# MANAGEMENT OF GIANT AFRICAN SNAIL, *Achatina fulica* Ferussac AND BROWN SLUG, *Laevicaulis alte* Ferussac IN FOREST AND HORTICULTURE NURSERIES

**PINKU PAUL**

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY**
**COLLEGE OF AGRICULTURE, DHARWAD**
**UNIVERSITY OF AGRICULTURAL SCIENCES,**
**DHARWAD - 580 005**

**JUNE, 2016**

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*in partial fulfillment of the requirements for the*
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**IN**

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***BY***

**PINKU PAUL**

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY**
**COLLEGE OF AGRICULTURE, DHARWAD**
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# CERTIFICATE

This is to certify that the thesis entitled "MANAGEMENT OF GIANT AFRICAN SNAIL, *Achatina fulica* Ferussac AND BROWN SLUG, *Laevicaulis alte* Ferussac IN FOREST AND HORTICULTURE NURSERIES" submitted by Mr. PINKU PAUL, for the degree of MASTER OF SCIENCE (Agriculture) in AGRICULTURAL ENTOMOLOGY to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associate ship, fellowship or other similar titles.

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**Members:** **1.** ______________________

**(R. A. BALIKAI)**

**2.** ______________________

**(M. S. BIRADAR)**

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# 1. INTRODUCTION

Mollusca is the second largest phylum of the animal kingdom, forming a major part of the world fauna (Serb and Lydeard, 2003). The Gastropoda is the only class of molluscs which have successfully invaded land. Mollusca is probably the third most important animal group after the arthropods and vertebrates (South, 1992). Snails and slugs belong to the class Gastropoda. Slugs are often described as snails without a shell, while snail bodies are enclosed in calcareous shells (Barker, 2001; Ramzy, 2009). These are one of the most diverse groups of animals, both in shape and habit. Many species of land snails and slugs are among the important pests for agriculture, horticulture and garden crops in different parts of the world. Invasive species are recognized globally as a major threat to biodiversity and ecosystem health. Globally, nearly 35,000 species of land snails have been described and there may be 30,000 to 60,000 additional species yet to be described (Lydeard *et al.,* 2004). Within modern India's boundaries 1129 species belonging to 140 genera and 26 families of land snails have been recorded (Ramakrishna *et al.,* 2010).

Research has to be focused on the methods of population control of the pestiferous malacofauna, owing to their pest and vector status. *Achatina fulica* Bowdich Ferussac belongs to phylum: Mollusca, Class: Gastropoda, Order: Stylommataphora and family: Achatinidae. The snail is popularly called as giant African snail (GAS) because of its big size and nativity. It is known for its destructive nature on cultivated plants wherever it occurs and is one of the world's largest and most damaging land snail pests. It has spread to most of the Indo-Pacific areas including India, Sri Lanka, Taiwan, Japan, Philippines, Malaysia, China, Hawaii, Samoa, Tahiti, New Guinea and Indonesia (Anon., 2000). In India, it was believed to have been introduced in Chouringhie gardens of Calcutta in 1847 by the British Conchologist William Henry Benson and from there on spread to many states of the country in course of time (Mead, 1961). It is a nocturnal and bisexual land snail, reached most of the continents mainly through horticultural trade (Srivastava, 1973). Now, it has assumed a pest status in all the ornamental nurseries in all the states of India. In addition, mucus and the excreta falling on the economic plant parts will reduce the market ability. Heavy damage was observed in planted young cuttings by feeding on the sprouted buds and affected the standing vine. *A. fulica* though prefer and thrive in more humid and warm conditions, could highly adapt to dry and cooler climates and hibernate 10 to 15 cm deep in soft soil during less favourable conditions for up to one year and feed over 500 different plant species, including breadfruit, cocoa, papaya, peanut, rubber and most types of beans, peas, cucumbers and melons.

In India, minimal number of studies has been carried out in last few decades on the pest and invasive land snails. In Karnataka, it was reported for the first time causing damage to ornamental plants and vegetables in Bengaluru (Veeresh *et al.,* 1979). Javaregouda (2006) recorded the snail infestation on betelvine in Davanagere and Haveri districts of Karnataka. Further, Jayashankar *et al.* (2010) and Sridhar *et al.* (2012) reported that snails and slugs as the pests on ornamental and agri-horticultural crops in Bengaluru and Kolar, South India. It is known to infest many crops like cereals, commercial crops, vegetables, fruits and ornamentals. The damage is seen in most of the districts of Karnataka on field and horticultural crops. Many times resowing of groundnut and soybean was taken up due to severe attack by this pest in early crop stage.

Slugs are categorized as pests in terms of their damage to crops and as secondary hosts of vertebrate parasites. Brown slug, *Filicaulis alte* Ferussac occurs in many parts of the world and it attains pest status in cool and moist climate. In India, 14 species of slugs have been reported to be pests of ornamental plants, vegetables and other crops causing damage by their rasping and feeding (Kaur and Kaur, 2008).

Slugs are the major pests in agriculture, horticulture and floriculture, causing considerable damage to wheat, alfalfa, corn, soybean and tobacco (Donnell *et al.,* 2008). Slugs injure plants by chewing holes in various sizes in the leaves and stems. These holes may be in the middle of the leaf or on the edge. The early seedling stages are most susceptible to slugs, once the seedling passes 6-leaf stage, the damage is generally superficial. Slugs can sometimes consume the entire seedling. However, the slug damage may reduce the vigour of some plants by destroying the growing points of stems or branches or reducing the leaf area (Jagtap, 2000) and in some cases of slug damage to tomato, complete fruit pericarp was eaten away within an overnight period leaving behind the inner core. More was the organic matter, phosphorous and potassium in soil, the more was the slug, *F. alte* density and the more was the damage inflicted to ornamental plants (Chhabra, 2008).

Besides reduction in yield, presence of mucus trails, faeces or presence of slugs on the produce devalues the produce. Slug damage may also lead to mould growth or rotting. Kaur (2002) reported that seedlings of vegetable crops are often attacked by slug in Punjab. Slugs make holes in radish, spinach, cabbage and cauliflower leaves and also attack stem bark of brinjal, tomato and sponge gourd. The damage is often severe necessitating replanting. The brown slug, *Mariella dussumieri* Gray, 1855 (Gastropoda: Ariophantidae) is reported feeding voraciously on the succulent buds and leaves of vanilla plants in the Western Ghats (Mavinkurve *et al.,* 2004) and pestiferous on areca palms at Kasargod, Kerala (Anon., 2007), *Hibiscus rosa-sinensis* Linn., *Anthurium andraeanum* Linn., *Piper nigrum* L., *Theobroma cacao* Linn. and *Musa* sp. in Dakshina Kannada, Karnataka (Daniel and Vanavasan, 2009).

Recently the damage inflicted by both slugs and snails on forest nursery and in protected cultivation is enormous. Mallappa (2014) registered up to 100 per cent damage to forest nurseries grown in Khanapur taluk of Belagavi district by *A. fulica.* Likewise, the severe damage by slugs to capsicum seedings grown under protected cultivation was noticed at Hi-tech Horticulture Unit of UAS, Dharwad.

Scanning of literature pertaining to this aspect revealed that, studies related to the management of snails/slugs in forest/horticulture nurseries and in protected cultivation are lacking. In this background, the present investigations are planned with the following objectives.

1. Survey for snails and slugs infesting forest and horticulture nurseries.
2. To assess the damage potential caused by giant African snail, *A. fulica* in various forest and horticultural nurseries.
3. To assess the damage potential of slugs in various forest and horticultural nurseries.

4. Management of snail, *A. fulica*

    a. In forest/ horticulture nursery.

    b. In protected cultivation on capsicum.

5. Management of slugs

    a. In forest/ horticulture nursery.

b. In protected cultivation on capsicum.

# 2. REVIEW OF LITERATURE

The literature pertaining to the survey of snails and slugs, damage potential caused by giant African snail (GAS), *Achatina fulica* Ferussac and slugs in various forest and horticultural nurseries, management of giant African snail and slugs by using different chemicals/ poison baits in protected cultivation on capsicum and forest/ horticulture nursery is presented in this chapter.

## 2.1 Survey for snails and slugs infesting forest/horticulture nurseries and in protected cultivation

### 2.1.1 Giant African snail, *Achatina fulica*

*Achatina fulica* was reported for the first time causing damage to ornamental plants and vegetables in Bengaluru, Karnataka during *Kharif*, 1979 and these snails were more active during rainy season from June to October and from November onwards they were found buried in the soil without feeding for several days and known to bred on the onset of monsoon once in a year (Veeresh *et al.,* 1979).

Subramanya (1982) narrated seven species of snails distributed in different parts of Bengaluru *viz.*, *Indoplanobia exustus* (Deshayes), *Lymnea luteola f. succinea* (Deshayes), *Ariophanta bistrialis* (Beck), *Ariophanta belangeri* (Deshayes), *Rachia punctatus* (Anton), *Glessula dikrangense* (Godwin-Austen) and *Opeas gracile* (Hutton). and are found that *O. gracile* (Hutton), *A. belangeri* and *L. luteola F. succinea* were pests.

Raut and Ghose (1984) studied the distribution of *A. fulica* in West Bengal and noted its spread from Kolkata (Balurghat- 8.12/$m^2$) to Coochbehar (32.68/$m^2$). In the North-eastern region of India snail infested pockets were studied in nine locations namely Silonijan, East Sarani, Golaghat, Jhalukbari, Lachitnagar, Panbazar, Tezpur, Ulubari and Jorhat in Assam. The population ranged from 8/$m^2$ at Silonijan to 26/$m^2$ at Jorhat. In Nagaland, snail infested pockets located at two places *i.e.*, Chumukedima (4.12/$m^2$) and Dimapur (24/$m^2$). In Meghalaya at Nongpoh, Tripura at Kumarghat, Manipur at Imphal had the average populations of 11, 17.22 and 13/$m^2$, respectively. In Bihar, GAS was noticed in large number of places which were spread over 32 places from Telecocolony (6 /$m^2$) to Chaibasa (38 /$m^2$). GAS was also reported from Kerala, Tamil Nadu and Karnataka states. In Uttar Pradesh at Bijnor, Dhampur and Moradabad, the average population recorded were 19.22, 27.32 and 34.40/$m^2$, respectively. The snail was in Malappuram, Palghat and Calicut in Kerala, the average population being 15, 24 and 34/$m^2$, respectively. It has been recorded from Chennai, Annamalai Nagar, Pollachi and Tambaram, the average population recorded was 15.12, 22.11, 22.44 and 34/$m^2$, respectively. With regards to Karnataka, there is record of snail infested pocket from Bengaluru only, the average population being 9/$m^2$. The snails were generally active during the rainy season from dusk to dawn.

The seasonal variation of population at Port Blair indicated that snail population recorded in a 25 $m^2$ plots was maximum during August (153.50/week) and September (121.25/week) while minimum during January (14.00/week), February (3.00/week) and March (1.00/week) and nil during April months (Gupta and Doharey, 1985).

It is reported from Odisha in Anandapur, Baliapal, Balasore and Baripada, the average population of snails was 22.32, 25, 27 and 32/$m^2$, respectively (Srivastava, 1992). Thakur (1998) from Bihar reported that infestation of *A. fulica* commenced with the onset of monsoon rains and remained active throughout rainy season and started declining gradually from middle of November. Thakur and Kumari (1998) in Bihar, were assessing the snail population in an area of 9m x 6m observed maximum population during August and September (28.15 and 28.00 snails/week) and minimum during February (2.25 snails/week) and practically nil in January.

During the survey in Villupuram district of Tamil Nadu, the banana plants were found damaged by snail, *A. fulica* by 2 to 8 snails per plant clinging to the leaves, pseudostem, bunch and base of the plant. On the leaf, silvery line as well as excretary material was found indicating the snail's movement. Two to six leaves were found damaged by snails/plant with 24 per cent leaf damage (Padmanaban *et al.,* 2000).

Tehsin and Sharma (2000) while conducting conchological survey of fresh water bodies and other damp localities in around the Udaipur city in Rajasthan got few specimens of giant African snail, *A. fulica* feeding on fallen fruits of *Coccinia cordifolia* Cogn. during July 1996.

Ramakrishna *et al.* (2005) collected freshwater and terrestrial mollusc species from the Itanagar Wildlife Sanctuary, Arunachal Pradesh, India, during 1986-96. There were 18 species under 16 genera and 12 families, including *Indoplanorbis exustus* Deshayes, a known intermediate host for a large number of cattle-infesting parasites and three species recorded for the first time from the state (*A. fulica, Macrochlamys atriculor* Godwin-Austen and *Cryptaustenia silcharensis* Godwin-Austen.

Reddy and Sreedharan (2006) reported high incidence of GAS from coffee growing areas of Arakuvalley zone in visakha agency areas of Andhra Pradesh during rainy season, 2003. In majority of the cases 1 to 2 snails /coffee plant were observed. The population of 2 to 4 numbers/ $m^2$ was noticed on the ground, surrounding paths and open places of coffee arms. The severe damage was noticed on crops like banana, beans, cabbage, cucumber, cauliflower, tomato and chillies. The damage was more pronounced in young seedlings in the field and nursery of these crops in Arakuvalley zone.

Shree *et al.* (2006) reported the occurrence of the giant African snail in different parts of Karnataka on Mulberry. Ravikumara *et al.* (2007) recorded the population of GAS throughout the year ranging from 1.00 to 91.25 snails/10 $m^2$ in arecanut at Shimoga. The highest population (91.25 snails/10 $m^2$) was observed during second fortnight of September, 2004 while the lowest population (1.00 snail/10 $m^2$) during first fortnight of February, 2005.

Albuquerque *et al.* (2008) stated that though *A. fulica* was most active at dusk and dawn but on some cloudy and rainy days it was possible to observe them all day long.The abundance and distribution of *A. fulica* was most representative in urban area, mainly near the coastline. Lots (8/$m^2$) and house gardens (5/$m^2$) were the most preferred sites during active hours. The snail activity started at the end of the evening stopped in mid-morning. In general, *A. fulica* activity in Lauro de Freitas, Brazil starts around 06:00 pm and the mean time for ceasing activities is 08:00 am.

Prem and Naggs (2008) reported that *A. fulica* first entered the southern part of Nepal in the east. It then spread to western limits of the Western development region of the Terai and extended north across the Siwalik hills to Makwanpur, Chitwan and Tanahun. It has crossed the mid hill range and ascended the lower slopes of the Mahabharat Range at Baglung, Parbat, Arghakhanchi, Gulmi, Dhading Kaski and Syangjha. However, the higher elevations are undoubtedly too cold in winter for it to survive and *A. fulica* has not crossed into the Kathmandu valley.

Basavaraju *et al.* (2010) reported the highest population of 620 snails/100 sq.feet in coconut garden followed by 431 on elephant foot yam, 102 on ginger, 89 on mulberry, 104 on cowpea, 82 on field bean at Tamalapur village of Hassan taluk. In Belur taluk 136 snails/100 sq.feet were recorded in banana garden. In Channarayapattan taluk, Nagaranavile village snails were found feeding on cowpea, field bean, maize and other cultivated plants.

Vanitha *et al.* (2011) reported different species of snails in vanilla ecosystem in Tamil Nadu *viz.*, *A. fulica*which appeared in the month of September and January, *Macrochlamys* sp. occurred during October, *Cryptozona* sp. and *Euplecta* sp. occurred during August and the snail, *Kaliella barrakporensis* Grey observed during September.

Occurrence of *A. fulica* was noticed on mulberry from Gangapur, Aurangabad district, Maharashtra throughout year and active during rainy season. Type of damage inflicted by snail was extensive chewing of blossoms, leaves and reduced the growth of young trees. Land snail feeding is not a problem in mature groves as the large trees could tolerate any modest damage (Sunil and Chandrashekar, 2013)

Rafee *et al.* (2013a) recorded number of snails/25 m$^2$ in the month of July on crops like sapota (122.25), mango (144.43), guava (113.01), mulberry (101.42), maize (23.02) chilli (25.53), brinjal (24.52) and groundnut (23.30). Further, during September higher population was registered in all the crops viz., sapota (204.28), mango (140.07), guava (145.70), mulberry (136.93), maize (44.83) chilli (42.40), brinjal (34.98) and groundnut (36.92) wherein high rainfall was received during this month. Further, due to cessation of rainfall in the month of January the snail population was declined and ranged from 24.00 to 33.83 snails/25 m$^2$ area in perennial horticulture crops under survey. The higher number of snails recorded in the month of September during both years because of high rainfall and lower temperature which helped in multiplication of snails.

Mallappa and Patil (2014) reported that population of giant African snail, *A. fulica* in betelvine garden in Belagutti village of Davanagere district occurred throughout the year ranging from 3.41 to 114.71 snails per 5 m$^2$ during 2011-12. The highest population of 114.71 snails per 5 m$^2$ was observed during second fortnight of October, 2011. The lowest population of 3.41 snails per 5 m$^2$ was recorded during second fortnight of March, 2012. During 2012-13 also population of snails was recorded throughout the year and ranged from 3.26 to 93.22snails per 5 m$^2$. The maximum population (93.22 snails/5 m$^2$) was observed during second fortnight of August, 2012. The lowest population (3.26 snails/5 m$^2$) was documented during first fortnight of March, 2013.

## 2.1.2 Survey and incidence of other terrestrial snails

Two important land snail pests, *Opeas gracile* (Hutton) and *Zootecus insularis* (Ehrenberg) falling under the family Subulinidae. *O. gracile* is a tiny international land snail pest distributed all over the world except Australia in the tropical and sub-tropical regions infesting of green house and other potted plants and got distributed in Delhi, Uttar Pradesh, Bihar, Gujarat, Maharashtra, Kashmir, Tiruchirapalli (Gude, 1914).

*Burtoa* genus of snail comprises a single species (*Burtoa nilotica* (Pfeiffer)) widely distributed from the Sudan, south of $10^{o}$N, throughout the region of the Great Lakes to the Amanze Inyama river in the south and into the upper Congo, upper Kasi and Lake Chad regions in the west (Crowley and Pain, 1959).

Bishara *et al.* (1968) found *Euparypha pisana* (Muller), *Theba* sp., *Eobania vermiculata* (Muller), *Rumina decollata* (L.), *Helicella* spp. and *Cochlicella acuta* Mull.common snail species in field and orchards of the northern Delta Nile in Egypt.

The family Ariophantidae has four important genera namely, *Ariophanta, Cryptozona, Macrochlamys* and *Bensonia.* Some species of these are pests. *Ariophanta* has three important species, *Ariophanta bajadera* (Pfeiffer), *Ariophanta solata* Benson and *Ariophanta ligulata* Ferrusc. However, *A. bajadera* is distributed in Gujarat and Maharashtra. It has been observed to cause damage on okra, money plant, shoe flower (China rose), groundnut, seedlings of jack fruit and teak. The seriously affected crop in Konkan region of Maharashtra is groundnut (Srivastava, 1992).

*Ariophanta ligulata* Ferrusc is distributed in the eastern parts of the peninsular region, parts of Karnataka, Tamil Nadu, Odisha and Bihar. It is a pest of vegetables and ornamentals. Three species of genus *Cryptozona i.e*., (i) *C. bistrialis* (Beck) (ii) *C. semirugata* (Beck) and III. *C. belangiri* (Beck) are fairly common pests of horticultural crops mainly in the peninsular region of the country. *C. bistrialis* is distributed in certain parts of Andhra Pradesh, Tamil Nadu, Karnataka, Kerala and Maharashtra. It feeds upon the tender parts of rubber plants mainly in the nursery. *C. semirugata* is common in certain parts of Gujarat, Tamil Nadu and West Bengal. It has been observed feeding on the leaves of Oleander (*Thevetia* spp.) and on an evergreen shrub *Adhatoda vasica* L. of medicinal importance (Subba Rao, 1975).

Adimani (1976) reported that young seedlings of soybean damaged by the snail *C.semirugata* at Bengaluru.

Subba Rao and Mitra (1979) have recorded snail, *Zootecus insularis* (Ehrenberg) from Andhra Pradesh, Maharashtra, Gujarat, Rajasthan, Punjab, Kashmir, Madhya Pradesh, Uttar Pradesh and Bihar. It is a pest of okra, *Abelmoschus esculentus* (L.) Moench. and mint (*Mentha arvensis* L.) in Delhi.

Govindan *et al.* (1980) reported the occurrence of the snail, *Cochliopa* spp. (Pectini-Branchita: Amnicolidae) on mulberry during July- November 1979, Dharwad. They mentioned that snails are more active during the monsoon season. Both tender and mature leaves were damaged during night and early morning hours and the damaged leaves showed more or less irregularly cut holes and black excreta on leaves. An individual snail on an average fed 3.49 sq.cm tender leaves while it fed 4.36 sq.cm of coarse mulberry leaf in a day indicating its preference to coarse mulberry leaves.

Puttaswamy *et al.* (1981) conducted survey at Regional Research Station, Dharwad from June to September 1980 for the snail, *C. semirugata* which was feeding on leaves of castor, brinjal, cotton, greengram, cowpea, spinach, amaranthus, marigold, sarpagandha, horse purslane (*Boerhavia diffusa* L.) and flowers of groundnut.

*Ariophanta solata* Benson appears to be restricted only to the southern region, especially parts of Tamil Nadu, Andhra Pradesh, Kerala and Karnataka This snail causes damage to coffee (*Coffea arabica* L.) and coral tree (*Erythrina variegate* L.). The snails feed upon the green parts of the tender stems, leaves and also green berries. The tender stems fed upon by the snail break when exposed to strong winds (Raut and Ghose, 1984). Small chilli seedlings were severly damaged by snail, *C. semirugata* at Dharwad (Reddy and Puttaswamy, 1984).

About 84 species of this genus *Macrochlamys* sp.are distributed in the coastal, hilly regions and plains of the country. *M. indica* is the common garden snail reported from certain parts of Assam, Bihar, Orissa, West Bengal, Kerala and Tamil Nadu, Delhi, Pusa (Bihar) and Port Blair. It is a pest of cucurbitaceous plants e.g., *Luffa* spp. beans, lettuce, cole crops, drum stick (*M. oleifera* Lam.), amaranth (*A. blitum* L.), okra (*A. esculentus* L.), marigold (*Tagetes* spp.) *Chrysanthemum* sp. and money plant (*Scindapsus aureus* Linden and Andre) (Raut and Ghose, 1984). However, snail, *Macrochlamys pedina* (Benson) was recorded on mulberry by Kotikal and Devaiah (1987).

There is only one species of genus, *Bensonia i.e.*, *Bensonia monticola* Hutton a land snail of mountain regions. Bhalla and Pawar (1977) have reported this snail to be a pest of papaya (*Carica papaya* L.) and *Citrus* spp. It has been reported to practically defoliate bean plants. It also feeds on *Ipomea* and okra (Bhardwaj and Thakur, 1973). It is distributed in Sikkim, Himachal Pradesh, Jammu and Kashmir, Kumaon, Garhwal and Mussoorie of Uttar Pradesh (Raut and Ghose, 1984).

Baker (1988) reported that, *Cernuella virgata* (Da Costa) was most abundant in the pasture during spring and roadside vegetation in summer. The snails were aggregated within the pasture at all times of the year but especially during summer when large proportions of the population (>50 %) aestivated on the weeds. *C. virgata* and snail, *Theba pisana* (Muller) were rarely found together in large numbers in small areas (25 $m^2$) within the pasture although both had similar general distribution.

Baker (1989) accounted that, land snails *T. pisana*, *C. virgata* Da Costa, *Cochlicella acuta* da Costa and *C. barbara* Linn. were introduced as agricultural pestsin Southern Australia. They climbed on the heads, stalks and leaves of cereal crops to aestivate, the snails also fed upon crops and pastures.

Jagtap *et al.* (1989) reported that, *C. belangiri* (Deshayes) is distributed in the southern region and Kolhapur (Maharastra) on groundnut, beans greengram, blackgram, chilli, sunflower, grape, betel pepper and turmeric in the moist areas of submontane zone of Maharashtra during the rainy season.

Baker *et al.* (1991) found the land snail, *Cochlicella acuta* was more common in pastures than in crops, especially in spring and summer. In autumn, the snail numbers decreased markedly when the old pastures were burnt in preparation for the next crop. The death of large numbers of snails was directly observed at the time of burning.

Mead and Palcy (1992) reported that *Limicolaria aurora* (Jay) occurred in considerable numbers in the infested area of Martinique, causing damage to yam (*Dioscorea alata* Linnaeus), kidney bean (*Phaseolus vulgaris* Linnaues), black pepper (*Piper nigrum* Linnaeus), Jerusalem artichoke (*Helianthus tuberosus* Linnaeus), cucumber (*Cucumis sativus* Linnaeus), okra (*Abelmoschus esculentus* (Linnaeus) Moench), rose-mallow (*Hibiscus* spp.) and sweet potato (*Ipomoea batatas* (Linnaeus) de Lamarck) within eight months of being first recorded there.

Chang and Emelen (1993) reported that food and shelter were shown to be important in determining the distribution of the snail, *Cepaea nemoralis* (Linnaeus) over habitats in New York in 1983-1985. Food was primarily responsible for snail distribution in early summer. As the weather became hot and dry, the importance of shelter became more evident

Narayanaswamy and Geethabai (1997) recorded the land snail, *Indoplanorbis exustus* (Deshayes) (Basometaphora: Planorbidae) was found feeding on mulberry leaves in Sunnakallupalya village of Tumkur district during November to December, 1994.

The incidence of *C. semirugata* from Bijapur, Karnataka, India, was recorded during September and October in 1998. The nature of damage caused by *C. semirugata* was diverse. Per cent plant damage varied from 4.3 per cent in *Clerodendron inerme* L. to 95.3 per cent in *Beta vulgaris* L.var. *bengalensis*. Percentage leaf area consumption was greatest in *B. vulgaris var. bengalensis* (90.3 %) and *Solanum melongena* L. (85.2 %). The highest number of snails per plant was recorded on *Luffa acutangula* (8.9) and *S. melongena* (7.8). *Cryptozona semirugata* displayed a host preference for *B. vulgaris var. bengalensis, S. melongena, Trigonella foenum-graecum* L.*, L. acutangula,* tomatoes, chillies and *Tagetes erecta*, in comparison with *Clerodendron inerme* and *Hibiscus rosa-sinensis* (Balikai, 1999).

Shilpa (2013) reported that the comparative data on incidence of *C. semirugata* on bund varied from 6.90 to 8.35 snails/5 $m^2$ followed by field near the bund and inside the field in different crops varied from 1.67 to 3.34 and 0.88 to 2.04 /25 $m^2$, respectively However, the incidence of *C. semirugata* in groundnut revealed that the pest appeared during 23$^{rd}$ standard week (7.60/ 5 $m^2$ on bund, 1.40/ 25 $m^2$ and 0.60 snails/25 $m^2$) and peak population during 29$^{th}$ standard week (11.40/5 $m^2$, 4.60/ 25 $m^2$ and 3.60/ 25 $m^2$). The maximum damage was recorded during 23$^{rd}$ standard week (early stage of the crop) with 14.51 and 6.90 per cent in field near bund and inside the field and it became nil during 33$^{rd}$ to 36$^{th}$ standard week (maturity stage of the crop).

### 2.1.3 Survey and incidence of slugs

The brown slug, *Mariella dussumieri* Gray, 1855 (Gastropoda: Ariophantidae) is reported to be pestiferous on coffee in South India (Bhat and Shamanna, 1973), young rubber plants, green and wing beans in Sri Lanka (Naggs *et al.,* 2003), areca palms at Kasargod, Kerala (Anon; 2007).

Jayashankar *et al.* (2012) reported six species of slugs in Bengaluru. Among these, three each of snail and slug species were identified, *A. fulica*, *Ariophanta solata* (Benson), *Macrochlamys indica* Godwin-Austen and three species of slugs *Laeviculis alte* (Ferrussac),*Mariaella dussumierei* (Gray) and *Deroceros leave* (Muller). The slug, *Deroceros leave* (Muller) is recorded for the first from Southern India. Species *A. fulica, L. alte* and *D. leave* are introduced alien species.

Kaur and Mehta (2013) observed brown slug with black spots (*Filicaulis alte* Ferussac) was found to inhabit vegetable crop fields in Kaddon village of Ludhiana District of Punjab.

The brown slug, *F. alte* were found damaging vegetable crops in Punjab. Two villages *viz*; Bhadalwad and Sanghera of district Barnala and one village *i.e.* Dasaunda Singh Wala of district Sangrur were surveyed. Maximum leaf damage was observed in cabbage in all the three villages during the month of November (Kaur and Kaur, 2014).

Naik *et al.* (2014) reported the incidence of brown slug, *Mariella dussumieri* Gray was observed in Puttaswamayyana Palya, Tumkur district of Karnataka during *rabi,* 2013.

## 2.2 Damage potential of giant African snail, *Achatina fulica* in various forest and horticultural nurseries

The seedling or nursery stage is most preferred and most vulnerable. In more mature plants, the nature of the damage varies with the plant species, sometimes involving defoliation and in others involving damage to stem, flower or fruits (Chemberlin, 1952).

Schotman (1989) reported that the economic crops generally suffering little damage from *A. fulica* include coconut (*Cocos nucifera* L.), pineapple (*Ananas comosus* (L.) Merrill), screw pine (*Pandanus tectorius* Parkinson Zuccarini) sugarcane (*Saccharum officinarum* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.).

It has been recorded on a large number of plants including most of the ornamentals, vegetables and leguminous cover crops. The bark of relatively large trees such as citrus, papaya, rubber and cocoa is subject to attack. Poaceous crops (sugarcane, maize, rice) suffer little or no damage. There are reports of feeding on hundreds of species of plants. The growers of water melon (*Cetrullus lanatus* Thunberg) and papaya in Mariana Islands and India were unable to grow these crops. Thus production of some crops has proved unsustainable in certain infested areas. *A. fulica* rarely attack *Cannabis indica* L. but often use this species for daytime shelter (Raut and Ghose, 1984). In contrast, *C. indica* was completely defoliated within a few days when the preferred host plants were no longer available (Manna and Raut, 1986).

Giant African snail is a serious pest on many fruits and vegetables *viz*., banana, beans, brinjal, cabbage, cauliflower, chilli, coconut, coffee, all cucurbits, garlic, knolkhol, okra, lettuce, onion, papaya, tomato and other crops like maize, paddy, sorghum and sugarcane. However, small seedlings were completely eaten by the snail (Sharma and Agarwal, 1989).

Sunita (2007) reported 20 per cent damage of chilli seedlings by giant African snail at Dharwad district in Karnataka.

Balikai (2008) reported that the per cent plant damage of various horticultural crops by snails (*C. semirugata*) varied from minimum of 4.3 in Clerodendron to a maximum of 95.3 in Palak. Maximum number of plants was damaged in Palak (95.3 %), Brinjal (90.2 %), Methi (90.1 %), Ridge gourd (82.3 %) and Chillies (80.2 %). During the years of high rainfall when continuous drizzling and cloudy weather prevails, the management of this pest becomes very much essential.

Giant African snail is a serious pest of vegetables and considered to be a major problem in kitchen home gardens. Many farmers complained that they could not grow vegetables by transplanting them into the fields because they are immediately eaten by *A. fulica.* They completely wiped out vegetable crops such as cauliflower, potato, cabbage, pumpkin, cucumber, bottle gourd, white gourd, spinach, radish and tomato. Pulses and cereals such as hyacinth bean, cowpea, black gram, maize and millet and fruits *viz.,* banana, guava, papaya and jack fruit are all considered to be vulnerable (Prem and Naggs, 2008).

Basavaraju *et al.* (2010) reported 8-15 per cent infestation of *A. fulica* on biofuel nursery plants, vegetables crops, garden plants and areca garden.

The seeding damage by GAS in the forest nursery and worked out the damage percentage of the seedlings in the nursery bed of 15 m×1 m.The results are as follows. In teak (*T. grandies* L) number of snail was 35.90 with seedling damage of 100 per cent. In this way he also measured the number of snails in other seedlings like amla (*Phyllanthus Emblica* L), pongamia (*Pongamia* sp.), silver oak (*Grevilla Robabus*ta A.Cunn), neem (*Azadirachta indica*), tamarind (*Tamarindus Indica* L.), moringa (*Moringa oleifera* lam.), cashew (*Anacardium occidentale* L.), sisso (*Delbergia sissoo* Rosb.), jamun (*Syzeygium cumini* L.), almond (*Prunus amygdalus*), banyan (*Ficus bengalensis* L.), peepal (*Ficus religiosa* L.), guava (*Psidium guajava* L.), citrus (*Citrus* sp.) and papaya (*Carica papaya* L.) were 46.20, 45.30, 57.40, 55.10, 46.60, 35.70, 32.30, 54.50, 29.90, 34.60, 43.20, 38.10, 47.50, 58.10 and 51.10 respectively and in every case seedlings were damaged to the tune of 100 per cent (Mallappa, 2014).

## 2.3 Damage potential of slugs in various forest and horticultural nurseries

Slugs usually feed on surface of potato tubers, tomato and egg plant fruits, but sometimes dug into the flesh of these vegetables (Jagtap, 2000).

Kaur and kaur (2003) reported *F. alte* inflicted three types of damage to seedlings/saplings of vegetables and flower plants in laboratory feeding tests viz., leaves eaten from the margins, consumption of whole upper portion of seedling and stem girdling with resultant wilting of plants causing damage to sponge gourd (67 %), coriander (67 %), cabbage (76 %), brinjal (27 %), spinach (72 %) and cauliflower (47 %).

The brown slug, *Mariella dussumieri* (Gastropoda: Ariophantidae) is reported feeding voraciously on the succulent buds and leaves of vanilla plants in the Western Ghats (Mavinkurve *et al.,* 2004).

Daniel and Vanavasan (2009) reported the incidence of brown slug, *Mariella dussumieri* on *Hibiscus rosa-sinensis*, *Anthurium andraeanum*, *Piper nigrum*, *Theobroma cacao* and *Musa* sp. in Dakshina Kannada, Karnataka.

The maximum damage of seedling caused by Brown slug (*F. alte* Ferussac) was 32.8 per cent in brinjal during last week of February, 22.5 per cent in tomato during mid-March, 44.4 per cent in bottle gourd during early July, 91.6 per cent in squash melon, 65.6 per cent in summer squash, 63.4 per cent in cucumber, 62.8 per cent in long melon, 30.2 per cent in sponge gourd, 35.5per cent in turnip, 30.9 per cent in radish during September, 43.1 per cent in spinach, 50.8 per cent in cabbage, 41.3 per cent in cauliflower during October and 47.7 per cent in mustard during first week of November (Kaur and Mehta, 2013).

Kaur and kaur (2014) reported the brown slug, *F. alte* were found damaging vegetable crops in Punjab. The study revealed that the highest damage was observed in cauliflower at 6-leaf stage during October (25.03 %) and at 4-leaf stage during September (26.58 %) respectively and turnip was the most affected crop at 2-leaf stage (22.98 %). The least affected crop at 6- leaf stage and at 2- leaf stage with mean per cent of damage 17.11 and 17.57 respectively. Maximum leaf damage was observed in cabbage during the month of November.

Naik *et al*. (2014) reported the incidence of brown slug, *M. ariella dussumieri* inflicting damage to the marigold (*Tagetetes* sp.) var. RR Gold, was observed in Puttaswamayyana Palya, Tumkur district of Karnataka during *rabi,* 2013. Feeding damage up to 30 per cent loss was recorded in young plants in 2013 compared to 15 per cent loss observed during 2012.

## 2.4 Management of snails

### 2.4.1 Chemicals/poison baits

#### 2.4.4.1 Copper sulphate

Amongst the copper compounds, copper sulphate has been generally used to control the giant African snails. Pangga (1949) used one to 10 per cent solutions of copper sulphate against snail and stated that these solutions killed the young snails readily but not many adult snails.

Peterson (1957a) reported that the areas not enclosed by wall could get temporary protection from *Achatina* by a line of wood ash about 6 inches (15 cm) wide and 1-2 inches (2.5-5 cm) deep over which was sprayed 10 per cent solution of $CuSO_4$ and this acted as a barrier.

Saxena and Dubey (1970) used $CuSO_4$ dust @ 5.5 kg/ha against *A. fulica* and recorded 93 per cent mortality. Bhardwaj (1972) reported 95.8 per cent mortality within 120 hours after dusting with a mixture of copper sulphate and lime in the ratio of 40:60 in small scale field cage experiments. Snail-infested areas are prone to heavy rains; the dusted chemical is washed away and dusting has to be done over and again which is obviously uneconomical. Moreover, continued use of copper sulphate is likely to increase acidity of soil, which may be harmful to crops which are susceptible to acidity. In addition, plants which have been injured due to the feeding by *A. fulica* absorb $CuSO_4$ rapidly at the site of injury and die. Copper sulphate mixed with lime also has been recommended for dusting over the snail in the ratio of 1:4 or 1:5. This reduces the chances of increase in the acidity of soils.

Kakoty and Das (1987) tested two fungicides and two insecticides and copper sulphate solution against giant African snail. Of these, only copper sulphate caused 100 per cent mortality after one week of treatment

Among the different types of chemicals/ baits evaluated in guava ecosystem against *A. fulica*, $CuSO_4$ @ 60 kg poison bait/ha was next best treatment by recording the mortality of 28.28, 33.17, 47.31, 71.27 at 1, 3, 5 and 7 DAT, respectively (Rafee *et al.,* 2013b). However, Shilpa (2013) revealed that copper sulphate poison bait @ 60 kg/ha (100 g copper sulphate/kg of rice bran) recorded cumulative mortality of 72.22 per cent of a snail, *C. semirugata* in green gram.

2.4.4.2 Common Salt

Sodium chloride has been used by many scientists in India as well as in foreign countries for the control of snails and slugs. It has been used as a spray as well as in crystal form. Like copper sulphate and lime, sodium chloride crystals also are hygroscopic therefore when the crystals fall on the muscular part of the snail, it dies due to dehydration.

Hall (1932) advocated the use of aqueous solution of $NaCl_2$ instead of crystals. Latif (1933) used sodium chloride to protect potted orchids from *A. fulica.* Pangga (1949) reported the mortality of young *A. fulica* with salt solution. Peterson (1957a) found salt water spray either prepared from sodium chloride or as sea water to be effective in killing snails in Guam, but it caused burning of foliage. He considered such sprays to be of some practical utility only in sea beach areas and along side of roads where damage to vegetation or soil was of no consequence.

Singh and Birat (1969) reported the dusting of common salt on the crawling *A. fulica.* Saxena and Dubey (1970) dusted common salt @ 200 kg/ha and got 98 per cent mortality of *A. fulica* in the field six hours after the treatment. Raut and Ghose (1984) have used common salt in the Eastern region of the country to destroy *A. fulica.* Shah (1992) suggested that giant African snails could be killed by sprinkling the salt or leaving exposed to the sun. Karnatak *et al.* (1998) reported that 100 per cent mortality after 96 hours at 5 per cent spray of sodium chloride. Prasad *et al.* (2004) reported that sodium chloride (common table salt) is an effective dehydrating agent; it may be applied as a 12-inch barrier application on the perimeter of known or suspected snail-infested areas, during periods of rain or high relative humidity, salt barriers should be renewed frequently

Application of crystal salt @ 25 kg/ha was significantly superior by recording the highest per cent mortality of 37.75, 54.41, 80.88 and 95.08 at 1, 3, 5 and 7 DAT (day after treatment), respectively in guava ecosystem against *A. fulica* (Rafee *et al.* (2013b). However, Shilpa (2013) also endorsed the use of crystal salt @ 25 kg/ha recorded cumulative mortality of 89.03 per cent against snail, *C. semirugata* in greengram. Vanitha *et al.* (2008) reported that the barrier substances can be used to arrest the movement of GAS from one place to another. Common salt at 6 cm thickness was found to be very effective barriers against these snails.

2.4.4.3 Bleaching powder

The application of bleaching powder @ 25 kg/ha against *A. fulica* recorded the mortality of 33.16, 51.98, 73.77, 82.67 at 1, 3, 5 and 7 DAT, respectively in guava ecosystem (Rafee *et al.,* 2013b). Shilpa (2013) reported that bleaching powder @ 25 kg/ha recorded cumulative mortality of 70.08 per cent against snail, *C. semirugata* in greengram.

2.4.4.4 Chlorinated Hydrocarbons

Pereira and Goncalves (1949) reported that BHC was inferior to metaldehyde for the control of snails and slugs. Rao *et al.* (1953) dusted five per cent BHC in a drained paddy field at 62 pounds/ha which killed most of the snails in the field and found BHC to be superior to 2 per cent metaldehyde baits. Pappas and Carman (1955), working on *Helix aspersa* Muller found this pesticide to be slightly less than moderately effective in killing the snail.

Manna and Ghose (1972) found 2 per cent endrin bait to give cent per cent mortality of *A. fulica*. Bhardwaj (1972) tested 1.0 and 1.5 per cent endrin dust against *A. fulica* in the field cage at Delhi during July-August when the relative humidity varied from 80 to 97 per cent. The highest mortality obtained was 28.0 per cent from 1.5 per cent dust, 120 hours after the treatment. Jagtap *et al.* (1989) reported that five per cent BHC (100 kg/ha) bait gave 81.11 per cent mortality of the land snail, *C. belangiri* infesting bean, *Dolichos lablab.*

2.4.4.5 Organophosphates

Manna (1976) has tested diazinon and fenitrothion in the form of bait. Baits were prepared with bran, molasses and the chemical. Two per cent and one per cent diazinon baits gave 70 and 60 per cent mortality of *A. fulica* respectively. Two per cent fenitrothion bait gave 50 per cent mortality. Jagtap *et al.* (1989) in a three year trials got 25.55 per cent mortality of *C. belangiri* with phorate @ 1.5 kg ai/ha in the form of bait. Panigrahi and Raut (1993) determined the effectiveness of insecticides dimethoate and nuvan at 0.5 and 1 ml by injecting into 15-20 g pieces of vegetables or fruit baits (tomato, cucumber, *Trichosanthes dolica, Vigna unguculata* and *Hibiscus esculentus*) against *A. fulica.* The poisoned tomato and *T. dolica* were accepted by snails irrespective of insecticides used and in both the cases the pest died after consuming the baits both in laboratory and field.

Sarkar *et al.* (1997) studied the effectiveness of 3 bait types *viz.*, insecticide + sugar + boiled rice, insecticide + sugar + bread and insecticide + sugar + wheat bran on *A. fulica* under laboratory condition. The insecticides tested were: BHC (HCH), sumithion (fenitrothion), lebaycid (fenthion), aldrin, dimecron (phosphamidon), metacid (parathion-methyl), tafethion (ethion), coroban (chlorpyrifos), ekalux (quinalphos) and agrosulfon. The snails preferred bread and boiled rice as bait materials. Bait materials were taken up within 48 h of baiting. Snails were effectively controlled within 5 days by an application of baits containing sugar, bread and lebaycid or metacid at a ratio of 10:85:5. Baits prepared with phosphamidon killed the snails within 10 days. Generally, baits prepared with organochlorine insecticides were less effective than those with organophosphorus insecticides.

Saxena and Mahendra (2000) conducted an experiment in Uttar Pradesh, India to evaluate the efficacy of different baits (wet wheat, gram, barley and corn flour) and insecticides (dichlorvos, malathion, trichlorfon and mexacarbae) against the giant African snail. The baits were applied @ 5-10 g per snail, respectively. The results showed that wet wheat flour was the best bait and dichlorvos was the most potent molluscicide. The bait mixed with dichlorvos provided more than 90 per cent mortality in less than 96 h. Shilpa (2013) reported the least effectiveness of monocrotophos poison bait @ 60 kg/ha and malathion 5 % dust @ 25 kg/ha with cumulative mortality of 10.82 and 3.92 per cent, respectively in green gram against *C. semirugata.*

2.4.4.6 Carbamates

Crowell (1967) reported the use of carbamates especially mesurol in the form of bait to be useful for the control of land snails. Saxena and Dubey (1970) got 98.00 and 84.00 per cent kill of *A. fulica* with 10 per cent sevin dust used @ 100 and 60 kg/ha, respectively. Bhat and Shamanna (1973) reported 100 per cent mortality of land snails in south India with 5 per cent sevin as bait.

Olson (1973) screened a large number of pesticides including 46 carbamates against *A. fulica* the carbamate compounds Shell's SD-17250 and the union carbide's µC-30045 produced consistently high mortality of *A. fulica.*

Symonds (1975) reported the mortality of snails and slugs by mesurol bait and stated that it also kills earthworms. Mesurol was tested in Mauritius against *A. fulica* and is still being used along with metaldehyde (Mead, 1979). Jagtap *et al.* (1989) reported as an average of three years trails, 51.18 per cent kill of *C. belangiri* by 5 per cent sevin bait and 28.88 per cent kill by carbofuran when used @ 1.5 kg ai/ha as bait.

Ebenso *et al.* (2005) studied the effect of 50, 100, 200, 300, 400 and 500 mg/ml of carbamate molluscicide on behavioural and macroscopic changes of *L. aurora* in the laboratory using *Carica papaya* L. as bait for 120 h. The data showed that 48 hr after dosing the organism with furadan, 60 per cent mortality was recorded. Above 200 mg/ml deters snails from feeding and becomes sub-lethal.

Among the different types of chemicals/ baits evaluated against *A. fulica*, the application of methomyl 40 SP @ 60 kg poison bait/ha recorded the mortality of 23.58, 33.49, 57.06, 72.63 at 1, 3, 5 and 7 DAT, respectively in guava ecosystem (Rafee *et al.* 2013b).

Methomyl 40 SP poison bait @ 60 kg/ha recorded cumulative mortality of 47.22 per cent against snail, *C. semirugata* in greengram (Shilpa, 2013).

2.4.4.7 Metaldehyde/other baits

Metaldehyde for the first time used as a molluscicide in South Africa in 1934 (Gimingham, 1940) whereas in England it was used as a molluscicide in 1936 (Jary, 1939).

Barnes and Weil (1942) tried a number of carriers for formulating more effective bait but none proved better than the old standby wheat bran. To add durability to the bait, Altson (1950) mixed cement and lime with metaldehyde to get hard brick-like bait. He found that the addition of rice bran to the bait made it more attractive to snails and slugs. Metaldehyde, lime, rice bran and cement were mixed in the ratio of 1:2:6:6. Jefferson (1952) and Moreton (1953) found the dusts and sprays of metaldehyde have no phytotoxic effect even on such delicate plants as orchids. Thus, before transporting the seedlings from one place/island to another, these should be treated with 5 per cent metaldehyde dust so that if any snails happen to be carried with the seedlings/saplings they would die. This can be adopted as a domestic quarantine measure.

Blowers (1954) stated that commercial suspension of metaldehyde leaves a semi-persistent coating of metaldehyde sufficient for many weeks. Weber (1954) reported that on the Hawaiian Islands, metaldehyde dusts and sprays have been used against *A. fulica* and the spray was found to give better results. In Brazil snails are a serious pest of coffee, stripping the leaves and bark during the night. They could be controlled by spraying the trees with an emulsion consisting of 250 c.c. linseed oil, 250 c.c. skimmed milk and 750 g of metaldehyde in 100 liters of water. A single spray was generally sufficient for the season and it should be applied after the first 2 or 3 rains of summer (Mariconi and De, 1955).

Peterson (1957c) used commercial bait in the form of pellet prepared by mixing bran, 1.6 per cent metaldehyde and 5 per cent calcium arsenate which proved to be effective. However, pallets degraded soon during the rainy season. And he states that snails gets paralyzed in 10-15 minutes and died in half to one hour after feeding. Mead (1960) reported that from India, Mauritius, the Seychelles, Sarawak, New Guinea, Hong Kong, Taiwan, Yap and Tahiti, metaldehyde remains virtually the sole molluscicide being used against *A. fulica.* The most common mode of its use is in the form of bait.

Nair *et al.* (1968) used metaldehyde dust and suspension. In the laboratory, one per cent metaldehyde suspension gave 100 per cent kill in two days whereas in the field cage 1.0 per cent gave the same result in four days. However, in the field test, one per cent suspension gave 93.3 per cent kill, one day after the treatment and 2 per cent dust gave 100 per cent kill in 2 days in the laboratory and in five days in the field cage. One per cent metaldehyde suspension spray persisted in the field at a toxic level for four days.

Srivastava *et al.* (1968) made field trials with 3 and 5 per cent metaldehyde pellets as bait against *A. fulica* at Port Blair (Andaman) and found 5 per cent bait was better than 3 per cent. Regarding the poisoning symptoms, as soon as the snails came in contact with metaldehyde pellets, they secreted mucous profusely, became black on exposure to sun and soon died.

Saxena and Dubey (1970) used $CuSO_4$ dust @ 5.5 kg/ha against *A. fulica* and recorded 93 per cent mortality. Bhardwaj (1972) reported 95.8 per cent mortality within 120 hours after dusting with a mixture of copper sulphate and lime in the ratio of 40:60 in small scale field cage experiments. Snail-infested areas are prone to heavy rains; the dusted chemical is washed away and dusting has to be done over and again which is obviously uneconomical. Moreover, continued use of copper sulphate is likely to increase acidity of soil, which may be harmful to crops which are susceptible to acidity. In addition, plants which have been injured due to the feeding by *A. fulica* absorb $CuSO_4$ rapidly at the site of injury and die. Copper sulphate mixed with lime also has been recommended for dusting over the snail in the ratio of 1:4 or 1:5. This reduces the chances of increase in the acidity of soils.

Gorokhov and Aliev (1971) and Gorokhov and Krylov (1972) tested more than 200 molluscicide under different conditions against endemic and introduced land snails and slugs and metaldehyde emerged as the one preferred. They used metaldehyde as spray and in bait form. A spray of 4-8 kg of metaldehyde in 600 litres of water/ha gave 98.7 per cent kill whereas 5 per cent bait as granule scattered @ 30-40 kg/ha gave only 75 per cent mortality. However, they preferred the bait because it is less toxic than spray, to fauna and flora.

Bhardwaj (1972) studied mortality of *A. fulica* at different concentration of various pesticides. The baits of 20 per cent calcium arsenate and 5 per cent metaldehyde gave 92 and 96.7 per cent mortality of *A. fulica,* respectively. Srivastava and Abbas (1973) treated seedlings of papaya, cashewnut, lemon, orange, guava, sapota, emblic (*Emblica officinalis*) tamarind, tomato, brinjal, chillies, cotton, marigold, bougainvillea, arecanut, coconut, coffee *etc.*, with 5 per cent metaldehyde dust. The snails (*A. fulica*) which approached the seedlings were trapped in the metaldehyde dust lying on the soil surface and seedlings were not damaged. The seedlings were observed for eight days and there was no phytotoxic effect. Srivastava (1973) used five per cent metaldehyde pellets on clean pathways of snails so to cover as much of pathways to get the highest mortality of giant African snails.

Veeresh *et al.* (1979) reported that application of poison baits containing six per cent lead arsenate or 5 per cent metaldehyde or 3.5 per cent parisgreen prepared out of wheat bran was effective in killing the giant African snails on ornamentals, vegetables and fruit plants with no phytotoxic effect. Subramanya (1982) studied the efficacy of different chemicals on 12 months old giant African snails in the laboratory. Among different chemicals used, vegfru snail kill had given the highest mortality of 83.86 per cent at 15 kg per acre followed by mesurol bait (66.15 %) at 6 kg per acre. These two effective baits were also tested in field but there was no significant difference between these. Vergfru snail kill and mesurol baits killed 12 and 8 snails, respectively in 50 $m^2$ area.

Sharma and Agarwal (1989) recommended the use of metaldehyde pellets (5 per cent) at 25 kg per hectare to control the giant African snails effectively. These pellets should be kept around the field. In case of plantation crops the pellets should be kept near the root zone. Shah (1992) reported that pathways of giant African snails should be covered and the area all around should be protected by shower proof 5 per cent metaldehyde.

Karnatak *et al.* (1998) recorded 100 per cent mortality of *A.fulica* within a day at 5 per cent sprays of both decamethrin and fenvalerate in the laboratory. Metaldehyde in the form of suspension gave 95.5 per cent mean mortality at 4 per cent concentration. Basavaraju *et al.* (2000) reported that application of 2.5 per cent metaldehyde was effective in controlling the giant African snail. Salmijah *et al.* (2000) recorded cent per cent mortality of *A. fulica* within 24 hours at 5 per cent metaldehyde bait. Ismail *et al.* (2005) evaluated six chemicals namely, methomyl, chlorpyrifos, lufenuron, spinosad, copper sulfate and ferrous sulfate against *Monacha cartusiana* Muller under field conditions in two fields cultivated with onion and broad bean. Methomyl showed the highest effect while spinosad was least effective.

Javaregowda (2006) tested the various chemicals against the giant African snail among these, metaldehyde 2.5 per cent was found to be the most effective and registered highest mortality of 30.65 and 43.2 per cent after one day at both the localities tested followed by monocrotophos bait.

Shevale and Bedse (2009) from Maharashtra reported that after three and seven days of application of different poison baits in soybean, metaldehyde 2.5 % @ 25 kg/ha was most effective (77.7 and 69.3 % mortality) and was closely followed by poison bait consisting methomyl 40 SP @ 10 g/kg of fermented food bait (wheat bran + Jaggery) (83.0 and 68.1 % mortality). Both the treatments were significantly superior to rest of the treatments. Metaldehyde 2.5 % with its reduced dose of 5.0 kg/ha along with food bait (50 kg/ha) (wheat bran + Jaggery) also showed good efficacy with 68.7 and 40.7 per cent snail mortality and ranked third in order of efficacy.

Kumar *et al.* (2013) reported that compared to standard bait metaldehyde, methomyl bait with ripened papaya fruit pieces attracted and killed the highest number of snails (*A. fulica*) compared to endosulphan and imidachloprid.

Metaldehyde 2.5 % pellets @ 5 kg/ha recorded significantly highest mortality of 35.83, 37.21, 83.85and 97.60 per cent at 1, 3, 5 and 7 days after treatment in guava ecosystem against giant African snail (Rafee *et al.,* 2013b).

Shilpa (2013) reported that metaldehyde 2.5 % pellets @ 5 kg/ha given a cumulative mortality of 94.83 per cent and it was significantly superior to rest of the chemicals/baits and fenvalerate 0.4 % @ 25 kg/ha dust was found least effective (0.47 %) against snail, *C. semirugata* in greengram.

## 2.5 Management of slugs

Barker *et al.* (1989) reported that broadcasted metaldehyde and methiocarb bait (10 kg /ha) were exerted similar effect on mortality (54- 68 %) of slug in direct drilled maize crop. South (1992) reported that carbaryl (Sevin) was effective when formulated as a bait, but was ineffective when applied as a spray. Methomyl (Lannate LV) currently is being explored as a slug control option. Hata *et al.* (1998) reported that Metaldehyde- Methiocarb G 2-1 and Deadline granules caused 62.4 and 81 per cent mortality respectively on slug, *Vaginula plebeia* population. Bailey (2002) registered metaldehyde based baits as effective in controlling slug populations because of their selectivity.

Henderson and Triebskorn (2002) reported that carbamate insecticides can be used to control slugs. Methiocarb formulated as bait was used for slug control in non food crop settings such as ornamental production in nurseries and greenhouses. Thiodicarb could exert slugs control property in soybean ecosystem.

Different concentrations of three pesticides (Malathion 50 EC, Rogor 30 EC and Furadan 3G) were tested against slug, *F. alte* in no-choice laboratory feeding tests. Three per cent mango flavour in 10 % malathion bait improved the bait acceptance and increased the slugs mortality. However, 10 % rogor poison bait caused more mortality (30 %) without any additive. Furadan (0.75 %) proved to be the most effective poison bait resulting in 86.6 per cent mortality of slugs. The efficacy of three poison baits was found in the following order- Furadan (0.75 %), rogor (10 %), malathion (10 %) treated with 3 per cent mango flavour. Hence, furadan (0.75 %) should be used to control slug, *F. alte* (Kaur and Mehta, 2010).

Naik *et al.* (2014) reported application of lanate powder (Methomyl) (90 SP, 1 g/l of water) minimized the incidence and damage incurred by slugs (*Mariella dussumiri* Gray).

Selvi *et al.* (2015) reported that the maximum amount of liquid loss was shown with tobacco coated silica (49.51 %), followed by neem coated silica (48.58 %) and uncoated silica (48.51 %).

# 3. MATERIAL AND METHODS

The material used and methodologies followed in conducting objectives *viz*., survey for snails and slugs infesting forest/horticulture nurseries, assessment of damage potential and management of giant African snail (GAS) and slugs in various forest/horticultural nurseries and in protected cultivation were carried out during *kharif,* 2015 at Hi-Tech Horticulture Unit of University Agricultural Sciences, Dharwad.

Dharwad is situated in the transitional tract of Karnataka at 15° 26' North latitude and 75° 07' East longitude with an altitude of 678 meters above mean sea level (MSL). The actual annual rainfall of 468.00 mm distributed over a period of seven months (June to December) with one peak occurring in October, 2015. The period from March to May is very hot with mean maximum temperature ranging between 33 to 37°C. Similarly, during December and January, which are cooler months with mean minimum temperature, ranging between 11.00 and 21.74°C, the relative humidity fluctuates between 40 and 85 per cent. The details of materials used and the methodology adopted during the course of investigation are described here under.

## 3.1 Survey for snails and slugs infesting forest/horticulture nurseries and in protected cultivation

### 3.1.1 Survey

Fixed plot survey was conducted in different forest/horticulture nurseries and in protected cultivation at weekly interval from 15$^{th}$ June, 2015 to 15$^{th}$ January, 2016.

Nurseries surveyed during the study period.

1. Forest nursery, MARS, Dharwad.
2. Forest nursery, Sanjeevini park, Navanagar
3. High –Tech Horticulture Unit, UAS, Dharwad.
4. Forest nursery near KC Park
5. Medicinal/aromatic nursery, Saidpur Farm, UAS, Dharwad.
6. Forest nurseries near kelageri water tank.
7. Forest nursery, Gungargatti, Dharwad.
8. Forest nursery, Sirsi, College of Forestry, Uttara Kannada district.
9. Forest nursery, ARS, Malagi, Uttara Kannada district.
10. Horticultural nursery, ZHRS, Kumbhapur, Dharwad

During survey at each nursery the following observations were made on different types of seedlings/saplings.

1. No. of snails and slugs/4m$^2$ nursery saplings at 10 spots.
2. Age of nursery plants in (months).
3. Foliar damage (%) caused by snails/slugs on 10 different saplings/seedlings.

$$\text{Per cent leaf damage} = \frac{\text{Number of damaged leaves/ plant}}{\text{Total number of leaves/plant}} \times 100$$

### 3.1.2 Correlation studies with weather parameters

The fixed plot survey data on the incidence of GAS/slugs on different nurseries were subjected to correlation analysis to know the relationship between pest incidence and weather parameters prevailed in Dharwad by using SPSS (Statistical Package for Social Sciences) software.

### 3.1.3 Collection, identification of snail and slug species

Snails were collected from the infested fields/nurseries from various localities and brought to the laboratory, reared in the cages and specimens were preserved in 70 per cent alcohol. Only the shells of the snails and entire slugs were sent for identification to Dr. Venkitesan, Scientist C, Zoological Survey of India, Southern Regional Centre, Chennai.

## 3.2 To assess the damage potential caused by giant African snail, *A. fulica* and slugs in various forest and horticultural nurseries

The experiments to assess the damage potential of GAS and slug on forest and horticulture nurseries were laid out in RCBD with 17 treatments replicated twice at the High –Tech Horticulture Unit of UAS, Dharwad. The forest and horticulture nursery seedlings selected for investigation are mentioned hereunder.

Table 1. Details of forest/ horticultural saplings for assessment of damage by giant African snail

| Treatment | Forest/ Horticulture seedling |
|---|---|
| 1 | Neem (*Azadirachta indica* A.) |
| 2 | Tabubia (*Tabebuia chrysotricha* Mart.) |
| 3 | Pongamia (*Pongamia* sp.) |
| 4 | Almond (*Prunus amygdalus* L.) |
| 5 | Teak (*Techtona grandies* L.) |
| 6 | Silver oak (*Grevilla robabus*ta A.Cunn) |
| 7 | Tamarind (*Tamarindus indica* L.) |
| 8 | Sisso (*Delbergia sissoo* Rosb.) |
| 9 | Banayan (*Ficus bengalensis* L.) |
| 10 | Subabul (*Leaucaena leucocephala* Lam.) |
| 11 | Jamun (*Syzeygium cumini* L.) |
| 12 | Citrus (*Citrus* sp.) |
| 13 | Moringa (*Moringa oleifera* Lam.) |
| 14 | Guava (*Psidium guajava* L.) |
| 15 | Papaya (*Carica papaya* L.) |
| 16 | Mango (*Mangifera indica* L.) |
| 17 | Curry (*Murraya koenigii* L.) |

Field collected medium sized either GAS (40 to 50 mm) or slugs were released in different treatments to assess damage potential of seedlings. Each treatment was covered with 50 seedlings and 10 snails or slugs were artificially released in each treatment. All the plots with seedlings were covered with nylon net for a week period to prevent the escape of snail from one plot to another (Plate 1). All the snails/ slugs were removed one week after release. Further, the per cent leaf damage per plant was calculated by using the given formula.

$$\text{Defoliation (\%)} = \frac{\text{Number of leaves damaged/plant}}{\text{Total number of leaves/plant}} \times 100$$

The observations on per cent damage inflicted by snail pests was done on 1, 3, 5, 7 and 10 days after release of snails on 10 randomly selected saplings.

## 3.3 Management of giant African snail, *A. fulica* and slugs.

### 3.3.1 At forest/ horticulture nursery.

The experiment was laid out in RCBD with nine treatments replicated thrice at HHU, UAS, Dharwad using different forest/horticulture seedlings. Each treatment was imposed on 50 nursery plants covered with nylon net (Plate 2).

Table 2. Details of chemicals/poison bait for management of giant African snail in forest and horticulture nursery

| Sl. No | Treatment | Dosage (kg/ha) |
|---|---|---|
| $T_1$ | Bleaching powder | 25 |
| $T_2$ | Crystal salt | 25 |
| $T_3$ | Methomyl 40 SP poison bait | 60 |
| $T_4$ | $CuSo_4$ poison bait | 60 |
| $T_5$ | Thiodicarb 75 WP poison bait | 60 |
| $T_6$ | Tobacco powder | 25 |
| $T_7$ | Boric powder | 25 |
| $T_8$ | Metaldehyde 2.5 % pellets | 5 |
| $T_9$ | Untreated control | -- |

The above mentioned treatments including molluscicide, dehydrating agents and poison baits were broadcast in the nursery plants covered in nylon nets during evening hours. Later on 25 snails/ slugs per plot were released and dead snail count was made on 1, 3, 7, 10 and 15 days after treatment (DAT) at morning 7.00 to 8.00 am and the data were subjected to statistical analysis. Second application was taken after 15 days interval to confirm the result of first application.

**Plate 1: General experimental view of nursery studies**

**Plate 2: General experimental view of capsicum studies**

### 3.3.2 At protected cultivation on capsicum.

To evaluate the efficacy of different treatments mentioned here under, an experiment was laid out in RCBD on capsicum grown in protected cultivation with nine treatments and three replications. The capsicum variety Indra was grown at a spacing of 35 x 45 $cm^2$ with a plot size 2 x 1 $m^2$.

Table 3. Details of chemicals/poison bait for management of giant African snail in protected cultivation of capsicum

| Sl. No | Treatment | Dosage (kg/ha) |
|---|---|---|
| $T_1$ | Bleaching powder | 25 |
| $T_2$ | Crystal salt | 25 |
| $T_3$ | Methomyl 40 SP poison bait | 60 |
| $T_4$ | $CuSo_4$ poison bait | 60 |
| $T_5$ | Thiodicarb 75 WP poison bait | 60 |
| $T_6$ | Tobacco powder | 25 |
| $T_7$ | Boric powder | 25 |
| $T_8$ | Metaldehyde 2.5 % pellets | 5 |
| $T_9$ | Untreated control | -- |

At 30 days after planting of capsicum 10 snails or slugs were artificially released in each plot and all the plots were covered with nylon net for a week period to prevent the escape of snail from one plot to another. The above mentioned poison baits were broadcast in each plot during evening hours as per the dosages mentioned and dead snail count was made at 1, 3, 7, 10 and 15 days after treatment (DAT) during morning 7.00 to 8.00 am. Further, to calculate per cent mortality the data were subjected to statistical analysis with suitable conversions.

Percent increase in yield was calculated by using the formula:

$$\text{Per cent yield increase (\%)} = \frac{\text{Yield in respective treatment -Yield in control}}{\text{Yield in respective treatment}} \times 100$$

Preparation of poison baits

For 60 kg of rice bran, 12 kg of jaggery and 24 litres of water was added and mixed well in a container. The mouth of the container was tied with cloth and kept 48 h for fermentation. After 48 h, respective chemicals were added and broadcast in the capsicum field @ 60 kg/ha.

### 3.3.3 Economic analysis

#### 3.3.3.1 Cost of cultivation

The prevailing price of input materials and labour cost were considered for computing the cost of cultivation which was expressed in ₹/ha.

#### 3.3.3.2 Gross returns

The income from yield of capsicum was considered for accounting gross returns. The price prevailed at vegetable market of Dharwad, was considered to calculate the gross returns (₹/ ha).

#### 3.3.2.3 Net returns

Net returns (₹/ ha) was calculated by subtracting the cost of cultivation (₹/ ha) from the gross returns.

#### 3.3.2.4 Benefit Cost ratio

The net returns (₹/ha) was divided by the total cost of cultivation (₹/ha) to get B:C ratio.

$$\text{B:C ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

# 4. EXPERIMENTAL RESULTS

The results of the investigations on survey for snails and slugs infesting forest /horticultural nurseries, damage potential of giant African snail (GAS), *Achatina fulica* Ferussac and slugs on different forest and horticultural saplings, their management in protected cultivation of capsicum and in forest /horticultural nursery by using different chemicals /poison baits are presented in this chapter.

## 4.1 Survey for snails and slugs infesting forest/horticulture nurseries and in protected cultivation

### 4.1.1 Fixed plot survey

Fixed plot survey was carried out in forest/ horticultural nurseries located in and around Dharwad during *kharif* and *rabi*, 2015 and information was collected regarding its population density as well as extent of damage caused by GAS and slugs. The fixed plot survey was made once in a week from June, 2015 to January, 2016 and results are presented in tables 4 and 5.

During survey the mean number of snail population per 4 $m^2$ field inside the nursery was recorded on different saplings like mango, papaya, jamun, curry leaf, moringa, silver oak, teak, neem, pongamia, citrus and guava. The incidence of snails and their damage on seedlings was observed from 24$^{rd}$ standard week on different saplings grown in forest and horticultural nurseries of Dharwad district.

4.1.1.1 Dharwad district

4.1.1.1.1 Hi-Tech Horticulture Unit (HHU), UAS, Dharwad

The snail population and per cent leaf damage were recorded on different forest/ horticulture seedlings at HHU, Dharwad from 24$^{th}$ standard week to 4$^{th}$ standard week are presented in the table 1. Among the different nurseries surveyed in HHU during 2015, the mean population of snails varied from 2.01 to 5.54 per 4 $m^2$. The higher snail population was recorded in moringa seedlings (5.54/4 $m^2$) followed by mango (4.79/4 $m^2$), jamun (2.40/4 $m^2$) and lower snail population observed in curry leaf (2.01/4 $m^2$). Whereas, maximum per cent leaf damage observed in moringa (23.35 %) followed by mango (12.89 %), curry leaf (10.25 %) and minimum in jamun (7.27 %). No slug damage was recorded in HHU during survey period.

4.1.1.1.1.1 On moringa

The data presented in table 4 on the incidence of *A. fulica* on moringa (4-5 months) revealed, that the first appearance of snail was noticed during 24$^{th}$ standard week (2.40/ 4$m^2$) and persisted in nursery up to 51$^{st}$ standard weeks (Dec. 4$^{th}$ week).

Population density of snail found inside the nursery was ranged from 0.00 to 13.70 per 4$m^2$ with a mean population of 5.54/4$m^2$. Whereas, the maximum snail damage (55.82 %) was at 42$^{nd}$ standard week with a mean of 23.35 per cent.

4.1.1.1.1.2 On mango

From table 4 it is clear that, the maximum snail population on mango nursery (12.90/ $4m^2$) was recorded more during 37th standard week with average population of 4.79 per $4m^2$ with maximum leaf damage of 27.32 per cent 44th std week having a mean leaf damage of 12.89 per cent.

4.1.1.1.1.3 On jamun

It was evident from the table 4 that, the first appearance of snails started during 24th standard week and persisted in nursery up to 46th standard week. The population density on jamun seedlings varied from 0.00 to 6.90 per $4m^2$ with the mean population 2.40. Maximum leaf damage of was recorded 21.82 per cent at 41st std week with a mean of 7.27 per cent.

4.1.1.1.1.4 Curry leaf

The first appearance of snails was noticed during 25th standard week and persisted in nursery up to 49th standard week. The average population ranged from 0.00 to 6.30 per $4m^2$ with a seasonal mean of $2.01/4m^2$. Maximum leaf damage of 30.56 per cent was recorded at 42nd std week with average of 10.25 per cent. After 52nd std week onwards there was no leaf damage.

4.1.1.1.2 In forest Nursery, MARS, Dharwad

4.1.1.1.2.1 On mango

The data presented in table 5 on the incidence of *A. fulica* on mango nursery revealed that, the first appearance of snails was noticed during 24th standard week and persisted up to 49th standard week in nursery. The snail population inside the field ranged from 0.00 to 11.40 per 4 $m^2$ with average of $4.69/4m^2$. Whereas, the maximum damage of 35.10 per cent was recorded in 41st standard week which coincided with the highest snail population ($11.40/4m^2$). The mean leaf damage by the population of snail on mango nursery was 12.29 per cent and no damage was found after 49th std week.

4.1.1.1.2.2 On silver oak

The population density of GAS in silver oak nursery ranged from 0.00 to $5.20/4m^2$ with mean of 2.15/ $4m^2$. The first appearance of snails was noticed during 25th standard week and persisted in nursery up to 50th standard week in silver oak nursery.The maximum leaf damage (13.55 %) was recorded at 45th std week with seasonal mean damage of 4.95 per cent.

4.1.1.1.3 In forest nursery, KC Park, Dharwad

4.1.1.1.3.1 On teak

The average snail population in teak nursery ranged from 0.00 to 4.10 per $4m^2$ with average of 0.97 snails per $4m^2$ (Table 5). The first incidence of snail was noticed at 27th std week and persisted up to 48th std week. The maximum leaf damage was recorded at 43rd std week *i.e.,* 11.50 per cent with average damage of 3.83 per cent.

**Table 4: Incidence of *Achatina fulica* and *Laevicaulis alte* on moringa, mango, jamun and curry leaf in Hi-Tech Horticulture Unit of UAS, Dharwad**

| Period | S MW | Hi –Tech Horticulture Unit | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Moringa (4 to 5 months) | | | | Mango (6 to 8 months) | | | | Jamun (10 to12 months) | | | | Curry leaf (6 to 8 months) | | | |
| | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | |
| | | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) |
| June 3rd week | 24 | 2.40 | 3.80 | - | - | 4.50 | 3.43 | - | - | 1.50 | 2.23 | - | - | 2.23 | 2.23 | - | - |
| June 4th week | 25 | 5.40 | 6.65 | - | - | 6.20 | 4.32 | - | - | 3.30 | 2.50 | - | - | 2.50 | 2.50 | - | - |
| June 5th week | 26 | 5.80 | 8.93 | - | - | 3.60 | 5.48 | - | - | 1.60 | 2.76 | - | - | 2.76 | 2.76 | - | - |
| July 1st week | 27 | 4.20 | 11.85 | - | - | 3.10 | 5.90 | - | - | 1.50 | 2.85 | - | - | 2.85 | 2.85 | - | - |
| July 2nd week | 28 | 3.80 | 13.16 | - | - | 2.90 | 6.52 | - | - | 2.10 | 3.30 | - | - | 3.30 | 3.30 | - | - |
| July 3rd week | 29 | 3.40 | 16.33 | - | - | 3.80 | 6.68 | - | - | 2.40 | 4.35 | - | - | 4.35 | 4.35 | - | - |
| July 4th week | 30 | 6.50 | 18.67 | - | - | 2.90 | 7.30 | - | - | 3.50 | 5.50 | - | - | 5.50 | 5.50 | - | - |
| Aug. 1st week | 31 | 7.20 | 20.17 | - | - | 4.50 | 8.56 | - | - | 2.60 | 7.68 | - | - | 7.68 | 7.68 | - | - |
| Aug. 2nd week | 32 | 8.40 | 25.60 | - | - | 6.90 | 8.95 | - | - | 3.10 | 8.85 | - | - | 8.85 | 8.85 | - | - |
| Aug. 3rd week | 33 | 9.80 | 28.55 | - | - | 4.50 | 9.05 | - | - | 3.80 | 9.06 | - | - | 9.06 | 9.06 | - | - |
| Aug. 4th week | 34 | 5.30 | 30.50 | - | - | 4.20 | 12.20 | - | - | 4.10 | 11.08 | - | - | 11.08 | 11.08 | - | - |
| Sept. 1st week | 35 | 8.50 | 34.85 | - | - | 5.40 | 13.35 | - | - | 3.70 | 11.15 | - | - | 11.15 | 11.15 | - | - |
| Sept. 2nd week | 36 | 10.20 | 37.16 | - | - | 3.70 | 15.86 | - | - | 4.50 | 11.96 | - | - | 11.96 | 11.96 | - | - |
| Sept. 3rd week | 37 | 8.70 | 39.32 | - | - | 12.90 | 16.50 | - | - | 4.60 | 13.35 | - | - | 13.35 | 13.35 | - | - |

$N/4m^2$ - No. of snails/ $4m^2$, D (%) - Leaf damage (%)

*Contd…..*

*Table 4: Contd.*

| Period | S MW | Hi –Tech Horticulture Unit | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Moringa (4 to 5 months)** | | | | **Mango (6 to 8 months)** | | | | **Jamun (10 to12 months)** | | | | **Curry leaf (6 to 8 months)** | | | |
| | | ***A. fulica*** | | ***L. alte*** | | ***A. fulica*** | | ***L. alte*** | | ***A. fulica*** | | ***L. alte*** | | ***A. fulica*** | | ***L. alte*** | |
| | | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) | $N/4m^2$ | D (%) |
| Sept. 4th week | 38 | 12.30 | 43.76 | - | - | 11.40 | 16.80 | - | - | 5.50 | 16.66 | - | - | 5.50 | 17.05 | - | - |
| Sept. 5th week | 39 | 6.60 | 45.25 | - | - | 6.70 | 17.30 | - | - | 3.10 | 16.85 | - | - | 3.10 | 22.08 | - | - |
| Oct.1st week | 40 | 13.70 | 48.85 | - | - | 12.10 | 18.63 | - | - | 6.70 | 18.38 | - | - | 6.30 | 25.15 | - | - |
| Oct. 2nd week | 41 | 12.70 | 49.60 | - | - | 9.60 | 19.85 | - | - | 6.90 | 21.82 | - | - | 5.70 | 28.32 | - | - |
| Oct. 3rd week | 42 | 9.50 | 55.82 | - | - | 7.50 | 20.96 | - | - | 5.10 | 19.02 | - | - | 3.30 | 30.56 | - | - |
| Oct. 4th week | 43 | 7.20 | 52.30 | - | - | 6.10 | 24.60 | - | - | 4.20 | 17.13 | - | - | 2.20 | 26.63 | - | - |
| Nov. 1st week | 44 | 11.50 | 45.00 | - | - | 5.80 | 27.32 | - | - | 3.20 | 14.50 | - | - | 2.70 | 22.92 | - | - |
| Nov. 2nd week | 45 | 7.60 | 35.45 | - | - | 5.20 | 23.30 | - | - | 1.50 | 11.65 | - | - | 2.20 | 18.75 | - | - |
| Nov. 3rd week | 46 | 3.20 | 29.02 | - | - | 4.70 | 22.46 | - | - | 0.60 | 7.14 | - | - | 0.60 | 13.08 | - | - |
| Nov. 4th week | 47 | 4.90 | 24.17 | - | - | 5.10 | 19.56 | - | - | 0.00 | 0.00 | - | - | 1.30 | 9.50 | - | - |
| Dec. 1st week | 48 | 2.40 | 17.33 | - | - | 4.40 | 17.52 | - | - | 0.00 | 0.00 | - | - | 0.50 | 7.44 | - | - |
| Dec. 2nd week | 49 | 1.20 | 13.50 | - | - | 3.90 | 14.16 | - | - | 0.00 | 0.00 | - | - | 0.20 | 6.53 | - | - |
| Dec. 3rd week | 50 | 00 | 9.05 | - | - | 2.70 | 11.25 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - |
| Dec. 4th week | 51 | 0.40 | 5.86 | - | - | 1.50 | 8.63 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - |
| Dec. 5th week | 52 | 0.00 | 0.00 | - | - | 1.10 | 7.50 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - |
| Jan. 1st week | 1 | 0.00 | 0.00 | - | - | 0.70 | 3.58 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - |
| Jan. 2nd week | 2 | 0.00 | 0.00 | - | - | 0.50 | 2.10 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - |
| Jan. 3rd week | 3 | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - |
| Jan. 4th week | 4 | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - |
| Mean | | 5.54 | 23.35 | | - | 4.79 | 12.89 | | - | 2.40 | 7.27 | | - | 2.01 | 10.25 | | - |

$N/4m^2$ - No. of snails/ $4m^2$, D (%) - Leaf damage (%)

**Table 5. Incidence of *Achatina fulica* and *Laevicaulis alte* on forest/horticulture seedlings in different forest nurseries (FN) located in and around Dharwad (2015-16)**

| Period | SMW | FN, MARS, Dharwad | | | | | | | | FN, KC Park | | | | | | | | FN, Sanjeevini Park | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mango (4-5 m) | | | | Silver oak (10- 11 m) | | | | Teak (9- 10 m) | | | | Neem (1 year) | | | | Papaya (4- 5m) | | | | Teak (5-6 m) | | | |
| | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | |
| | | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D |
| June 3rd week | 24 | 1.40 | 2.50 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.40 | 0.75 | - | - | 1.8 | 2.56 | - | - |
| June 4th week | 25 | 2.40 | 3.19 | - | - | 1.80 | 1.04 | - | - | 0.00 | 0.00 | - | - | 0.50 | 0.00 | - | - | 3.90 | 3.5 | - | - | 2.4 | 3.45 | - | - |
| June 5th week | 26 | 3.80 | 4.20 | - | - | 1.50 | 1.65 | - | - | 0.00 | 0.00 | - | - | 1.20 | 0.60 | - | - | 2.50 | 5.68 | - | - | 2.8 | 4.90 | - | - |
| July 1st week | 27 | 5.20 | 5.33 | - | - | 1.30 | 1.86 | - | - | 1.10 | 1.50 | - | - | 0.40 | 0.70 | - | - | 1.20 | 5.8 | - | - | 3.5 | 5.85 | - | - |
| July 2nd week | 28 | 4.80 | 5.67 | - | - | 2.20 | 2.25 | - | - | 1.40 | 2.50 | - | - | 0.60 | 0.90 | - | - | 3.80 | 7.1 | - | - | 3.8 | 6.65 | - | - |
| July 3rd week | 29 | 3.40 | 7.10 | - | - | 2.40 | 2.57 | - | - | 1.20 | 2.80 | - | - | 0.00 | 1.20 | - | - | 2.50 | 8.5 | - | - | 4.2 | 7.85 | - | - |
| July 4th week | 30 | 5.50 | 7.50 | - | - | 3.60 | 2.75 | - | - | 1.40 | 3.20 | - | - | 0.90 | 1.60 | - | - | 3.10 | 10.4 | - | - | 3.7 | 8.52 | - | - |
| Aug. 1st week | 31 | 5.80 | 8.30 | - | - | 3.90 | 3.15 | - | - | 2.50 | 3.50 | - | - | 0.70 | 1.80 | - | - | 6.40 | 13.5 | - | - | 4.3 | 8.78 | - | - |
| Aug. 2nd week | 32 | 6.30 | 8.50 | - | - | 2.80 | 3.37 | - | - | 2.70 | 3.90 | - | - | 1.40 | 2.10 | - | - | 8.70 | 14.5 | - | - | 6.5 | 9.95 | - | - |
| Aug. 3rd week | 33 | 6.50 | 10.60 | - | - | 3.70 | 3.62 | - | - | 0.70 | 4.50 | - | - | 0.50 | 2.90 | - | - | 5.00 | 15.7 | - | - | 4.6 | 10.05 | - | - |
| Aug. 4th week | 34 | 7.20 | 13.30 | - | - | 4.20 | 3.50 | - | - | 0.60 | 4.80 | - | - | 0.40 | 3.20 | - | - | 5.30 | 16.64 | - | - | 4.3 | 12.45 | - | - |
| Sept. 1st week | 35 | 7.70 | 13.80 | - | - | 2.60 | 3.80 | - | - | 0.50 | 4.90 | - | - | 0.90 | 3.80 | - | - | 7.40 | 18.8 | - | - | 3.4 | 13.67 | - | - |
| Sept. 2nd week | 36 | 8.30 | 19.90 | - | - | 3.90 | 4.20 | - | - | 0.70 | 5.10 | - | - | 1.60 | 3.50 | - | - | 10.30 | 22.4 | - | - | 3.9 | 15.40 | - | - |
| Sept. 3rd week | 37 | 8.60 | 22.10 | - | - | 2.20 | 5.55 | - | - | 1.90 | 5.30 | - | - | 1.90 | 2.70 | - | - | 6.40 | 24.5 | - | - | 4.8 | 16.50 | - | - |
| Sept. 4thweek | 38 | 9.30 | 25.30 | - | - | 4.10 | 6.90 | - | - | 2.30 | 5.60 | - | - | 1.10 | 2.15 | - | - | 9.50 | 26.85 | - | - | 4.3 | 17.50 | - | - |
| Sept. 5th week | 39 | 8.70 | 28.50 | - | - | 2.20 | 8.01 | - | - | 1.20 | 6.80 | - | - | 0.70 | 2.40 | - | - | 6.70 | 30.4 | - | - | 6.6 | 18.00 | - | - |
| Oct.1st week | 40 | 10.80 | 31.80 | - | - | 5.20 | 9.50 | - | - | 3.50 | 6.90 | - | - | 1.80 | 3.50 | - | - | 12.90 | 35.7 | - | - | 7.5 | 19.36 | - | - |
| Oct. 2nd week | 41 | 11.40 | 35.10 | - | - | 4.20 | 10.20 | - | - | 4.10 | 7.80 | - | - | 2.10 | 4.30 | - | - | 9.40 | 37.2 | - | - | 8.2 | 20.56 | - | - |
| Oct. 3rd week | 42 | 9.50 | 33.50 | - | - | 3.80 | 10.64 | - | - | 1.50 | 9.60 | - | - | 1.70 | 2.90 | - | - | 6.20 | 36.2 | - | - | 9.6 | 25.85 | - | - |

N- No. of snails/ 4m$^2$, D- Leaf damage (%)

*Contd…..*

*Table 5: Contd.*

| Period | SMW | FN, MARS, Dharwad | | | | | | | | FN, KC Park | | | | | | | | FN, Sanjeevini Park | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mango (4-5 m) | | | | Silver oak (10- 11 m) | | | | Teak (9- 10 m) | | | | Neem (1 year) | | | | Papaya (4- 5m) | | | | Teak (5-6 m) | | | |
| | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | | *A. fulica* | | *L. alte* | |
| | | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D | N | D |
| Oct. 4th week | 43 | 7.20 | 29.50 | - | - | 2.90 | 11.35 | - | - | 1.40 | 11.50 | - | - | 1.30 | 2.10 | - | - | 3.60 | 31.56 | - | - | 7.5 | 26.60 | - | - |
| Nov. 1st week | 44 | 5.50 | 25.65 | - | - | 3.20 | 11.45 | - | - | 0.80 | 10.13 | - | - | 0.60 | 1.40 | - | - | 2.40 | 28.03 | - | - | 5.8 | 27.32 | - | - |
| Nov. 2nd week | 45 | 4.60 | 21.30 | - | - | 2.30 | 13.55 | - | - | 0.50 | 8.30 | - | - | 0.00 | 0.00 | - | - | 1.30 | 25.05 | - | - | 4.4 | 24.30 | - | - |
| Nov. 3rd week | 46 | 3.20 | 15.20 | - | - | 1.90 | 10.67 | - | - | 0.40 | 7.74 | - | - | 0.00 | 0.00 | - | - | 1.20 | 19.02 | - | - | 3.2 | 22.46 | - | - |
| Nov. 4th week | 47 | 3.90 | 13.80 | - | - | 2.30 | 9.64 | - | - | 1.30 | 6.05 | - | - | 0.00 | 0.00 | - | - | 0.60 | 13.54 | - | - | 2.9 | 19.56 | - | - |
| Dec. 1st week | 48 | 2.40 | 8.01 | - | - | 1.40 | 7.57 | - | - | 0.50 | 3.95 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 1.8 | 17.52 | - | - |
| Dec. 2nd week | 49 | 1.20 | 6.16 | - | - | 0.90 | 7.45 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.9 | 14.16 | - | - |
| Dec. 3rd week | 50 | 0.00 | 0.00 | - | - | 0.40 | 6.83 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0 | 0.00 | - | - |
| Dec. 4th week | 51 | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0 | 0.00 | - | - |
| Dec. 5th week | 52 | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0 | 0.00 | - | - |
| Jan. 1st week | 1 | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0 | 0.00 | - | - |
| Jan. 2nd week | 2 | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0 | 0.00 | - | - |
| Jan. 3rd week | 3 | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0 | 0.00 | - | - |
| Jan. 4th week | 4 | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - | - | 0 | 0.00 | - | - |
| **Mean** | | **4.69** | **12.29** | - | - | **2.15** | **4.95** | - | - | **0.97** | **3.83** | - | - | **0.62** | **1.33** | - | - | **3.66** | **13.68** | - | - | **3.53** | **11.51** | - | - |

N- No. of snails/ $4m^2$, D- Leaf damage (%)

4.1.1.1.3.2 On neem

From table 5 it is clear that, during 41st std week the mean maximum number of snails were recorded 2.10/4m$^2$. The mean snail population was ranged from 0.00 to 2.10 per 4 m$^2$ nursery with mean of 0.62/4m$^2$. The average leaf damage from June 2015 to January 2016 was 1.33 per cent per 4 m$^2$ inside the neem nursery. While during 41st std week, the maximum damage was 4.30 per cent which coincide with the highest snail population.

4.1.1.1.4 In forest nursery, Sanjeevini Park, Dharwad

4.1.1.1.4.1 On papaya

The data presented in table 5 on the incidence of *A. fulica* on papaya revealed that, the first appearance of snails was noticed during 24th standard week and persisted in nursery up to 47th standard week. The snail population inside the nursery ranged from 0.00 to 12.90 per 4 m$^2$ with average of 3.66. The maximum leaf damage of snails was (37.20 %) was noticed in 41st standard week with a mean of 13.68 per cent.

4.1.1.1.4.2 On teak

The activity of snails on teak nursery was recorded from 24th std week to 49th std week. The average population ranges from 0.00 to 9.60 per 4m$^2$ with a seasonal mean of 3.53/4m$^2$. The highest leaf damage of 27.32 per cent was recorded at 44nd std week with average of 11.51 per cent.

4.1.1.1 4 Other places

Survey was also conducted in other nurseries like forest nurseries, Kelageri water tank; forest nurseries, Gungargatti; forest nurseries, Sirsi; ARS, Malagi, ZHRS, Kumbhapur; medical/aromatic nursery, Saidpur Farm on different seedlings *viz.* guava, papaya, pongamia, *Myristica sp, Beilschmiedia sp.* and citrus. But there was no infestation of snail during *kharif*, 2015. Similarly, the incidence of slugs was also not noticed in different nurseries surveyed during June to January, 2015-16.

## 4.1.2 Correlation Co-efficient between population of snails and weather parameters during *kharif*, 2015.

The data on population of snails collected in Dharwad was correlated with the prevailing climatic weather parameters and the results are given in the table 6. Data revealed that, snail population positively correlated with rainfall, relative humidity and minimum temperature irrespective of the nurseries where it was negatively correlated with maximum temperature.

## 4.1.3 Collection and identification of snail and slug species

Snails/ slugs were collected from the infested fields from various localities of Hangal and Ranebennur taluks of Haveri district and identified by Dr. Venkitesan, Sr. Scientist, Zoological Survey of India, Southern Regional Centre and Chennai.

**Table 6. Correlation coefficient between snail population of *Achatina fulica* and weather parameters (*Kharif*, 2015)**

| Parameters | Moringa (HHU) | Mango | Jamun | Curry Leaf | Silver oak | Teak (KC park) | Neem | Papaya |
|---|---|---|---|---|---|---|---|---|
| **Max. temp.** | -0.022 | -0.004 | -0.010 | -0.013 | -0.027 | -0.028 | -0.013 | -0.017 |
| **Min. temp.** | 0.654** | 0.547** | 0.635** | 0.514** | 0.653** | 0.466** | 0.514** | 0.586** |
| **RH** | 0.669** | 0.665** | 0.578** | 0.604** | 0.647** | 0.504** | 0.481** | 0.616** |
| **Rain fall** | 0.457** | 0.481** | 0.454** | 0.441* | 0.452** | 0.461** | 0.380* | 0.544** |

** Significant at 0.01 level (2-tailed)

*. Significant at 0.05 level (2-tailed)

4.1.3.1 Identification of snails

Phylum : Mollusca

Class :Gastropoda

Order: Stylommatophora

A. Superfamily :Helicarionoidea

Family: Ariophantidae

Genus: *Mariaella*

*Mariaella dussumieri* (Godwin-Austen, 1888)

*Mariaella beddomei* (Godwin-Austen, 1888) (Plate 3a, 3b)

Place of collection: Shirodagi village in Haveri District

Crop: Banana and Arecanut.

B. Superfamily :Veronicelloidea

Family: Veronicellidae

Genus: *Laevicaulis*

*Laevicaulis alte* (Plate 4)

Place of collection: Galipuji village in Haveri District

Crop: Banana

C. Superfamily: Helicarionoidea

Family: Helicarionidae

Genus: *Pseudaustenia*

*Pseudaustenia ater* (Godwin-Austen, 1888). (Plate. 5a, 5b)

Place of collection: Shirodagi village in Haveri District

Crop: Arecanut

4.1.3.2 Identification of snails.

Phylum : Mollusca

Class :Gastropoda

Order: Stylommatophora

A. Superfamily: Helicarionoidea

Family: Ariophantidae

Subfamily: Macrochlamydinae

**Plate 3a. Mariaella beddomei (Godwin-Austen, 1888). Brown**

**Plate 3b. Mariaella beddomei (Godwin-Austen, 1888)**

Juvenile Adult

**Plate 4. Laevicaulis alte (Férussac, 822)**

**Plate 5a. Pseudaustenia ater(Godwin-Austen, 1888)**

**Plate 5b. Pseudaustenia ater (Godwin-Austen, 1888)**

**Plate 6. Macrochlamys indica (Godwin – Austen 1908)**

**Plate 7a Macrochlamys pedina (Benson, 1865)**

**Plate 8. Ventral and dorsal view of Rachis punctatus (Anton, 1838)**

**Plate 9. Ventral and dorsal view of Allopeas gracile (Hutton, 1834)**

*Genus: Macrochlamys*

*Macrochlamys indica* Godwin – Austen 1908 (Plate 6)

*Macrochlamys pedina* (Benson, 1865) (Plate 7)

Place of collection: Kakol

Crop: Betelvine

B. Superfamily: Buliminoidea

Family: Cerastuidae

Genus : Rachis

*Rachis punctatus* (Anton 1839) (Plate 8)

Place of collection: Hangal

Crop: Areca nut and pepper

C. Superfamily: Achatinoidea

Family: Subulinidae

Genus: *Allopeas*

*Allopeas gracile* (Hutton, 1834) (Plate 9)

Place of collection: Hangal

Crop: Areca nut and pepper

## 4.2 To assess the damage potential caused by giant African snail, *Achatina fulica* in various forest and horticultural nurseries

### A. Per cent foliage damage

### 4.2.1 One day after release (DAR)

The damage potential of giant African snail, *A. fulica* on different forest and horticulture saplings of 3 to 5 months age (Table 7) indicated that, among the saplings moringa recorded significantly the highest leaf damage of 15.23 per cent at 1 DAR. The damage on citrus, papaya and curry leaf was 12.78, 11.50 and 9.69 per cent, respectively indicated the preference of snails next to moringa. Whereas, least damage noticed on the rest of the saplings *viz.,* pongamia, neem, banyan, almond and silver oak which had recorded 2.95, 2.90, 2.75, 2.35 and 1.10 per cent leaf damage, respectively.

### 4.2.2 Three days after release

At 3 DAR, moringa, papaya and teak recorded highest damage of 33.12, 29.22 and 25.25 per cent, respectively and on par with each other. While damage on citrus, curry, tabubia, sisso, neem, guava, tamarind, pongamia, silver oak and almond was 22.50, 18.81, 16.69, 13.99, 11.15, 10.77, 10.42, 7.60 and 7.30 per cent, respectively. Whereas, the least damage was observed on the other saplings *viz.,* subabul, mango, banyan and jamun were 6.80, 6.35, 5.30, 4.75 per cent, respectively.

**Table 7. Per cent of leaf damage by giant African snail, *Achatina fulica* on different forest and horticulture saplings (3 to 5 months) during *kharif,* 2015**

| Sl. No | Saplings | Cumulative leaf damage (%) | | | | |
|---|---|---|---|---|---|---|
| | | 1 DAR | 3 DAR | 5 DAR | 7 DAR | 10 DAR |
| 1 | Neem (*Azadirachta indica* A.) | 2.90 (9.80) ij** | 11.15 (19.51) fgh | 22.75 (28.49) cde | 40.95 (39.79) c | 44.65 (41.93) def |
| 2 | Tabubia (*Tabebuia chrysotricha* Mart.) | 7.00 (15.53) d | 16.69 (24.11) def | 28.87 (32.50) c | 40.50 (39.52) c | 54.04 (47.32) cd |
| 3 | Pongamia (*Pongamia* sp.) | 2.96 (9.91) hij | 7.54 (15.94) hi | 13.37 (21.45) fgh | 17.35 (24.62) fgh | 19.79 (26.41) hi |
| 4 | Almond (*Prunus amygdalus* l.) | 2.35 (8.82) j | 7.30 (15.68) hi | 13.75 (21.77) fgh | 20.95 (27.24) efg | 30.35 (33.43) fgh |
| 5 | Teak (*Techtona grandies* L.) | 6.90 (15.23) d | 25.25 (30.17) abc | 45.50 (42.42) b | 59.75 (50.62) b | 68.55 (55.89) bc |
| 6 | Silver oak (*Grevilla robabus*ta A.Cunn) | 1.10 (6.02) k | 7.60 (16.00) hi | 15.60 (32.26) efg | 23.20 (28.79) def | 28.00 (31.95) gh |
| 7 | Tamarind (*Tamarindus indica* L.) | 4.26 (11.91) efg | 10.42 (18.83) gh | 18.55 (25.51) ef | 26.13 (30.74) def | 35.03 (36.29) efg |
| 8 | Sisso (*Delbergia sissoo* Rosb.) | 4.12 (11.71) efgh | 13.99 (21.96) efg | 24.86 (29.91) cd | 35.03 (36.21) cd | 53.46 (46.98) cd |
| 9 | Banyan (*Ficus bengalensis* L.) | 2.75 (9.55) ij | 5.30 (13.31) i | 7.49 (15.88) h | 10.41 (18.82) h | 13.74 (21.76) i |
| 10 | Subabul (*Leaucaena leucocephala* Lam.) | 4.74 (12.57) ef | 6.80 (15.12) hi | 12.55 (20.75) fgh | 15.28 (23.09) fgh | 17.66 (24.85) hi |
| 11 | Jamun (*Syzeygium cumini* L.) | 3.35 (10.55) ghij | 4.75 (12.59) i | 9.20 (17.66) gh | 12.72 (20.89) gh | 17.87 (25.01) hi |
| 12 | Citrus (*Citrus* sp.) | 12.78 (20.95) b | 22.50 (28.32) bcd | 42.86 (40.90) b | 59.28 (50.35) b | 71.20 (57.54) b |
| 13 | Moringa (*Moringa oleifera* Lam.) | 15.23 (22.97) a | 33.12 (35.13) a | 60.93 (51.31) a | 81.33 (64.40) a | 95.78 (78.15) a |
| 14 | Guava (*Psidium guajava* L.) | 3.55 (10.86) fghi | 10.77 (19.16) fgh | 18.93 (25.79) def | 30.05 (33.24) cde | 48.03 (43.87) de |
| 15 | Papaya (*Carica papaya* L.) | 11.50 (19.82) bc | 29.22 (32.72) ab | 47.83 (43.76) b | 72.82 (58.58) a | 94.81 (76.83) a |
| 16 | Mango (*Mangifera indica* L.) | 5.35 (13.37) e | 6.35 (14.60) hi | 9.00 (17.46) gh | 11.55 (19.87) gh | 14.79 (22.62) i |
| 17 | Curry leaf (*Murraya* koenigii L.) | 9.69 (18.14) c | 18.81 (25.70) cde | 28.02 (31.98) cd | 40.16 (39.33) c | 55.24 (48.01) cd |
| S.Em± | | 0.59 | 1.59 | 2.69 | 2.00 | 2.79 |
| C.D. @ 5% | | 1.79 | 4.77 | 8.07 | 6.00 | 8.38 |
| C.V. (%) | | 14.31 | 16.14 | 15.37 | 9.47 | 8.84 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at p = 0.05 as per DMRT.

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### 4.2.3 Five days after release

Similarly at 5 DAR also moringa was the most preferred host by recording significantly the highest cumulative leaf damage (60.93 %). The next best preferred hosts included papaya (47.83 %), teak (45.50 %) and citrus (42.86 %). However, the least preferred hosts included subabul, jamun, mango and banyan which registered the foliage damage ranging from 7.49 to 12.55 per cent.

### 4.2.4 Seven days after release

The cumulative damage inflicted by snail at 7 DAR ranged from 10.41 to 81.33 per cent. Moringa and papaya were the most preferred hosts by recording the significantly the highest damage (81.33 and 72.83 per cent) which were at par with each other but differ significantly with all other hosts like, teak (59.75 %), citrus (59.28 %), neem (40.95 %), tabubia (40.50 %), curry (40.16 %), sisso (30.03 %), guava (30.05 %), tamarind (26.13 %), silver oak (23.20 %), almond (20.95 %), pongamia (17.35 %), subabul (15.28 %), jamun (12.72 %) and mango (11.55 %) were next best preferred hosts. Whereas, the least damage of 10.41 per cent recorded on banyan.

### 4.2.5 Ten days after release

Similar trend was continued with respect to cumulative per cent foliage damage recorded at 10 DAR. Moringa and papaya by recording 95.78 and 94.81 per cent damage did not differ significantly with each other but significantly differ with all other hosts. Likewise the next best preferred hosts includes citrus, teak, curry, tabubia, sisso, guava, neem, tamarind, almond, silver oak, pongamia, jamun and subabul which recorded 17.66 to 71.20 per cent damage.

### B. Per cent plant damage at ten days after release by GAS

The data presented in the table 8 on per cent damage to different forest and horticulture samplings of 3 to 5 months by giant African snail, *A. fulica* indicated that the per cent sapling damage ranged from 31.00 to 96.00 per cent at 10 DAR. Among the different saplings, moringa recorded the highest damage of 96.00 per cent. While damage on other saplings like papaya, sisso, citrus, tabubia, teak/guava, tamarind, curry leaf, almond, subabul, silver oak, mango, neem jamun was recorded 94.00, 92.00, 81.00, 73.00, 72.00, 67.00, 65.00, 55.00, 54.00, 52.00, 48.00 and 47.00 per cent, respectively. And the least damage noticed on pongamia and banyan were 37.00 and 31.00 per cent, respectively (Plate 10).

## 4.3 To assess the damage potential caused by brown slug, *Laevicaulis alte* Ferussac in forest and horticultural nurseries

### A. Per cent foliage damage

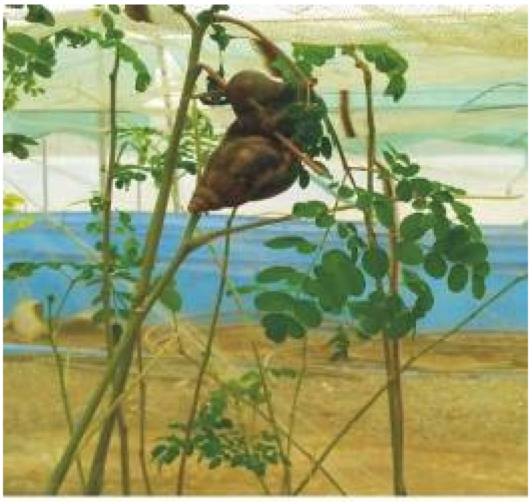
### 4.3.1 One day after release

The damage potential of brown slug, *L. alte* on different forest and horticulture samplings of 3 to 5 months (Table 9) concurred that, among the sampling moringa had the highest leaf damage of 1.71 per cent.

The cumulative leaf damage indicated that the next best preferred hosts were papaya, tabubia, citrus, teak and curry recorded 1.47, 1.32, 1.32, 0.93 and 0.56 per cent, respectively. While the rest of the saplings *viz.,* sisso, guava, neem, tamarind, almond, silver oak, pongamia, jamun, subabul, mango and banyan were not affected at 1 DAR.

**Table 8. Preference difference by giant African snail, *Achatina fulica* to different forest and horticulture saplings (3 to 5 months) during *kharif,* 2015.**

| Sl. No | Saplings | % seedling damage at 10 DAR |
|---|---|---|
| 1 | Neem (*Azadirachta indica* A.) | 45.00 |
| 2 | Tabubia (*Tabebuia chrysotricha* Mart.) | 73.00 |
| 3 | Pongamia (*Pongamia* sp.) | 37.00 |
| 4 | Almond (*Prunus amygdalus* l.) | 55.00 |
| 5 | Teak (*Techtona grandies* L.) | 72.00 |
| 6 | Silver oak (*Grevilla robabus*ta A.Cunn) | 52.00 |
| 7 | Tamarind (*Tamarindus indica* L.) | 67.00 |
| 8 | Sisso (*Delbergia sissoo* Rosb.) | 92.00 |
| 9 | Banyan (*Ficus bengalensis* L.) | 31.00 |
| 10 | Subabul (*Leaucaena leucocephala* Lam.) | 54.00 |
| 11 | Jamun (*Syzeygium cumini* L.) | 47.00 |
| 12 | Citrus (*Citrus* sp.) | 81.00 |
| 13 | Moringa (*Moringa oleifera* Lam.) | 96.00 |
| 14 | Guava (*Psidium guajava* L.) | 72.00 |
| 15 | Papaya (*Carica papaya* L.) | 94.00 |
| 16 | Mango (*Mangifera indica* L.) | 48.00 |
| 17 | Curry leaf (*Murraya* koenigii L.) | 65.00 |
| S.Em± | | 3.06 |
| C.D. @ 5% | | 9.18 |
| C.V. (%) | | 7.02 |



Moringa

Papaya

Citrus

Teak

Sisso

**Plate 10. Snail damage on different nursery seedlings – Most Preferred**

### 4.3.2 Three days after release

At 3 DAR, moringa continued to be the most preferred seedlings by recording significantly highest damage of 3.07 per cent. While leaf damage on papaya, citrus, teak, tabubia, curry leaf, neem and sisso were 2.84, 2.52, 2.32, 2.21, 2.11, 0.48 and 0.22 per cent, respectively. Whereas, damage to subabul, guava, tamarind, silver oak, almond, mango, banyan, pongamia and jamun was not noticed at 3 DAR.

### 4.3.3 Five days after release

The cumulative damage inflicted by slug at 5 DAR ranged from 0.00 to 5.26 per cent. Moringa and papaya were the most preferred hosts by recording the significantly highest damage (5.26 and 5.12 %) which were at par with each other but differed significantly with all other hosts. Whereas, citrus (4.65 %), teak (4.36 %), tabubia (3.66 %), curry leaf (3.47 %), neem (2.05 %) and sisso (1.03 %) were next the best preferred hosts. Subabul, guava, tamarind, silver oak, almond, mango, banyan, pongamia and jamun saplings were unaffected by slug pest.

### 4.3.4 Seven days after release

At 7 DAR, the brown slug preferred curry leaf (5.23 %), citrus (7.16 %), teak (6.10 %) and tabubia (5.97 %) along with moringa (7.34 %) and papaya (6.25 %) were at par with each other. Further, the non preference trend on guava, tamarind, silver oak, almond, pongamia, subabul, jamun, mango and banyan saplings was continued.

#### 4.3.1.5 Ten days after release

Moringa, citrus and papaya were continued to be the best preferred hosts by recording significantly the highest leaf damage of 10.18, 10.15 and 9.88 per cent, respectively did not differ significantly with each other but significantly differ with all other hosts. While, non preference trend in recording damage on foliage of guava, tamarind, silver oak, almond, pongamia, subabul, jamun, mango and banyan was continued here also (Plate 11).

### 4.3.2 Per cent plant damage at 10 days after release by slugs.

The data presented in the table 10 on per cent damage inflicted to different forest and horticulture saplings of 3 to 5 months age by brown slug, *L. alte* indicated that the sapling damage ranged from 0.00 to 43.00 per cent at 10 DAR. Among the different saplings papaya had the highest damage of 43.00 per cent. However, damage on other saplings like moringa, citrus, teak, curry, tabubia, sisso and neem were recorded 41.00, 37.00, 36.00, 35.00, 32.00, 25.00 and 15.00 per cent, respectively. There was no damage recorded on other sapling *viz.,* subabul, guava, tamarind, silver oak, almond, mango, pongamia, jamun and banyan.

## 4.4 Management of giant African snail, *Achatina fulica*

### 4.4.1 In forest/ horticulture nursery.

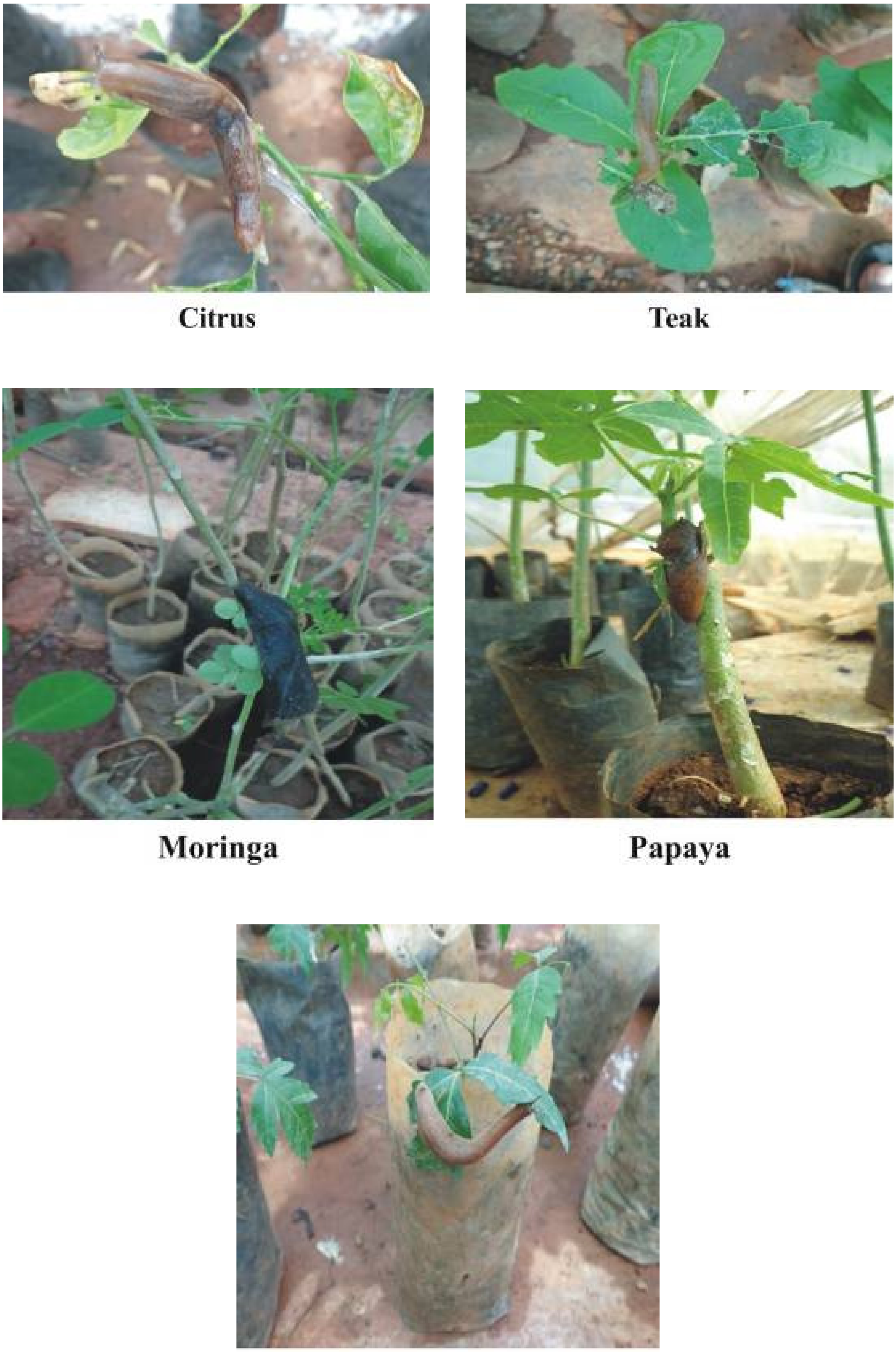
#### 4.4.1.1 First Application.

Nine different treatments were imposed to know their efficacy against GAS (Table 11). Uniform sized *A. fulica* snails were collected from fields and released at 25 numbers for each treatment containing 50 saplings enclosed in nylon net.

**Table 9. Per cent of leaf damage by brown slug, *Laevicaulis alte* Ferussac on different forest and horticulture saplings (3 to 5 months) during *kharif*, 2015**

| Sl. No | Saplings | Cumulative leaf damage (%) | | | | |
|---|---|---|---|---|---|---|
| | | 1 DAR | 3 DAR | 5 DAR | 7 DAR | 10 DAR |
| 1 | Neem (*Azadirachta indica* A.) | 0.00 (0.90) g | 0.48 (3.97) f | 2.05 (8.23) d | 3.62 (10.97) b | 4.88 (12.76) e |
| 2 | Tabubia (*Tabebuia chrysotricha* Mart.) | 1.32 (6.58) c** | 2.21 (8.55) de | 3.66 (11.03) c | 5.97 (14.14) a | 7.98 (16.41) c |
| 3 | Pongamia (*Pongamia* sp.) | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) d | 0.00 (0.90) g |
| 4 | Almond (*Prunus amygdalus* l.) | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) d | 0.00 (0.90) g |
| 5 | Teak (*Techtona grandies* L.) | 0.93 (5.53) d | 2.32 (8.76) d | 4.36 (12.05) b | 6.10 (14.03) a | 8.89 (17.35) b |
| 6 | Silver oak (*Grevilla robabus*ta A.Cunn) | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) d | 0.00 (0.90) g |
| 7 | Tamarind (*Tamarindus indica* L.) | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) d | 0.00 (0.90) g |
| 8 | Sisso (*Delbergia sissoo* Rosb.) | 0.00 (0.90) g | 0.22 (2.69) g | 1.03 (5.82) e | 1.67 (7.43) c | 2.07 (8.27) f |
| 9 | Banyan (*Ficus bengalensis* L.) | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) d | 0.00 (0.90) g |
| 10 | Subabul (*Leaucaena leucocephala* Lam.) | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) d | 0.00 (0.90) g |
| 11 | Jamun (*Syzeygium cumini* L.) | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) d | 0.00 (0.90) g |
| 12 | Citrus (*Citrus* sp.) | 1.32 (6.60) c | 2.52 (9.13) c | 4.65 (12.45) b | 7.16 (15.52) a | 10.15 (18.58) a |
| 13 | Moringa (*Moringa oleifera* Lam.) | 1.71 (7.51) a | 3.07 (10.09) a | 5.26 (13.26) a | 7.34 (15.72) a | 10.18 (18.61) a |
| 14 | Guava (*Psidium guajava* L.) | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) d | 0.00 (0.90) g |
| 15 | Papaya (*Carica papaya* L.) | 1.47 (6.96) b | 2.84 (9.70) b | 5.12 (13.07) a | 6.25 (14.48) a | 9.88 (18.32) a |
| 16 | Mango (*Mangifera indica* L.) | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) d | 0.00 (0.90) g |
| 17 | Curry leaf (*Murraya* koenigii L.) | 0.56 (4.29) f | 2.11 (8.35) e | 3.47 (10.74) c | 5.23 (13.22) ab | 7.03 (15.58) d |
| S.Em± | | 0.04 | 0.09 | 0.13 | 0.91 | 0.25 |
| C.D. @ 5% | | 0.13 | 0.27 | 0.40 | 0.56 | 0.76 |
| C.V. (%) | | 16.14 | 13.67 | 10.90 | 10.34 | 9.91 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at $p = 0.05$ as per DMRT.



Citrus

Teak

Moringa

Papaya

Neem

**Plate 11. Brown slug, Laevicaulis alte damage on different nursery seedlings**

**Table 10. Preference difference by brown slug, *Laevicaulis alte* on different forest and horticulture saplings (3 to 5 month during *kharif*, 2015.**

| Sl. No | Saplings | % seedling damage at 10 DAR |
|---|---|---|
| 1 | Neem (*Azadirachta indica* A.) | 15.00 |
| 2 | Tabubia (*Tabebuia chrysotricha* Mart.) | 32.00 |
| 3 | Pongamia (*Pongamia* sp.) | 0.00 |
| 4 | Almond (*Prunus amygdalus* l.) | 0.00 |
| 5 | Teak (*Techtona grandies* L.) | 36.00 |
| 6 | Silver oak (*Grevilla robabus*ta A.Cunn) | 0.00 |
| 7 | Tamarind (*Tamarindus indica* L.) | 0.00 |
| 8 | Sisso (*Delbergia sissoo* Rosb.) | 25.00 |
| 9 | Banyan (*Ficus bengalensis* L.) | 0.00 |
| 10 | Subabul (*Leaucaena leucocephala* Lam.) | 0.00 |
| 11 | Jamun (*Syzeygium cumini* L.) | 0.00 |
| 12 | Citrus (*Citrus* sp.) | 37.00 |
| 13 | Moringa (*Moringa oleifera* Lam.) | 41.00 |
| 14 | Guava (*Psidium guajava* L.) | 0.00 |
| 15 | Papaya (*Carica papaya* L.) | 43.00 |
| 16 | Mango (*Mangifera indica* L.) | 0.00 |
| 17 | Curry leaf (*Murraya* koenigii L.) | 35.00 |
| S.Em± | | 1.61 |
| C.D. @ 5% | | 4.83 |
| C.V. (%) | | 14.34 |

**Table 11. Evaluation of different chemicals and poison baits against giant African snail in forest/ horticulture nursery during *kharif*, 2015 (1st Application)**

| Sl. No. | Treatment | Dosage (kg/ha) | Cumulative mortality of snails (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 DAT | 3 DAT | 5 DAT | 7 DAT | 10 DAT | 15 DAT |
| 1 | Bleaching Powder | 25 | 26.67 (31.09) b | 38.67 (38.45) c | 53.33 (46.89) b | 65.33 (53.92) c | 73.33 (58.90) c | 84.00 (66.42) c |
| 2 | Crystal Salt | 25 | 44.00 (41.55) a | 62.67 (52.34) a | 73.33 (58.91) a | 88.00 (69.73) a | 92.00 (73.57) a | 92.00 (73.57) b |
| 3 | Methomyl 40 SP poison bait | 60 | 21.33 (27.27) c | 34.67 (36.07) d | 42.67 (40.78) c | 54.67 (47.67) d | 65.33 (53.93) d | 78.67 (62.49) d |
| 4 | $CuSo_4$ poison bait | 60 | 18.67 (25.60) d | 29.33 (32.79) e | 38.67 (38.45) cd | 49.33 (44.62) e | 62.67 (52.33) d | 72.00 (58.05) e |
| 5 | Thiodicarb 75 WP poison bait | 60 | 17.33 (24.60) d | 28.00 (31.94) ef | 37.33 (37.66) d | 46.67 (43.09) e | 54.67 (47.67) f | 70.67 (57.20) e |
| 6 | Tobacco Powder | 25 | 13.33 (21.41) e | 25.33 (30.21) f | 40.00 (39.23) cd | 49.33 (44.62) e | 58.67 (49.99) e | 62.67 (52.34) f |
| 7 | Boric Powder | 25 | 4.00 (11.53) f | 10.67 (19.06) g | 13.33 (21.41) e | 14.67 (22.52) f | 18.67 (25.60) g | 24.00 (29.33) g |
| 8 | Metaldehyde2.5% pallets | 5 | 28.00 ** (31.94) b | 48.00 (43.85) b | 57.33 (49.21) b | 74.67 (59.78) b | 86.67 (68.58) b | **93.33** (75.03) a |
| 9 | Control | --- | 0.00 (0.60) g | 0.00 (0.60) h | 0.00 (0.60) f | 0.00 (0.60) g | 0.00 (0.60) h | 0.00 (0.60) h |
| S.Em± | | | 0.48 | 0.71 | 0.92 | 0.80 | 0.71 | 0.45 |
| C.D. @ 5% | | | 1.44 | 2.14 | 2.75 | 2.40 | 2.12 | 1.36 |
| C.V. (%) | | | 17.25 | 16.02 | 16.08 | 11.29 | 8.61 | 4.91 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at p = 0.05 as per DMRT.

4.4.1.1.1 A day after treatment

The results on the effect of various insecticides, poison baits, dehydrating chemicals in comparison with metaldehyde as standard check revealed that crystal salt produced the maximum snail mortality of 44.00 per cent was significantly superior over all other treatments. The standard check metaldehyde and bleaching powder which documented, 28.00 and 26.67 per cent snail mortality, respectively by exerted similar effect. The next best treatment was methomyl with 21.3 per cent snail mortality. Whereas $CuSO_4$ and thiodicarb documented 18.67 and 17.33 per cent, respectively mortality which were on par with each other. The tobacco powder and boric powder were least effective by recording 13.00 and 4.00 per cent mortality.

4.4.1.1.2 Three days after treatment

At 3 DAT, crystal salt @ 25 kg/ha resulted the snail mortality of 62.67 per cent was significantly superior over all other treatments including the standard check metaldehyde (48.00 %). The next best were bleaching powder and methomyl by recording 38.67 and 34.67 per cent mortality,respectively, significantly differ from each other. Again copper sulphate poison bait and thiodicarb 75 WP recorded 29.33 and 28.00 per cent mortality, respectively and produced similar effect. Tobacco powder documented 25.33 per cent mortality. Boric powder recorded the lowest mortality with 10.67 per cent snail death.

4.4.1.1.3 Five days after treatment

Again crystal salt emerged as the best treatment by recording significantly highest mortality of 73.33 per cent at 5 DAT was superior over other treatments including standard check. However, metaldehyde and bleaching powder produced 57.33 and 53.33 per cent snail mortality, respectively and exerted similar effect. Methomyl, tobacco powder and copper sulphate poison bait had 42.67, 40.00 and 38.67 per cent mortality, respectively which were on par with each other. Thiodicarb and Boric powder documented 37.33 and 13.33 per cent mortality, respectively (Plate 12).

4.4.1.1.4 Seven days after treatment

At 7 DAR, crystal salt continued to be the effective treatment by recording significantly highest snail mortality of 88.00 per cent and excelled over standard check metaldehyde (74.67 %). This was followed by bleaching powder and methomyl poison bait with maximum mortality of 65.33 and 54.67 per cent, respectively. While, copper sulphate poison bait (49.33 %), tobacco powder (49.33 %) and thiodicarb poison bait (46.67 %) were next best and were on par with each other. Boric powder was least effective by recording lowest mortality (14.67 %). All the treatments except crystal salt were inferior to the standard check.

4.4.1.1.5 Ten days after treatment

Among the different treatments crystal salt again excelled standard check metaldehyde (86.67 %) by recording significantly highest mortality of 92.00 per cent. The bleaching powder (73.33 %), methomyl poison bait (65.33 %) and copper sulphate poison bait (62.67 %) snails effectively on par with each other but inferior to the standard check. The treatments *viz.*, thiodicarb poison bait, tobacco powder and boric powder recorded 58.67, 54.67 and 18.67 per cent mortality which were significantly differ from each other.

Metaldehyde

Crystal salt

Bleaching powder

Methomyl PB

Thiodicarb PB

Tobacco powder

**Plate 12. Mortality of GAS, *Achatina fulica* due to different**

4.4.1.1.6 Fifteen days after treatment

Significantly higher mortality was documented in standard check metaldehyde (93.33 %) at 15 DAT. This was followed by crystal salt (92.00 %), bleaching powder (84.00 %) and methomyl poison bait (78.67 %). Whereas, copper sulphate poison bait and thiodicarb recorded 72.67 and 72.00 per cent mortality, respectively which were on par with each other but inferior to the standard check. Tobacco powder and boric powder registered mortality of 62.67 and 24.00 per cent, respectively.

4.4.1.2 Second Application.

After 15 days of the first application second application was imposed. Nine different treatments were evaluated to know their efficacy against GAS (Table 12).

4.4.1.2.1 A day after treatment

At 1 DAT, application of crystal salt @ 25 kg $ha^{-1}$ recorded the maximum mortality of 54.67 per cent was significantly superior over all other treatments including standard check metaldehyde (34.67 %). This was followed by bleaching powder @ 25 kg $ha^{-1}$ by documenting, 36.00 per cent snail mortality was at par with the standard check. Whereas, methomyl and $CuSo_4$ poison baits recorded 26.67 and 25.33 per cent mortality which were on par with each other. Thiodicarb poison bait, tobacco powder recorded 24.00 and 17.33 per cent mortality which significantly differed from each other. Application of boric powder resulted that the lowest mortality (6.00 %). All the treatments except crystal salt were inferior to the standard check.

4.4.1.2.2 Three days after treatment

At 3 DAT, crystal salt revealed the maximum mortality of 66.67 per cent was significantly superior over all other treatments including the standard check metaldehyde (46.67 %). However, bleaching powder effected 57.33 per cent mortality was at par with the standard check. Whereas, thiodicarb poison bait and methomyl poison baits were registered 40.00 and 38.67 per cent mortality, respectively which were on par with each other. While, copper sulphate poison bait (33.33 %) and tobacco powder (29.33 %) were the next best treatments. Again, boric powder could produce the lowest mortality of 8.00 per cent.

4.4.1.2.3 Five days after treatment

Among the different treatments the crystal salt by recording significantly the highest mortality of 76.00 percent excelled over the treatments including the standard check (57.33 %). While, standard check metaldehyde 2.5 % pellets and methomyl poison baits registered 57.33 and 54.67 per cent mortality, respectively which were on par with each other. The treatments *viz.*, copper sulphate poison bait, thiodicarb poison bait, tobacco powder and boric powder recorded 49.33, 46.00, 42.67 and 10.00 per cent mortality which were significantly differ from each other and inferior to the standard check.

**Table 12. Evaluation of different chemicals and poison baits against giant African snail in forest/ horticulture nursery during *kharif*, 2015 (2[nd] Application)**

| Sl. No. | Treatment | Dosage (kg/ha) | Cumulative mortality of snails (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 DAT | 3 DAT | 5 DAT | 7 DAT | 10 DAT | 15 DAT |
| 1 | Bleaching Powder | 25 | 36.00 (36.87) b | 57.33 (49.22) b | 64.00 (53.13) b | 73.33 (58.91) b | 82.67 (65.40) c | 88.00 (69.73) c |
| 2 | Crystal Salt | 25 | 54.67 (47.68) a | 66.67 (54.74) a | 76.00 (60.67) a | 82.67 (65.40) a | 86.67 (68.58) b | 90.67 (72.21) b |
| 3 | Methomyl 40 SP poison bait | 60 | 26.67 (31.09) c | 38.67 (38.45) d | 54.67 (47.68) c | 65.33 (53.93) c | 76.00 (60.67) d | 81.33 (64.40) d |
| 4 | $CuSo_4$ poison bait | 60 | 25.33 (30.22) cd | 33.33 (35.26) e | 49.33 (44.62) d | 60.00 (50.77) d | 70.67 (57.21) e | 76.00 (60.67) e |
| 5 | Thiodicarb 75 WP poison bait | 60 | 24.00 (29.33) d | 40.00 (39.23) d | 46.00 (42.71) e | 56.00 (48.45) e | 68.00 (55.55) f | 74.00 (59.34) e |
| 6 | Tobacco Powder | 25 | 17.33 (24.60) e | 29.33 (32.79) f | 42.67 (40.78) f | 52.00 (46.15) f | 58.67 (49.99) g | 65.33 (53.93) f |
| 7 | Boric Powder | 25 | 6.00 (14.18) f | 8.00 (16.43) g | 10.00 (18.43) g | 14.00 (21.97) g | 18.00 (25.10) h | 20.00 (26.57) g |
| 8 | Metaldehyde2.5% pallets | 5 | 34.67 ** (36.07) b | 46.67 (43.09) c | 57.33 (49.22) c | 70.67 (57.21) b | 89.33 (70.93) a | 94.67 (76.65) a |
| 9 | Control | --- | 0.00 (0.60) g | 0.00 (0.60) h | 0.00 (0.60) h | 0.00 (0.60) h | 0.00 (0.60) i | 0.00 (0.60) h |
| S.Em± | | | 0.56 | 0.70 | 0.59 | 0.59 | 0.54 | 0.54 |
| C.D. @ 5% | | | 1.68 | 2.11 | 1.77 | 1.77 | 1.61 | 1.62 |
| C.V. (%) | | | 15.49 | 13.81 | 9.17 | 7.80 | 6.10 | 5.69 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at p = 0.05 as per DMRT.

#### 4.4.1.2.4 Seven days after treatment

Among the different dehydrating chemicals and poison baits, crystal salt continued to record the maximum mortality of 82.67 per cent was significantly superior over all other treatments including standard check (70.67 %). This was followed by bleaching powder (73.33 %) which was on par with the standard check. Whereas, methomyl, copper sulphate, thiodicarb, tobacco powder and boric powder registered 65.33, 60.00, 56.00, 52.00 and 14.00 per cent snail mortality, respectively this significantly differed from each other and inferior to the standard check.

#### 4.4.1.2.5 Ten days after treatment

At 10 DAT, metaldehyde registeded the maximum mortality of 89.33 per cent was significantly superior over all other treatments. However, crystal salt and bleaching powder were proved as next best treatments causing 86.67 and 82.00 per cent mortality. Whereas, methomyl 40 SP, copper sulphate, thiodicarb 75WP and tobacco powder produced, 76.00, 70.67, 68.00 and 58.67 per cent mortality, respectively. Again boric powder had the least per cent mortality (18.00 %).

#### 4.4.1.2.6 Fifteen days after treatment

At 15 DAT the trend observed at 10 DAT was continued with efficacy of various treatments. Metaldehyde, crystal salt, bleaching powder and methomyl poison bait resulted the maximum mortality of 94.67, 90.67, 88.00 and 81.33 per cent, respectively, while, copper sulphate and thiodicarb poison bait recorded with 76.00 and 74.00 per cent mortality which were produced similar effect. Tobacco powder and boric powder had 65.33 and 20.00 per cent mortality, respectively.

### 4.4.2 In protected cultivation of capsicum.

#### 4.4.2.1 First Application

The observations recorded on the per cent mortality of giant African snail to evaluate the efficacy of different dehydrating chemicals and poison baits on capsicum crop (30 days after sowing) are presented in table 13. Before imposition of treatment uniform sized *A. fulica* were collected from fields and released at 10 numbers for each treatment.

#### 4.4.2.1.1 A day after treatment

The data on mortality of snails obtained at 1 DAT ranged from 0.00 to 43.33 per cent. The maximum mortality of 43.33 per cent was recorded in crystal salt and was significantly superior over all other treatments including the standard check metaldehyde (36.67 %). This was followed by bleaching powder (30.00 %) copper sulphate (26.67 %) and thiodicarb poison baits (26.67 %). Tobacco powder and methomyl poison bait effected 23.33 and 20.00 per cent mortality, respectively. While boric powder could cause only 3.33 per cent snail mortality.

#### 4.4.2.1.2 Three days after treatment

At 3 DAT, the trend in treatment efficacy observed at 1 DAT was continued. Application of crystal salt registered significantly the highest mortality of 63.33 per cent proved to be superior over others including the standard check metaldehyde (56.67 %). The bleaching powder were next best treatment to be followed by recording 46.67 per cent. As seen in earlier application boric powder was the least effective by registering only 6.67 snail mortality.

4.4.2.1.3 Fifth day after treatment

At 5 DAT, standard check metaldehyde registered the highest mortality (76.67 %) instead of crystal salt and found significantly superior to other treatments. However, application of crystal salt and bleching powder/ thiodicarb stood next best options by recording 73.33 and 56.67 per cent snail mortality. Application of tobacco powder and boric powder brought mortality of 50.00 and 16.67 per cent, respectively.

4.4.2.1.4 Seven days after treatment

The treatment efficacy trend observed at 5 DAT was repeated at 7 DAT also wherein standard check molluscicide once again proved effective by recording 83.33 per cent snail mortality. Again application of crystal salt (80 %) and bleching powder (63.33 %) were found effective alternatives of snail management. Application copper sulphate, methomyl and thiodicarb as poison baits were found effective treatments compared to tobacco powder and boric powder.

4.4.2.1.5 Ten days after treatment

At 10 DAT, metaldehyde as standard check continued to be the effective treatment by registering the highest mortality of (86.67 %) which was significantly superior over all other treatments. Application of crystal salt (83.33 %), bleaching powder (70 %) and methomyl poison bait (63.33 %) were proved next best effective treatments for management of GAS under poly house condition. The significantly least mortality was continued in the application of boric powder (30 %).

4.4.1.2.6 Fifteen days after treatment

Significantly the highest mortality of GAS was documented in standard check metaldehyde (90.00 %) at 15 DAT. This was followed by crystal salt (86.67 %), bleaching powder (83.33 %), methomyl poison bait (76.67 %), copper sulphate poison bait (73.33), thiodicarb poison bait (70.00 %) and tobacco powder (66.67 %). However, boric powder recorded 36.67 per cent mortality (Plate 13).

4.4.2.2 Second Application

After 15 days of the first application second application was imposed. Nine different treatments were evaluated including the standard check metaldehyde pellets to know their efficacy against GAS (Table 14). Uniform sized *A. fulica* were collected from fields and released at 10 numbers for each treatment.

4.4.2.2.1 A day after treatment

The data on mortality of snails obtained at 1 DAT ranged from 0.00 to 56.67 per cent. The maximum mortality of 56.67 per cent was recorded in crystal salt and was significantly superior over all other treatments including the standard check metaldehyde (36.67 %). This was followed by bleaching powder with 40.00 per cent mortality, thiodicarb poison bait with 33.33 per cent mortality and methomyl poison bait with 30.00 per cent mortality, which differed from each other. Whereas, copper sulphate poison bait and tobacco powder both were observed found to be less effective with 26.67 per cent mortality. No mortality was recorded in boric powder treatment.

**Table 13. Evaluation of different chemicals and poison baits against giant African snail in protected cultivation of capsicum during *kharif*, 2015 (1st Application)**

| Sl. No. | Treatment | Dosage (kg/ha) | Cumulative mortality of snails (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 DAT | 3 DAT | 5 DAT | 7 DAT | 10 DAT | 15 DAT |
| 1 | Bleaching Powder | 25 | 30.00 (33.21) c | 46.67 (43.09) c | 56.67 (48.83) c | 63.33 (52.73) c | 70.00 (56.79) c | 83.33 (65.90) c |
| 2 | Crystal Salt | 25 | 43.33 (41.17) a | 63.33 (52.73) a | 73.33 (58.91) b | 80.00 (63.43) b | 83.33 (65.90) b | 86.67 (68.59) b |
| 3 | Methomyl 40 SP poison bait | 60 | 20.00 (26.56) f | 30.00 (33.21) f | 46.67 (43.09) e | 56.67 (48.83) e | 63.33 (52.73) b | 76.67 (61.12) d |
| 4 | $CuSo_4$ poison bait | 60 | 26.67 (31.09) d | 36.67 (37.27) e | 43.33 (41.17) f | 60.00 (50.76) d | 66.67 (54.73) d | 73.33 (58.91) e |
| 5 | Thiodicarb 75 WP poison bait | 60 | 26.67 (31.09) d | 43.33 (41.17) d | 56.67 (48.83) c | 63.33 (52.73) c | 66.67 (54.73) d | 70.00 (56.79) f |
| 6 | Tobacco Powder | 25 | 23.333 (28.88) e | 36.67 (37.27) e | 50.00 (45.00) d | 53.33 (46.91) f | 63.33 (52.73) e | 66.67 (54.73) g |
| 7 | Boric Powder | 25 | 3.33 (10.51) g | 6.67 (14.97) g | 16.67 (24.08) g | 23.33 (28.88) g | 30.00 (33.21) f | 36.67 (37.26) h |
| 8 | Metaldehyde 2.5% pallets | 5 | 36.67 ** (37.26) b | 56.67 (48.83) b | 76.67 (61.12) a | 83.33 (65.90) a | 86.67 (68.59) a | 90.00 (71.57) a |
| 9 | Control | --- | 0.00 (0.90) h | 0.00 (0.90) h | 0.00 (0.90) h | 0.00 (0.90) h | 0.00 (0.90) g | 0.00 (0.90) i |
| S.Em± | | | 0.25 | 0.40 | 0.47 | 0.48 | 0.45 | 0.32 |
| C.D. @ 5% | | | 0.72 | 1.21 | 1.41 | 1.44 | 1.35 | 0.95 |
| C.V. (%) | | | 18.90 | 19.61 | 17.50 | 15.47 | 13.27 | 8.46 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at p = 0.05 as per DMRT.

Metaldehyde

Bleaching powder

Thiodicarb

Tobacco powder

Boric powder

**Plate 13. Mortality of GAS, Achatina fulica due to different treatment incapsicum under protected cultivation**

**Table 14. Evaluation of different chemicals and poison baits against giant African snail in protected cultivation of capsicum during *kharif*, 2015 (2nd Application)**

| Sl. No. | Treatment | Dosage (kg/ha) | Cumulative mortality of snails (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 DAT | 3 DAT | 5 DAT | 7 DAT | 10 DAT | 15 DAT |
| 1 | Bleaching Powder | 25 | 40.00 (39.23) b | 46.67 (43.09) c | 53.33 (46.91) c | 66.67 (54.74) b | 76.67 (61.12) c | 80.00 (63.43) c |
| 2 | Crystal Salt | 25 | 56.67 (48.83) a | 63.33 (52.73) a | 80.00 (63.43) a | 83.33 (65.91) a | 86.67 (68.58) b | 90.00 (71.57) b |
| 3 | Methomyl 40 SP poison bait | 60 | 30.00 (33.21) e | 40.00 (39.23) d | 50.00 (45.00) d | 56.67 (48.83) c | 60.00 (50.77) e | 73.33 (58.91) d |
| 4 | $CuSo_4$ poison bait | 60 | 26.67 (31.09) f | 33.33 (35.26) f | 43.33 (41.17) e | 56.67 (48.83) c | 60.00 (50.77) e | 66.67 (54.74) e |
| 5 | Thiodicarb 75 WP poison bait | 60 | 33.33 (35.26) d | 36.67 (37.27) e | 40.00 (39.23) f | 53.33 (46.91) d | 63.33 (52.73) d | 73.33 (58.91) d |
| 6 | Tobacco Powder | 25 | 26.67 (31.09) f | 33.33 (35.26) f | 43.33 (41.17) e | 53.33 (46.91) d | 56.67 (48.83) f | 63.33 (52.73) f |
| 7 | Boric Powder | 25 | 0.00 (0.90) g | 6.67 (14.96) g | 13.33 (21.42) g | 20.00 (26.57) e | 23.33 (28.88) g | 30.00 (33.21) g |
| 8 | Metaldehyde 2.5% pallets | 5 | 36.67 **(37.27) c | 56.67 (48.83) b | 73.33 (58.91) b | 83.33 (65.91) a | 90.00 (71.57) a | 93.33 (75.04) a |
| 9 | Control | --- | 0.00 (0.90) g | 0.00 (0.90) h | 0.00 (0.90) h | 0.00 (0.90) f | 0.00 (0.90) h | 0.00 (0.90) h |
| S.Em± | | | 0.30 | 0.37 | 0.41 | 0.55 | 0.51 | 0.45 |
| C.D. @ 5% | | | 0.91 | 1.11 | 1.24 | 1.65 | 1.54 | 1.35 |
| C.V. (%) | | | 18.97 | 18.24 | 16.19 | 18.15 | 15.58 | 12.33 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at p = 0.05 as per DMRT.

4.4.2.2.2 Three days after treatment

At 3 DAT, crystal salt once again proved to be effective by recording significantly the highest mortality of 63.33 per cent while the standard check metaldehyde and bleaching powder were next to follow by recording 56.67 and 46.67 per cent snail mortality, respectively.While, copper sulphate poison bait and tobacco powder both resulted in 33.33 per cent mortality and produced similar effect. Boric powder was the least effective by recording only 6.67 per cent mortality.

4.4.2.2.3 Five days after treatment

At 5 DAT, crystal salt onceagain emerged as effective treatment (80.00 %) than standard check metaldehyde (73.33 %). While, bleaching powder (53.33 %) and methomyl poison bait (50.00 %) were the next best treatments. Copper sulphate poison bait and tobacco powder produced 43.33 per cent mortality and were on par with each other. Thiodicarb and boric powder had 40.00 and 13.33 per cent mortality, respectively.

4.4.2.2.4 Seven days after treatment

At 7 DAT, standard check metaldehyde and crystal salt registering maximum mortality of 83.33 per cent were significantly superior to other treatments. Bleaching powder documented 66.67 per cent mortality. Both methomyl and copper sulphate recording 56.67 per cent mortality, were on par with each other. Again, both thiodicarb and tobacco powder were on par with each other which causing mortality of 53.33 per cent. Boric powder could produce only the least mortality of 20.00 per cent.

4.4.2.2.5 Ten days after treatment

Significantly the highest snail mortality was documented in the standard check metaldehyde pellets (90.00 %) at 10 DAT. This was followed by crystal salt (86.67 %), bleaching powder (76.67 %) and thiodicarb 75 WP (63.33 %). However, both of methomyl and copper sulphate poison baits produced 60.00 per cent mortality and were on par with each other. Tobacco powder and boric powder registered 56.67 and 23.33 per cent mortality, respectively.

4.4.2.2.6 Fifteen days after treatment

Significantly the highest mortality was documented in the standard check metaldehyde pellets (93.33 %) at 15 DAT. This was followed by crystal salt (90.00 %), bleaching powder (80.00 %), methomyl 40 SP/ thiodicarb 75 WP (73.33 %), copper sulphate (66.67) and tobacco powder (63.33 %). However, the lowest snail mortality was documented in boric powder treatment (30.00 %).

### 4.4.4 Yield

Data presented in table 18 indicate yield of capsicum ranged from 548.33 to 1212.30 q/ha obtained in different poison baits/chemical treatments. Significantly highest yield was registered in the standard check, metaldehyde (1212.33 q/ha) which was significantly superior to all the treatments. This was followed by crystal salt @ 25 kg/ha (1196.33 q/ha), bleaching powder (1180.67 q/ha), methomyl (1110.67 q/ha), thiodicarb (1106.33 q/ha), copper sulphate (1083.67 q/ha) and tobacco powder (928.00 q/ha). The least yield of 575.67 q/ha was from boric powder.

### 4.4.5 Per cent increase in yield

The maximum yield increase over control was obtained in the treatment with metaldehyde (54.77 %) followed by crystal salt (54.17 %). The next best treatments were bleaching powder (53.56 %), methomyl (50.63 %), thiodicarb (50.44 %), copper sulphate (49.40 %) and tobacco powder (40.91 %). The lowest yield increase of 4.75 per cent over control was recorded due to boric powder treatment.

### 4.4.6 Cost economics

Cost economics of different treatments under investigation revealed that the standard check metaldehyde and crystal salt gave net profit of Rs. 2227632.70 and Rs. 2190307.70 /ha, respectively. These were followed by bleaching powder, methomyl, thiodicarb, copper sulphate and tobacco powder which documented net returns of Rs. 21,51,407.70, 19,74,482.70, 1963632.70, 19,06,282.70 and 15,17,307.70 $ha^{-1}$ respectively. The lowest net profit of Rs. 6,35,232.70 $ha^{-1}$ was obtained from boric powder.

The highest benefit cost ratio was obtained from metaldehyde (2.77). This was followed by crystal salt 25 kg/ha (2.74), bleaching powder @ 25 kg/ha (2.69), methomyl 40 SP (2.50), thiodicarb 75 WP (2.45), copper sulphate @ 60 kg/ha (2.37) and tobacco powder (1.89). The lowest benefit-cost ratio was obtained from boric powder (0.79) (Table 15).

## 4.5 Management of brown slug, *Laevicaulis alte*

### 4.5.1 In forest/ horticulture nursery.

#### 4.5.1.1 First Application

Nine different treatments including standard check metaldehyde pellets were evaluated to know their efficacy against brown slug nurseries (Table 16). Uniform sized *L. alte* were collected from fields and released at 25 numbers for each treatment.

##### 4.5.1.1.1 A day after treatment

At 1 DAT, crystal salt registering the maximum mortality of 36.00 per cent was significantly superior over all other treatments including the standard check metaldehyde (25.33 %). This was followed by thiodicarb and methomyl poison bait @ 60 kg/ha documenting, 25.33 and 24.00 per cent mortality, respectively by exerting similar effect. The next best treatment was tobacco powder @ 25 kg/ha with 22.67 per cent mortality. Whereas bleaching powder and $CuSO_4$ poison baits resulting 18.67 and 17.33 per cent mortality, respectively were on par with each other and were followed by boric powder registered (2.67 %).

##### 4.5.1.1.2 Three days after treatment

Among the different treatments, crystal salt, metaldehyde 2.5 % pellets and thiodicarb recorded maximum mortality of 58.67, 41.33 and 37.33 per cent, respectively which were significantly superior to other treatments without differing each other. While, methomyl and bleaching powder had 32.00 and 30.67 per cent mortality, respectively and produced similar effect. Tobacco powder, copper sulphate and boric powder recorded 28.00, 24.00 and 2.67 per cent mortality, respectively.

**Table 15. Cost economics of different chemicals and poison bait against giant African snail, *Achatina fulica* Ferussac under protected cultivation of capsicum**

| Sl. No. | Treatments | Dosage/ha | Avg. yield (q/ha) | Per cent yield increase over control | Gross returns (Rs./ha) | Cost of cultivation (Rs./ha) | Net return (Rs./ha) | B:C ratio | Rank |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Bleaching powder | 25 kg/ha | 1180.67 | 53.56 | 29,51,675.00 | 8,00,267.30 | 21,51,407.70 | 2.69 | III |
| 2 | Crystal salt | 10 g/kg bait @ 60 kg | 1196.33 | 54.17 | 29,90,825.00 | 8,00,517.30 | 21,90,307.70 | 2.74 | II |
| 3 | Methomyl 40 SP poison bait | 10 g/kg bait @ 60 kg | 1110.67 | 50.63 | 27,76,675.00 | 8,02,192.30 | 19,74,482.70 | 2.50 | IV |
| 4 | $CuSo_4$ poison bait. | 100 g/kg bait @ 60 kg | 1083.67 | 49.40 | 27,09,175.00 | 8,02,892.30 | 19,06,282.70 | 2.37 | VI |
| 5 | Thiodicarb 75WP poison bait | 10 g/kg bait @ 60 kg | 1106.33 | 50.44 | 27,65,825.00 | 8,02,192.30 | 19,63,632.70 | 2.45 | V |
| 6 | Tobacco powder | 25 kg/ha | 928.00 | 40.91 | 23,20,000.00 | 8,02,692.30 | 15,17,307.70 | 1.89 | VII |
| 7 | Boric powder | 25 kg/ha | 575.67 | 4.75 | 14,39,175.00 | 8,03,942.30 | 6,35,232.70 | 0.79 | VIII |
| 8 | Metaldehyde 2.5% pellets | 5 kg/ha | 1212.33 | 54.77 | 30,30,825.00 | 8,03,192.30 | 22,27,632.70 | 2.77 | I |
| 9 | Control | -- | 548.33 | --- | -- | -- | -- | -- | |

Whole sale market price of hybrid capsicum during the season 2500/q. B: C ratio: Benefit cost ratio.

**Table 16. Evaluation of different chemicals and poison bait against slug (*L. alte*) in forest/ horticultural nursery during *kharif*, 2015 (1ST Application)**

| Sl. No. | Treatment | Dosage (kg/ha) | Cumulative mortality of slug (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 DAT | 3 DAT | 5 DAT | 7 DAT | 10 DAT | 15 DAT |
| 1 | Bleaching Powder | 25 | 17.33 (24.60) d | 30.67 (33.63) de | 38.67 (38.45) d | 50.67 (45.38) c | 58.67 (49.99) c | 68.00 (55.55) c |
| 2 | Crystal Salt | 25 | 36.00 (36.87) a | 58.67 (49.99) a | 69.33 (56.37) a | 77.33 (61.57) a | 85.33 (67.48) a | 88.00 (69.73) a |
| 3 | Methomyl 40 SP poison bait | 60 | 24.00 (29.33) b | 32.00 (34.45) d | 44.00 (41.55) c | 56.00 (48.45) b | 66.67 (54.74) b | 74.67 (59.78) b |
| 4 | $CuSo_4$ poison bait | 60 | 16.00 (23.58) d | 24.00 (29.33) f | 37.33 (37.66) d | 46.67 (43.03) d | 54.67 (47.68) e | 58.67 (49.99) d |
| 5 | Thiodicarb 75 poison bait | 60 | 25.33 (30.22) b | 37.33 (37.66) c | 45.33 (42.33) c | 53.33 (46.91) bc | 64.00 (53.13) b | 73.33 (58.90) b |
| 6 | Tobacco Powder | 25 | 22.67 (28.42) c | 28.00 (31.94) e | 42.67 (40.79) c | 52.00 (46.15) c | 56.00 (48.45) cd | 60.00 (50.77) d |
| 7 | Boric Powder | 25 | 2.67 (9.40) e | 2.67 (9.40) g | 5.33 (13.35) e | 16.00 (23.58) e | 21.33 (27.50) e | 25.33 (30.22) e |
| 8 | Metaldehyde2.5% pallets | 5 | 25.33 ** (30.22) b | 41.33 (40.00) b | 58.67 (49.99) b | 74.67 (59.78) a | 85.33 (67.48) a | 89.33 (70.93) a |
| 9 | Control | --- | 0.00 (0.60) f | 0.00 (0.60) h | 0.00 (0.60) f | 0.00 (0.60) f | 0.00 (0.60) f | 0.00 (0.60) f |
| S.Em± | | | 0.49 | 0.62 | 0.70 | 0.67 | 0.57 | 0.48 |
| C.D. @ 5% | | | 1.47 | 1.85 | 2.11 | 2.00 | 1.72 | 1.44 |
| C.V. (%) | | | 18.01 | 15.15 | 12.48 | 9.75 | 7.27 | 5.56 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at $p = 0.05$ as per DMRT.

#### 4.5.1.1.3 Five days after treatment

Crystal salt and standard check, metaldehyde recorded maximum mortality of 69.33 and 58.67 per cent, respectively and significantly differed from each other. Whereas, thiodicarb, methomyl and tobacco powder registering 45.33, 44.00 and 42.67 per cent were on par with each other. Bleaching powder and copper sulphate poison bait produced 38.67 and 37.33 per cent mortality, respectively and were significantly at par with each other. While, boric powder produced 5.33 per cent mortality.

#### 4.5.1.1.4 Seven days after treatment

Crystal salt and standard check metaldehyde recording maximum mortality of 77.33 and 74.67 per cent were on par with each other but significantly superior to all other treatments. Mortality of slugs was documented in methomyl poison bait, thiodicarb, tobacco powder to the same time of 56.00, 53.33 and 52.00 per cent, respectively and were on par with each other. Mortality due to bleaching powder was 50.67 per cent followed by copper sulphate poison bait (46.67 %) and boric powder (16.00 %).

#### 4.5.1.1.5 Ten days after treatment

At 10 DAT, crystal salt and metaldehyde were significantly superior to all other treatments with maximum mortality of 85.33 per cent and were at par with each other. While, methomyl poison bait (66.67 %) and thiodicarb (64.00 %) were next best treatments and were on par with each other. Bleaching powder and tobacco powder recording 58.67 and 56.00 per cent mortality were significantly similar to each other. Boric powder resulted the lowest mortality of 21.33 per cent.

#### 4.5.1.1.6 Fifteen days after treatment

Significantly the highest mortality was envisaged in the standard check metaldehyde (89.33 %) and crystal salt (88.00 %) at 15 DAT which were on par with each other but differed significantly with rest of the treatments. This was followed by methomyl (74.67 %) and thiodicarb (73.33 %) were at par with each other. Bleaching powder had 68.00 per cent mortality. However, tobacco powder and copper sulphate produced 60.00 and 58.667 per cent mortality, respectively and exerted similar effect. Boric powder was found to cause the lowest mortality of 25.33 per cent (Plate 14).

### 4.5.1.2 Second Application

After 15 days of the first application second application was imposed. Nine different treatments including the standard check, metaldehyde pellets were evaluated to know their efficacy against brown slug (Table 17). Uniform sized *L. alte* were collected from fields and released at 25 numbers for each treatment.

#### 4.5.1.2.1 A day after treatment

The data on mortality of slugs obtained at 1 DAT after second application ranged from 0 (control) to 32.00 per cent. Crystal salt which was significantly superior over all other treatments including the standard check, metaldehyde (29.33 %). This was followed by methomyl poison baits with (28.00 %) mortality. Whereas thiodicarb poison bait had 25.33 per cent mortality. Bleaching powder and tobacco powder recording 22.67 and 21.33 per cent mortality, respectively exerted similar effect. Copper sulphate recorded 20.00 per cent slug mortality. While, boric powder was recording 1.33 per cent mortality.

4.5.1.2.2 Three days after treatment

At 3 DAT, crystal salt registered the highest mortality (52.00 %) and significantly superior to others including the standard check. However, application of metaldehyde, bleaching powder and methomyl stood next best treatments by recording 34.67, 33.33 and 30.67 per cent slug mortality, respectively. Application of tobacco powder and boric powder brought the mortality of 32.00 and 6.67 per cent, respectively.

4.5.1.2.3 Fifth days after treatment

At 5 DAT, the trend in treatment efficacy observed at 3 DAT was continued. Application of crystal salt registering significantly the highest mortality of 68.00 per cent proved to be superior over others. Metaldehyde (53.33 %) and bleaching powder (50.67 %) were the next best treatments. As seen in earlier application boric powder was least effective by registering only 37.33 and 9.33 slug mortality at 3 DAT, respectively.

4.5.1.2.3 Seven days after treatment

The treatment efficacy trend observed at 5 DAT was repeated at 7 DAT also wherein crystal salt and metaldehyde once again proved to be effective treatments by recording 78.67 and 64.00 per cent slug mortality, respectively. Again application of bleaching powder (58.67 %) and thiodicarb/methomyl poison bait (56.00 %) were found to be effective alternatives for slug management following crystal salt and metaldehyde. Application copper sulphate as poison bait was found more effective than tobacco powder and boric powder.

4.5.1.2.5 Ten days after treatment

At 10 DAT, the standard check metaldehyde registered the highest mortality (84.00 %) instead of crystal salt and found to be significantly superior to others. However, application of crystal salt and bleching powder stood next best treatments with 80.00 and 70.67 per cent slug mortality, respectively. Thiodicarb and methomyl poison bait resulted in 64.00 and 62.67 per cent mortality, respectively. Application of tobacco powder and boric powder brought 53.33 and 17.33 per cent mortality, respectively.

4.5.1.2.6 Fifteen days after treatment

At 15 DAT the trend observed at 10 DAT was continued with respect to efficacy of various treatments. Metaldehyde, crystal salt, bleaching powder, methomyl and thiodicarb poison bait resulted in maximum mortality of 88.00, 84.00, 74.67, 72.00 and 70.67 per cent, respectively. Copper sulphate poison bait and tobacco powder with 62.67 and 60.00 per cent mortality were with similar effect. Boric powder exerted the least effect on mortality (21.33 %) of slugs.

Thiodicarb PB

Tobacco powder

Bleaching powder

Crystal salt

**Plate 14. Mortality Brown slug, Laevicaulis alte due to different treatment in nursery**

**Table 17. Evaluation of different chemicals and poison bait against slug (*L. alte*) in forest/ horticultural nursery during *kharif*, 2015 (2nd Application)**

| Sl. No. | Treatment | Dosage (kg/ha) | Cumulative mortality of slug (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 DAT | 3 DAT | 5 DAT | 7 DAT | 10 DAT | 15 DAT |
| 1 | Bleaching Powder | 25 | 22.67 (28.43) d | 34.67 (36.07) c | 50.67 (45.38) bc | 58.67 (49.99) C | 70.67 (57.21) c | 74.67 (59.78) c |
| 2 | Crystal Salt | 25 | 32.00 (34.45) a | 52.00 (46.15) a | 68.00 (55.55) a | 78.67 (62.49) a | 80.00 (63.44) b | 84.00 (66.42) b |
| 3 | Methomyl 40 SP poison bait | 60 | 28.00 (31.95) b | 30.67 (33.63) d | 44.00 (41.55) d | 56.00 (48.45) c | 62.67 (52.34) d | 72.00 (58.05) cd |
| 4 | $CuSo_4$ poison bait | 60 | 20.00 (26.57) e | 24.00 (29.33) e | 37.33 (37.66) e | 44.00 (41.55) d | 56.00 (48.45) e | 62.67 (52.34) e |
| 5 | Thiodicarb 75 poison bait | 60 | 25.33 (30.22) c | 33.33 (35.26) cd | 48.00 (43.85) cd | 56.00 (48.45) c | 64.00 (53.13) d | 70.67 (57.21) d |
| 6 | Tobacco Powder | 25 | 21.33 (27.51) de | 32.00 (34.45) cd | 37.33 (37.66) e | 48.00 (43.85) d | 53.33 (46.91) e | 60.00 (50.77) e |
| 7 | Boric Powder | 25 | 1.33 (6.63) f | 6.67 (14.96) f | 9.33 (17.79) f | 14.67 (22.52) e | 17.33 (24.60) f | 21.33 (27.51) f |
| 8 | Metaldehyde2.5% pallets | 5 | 29.33 ** (32.79) b | 38.67 (38.45) b | 53.33 (46.91) b | 64.00 (53.13) b | 84.00 (66.42) a | 88.00 (69.73) a |
| 9 | Control | --- | 0.00 (0.60) g | 0.00 (0.60) g | 0.00 (0.60) g | 0.00 (0.60) f | 0.00 (0.60) g | 0.00 (0.60) g |
| S.Em± | | | 0.40 | 0.62 | 0.80 | 0.91 | 0.84 | 0.68 |
| C.D. @ 5% | | | 1.21 | 1.85 | 2.40 | 2.71 | 2.51 | 2.03 |
| C.V. (%) | | | 13.94 | 15.33 | 14.32 | 13.44 | 10.72 | 7.94 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at p = 0.05 as per DMRT.

## 4.5.2 Management of brown slug, *Laevicaulis alte* in protected cultivation of capsicum

### 4.5.2.1 First Application

The observations recorded on the per cent mortality of brown slug to evaluate the efficacy of different chemicals and poison baits on capsicum (30 days after sowing) are presented in table 18. Before imposition of the treatments, uniform sized slugs were collected from fields and released at 10 numbers in each treatment.

#### 4.5.2.1.1 A day after treatment

The data on mortality of slugs obtained at 1 DAT ranged from 0.00 (control) to 36.67. Crystal salt was significantly superior over all other treatments including the standard check, metaldehyde (36.67 %). This was followed by thiodicarb poison bait with 26.67 per cent mortality. Bleaching powder, copper sulphate and methomyl both recording 23.33 per cent mortality, produced similar effect. Tobacco powder and boric powder registered 6.67 and 3.33 per cent mortality, respectively.

#### 4.5.2.1.2 Three days after treatment

At 3 DAT, crystal salt, metaldehyde, bleaching powder and methomyl poison bait treatments recorded maximum mortality of 60.00, 46.67, 36.67 and 33.33 per cent, respectively, while, copper sulphate and thiodicarb poison with 30.33and 30.00 per cent, the latter two were produced similar effect. Tobacco powder and boric powder resulted in mortality of 26.67 and 6.67 per cent, respectively.

#### 4.5.2.1.3 Five days after treatment

At 5 DAT, crystal salt continued to be the effective treatment by registering the highest mortality of (66.67 %) which was significantly superior over other treatments treatments including the standard check, metaldehyde 5.0 kg/ha (53.33 %). Application of methomyl poison bait (50.00 %) and copper sulphate poison/ bleaching powder (43.33 %) were proved next best effective treatments for management of slug under poly house. The significantly least mortality was found to be continued due to the application of boric powder (10.00 %).

#### 4.5.2.1.4 Seven days after treatment

The treatment efficacy trend observed at 5 DAT was repeated at 7 DAT also wherein crystal salt and metaldehyde once again proved to be effective by recording 80.00 and 73.33 per cent slug mortality. Again application of methomyl (66.67 %) and thiodicarb/bleaching powder (60.00 %) were found to be effective alternatives of slug management. Application copper sulphate as poison bait was found effective treatments compare to tobacco powder and boric powder.

#### 4.5.2.1.5 Ten days after treatment

Significantly the highest mortality was documented in the standard check, metaldehyde (86.67 %) at 10 DAT. This was followed by crystal salt (83.33 %) and methomyl (70.00 %). However, both of bleaching powder and thiodicarb 75 WP poison bait produced 66.67 per cent mortality and found to be on par with each other. Application of copper sulphate poison bait, tobacco powder and boric powder brought mortality of 56.67, 53.33 and 23.33 per cent, respectively.

**Table 18. Evaluation of different chemicals and poison bait against slug (*L. alte*) in protected cultivation of capsicum during, *kharif,* 2015 (1$^{ST}$ Application)**

| Sl. No. | Treatment | Dosage (kg/ha) | Cumulative mortality capsicum of slug (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **1 DAT** | **3 DAT** | **5 DAT** | **7 DAT** | **10 DAT** | **15 DAT** |
| 1 | Bleaching Powder | 25 | 23.33 (28.88) $^{d}$ | 36.67 (37.27) $^{c}$ | 43.33 (41.17) $^{d}$ | 60.00 (50.77) $^{d}$ | 66.67 (54.74) $^{d}$ | 73.33 (58.91) $^{d}$ |
| 2 | Crystal Salt | 25 | 36.67 (37.26) $^{a}$ | 60.00 (50.77) $^{a}$ | 66.67 (54.74) $^{a}$ | 80.00 (63.43) $^{a}$ | 83.33 (65.59) $^{b}$ | **86.67** (68.59) $^{b}$ |
| 3 | Methomyl 40 SP poison bait | 60 | 23.33 (28.88) $^{d}$ | 33.33 (35.26) $^{d}$ | 50.00 (45.00) $^{c}$ | 66.67 (54.74) $^{c}$ | 70.00 (56.80) $^{c}$ | **76.67** (61.12) $^{c}$ |
| 4 | $CuSo_4$ poison bait | 60 | 23.33 (28.88) $^{d}$ | 30.33 (33.42) $^{e}$ | 43.33 (41.17) $^{d}$ | 50.00 (45.00) $^{e}$ | 56.67 (48.83) $^{e}$ | 60.00 (50.77) $^{e}$ |
| 5 | Thiodicarb 75 WP poison bait | 60 | 26.67 (31.09) $^{c}$ | 30.00 (33.21) $^{e}$ | 40.00 (39.23) $^{e}$ | 60.00 (50.77) $^{d}$ | 66.67 (54.74) $^{d}$ | 73.33 (58.91) $^{d}$ |
| 6 | Tobacco Powder | 25 | 6.67 (14.97) $^{e}$ | 26.67 (31.09) $^{f}$ | 36.67 (37.27) $^{f}$ | 46.67 (43.03) $^{f}$ | 53.33 (46.91) $^{f}$ | 60.00 (50.77) $^{e}$ |
| 7 | Boric Powder | 25 | 3.33 (10.51) $^{f}$ | 6.67 (14.97) $^{g}$ | 10.00 (18.43) $^{g}$ | 16.67 (24.10) $^{g}$ | 23.33 (28.88) $^{g}$ | 23.33 (28.88) $^{f}$ |
| 8 | Metaldehyde 2.5% pallets | 5 | 33.33 ** (35.26) $^{b}$ | 46.67 (43.03) $^{b}$ | 53.33 (46.91) $^{b}$ | 73.33 (58.91) $^{b}$ | 86.67 (68.59) $^{a}$ | **90.00** (71.57) $^{a}$ |
| 9 | Control | --- | 0.00 (0.90) $^{g}$ | 0.00 (0.90) $^{h}$ | 0.00 (0.90) $^{h}$ | 0.00 (0.90) $^{h}$ | 0.00 (0.90) $^{h}$ | 0.00 (0.90) $^{g}$ |
| SEm± | | | 0.21 | 0.26 | 0.39 | 0.34 | 0.25 | 0.99 |
| C.D. @ 5% | | | 0.67 | 0.79 | 1.18 | 1.03 | 0.76 | 1.37 |
| C.V.% | | | 18.67 | 15.21 | 16.48 | 11.85 | 7.83 | 9.50 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at p = 0.05 as per DMRT.

4.5.2.1.6 Fifteen days after treatment

At 15 DAT, metaldehyde continued to be the effective treatment by recording highest mortality of 90.00 per cent. Application of crystal salt (86.67 %) and methomyl 40 SP (76.67 %) were proved to be the next best effective treatments for management of brown slug in poly house condition. Whereas, bleaching powder and thiodicarb 75 WP poison bait recording 73.33 per cent mortality, were on par with each other. Tobacco powder and boric powder resulted in 60.00 and 23.33 per cent mortality, respectively (Plate 15).

4.5.2.2 Second Application

After 15 days of the first application second application was imposed. Nine different treatments were evaluated to know their efficacy against brown slug (Table 19). Uniform sized slugs (*L. alte*) were collected from fields and released at 10 numbers in each treatment.

4.5.2.2.1 A day after treatment

At 1 DAT, application of crystal salt exerting mortality of 46.67 per cent was significantly superior over all other treatments treatments including the standard check, metaldehyde (36.36 %). This was followed by methomyl (33.33 %), thiodicarb (30.00 %), bleaching powder (26.67 %). Copper sulphate and boric powder documented 23.33 and 3.33 per cent slug mortality, respectively, while of boric powder the lowest mortality (3.33 %).

4.5.2.2.2 Three days after treatment

At 3 DAT, crystal salt, metaldehyde and thiodicarb poison bait registered higher mortality of 60.00, 50.00 and 40.00 per cent, respectively. Both the bleaching powder, methomyl and tobacco powder producing 33.33 per cent mortality were on par with each other. Copper sulphate poison bait and boric powder recorded 30.00 and 6.67 per cent mortality, respectively.

4.5.2.2.3 Five days after treatment

Among the different treatments, crystal salt and metaldehyde recorded maximum mortality of 70.00 and 60.00 per cent, respectively. Whereas, both thiodicarb and methomyl registering 46.67 per cent were on par with each other. Bleaching powder, copper sulphate poison bait and tobacco powder exerting 40.00 per cent mortality were on par with each other. Again boric powder produced the lowest mortality of 13.33 per cent.

4.5.2.2.4 Seven days after treatment

At 7 DAT, significantly the highest mortality was documented crystal salt (73.33 %). This was followed by metaldehyde (70.00 %), thiodicarb (60.00 %), metomyl (56.67 %) and tobacco powder (50.00 %). However, both bleaching powder and copper sulphate poison bait producing 46.67 per cent mortality were on par with each other. The significantly least mortality was evident to be continued in application of boric powder (20.00 %).

Metaldehyde

Crystal salt

Bleaching powder

Thiodicarb PB

Tobacco powder

**Plate 15. Mortality of Laevicaulis alte  due to different treatment in nursery**

**Table 19. Evaluation of different chemicals and poison bait against slug (*L. alte*) in protected cultivation of capsicum during, *kharif,* 2015 (2nd Application)**

| Sl. No. | Treatment | Dosage (kg/ha) | Cumulative mortality capsicum of slug (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 DAT | 3 DAT | 5 DAT | 7 DAT | 10 DAT | 15 DAT |
| 1 | Bleaching Powder | 25 | 26.67 (31.09) e | 33.33 (35.26) d | 40.00 (39.23) d | 46.67 (43.09) f | 60.00 (50.77) e | 66.67 (54.74) d |
| 2 | Crystal Salt | 25 | 46.67 (43.09) a | 60.00 (50.77) a | 70.00 (56.79) a | 73.33 (58.91) a | 80.00 (63.43) b | 83.33 (65.91) b |
| 3 | Methomyl 40 SP poison bait | 60 | 33.33 (35.26) c | 33.33 (35.26) d | 46.67 (43.09) c | 56.67 (48.83) d | 66.67 (54.74) c | 73.33 (58.91) c |
| 4 | $CuSo_4$ poison bait | 60 | 23.33 (28.88) f | 30.00 (33.21) e | 40.00 (39.23) d | 46.67 (43.09) f | 53.33 (46.91) g | 63.33 (52.73) e |
| 5 | Thiodicarb 75 WP poison bait | 60 | 30.00 (33.21) d | 40.00 (39.23) c | 46.67 (43.09) c | 60.00 (50.77) c | 63.33 (52.73) d | 73.33 (58.91) c |
| 6 | Tobacco Powder | 25 | 23.33 (28.88) f | 33.33 (35.26) d | 40.00 (39.23) d | 50.00 (45.00) e | 56.67 (48.83) f | 56.67 (48.83) f |
| 7 | Boric Powder | 25 | 3.33 (10.52) g | 6.67 (14.96) f | 13.33 (21.42) e | 20.00 (26.57) g | 20.00 (26.57) h | 20.00 (26.57) g |
| 8 | Metaldehyde 2.5% pallets | 5 | 36.67 ** (37.27) b | 50.00 (45.00) b | 60.00 (50.77) b | 70.00 (56.79) b | 83.33 (65.91) a | 86.67 (68.58) a |
| 9 | Control | --- | 0.00 (0.90) h | 0.00 (0.90) g | 0.00 (0.90) f | 0.00 (0.90) h | 0.00 (0.90) i | 0.00 (0.90) h |
| SEm± | | | 0.25 | 0.32 | 0.41 | 0.46 | 0.38 | 0.30 |
| C.D. @ 5% | | | 0.75 | 0.97 | 1.23 | 1.39 | 1.14 | 0.91 |
| C.V.% | | | 17.56 | 17.61 | 18.00 | 17.11 | 12.34 | 9.12 |

Figures in the parenthesis are arc sin** transformed values, DAR- Days after Release. Values in the column followed by common letters are non significant at p = 0.05 as per DMRT.

4.5.2.2.5 Ten days after treatment

At 10 DAT, the standard check, metaldehyde registered the highest mortality (83.33 %) instead of crystal salt and found significantly superior to others. However, application of crystal salt, methomyl, thiodicarb and bleaching powder stood the next best weapons by recording 80.00, 66.67, 63.33 and 60.00 per cent slug mortality, respectively. Application of tobacco powder and copper sulphate led to the mortality of 56.67 and 53.33 per cent, respectively. As seen in earlier application boric powder was the least effective by registering only 20.00 per cent slug mortality.

4.5.2.2.6 Fifteen days after treatment

Significantly the highest mortality was documented at 15 DAT in metaldehyde (86.67 %) followed by crystal salt (83.33). Both methomyl and thiodicarb registering the mortality of 73.33 per cent were on par with each other. Again, bleaching powder, copper sulphate poison bait and tobacco powder recorded 66.67, 63.33 and 56.67 per cent mortality, respectively. Whereas, boric powder was the least effective chemicals among all produced only 20.00 per cent mortality.

## 4.5.3 Yield

Data presented in table 23 indicate yield of capsicum ranged from 1013.76 to 1190.67 quintal per hectare obtained in different poison baits/chemical treatments. Significantly the highest yield was registered due to metaldehyde (1190.66 q/ha) and crystal salt (1176.33/ha). These were followed by methomyl (1154.33 q/ha), bleaching powder (1123.67 q/ha), thiodicarb (1097.67 q/ha), copper sulphate (1065.67 q/ha) and tobacco powder (1048.33 q/ha). Whereas, the least yield of 1022.67 was recorded in boric powder.

## 4.5.4 Per cent increase in yield

The maximum yield increase over control was obtained in the treatment with metaldehyde (14.86 %) followed by crystal salt (13.82 %). Methomyl (12.18 %), bleaching powder (9.78 %), thiodicarb (7.64 %), copper sulphate (4.87 %) and tobacco powder (3.30 %) and the lowest of 0.87 per cent over control in boric powder.

## 4.5.5 Cost economics

Table 20 showed that cost of cultivation and returns in capsicum cultivation under protected condition. Cost economics of different treatments under investigation revealed that standard check metaldehyde and crystal salt gave net profit of Rs. 21,78,457.70 and Rs. 21,40,307.70 /ha, respectively. These were followed by methomyl, bleaching powder, thiodicarb, copper sulphate, tobacco powder and boric powder which documented net returns of Rs. 20,83,632.70, 20,08,907.70, 19,41,982.70, 18,18,132.70 and 17,52,732.70 $ha^{-1}$, respectively.

The benefit-cost ratio indicates the return per rupee investment on capsicum under protected condition. The magnitude of the ratio also indicates the priority to be assigned for each of the alternative investment. The highest B:C ratio was the highest with metaldehyde (2.71) and crystal salt (2.67), methomyl (2.60), bleaching powder (2.51), thiodicarb (2.42), copper sulphate poison bait (2.32), tobacco power (2.72) and boric powder (2.18).

**Table 20. Cost economics of different chemicals and poison bait against brown slug, *Laevicaulis alte* under protected cultivation of capsicum**

| Sl. No. | Treatments | Dosage/ha | Avg. Yield (q/ha) | Per cent yield increase over control | Gross returns (Rs./ha) | Cost of cultivation (Rs./ha) | Net return (Rs./ha) | B:C ratio | Rank |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Bleaching powder | 25 kg/ha | 1123.67 | 9.78 | 28,09,175.00 | 8,00,267.30 | 2008907.70 | 2.51 | IV |
| 2 | Crystal salt | 10 g/kg bait @ 60 kg | 1176.33 | 13.82 | 29,40,825.00 | 8,00,517.30 | 2140307.70 | 2.67 | II |
| 3 | Methomyl 40 SP | 10 g/kg bait @ 60 kg | 1154.33 | 12.18 | 28,85,825.00 | 8,02,192.30 | 2083632.70 | 2.60 | III |
| 4 | $CuSo_4$ poison bait. | 100 g/kg bait @ 60 kg | 1065.67 | 4.87 | 26,64,175.00 | 8,02,192.30 | 1861282.70 | 2.32 | VI |
| 5 | Thiodicarb 75WP | 10 g/kg bait @ 60 kg | 1097.67 | 7.64 | 27,44,175.00 | 8,02,892.30 | 1941982.70 | 2.42 | V |
| 6 | Tobacco powder | 25 kg/ha | 1048.33 | 3.30 | 26,20,825.00 | 8,02,692.30 | 1818132.70 | 2.27 | VII |
| 7 | Boric powder | 25 kg/ha | 1022.67 | 0.87 | 25,56,675.00 | 8,03,942.30 | 1752732.70 | 2.18 | VIII |
| 9 | Metaldehyde 2.5% pellets | 5 kg/ha | 1190.67 | 14.86 | 29,76,675.00 | 8,03,192.30 | 2173482.70 | 2.71 | I |
| 9 | Control | -- | 1013.67 | -- | -- | -- | -- | -- | |

Whole sale market price of hybrid capsicum during the season 2500/q. B: C ratio: Benefit cost ratio.

# 5. DISCUSSION

The results of the investigations on survey for snails and slugs, estimation of damage potential due to giant African snail (GAS), *Achatina fulica* and brown slug, *Laevicaulis alte* in different forest/horticultural nurseries and management of giant African snail/brown slug by using different chemicals and poison baits in forests/horticultural nursery and in protected cultivation of capsicum are discussed in this chapter.

## 5.1 Survey

Survey is used to sample insect/pest over number of seasons and years. The method can be used to identify the pests present at a given location and to compare relative changes in pest numbers between seasons. It can provide a general overview of pest abundance and may be useful if related to other pest estimates for forecasting out breaks on a regional basis.

Servey was made at different forest and horticultural nurseries in Dharwad district at weekly intervals are discussed below.

### 5.1.1 Fixed plot survey on incidence of snails and slugs in forest and horticultural nurseries

During survey the major snail noticed was GAS, *A. fulica* damaging both forest and horticultural nurseries. Investigation on the occurrence of snails and slugs in forest and horticultural nurseries in Dharwad district revealed that, the activity of snails was started during 24$^{th}$ standard week (June 3$^{rd}$ week) of 2015 and persisted up to 2$^{nd}$ standard week of 2016 with peak infestation during 41$^{st}$ standard week (Octo. 2$^{nd}$ week) to 45$^{th}$ standard week (Nov. 2$^{nd}$ week). Whereas, no slug incidence or damage was reported during study period at different surveyed nurseries.

The mean snail population and per cent leaf damage were maximum in moringa (5.54 snail/m$^2$ and 23.35 % leaf damage) (Fig. 1). While minimum snail population and leaf damage was noticed in neem (0.62 snail/m$^2$ and 1.32 % leaf damage) (Fig. 2). Due to low and scattered rainfall from July to December, 2015 (468.00 mm) the incidence of snail was very less. Further, higher number of snails recorded in October, 2015 was due to receipt of higher amount of rainfall (179.80 mm).

The present investigation is in line with Basavaraju *et al.* (2000) who opined that the infestation of GAS on biofuel nursery, vegetable nursery, arecanut nursery and mulberry garden ranged from 8 to 15 per cent in Hassan district of Karnataka.

The activity of GAS started during 24$^{th}$ standard is an agreement with the work of Mallappa. Further, Rafee *et al.* (2013a) stated that the number of snails recorded in different agriculture and horticultural crops was higher during September due to receipt of high rainfall. Similarly, during 2015 also the higher snail population was coincided with the receipt of higher rainfall in October month is endorsed with this study. Further, the snail population was declined due to cessation of rainfall in the month of January.

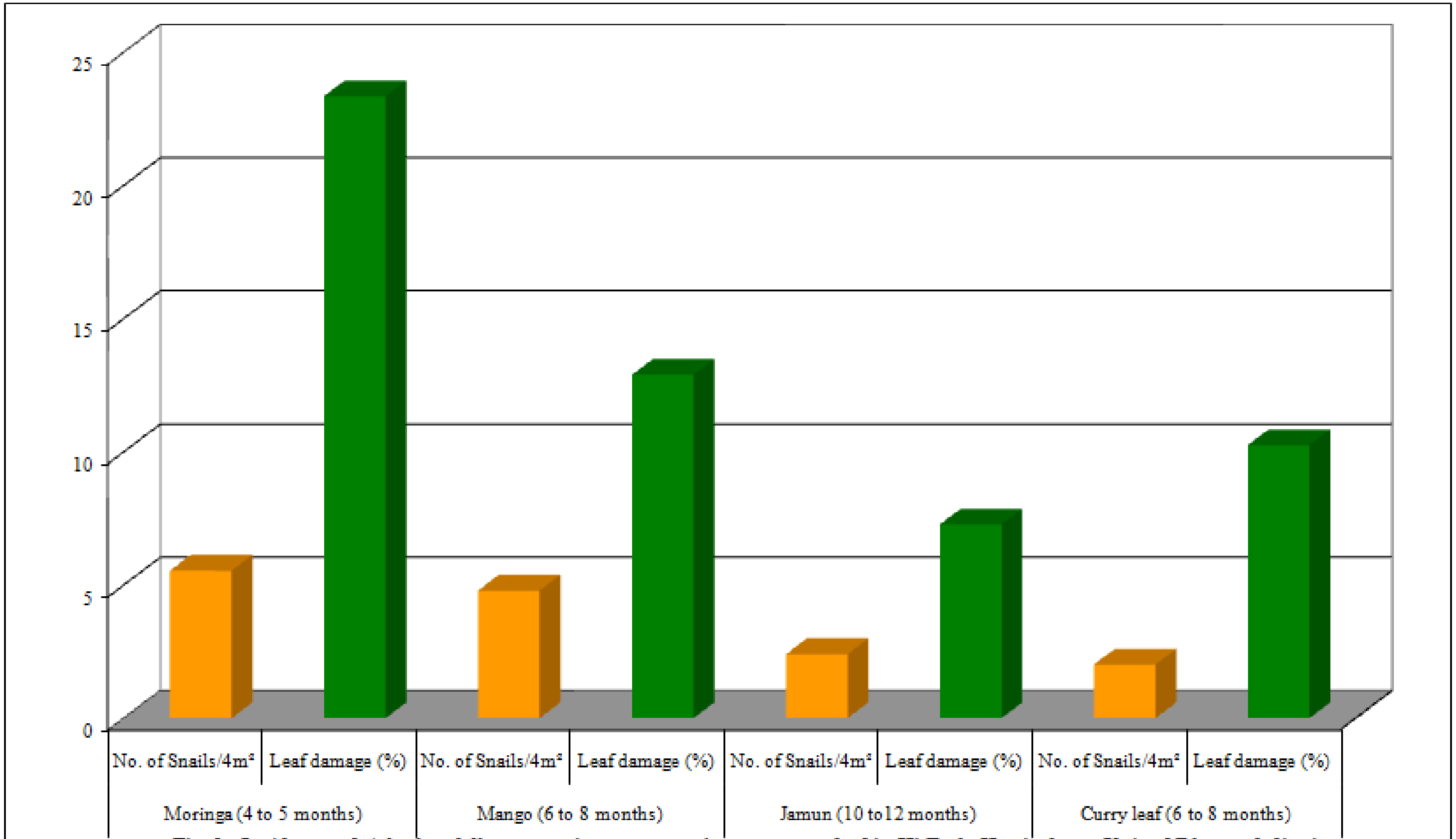



**Fig. 1: Incidence of *Achatina fulica* on moringa, mango, jamun, curry leaf in Hi-Tech Horticulture Unit of Dharwad district**

**Fig. 1: Incidence of *Achatina fulica* on moringa, mango, jamun, curry leaf in Hi-Tech Horticulture Unit of Dharwad district**

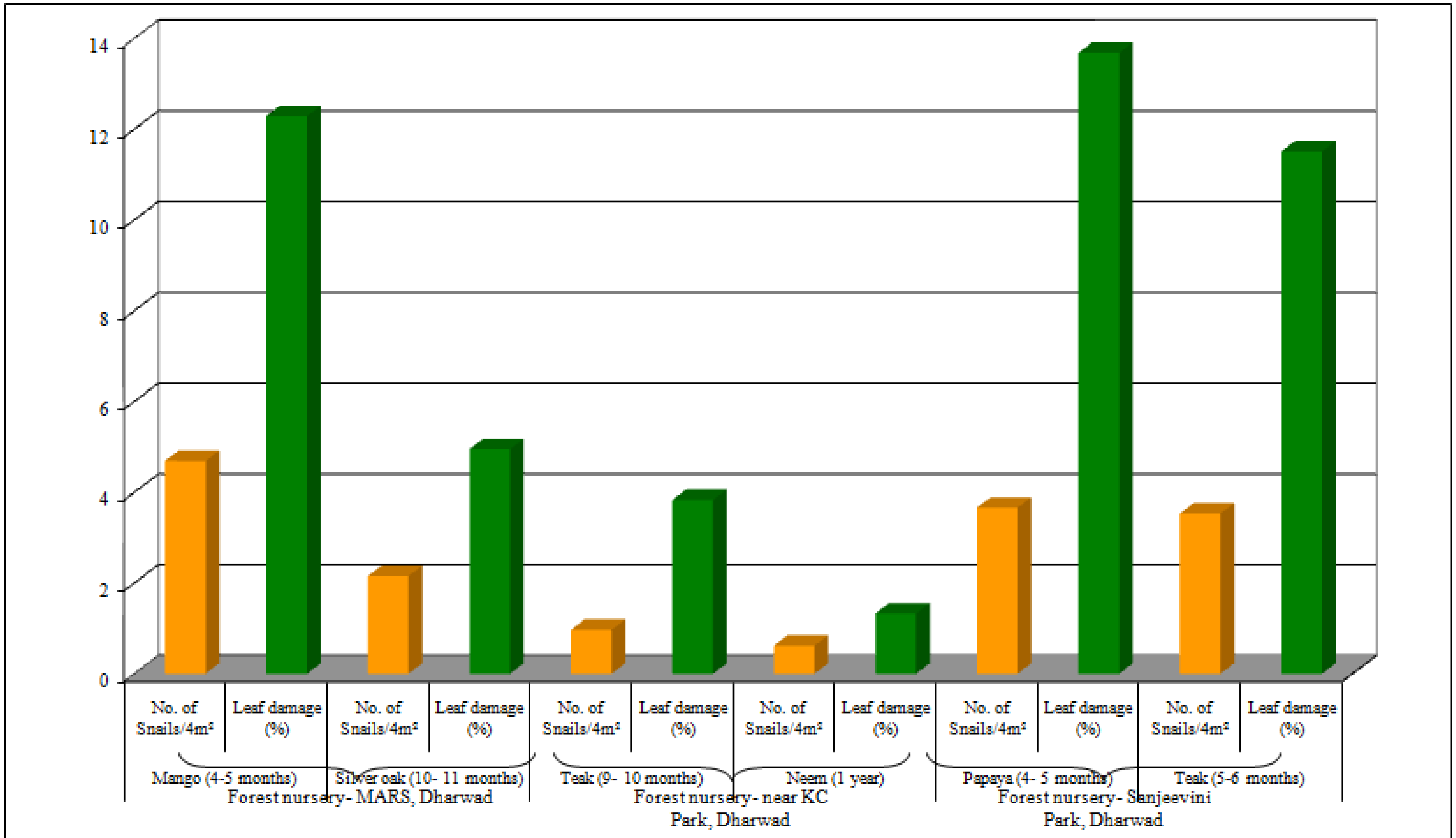



**Fig. 2: Incidence of Achatina fulica forest/horticulture seedlings in different forest nurseries (FN) of Dharwad district (2015-16)**

**Fig. 2: Incidence of Achatina fulica forest/horticulture seedlings in different forest nurseries (FN) of Dharwad district (2015-16)**

The present study damage to various nursery seedlings (1.33 to 23.35 %) in close agreement with the studies of Mallappa (2014) who registered that three to four months old seedlings were severely damaged by GAS on forest nursery in Bealgavi district during August 2011. The mean number of snail population in seedlings like teak, silver oak, amla, pongamia, neem, tamarind, moringa, cashew, sisso, jamun, citrus, papaya and almond ranged from 29.30 to 58.10 per 15 $m^2$ nursery bed with cent per cent damage.

5.1.1.2 Correlation studies between snail population and weather parameters

Maximum temperature exerted negative and significant relationship, but highly significant and positive relationship was noticed with rainfall (Fig. 3). Likewise, highly significant and positive correlation was with relative humidity. This finding corroborates with Yogesh (2015) who endorsed the rainfall and relative humidity were significant and positive with respect to snail, *A. fulica* and negative and significant with maximum temperature. Likewise, Mallappa (2014) reported correlation between snail incidence and weather factor indicated that the highly significant and positive relationship with rainfall (r =0.652**). During the year 1998 as high as 1006 mm of annual rainfall was received which was second the highest in the century and thus recorded the highest population of 257.2 snails/100 square meter area (Balikai, 2008). This corroborates with Thakur (2003) from Bihar who opined positive and significant relationship between snail population and relative humidity.

Vanitha *et al.* (2011) from Tamil Nadu furnished that the population of *Cryptozona semirugata* (Beck) on vanilla had significant positive correlation with minimum temperature (r = 0.562*) and relative humidity (r = 0.667**). Shilpa (2013) also inferred that rainfall had significant positive relationship with snail population (*C. semirugata*). Likewise, the activity of snails was high during rainy season and less during non rainy season in different crops as reported by workers like Ravikumara *et al.* (2007) and Vanitha *et al.* (2011).

## 5.2 Estimation of damage potential of giant African snail, *A. fulica* in various forest and horticultural nurseries

Any organism is considered as a pest when it causes damage or loss to the crop. Depending upon this the plant protection measures have to be tailored for getting higher economic returns. So assessment of damage due to pest becomes essential for any planned crop protection against a particular pest in a particular crop. To determine the damage potential for taking proper control measure the present work was carried out.

The highest cumulative mean per cent leaf damage to forest/ horticultural saplings (3 to 5 months) was maximum in moringa (95.78 %), followed by papaya (94.81 %), citrus (71.20 %) and teak (68.55 %) at 10 days after release (DAR). However, the lowest damage was recorded in banyan (13.74 %), followed by mango (14.79) and subabul (17.66) (Fig. 4). The probable reason for higher damage is the succulency of foliage of the particular sapling. Again out of 50 saplings provided under each replication the highest per cent of damage to saplings was recorded in moringa (96.00), papaya (94.00) and sisso (92.00) due to their succulent foliage and soft stem and the least damage noticed on pongamia and banyan with 37.00 and 31.00 per cent, probably due to their hardy nature.

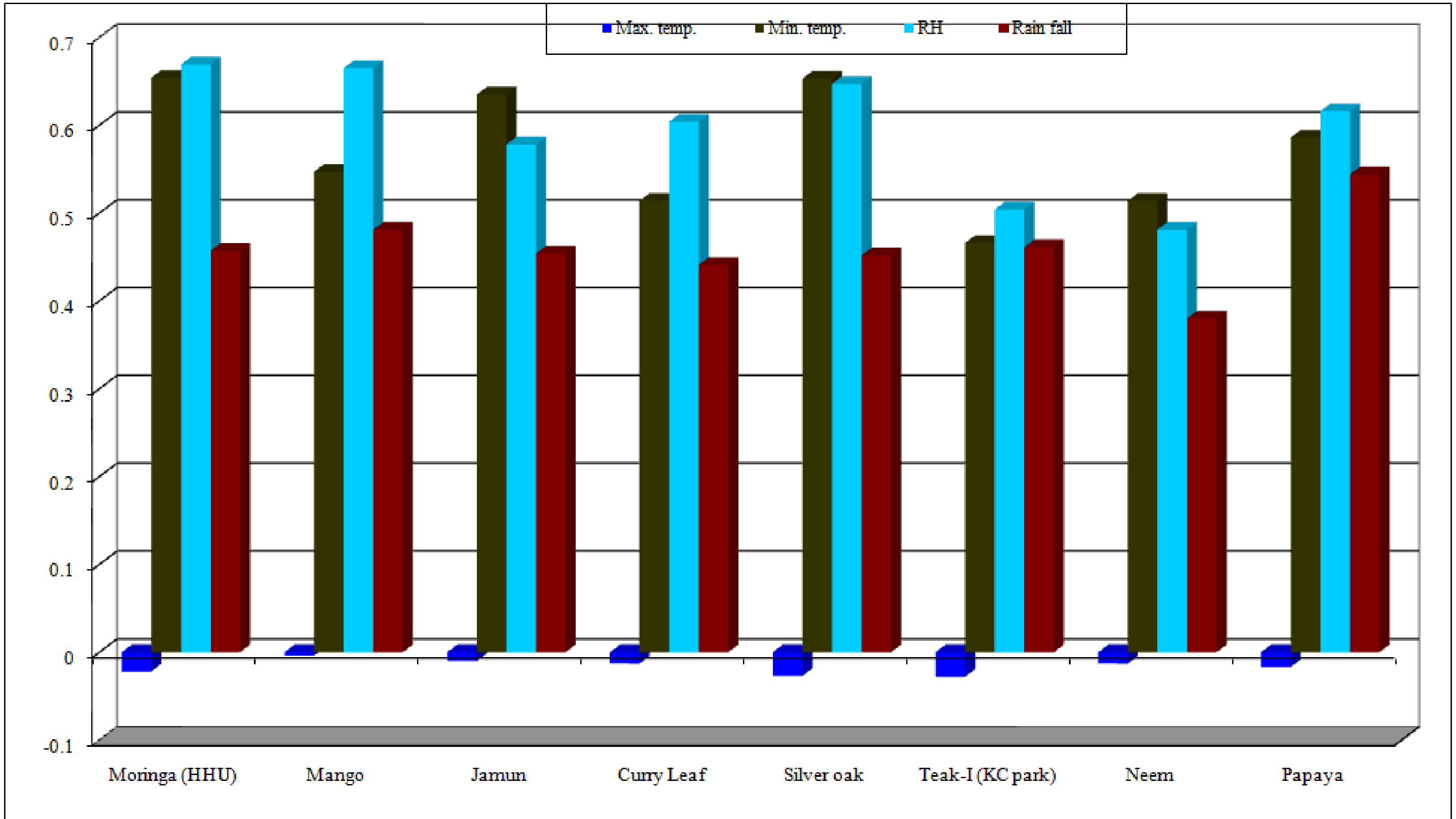



**Fig. 3: Correlation coefficient between snail population of *Achatina fulica* and weather parameter on different saplings (*Kharif,* 2015)**

**Fig. 3: Correlation coefficient between snail population of *Achatina fulica* and weather parameter on different saplings (*Kharif,* 2015)**

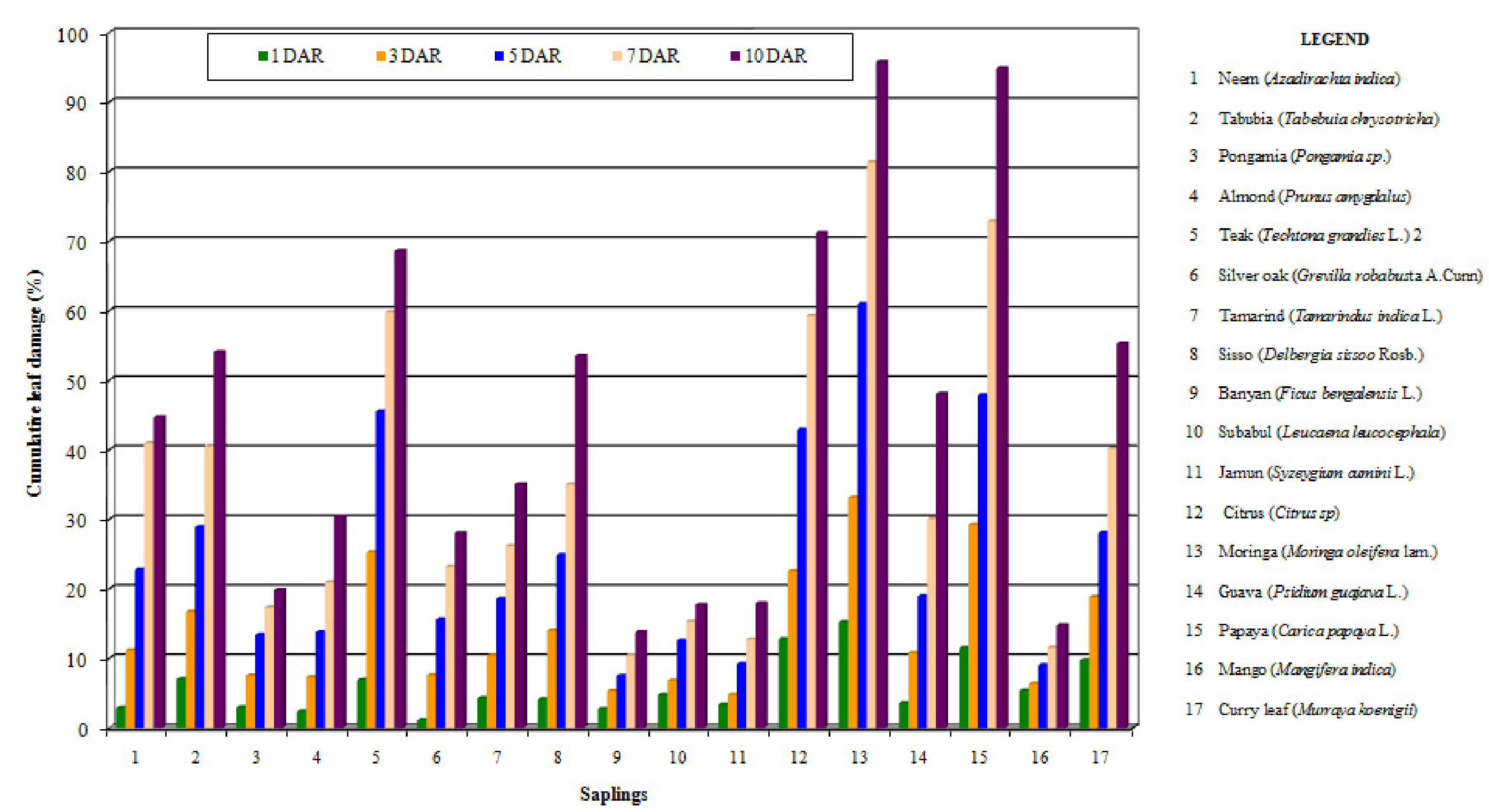



**Fig. 4: Per cent of leaf damage by giant African snail, *Achatina fulica* Ferussac on different forest and horticultur saplings (3 to 5 months) during *kharif*, 2015**

**Fig. 4: Per cent of leaf damage by giant African snail, *Achatina fulica* Ferussac on different forest and horticultur saplings (3 to 5 months) during *kharif*, 2015**

The literature pertaining to damage potential of GAS on different forest and horticultural nurseries is not available. Hence, this seems to be the first study carried out on the estimation of damage potential of GAS on different nursery plants. But the result of present investigations are in line with Balikai (2008) who registered the damage by the snail, *C. semirugata* on different succulent and non-succulent horticultural crops in Vijayapur. The per cent plant damage varied from minimum of 4.3 in *Clerodendron* to a maximum of 95.3 in palak. Maximum number of plants damaged was observed in palak (95.3 %), brinjal (90.2 %), methi (90.1 %), ridge gourd (82.3 %) and chillies (80.2 %). The leaf area consumption was highest on Palak followed by brinjal, methi and ridge gourd. Thus palak, brinjal, methi, ridge gourd, tomato, potato, chillies and marigold were preferred by this snail, while *Hibiscus* and *Clerodendron* were least preferred. Similarly, Shilpa (2013) also opined that seedling stage of the crops were highly susceptible to snail (*C. semirugata*) damage than later stages of crop growth where no damage was noticed in green gram. Sunita (2007) reported 20 per cent damage of chilli by GAS in Dharwad. According to Giraddi *et al* (1996) the per cent seedlings damaged varied from 4.3 on groundnut to 30.6 on chilli with mean damage of 19.05 per cent due to *C. semirugata* at Dharwad district of Karnataka.

## 5.3 Damage potential of brown slug, *Laevicaulis alte* in various forest and horticultural nurseries

Slugs are categorized as pests in terms of their damage to crops. It injures plants by chewing holes of various shapes and sizes in leaves, stems and fruits. The early seedling stage is more susceptible to slug damage and sometimes the entire seedling may be consumed. To determine the extent of damage due to slugs in different forest and horticultural the present work was conducted.

The highest cumulative mean per cent leaf damage to forest/ horticultural saplings (3 to 5 months) was maximum in moringa (10.18 %), followed by citrus (10.15 %), papaya (9.88 %) and teak (8.89 %), tabubia (7.98 %) and curry leaf (7.03 %) at 10 DAR (Fig. 5). While, the lowest damage was recorded in sisso (2.07 %) and neem (4.88 %). The probable reason for higher damage is the succulence nature of foliage of the particular sapling. However, no damage was recorded in pongamia, banayan, subabul, mango, silver oak, tamarind, almond and guava probably due to their unappetizing nature.

Again out of 50 saplings provided under each treatment the highest per cent of damage to saplings was recorded in papaya (43.00), moringa (41.00), citrus (37.00), teak (36.00), curry leaf (35.00) and tabubia (32.00) due to their succulent foliage or soft stem and on the contrary least damage noticed sisso (25.00 %) and neem (15.00 %).

The perusal of literature revealed that the reviews pertaining to damage potential of brown slug on different forest and horticultural nursery is not available. Hence, this is going to be first study carried out on estimation of brown slug damage on different nursery seedlings. Such findings are somewhat related to the findings of Kaur and Mehta (2013) who reported the maximum damage of seedling caused by brown slug (*Filicaulis alte* Ferussac) was 32.8 per cent in brinjal during last week of February, 22.5 per cent in tomato during mid-March, 44.4 per cent in bottle gourd during early July,

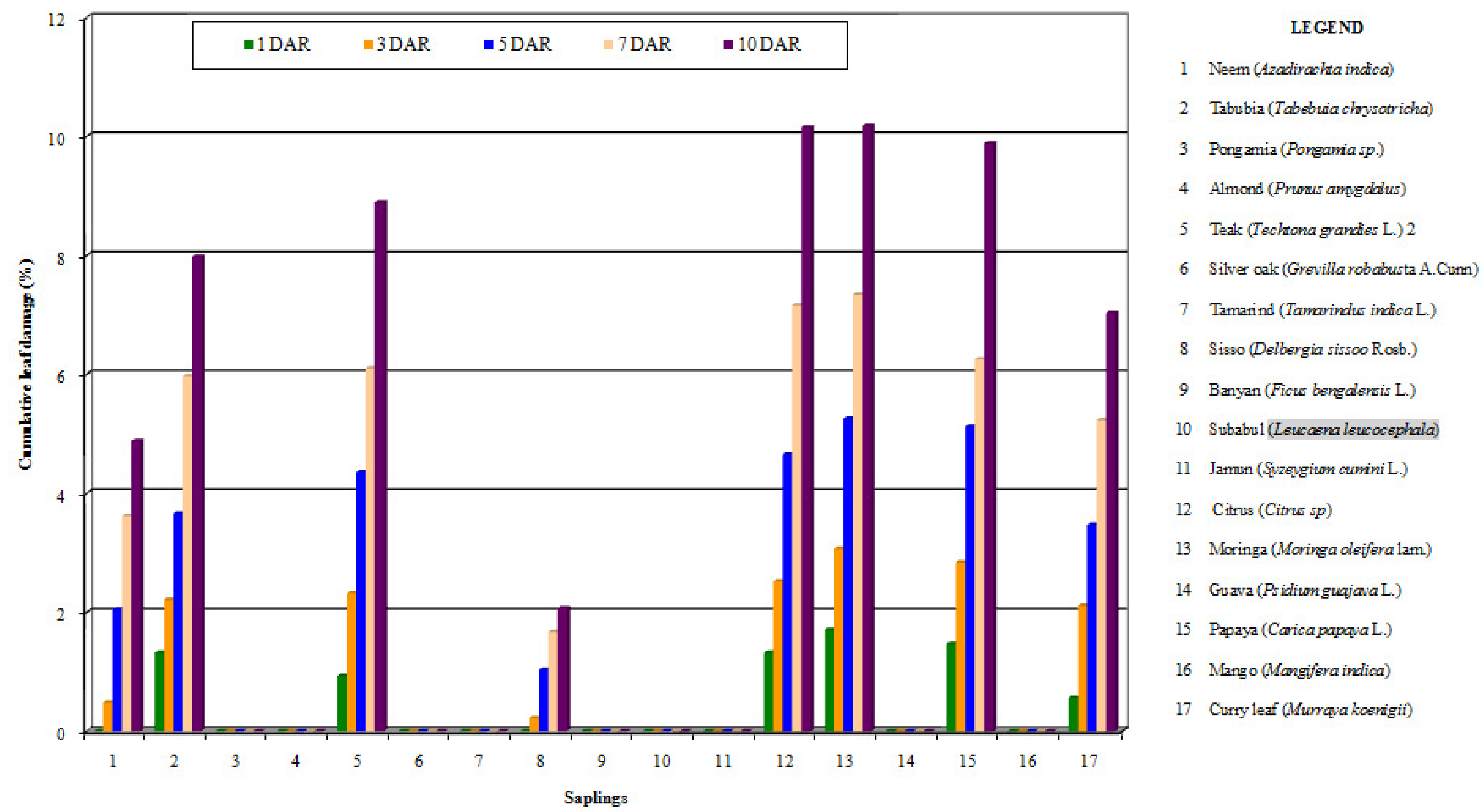



**Fig. 5: Per cent of leaf damage by brown slug, *Laevicaulis alte Ferussac* on different forest and horticulture saplings (3 to 5 months) during kharif, 2015**

**Fig. 5: Per cent of leaf damage by brown slug, *Laevicaulis alte Ferussac* on different forest and horticulture saplings (3 to 5 months) during kharif, 2015**

91.6 per cent in squash melon, 65.6 per cent in summer squash, 63.4 per cent in cucumber, 62.8 per cent in long melon, 30.2 per cent in sponge gourd, 35.5per cent in turnip, 30.9 per cent in radish during September, 43.1 per cent in spinach, 50.8 per cent in cabbage, 41.3 per cent in cauliflower during October and 47.7 per cent in mustard during first week of November. Again Naik *et al.* (2014) reported the incidence of brown slug, *Mariella dussumieri* Gray inflicting damage to the marigold (*Tagetetes sp.*) var. RR Gold, was observed in Puttaswamayyana Palya, Tumkur district of Karnataka during *rabi,* 2013. Feeding damage up to 30 per cent was recorded in young plants in 2013 compared to 15 per cent loss in 2013. Kaur and Kaur (2014) registered that the brown slug, *Filicaulis alte* were found damaging vegetable crops in Punjab and the highest damage was observed in cauliflower at 6-leaf stage during October (25.03 %) and at 4-leaf stage during September (26.58 %) and turnip was the most affected crop at 2-leaf stage (22.98 %). The least affected crop at 6- leaf stage and at 2- leaf stage with mean per cent of damage 17.11 and 17.57, respectively. Maximum leaf damage was observed in cabbage during the month of November.

## 5.4 Management of giant African snail, *Achatina fulica*

### 5.4.1 In forest/horticultural nursery

Different chemicals and poison baits were evaluated against the GAS in different forest and horticultural nursery during *kharif*, 2015 at UAS, Dharwad. The molluscicide metaldehyde 2.5 % pellets @ 5 kg $ha^{-1}$ (93.33 %), crystal salt @ 25 kg $ha^{-1}$ (92.00 %) and bleaching powder @ 25 kg $ha^{-1}$ (84.00 %) were superior over rest of the treatments in bringing the mortality of snail. Whereas, poison baits like, methomyl 40 SP poison bait @ 60 kg/ha (78.67 %), copper sulphate @ 60 kg/ha rice bran (72.67 %), thiodicarb 75 WP @ 60 kg/ha (72.00 %) and tobacco powder (62.67 %) recorded mortality of snails after 15 days were also proved to be effective. While, boric powder registered mortality of only 24.00 per cent was not effective. Hence, the study concludes that for the management of GAS use, metaldehyde crystal salt, bleaching powder, tobacco powder and poison baits (methomyl, copper sulphate and thiodicarb) at the tested concentrations are effective (Fig. 6).

The above results regarding the superiority of metaldehyde against snails in different crops are in line with the findings of several workers Mead (1960); Nair *et al.* (1968); Srivastava *et al.* (1968); Saxena and Dubey (1970); Veeresh *et al.* (1979); Sharma and Agarwal (1989); Karnatak *et al.* (1998); Basavaraju *et al.* (2000); Salmijah *et al.* (2000); Javaregowda (2006); Shevale and Bedse (2009); Kumar *et al.* (2013); Rafee *et al.* (2013b); Shilpa (2013) and Mallappa (2014).

Sodium chloride has been used by many scientists in India as well as in abroad for the management of snails and slugs. In the present study it was found that salt treatment was more effective than bleaching powder treatment. These findings are in line with reports of Hall (1932) who advocated the use of aqueous solution of NaCl instead of crystals for control of snails. Latif (1933) used sodium chloride to protect potted orchids from *A. fulica*. Pangga (1949) stated the mortality of *A. fulica* with salt solution. Peterson (1957a) revealed salt water spray either prepared from sodium chloride or as sea water to be effective in killing snails. Singh and Birat (1969) dusted common salt on the crawling *A. fulica* to kill.

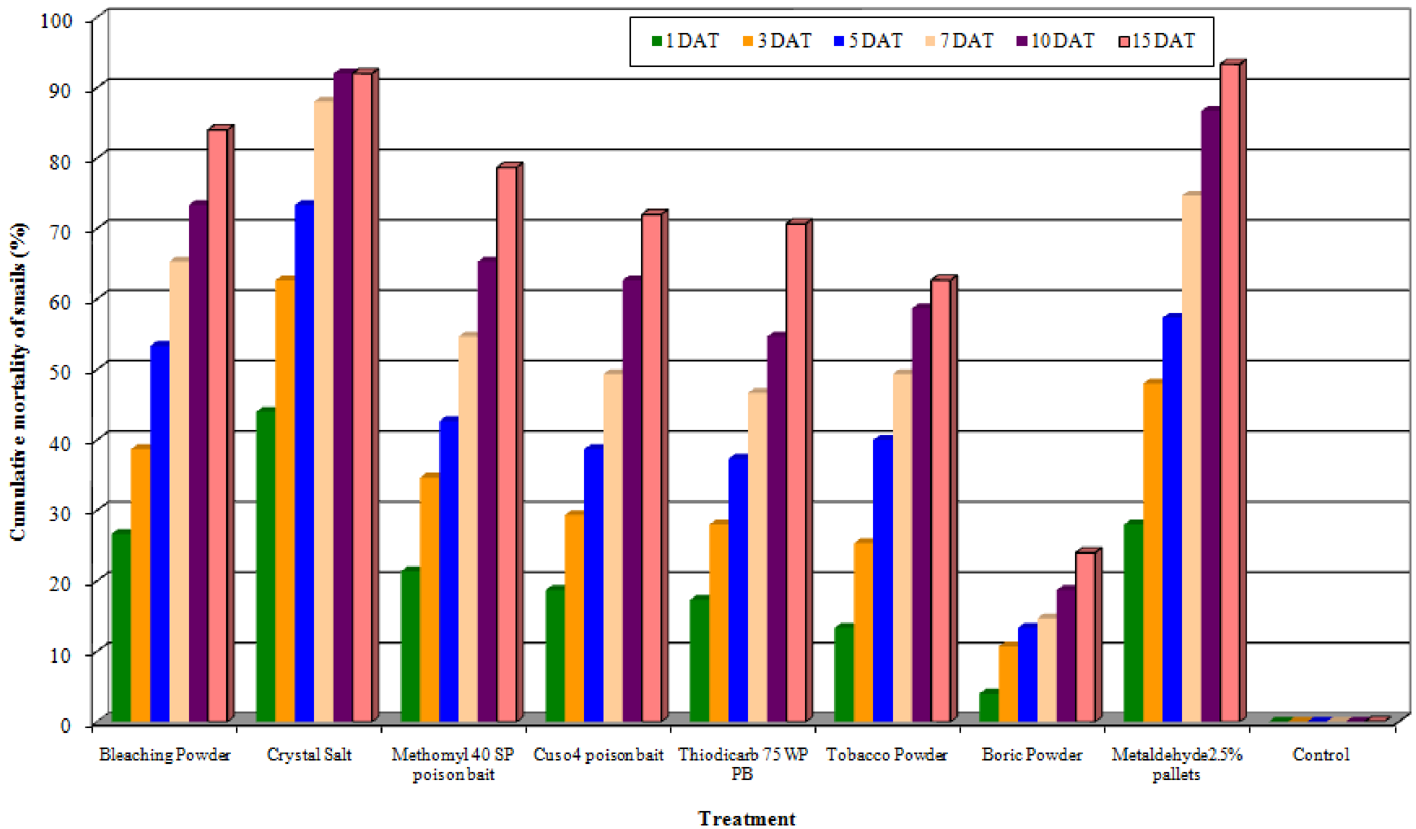



**Fig. 6: Evaluation of different chemicals and poison baits against giant African snail in forest/ horticulture nursery during *kharif*, 2015 (1st Application)**

**Fig. 6: Evaluation of different chemicals and poison baits against giant African snail in forest/ horticulture nursery during *kharif*, 2015 (1st Application)**

Saxena and Dubey (1970) stated that common salt 200 kg/ha and got 98.00 per cent mortality of *A. fulica* in the field six hours after the treatment. Likewise, Raut and Ghose (1984) also reported the use of common salt in the Eastern region of the *A. fulica*. Shah (1992) managed GAS by sprinkling the salt or leaving exposed to the sun. Karnatak *et al.* (1998) revealed 100 per cent mortality after 96 hours at 5 per cent spray of sodium chloride. Rafee *et al.* (2013b) achieved 95.08 per cent control using crystal salt @ 25 kg/ha against *A. fulica* in guava-sapota ecosystem. Crystal Salt @ 25 kg/ha was found to be effect 92.52 per cent mortality of *A. fulica* on betelvine ecosystem (Mallappa, 2014).

Bleaching powder is another effective dehydrating agent for killing snails. After application of bleaching powder, snails immediately withdraw their body parts in to the shell and get dehydrated by continuously releasing mucus from the body. The efforts has revealed in the study is line with the findings of Rafee *et al.* (2013b) who reported that using bleaching powder against *A. fulica* in guava ecosystem given 82.67 per cent cumulative mortality after 7 days of treatment and 70.08 per cent mortality of snail, *C. semirugata* in greengram (Shilpa, 2013). Likewise, findings Mallappa (2014) on per cent mortality of *A. fulica* in betelvine ecosystem by using bleaching powder @ 25 kg/ha was 64.11, 76.48, 78.50 and 86.10 per cent at 1, 3, 5 and 7 days after treatment, respectively.

The poison baits like, methomyl 40 SP, copper sulphate and thiodicarb 70 WP were next best treatments in recording the mortality of snails. The present findings are in line with Shevale and Bedse (2009) who revealed that after three and seven days of application of methomyl 40 SP @ 10 g/kg poison bait (wheat bran + jaggery) effected 83.00 and 68.10 per cent mortality of *A. fulica* in soybean, respectively. While, Kumar *et al.* (2013) reported that methomyl bait with ripened papaya fruit pieces attracted and killed the highest number of snails. Further, Rafee *et al.* (2013b) opined that application of methomyl 40 SP poison bait @ 60 kg/ha and $CuSo_4$ @ 60 kg/ha resulting the cumulative mortality of GAS 72.63 and 71.27 at 7 DAT, respectively, corroborates with present findings. Likewise, Ismail *et al.* (2005) evaluated different chemicals against snail, *M. cartusiana* under field conditions in two fields cultivated with onion and broad bean found that methomyl found highly effective on snails and Yogesh (2015) evoluating among the eight chemical/ poison baits revealed methomyl 40 SP poison bait @ 60 kg/ha causing 81.26 per cent mortality against GAS under field condition in soybean ecosystem.

The present finding on the effectiveness of copper sulphate bait against GAS is in agreement with the results of many earlier workers. Shevale and Bedse (2009) revealed that copper sulphate bait @ 100 g/kg food bait produced 64.60 and 34.00 per cent mortality of *A. fulica* in soybean after 3 and 7th day of application, respectively. Similarly, Kakoty and Das (1987) also found that copper sulphate caused 100 per cent mortality after one week of treatment against GAS. While, Pangga (1949) reported that 1 to 10 per cent solutions of copper sulphate killed the young snails than adults. Further, Saxena and Dubey (1970) revealed that $CuSo_4$ dust @ 5.5 kg/ha against *A. fulica* gave 93.00 per cent mortality. Bhardwaj (1972) observed that 95.8 per cent mortality within 120 h. After dusting with a mixture of copper sulphate and lime the in ratio of 40:60 in small scale field cage experiments. The findings are also in line with Shilpa (2013) and Mallappa (2014) who reported effectiveness of $CuSo_4$ poison bait against *A. fulica* and *C. semirugata*, respectively.

In the present study it was reported that the mortality of snails due to tobacco powder application was 62.67 per cent. But, Mallappa (2014) registered that tobacco decoction with copper sulphate solution caused mortality up to 59.97 per cent after 7 DAT in betelvine ecosystem.

After application of common crystal salt and bleaching powder on snails there was profuse mucus release immediately from body and snails get dehydrated and leads to death. In case of metaldehyde, poison bait and tobacco powder poisoning the snails were unable to withdraw their exposed body parts and release of mucus from the body and later snails were died.

### 5.4.2 Management in protected cultivation of capsicum

Evaluation of different chemicals and poison baits were carried out against GAS in capsicum cultivation under poly house condition revealed that significantly the highest mortality (90.00 %) was recorded due to metaldehyde (Fig. 7). The present study under protected cultivation on capsicum seems to be first of its kind. However, the above results regarding the superiority of metaldehyde against snails in other different crops are in line with the findings of several workers like Saxena and Dubey (1970); Veeresh *et al.* (1979); Sharma and Agarwal (1989); Basavaraju *et al.* (2000); Salmijah *et al.* (2000); Javaregowda (2006); Shevale and Bedse (2009); Kumar *et al.* (2013), Rafee *et al.* (2013b); Shilpa (2013) and Mallappa (2014).

Crystal salt registered as a next best treatment followed by metaldehyde caused 86.67 per cent mortality. The present findings are in line with Vanita *et al* (2011), opined that common salt at 6 cm thickness was found effective barrier against the snails. While, Prasad *et al.* (2004) advocated common table salt effective dehydrating agent; it may be applied as a 12-inch barrier application on the perimeter of known or suspected snail-infested areas. Shilpa (2013) revealed that crystal salt 25 kg/ha recorded 89.03 per cent mortality of *C. semirugata* infesting greengram.

Bleaching powder the next best dehydrating material for killing snails. It caused 83.33 per cent mortality of GAS under poly house condition at 15 DAT. These findings are in conformity with the findings of Rafee *et al.* (2013b) and (Shilpa, 2013). While Mallappa (2014) reported 86.10 per cent per cent mortality of *A. fulica* in betelvine ecosystem by using bleaching powder @ 25 kg/ha at 7 days after treatment.

The next best treatments were methomyl poison bait, copper sulphate, thiodicarb and tobacco powder which caused mortality of 76.67, 73.33, 70.00 and 66.67 per cent, respectively. The present findings are in line with Shevale and Bedse (2009) who revealed that 70 per cent snail population was controlled by using methomyl 40 SP @ 10 kg/ha of fermented food bait (50 kg wheat bran + 5 kg jaggery + 1500g yeast) /ha. Further, Rafee *et al.* (2013b) suggested that application of methomyl 40 SP @ 60 kg/ha and $CuSO_4$ @ 60 kg/ha for achieving the mortality of 72.63 and 71.27 at 7 DAT, respectively to also corroborate with present findings. The present finding on the effectiveness of copper sulphate bait against GAS is agreement with result of Shevale and Bedse (2009) who used copper sulphate bait @ 100 g/kg food bait and achieve 64.60 and 34.00 per cent mortality of *A. fulica* in soybean after 3 and 7th day of application, respectively, Kakoty and Das (1987) who found that copper sulphate causing 100 per cent mortality after one week of treatment, Shilpa (2013) and Mallappa (2014) who reported the effectiveness of $CuSO_4$ poison bait against *A. fulica* and *C. semirugata*, respectively.

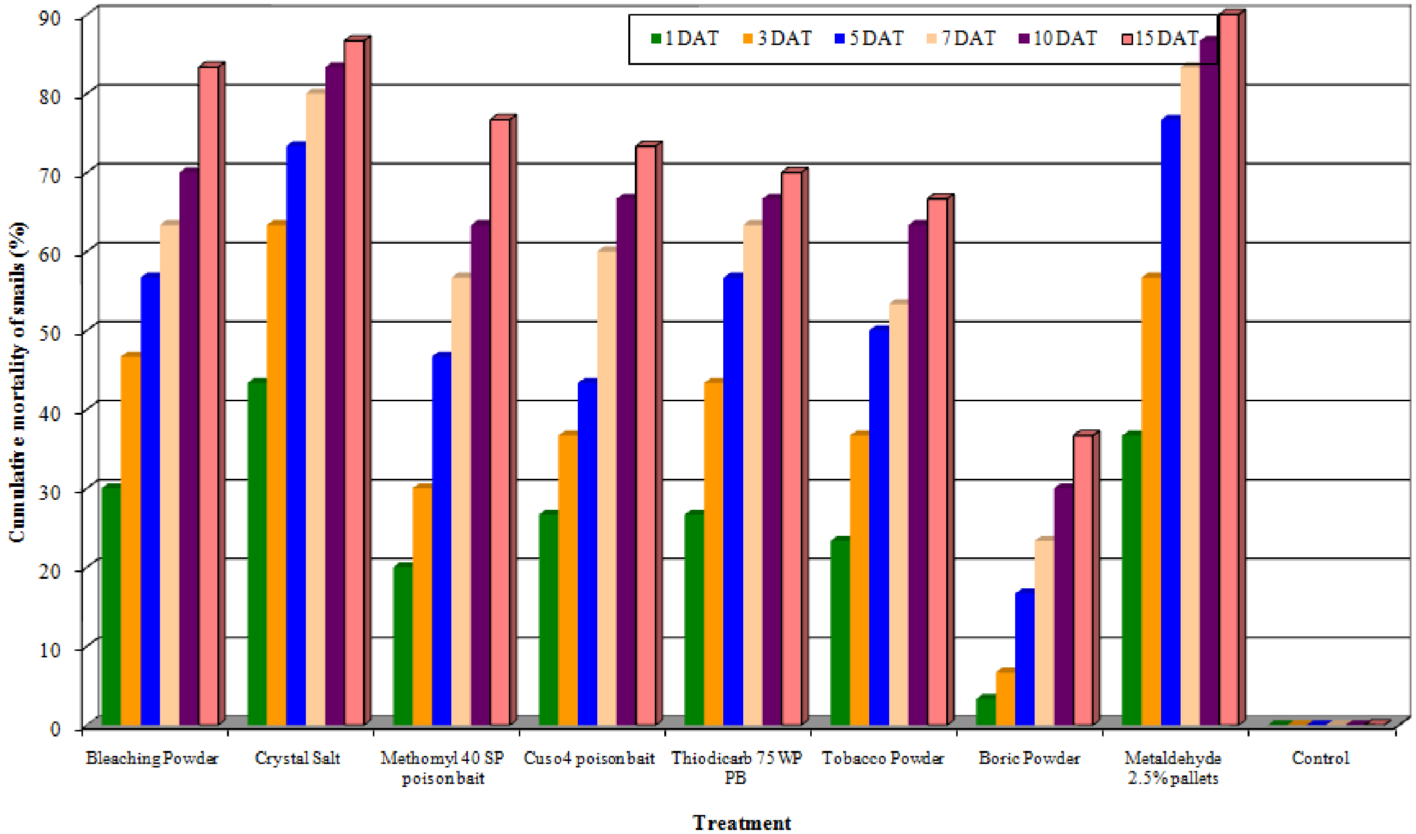



**Fig. 7: Evaluation of different chemicals and poison baits against giant African snail in protected cultivation of capsicum during *kharif,* 2015 (1st Application)**

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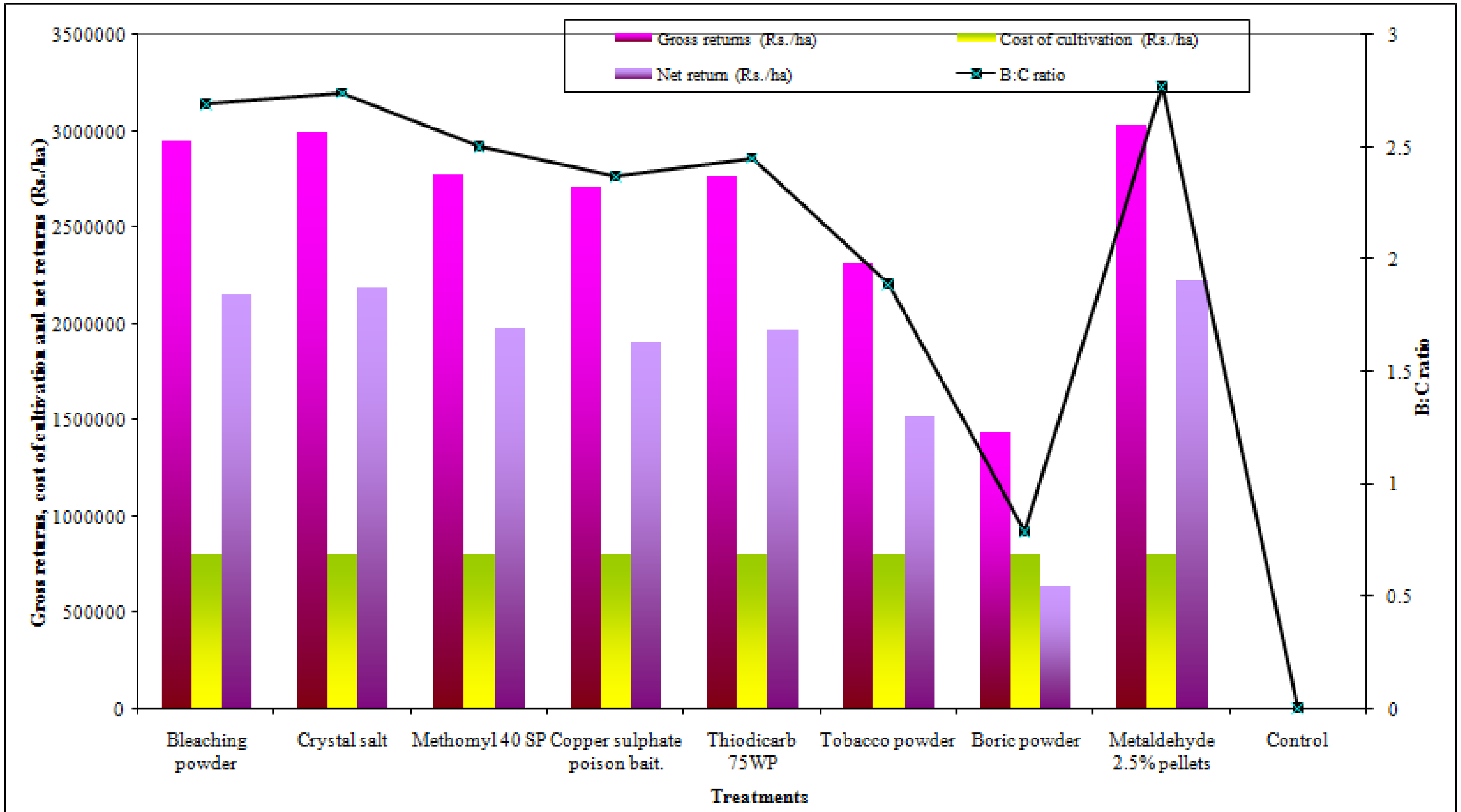


**Fig. 8: Cost economics of different chemicals and poison bait against giant African snail, *Achatina fulica Ferussac* under protected cultivation of capsicum**

**Fig. 8: Cost economics of different chemicals and poison bait against giant African snail, *Achatina fulica Ferussac* under protected cultivation of capsicum**

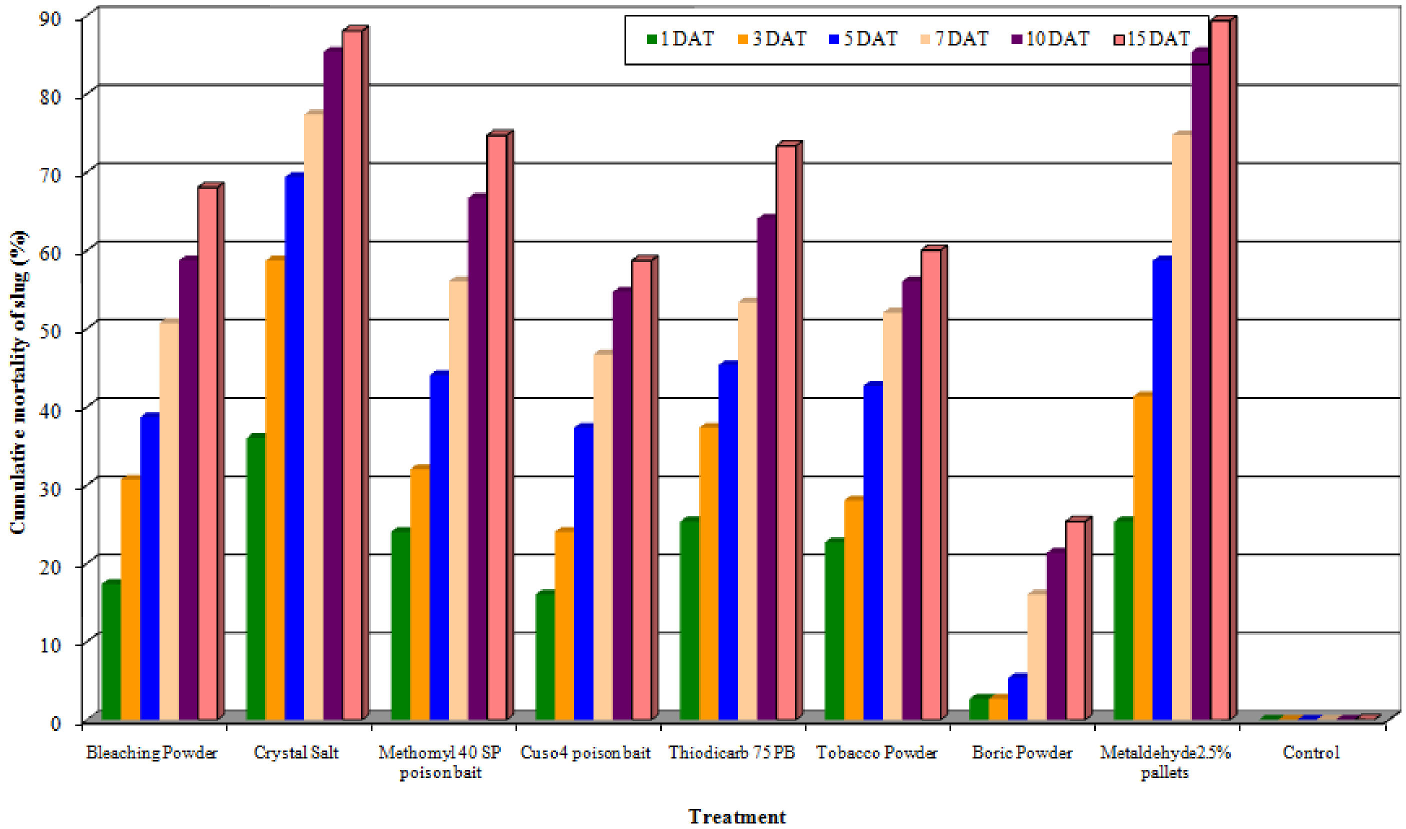


**Fig. 9: Evaluation of different chemicals and poison bait against slug in forest/ horticultural nursery during *kharif*, 2015 (1st Application)**

**Fig. 9: Evaluation of different chemicals and poison bait against slug in forest/ horticultural nursery during *kharif*, 2015 (1st Application)**

The highest benefit cost ratio was obtained from metaldehyde (2.77). This was followed by crystal salt 25 kg/ha (2.74), bleaching powder @ 25 kg/ha (2.69), methomyl 40 SP (2.50), Thiodicarb 75 WP (2.45), copper sulphate @ 60 kg/ha (2.37) and tobacco powder (1.89). The lowest benefit-cost ratio was due to boric powder (0.79). The persual of literature revealed that the reviews pertaining to yield loss of capsicum due to GAS was not available. Hence, this appears to be the first study carried out on yield loss of capsicum due to GAS (Fig. 8).

## 5.5 Management of brown slug, *Laevicaulis alte* in forest/ horticultural nursery and in protected cultivation of capsicum

Evaluation of different chemicals and poison baits against brown slug, *L. alte* in different forest and horticultural nursery was made during *kharif*, 2015. The treatment metaldehyde 2.5 % pellets @ 5 kg $ha^{-1}$ (89.33 %), crystal salt @ 25 kg $ha^{-1}$ (88.00 %) and methomyl 40 SP poison bait @ 60 kg/ha (74.67 %) were superior over rest of the treatments in bringing the mortality of slug. Whereas, the other treatments like, thiodicarb 75 WP poison bait @ 60 kg/ha recorded mortality of 73.33 per cent which is followd by bleaching powder @ 25 kg $ha^{-1}$ (68.00 %) and tobacco powder @ 25 kg/ha (60.00 %) at 15 days after application. While, $CuSo_4$ poison bait and boric powder registered mortality of 58.67 and 25.33 per cent, respectively. Hence, the study concludes that for the management of brown slug by use of metaldehyde, crystal salt, bleaching powder, tobacco powder and poison baits (methomyl, copper sulphate and thiodicarb) at the tested concentrations are effective (Fig. 9).

Some of the chemicals/ poison baits were used in the present study were also evaluated by the previous workers on other crops and the findings of the present study are in agreement with the findings of Hata *et al.* (1998) who reported that metaldehyde (methiocarb G 2-1 and Deadline) caused 62.4 and 81 per cent mortality, respectively on slug, *Vaginula plebeian* Fischer population and Barker *et al.* (1989) who documented that broadcast metaldehyde and methiocarb bait (10 kg/ha) and found that both exerted similar effect on mortality (54- 68 %) of slug in direct drilled maize crop.

Findings of South (1992) and Naik *et al.* (2014) revealing that methomyl (Lannate LV)/methomyl 40 SP (1 g/ l of water) minimized the incidence and damage incurred by slugs is an agreement with present finding exhibiting the methomyl poison bait.

The poison bait with thiodicarb 75WP @ 60 kg/ha proved effective in producing the mortality of brown slug which is supported by two the findings of Henderson and Triebskorn (2002) who reported carbamate insecticide (thiodicarb) having slugs control property in soybean ecosystem.

Tobacco powder @ 25 kg/ha tested against *L. alte* under poly house and nursery condition proved to produce more than 50 per cent of mortality (Fig. 10). However, Selvi *et al.* (2015) also proved that the maximum amount of liquid loss was shown with tobacco coated silica (49.51 %), followed by neem coated silica (48.58 %) and uncoated silica (48.51 %).

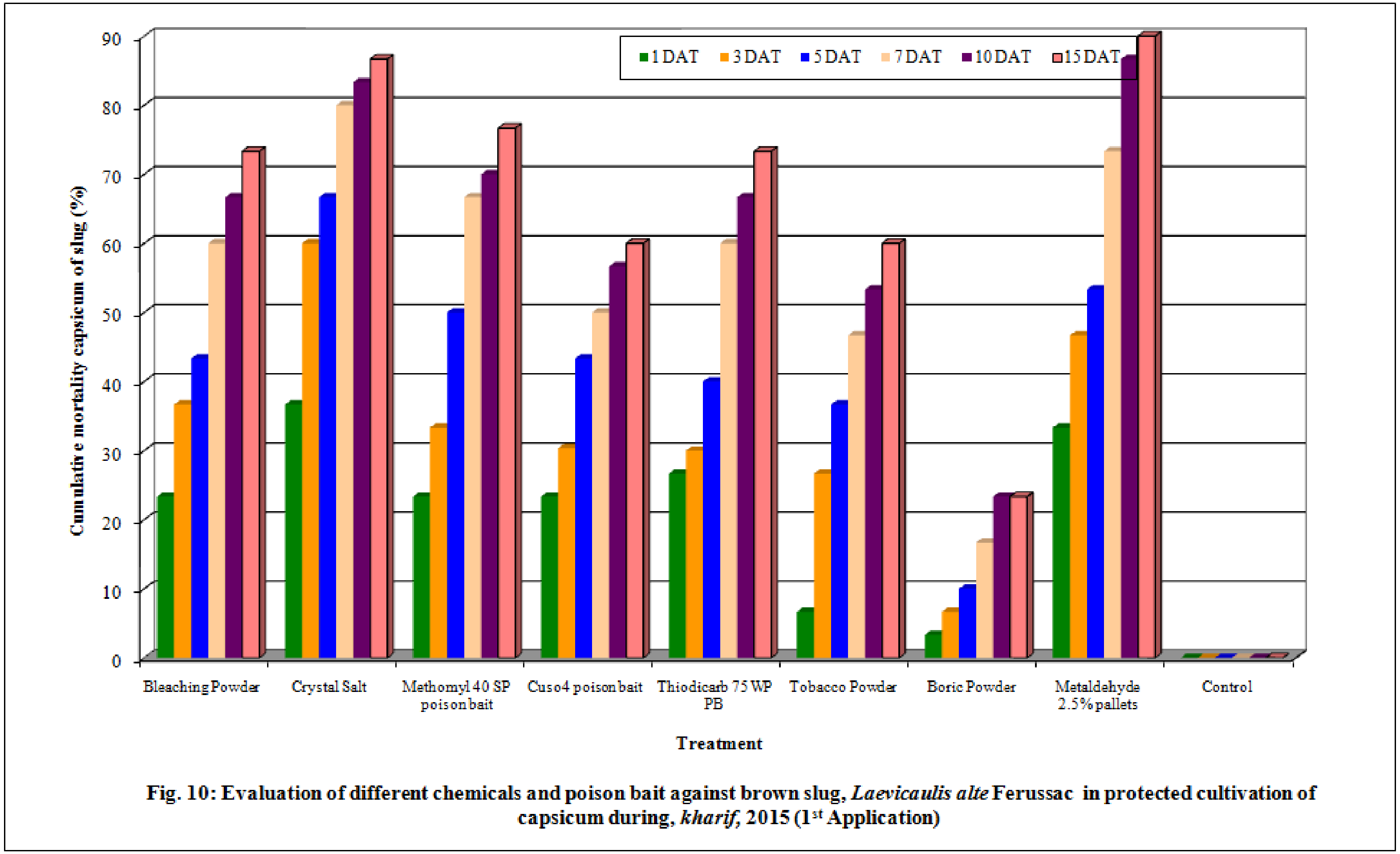


**Fig. 10: Evaluation of different chemicals and poison bait against brown slug, *Laevicaulis alte* Ferussac in protected cultivation of capsicum during, *kharif,* 2015 (1st Application)**

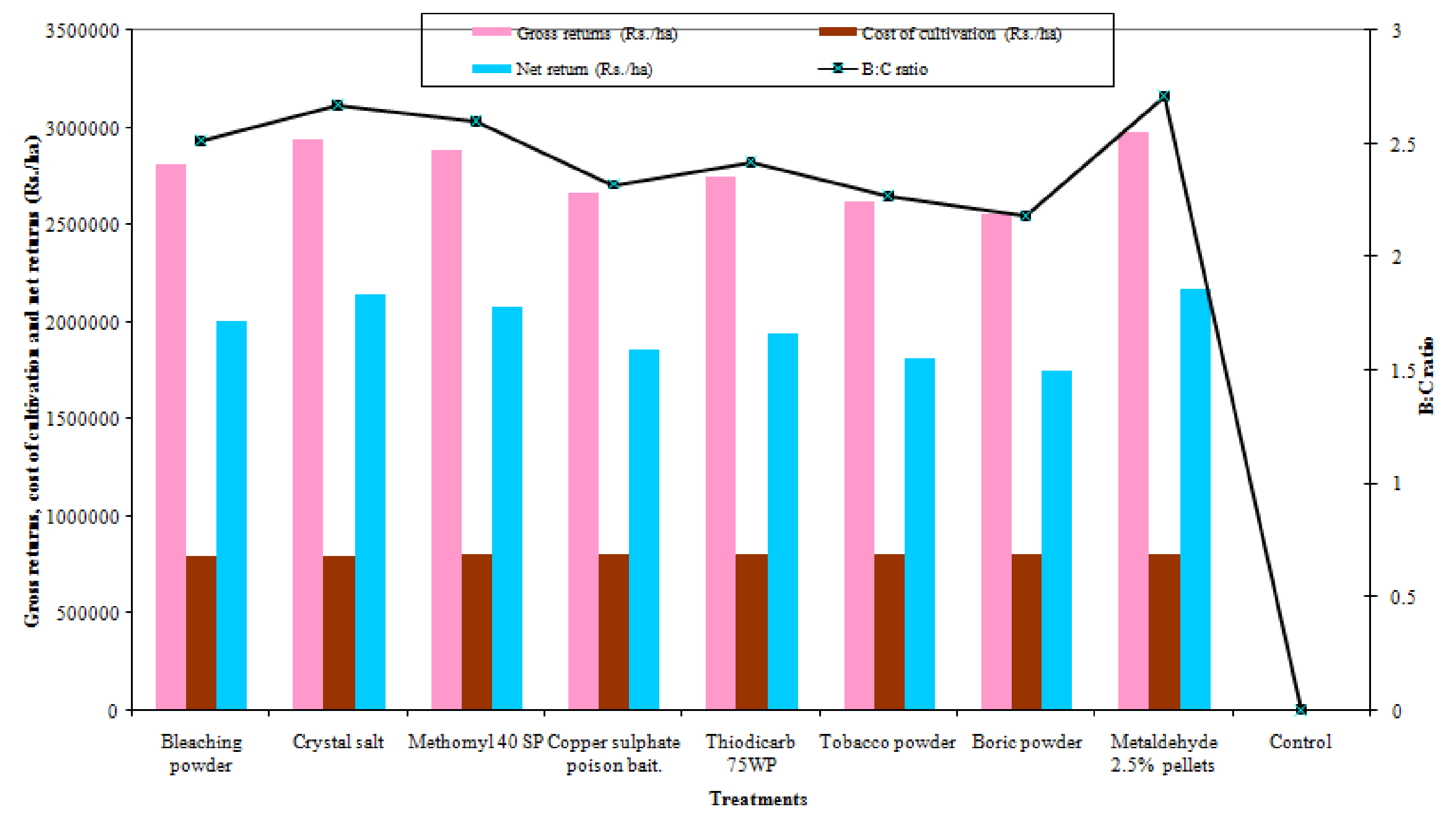


Fig. 11: Cost economics of different chemicals and poison bait against brown slug, *Laevicaulis alte* under protected cultivation of capsicum

**Fig. 11: Cost economics of different chemicals and poison bait against brown slug, *Laevicaulis alte* under protected cultivation of capsicum**

The magnitude of the ratio also indicates the priority to be assigned for each of the alternative investment. The highest B:C ratio was recorded in metaldehyde 2.5 % pellets (2.71) and crystal salt (2.67). Whereas, methomyl 40 SP (2.60), bleaching powder (2.51), Thiodicarb 75 WP (2.42), copper sulphate poison bait (2.32), tobacco power (2.72) and boric powder (2.18) were in the order of decreasing to record B:C ratio (Fig. 11). The literature pertaining to benefit cost ratio on capsicum is not available. Hence, this study carried out on the estimation of benift cost ratio on capsicum under polyhouse condition, is first of its kind.

## Future Line of work

1. To find out EIL for snails and slugs in crops grown under protected cultivation.
2. To find out effective biological/ botanicals for snails and slugs in crops grown under protected cultivation.

# 6. SUMMARY AND CONCLUSIONS

Investigations on “management of giant African snail (GAS), *Achatina fulica* Ferussac and slug *Laevicaulis alte* Ferussac in forest /horticulture nurseries and in protected cultivation” were carried out at High-Tech Horticulture Unit (HHU), UAS, Dharwad in Karnataka during *kharif,* 2015-16. The main objectives of the investigation are “survey for snails and slugs infesting forest/horticulture nurseries and in protected cultivation, to assess the damage potential caused by GAS and slugs on nursery plants, management of snails and slugs by using different chemicals/ poison bait in forest/horticultural nursery and in protected cultivation of capsicum”. The results of the findings are summarised here under.

The activity of snails started during 24$^{th}$ standard week (June 3$^{rd}$ week) of 2015 and persisted up to 2$^{nd}$ standard week of 2016 with peak infestation during 41$^{st}$ standard week (Octo. 2$^{nd}$ week) to 45$^{th}$ standard week (Nov. 2$^{nd}$ week). Whereas, no slug incidence or damage was reported during study period at different surveyed nurseries.

The mean snail population and per cent leaf damage were maximum in moringa (5.54 snail/m$^2$ and 23.35 % leaf damage), while minimum in neem (0.62 snail/m$^2$ and 1.32 % leaf damage). Due to low and scattered rainfall from July to December, 2015 (468.00 mm) the incidence of snail was very less. Further, higher number of snails recorded in October, 2015 was due to receipt of higher amount of rainfall (179.80 mm).

Among the different nurseries surveyed in HHU during *Kharif,* 2015, the mean population of snails varied from 2.01 to 5.54 per 4 m$^2$. The higher snail population was recorded in moringa nursery (5.54/4m$^2$) followed by mango (4.79/4m$^2$), jamun (2.40/4m$^2$) and minimum snail population observed in curry leaf (2.01/4m$^2$). Whereas maximum per cent leaf damage was observed in moringa (23.35 %) followed by mango (12.89 %), curry leaf (10.25 %) and lower in jamun (7.27 %).

During survey in other places of Dharwad the highest number of snail population observed in mango (4.69/4m$^2$) followed by papaya (3.66/4m$^2$), teak (3.53/4m$^2$, Sanjeevini Park), silver oak (2.15/4m$^2$), teak (0.97/4m$^2$ at MARS Dharwad). The highest damage observed in papaya (13.68 %) followed by mango (12.29 %), teak (11.51 % at Sanjeevini Park), silver oak (4.82 %), teak (3.83 % at MARS Dharwad) and the lowest damage observed on neem (1.32 %).

No slug damage was recorded during study period at different surveyed places probably due to less average rainfall received in *Kharif,* 2015.

Correlation between incidence snails and weather parameters revealed that snail population was positively and significantly correlated with rainfall, RH and minimum temperature irrespective of the nursery plants. Whereas, it was negatively correlated with maximum atmospheric temperature.

During survey four species of snails *viz., Allopeas gracile* (Hutton, 1834), *Rachis punctatus* (Anton 1839), *Macrochlamys pedina* (Benson, 1865), *Macrochlamys indica* (Godwin Austen 1908) and three species of slugs *viz., Pseudaustenia ater* (Godwin-Austen, 1888), *Laevicaulis alte* and *Mariaella beddomei* (Godwin-Austen, 1888) were collected from farmers field in Dharwad and Haveri district were identified from ZSI, Chennai.

With respect to assessment of damage potential under confined condition the soft-succulent seedlings *viz.*, papaya (96.00 %), moringa (94.00 %) and sisso (92.00 %) were severely damaged by GAS. However, the hardy seedlings like jamun (47.00 %), pongamia (37.00 %) and banyan (31.00 %) had comparatively less damage. During day time snails were found hiding at the seedling base inside the pot. It was noticed that damage infestation was more on horticultural seedlings compared to forest saplings. Out of 50 saplings provided under each replication the highest per cent of damage to saplings was recorded in moringa (96.00), papaya (94.00) and sisso (92.00) due to their succulent foliage and soft stem and the least damage noticed on pongamia and banyan were 37.00 and 31.00 per cent, probably due to their hardy nature.

The per cent sapling damage due to slug, *L. alte* ranged from 0.00 to 43.00 per cent at 10 days after release (DAR). Papaya suffered the highest per cent damage of 43.00. This was followed by moringa, citrus, teak, curry, tabubia, sisso and neem having 41.00, 37.00, 36.00, 35.00, 32.00, 25.00 and 15.00 per cent damage, respectively. While saplings like subabul, guava, tamarind, silver oak, almond, mango, pongamia, jamun and banyan were not affected any damage by slugs due to their hardiness. Again out of 50 saplings provided under each treatment the highest per cent of damage to saplings was recorded in papaya (43.00), moringa (41.00), citrus (37.00), teak (36.00), curry (35.00) and tabubia (32.00) due to their succulent foliage or soft stem and on the contrary least damage noticed sisso (25.00 %) and neem (15.00 %).

Evaluation of different chemicals and poison baits in forest/horticultural nursery revealed that, the highest per cent mortality of GAS was recorded due to metaldehyde treatment @ 5 kg/ha (93.33 %) followed by crystal salt @ 25.00 kg/ha (92.00 %), bleaching powder @ 25.00 kg/ha (84.00 %) and methomyl 40 SP poison bait @ 60 kg/ha (78.67 %). Whereas, copper sulphate, thiodicarb 75WP poison bait and tobacco powder resulted in 72.00, 70.67 and 62.67 per cent snail mortality, respectively and boric powder documented the lowest mortality of 24.00 per cent during first application at 15 DAT. The similar trend in the efficacy of above treatments was continued during second application also.

Likewise, significantly the highest mortality of GAS was documented due to metaldehyde 2.5 % pellets @ 5 kg/ha (90.00 %) at 15 DAT under protected cultivation of capsicum. This was followed by crystal salt @ 25 kg/ha (86.67 %), bleaching powder @ 25 kg/ha (83.33 %), methomyl 40 SP poison bait @ 60 kg/ha (76.67 %), copper sulphate poison bait @ 60 kg/ha (73.33), thiodicarb 75WP poison bait @ 60 kg/ha (70.00 %) and tobacco powder (66.67 %). However, boric powder effected only 36.67 per cent mortality during the first application. Similar trend was found with the respect to snail mortality in second application also.

With respect to management of snails under protected cultivation of capsicum the highest net returns (Rs. 2227632.70/ha) and benefit cost ratio (2.77) was reaped from metaldehyde 2.5 % pellets @ 5.0 kg/ha. The next best treatments to record the highest net returns and B: C ratio were crystal salt (Rs. 21,90,307.70/ha and 2.74) and bleaching powder (Rs. 21,51,407.70 and 2.69).

For management of slugs in forest/horticulture nursery different chemicals and poison baits were evaluated. The highest cumulative mortality was recorded in metaldehyde 2.5 % pellets (89.33 %) and crystal salt (88.00 %) at 15 DAT which were significantly superior over the rest of the treatments. The methomyl 40 SP (74.67 %), thiodicarb 75WP (73.33 %) and bleaching powder (68.00 %) were the next best treatments. Tobacco powder and copper sulphate documented 60.00 and 58.67 per cent mortality, respectively. Whereas, the application of boric powder was least effective (25.33 %).

Among the different chemicals and poison baits evaluated at 15 DAT for the control of brown slug, *Laevicaulis alte* metaldehyde 2.5 % pellets could cause the highest mortality of 90.00 per cent. This was followed by crystal salt, methomyl 40 SP, bleaching powder/ thiodicarb 75WP, tobacco powder and boric powder produced 86.67, 76.67, 73.33, 60.00 and 23.33 per cent slug mortality, respectively. Hence, metaldehyde, crystal salt and methomyl are the best treatments for management of *L. alte.*

With respect to the net returns and benefit cost ratio reaped, metaldehyde 2.5 % pellets @ 5 kg $ha^{-1}$ (yield of 1190.67 q/ha) was recorded net returns of Rs. 2178482.70 which got B:C ratio of 2.71 and yield of 1176.33 q/ha was registered in crystal salt @ 25 kg $ha^{-1}$ treated plot which has got next best net returns (Rs. 21,40,307.70) with highest B:C ratio (2.67). The lowest yield (1022.67 q/ha), net returns (Rs. 17,52,732.70) and B:C ratio (2.18) were due to boric powder.

# REFERENCES


Adimani, B. D., 1976, Studies on the insects of soybean, *Glycine max* (L.) Merill with special reference to bionomics and control of pod borer, *Cydia ptychora* Meyrick (Lepidoptera : Torticidae). *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bengaluru, Karnataka (India).

Albuquerque, F. S., Peso-Aguiar, M. C. and Assunçao-Albuquerque, M. J. T., 2008, Distribution, feeding behavior and control strategies of the exotic land snail, *Achatina fulica* (Gastropoda : Pulmonata) in the northeast of Brazil. *Brazilian J. Biol.*, 68 (4) : 837-842.

Altson, R. A., 1950, Giant snail report (1941- 1945). Rubber Reseach Institute, Malaya, p. 67.

Anonymous, 2000, DPI notes on giant African snail, Animal and Plant Health Service, DPT, Queens land, pp. 1-9.

Anonymous, 2007, *Annu. Rep. 2006-07*, Central Plantation Crops Research Institute, Kasaragod - 671 124, Kerala, India, 124 p.

Bailey, S. E. R., 2002, Molluscidical baits for control of terrestrial gastropods. In: *Molluscs as crop pests,* Ed. Barker, G. M., CAB International, Wallingford, United Kingdom, pp. 33-54.

Barker, G. M., Pottinger, R. P., Mcghie, R. A. and Addison, P. J., 1989, Slug control in direct-drilled maize. *New Zealand J. Exp. Agric.,*12: 155-159.

Baker, G. H., 1988, The life history, population dynamics and polymorphism of *Cernuella virgata* Aust. (Mollusca : Helicidae). *J. Zool.*, 36 : 497-512.

Baker, G. H., 1989, Damage, population dynamics, movement and control of pest helicid snails in Southern Australia. In : *Slugs and Snail Pests in Agriculture*. Ed. Henderson, I. F, Monograph, No. 41 British Crop Protection Council (BCPC), England, pp. 175-185.

Baker, G. H., Hawke, B. G. and Vogelzeng, B. K., 1991, Life history, population dynamics of *Cochlicella acuta* Muller (Gastropoda : Helicidae) in a pasture cereal-rotation. *J. Moll. Stud.*, 57 : 259- 266.

Barker, G. M., 2001, The biology of terrestrial Molluscs. CABI Publishing, New York, USA.

Balikai, R. A., 1999, Incidence of snail, *Cryptozona semirugata* (Beck) on some horticultural crops in Northern Karnataka. *Pest Manag. Hort. Ecosys.*, 5 (1) : 70-71.

Balikai, R. A., 2008, Potential of snails as crop pests in northern dry zone of Karnataka. *Intl. J. Agric. Sci.,* 4 (1) : 394-396.

Barnes, H. F. and Weil, J. W., 1942, Baiting slugs using metaldehyde mixed with various substances. *Ann. Appl. Biol.*, 29 (1) : 56-68.

Basavaraju, S. B., Kulapati, H., Gowda, C. C., Sharanappa, J., Murthy, N. K. and Hipparagi, K, J. S., 2000, Preliminary survey on the incidence of *Achatina fulica* Bowdich in Davanagere district. *Curr. Res.*, 29 (7-8) : 129.

Basavaraju, B. S., Girish, A. C., Thyagaraj, N. E. and Chakravarty, A. K., 2010, Giant African snail, *Achatina fulica* Bowdich: A menace in Hassan district, southern transitional zone of Karnataka: A Survey. Paper presented In : *34th Ann. Conf. of ethological Soc. of India and Natioal sympogium on Ethology from organism Down to Ethobomolecule*. Centre for Arthropod Bioresources and Biotechnology (CABB), University of Kerala, Thiruvananthapuram and Ethological Society of India, December. 16-18, 2010, p.38.

Bhalla, O. P. and Pawar, A. D., 1977, A survey of insect and non insect pests of economic importance in Himachal Pradesh. Dept. of Entomology Zoology, College of Agriculture, Chambalghat, Solan (H. P), Monograph. p. 80.

Bhardwaj, A. K., 1972, Testing of pesticides against the giant African snail, *Achatina fulica* Bowdich. *Indian J. Entomol.,* 34 (1) : 42-45.

Bhardwaj, A. K. and Thakur, J. R., 1973, Record of snail, *Bensonia monticola* Hutton as pest of Beans. *Curr. Sci.,* 42 (21) : 769.

Bhat, P. K. and Shamanna, H. V., 1973, Screening of poison baits against snails in South India. *J. Coffee Res*., 3 (1) : 24-27.

Bishara, S. I., Hassan, M. S. and Kalliny, A. S., 1968, Studies on some land snails injurious to agriculture in U. A. R. *Revue de zoologie et de botanique africaines, LXX VII* (3-4) : 239-252.

Blowers, J. W., 1954, A new method of controlling slugs and snails. *Orchid Rev*., 62 (73) : 56.

Chang, H. W. and Emelen, J. M., 1993, Seasonal variation of microhabitat distribution of the polymorphic land snail, *Cepaea nemoralis*. *Oecologia*, 93 (4) : 501-507.

Chemberlin, I. J., 1952, Final report on an ecology and population study of the giant African snail on Tinian, Marianas Islands. Pacific Science Board of the National Research Council. Invertebrate Consultants committee for the Pacific, p. 27.

Chhabra, E., 2008, Gastropod problem and its management in ornamental plant nurseries. *M.Sc. (Agri.) Thesis*, Pub. Agric. Univ., Ludhiana (India).

Crowell, H. H., 1967, Slug and snail control with experimental poison baits. *J. Econ. Entomol*., 60 : 1048-1050.

Crowley, T. E. and Pain, T., 1959, A monographic revision of the African land snails of the genus *Burtoa* (Mollusca: Achatinidae). *Annales du Musee Royal de lAfrique Centrale, Tervuren, Belgique*. *Sci. Zool*., 79 : 1-35.

Daniel, M. and Vanavasan, N. K., 2009, The slug, *Mariaella dussumieri* Gray - an economically important pest of arecanut palms. *J. Plantation Crops,* 37 (1) :88-90.

Donnell, R. J. M., Paine, T. D., Stouthamer, R., Gormally, M. J. and Harwood, J. D., 2008, Molecular and morphological evidence for the occurrence of two new species of invasive slugs in Kentucky, *Arion intermedius* Normand and *Arion hortensis* Férussac (Arionidae: Stylommatophora). *J. Kentucky Aca. Sci.* 69 (2) : 117-123.

Ebenso, I. E., Ita, B., Umoren, E. P., Ita, M., Binang, W., Edet, G., Izah, M., Udo, I. O., Ibanga, G. and Ukpong, E. E., 2005, Effect of carbamates molluscicide on African giant land snail, *Limicolaria aurora*. *J. Appl. Sci. Env. Manag*., 9 (1) : 99 – 102.

Gimingham, C. T., 1940, Some recent contributions by english workers to the development of methods of insect control: Slugs. *Ann. Appl. Biol*., 27 (2) : 167-168.

Giraddi, R. S., Kulkarni, K. A. and Manjunath, M., 1996, Outbreak of snail, *Cryptozona semirugata* (Beck) on field crops. *Karnataka J. Agric. Sci*., 9 (3) : 533-534.

Gorokhov, V. V. and Aliev, N, A., 1971, Application of carboxylic acid amides to control ground mollusks. *Byull. Vses. Inst. Gelmint*., 5 : 15-19.

Gorokhov, V. V. and Krylov, A. I., 1972, Comparative test of molluskocidal efficacy of various application forms of metaldehyde and preparation No. 19 in field conditions. *Byull. Vses. Inst. Gelmint*., 6 : 31-36.

Govindan, R., Deviah, M. C., Rajashekaragouda, R. P. and Tippeswamy, C., 1980, The Snail, *Cochliopa* sp. (Pectin-Branchiata : Amnicolidae) - A pest of mulberry. *Indian J. Seri*., 19 : 43-44.

Gude, G. K., 1914, Fauna of British India : Mollusca II, Taylor and Francis, London.

Gupta, G. P. and Doharey, K. L., 1985, Non insect pest and predators, All India Scientific Writers Society, New Delhi.

Hall, A. H., 1932, Eradication of slugs and snails. Nature. 130 (3274) : 170.

Hata, T. Y., Hara, A. H. and Hu, B. K., 1998, Molluscicides and mechanical barriers against slugs, *Vaginula plebeia* and *Veronicella cubensis* (Stylommatophora : Veronicellidae). *Crop Protec.,* 16 (6) : 501-506.

Henderson, I. and Triebskorn, R., 2002, Chemical control of terrestrial gastropods. In: Ed. Barker, G. M, *Molluscs as crop pest*, CAB International, Willingford, UK, pp. 1-32.

Ismail, S. A., Abdallah, A. A., El-Massry, S. A. and Hegab, A. M., 2005, Evaluation of certain chemicals and insecticides against *Monacha cartusiana* snails infesting some vegetable crops at Sharkia Governorate. *J. Agric. Sci., Mansoura Univ*., 30 (10) : 6283-6291.

Jagtap A. B., Mali, M. S. and Moholkar, P. R., 1989, Chemical control of snail, *Cryptozona belangiri* D. infesting bean crop *Dolichos lablab*. *Pestology,* 13 (2) : 13-15.

Jagtap, A. B., 2000, Snails and slugs problem of crops and their integrated management. *In*: Eds.Upadhyay R. K., Mukerji, K. G. and Dubey, D. P. *IPM System in Agriculture*, (7): 309 Key Animal Pests. Published by Aditya Book Pvt. Ltd., New Delhi, India, p. 309.

Jary, S. G., 1939, Meta-fuel for the control of slugs and snails. *Sci. Hort*., 7 : 180 85.

Javaregouda, 2006, Incidence of snail, *Achatina fulica (*Bowdich) in betelvine and its management. *Pest Manag. Hort. Ecosys*., 12 (1) : 41- 46.

Jefferson, R. N., 1952, The control of slugs, varying degrees of success achieved with metaldehyde sprays and dusts. *Florists Rev.*, 111 : 29-30.

Jayashankar, M.,Veeresh G. K., Rajagopal, D. and Reddy, M. S., 2010, Evaluation of management strategies of the global pest, giant African snail *Achatina fulica* (Bowdich). *Proc. Intl. Conf. Env. Agriculture and Food Security in India,* pp. 180-186.

Jayashankar, M., Aravind, N. A. and Reddy, M. S., 2012, Distribution of pestiferous terrestrial molluscs in Bengaluru region, Karnataka. Department of Zoology, Bengaluru. *Biodiversity and Taxonomy,* pp. 55–60.

Kakoty, N. N. and Das, S. C., 1987, The giant African snail, *Achatina fulica* Bowdich a non-arthropod pest. *Two and Bud.*, 34 (1-2): 33-35.

Karnatak, A. K., Srivastava, R. M. and Kanaujra, K. R., 1998, Management of giant African snail, *Achatina fulica* Bowdich, Tarai region of Uttar Pradesh. *Indian J. Ecol.,* 25 : 81-83.

Kaur, H., 2002, Nature of damage inflicted by the brown slug with black spots, *Filicauli alte* (Ferussac) and its control with some chemicals. *Pestology,* 26 (8) : 38-40.

Kaur, H. and Kaur, A., 2003, The nature and extent of damage by the black/black brown slug, *Filicaulis alte* (Ferrussac) to seedlings of some economically important plants. *Pest. Mngt. and Econ. Zol.,* 11 (2) : 199-201.

Kaur, H. and Kaur, R., 2008, Field evaluation of two additives for improving the acceptance of some molluscicide baits by the slug, *Filicaulis alte* Ferussac in vegetable fields at Malerkotla (Punjab). *Environ & Ecol.,* 26 (4) : 1602-1606.

Kaur, H. and Mehta, R., 2013, Damage in vegetable crops caused by brown slug *Filicaulis Alte* Ferussac. *J. Res. Punjab. Agric. Univ.,* 50 (3 & 4) : 131-135.

Kaur, N. and Kaur. H., 2014, The nature and extent of damage by the brown slug, *Filicaulis alte* ferussac, to some vegetable crops in Barnala and Sangrur districts, Punjab. *Inter. J. Adv. Res.*, 2 (2) : 771-781.

Kotikal, Y. K. and Devaiah, M. C., 1987, Insect and non-insect pests of mulberry, *Morus alba* L. *Proc. Sem. Pros. Probl. Seric. India*. Vellore, Tamilnadu, India, p. 65.

Kumar, A. R. V., Chandrashekara, K. and Prabhu, C. G., 2013, Studies on the management of giant African snail, *Achatina fulica* Bowdich. Paper presented In: *10$^{th}$ National Symposium on Soil Biology and Ecology- Soil Biota and Social Insects for Sustainable Agriculture,* Univ. Agric. Sci., Bangaluru, Karnataka, India, December, 2013, 19– 21, p.134.

Latif, S. M., 1933, Een gevaarlijke vijand. *De Orchidee*, 2 (5) : 108-110.

Lydeard, C., Cowie, R. H., Ponder, W. F., Bogan, A. E., Bouchet, P., Clark, S. A., Cummings, K. S., Frest, T. J., Gargominy, O., Herbert, D. G., Hershler R., Perez, K. E., Roth, B., Seddon, M., Strong, E. E. and Thompson. F. G., 2004, The global decline of non-marine molluscs. *Bio Sci.*, 54 : 321–330.

Mallappa, C., 2014, Crop los estimation due to giant Afgrican snail, *Achatina fulica* Ferussac at different phonological stages of groundnut during 2012-13 and 2013-14, *Ph. D. Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).

Mallappa, C. and Patil, R. K., 2014, Population dynamics of giant African snail, *Achatina fulica* Ferussac (Stylommataphora : Achatinidae) in betelvine ecosystem. *J. Exp. Zool. India*, 17 (1) : 285-288.

Mavinkurve, R. G., Shanbhag S. P. and Madhyastha, N. A., 2004, Checklist of terrestrial gastropods of Karnataka, India. *Zoos' Print J.*, 19 (11) : 1684-1686.

Manna, B., 1976, Possibility of the use of organophosphorus chemicals, diazinon and fenitrothion as gut poison in the control of *Achatina fulica*. *Ph. D Thesis*, University of Kolkata, Kolkata (India).

Manna, B. and Ghose, K. C., 1972, Histo-pathological changes in the gut of *Achatina fulica* caused by endrin, a molluscicide. *Indian J. Exp. Biol.*, 10 : 461-463.

Manna, B. and Raut, S. K., 1986, Feeding adaptation of the gaint African land snail, *Achatina fulica*. *Environ. Ecol.,* 4 : 158-159.

Mariconi and De, A. M. F., 1955, Snails as pests of coffee. *Folha da Manha*, 30 (338) : 37-38.

Mead, A. R., 1949, The giant snails. *Atlantic*, 184 (2) : 38-42.

Mead, A. R., 1960, An epizootic in the giant African snail. *American Malacol. Union*, p. 40.

Mead, A. R., 1961, The Giant African Snail : A problem in economic malacology. The University of Chicago Press, Chicago, p. 257.

Mead, A. R., 1979*,* Economic malacology with particular reference to *Achatina fulica*. In : *Pulmonates*, Ed. Fretter, V. and Peake, J., Academic Press, London, p. 150.

Mead, A. R. and Palcy, L., 1992, Two giant African land snail species spread to Martinique, French West Indies. *The Veliger*, 35 : 74-77.

Moreton, B. D., 1953, Preliminary experiments with metaldehyde suspensions against slugs. *Plant Path*., 2 : 49-51.

Naik, S. O., Jayashankar, M., Sridhar, V. and Chakravarthy, A. K., 2014, Record of the brown slug, *Mariella dussumieri* Gray, 1855 (Gastropoda: Ariophantidae) in marigold (*Tagetes* sp.) *Curr. Biotica.,* 8 (2) :183-186.

Nair, M. R. G. K., Das, N. M. and Abraham. J., 1968, Use of metaldehyde as dusts and sprays to control the giant African snail, *Achatina fulica* Bowdich. *Indian J. Entomol*., 30 (1) : 58-60.

Narayanaswamy, K. C. and Geethabai, M., 1997, *Indoplanorbis exustus* (Deshayes) (Basammatophora : Planorbidae) - A new pest of mulberry, *Curr. Res.,* 26 (3) : 52.

Olson, F. J., 1973, The screening of candidate molluscicides against the giant African snail, *Achatina fulica* Bowdich (Stylommatophora : Achatinidae), *Ph. D Thesis*, University of Hawaii.

Padmanaban, B., Thangavelu, R. and Sundararaju, P., 2000, Occurrence of giant African snail, *Achatina fulica* on banana (in Tamil Nadu). *Indian J. Entomol*., 62 (1) : 95-97.

Pangga, G. A., 1949, A preliminary report on the biology, ecology and control of the giant African snail (*Achatina fulica* Fer.). *Philippine J. Agric*., 14 (4) : 337-347.

Panigrahi, A. and Raut, S. K., 1993, On the safe use of pesticides in controlling the terrestrial mollusc pests, Mem Inst. *Oswaldo Cruz*., 88 (2) : 293-298.

Pappas, J. L. and Carman, G. E., 1955, Field screening tests with various materials against the European brown snail on citrus in California. *J. Econ. Entomol*., 48 (6) : 698-700.

Pereira, H. P. and Goncalves, L. I., 1949, Caramujos, caracois e lesmas nocivos e meios de combate. *O Biologico* (Sao Paulo), 15 (4) : 65-73.

Peterson, G. D., 1957a, Studies on control of the giant African snail on Guam. *Hilgardia*, 26 (16) : 643-658.

Peterson, G. D., 1957b, Studies on control of the giant African snail on Guam. *Hilgardia*, 26 (16) : 643-658.

Peterson, G. D., 1957c, Studies on control of the giant African snail on Guam. *Hilgardia*, 26 (16) : 643-658.

Prasad, S. G., Singh, D. R., Senani and Medhi, R. P., 2004, Ecofriendly way to keep away pestiferous giant African snail, *Achatina fulica* Ferussac from nursery beds. *Curr. Sci*., 87 (12) : 1657-1659.

Prem, B. B. and Naggs, F., 2008, The giant African land snail, *LissAchatina fulica* (Bowdich) in Nepal, *The Malacol*., 50 : 19-21.

Puttaswamy, Reddy, D. N. R. and Krishna Naik, L., 1981, Occurrence of *Cryptozona semirugata* on cultivated plants. *Curr. Res*., 10 : 1-62.

Rafee, C. M., Patil, R.R., Goud, K. B., Patil, R. K., Krishna Naik, L. and Patil, R. H., 2013a, Survey for infestation of giant African snail in Hubli taluka. Paper presented In: *10th Nat. Symp. on Soil Biol. and Ecology- Soil Biota and Social Insects for Sustainable Agriculture*, Univ. Agric. Sci., Bangaluru, Karnataka, , India, December 19-21, 2013, p.155.

Rafee, C. M., Patil, R. R., Goud, K. B., Patil, R. K., Krishna Naik, L. and Patil, R. H., 2013b, Management of giant African snail, *Achatina fulica* Bowdich in Guava. Paper presented In: *10th Nat. Symp. on Soil Biol. and Ecology- Soil Biota and Social Insects for Sustainable Agriculture*, Univ. Agric. Sci., Bangaluru, December 19-21, p. 141.

Ramakrishna, Mitra, S. C. and Mukherjee, A. K., 2005, Mollusca fauna of Itanagar wildlife sanctuary, Arunachal Pradesh. *Rec. Zool. Surv. India*, 104 (3/4) : 1-12.

Ramakrishna, Mitra S. C. and Dey, A., 2010, Annotated checklist of Indian land mollusc. *Zool. Surv. India*, Kolkata, p. 359.

Ramzy, R. R., 2009, Biological and ecological studies on land snails at Assiut, Egypt. *M. Sc. Thesis,* Faculty of Sc., Agric.Univ. Egypt.

Rao, V. T., Ramadoss, P. and Rao, M. K., 1953, Snails damage to paddy in the northern Circars and their control. *Madras Agric. J.*, 40 (10) : 445-452.

Raut, S. K. and Ghose, K. C., 1984, Pestiferous land snails of India. Zoological Survey of India, Bani Press, Calcutta, India.

Ravikumara, Mohan, I. N., Manjunath, M. and Pradeep, S., 2007, Seasonal incidence of giant African snail, *Achatina fulica* Ferussac (Gastropoda: Achatinidae) in areca ecosystem. *Karnataka J. Agric. Sci.*, 20 (1) : 157-158.

Reddy, D. N. R. and Puttaswamy, 1984, Pests infesting chilli (*Capsicum annum* L.) in the nursery. *Mysore J. Agric. Sci.*, 18 : 122-125.

Reddy, K. B. and Sreedharan, K., 2006, Record of giant African snail, *Achatina fulica* Bowdich on coffee in Visakha agency areas, Andhra Pradesh. *Indian Coffee*, 70 (12) : 17-19.

Salmijah, S., Chan, M. K., Kong, B. H., Maimon, A. and Ismail, B. S., 2000, Development of resistance in *Achatina fulica* Fer. and *Bradybaena similaris* Fer. towards metaldehyde. *Pl. Protec. Quart.,* 15 (1) : 2-5.

Sarkar, B. B., Chauhan, R., Chaudhury, D. M., Majumder, B. I., Dasgupta, A. and Debbarma, B. L., 1997, Studies on habitat, bionomics and bio efficacy of insecticidal bait against giant African snail (*Achatina fulica* Ferussac). *Indian J. Hill Farm.,*10 (1/2) : 32-37.

Saxena, B. N. and Dubey, D. N., 1970, Field trials on the control of land snails. *Pesticides*, 4 (5) : 20-23.

Saxena, R. M. and Mahendra, V. K., 2000, An introduction to giant African snail, *Achatina fulica*, its destructive ability and an attempt to control by using bait technique. *Flora and Fauna*, 6: 27-28.

Schotman, C. Y. L., 1989, Data sheet on the gaint African Snail *Achatina fulica* Bowdich (Mullusca; Achatinidae). PROVEG-19. FAO Regional Office of Latin America and the Caribbean Plant Quarantine Action Programme, pp. 16-21.

Selvi, V, A., Ram, L. C. and Masto, R. E., 2015, Molluscicidal effect of biogenic silica and botanical pesticides for the control of *Achatina fulica* (giant African land snail) and *Laevicaulis alte* (garden slug), *J. Phytopath. and Pest Manage.,* 2 (1) : 12-21

Serb, J. M. and Lydeard, C., 2003, Complete mtDNA sequence of the North American freshwater mussel, *Lampsilis ornata* (Unionidae) : an examination of the evolution and phylogenetic utility of mitochondrial genome organization in Bivalvia (Mollusca), *Mol. Bio. Evo.*, 20:1854–1866.

Shah, N. K., 1992, Management of the giant African snail. *Indian Farm.,* 41 : 21.

Sharma, D. D. and Agarwal. M. L., 1989, Save your crops from giant African snail. *Indian Farm.*, 38 : 15-22.

Shevale, B. S. and Bedse, V. L., 2009, Evaluation of different poison baits for the management of giant African snail, *Achatina fulica* Bowdich. *Pest Manage. Hort. Ecosys.*, 15 (2) : 147-149.

Shilpa A. G., 2013, Studies on snail, *Cryptozona semirugata* (Beck.) in major agricultural crops. *M.Sc. (Agri.) Thesis*. Univ. Agril. Sci., Dharwad, Karnataka (India).

Shree, M. P., Ravi Kumar, K. and Nagaveni, V., 2006, Infestation of giant African snail on mulberry. *Indian Silk*, 45 (6) : 14-16.

Singh, C. and Birat, R. B. S., 1969, The giant African land snail, *Achatina fulica* Bowdich in Bihar. *J. Bombay Nat. Hist. Soc.*, 66 : 201-203.

South, A., 1992, *Terrestrial Slugs. Biology and Control*. Dept. of Biological Sciences, City of London polytechnic Chapman & Hall London New York, Tokoy of Melbourne, Marras., 2(1) : 169–180.

Sridhar, V., Jayashankar, M., Vinesh, L. S. and Abraham, V., 2012, Severe occurrence of the giant African snail, *Achatina fulica* (Bowdich) (Stylommatophora: Achatinidae) in Kolar district, Karnataka. *Pest Manage. Hort. Ecosys.*, 18 (2) : 228-230.

Srivastava, P. D., 1973, The giant African snail and its control. *Indian Farm.*, 33-36.

Srivastava, P. D., 1992, Problem of land snail pests in agriculture: A study of the giant African snail. Concept Publishing Company, New Delhi, India.

Srivastava, P. D. and Abbas, S. R., 1973, How to check the spread of giant African snail. *Entomol. Newslett.*, 3: 36.

Srivastava, P. D. and Srivastava, Y. N., 1968, Role of snails desease in the biological control of *Achatina fulica* Bowdich in the Andamans. *The Veliger*, 10: 320-321.

Srivastava, P.D., Srivastava, Y. N. and Singh, J., 1968, Observations on tne control of *Achatina fulica* Bowdich the giant African snail with metaldehyde, *Indian J. Entomol.*, 3 (2) : 175-176.

Subba Rao, N. V., 1975, Notes on some pestiferous snails (Mollusca: Gastropoda: Ariophantidae). In : Dr. B. S. Chauhan Comm., pp. 165-170.

Subba Rao, N. V. and Mitra, S. C., 1979, On the land and freshwater molluscs of Pune district, Maharashtra. *Rec. Zool. Surv. India*, 75 : 1-37.

Subramanya, K. B., 1982, Studies on the snails with special reference to giant African snail, *Achatina fulica* (Bowdich) (Gastropoda : Achatinidae), *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bengaluru, Karnataka (India).

Sunil, B. A. and Chandrashekar, J. H., 2013, Giant African snail (*Achatina fulica* Bowdich) -As a Molluscan Pest : *First Report on Mulberry from Aurangabad* (M. S), India. silk wormmori.

blogspot. In/2013/04/giant-african-snail-achatina-fulica. html. Accessed on April 1, 2013. pp 1-2.

Sunita, T. R., 2007, Insect pests of *Capsicum annum* var. Frutescence (L.) and their managrment. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).

Symonds, B. V., 1975, Evaluation of potential molluscicides for the control of the field slug, *Agriolimax reticulatus* (Mull). *Pl. Path.*, 24 : 1-9.

Tehsin, H. R. and Sharma, S., 2000, First record of giant African land snail, *Achatina fulica* from Rajasthan. *Zoos Print J.*, 15 (3) : 231.

Thakur, S., 1998, Studies on food preference and biology of giant African snail, *Achatina fulica* in Bihar. *J. Ecobiol.*, 10 (2) : 103-108.

Thakur, S., 2003, Population dynamics of giant African snail, *Achatina fulica* Bowdich (Stylommatophora : Achatinidae) in North Bihar. *J. Appl. Zool. Res.,* 14 : 151-154.

Thakur, S. and Kumari, R., 1998, Seasonal behavior of giant African snail, *Achatina fulica* in Bihar. *J. Ecotox. Environ. Monitor.*, 8 : 153-160.

Vanitha, K., Karuppuchamy, P., Sivasubramaniam, P., 2008, Comparative effectiveness of bait traps against the giant African snail, *Achatina fulica* attacking vanilla. *Ann. Pl. Prot. Sci.,* 16 (1) : 221-222.

Vanitha, K., Karuppuchamy, P. and Sivasubramaniam, P., 2011, Record of gastropod pests on venilla and their population dynamics in relation to weather parameters. *Pest Manage. Hort. Ecosys.,* 17 (1) : 56-59.

Veeresh, G. K., Rajagopal, D. and Puttarudraiah, M., 1979, First record of African giant snail, *Achatina fulica* Bowdich (Mollusca : Gastropoda) as a serious pest of ornamental crops in Bengaluru. *Curr. Res.,*8 : 202-204.

Weber, P. W., 1954, Studies on the giant African snail. *Ibid.*, 15 (2) : 363-67.

Yogesh, G. M., 2015, Management of giant African snail, *Achatina fulica* Ferussac in soybean crop, *M. Sc. Thesis*, Univ. Agric. Sciences, Dharwad, Karnataka (India).

**Appendix I: Meteriological data recorded for the year 2015-16 at Main Agricultural Research station, Dharwad (June, 2015 to January, 2016)**

| Months | Meteorological standard weeks (MSW) | Max Temp. (℃) | Min Temp. (℃) | Humidity (%) | Total Rainfall (mm) |
|---|---|---|---|---|---|
| June 3rd week | 24 | 28.4 | 20.9 | 67.9 | 4 |
| June 4th week | 25 | 26.1 | 21 | 87.1 | 51 |
| June 5th week | 26 | 28 | 21.5 | 82.5 | 22.2 |
| July 1st week | 27 | 29.2 | 20.9 | 77.9 | 12.6 |
| July 2nd week | 28 | 29.6 | 22.2 | 78.1 | 7.6 |
| July 3rd week | 29 | 28.8 | 21.3 | 76.6 | 4.8 |
| July 4th week | 30 | 27.7 | 20.7 | 76.8 | 8.6 |
| Aug. 1st week | 31 | 28.4 | 20.4 | 82.1 | 27.7 |
| Aug. 2nd week | 32 | 27.7 | 20.8 | 85.1 | 4.2 |
| Aug. 3rd week | 33 | 29 | 20.7 | 78 | 2.8 |
| Aug. 4th week | 34 | 29.9 | 20.6 | 77.3 | 6.2 |
| Sept. 1st week | 35 | 28.6 | 20.3 | 86.1 | 14 |
| Sept. 2nd week | 36 | 30.1 | 20.4 | 83.5 | 17.8 |
| Sept. 3rd week | 37 | 28.4 | 20.6 | 92.4 | 4.2 |
| Sept. 4thweek | 38 | 28.8 | 20.6 | 86.9 | 28.4 |
| Sept. 5th week | 39 | 36.7 | 20.9 | 80.9 | 0.2 |
| Oct.1st week | 40 | 29.7 | 20.4 | 95.3 | 165.8 |
| Oct. 2nd week | 41 | 30.2 | 20.5 | 81.6 | 11.6 |
| Oct. 3rd week | 42 | 32.4 | 19.3 | 51.4 | 0 |
| Oct. 4th week | 43 | 32.2 | 17.9 | 44.8 | 0 |
| Nov. 1st week | 44 | 30.9 | 20 | 79.5 | 7.6 |
| Nov. 2nd week | 45 | 30.8 | 18.3 | 68.9 | 0 |
| Nov. 3rd week | 46 | 30.3 | 17.9 | 71.1 | 0 |
| Nov. 4th week | 47 | 28.6 | 19.6 | 76.6 | 23.4 |
| Dec. 1st week | 48 | 30.6 | 16.8 | 67.3 | 0 |
| Dec. 2nd week | 49 | 29.4 | 14.6 | 59.5 | 0 |
| Dec. 3rd week | 50 | 31.7 | 18.1 | 66 | 0 |
| Dec. 4th week | 51 | 31.5 | 17 | 62.1 | 0 |
| Dec. 5th week | 52 | 29.8 | 13 | 44.2 | 0 |
| Jan. 1st week | 1 | 30.7 | 14.4 | 37.2 | 0 |
| Jan. 2nd week | 2 | 29.4 | 12.2 | 34.7 | 0 |
| Jan. 3rd week | 3 | 28.5 | 14.2 | 13.3 | 0.4 |
| Jan. 4th week | 4 | 30.2 | 15.9 | 14.2 | 0 |

# MANAGEMENT OF GIANT AFRICAN SNAIL, *Achatina fulica* Ferussac AND BROWN SLUG, *Laevicaulis alte* Ferussac IN FOREST AND HORTICULTURE NURSERIES

**PINKU PAUL** **2016** **DR. C. M. RAFEE**
**MAJOR ADVISOR**

## ABSTRACT

The survey on incidence of snails and slugs revealed that, the activity of snails was started during 24th standard week (June 3rd week) of 2015 and persisted up to 2nd standard week of 2016 with peak infestation during 41st standard week (Oct. 2nd week) to 45th standard week (Nov. 2nd week). Whereas, no slug incidence or damage was reported during study period at different nurseries surveyed. Snail population was positively and significantly correlated with rainfall, relative humidity and minimum temperature irrespective of the nursery plants. Whereas, it was significant and negatively correlated with maximum atmospheric temperature. The damage potential under confined condition revealed that, the soft-succulent seedlings *viz.*, moringa (96.00 %), papaya (94.00 %) and sisso (92.00 %) were severely damaged by giant African snail. Again the per cent sapling damage due to brown slug, *Laevicaulis alte* ranged from 0.00 to 43.00 per cent at 10 days after release. Papaya registered the highest damage of 43.00 per cent. This was followed by moringa and citrus which were recorded 41.00 and 37.00 per cent damage, respectively.

With respect to management of snails in forest/ horticultural nursery the highest per cent mortality of giant African snail was recorded in metaldehyde treatment 2.5 % pellets @ 5 kg/ha (93.33 %) followed by crystal salt @ 25.00 kg/ha (92.00 %) and bleaching powder @ 25.00 kg/ha (84.00 %). The benefit cost ratio of snail management in capsicum was reported (2.77) from metaldehyde, followed by crystal salt (2.74) and bleaching powder (2.69).

The highest cumulative mortality of slug was recorded in metaldehyde pellets (89.33 %), followed by crystal salt (88.00 %) and methomyl (74.67 %) at 15 DAT. The similar trend was noticed with the respect to slugs mortality under protected cultivation of capsicum. With respect to the benefit cost ratio metaldehyde pellets reaped 2.71 this was followed by crystal salt (2.67).