein content of host plant plays a crucial role in insect development which is a key component in the enzymes required for developmental stages and metamorphosis. If the enzymatic activities and development is perfect, it hastens the population build up of the pest, ultimately leading to higher infestations and yield losses. Hence the host having highest protein content *i.e.*, oil palm (12.90 g/100g) was affected with highest infestation (83.92 %) of RSW.

Phenol content was found high in cocoa leaves (12.40 mg/g) whereas in guava, coconut, oil palm and banana leaves the phenol content was recorded as 6.81, 6.02, 2.68 and 0.31%, with RSW infestation of 72.90, 76.84, 83.92 & 79.66%, respectively (Table-1). The phenol content in the leaves was highly significantly negatively associated ($r=-0.879$) with pest infestation. Among plant constituents, it is the plant phenolics which plays a role in protecting plants from both insect and mammalian herbivory. Plants respond to insect

feeding by increasing the synthesis of the phenolic toxins. Finally, the concentration of the toxic phenolic compounds in the plant is a key factor in deterrence and it is the accumulation of phenols in particular parts of the plant which represents a feeding barrier leading to the non preference of the host. Hence, the high phenol content in leaves of crop leads to less attack by the pest.

The fiber and lignin contents in host plant leaves ranged from 24.65 to 43.25 % and 6.37 to 37.40 %, respectively (Table-1). The fiber content in coconut, oil palm, banana and guava leaves was recorded as 43.25, 36.26, 29.02 & 26.45%, respectively and lowest *i.e.*, 24.65% was observed in cocoa leaves which is least affected by pest. The lignin content was observed as 37.40, 29.61, 24.92 & 13.98% in coconut, oil palm, guava and banana leaves, respectively and in case of cocoa leaves it was least *i.e.*, 6.37% with RSW infestation of 76.84, 83.92, 72.90, 79.66 & 24.74%, respectively. With the pest infestation, the fiber ($r=0.564$) and lignin ($r=0.712$) were found non-significant and positively correlated.

Table-1: Status of biochemical components in host plant leaves and infestation levels of *A. rugipericulatus*

Host	Moisture content (%)	Chlorophyll content (SPAD Units)	Total protein content (g/100g)	Total phenol (mg/g)	Fibre content (%)	Lignin content (%)	Total sugars (%)	RSW infestation (%)
Coconut	57.29	51.12	11.80	6.02	43.25	37.40	3.40	76.84
Oil palm	68.91	64.18	12.90	2.68	36.26	29.61	5.60	83.92
Guava	59.35	43.52	9.80	6.81	26.45	24.92	3.20	72.90
Banana	62.73	55.48	7.40	0.31	29.02	13.98	3.60	79.66
Cocoa	36.07	28.62	2.20	12.40	24.65	6.37	0.90	24.74
C. D. (p=0.05)	1.893	5.803	1.206	0.674	1.937	1.823	0.34	3.518
SE(d)	0.885	2.714	0.564	0.315	0.906	0.853	0.159	1.645
Correlation coefficient	0.973**	0.912**	0.885**	-	0.564 ^{NS}	0.712 ^{NS}	0.890*	-

* - Significant at $p < 0.05$; ** - Highly significant $p < 0.01$; NS – Non-significant

From the study, it was observed that, the oil palm crop with highest moisture, chlorophyll and total sugars showed higher infestation whereas decreased infestation levels in banana, coconut, guava and cocoa were observed with decrease in these contents which is *vice versa* with total phenols. In comparison with the coconut, the decrease in lignin content in oil palm and banana might have resulted in increased RSW infestation. Whereas in guava, moderate levels of protein, fiber, lignin and RSW infestation was observed. But in case of cocoa, the lesser content of moisture, chlorophyll, total sugars, protein, fiber and lignin; and high total phenols resulted in lesser pest infestation. The biochemical characteristic of a plant

affects the metabolism of insects inhibiting their population growth and hence ultimately reduces the damage caused by these insects. Population of pest varies from plant to plant and may be due to external or internal physiology of the plant. This is because plants have the ability to alter the behaviour of feeding insect (KARBAN and BALDWIN, 1997) through accumulation and excretion of toxic exudates. This elaborative array of phytochemicals may act as repellents, phagodeterrents and oviposition deterrents thus imparting the defensive mechanisms (HARIJAN *et al.*, 2017).

Biochemical factors of the host plant have been reported to play a vital role in resistance to various insect pests (PANDA and KHUSH, 1995) and relatively resistant genotypes contained higher amount of phenols inherently (DHALIWAL and DILAWARI, 1993) as these are often associated with the feeding deterrence, growth inhibition and in higher concentration could ward off insect pests because of the direct toxicity. There is a positive correlation between the nitrogen content in a plant and the leaf chlorophyll content (SCHADCHINA and DMITRIEVA, 1995), which probably explains why even non-flowering plants with higher LCI had a greater species richness and abundance of bark and wood-boring insects. Insects prefer plant tissues rich in nitrogen, since it is a limiting factor for development, and production of eggs by females (EUBANKS and STYRSKY, 2005; COELHO *et al.*, 2009; MADRITCH and LINDROTH, 2015). These nitrogen-rich tissues can be used by females as preferred oviposition sites, since egg laying occurs on sites (leaves or stems) used by the larval phase (LARA, 1991).

SUNITHA *et al.* (2008) in cowpea and SINGH and SINGH (2014) in pigeon pea also reported a significant positive correlation of pod borer damage with moisture content. BOMMESHIA *et al.* (2012) in pigeon pea reported a significant positive correlation between the incidence of leaf hopper and leaf roller with protein and chlorophyll content. In brinjal the low sugar content and higher total phenols in leaves offered a significant level of resistance to various biotic stresses (RAO and PANWAR, 2001; SOUNDARAJAN and BASKARAN, 2001; KHORSHEDUZZAMAN *et al.*, 2010; KUMARI *et al.*, 2014; PRASAD *et al.*, 2014). DAR *et al.* (2014) also observed that crude fibre, ash, lignin had negative correlation and moisture content had positive correlation with *L. orbonalis* infestation in brinjal. Fiber and lignin contents were found non significantly correlated with pest infestation and the results were found contradictory to BARAD *et al.* (2016) in cowpea.

Thus moisture, chlorophyll, proteins, phenols and total sugars were found positively significantly correlated with RSW infestation except phenols whereas the constituents fiber and lignin contents were non-significantly correlated with the RSW infestation in host plants viz., coconut, oil palm, guava, banana and cocoa. High phenol content in cocoa might have imparted resistance against pest whereas higher levels of moisture, chlorophyll, sugar and protein in oil palm helped to feed the insect and hence is susceptible. Thus present studies proved that biochemical factors played a major role in the resistance mechanism against the test insect. This study result may help in developing varieties which could provide resistance to sucking insect pests, if their biochemical constituents/ contents are improved through various breeding process.

REFERENCES

- BARAD, C. S., PATEL, P. S., RABARI, G. N. and BINDU, P. 2016. Biochemical basis of resistance against *Maruca vitrata* in selected genotypes of cowpea. *Indian J. Pl. Prot.* **44**(1): 59-62.
- BOMMESH, B., NAIK, M. I., MUTTHURAJU, G. P., IMRAN, A. P. S. and PRASHANTA, C. 2012. Effect of organic manures on biochemical components of pigeon pea, *Cajanus cajan* (L.) Millsp. and their impact on the incidence of insect pests. *Current Biotica*. **6**(2): 171-80.
- COELHO, R. R., VEIGA, A. F. S. L. and TORRES, J. B. 2009. Preferencia alimentar e desempenho de *Brontocoris tabidus* Signoret (Hemiptera, Pentatomidae) em plantas hospedeiras. *Revista Brasileira de Entomologia*. **53**: 475-481.
- DHALIWAL, G. S. and DILAWARI, V. K. 1993. Advances in Host Resistance to insects. *Kalyani Publishers, India*. pp. 443.
- DAR, S. A., WANI, A. R., NEHRU, R. K., MIR, S. H. and JEELANI, M. I. 2014. Physio-chemical characteristics of the brinjal genotypes imparting the tolerance to the brinjal shoot and fruit borer (*Leucinodes orbonalis*) under field conditions of the Kashmir, India. *Ecology, Environment and Conservation*. **20**(4): 1605-1611.
- DAR, S. A., WANI, A. R., RATHER, B. A., PAREY, S. H. and KANDOO, A. 2017. Biochemical basis of resistance in brinjal genotypes against shoot and fruit borer (*Leucinodes Orbonalis*, Guenee). *Chem Sci Rev Lett*. **6**(22): 1062-1073.
- EUBANKS, M. D. and STYRSKY, J. D. 2005. Effects of plant feeding on the performance of omnivorous predators. In: *Jervis MA, Kidd NAC, editors. Insect natural enemies: practical approach to their study and evolution. Chapman & Hall; London*. pp. 148-177.
- FRANCIS, A. W., STOCKS, I. C., SMITH, T. R., BOUGHTON, A. J., MANNION, C. M. and OSBORNE, L. S. 2016. Host plants and natural enemies of rugose spiraling whitefly (Hemiptera: Aleyrodidae) in Florida. *Florida Entomologist*. **99**(1): 150-53.
- HALDER, J. and SRINIVASAN, S. 2011. Varietal screening and role of morphological factors on distribution and abundance on spotted pod borer, *Maruca vitrata* (Geyer) on cow pea. *Annals of Plant Protection Sciences*. **19**(1): 71-4.
- HARIJAN, Y., NISHANTH, G. K., KATAGERI, I. S., KHADI, B. M. and PATIL, B. R. 2017. Biochemical and Anatomical Factors Imparting Resistance against Sucking Pests in Cotton. *International Journal of Current Microbiology and Applied Sciences*. **6**(7): 2542-2553.
- HUSSAIN, M. A., EMDADUL, M. H., RAHMAN, S. M. and AHMED, Z. 2002. Estimation of lignin in jute by titration method. *Pakistan Journal of Biological Sciences*. **5**(5): 521-22.
- KARBAN, R. and BALDWIN, I. T. 1997. Induced Responses to Herbivory. *Univ. Chicago Press*
- KHORSHEDUZZAMAN, A. K. M., ALAM, M. Z. and MIAN, I. H. 2010. Biochemical basis of resistance in eggplant (*Solanum melongena*. L) to *Leucinodes orbonalis* Guen. and their correlation with shoot and fruit infestation. *Bangladesh Journal of Agricultural Research*. **35** (1): 149-155.
- KRISHNA RAO, G. and N.B.V. CHALAPATHI RAO, 2019. Surveillance ad eco-friendly management of new invasive alien pest, Rugose Spiralling whitefly, *Aleurodicus rugioperculatus* Martin: Inheent menance, *J. Appl. Zool. Res.* **30**(2): 148-158.
- KUMARI, A., NEENA, C. and AJMER, S. D. 2014. Comparison of eggplant genotypes for phenolic compounds and other biochemical parameters. *Intern. J. Adv. Res.* **2**(9), 615-622.
- LANE and EYON. 1965. *Association of official Agricultural Chemists. Official Methods of Analysis AOAC, Washington D C.*
- LARA, F. M. 1991. Princípios de resistencia de plantas aos insetos. *Sao Paulo, Editora Icone*.
- LOWRY, O. H., BROUGH, R. N., J, FARR, A. L. and RANDAL, R. J., 1951. Plant biochemical analysis. *Journal of Biological Chemistry*. 193-265.
- MADRITCH, M. D. and LINDROTH, R. L. 2015. Condensed tannins increase nitrogen recovery by trees following insect defoliation. *New Phytologist*. **208**: 410-420.
- PAINTER, R. H. 1958. Resistance of plants to insects. *Ann. Reviews of Entomol.* **3**: 267-290.

- PANDA, N. and KHUSH, G. S. 1995. Host Plant Resistance to Insects. *IRRI-CABI*, pp.431
- PRASAD, T.V., RAKESH, B. K. K., GANGOPADHYAY, M., ARIVALAGAN, M. K., BAG, B. L., MEENA, L. and DUTTA, M. 2014. Biophysical and biochemical basis of resistance to fruit and shoot borer (*Leucinodes orbonalis* Guenee) in eggplant. *Indian Journal of Horticulture*. **71**(1): 67-71.
- RAO, C. N. and PANWAR, V. P. S. 2001. Biochemical plant factors affecting resistance to *Atherigona* spp. in maize. *Annals of Plant Protection Sciences*. **14**: 69-72.
- RAO, N. B. V., ROSHAN, D. R., KRISHNARAO, G. and RAMANANDAM, G. 2018. A review on rugose spiralling whitefly, *Aleurodicus rugioperculatus* martin (Hemiptera: Aleyrodidae) in India. *Journal of Pharmacognosy and Phytochemistry*. **7**(5): 948-53.
- SADASIVAM, M. S. and MANICKAM, A. 2009. *Biochemical methods*. Newage International Publishers. **3**: 18-263.
- SATHYANARAYANA, N. and SATYAGOPAL, K. 2013. Invasive alien species : Problems and the way forward. *Pest Management in Horticultural Ecosystems*. **19**(1): 85-91..
- SCHADCHINA, T. M. and DMITRIEVA, V. V. 1995. Leaf chlorophyll content as a possible diagnostic mean for the evaluation of plant nitrogen uptake from the soil. *Journal of Plant Nutrition*. **18**: 1427-1437.
- SELVARAJ, K., SUNDARARAJ, R., VENKATESAN, T., CHANDISH R. B., JALALI, S. K., GUPTA, A. and MRUDULA, H. K. 2016. Potential natural enemies of the invasive rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin in India. *Journal of Biological Control*. **30**(4): 236-39.
- SINGH, B. D. 1983. Breeding for resistance to biotic stresses II. Insect resistance In: Plant breeding principles and methods. *Kalyani Publishers, Ludhiana, India*. pp. 494.
- SINGH, D. K. and PANCHBHAIYA, A. 2018. First report of tomato leaf miner, an invasive pest in Uttarakhand, India under polyhouse condition. *J. Hill Agric.*, **9**(1) 127-130.
- SINGH, C. and SINGH, N. N. 2014. Evaluation of responses of cowpea genotypes (*Vigna unguiculata* Walpers) genotypes to infestation of legume pod borer (*Maruca vitrata* Fabricius). *Journal of Food legumes*. **27**(4): 334-39.
- SOUNDARAJAN, R.P. and BASKARAN, P. 2001. Effect of antibiosis components of eggplant on the development biology of whitefly parasitoids. *Encarsia transvena* and *Eretmocerus mundus* M (Aphelinidae: Hymenoptera). In *National Seminar on Sustainable Insect Pest Management*, Loyola College, Chennai. pp. 298
- SUNITHA, V., RAO, G. V. R., VIJAYA LAXMI, K., SAXENA, K. B., RAO, V. R. and REDDY, Y. V. R. 2008. Morphological and biochemical factors associated with resistance to *Maruca vitrata* (Lepidoptera : Pyralidae) in short duration pigeon pea. *International Journal of Tropical Insect Science*. **28**(1): 45-52.
- WAR, A. R., PAULRAJ, M. G., AHMAD, T., BUHROO, A. A., HUSSAIN, B., IGNACIMUTHU, S. and SHARMA, H. C. 2012. Mechanisms of plant defense against insect herbivores. *Plant Signaling and Behavior*. **7**(10): 1306-1320.



J. Appl. Zool. Res. (2020) **31**(1): 71-80
ISSN 0970-9304

SEASONAL OCCURRENCE OF DIFFERENT INSECT PESTS OF POTATO CROP IN ANDHRA PRADESH

P. DAMODAR REDDY, A. SUJATHA, C.P.VIJI and K.UMA JYOTHI

College of Horticulture, Dr. Y. S.R. Horticultural University, Venkataramannagudem-534101, Andhra Pradesh, India; Corresponding Email: sujathaavvaru1977@gmail.com

Received: 31 March, 2020

Accepted: 6 May, 2020

ABSTRACT: Studies were conducted for first time on eight potato crop varieties to know the pest scenario and impact of weather parameters on its population in two districts of Andhra Pradesh in two different locations [1. Venkataramannagudem, West Godavari district (L1) and 2. Pandirimamidi, East Godavari district (L2)]. The total number of pests were recorded according to the standard meteorological week and the correlation studies of pest population with different weather parameters viz., Temperature (°C) (maximum and minimum), Relative humidity (%) (Morning and evening) and Rainfall (mm) were recorded. Results revealed that the occurrence of sucking pests during 41st SMW where as the occurrence of foliage feeding pests during 42nd and peak occurred during the 45th SMW in Venkataramannagudem, West Godavari. The lowest incidence of insect pests was observed in the variety Kufri Badshah and the highest incidence was noticed in the variety Kufri Khyati in L1. While, in Pandirimamidi, East Godavari, the occurrence of foliage feeding and sucking insect pests were recorded during 42nd SMW and attained peak during 44th SMW. Variety Kufri Himalini recorded the lowest incidence and Kufri Jyothi recorded the highest incidence in L2 i.e., Pandirimamidi, East Godavari (dist.). Temperature (°C) (maximum and minimum) was positively correlated with pest population where as Relative humidity (%) and Rainfall (mm) were negatively correlated with pest population. The study concluded that the two varieties i.e., Kufri Badshah and Kufri Himalini with lowest incidence of pests in both locations proved their suitability for successful cultivation both the test locations.

Key words: Potato varieties, seasonal incidence and insect pests.

INTRODUCTION

India has a great diversity of insect pests that attack potato. A wide variety of insects can damage potato crop, either directly, spoils the tubers by feeding or indirectly by feeding on leaves or stems, or transmitting pathogens (RADCLIFFE, 1982). In India, approximately 60 billion rupees (US\$1.2 billion) worth of potato tubers are lost annually due to pest damage, which accounts for 10–20% of total production (MISRA *et al.*, 2003). Among the various insects, aphids (*Myzus persicae* Sulzer), thrips, (*Thrips palmi* Karny); leaf hopper, (*Amarasca biguttula biguttula* Ishida); white fly, (*Bemisia tabaci* Gennadius); and soil insects like cut worm, (*Agroti sipsilon* Hufnagel); potato tuber moth, (*Pthoromea operculella* Povolny) have significant influence on potato yield (MISHRA, 1995; 2019; BHATNAGAR, 2013).

Scan of information shows that insect pests like aphids, white fly, leaf hopper, tobacco caterpillar and *Epilachna* beetle are greatly influencing the potato crop yield directly or indirectly. The crop is largely grown in West Bengal, Chattisgarh, Uttar Pradesh, Himachal Pradesh and in Andhra Pradesh, the area under potato is very limited (2%) of total cultivated area. Very recently investigations have been carried out to assess the suitability of conditions in Andhra Pradesh for growing potato crop especially in Godavari districts. After establishing the success of potato crop in two districts one is coastal zone (Venkataramannagudem, West Godavari dist) and the other one is in high altitude zone (Pandirimamidi, East Godavari dist) of A. P. Results of these studies indicated positive scope for potato cultivation and oriented towards the studies of pest scenario in Godavari districts of Andhra Pradesh. As the crop is newly being introduced in costal Andhra Pradesh *i.e.* in Godavari districts, it is essential to inquire about the biotic stress on the crop. In this region so far no information is available on pest scenario of potato in Godavari districts of Andhra Pradesh. Hence, it is highly essential to have preamble information about pests occurring *etc.*, to work out effective pest management measures.

MATERIALS AND METHODS

The present investigation was carried out during *Rabi*, 2017-18 in two locations on eight potato varieties *i.e.* Kufri Badshah, Kufri Surya, Kufri Chandramukhi, Kufri Chipsona-3, Kufri Jyoti, Kufri Himalini, Kufri Phukraj and Kufri Khyati in two locations, Venkataramannagudem, West Godavari District (L1)-coastal zone and Pandirimamidi, West Godavari District (L2)-high attitude zone. Sucking pests like hoppers and white flies were recorded by visual observation on both surfaces of all the leaves on 5 randomly selected plants per plot and the average number of hoppers per plant was worked out and the value was taken as a mean number of hoppers per plant. Similarly, tobacco caterpillar was recorded by visual observation on both surfaces of all the leaves on 5 randomly selected plants/plot and the average number of tobacco caterpillars/plant was worked out and the value was taken as a mean number of tobacco caterpillars/plant. *Epilachna* beetle population *i.e.*, eggs, grubs, pupae, adults were recorded by visual observation on both surfaces of all the leaves on five randomly selected plants/ plot and the average number of *Epilachna* beetle/plant was calculated and the value was taken as a mean number of *Epilachna* beetle/plant (NAG, 2016).

Incidence of foliage feeding insect pests:

Incidence of foliage feeding insect pests were determined at both the locations of two districts as mentioned above and from each location twenty plants were selected randomly from all these three replicated plots of each variety from each location. The whole plant was examined to work out the incidence of foliage feeding insect pests. The number of plants infested (A) and the number of plants assessed *i.e.*, 20 plants per variety (B) was taken and worked out the value(I) by using the formula given by (MOHAMMAD, 2000) and the value taken as per cent incidence of foliage feeding insect pests.

$$\text{Incidence of foliage feeding insect pests (I)} = \frac{\text{Number of plants infested (A)}}{\text{Total number of plants assessed (B)}} \times 100$$

Incidence of foliage sucking insect pests:

For recording the incidence of foliage sucking pests the data were collected in both the mentioned districts. From each location, five plants were randomly selected and from each plant all leaves were examined for determining the sucking insect pest incidence. The sucking pest incidence was determined by dividing the mean number of infested leaves and mean number of total healthy leaves per plant by using the formula given by (MOHAMMAD, 2000).

$$\text{Percent of incidence of sucking pests} = \frac{n}{N} 100$$

Where,

n = Number of leaves infested

N = Total number of leaves examined

The meteorological data on mean maximum and minimum temperature (°C), relative humidity [morning and evening(%)] and rainfall (mm) was recorded during the period of investigation (Rabi season–2017-18) *i.e.*, from 41st SMW of October, 2017 to 2nd SMW of January, 2018 at two locations, one Venkataramannagudem, West Godavari District and second Pandirimamidi, East Godavari District. Based on this data mean monthly maximum, minimum temperatures, relative humidity (morning and evening) and rainfall were worked out and correlated with the pest population.

RESULTS AND DISCUSSION

The occurrence of different sucking pests *viz.*, whitefly, *Bemisia tabaci* G. (Aleyrodidae, Homoptera); leaf hopper, *Amarasca biguttula biguttula* L. (Cicadellidae, Hemiptera); and foliage pests tobacco caterpillar, *Spodoptera litura* F. (Noctuidae, Lepidoptera) and epilachna beetle (*Henosepilachna vigintioctopunctata* F. (Coccinellidae, Coleoptera) on potato crop at Venkataramannagudem (L1) and Pandirimamidi (L2) in Rabi season was recorded at weekly intervals during the crop growth period. Population counts of each pest (No/ plant) were recorded in each SMW *i.e.*, from 41st to 1st SMW (Thirteen weeks) at L₁ and 42nd to 2nd SMW at L₂. Weather parameters *viz.*, Temperature (°C) [max. & min.], Relative humidity (%), and Rainfall (mm) were also recorded correspondingly and data was subjected to Karl Pearson's correlation coefficient analysis and results were presented.

1. Location-1 (Venkataramannagudem, West Godavari District)**A. Occurrence and correlation****i. Foliage sucking pests**

The *B. tabaci* population (No/ plant) was ranged from 3.81 to 21.40 with seasonal mean of 13.17 number/plant. The pest appeared first on the crop in the 41st SMW with initial population of 3.81 number/plant. Thereafter, the population of *B. tabaci* gradually increased and attained peak of 21.40/plant in the 45th SMW. Later decreased in a gradual way and recorded to a level of 8.00 (No/ plant) in 1st SMW (Table-1). The population of *B. tabaci* (No/ plant) was significantly and positively ($r = 0.60^*$, $p = 0.05$) correlated with maximum temperature. The minimum temperature was non significantly negatively ($r = -0.15$) correlated with *B. tabaci* population (No/ plant). Morning relative humidity, evening relative

humidity and rainfall were negatively correlated with *B. tabaci* population (No/ plant) with correlation coefficient values ($r = -0.40$), ($r = -0.55$) and ($r = -0.36$), respectively (Table-3).

Similarly *A. biguttula biguttula* population was recorded with minimum number 3.20 to 20.90 of maximum population per plant with seasonal mean of 11.83/ plant. It was first appeared on the crop in the 41st SMW with initial population 3.20 (No/ plant). Later, the population of *A. biguttula biguttula* gradually increased with a peak of 20.90/plant in the 45th SMW and gradually decreased to 8.17 (No/ plant) (Table-1). *A. biguttula biguttula* population (No/ plant) was also significantly positively ($r = 0.62^*$, $p = 0.05$) correlated with maximum temperature and non-significantly and negatively correlated with minimum temperature ($r = -0.18$), morning relative humidity ($r = -0.47$), evening relative humidity ($r = -0.62$) and rainfall ($r = -0.44$) (Table-3).

ii. Foliage feeding pests

The data on foliage pests, *S. litura* occurrence also as that of *B. tabaci* and *A. biguttula biguttula* and population was recorded from minimum level of 7.40 to maximum level of 19.60/plant with seasonal mean of 11.92 (No/ plant). The pest appeared in the 42nd SMW on the crop with a mean population of 7.54 (No/ plant) and reached of 19.60 (No/ plant) in the 45th SMW again declined to 7.40 (No/ plant) (Table-1). Maximum temperature was significantly positively ($r = 0.36^*$, $p = 0.05$) correlated with *S. litura* population while significantly negatively correlated with morning relative humidity ($r = -0.64^*$, ($p = 0.05$) and evening relative humidity ($r = -0.66^*$, $p = 0.05$). Whereas weather parameters viz., minimum temperature ($r = -0.18$) and rainfall ($r = -0.58$) were non-significantly negatively correlated with *S. litura* population (Table-3).

The occurrence of *H. vigintioctopunctata* was also found in the same trend as that of other pests. The population was ranged from 7.00 to 19.74/plant with seasonal mean of 12.37 (No/ plant). The pest was seen first on the crop in the 42nd SMW with a minimum population of 7.00 (No/plant). subsequently the count of *H. vigintioctopunctata* increased gradually and reached the peak of 19.74 (No/ plant) in the 45th SMW and became low i.e., 7.80 (No/plant) in 1st SMW (Table-1). *H. vigintioctopunctata* population (No plant) was significantly positively ($r = 0.62^*$, $p = 0.05$) correlated with maximum temperature whereas, the weather parameters viz., morning relative humidity ($r = -0.64^*$, $p = 0.05$) and evening relative humidity ($r = -0.69^{**}$, $p = 0.01$) were significantly negatively correlated with minimum temperature ($r = -0.19$), rainfall ($r = -0.59$) was non significantly negatively correlated (Table-3).

B. Incidences

The incidence of different insect pests on different varieties of potato was calculated during the Rabi season at L₁, Venkataramannagudem (Table-5). Incidence of foliage sucking insect pests i.e. *B. tabaci* and *A. biguttula biguttula* were recorded during study period and found to be lowest in the Kufri Badshah [*B. tabaci* (8.00%) and *A. biguttula biguttula* (6.90%), respectively]. While highest incidence was recorded in Kufri Khyati [*B. tabaci* (33.00%) and *A. biguttula biguttula* (33.00%), respectively].

Foliage feeding insect pests i.e. *S. litura* & *H. vigintioctopunctata* were recorded during study period (75). The incidence was lowest in the Kufri Badshah [*S. litura* (25.00%) & *H. vigintioctopunctata* (15.00%), respectively]. While highest incidence was recorded in Kufri Khyati [*S. litura* (70.00%) & *H. vigintioctopunctata* (65.00%), respectively].

2. Location-2 (Pandirimamidi, East Godavari District)

A. Occurrence and correlation

i. Foliage sucking pests

Initial occurrence of *B. tabaci* on potato crop population counts was observed in 42nd SMW with population level of 13.70 (No/ plant), whereas minimum count of 9.80 (No/ plant) noticed in 2nd SMW. The pest reached maximum level of 22.30 (No/ plant) in 44th SMW thereafter, the population was decreased till 2nd SMW (Table-2). The population counts of *B. tabaci* were significantly positively correlated with maximum temperature and evening relative humidity with correlation value ($r=0.67^*$, $p=0.05$) and ($r=0.59^{**}$, $p=0.01$), respectively. Whereas morning relative humidity ($r=0.30$) and rainfall ($r=0.19$) were positively correlated with the population of *B. tabaci* (No/ plant) but the weather parameter minimum temperature ($r=-0.08$) was non-significantly negatively correlated (No/ plant) (Table-4).

Similar trend of population levels was recorded in case of *A. biguttula biguttula* and the pest appeared in the 42nd SMW with a count of 13.30 (No/ plant). The population was ranged from 9.70 to 21.94 (No/ plant) with seasonal mean of 15.40 (No/ plant) from 42nd to 2nd SMW and gradually declined from 21.94 to 9.70 (No/ plant) population from 44th SMW to 2nd SMW (Table-2). *A. biguttula biguttula* population was significantly positively correlated with maximum temperature ($r=0.66^*$, $p=0.05$) and evening relative humidity ($r=0.58^*$, $p=0.05$). But, morning relative humidity ($r=0.30$) and rainfall ($r=0.18$) were non-significantly positively correlated. Minimum temperature ($r=-0.09$) showed non-significant negatively correlation with *A. biguttula biguttula* population (No/ plant) (Table-4).

ii. Foliage feeding pests

S. litura population appeared first in 42nd SMW with 11.90 (No/ plant) and ranged from 10.10 to 21.30 with seasonal mean of 15.27 (No/ plant). The population reached peak i.e., 21.30 (No/ plant) after which it declined to minimum 10.10 (Table-2). *S. litura* population was significantly positively correlated ($r=0.59^*$, $p=0.05$) with maximum temperature, minimum temperature ($r=-0.16$) non-significantly negatively correlated and morning humidity ($r=0.25$), evening relative humidity (0.48) and rainfall ($r=0.11$) were non significantly positively correlated with *S. litura* (No/ plant) (Table-4). The population count of *H. vigintioctopunctata* increased gradually from 9.48-21.81 which effect 42nd to 2nd. Reaching peak level of population, 21.81 (No/ plant) and declining gradually was occurred similar to as that of other pests (Table-2). The population of *H. vigintioctopunctata* (number per plant) was non significantly positively correlated with maximum temperature ($r=0.50$), morning relative humidity ($r=0.11$), evening relative humidity ($r=0.42$) and rainfall ($r=0.09$). Whereas the minimum temperature ($r=-0.24$) was non-significantly negatively correlated with *H. vigintioctopunctata* population (No/ plant) (Table-4).

Table-1: Seasonal occurrence of different insect pests on potato crop at Venkatarannagudem (Rabi, 2017-18)

SMW (No)	<i>B. tabaci</i> (No/plant)	<i>A. biguttula</i> (No/plant)	<i>S. litura</i> (No/plant)	<i>H. vigintioctopunctata</i> (No/plant)	Temperature (°C)		Humidity (%)		Rainfall (mm)
					Maximum	Minimum	Morning	Evening	
41	3.81	3.20	0	0	37.57	24.65	81.71	71.51	15.5
42	9.00	7.62	7.54	7.00	35.27	21.80	78.24	72.44	18.5
43	14.00	13.00	9.62	10.70	34.30	21.51	81.40	66.10	18.7
44	16.22	16.70	15.16	15.13	47.58	20.25	72.56	65.25	0
45	21.40	20.90	19.60	19.74	50.52	20.86	68.20	63.77	0
46	16.30	15.80	15.24	15.84	45.09	21.83	67.56	64.87	0
47	14.20	14.40	14.60	14.70	38.03	23.77	68.11	64.06	0
48	14.10	13.42	13.10	13.70	39.04	25.96	70.12	66.74	0
49	12.31	12.18	12.10	13.00	40.16	23.80	71.37	67.47	0
50	10.20	10.24	10.30	11.84	43.04	19.36	69.49	64.63	0
51	9.64	9.70	9.80	10.20	42.31	22.86	69.53	65.19	0
52	8.51	8.51	8.61	8.90	43.14	20.67	68.75	64.14	0
1	8.00	8.17	7.40	7.80	29.23	20.66	69.14	65.41	0

Table-2: Seasonal occurrence of different insect pests on potato crop at Pandiramanidi (Rabi, 2017-18)

SMW (No)	<i>B. tabaci</i> (No/plant)	<i>A. biguttula</i> (No/plant)	<i>S. litura</i> (No/plant)	<i>H. vigintioctopunctata</i> (No/plant)	Temperature (°C)		Humidity (%)		Rainfall (mm)
					Maximum	Minimum	Morning	Evening	
42	13.70	13.30	11.90	9.84	32.14	22.12	87.41	78.20	14.60
43	19.91	20.57	20.33	19.20	29.62	20.14	82.62	75.32	15.30
44	22.30	21.94	21.30	21.81	34.20	19.16	84.81	76.12	0
45	19.30	19.80	19.65	19.31	30.20	16.12	78.32	71.58	0
46	18.35	18.50	18.10	17.83	26.61	17.52	71.60	67.23	0
47	17.50	17.25	16.01	17.10	25.12	18.61	69.86	76.12	19.30
48	15.80	15.52	15.40	15.60	26.12	16.62	74.52	70.12	16.40
49	15.00	14.60	15.10	14.70	27.36	20.12	76.25	72.23	17.40
50	13.85	13.61	14.22	14.20	18.20	18.13	71.23	61.40	0
51	13.14	12.81	13.10	12.80	20.20	16.32	72.35	61.60	0
52	12.50	12.10	12.50	12.30	17.60	15.53	74.30	62.13	0
1	11.00	10.50	10.85	10.20	25.10	20.20	76.58	69.20	0
2	9.80	9.70	10.10	9.48	22.30	19.64	75.30	63.10	0

Table-3: Correlation studies on Seasonal occurrence of different insect pests on potato crop with weather parameters at, Venkataramannagudem (Rabi, 2017-18)

Name of the insect pest	Maximum Temperature(°c)	Minimum Temperature (°c)	Morning Humidity(%)	Evening Humidity (%)	Rainfall(mm)
<i>B. tabaci</i>	0.60*	-0.15	-0.40	-0.55	-0.36
<i>A. biguttula biguttula</i>	0.62*	-0.18	-0.47	-0.62	-0.44
<i>S. litura</i>	0.36*	-0.18	-0.64*	-0.66*	-0.58
<i>H. vigintioctopunctata</i>	0.62*	-0.19	-0.64*	-0.69**	-0.59

Table-4: Correlation studies on Seasonal occurrence of different insect pests on potato crop with weather parameters at, Pandirimamidi (Rabi, 2017-18)

Name of the Insect pest	Maximum Temperature(°c)	Minimum Temperature (°c)	Morning Humidity(%)	Evening Humidity (%)	Rainfall(mm)
<i>B. tabaci</i>	0.67*	-0.08	0.30	0.59*	0.19
<i>A. biguttula biguttula</i>	0.66*	-0.09	0.30	0.58*	0.18
<i>S. litura</i>	0.59*	-0.16	0.25	0.48	0.11
<i>H. vigintioctopunctata</i>	0.50	-0.24	0.11	0.42	0.09

Table-5: Seasonal incidence of different pests on different varieties of potato at Venkataramannagudem

Treatments	<i>B. tabaci</i> (%)	<i>A. biguttula biguttula</i> (%)	<i>S. litura</i> (%)	<i>H. vigintioctopunctata</i> (%)
Kufri Surya	15.20	11.5	35.00	20.00
Kufri Khyati	33.00	33.00	70.00	65.00
Kufri Chipsona-3	16.57	15.00	50.00	35.00
Kufri Chandramukhi	16.00	14.10	40.00	30.00
Kufri Badshah	8.00	6.90	25.00	15.00
Kufri Phukraj	31.00	32.6	65.00	55.00
Kufri Jyoti	22.70	25.00	60.00	45.00
Kufri Himalini	25.00	30.00	62.25	50.00

Table-6: Seasonal incidence of different pests on different varieties of potato at Pandirimamidi

Treatments	<i>B. tabaci</i> (%)	<i>A. biguttula biguttula</i> (%)	<i>S. litura</i> (%)	<i>H. vigintioctopunctata</i> (%)
Kufri Surya	16.90	13.00	30.00	30.00
Kufri Khyati	26.30	25.00	55.00	55.00
Kufri Chipsona-3	31.50	31.00	65.00	60.00
Kufri Chandramukhi	21.20	18.00	40.00	43.00
Kufri Badshah	14.20	12.20	25.00	20.00
Kufri Phukraj	25.50	23.00	45.00	45.00
Kufri Jyoti	36.80	36.00	70.00	70.00
Kufri Himalini	9.70	8.60	15.00	10.00

B. Incidences:

The incidences of different insect pests on different varieties of potato were recorded during the Rabi season at Pandirimamidi (Table-6). Incidences of foliage sucking insect pests (*B. tabaci* and *A. biguttula biguttula*) recorded were lowest in the Kufri Himalini [*B. tabaci* (9.70%) & *A. biguttula biguttula* (8.60%), respectively]. While highest incidences were recorded in Kufri Jyoti [*B. tabaci* (36.80%) & *A. biguttula biguttula* (36.00%), respectively]. Foliage feeding insect pests (*S. litura* & *H. vigintioctopunctata*) were also recorded during study period and their incidence was lowest in the Kufri Himalini [*S. litura* (15.00%) & *H. vigintioctopunctata* (10.00%) respectively]. While highest incidence was recorded in Kufri Jyoti [*S. litura* (70.00%) and *H. vigintioctopunctata* (70.00%), respectively].

Results were in accordance with the finding of (ALEMLA and PANKAJ, 2012) in Nagaland who recorded the peak occurrence of *B. tabaci* in 43rd and 45th SMW. (ANWAR *et al.*, 1987) also reported peak occurrence of white fly in Karachi (Pakistan) at 6th SMW and peak occurrence of *A. biguttula biguttula* at 3rd SMW. The present findings differ from the studies (OMEN and KUMAR, 2004) who reported the occurrence of peak population *B. tabaci* in the first week of September in Samistipur (Pusa). The differences in the time of sowing and climatic conditions prevailing during the cropping period between the locations studied may be a reason which influenced the pest build up. It is found from the present investigation: mainly weather parameters *i.e.*, minimum temperature and rainfall were negatively correlated with pest population. PAUL and KONAR (2005); ALEMLA and PANKAJ (2012) also reported *B. tabaci* population was non significantly negatively correlated with minimum temperature, which were similar to present findings.

CHANDRAKUMAR *et al.* (2008) reported that incidence of ash weevil and epilachna beetle in GKVK, Bangalore was maximum during November, December. Subsequently they reported that highly significant positive correlation existed with maximum and minimum temperature (0.734 and 0.763), and highly significant, negative correlation was found with rainfall which was on-par with present findings. Similarly, (PRIYADARSHINI *et al.*, 2018) from West Bengal reported that the highest incidence of *B. tabaci* and *A. biguttula biguttula* in 44 and 45th SMW on chilli crop and the incidence was significantly positively correlated with maximum and minimum temperature whereas negatively correlated with relative humidity and rainfall, which was similar to present findings from Andhra Pradesh. RAWAT and BANDARI (2019) reported that maximum incidence of *B. tabaci* and *A. biguttula biguttula* at GBPUAT, Pantnagar was highest in 43rd and 44th SMW on tomato which was slightly vary due to the difference in time of planting.

Conclusion: The potato varieties grown in coastal and high attitude districts of AP, Kufri Badshah were less affected with insect pests at Venkataramannagudem and Kufri Himalini showed promising results in L₂. It is established that the practicality of conditions in Andhra Pradesh regarding the attack of diverse insect pests of potato. Kufri Badshah and Kufri Himalini were found suitable against the attack of recorded insect pests especially in coastal zone and high altitude zones of Godavari districts. Further, the study highlighted the pest's

occurrence, period of peak occurrence in both the districts so that the plant protection measures can be planned well in advance to suppress the pest population. However, further confirmative studies are essential to develop pest forecasting model in the above region to formulate IPM models for the successful cultivation of potato crop.

REFERENCES

- ALEMLA, L. and PANKAJ, M. 2012. Incidence of Aphid and White fly on Different Planting Dates in Relation to Abiotic Factors in Potato Variety Kufri jyoti. *International J. of Bio- resource and Stress Management*, **3**(2): 239 -241.
- ANWAR, M. P., MUNSHI, G. H., HUSSAIN, T. and SHAHWANI, M. I. 1987. Insect pests associated with potato crop at Tandojam. *Proceedings of the 5th Pakistan Congress of Zoology*. January 8-11, pp. 149-151.
- BHATNAGAR, A. 2013. Management of sap sucking and soil insect pest of potato with insecticides. *Pesticides Research Journal* **25**(2): 170-173.
- CHANDRAKUMAR, H. L., ASHOKKUMAR, C. T., KUMAR, N. G., CHAKRAVARTHY, A. K. and PUTTA RAJU. T. B. 2008. Seasonal occurrence of major insect pests and their natural enemies on brinjal. *Current Biotica*. **2**(1), 63-73.
- MISRA, S. S. 1995. Potato pests and their management. *Tech. Bull.* (No. 45) CPRI, Shimla, India.
- MISRA, S. S. 2019. Potato: quality seed production technologies through vector management in the northern plains of India. *J. Appl. Zool. Res.* **30**(1):1-12.
- MISRA, S. S. and CHANDEL, R. S. 2003. Potato white grubs in India. *Tech. Bull.* (No. 60) CPRI, Shimla, India.
- MOHAMMAD, S. K. 2000. Incidence of different insect pests of potato pests. Jammu & Kashmir *M.Sc. (Ag) Thesis*, pp130.
- NAG, D. 2016. Seasonal incidence and management of major insect pests on rabi potato at Raipur *M.Sc. (Ag) Thesis*, pp136.
- OOMMEN, S. and KUMAR, A. 2004. Seasonal incidence of insect pests of potato. *Indian Journal of Applied Entomology*. **18**(1): 65-66.
- PAUL, S. and KONAR, A. 2005. Population dynamics of whitefly on potato planted on different dates. *Tat. Journal of Science* **1**: 251-254.
- PRIYADARSHIN, S., MISHRA, A., ANJAN KUMAR, N. and PAVAN. T. 2018. Seasonal Incidence of Different Sucking Pests of Chilli and their Natural Enemies under West Bengal Condition. *International Journal of Current Microbiology and Applied Sciences*. **7**(10): 2936-2948.
- RADCLIFFE, E. B. 1982. Insect Pests of Potato. *Annu. Rev. Entomol.* **27**: 173–204.
- RAWAT, N. and BHANDARI. D. 2019. Seasonal Incidence of Whitefly and Aphid on Tomato Crop at Tarai Region of Uttarakhand. *Indian Journal Pure Applied Biosciences*. **7**(5): 214-221.



HAEMADIPSA LOLEGAONSIS SP. NOV. (HIRUDINEA: HAEMADIPSIDAE): A NEW LEECH FROM WEST BENGAL, INDIA

CHANDRAKANTA, K., MANDAL¹; HIMANI TARIYAL¹, P. NAIWAL¹, D. THAKUR¹
AND SHYAMASREE GHOSH²

¹=Zoological Survey of India, NRC, Dehradun, Uttarakhand

²= School of Biological Sciences, National Institute of Science, Education and Research (NISER), HBNI, Bhubaneswar, Odisha - 752050

E-mail: mandalsucker@gmail.com : sree.s@niser.ac.in

Received: 30 April, 2020

Accepted: 15 May, 2020

ABSTRACT: This new species of leech, *Haemadipsa lolegaonensis* is collected from lolegaon, Darjeeling, West Bengal, India. This species is distinguished from other species by possessing the following characters. Body is elongated somewhat round. Eyes five pairs and round shaped. Five pairs of eyes. Somite VI 3 annulate, somite VIII 5 annulate. No gap between 1st 2nd and 2nd 3rd pair of eyes. Eyes 3 and 4 separated by one annuli. Eyes fourth and fifth pairs separated by two annuli. Three black stripes. One median dorsal stripe and two dorsolateral black stripes. Table showing comparison of *Haemadipsa lolegaonensis* sp. nov. with the other five species of the genus *Haemadipsa* in India.

Key words: New species of leech, *Haemadipsa lolegaonensis*, Lolegaon, West Bengal

INTRODUCTION

Out of more than 700 species of leeches known in the world, 74 species are recorded in India (MANDAL, 2018). There are 21 species of leeches belonging to the genus *Haemadipsa* in the world. *Haemadipsa cavatuses*, *H. zeylanica* (Japanese mountain leech), *H. cochiniensis*, *H. crenata*, *H. hainana*, *H. interrupta*, *H. japonica*, *H. limuna*, *H. montana*, *H. ornata*, *H. picta* (Tiger leech of Borneo, Malaysia), *H. rjukjuana*, *H. sumatrana*, *H. sylvestris*, *H. trimaculosa*. Out of eleven species known from India, 9 species are endemic (*Haemadipsa moorei*, *H. kodaiensis*, *H. annaigundiensis*, *H. dussumieri*, *H. montana*, *H. cochiniensis* of South India; *H. ornata*, *H. zeylanica montivindicis* from Darjeeling hills and *H. koushiki* from buxa fort Alipurduar of West Bengal).

SOOS (1965) is the pioneer in Taxonomy of leeches in the world. He has described a number of new species. Majority of the new species of leeches were described by HARDING and MOORE (1924, 1927), BHATIA (1931). MANDAL (2004a, 2004b) has described two new species, collected from West Bengal. BANDYOPADHYAY (2004, 2005), MANDAL (2004a,b,c,d,e, & 2010a,b) have done some research work on ecology of leeches. SOOTA (1977), CHANDRA (1983), & GHOSH (1998) also contributed considerably to the taxonomy of leeches of India.

MATERIALS AND METHODS

After making the collection, leeches were sorted out and cleaned. The cleaned leeches were placed in a tray with a small quantity of water and were slowly killed by anaesthetizing with

70% alcohol by adding drop by drop at frequent intervals. Leeches usually die in an extended condition by this process. Just after death, the leeches were kept in 70% alcohol for permanent preservation. This new species *Haemadipsa lolegaonsis* has been collected from Lolegaon Darjeeling West Bengal by Priyanka Talukder taking personal endeavour. This new species is identified by ZSI, Kolkata. The new species is compared with the material of other species available in hand and information on other species is taken from literature.

***Haemadipsa lolegaonsis* sp. nov.**

Material examined:

Holotype: 1 ex. Lolegaon, West Bengal, 15.Viii.2015, Coll. Priyanka Talukder. An 6035/1.

Paratype: 7 ex. Lolegaon, West Bengal, 15.Viii.2015, Coll. Priyanka Talukder. An 6036/1.

Diagnostic characters: Somite VII 3 annulate and VIII 4 annulate. Caudal sucker well developed. Eyes 3 and 4 are separated by one annuli. Large sized, slender robust body. Colour in live is ash. Mid dorsal yellowish field bears two discontinuous median black line. Ventral region creamed coloured. Three blackish stripe broader than *Haemadipsa sylvestris* on the dorsal region. Dorsal region is having no tubercles. Anterior sucker having little deep areas of mouth. Three jaws are clearly seen. Ten muscular ridges in the mouth. Posterior sucker almost round. Sucker rays 82. 110 segments in the body. Male and female pore separated by 5 annules.

Distribution: India: Lolegaon, West Bengal; Arunachal Pradesh.

Etymology: The specific name is proposed according to the name of the place where from it was collected.

***Haemadipsa lolegaoensis* sp. nov.**

Diagnosis: Body (Photo plate-1): Large sized, Black stripes are seen on the dorsal region of the body.

Length: The total length of the body is 25.6cm inclusive anterior sucker and posterior suckers.

Breadth: 2.3 cm. Middle part almost half of the body.

Head: It is elongated, contains anterior sucker, mouth and eyes.

Sucker: Anterior sucker 1.2cm in diameter, posterior sucker 3.2cm. in diameter. Posterior sucker is round, anterior sucker almost round. Mouth is with muscular ridges but with jaws. Posterior sucker bears 82 sucker rays.

Stripe: Three stripes. One median dorsal stripe which is black in colour and two dorsomedial black stripes.

Eyes: Five pairs of eyes. Somite VI 3 annulate, somite VIII 5 annulate. No gap between 1st 2nd and 2nd 3rd pair of eyes. Eyes 3 and 4 separated by one annuli. Eyes fourth and fifth pairs separated by two annuli.

Rings: Total number of body rings is 110.

Sucker rays: 82 numbers.

Male and female pores: Open between the rings 17/18 and 22/23, respectively. Female pore is very small.

Eggs: Not found.

Colour: Black coloured. Colour fades up in preserved state.

Host and habitat: Mammals.

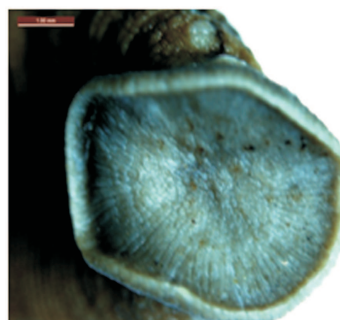
Distribution: India: West Bengal.

Etymology: The specific name is proposed according to the name of the place where from the first example was collected.

Remarks: The present described species *Haemadipsa lolegaonensis* somewhat similar to any species.



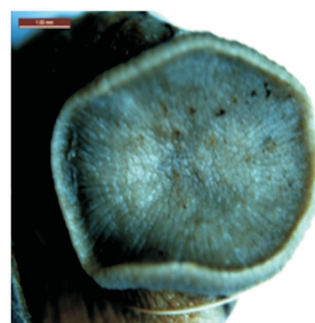
Ventro-lateral view



Sucker (anterior)



Ventral view



Sucker (anterior)

Photo plate-1: *Haemadipsa lolegaonensis* -whole body & sucker

Comparative material (Table-1):

Material: *Haemadipsa dussumieri*, Darjeeling, West Bengal Registration number is An 2858/1.

Material: *Haemadipsa montana*, Darjeeling, West Bengal. Registration number is An 2860/1.

Material: *Haemadipsa ornata*, Kalimpong, Darjeeling, West Bengal. Registration number is An 2857/1.

Material: *Haemadipsa zeylanica agilis* Darjeeling, West Bengal. Registration number is An 2857/1

Material: *Haemadipsa kaushiki* Buxa fort, Near Alipurduar, Jalpaiguri, West Bengal, India. Registration number is An 4083/1.

Distribution: India: West Bengal.

ACKNOWLEDGEMENTS: We are grateful to the Director, Zoological Survey of India, for lucid suggestions to work hard and my special thanks to Dr. Gourav Sharma O/C, ZSI NRC Dehradun for his inspiration and work independently.

REFERENCES

- CHANDRA, M. 1983. A check-list of leeches. *Rec. Zool. Surv. India*. **80(3&4)**: 265-290.
- GHOSH, G.C. 1998. Leech fauna of West Bengal. *State Fauna Series 3. Zool. Surv. India Part 10*: 227-249.
- GHOSH, G.C. and MANDAL, C.K. 2005. Leech fauna of Coastal Districts of Andhra Pradesh. *State Fauna Series 5. Zool. Surv. India: Part 5*: 339-355.
- HALDER, K. R. and MANDAL, C.K. 2010. Annelid fauna of some selected wetlands of Uttarakhand. *State Fauna Series 18(Part-3)*, 167-172.
- MANDAL, C. K. 2004a. Checklist of the Hirudinea (Leech) of India. *Rec. Zool. Surv. India*: **102** (Part1-2): 41-46.
- MANDAL, C. K. 2004b. *Paraclepsis gardensi* (Hirudinea: Glossiphonidae) a new species of Leech from West Bengal, India. *Rec. zool. Surv. India*: **103** (Part1-2): 111-114.
- MANDAL, C. K. 2004c. *Placobdella harasundarai* (Hirudinea: Glossiphonidae) a new species of Leech from West Bengal, India. *Rec. Zool. Surv. India*: **103** (Part1-2): 99-102.
- MANDAL, C.K. 2004d. Endemic leech fauna of India. *Rec. Zool. Surv. India*: **103** (Part1-2): 103-110.
- MANDAL, C.K. 2004e. On some leeches of Arunachal Pradesh, India. *State fauna series 13, Zool. Surv. India*: (part-2): 47-48.
- MANDAL, C.K. 2005. Leech fauna of coastal districts of Andhra Pradesh, *State Fauna Series, 5: Zool. Surv. India*: (part-5): 339-355.
- MANDAL, C. K. 2010a. Leech fauna of Uttarakhand. *State Fauna Series 18(Part-3)*, 193-197.
- MANDAL, C.K. 2010b. *Haemadipsa anaigundiensis* sp. nov. (Hirudinea: Haemadipsidae) a new species of leech from Tamil Nadu, India. *Rec. zool. Surv. India*: **109** (Part1-3): 27--31.
- MANDAL, C. K., DHANI, S, MITRA, SANTANU and MISRA, A. 2010. Annelid fauna of some selected wetlands of Uttarakhand. *State Fauna Series 18(Part-3)*, 173-180.
- MOORE, J.P. and HARDING, W.A. 1927. Fauna of British India, Hirudinea. *Tailor and Francis, London*.
- MOORE, J.P. 1924. Notes on some Asiatic Leeches. Principally from China. *Proc. Acad. Nat. Sec. Philad.*
- SOOS, A. 1965. Identification key to the leech (Hirudinoidea) genera of the World, with a Catalogue of the species. 111-IV. *Acta. Zool.. Acad. Hung.* **11(3-4)**: 415-464.
- SOOTA, T. D. and GHOSH, G.C. 1977. On some Indian Leeches. *Newsl. Zool. Surv. India*: **3(6)**: 359-360.

Table-1: Comparison of *Haemadipsa lolegaonensis* sp. nov. with the other five species of the genus *Haemadipsa* in india.

	<i>Haemadipsa lolegaonensis</i> sp. nov.	<i>H. dussumieri</i>	<i>H. moorei</i>	<i>H. montana</i>	<i>H. ornata</i>	<i>H. sylvestris</i>	<i>Haemadipsa anaguidensis</i>
Stripe	Three black stripes. One mid dorsal and two dorsolateral	No stripe	Complete, black, chain stripe, from the bottom of first pair of eyes to the base of posterior sucker	Complete, black, number of stripe three	Complete, black, creamed coloured, number of stripe three	Complete, black, number of stripe three	Complete, from first pair of eyes to the base of posterior sucker
Marginal stripe	No marginal stripe	Absent	Complete yellow coloured,	Complete pale yellow coloured	Complete creamed coloured	Complete bright orange	creamed coloured,
Colour	Black	Yellowish mottled black	Dark	Dark	Velvately black	Blakish brown	Ash green (in living)
Body length	25.6cm.	-	-	-	-	-	7mm.
Breadth	2.6cm.	-	-	-	-	-	4mm.
Breadth of ant. sucker	Anterior sucker 1.2cm in diameter.	-	-	-	-	-	0.5mm.
Breadth of post. sucker	posterior sucker 3.2cm. in diameter.	-	-	-	-	-	1mm.
Clitellum	Prominent	prominent	prominent	prominent	prominent	prominent	Not prominent
Breeding season	June-August	-	-	June-July	June-July	May-July	-
Eggs	-	-	-	5-7	3-7	13-15	-
Stomach	More than seven chambered	One chambered	-	-	-	-	More than seven chambered
Caeca	Branched	three pairs, short	-	-	-	-	Short, more than three pairs
Crop	Branched	Almost branched	-	-	-	-	Not branched
Vaginal stalk	Moderate	Long	-	-	-	-	Short
Caecum	Present	Present	-	-	-	-	Present
Altitude	1500-1800 mts.	1200mts.	1500-1800 mts.	3000mts.	3000 mts.	1500-2000 mts.	3000 mts.
Reference	Blanchard, 1894	Blanchard, 1917	Moore, 1927	Moore, 1927	Sanjeva Raj and Gladstone, 1981	Present author	Blanchard, 1894



HAEMADIPSA CHAMPHAIENSIS SP. NOV. (HIRUDINEA: HAEMADIPSIDAE): A NEW LEECH FROM MIZORAM, INDIA

CHANDRAKANTA.K. MANDAL¹, HIMANI TARIYAL¹, P. NAIWAL¹ AND SHYAMASREEGHOSH²

1=Zoological Survey of India, NRC, Dehradun, Uttarakhand

2=School of Biological Sciences, National Institute of Science, Education and Research (NISER), HBNI, Bhubaneswar, Odisha - 752050

E-mail: mandalsucker@gmail.com; sree.s@niser.ac.in

Received: 30 April, 2020

Accepted: 15 May, 2020

ABSTRACT: This new species of leech, *Haemadipsa champhaiensis* is collected from champhai falls, mizoram, India. This species is distinguished from other species by possessing the following characters. Body is elongated somewhat round. Eyes five pairs and almost round shaped. Five pairs of eyes. Somite VI 3 annulate, somite VIII 5 annulate. No gap between 1st 2nd and 2nd 3rd pair of eyes. Eyes 3 and 4 separated by one annuli. These annuli are almost half in size. Eyes fourth and fifth pairs separated by two annuli. Three black stripes. Median dorsal stripe is broader than dorsolateral two black stripes. There are two cream coloured areas both side of mid dorsal black lines. Cream coloured spots in catechu coloured background are present at the two sides of the two lateral black lines. Two lateral cream coloured stripe like region. The leech is reddish brown when it is alive. Length of a full-grown preserved specimen is 14.5mm and width is also 6.3mm. Anterior sucker 1mm in diameter, posterior sucker 2mm. in diameter. It is distinguished by its combination of stripes.

Key words: *Haemadipsa champhaiensis*, leech new species, Mizoram

INTRODUCTION

Out of more than 700 species of leeches known in the world, 74 species are recorded in India (MANDAL, 2010). There are 21 species of leeches belonging to the genus *Haemadipsa* in the world. *Haemadipsa cavatuses*, *H. zeylanica* (Japanese mountain leech), *H. cochiniensis*, *H. crenata*, *H. hainana*, *H. interrupta*, *H. japonica*, *H. limuna*, *H. montana*, *H. ornata*, *H. picta* (Tiger leech of Borneo, Malaysia), *H. rjukjuana*, *H. sumatrana*, *H. sylvestris*, *H. trimaculosa*. Out of eleven species known from India, 9 species are endemic (*Haemadipsa moorei*, *H. kodaiensis*, *H. annaigundiensis*, *H. dussumieri*, *H. montana*, *H. cochiniensis* of South India; *H. ornata*, *H. zeylanica montivindicis* from Darjeeling hills and *H. koushiki* from Buxa fort Alipurduar of West Bengal).

SOOS (1965) is the pioneer in Taxonomy of leeches in the world. He has described a number of new species. Majority of the new species of leeches were described by HARDING and MOORE (1924, 1927), BHATIA (1931), BLANCHARD (1917) worked on leech of India. MANDAL (2004a,b) has described two new species, collected from West Bengal. BANDYOPADHYAY (2004, 2005), MANDAL (2004a,b,c,d,e; 2005a,b; 2010), have done some work on ecology of leeches. SOOTA (1977), CHANDRA (1983), GHOSH (1998) also contributed considerably to the taxonomy of leeches of India.

MATERIALS AND METHODS

After making the collection, leeches were sorted out and cleaned. The cleaned leeches were placed in a tray with a small quantity of water and were slowly killed by anaesthetizing with 70% alcohol by adding drop by drop at frequent intervals. Leeches usually die in an extended condition by this process. Just after death, the leeches were kept in 70% alcohol for permanent preservation. This new species *Haemadipsa champhaiensis* has been collected from Champhai of Mizoram, Latitude 23° 28' 28" N. Longitude 93° 19' 32" E. Elevation 4191 ft. India during recent faunistic survey carried out by Zoological survey of India. The new species is compared with the material of other species available in hand and information on other species is taken from literature.

***Haemadipsa champhaiensis* sp. nov.**

Holotype: Z.S.I. Reg. No. An 3953/1, 1 ex., Coll. S. Mitra, 19.ii.2017, Champhai forest, District Champhai, Mizoram, India.

Diagnosis: Body (Photo plate-1): Medium sized, hard, coarse body. Black stripes are seen on the dorsal region of the body.



Dorsal view

Lateral view

Ventral view

Photo plate-1: *Haemadipsa champhaiensis*

Length: The total length of the body is 14.5mm inclusive anterior sucker and posterior suckers.

Breadth: 4.5 mm. Middle part almost half of the body.

Head: It is somewhat elongated, contains anterior sucker, mouth and eyes.

Sucker: Anterior sucker 1mm in diameter, posterior sucker 2mm. in diameter. Posterior sucker is round, anterior sucker almost round. Mouth is with muscular ridges but with jaws. Posterior sucker bears 72 sucker rays.

Stripe: Three stripes. One median dorsal stripe which is black in colour. Two cream coloured dorsal areas both side of mid dorsal black lines. Two dorso lateral black area containing Cream coloured spots. Two fine dorsolateral stripes containing white spots. Two lateral creamed coloured stripe like zone.

Eyes: Five pairs of eyes. Sommite VI 3 annulate, somite VIII 5 annulate. No gap between 1st 2nd and 2nd 3rd pair of eyes. Eyes 3 and 4 separated by one annuli. This annuli is almost half in size. Eyes fourth and fifth pairs separated by two annuli.

Rings: Total number of body rings is 93.

Sucker rays: 72 numbers.

Male and female pores: Open between the rings 17/18 and 22/23 respectively. Female pore is very small.

Eggs: Not found.

Colour: Mottled coloured (Catechu, black and cream). Ventral catechu coloured. Colour fades up in preserved state.

Host and habitat: Mammals of forest and human passerby.

Distribution: India: Mizoram.

Etymology: The specific name is proposed according to the name of the place where from the first example was collected.

Remarks: The present described species *Haemadipsa champhaiensis* somewhat similar to any species.

Comparative material (Table-1):

Material: *Haemadipsa dussumieri*, Darjeeling, West Bengal Registration number is An 2858/1.

Material: *Haemadipsa montana*, Darjeeling, West Bengal. Registration number is An 2860/1.

Material: *Haemadipsa ornata*, Kalimpong, Darjeeling, West Bengal. Registration number is An 2857/1.

Material: *Haemadipsa zeylanica agilis* Darjeeling, West Bengal. Registration number is An 2857/1

Material: *Haemadipsa kaushiki* Buxa fort, Near Alipurduar, Jalpaiguri, West Bengal, India. Registration number is An 4083/1.

Haemadipsa champhaiensis

Material examined: Holotype: Z.S.I. Reg. No. An 3953/1, 1 ex., Coll. S. Mitra, 19.ii.2017, Champhai forest, District Champhai, Mizoram, India.

Diagnosis: Eyes five pairs and almost round shaped. Five pairs of eyes. Sommite VI 3 annulate, somite VIII 5 annulated. No gap between 1st 2nd and 2nd 3rd pair of eyes. Eyes 3 and 4 separated by one annuli. These annuli are almost half in size. Eyes fourth and fifth pairs separated by two annuli.

Distribution: India: Mizoram.

ACKNOWLEDGEMENTS: We are grateful to the Director, Zoological Survey of India, for lucid suggestions to work hard and my special thanks to Dr. Gourav Sharma O/C, ZSI NRC Dehradun for his inspiration and work independently.

REFERENCES

- Blanchard, R. 1917. Monographie des Haemadipsines (sangsuesterrestes). *Bull. De la Soc. Pathologie Exotique*, **10**: 640-675.
- Bandyopadhyay, P. K. and Mandal, C.K. 2004. On the occurrence of five leeches, *Barbronia weberi*, *Glossiphonia annandalei*, *Glossiphonia heteroclite*, *Glossiphonia reticulate* and *Placobdella undulata* in West Bengal. *Rec. Zool. Surv. India*. **105** (part 3-4): 93-101.
- Bandyopadhyay, P.K. and Mandal, C.K. 2006. Studies on a new species (*Haemadipsa kodairensis*) of leech of the Genus *Haemadipsa* from the kodairforest of Tamil Nadu. *Rec. zool. Surv. India*. **106** (part-1): 33-37.
- Chandra, M.1983. A check-list of leeches. *Rec. Zool. Surv. India*. **80**(3&4): 265-290.
- Ghosh, G. C. 1998. Leech fauna of West Bengal. State Fauna Series 3. *Zool. Surv. India Part* **10**: 227-249.
- Ghosh, G. C. and Mandal, C. K.2005. Leech fauna of Coastal Districts of Andhra Pradesh. *State Fauna Series 5. Zool. Surv. India: Part* **5**: 339-355.
- Julka, J. M. and Chandra, M.1980. On a small collection of leeches collected during the Dhapabum and Subansir expeditions, Arunachal Pradesh. *Bombay Nat. Hist. Soc.* **77**: 160-161.
- Halder, K. R. and Mandal, C.K.2010. Annelid fauna of some selected wetlands of Uttarakhand. *State Fauna Series* 18(Part-3), 167-172.
- Mandal, C. K. 2004a. Checklist of the Hirudinea (Leech) of India. *Rec. Zool. Surv. India*: **102** (Part1-2): 41-46.
- Mandal, C. K. 2004b. *Paraclepsis gardensi* (Hirudinea: Glossiphonidae) a new species of Leech from West Bengal, India. *Rec. zool. Surv. India*: **103** (Part1-2): 111-114.
- Mandal, C. K. 2004c. *Placobdella harasundarai* (Hirudinea: Glossiphonidae) a new species of Leech from West Bengal, India. *Rec. zool. Surv. India*: **103** (Part1-2): 99-102.
- Mandal, C. K. 2004d. Endemic leech fauna of India. *Rec. Zool. Surv. India*: **103** (Part1-2): 103-110.
- Mandal, C. K. 2004e. On some leeches of Arunachal Pradesh, India. *State fauna series* **13**, *Zool. Surv. India*: (part-2): 47-48.
- Mandal, C. K. 2005a. Leech fauna of coastal districts of Andhra Pradesh, *State Fauna Series, 5: Zool. Surv. India*: (part-5): 339-355.
- Mandal, C. K. 2005b. Leech Fauna of Non coastal districts of Andhra Pradesh, State Fauna Series, 5: *Zool. Surv. India*: (part-5): 319-338.
- Mandal, C. K. 2006. Leech Fauna of Arunachal Pradesh, *State Fauna Series, 13* (part-2): 47-48.
- Mandal, C. K.2010. Leech fauna of Uttarakhand. *State Fauna Series* 18(Part-3), 193-197.
- Moore, J. P. and Harding, W.A.1927. Fauna of British India, Hirudinea. *Tailor and Francis, London*.
- Moore, J. P. 1924. Notes on some Asiatic Leeches. Principally from China. *Proc. Acad. Nat. Sec. Philad.*
- Soos, A.1965. Indentification key to the leech (Hirudinoidea) genera of the World, with a Catalogue of the species. 111-1V. *Acta. Zool.. Acad. Hung.* **11**(3-4): 415-464.
- Soota, T. D. and Ghosh, G.C. 1977. On some Indian Leeches. *News. Zool. Surv. India*: 3(6): 359-360.
- Mandal, C.K.2010. *Haemadipsa anaigundiensis* sp. nov. (Hirudinea:Haemadipsidae) a new species of leech from Tamil Nadu, India. *Rec. zool. Surv. India*: **109** (Part1-3): 27--31.
- Mandal, C. K, .Dhani, S, Mitra, Santanu and Misra, A. 2010. Annelid fauna of some selected wetlands of Uttarakhand. *State Fauna Series* **18**(Part-3): 173-180.

Table-1: Comparison of *Haemadipsa champhiensis* sp. nov. with the other five species of the genus *Haemadipsa* in India.

Characters	<i>Haemadipsa Champhiensis</i> sp. nov.	<i>H. dussumieri</i>	<i>H. moorei</i>	<i>H. montana</i>	<i>H. ornata</i>	<i>H. sylvestris</i>	<i>Haemadipsa anagundiensis</i>
Stripe	Three black stripes. One mid dorsal and two dorsolateral	No stripe	Complete, black, chain stripe, from the bottom of first pair of eyes to the base of posterior sucker	Complete, black, stripe three	Complete, black, creamed, number of stripe three	Complete, black, number of stripe three	Complete, from first pair of eyes to the base of posterior sucker
Marginal stripe	One pair cream coloured stripe like zone	Absent	Complete yellow coloured, posterior sucker	Complete pale yellow	Complete creamed coloured	Complete bright orange	creamed coloured,
Colour	Mottled coloured(Catechu, Black and cream colour)	Yellowish mottled black	Dark	Dark	Velvately black	Blakish brown	Ash green (in living)
Body length	14.5mm inclusive anterior sucker and posterior suckers.	-	-	-	-	-	7mm.
Breadth	4.5 mm. Middle part almost half of the body.	-	-	-	-	-	4mm.
Breadth of ant. sucker	Anterior sucker 1mm in diameter.	-	-	-	-	-	.5mm.
Breadth of post. sucker	posterior sucker 2mm. in diameter.	-	-	-	-	-	1mm.
Clitellum	Not prominent	prominent	prominent	prominent	prominent	prominent	Not prominent
Breeding season	July August	-	-	June-July	June-July	May-July	-
Eggs	-	-	-	5-7	3-7	13-15	-
Stomach	Seven chambered	1 chambered	-	-	-	-	More than 7 chambered
Caece	Little branched	3 pairs, short	-	-	-	-	Short, more than three pairs
Crop	Not branched	Almost branched	-	-	-	-	Not branched
Vaginal stalk	Moderate	Long	-	-	-	-	Short
Caecum	Present	Present	-	-	-	-	Present
Altitude	3000 mts.	1200mts.	1500-1800 mts.	3000mts.	3000 mts.	1500-2000 mts.	3000 mts.
References	Blanchard, 1894	Blanchard, 1917	Moore, 1927	Moore, 1927	Sanjewa Raj and Gladstone, 1981	Present author	Blanchard, 1894

AZRA-2020
Proceedings & Recommendations
of XVII AZRA International Conference on “**Frontier Research in Applied Zoology and Insect Pest Management Strategies: A way Forward for Food and Nutritional Security**” held during 12th to 14th February, 2020 at UAS, Raichur, Karnataka, India.

On 12 February, the Conference was inaugurated by Prof. S. N. Puri, Chief Guest & President of Entomological Society of India (ESI), New Delhi. After Welcome Address by Prof. A. G. Sreenivas, Organizing Secretary of the Conference, Prof. S. N. Puri addressed the participants, which was followed by the addresses of Guests of Honour Dr. B. V. David, President of AZRA, Dr. Premjit Singh (VC-CAU, Imphal), Dr. B. V. Patil, Ex-VC, UAS, Raichur & Vice President of ESI; Dr. K. N. Krishna Kumar, Vice-President, ESI; Dr. Anand Prakash, Founder & General Secretary, AZRA. Chairman of the Session, Dr. K. N. Kattimani, VC-UAS, Raichur delivered presidential address and the session was ended with Vote of thanks by Prof. A.K. Hosamani. This three days conference witnessed presentations of 410 research papers (163-oral & 267-posters) under ten themes in 16 concurrent sessions, in addition to inaugural session, and valedictory session. AZRA award ceremony was an independent event during this conference on 12 February evening. After inaugural session, two key note addresses delivered by Prof. S. N. Puri, President, ESI and Dr. Anand Prakash, General Secretary, AZRA. There were oral presentations of 16 invited papers, 23 lead papers, 133 selected oral papers by many leading applied zoologists from India, Australia, & Canada.

Based on oral and poster presentations and discussion following **recommendations** for frontier research in Applied Zoology and Insect Pest Management Strategies: A way Forward for Food and Nutritional Security” are emerged as:

1. Pest monitoring for early warnings and the development and validation of pest forecast models and decision support systems which are crucial for the design and implementation of the successful IPM. The development of long-term monitoring spatial data on crop–pest–weather relationships will narrow the gaps in knowledge required for reliable forecasts. Digital pest **surveillance facilities** (e-pest surveillance; drone imaginary pest population of damage modules.....) need to be developed and popularized among the farmers for crop pest management.
2. Understanding the pest population dynamics along with their natural enemies so to say life table studies of major pests of agriculture importance needs to be studied.
3. Urgent need to strengthen research on **taxonomy** and systematics using both conventional as well as modern biotechnological tools to identify the pests and other useful animals with special emphasis on changing pest scenario due o climate change; biodiversity and bio security.
4. Correct estimation of **crop losses** due to pests has been suggested through national network program. To minimise these crop losses use of **bio-intensive IPM** modules is also suggested to reduce the synthetic pesticides load in environment. **Bio-control agents** (Predators & parasitoids) as well as **semio-chemicals** can judiciously be integrated with botanical pesticides with reference to climate change.
5. There is a need to have **pesticides** safer to pollinators and natural enemies. Further, suitable acaricides and nematicides are needed to control mite and nematode pests, as no

specific pesticides are available in India to control these pests. Location specific studies on pesticide toxicity, residues as well as pesticide resistance need to be carried out in major food crops.

6. Under **Host Plant Resistance** (HPR) focus should be to develop varieties **tolerant** to pests rather than focusing on developing/ improving varieties based on antixenosis or antibiosis aspects.
7. In evaluation of reproduction toxicity of agrochemicals for regulatory registration, studies are to be carried out in animal testing facilities having at least **15 air changes per hour** to ensure good health of rats under Good Laboratory Practice (GLP) compliance in the country by contract research organizations. On the other hand a large number of laboratories in private and government institutions carry out animal studies using air conditioning without air change resulting in maintaining the test animals *viz.*, rats in rooms with accumulation of ammonia which would affect the integrity of the study. It was suggested that presently IVC (Individually ventilated cage systems) are available in the country and in an animal room 4-6 IVC units can be accommodated which would overcome air change problem and in addition a number of compounds can be tested in a single animal room.
8. The biopesticide formulations based on bacteria and fungi in general have short **shelf-life** and research is needed in liquid and other type of formulations with enhanced shelf life.
9. **Future pest management strategies** need to be developed considering climate change with reference to (i) Exploitation of mating disruption techniques for the control of key pests on community approach based (ii) Genetic transformation of insects and their utilisation in pest management (iii) Use of nano based pheromone formulations 4) use of green technology in pest management.
10. In **aquaculture**, conversion of single species fish seed hatcheries into multi-species fish seed hatcheries has been suggested as a measure of diversification of aquaculture covering a wide range of fresh/brackish water fish species. Further, establishment of cluster for specific species like magur, scampi, pearl spot, mystus and other regional important food fishes. Mission Mode Program on hygienic and speedy transport of fish through road, rail and air to retain quality and to avoid post-harvest losses and also quarantine measures and enforced rule of bio security for trans-boundary import of ornamental and food fishes.
11. For food and **nutritional security**, many new research areas like entomophagy (insect as food source), entomotherapy (insect as medicines), entomophily (insect pollinators), insects as nutraceuticals, insect as animal feed, insect bioindicators, and insect scavengers etc. have emerged to be explored and utilized.
12. Insects play a vital role in all terrestrial ecosystem services (food chain, pollinators, natural enemies, food & nutritional insects etc...) which in general is not visualized by the policy makers. Therefore, **conservation of insect diversity** may be covered and enforced under national animal protection act, as hitherto, only vertebrates are given importance and protected by this act. Destruction of the habitats of wild animals may be avoided to maintain natural/ ecological balance because when these wild animals, migrates to humans habitat after losing their habitats cause many microbial diseases.

Dr. Anand Prakash (General Secretary, AZRA)
Prof. A. G. Sreenivas (Organizing Secretary, AZRA-2020)



AZRA-2020

Welcome to Conference Hall, UAS, Raichur, Karnataka on 12-14 February, 2020

On 12 February, 2020



Sitting from left: Prof. A.G. Sreenivas, Organizing Secretary; Sri Amaresh Ballidava, Member, Board of Management, UAS, Raichur; Dr. Anand Prakash, Founder & General Secretary, AZRA; Dr. S. K. Meti, Director of Education, UAS, Raichur; Dr. Premjit Singh, Vice Chancellor, CAU, Imphal; Dr. S. V. Patil, Ex-Vice Chancellor, UAS, Raichur; K. N. Kattimani, Vice Chancellor, UAS, Raichur; Dr. S. N. Puri, Ex-VC & President, ESL, New Delhi; Dr. B. V. David, President, AZRA; Dr. K. N. Krishna Kumar, Vice President, ESL; Mr. Trivikram Joshi, Member, Board of Management, UAS, Raichur; Mr. Veeranagouda, Member, Board of Management, UAS, Raichur; Mr. Siddappa Bhandari, Member, Board of Management, UAS, Raichur; Dr. B. K. Desai, Director Research, UAS, Raichur



Felicitation of dignitaries of XVII AZRA Intern. Conference: Sitting from left:

Dr. Premjit Singh, Vice Chancellor, CAU, Imphal; Dr. S. V. Patil, Ex-Vice Chancellor, UAS, Raichur; Dr. S. N. Puri, Ex-VC & President, ESI, New Delhi;
Dr. B. V. David, President, AZRA; Dr. Anand Prakash, Founder & General Secretary, AZRA; Dr. K. N. Krishna Kumar, Ex-DDG, ICAR & Vice President, ESI



Prof. A. G. Sreenivas (Organizing Secretary) welcoming the participants



Prof. S. N. Puri (President, ESI & Ex-VC) addressing the delegates as Chief Guest



Dr. B. V. David (President, AZRA) addressing the audience as Guest of Honour



Prof. Premjit Singh, V.C., CAU, Imphal addressing the audience as Guest of Honour



Prof. B. V. Patil, Ex-VC, UAS Raichur & Vice President, ESI, addressing audience as Guest of Honour



Dr. N. K. Krishna Kumar, Vice President, ESI & Ex-DDG, ICAR addressing the audience as Guest of Honour



Dr. Anand Prakash, Founder & General Secretary, AZRA addressing the audience as Guest of Honour



Dr. K. N. Kattimani, VC, UAS, Raichur delivering presidential address



Dr. A. K. Hosamani giving vote of thanks



A glimpse of cultural program during AZRA-2020



Galleries-Right & Left (Middle view)



Gallery-Left (Front view)



Gallery-Left (middle)



Gallery-Left (Back view)



Gallery-Right (Back view)



Gallery-Right (Middle)



**Jury evaluating best oral presentation for Prof. P. Kameswara Rao Award-2019-20:
From the left Dr S. K. Shrivastava (Member), Dr. Mohd. Arif (Member), Dr. S. S. Misra (Chairman)
& Dr. Sangeeta Singh (Member).**



**Jury evaluating posters for Prof. S. K. Shrivastava Award (2019 & 2020):
Second from left – Dr. (Mrs.) N. Sushila (Member), 3rd –Prof. C. S. K. Mishra (Chairman)
& 4th Dr. J. K. Sundaray (Member)**



Participants of AZRA-Annual General Body Meeting (13 February, 2020)

Photos: A few prominent invited speaker during AZRA-2020



Dr. M. B. Malipatil (Australia)



Prof. D. S. Jayas (Canada)



Dr. J. K. Sundaray (CIFA, Bhubaneswar)



Dr. Chandish R. Ballal, Director, NBAIR



Dr. Madhu Bala (Director, DIBER-DRDO)



Dr A. Sujatha, Dean, DYSRHU



Prof. R. K. Seth (Delhi University)



Prof. J. S. Kennedy (Dean, TNAU)



Prof. L. K. Hazarika (Jorhat, Assam)



Dr. Rami Reddy (IIHR, Bengaluru)



Prof. R. W. A. Jesudasan (MCC, Chennai)



Prof. Premjit Singh (CAU, Imphal)



Dr. S. Mohan (Ex-Prof, TNAU, Coimbatore)



Dr. V. Sridhar (IIHR-Bengaluru)



Dr. S. Mallikarjunappa, Rallis Res. Centre



Dr. K. Sreedevi (NB AIR, Bengaluru)



AZRA Books Stall during AZRA 2020 at UAS, Raichur



A view of plant protection appliances during AZRA-2020 at UAS, Raichur

AZRA Awards-2019 & 2020



Dr. Basawaraj S. Kalmath (2nd left) receiving AZRA Young Scientist Award-2019 from Prof. D.S. Jayas (Canada)



Dr. Ankita Gupta (Middle) receiving AZRA Young Scientist Award-2020 from Prof. B. V. Patil & Dr. Alex (Extreme Rt.) coordinating Award Ceremony



Dr. Johnson Stanley (2nd to Left) receiving AZRA Young Scientist Award-2020 from Prof. R.W. Alexander Jesudasan



Dr. Uma Maheswari (Middle) receiving Dr. (Mrs.) Jagadiswari Rao Women Scientist Award- 2020 from Prof. B. V. Patil



**Dr. N. Sushila (2nd to Left) receiving
Dr. (Mrs.) Jagadiswari Rao Women Scientist Award- 2020 from Dr. K. Revathi**



**Dr. N. B. V. Chalapathi Rao (2nd to Left) receiving
Dr Anand Prakash Award-2019 from Dr. Anand Prakash**



**Dr. M. K. Bag (Left) receiving
Dr Anand Prakash Award-2020 from Dr. S. S. Misra**



**Dr. H. G. Hanchinal (Left) receiving
Dr Anand Prakash Award-2020 from Dr. S. K. Shivastava**



Dr. G. Krishana Rao (Middle) & Dr. N. B. V. Chalpathi Rao receiving Edita David Memorial Award-2019-20 from Dr. B. V. David



Dr. P. V. Rami Reddy (3rd from Rt.) receiving Dr. B. Vasantharaj David Award-2019 from Dr. B. V. Patil



**Dr. D. S. Jayas (Middle) receiving Dr. S. S. Misra Award-2019
from Dr. S. S. Misra and Dr. B. V. David**



Dr. Rajasekhara R. Korada (Middle) receiving Dr. B. Vasantharaj David Award-2020 from Dr. B. V. David and Dr N. Sakthivel



**Dr. K. Revathi (Left) receiving Dr. S. S. Misra Award-2020
from Dr. S. S. Misra**



**Dr. A. G. Sreenivas (Left) receiving Dr. S. S. Misra Award-2020
from Dr. S. S. Misra**



**Dr. K. Sreedevi (Rt) receiving AZRA Fellowship Award-2019
from Dr. B. V. David & Dr. B. V. Patil**



**Dr. Sangeeta Singh (2nd from Left) receiving AZRA Fellowship Award-2019
from Dr. B. V. David & Dr. B. V. Patil**



**Dr. R. S. Meena (Middle) receiving AZRA Fellowship Award-2020
from Dr. B. V. David & Dr. B. V. Patil**



**Dr. S. S. Udikeri (Middle) receiving AZRA Fellowship Award-2020
from Dr. B. V. David & Dr. B. V. Patil**



**Dr. R.V.S. K. Reddy (2nd from Rt.) receiving AZRA Fellowship Award-2020
from Dr. B. V. David & Dr. B. V. Patil**



**Dr. C. S. K. Mishra (2nd from Rt.) receiving AZRA Fellowship Award-2020
from Dr. B. V. David & Dr. B. V. Patil**



**Dr. Premjit Singh (2nd from Rt.) receiving
AZRA Honorary Fellowship Award-2019 from Dr. B. V. David & Dr. B. V. Patil**



**Dr. Madhu Bala (Middle) receiving
AZRA Honorary Fellowship Award-2019 from Dr. B. V. David & Dr. S.N.Puri**



**Dr. L. K. Hazarika (2nd from Rt.) receiving AZRA Honorary Fellowship Award-2019
from Dr. B. V. David**



**Dr. Sushil Kumar (2nd from Rt.) receiving AZRA Honorary Fellowship Award-2019
from Dr. B. V. David**



**Dr. B. V. Patil (2nd from Rt.) receiving AZRA Honorary Fellowship Award-2020
from Dr. B. V. David**



**Dr. S. Lingappa (2nd from Rt.) receiving AZRA Honorary Fellowship Award-2020
from Dr. B. V. David**



**Dr. C. V. Virakthmat (2nd from Rt.) receiving AZRA Honorary Fellowship Award-2020
from Dr. B. V. David**



**Dr. K.A. Kulkarni (2nd from Rt.) receiving AZRA Honorary Fellowship Award-2020
from Dr. B. V. David & Dr. B. V. Patil**



Dr. R.K. Thakur (2nd from Rt.) receiving AZRA Honorary Fellowship Award-2020 from Dr. B. V. David & Dr. B. V. Patil



Prof. L. K. Rath (middle) from OUAT, Bhubaneswar receiving Prof. Damodar Satapathy award for her student Ms. Subhashree Dash from Prof. B. V. Patil

**Prof. P. Kameswara Rao Award (2019-2020)
being received for best oral paper presentation**



K. Thamilrasi (ICAR-IINRG, Ranchi): 1st Rank



**S. Leela Praveen (Dr. YSR Univ., VR Gudem-AP):
2nd rank**



**Chinna Babu Naik (ICAR-CICR, Nagpur):
2nd rank**



Dr. P. R. Badriprasad (UAS, Raichur): 3rd rank



E. Sowmaya (UAS, Raichur): 3rd rank

Prof. S. K. Shrivastava Award-2019 & 2020 being received for best poster presentation



S. Santosh Kumar (UAS-GKVK, Bengaluru)



S. Kiran (UAHS, Shimogga, Karnataka)



K. R. Mahendra (College of Agriculture, Hyderabad, Telangana)



Swapna Lisa Mohapatra (AAU, Jorhat, Assam)



Shramik Dey (BCKV, Mohanpur, Nadia, W.B.)



Basavanjali (UAS, Raichur)



Safeena Majeed (UAHS, Shimogga, Karnataka)



G.S. Guruprasad (UAS, Raichur)



M. H. Poornima (UHS, Bagalkot, Karnataka)



K. N. Manjula (UHS, Bagalkot, Karnataka)



Rajeswari Hiramath (UAS, Raichur)



K. Haripriya (TNAU, Coimbatore, T. N.)



S. S. Pyagyan (OUAT, Bhubaneswar, Odisha)



Kamala D. Gaddennavas (College of Horticulture, Begaluru)

Books published by AZRA

1. **Insect pests of cereals and their management**, Applied Entomology Vol. 1, 1999, ISBN 81-90 0947-O-X, PB, pp. 168, Rs. 200/- in India and US \$ 40 outside India, Editors: Anand Prakash and Jagadiswari Rao.
2. **Mites in rice ecosystems**, 1999, ISBN 81-90 0947-1-8, PB, pp. 106, Rs. 200/- in India and US \$ 40 outside India, Authors: Jagadiswari Rao, Anand Prakash and S.K. Ghosh.
3. **Insect pests of pulses and oilseeds and their management**, Applied Entomology Vol. 2, 2000, ISBN 81-90 0947-4-2 (Contributory Chapters), PB, pp. 261, Rs. 300/- in India and US \$ 50 outside India, Editors: Anand Prakash and Jagadiswari Rao.
4. **Rice White-tip nematode**, 2002, ISBN 81-90 0947-3-4, PB, pp. 93, Rs. 150/- in India and US \$ 30 outside India; Authors: Jagadiswari Rao and Anand Prakash.
5. **Insect pests of stored products: a global Scenario**, 2003, ISBN 81-90 0947-5-0 (Contributory Chapters) HB, pp. 283, Rs. 500/- in India and US \$ 70 outside India, Editors: Anand Prakash, Jagadiswari Rao, Joseph Allotey and D. S. Jayas.
6. **Phytophagous heteropterans in rice ecosystems**, 2004, ISBN 81-90 0947-2-6, HB, pp. 104, Rs. 200/- in India and US \$ 40 outside India, Authors: Anand Prakash and Jagadiswari Rao.
7. **Poisonous animal bites and their management from Vedic era to modern medical science**, 2005, ISBN 81-90 0947-7-7, HB, pp 107, Price: Rs. 200/ (India & USD\$ 50 outside India) Authors: S.K. Shrivastava, A. C. Shrivastava, N. Mishra, S. Kumar and Anand Prakash,
8. **Rice: the Queen of Cereals**, 2007, ISBN 81-90 0947-9-3, HB, pp 215, Price 250 (India) & US \$ 50 outside India), Authors: Anand Prakash, Jagadiswari Rao, O.N. Singh, J.P. Tyagi, Sanjay Singh & P.C. Rath.
9. **Insect pests of fruits, vegetables, spices & condiments and their management**: Applied Entomology Vol. 3, 2007, (ISBN 81-90 0947-6-9) (Contributory Chapters - Editors: Anand Prakash, Jagadiswari Rao and V. Nandagopal), pp. 308, Rs. 400/- in India and US \$ 50 outside India.
10. **Pheromones: Principles and Practices**, 2008, ISBN 81-90 0947-8-5, HB, pp 330, Price Rs.1000/-in India and US \$ 85/- outside India, Authors: V. Nandagopal, Anand Prakash, Jagadiswari Rao, J. S. Yadav & A. R. Prasad
11. **Rice Pest Management**, 2008, ISBN 81-90 0947-9-5, HB, pp 383, Price Rs.500/-in India and US \$ 40/- outside India, (Contributory Chapters -Editors: Anand Prakash, S. Sasmal, Jagadiswari Rao, S. N. Tewari, K.S. Behera, S.K. Singh and V. Nandagopal
12. **Zootherapy for mankind: from medieval age to modern era**, 2013, ISBN 81-90 0947-7-5 HB, pp 210, Price Rs.500/-in India and US \$ 40/- outside India, Authors: Drs. S.K. Shrivastava, A.C. Shrivastava, Anand Prakash and Jagadiswari Rao
13. **Climate change: impact on crop pests**, 2014, ISBN 81-90 0947-2-7, HB, pp 254, Price Rs 800/- in India and US\$ 50/- outside India, Authors: Anand Prakash, Jagadiswari Rao, Arup Mukherjee, J. Berliner, Somnath S. Pokhare, Totan Adak, Sushmita Munda and P.R. Shashank
14. **Plant Protection in India: Challenges & Research Priorities**, 2014, ISBN 81-90 0947-5-2 HB, pp 156, Price Rs 500/- in India and US\$ 40 outside India, Authors: Anand Prakash, O.M. Bambawale and B. Vasantharaj David
15. **Pests of Stored Grains and Their Management**, 2016, ISBN 81-90 0947-3-1, HB, pp 170, Price Rs 400/- in India and US\$ 40 outside India, Authors: Anand Prakash, Jagadiswari Rao, B.K. Sahoo, K.I. Singh and I.T Asangla Jamir

Contd.....

16. **Recent Advances in Life Sciences: Proc. XV AZRA Intern. Conf.**, 2016, ISBN 81-90 0947-3-7, HB, pp 251, Price Rs 700/- in India and US\$ 50/- outside India, Editors: Drs. Anand Prakash, Jagadiswari Rao and K. Revathi.
17. **Biology of Insect & Mite Pests of Field Rice in India**, 2016, ISBN 81-90 0947-4 -7, HB, pp 232, Price Rs. 700/- in India and US\$ 50 outside India, Authors: Anand Prakash, Jagadiswari Rao, S.K. Shrivastava, Kanchan Saikia, K.I. Singh and N.K. Singh.
18. **Entomophagy: Insects as food source**, 2017, ISBN 81-90 0947-5-3, HB, pp 188, Price Rs 750/- in India and US \$ 50 outside India, Authors: S.K. Shrivastava, Joseph Allotey, Anand Prakash and Jagadiswari Rao.
19. **Entomotherapy: Medicinal Insects**, 2017, ISBN 81-90 0947-5-4, HB, pp 240, Price Rs 800/- in India and US \$ 50 outside India, Authors: S.K. Shrivastava, Joseph Allotey, Anand Prakash, Jagadiswari Rao and D. Suresh Chand.
20. **Biodiversity: Gift of Nature**, 2017, ISBN 81-90 0947-8-9, HB, pp 352, Price Rs 1500/- in India and US \$ 70 outside India, Authors: B. Bharatha Lakshmi, Anand Prakash, Jagadiswari Rao and B.T. Rao.
21. **India Towards Second Green Revolution**, 2018, ISBN 81-90 0947-6-4, HB, pp 278, Price Rs 900/- in India and US \$ 40 outside India, Authors: Anand Prakash, Jagadiswari Rao, J. P. Tyagi and S. K. Shrivastava.
22. **Entomophily: Insect Pollinators**, 2018, ISBN 81-90 0947-2-5, HB, pp 496, Price Rs 1500/- in India and US \$ 60 outside India, Authors: Anand Prakash, S. K. Shrivastava, Jagadiswari Rao, Joseph Allotey, K.I. Singh, Kolla Sreedevi, P.V.R. Reddy and B. Bharatha Lakshmi.
23. **Biodiversity: Strategies, Conservation & Sustainable Utilization**, 2018, ISBN 81-90 0947-3-9, pp 185, HB, Price Rs.500/- in India and US\$ 30/- outside India, Editors: Drs. K. Revathi, V. Malathi, and Anand Prakash.
24. **Industrial Entomology: Productive Insects**, 2019, ISBN 81-90 0947- 4-8, pp 347, HB, Price Rs.1500/- in India and US\$ 50/- outside India, Editors: Drs. Anand Prakash, S. K. Shrivastava, Jagadiswari Rao and Mohd.Arif.
25. **Biopesticides in Indian Agriculture**, 2019, ISBN 81-90 0947- 1-1, pp 324, HB, Price Rs.1200/- in India and US\$ 40/- outside India, Editors: Drs. Anand Prakash, S. K. Shrivastava, Jagadiswari Rao, Rajasekhar Rao, Korada and V. K. Mishra.
26. **Insect Bioindicator**, 2020, ISBN 81-90 0947- 1-3, pp 441, HB, Price Rs 1500/- in India & US\$ 50/- outside India, Authors: S. K. Shrivastava, Anand Prakash and Jagadiswari Rao.
27. **Bio-GOD : Biological : Genes of Dominance**, 2020, ISBN 81-90 0947-1-4, pp160, HB, Price Rs. 750/- in India & US\$ 20/- outside India, Author: Anand Prakash

How to obtain AZRA publications?

AZRA publications can be obtained from General Secretary, AZRA on request by sending Demand Draft as cost of the publications, addressed to Applied Zoologists Research Association, payable at State Bank of India, Nayabazar, Cuttack (Bank code: 2094) on the changed address: Dr Anand Prakash, General Secretary (AZRA), K9-B, 285 Bhagabanpur, Patrapada, Bhubaneswar-751 019, Odisha or **online** payment; **email:prakas52@yahoo.com**

Important: *All AZRA members may deduct 30% from the total cost of the books as membership rebate and no postal and handling charges for the members if books order is above Rs. 8000/- . However, Non-AZRA members have to include postal & handling charges as Rs. 50-200/-depending upon the weight of the book packet in India and US \$ 10-50 outside India.*



Applied Zoologists Research Association, (AZRA),
K9-B/285 Bhagabanpur, Patrapada, Bhubaneswar-751019, Odisha, India
Email: prakas52@yahoo.com M-9337110294

AZRA-Editorial Board 2020-25

Editor-in-Chief:

Dr. Damodar Satapathy (Berhampur)

Managing Editor:

Dr. Anand Prakash (H.Q.)

Sectional Editor-Crop Protection

Prof. L. K. Rath (OUAT, Bhubaneswar)

Sectional Editor-Fisheries & other Beneficial

Animals: Dr. Lakshman Sahoo (CIFA, BBSR)

Sectional Editor-Toxicology, Environment &

Biomedical Sciences: Prof. C.S.K. Mishra

(OUAT, BBSR)

Editorial Advisory Board Members

Prof. Joseph Allotey (Botswana)

Prof. Jayalakshmi Ganguly (Raipur)

Prof. Manendra Kumar (Muzaffarpur)

Prof. R. N. Singh (Varanasi)

Prof. L. K. Hazarika (Jorhat)

Prof. Akhtar Haseeb (Aligarh)

Dr. S. N. Sushil (Lucknow)

Dr. P.V. Rami Reddy (Bengaluru)

Dr. B. S. Gotyal (Barrakpore, Kolkata)

Dr. Shyamasree Ghosh (Bhubaneswar)

Dr. Kolla Sreedevi (Bengaluru)

Dr. N. B. V. Chalapathi Rao (Ambajipeta)

Dr. P. Suresh (Madurai)

Dr. J. Berliner (Wellington)

Dr. U. Sreedhar (Rajahmundry)

Dr. P.B. Meshram (Jabalpur)

Dr. Sangeeta Singh (Roorkee)

Dr. P. Sundararaj (Coimbatore)

Dr. P. R. Badariprasad (Raihur)

Dr. P. R. Shashank (New Delhi)

Dr. V. Sridhar (Bengaluru)

Dr. N. Sakthivel (Salem)

Dr. K. Vanitha (Puttur)

Dr. S.V.S. Gopala Swamy (Bapatla)

Notes to Authors: The original research papers & reviews contributed by the zoologists of any nationality dealing with applied zoology including animals in agriculture, horticulture, forests, plantation crops, fisheries science and

other applied fields are considered for publication. Manuscript may be formatted in MS Word, font size 12, Times New Roman, not more than 15 pages written in double space, photos in JPG format. The byline should comprise of the author(s) name and complete address, email. It should be preceded by a brief ABSTRACT, followed by INTRODUCTION, MATERIALS AND METHODS, RESULTS, DISCUSSION, ACKNOWLEDGEMENT, & REFERENCES.

All data may be given in metric system.

References should be cited in the text by name(s) in Capital letters and year and arranged alphabetically at the end of MS. The name of the journal may be abbreviated according to the World List of Scientific Periodicals.

Following style is to be adopted:

PRAKASH, A., PASALU, I. C. and JAGADISWARI RAO, 1984. Insect infestation and their pest status in stored rice in Orissa. *Tropical Stored Prod. Inf. (U.K.)*, **47**: 15-20.

PRAKASH, A. 1983. Factors affecting losses due to insects and their management in rice storage ecosystem. *Proc. Symp. Insect Ecol. Resource Manage*, pp 50-54.

PRAKASH, A. and JAGADISWARI RAO, 1996. Botanical Pesticides in Agriculture, *CRC/Lewis Publ., Boca Raton, Fl. USA*, pp. 480.

ANONYMOUS, 1979. Studies on stored grain pests of rice and methods to minimize losses caused by them, *Annual Tech. Report, Central Rice Research Institute, Cuttack (India)*: 167-169.

Table(s) should be short, concise and have statistically analyzed.

Submission of paper implies transfer of copy right from author(s) to the Managing Editor.

Author(s) have to pay printing charges @ Rs. 300/page for AZRA member and Rs. 350/ page for non-members. No reprints will be provided. One hard copy of the journal will be sent to corresponding author.

Manuscript may be emailed to Dr Anand Prakash, Managing Editor, Journal of Applied Zoological Researches, K-9B/285, Bhagabanpur Patrapada, Bhubaneswar-751019, Odisha, India: email: prakas52@yahoo.com

CONTENTS

Rahul Kumar, Shashank, P.R., Naresh, M. Meshram, Anooj, S.S. and Kolla Sreedevi, Evolution of modern insect classification: A comprehensive account.	1-15
Shyamasree Ghosh and Rishav Dasgupta, Nanoinformatics: an emerging bio-science.	16-23
Jayas, D. S., Research needs for stored product entomology.	24-31
Mandal, S. K., Mandal, R. K. and Barun, Field evaluation of eco-friendly IPM strategies against <i>Leucinodes orbonalis</i> Guenne in brinjal ecosystem.	32-35
Pathipati, V. L., T. Vijaya Lakshmi, Rajani, C. V. Ramana and L. Naram Naidu, Impact of weather parameters on incidence of chilli mite, <i>Polyphagotarsonemus latus</i> Banks in Andhra Pradesh.	36-43
Sharma, V. G. and Sushil Kumar, Bio-efficacy of different pesticides against mite, <i>Tetranychus urticae</i> on tomato (<i>Lycopersicon esculentum</i> Mill).	44-48
Patel, A. T. and Sushil Kumar, Seasonal incidence of mango leaf gall midge, <i>Procontarinia matteiana</i> Kieffer & Cecconi (Diptera: Cecidomyiidae).	49-53
Saugata Sasmal, Ankit Thakur, R. L. Sharma and Goutam Roy, Effect of growth and production of Indian major carps in fresh water Biofloc Aquaculture System.	54-57
Jatin, K., Shrivastava, V. K. and Dheerendra Mahor, Performance of sorghum genotypes against ear head bug and ear head worm.	58-61
Sushmitha, S., A. Sujatha, and N. Emmanuel, Impact of Biochemical Constituents of host plants on the Rugose spiraling whitefly, <i>Aleurodicus rugioperculatus</i> Martin infestation levels in Andhra Pradesh.	62-70
Damodar Reddy, P., A. Sujatha, C. P. Viji and K. Uma Jyothi, Seasonal occurrence of different insect pests of potato crop in Andhra Pradesh.	71-80
Mandal, Chandrakanta, K., Himani Tariyal, P. Naiwal, D. Thakur and Shyamasree Ghosh, <i>Haemadipsa lolegaonsis</i> sp. nov. (Hirudinea: Haemadipsidae): A new leech from West Bengal, India.	81-85
Mandal, Chandrakanta, K., Himani Tariyal, P. Naiwal, D. Thakur and Shyamasree Ghosh, <i>Haemadipsa satyanarayanai</i> sp. nov. (Hirudinea: Haemadipsidae): A new leech from Nagaland, India.	86-90
AZRA-2020: Proceedings & Recommendations of XVII AZRA International Conference on “Frontier Research in Applied Zoology and Insect Pest Management Strategies: A way Forward for Food and Nutritional Security” Photos.	91-124
Books published by AZRA.	125-126
Edited by Dr. Anand Prakash (Managing Editor) & Prof. D. Satapathy (Editor-in Chief) and published by Dr Anand Prakash (General Secretary) on behalf of Applied Zoologists Research Association (AZRA), K-9B/285, Bhagabanpur Patrapada, Bhubaneswar-751019 & Printed at Quality Printers & Stationers, Purani Basti, Raipur (C.G.) email: mks.qualityprinters@gmail.com; Mob. : 94255-61631	