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Development in Pesticides for Control and Prevention of African Giant Snails, Achatina *Fulica* in Jalgaon, Dapoli Dist. Ratnagiri (M.S.)

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Abstract: *In the present study the occurrence of the Giant African snail, Achatina fulica reported from Jalgaon, Dapoli District Ratnagiri (M.S), India in various field during rainy season but their occurrence is throughout the year. Due to hibernation, these are not much active as compared to rainy season. According to native people of the area, severe plant and vegetable loss was not only due to infestation but also due to the stinking smell of the mucus layer in wetland dry conditions released by the Giant African snail, Achatina fulica different plants. The pest, also classified as a large-scale invader, has been known to be difficult to exterminate without harming nearby organisms as well as ecosystems. Hence, there should be a proper method of control measure of this pest. The following article describes possible methods of control measures researched since ages chemical as well as non-chemical. Even though a lot were proven to be unsuccessful, some methods do play an important role in the extermination of this species with respect to collective efforts, destruction scale, costings etc. Mechanical extermination is a lot more effective than the chemicals introduced which have a possibility of getting washed away due to rains or other possible circumstances. This article mainly focuses on discussing previously studied control methods and defining the criteria needed to develop a suitable pesticide.*

Keywords: Achatina *fulica*, Pesticides, Eco-Friendly, Poison Baits, Cost-Friendly, etc.

I. INTRODUCTION

The giant African snail is an ecologically, economically as well as medically important species (Mead, 1979a) and hence, studied extensively across the globe. It belongs to the phylum–Mollusca, class–Gastropoda, subclass–Pulmonata, and order–Stylommatophora, family - Achatinidae. These land snails occur mostly in tropical countries and emerge during rainfalls. *A. fulica* is a major crop pest species that originated in East Africa but has been spreading across the globe since before the 1800's primarily through human activities (Mead, 1961, 1979b; Raut and Barker, 2002). The World Conservation Union (IUCN) has listed *A. fulica* as one of the world's 100 most invasive species. Besides its adaptability in different ecosystems, *A. fulica* also serves as an intermediate host of rat lungworm, Angiostrongylus cantonensis (Alicata, 1966). In India, the giant African snail, *A. Fulica* was reported for the first-time causing damage to ornamental and vegetable crops in Bangalore during Kharif season 1979 (Veeresh et al., 1979) and this snail was supposed to have been brought along with plant material from various parts of India including Calcutta, Kerala and Madras. As of now, *A. fulica* has been established in almost all states of India and there pausing a serious threat to agriculture.

This article has been aimed to observe and study various habitual as well as non-habitual behavior of the snails found in the region under study and to collectively study various methods of exterminating the pest species and design a suitable eco-friendly and cost-effective method applicable to the region. There have been various unusual occurrences observed in the region understudy (Jalgaon-Dapoli) making it a notable topic to research. Considering the seriousness of this pest's destructive abilities, this review article is aimed to enlighten many methods of extermination of this species used across India should an invasion take place in the area under study. It also clarifies the methods depending on their toxicity for humans as well as surrounding ecosystems and animals kept as resources due to interaction and involvement in the direct use of the chemicals for extermination.

Distribution:

The introduction of *A. fulica* outside its native range dates back to the early 1800s, when it was spread to Ethiopia, Somalia, Mozambique and Madagascar. The first occurrence outside Africa was in West Bengal (India) through Mauritius in 1847.

In the Asia-Pacific region, the snail is recorded from Bangladesh, China, Fiji, India, Indonesia, Japan, Kiribati, Malaysia, New Zealand, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Sri Lanka, Vanuatu and Vietnam and its range is still expanding. This pest can move a substantial distance under its own power. In the field, *A. fulica* can move 50 m (164 ft) over night (Anonymous, 2012). Under optimal field conditions *A. fulica* can reach high densities and biomass (Raut and Barker, 2002). Tillier (1982) recorded a biomass of up to 780 kg/ha in New Caledonia. Raut and Goshe (1984), Raut and Barker (2002) recorded population densities of up to 46 m2 in mainland India and up to 56 m2 in Andaman and Nicobar. Subsequently Muniappan et al. (1986) reported that 45 million *A. fulica* were collected and destroyed on 1600 hectares over a seven-month period. On Christmas Island, Lake and O'Dowd (1991) recorded a mean of 2 individuals/10m in the heavily infested areas.

II. Morphology of *A. Fulica*

The adult snail is around 7cm (2.8 in) in height and 20cm (7.9 in) or more in length. The shell has a conical shape, being about twice as high as it is broad. Shell coloration is highly variable, and dependent on diet. However, typically, brown is the predominant color and the shell is banded (Skelley et al., 2011). The mantle, the fleshy part inside the shell through which the foot protrudes, is a pale yellowish color. The columella, the smooth inner surface to the opening of the shell is also yellow. The 'head' portion of the foot is light brown but the rest of the foot is paler with markings. They move along on a single foot, driven by waves of muscle contraction in the sole. A gland at the front of the foot produces slime for the foot to slide over. Snails have teeth that cut up food as they eat, but a land snail has a rough tongue which has little hooks on it. These hooks scrape off tiny bits of leaves, fruits and other foods which the snail can then eat. These teeth are called radula.

The radula is functionally active when the snail is moving over the food and it will rasp pieces of food and eat. There are two pairs of tentacles on their head where one pair is longer than the other pair. The eyes are located on the longer pair which cannot focus well but they are very sensitive to light but the shorter pair is used for smelling and feeling its way around. The shell of *A. fulica* consists of 7 to 12 whorls, with moderately swollen body whorl and a sharply conical spire, which is distinctly narrowed but scarcely drawn out at the apex. The snail has no gill and operculum, but the mantle cavity serves as a lung. It has two pairs of retractile tentacles, with eyes at the tips of posterior tentacles. Being a herbivore, it feeds on leaves and fruits of different plants and the average litter size is 200 g/day. The average weight of a fully matured snail varies from 200-600g and speed of movement is 0.003 km/hour. The giant African Snail has a protective behavior by which when it disturbs, it pulls it body back into the shell and then seal the entrance with mucus plug. It can give off a protective coating by secreting a calcium compound that dries on contact with the air.

This species is a simultaneous hermaphrodite; each individual has both testes and ovaries and is capable of producing both sperm and ova. The testes typically mature first around 5–8 months, followed by the ovaries. Self-fertilization is not viable and therefore snails require a partner to reproduce. Snails typically mate with a snail of similar size. During the mating, the snails either simultaneously transfer gametes to each other (bilateral sperm transfer), or one snail transfers sperm into the other (unilateral sperm transfer).

Snails mate at night and their mating begins with courtship rituals that can last up to half an hour, including petting their heads and front parts against each other. One snail initiates the courtship, and if all goes well, they begin copulation. However, copulation does not always occur because snails show mate choice behavior, and observations have shown up to 90% of attempted courtships were rejected and did not end in copulation. Copulation can last anywhere from 1–24 hours, but tends to last 6–8 hours. Transferred sperm can be stored within the body up to two years.

The snails are oviparous and lay shelled eggs. The number of eggs per clutch and clutches per year varies by environment and age of the parent, but averages around 200 eggs per clutch and 5-6 clutches per year. The eggs hatch after 1–17 days and the snails emerge as juveniles. They reach adult size in about six months, after which growth slows, but does not cease until death. Life expectancy is 3–5 years in the wild and 5–6 years in captivity, but the snails can live for up to 10 years.

III. Life Stages

The average fecundity of *A. fulica* is around 200 in the soil. A snail may lay 5-6 clutches of eggs per year with a hatching viability of about 90 per cent. Adult size can be reached in just four months. The whole life cycle was found to be completed in 5-5.5 months with an egg stage, 7-10 of juvenile stage and 5 months of adult (Upatham et al., 1988). Active adult buried within three inches of soil while the dormant adults found in the surface of soil.

Aestivation and Hibernation:
A. fulica undergoes aestivation for a prolonged period without food or water. There is strong evidence that the period of quiescence is closely correlated with temperature. The aestivation period is about 5 to 10 months and hibernation generally occur in winter season.

Ecology:
Raut and Barker (2002) suggested that *A. fulica* is tolerant of a wide variety of environmental conditions. Smith and Fowler (2003) concluded that temperatures in the southern-border and Pacific coast states were likely to be suitable to the snail. A mild temperature of 15-25°C is best for snail reproduction, though most species can stand a wider range of temperature. The optimal temperature is 21°C for many species. When the temperature falls below 7°C, snails hibernate and under 12°C they become inactive. When the temperature raises much above 27°C or more, snails undergo aestivation. They thrive in damp but not waterlogged environments and thus a well-drained soil is required. Eggs are susceptible to all reducing temperature. The water content around 80 per cent of the carrying capacity of the soil and air humidity over 80 per cent (during darkness) is the most favorable conditions. Soil organic matter and other micronutrients like calcium, magnesium, potassium etc. play an important role in increasing the size of the snail. Snails are found in greater abundance at an optimum pH range from 6.3-6.7 and P2O5 concentration (0.002-0.004%). The snail hides during the daytime but can be seen at night with the aid of artificial lighting e.g., flashlight, ideally in moist and sheltered places.

Homing Behavior:
Tumiyama (1992) observed *A. fulicata* had homing abilities by following mark-recapture techniques. During his investigation, he observed that young adults dispersed for longer distance than old adults. Old adults changed their resting sites less often than young adults (who change their resting sites almost every day). He also concluded that this homing ability is age-dependent and is mostly observed in old adults.

Seasonal Occurrences:
Ravi Kumar et al. (2007) investigated the seasonal occurrence of *A. fulicata* in an arecanut ecosystem. He reported that mean population was highest in second fortnight of September than the second fortnight of August but in February the lowest mean population was observed in first fortnight and gradually decreased in the second fortnight. The lowest seasonal incidence was due to low temperature in the month of February and the highest seasonal incidence was in September due to favorable environmental condition.

IV. Nature And Extent of Damage

A. Fulicata is a macrophytophagous herbivore. It can damage a wide variety of plants, fruits and vegetables. It may also eat sand, very small stones, bones from carcasses, as well as concrete from surroundings for calcium sources for its shell. In very unusual circumstances, it may consume one of its kinds. Defoliation, slime trails or ribbon-like excrement, extensive scraping etc. seen on plants are signs of *A. fulica*. Giant African snails cause extensive damage on farms as well as in natural ecosystems. The characteristic nature of damage by *A. fulica* in papaya are loss of crop yield, death of papaya plants, increased fruit and stem blight caused by Phytophthora palmivora (as the snail spreads the pathogen within and among papaya plants in feces and by contact with its body) (Nelson, 2012).
A. fulica may also damage natural or native ecosystems by their herbivory, affecting nutrient cycles in different ecosystems. In many Asian, Pacific, and American communities, it transmits human parasites and pathogens in slime trails or when infested snails are eaten raw or undercooked. One such pathogen is rat lungworm (Angiostrongylus cantonensis), which causes meningitis, Eosinophilic meningoencephalitis in humans (Alicata, 1966).

Four categories of plants listed by Mead (1961) are likely to be damaged by this species. The first category is garden flowers and ornamentals, which were completely susceptible at any stage of development, the second category is mostly vegetables, the third category represented plants usually not eaten at the mature stage but are damaged earlier in development by bark being completely removed as is the case with breadfruit, cassava and teakwood. The final category includes crops upon which damage is indirectly incurred (Mead, 1961; Muniappan et al., 1986). Moreover, the extent of damage caused by *A. fulica* generally depends on size of the snail and age of the plants which makes it very difficult to estimate the damage of *A. fulica*. Sridhar et al. (2012) studied the extent of damage caused by *A. fulica* in six different crops in Kolar district, Karnataka and found that the extent of damage was highest in mulberry leaves i.e., 100 per cent followed by groundnut (40-50%) and papaya (40%) and the cucumber was the least preferred host (20%).

Host plants:
A. fulica feeds on more than 500 plant species specially stems, leaves, flowers or fruits of a broad range of agriculturally important plants. In India, some of the preferred host plants are banana (Musa spp.), bean (Phaseolus spp.), cabbage (Brassica oleracea), cassava (Manihot esculenta), cotton (Gossypium hirsutum), eggplant (Solanum melongena), papaya (Carica papaya) and pumpkin (Cucurbita pepo) etc.

V. Control And Prevention Methods

It is best not to rely on just one method as the effective control of pests can be carried out by traditional, biological as well as chemical methods. The various management practices studied are discussed below-

1. **Cultural Control**:
   Snails and slug's species can grow in places with ideal moisture levels, shelter and harbor sites, all three of which can be provided in farms with abundant ground cover and vegetation growth along with awed fence line. Weed control, proper hygiene and removal of refuses from time to time can improve baiting. more organic content soils attract these species. Raising unnecessary plants between trees can act as shelter for snails.
2. **Mechanical Control**
   Saw dust and ashes were used for keeping surfaces dry as snails do not like dry surfaces. But this method might be ineffective if they become wet, which might be due to unavoidable circumstances like rain and watering plants. Instead, lime and copper sulphate (which are pest repellents) can be used to prevent migration in an area. Snails repel copper so thin copper sheets can be used around tree trunks to prevent snails from climbing. This method must be combined with skirt pruning and control of under-canopy vegetation to stop snails getting into the trees by other routes (Peter et al., 2012). Fruits extract of Thevetia peruviana also reported to repel A. fulica (Raut and Barker, 2002). Use cuttings of alligator apple, Annona glabra to construct softwood fences as a snail repellant to protect nursery beds has also been reported by Prasad et al. (2004).
   Vanitha et al. (2010), Rao (1999) and Chandaragi (2014) reported higher mortality of snails with sapindus and shikakai extract. Prasad et al. (2004), Kumari (2011), Vanitha et al. (2011), Chandaragi (2014) and Paul et al. (2016) also reported the use of crystal salt to be highly effective. A study found neem seed powder and Madhuca seed powder were found next effective barrier substances against A. fulica in laboratory studies with only 20 per cent of snail crossing whereas in field studies no snail mortality was observed (). The present finding on the effectiveness of neem seed powder against A. fulica is in agreement with Selvi et al. (2015) who reported the effectiveness of dust formulation of neem coated silica against A. fulica. In Kerala, a salt-tobacco decoction was used to fight against these giant snails.
   As discussed earlier, due to snails' repellent nature towards copper, some amount of copper sulphate is added to the tobacco. During early phase of infestation, hand collection and destruction is the most effective methods. Farmers usually destroy hiding places of the snails, while some farmers grow marigold as a trap crop. One process is the application of salt. One has to dig a hole and line it with wet jute gunny bag. Layer the bags with papaya or cabbage leaves, or fermented coconut water or beer. The smell from the leaves and the fermented coconut water and beer will attract the pests. Once the snails fill the hole, pour salt into the hole. The snails will die. The shells can be crushed and used as manure for coconut trees.
3. **Chemical Control**

Although metaldehyde has been proven to be a useful pesticide, its use for large scale extermination is not encouraged as it is toxic to the livestock as well as humans along with the snails. if one happens to use them; the following measures should be taken:

- The chemical control should be preferably combined with cultural methods to be more effective
- The poisoned snils should not be discarded where it might come in contact with the livestock which feed on such matter (for example- pigs).
- The poisonous pellets should be properly kept in tin or bamboos in evening and collected in the morning on schedule.
- The livestock, pets as well as humans should be kept away from the poisoned pellets.

Recent developments have shown that iron-based poisons (iron phosphate and sodium ferric EDTA) are more effective and safer to use as molluscicides. Dicholorvos bait (Wheat flour- 1kg + Jaggery- 0.2 kg + Dicholorvos 76EC- 250ml) and methomyl bait (Rice bran1kg + Jaggery 0.2 kg + Methomyl 40 SP- 100 g) are suitable to control the infestation of the species. A small-scale cost-effective bait can be made by by heating the jaggery with wheat flour/ rice bran along with the poison. Proper care should be taken while making small balls and placing them in fields. The poultry and pet animals should be kept away from this bait. Application of copper sulphate and methomyl poison baits resulted in inability of snails to withdraw their exposed body parts inside the shell and profuse mucus secretion, and ultimately snails were died. A study revealed that application of copper sulphate as poison bait, and rice husk+ Acacia concinna powder (8:1), burnt rice husk + crystal salt (2:1), lime+ crystal salt (2:1), neem seed powder and Madhuca seed powder as barriers all along the border of snail infested area were effective in managing A. fulica. (Pahlavi HS, et. al; 2018).

Another case of invasion in northern parts of Kodagu district in Karnataka describes various methods of extermination as well as the costing. The giant snail invasions have been troubling planters for the recent years. These species somehow managed to arrive through trade and are voracious eaters of coffee plants. They wreaked havoc in 300 acres in 45 plantations in *Shanivarasanthe area of northern Kodagu. A catch-and-kill method devised by the Central Coffee Research Institute has been successful in containing the pestilence. The bait has been successful in killing 90% of snails in a co-ordinate operation.* The planters used baits made of rice-bran, jiggery, castor oil and a chemical- Thiodicarb. These are mixed together and made into pellets or balls placed between four coffee plants. The researchers experimented with methomyl, a broad-spectrum insecticide, but it has been banned because the cost to the soil is too high. Thiodicarb is considered a less harmful insecticide that is effective against in killing the giant snails. Manjunath Reddy, assistant entomologist, coffee research sub-station at Chettalli, Kodagu explained that they tried every method available to get rid of these pests but the poisonous baits were found to be most effective.

In 2015, the Coffee Board used this bait and killed as much as 30 tonnes of snails. Due to its effectiveness, bait kits were developed and distributed to the farmers. The kit consists of a pair of gloves, 25 kg of rice bran, 100 gm of Larvin branded thiodicarb, 3 kg of jaggery castor oil. It costs Rs. 1,000 but is distributed among the farmers at a subsidized rate of Rs. 100.and 100 ml Due to increasing infestations, there had to be method to discard the dead snails collected and also help the farmers recover their economical loss. So, the Coffee Board came up with an innovative idea of buying the dead snails. It initially offered Rs. 4 per kg of dead snails, which has since been increased to Rs. 8 per kg.

The dead snails are disposed of in a pit that’s one-and-a-half feet deep. Salt is put over the dead ones to ensure even the last of the caught snails are dead and then buried. This burial is a precautionary measure against the spread of any disease through the snails.

Effects of Chemical Control:

Although the invasions can be controlled, the chemicals used are toxic enough to be used in places where there is human activity. These chemicals are especially harmful to aquatic organisms.

VI. Conclusion And Discussion

The African giant snail has been an extreme level invasive species, such that it has been proven to destroy acres and acres of crop as well as human livelihood. Numerous methods to effectively exterminate this species have been studied from as long back as 1800s. This species is evidently a threat to biodiversity and is really difficult to control once it establishes itself and is able to find suitable growth conditions. A lot of control measures of this species have been found unsuccessful. Some have a hazardous effect on humans (metaldehyde). A lot of chemicals and toxic baits used for a large-scale extermination have seen to be affecting non-target species as well (Prasad et al., 2004). This has resulted in a great damage in the surrounding ecosystems too. A biological method to control this species was devised by introducing a species that would primarily attack this snail species, rosy wolf snails, which turned out to be more disastrous. In places where such chemicals are not available, infestations are best handled manually.

For instance, hand-picking and destroying the snails and their eggs, destroying their resting places as well, is also proven to be more effective. An alternative method is to guard the pathways through which these snails pass which requires fewer efforts than collecting and destroying them and is cheap as well. Another setback of molluscicides is that they might get washed away easily due to various sources of water like rain, which is the prime season for the snails to infest, making these molluscicides ineffective. Recently iron-based poisons have made some progress in being safer for use than other pesticides. Keeping in mind the loss various farmers and planters have to undergo to exterminate this pest, the developed method has to be eco-friendly as well as cost-effective. The same applies to human habitation infestation as well. The occurrences observed in the study sites (Jalgaon-Dapoli) have given rise to unusual behavioral patterns.

This species has been found dwelling in cracks and crevices in construction areas, walls, crowding on organic matters like animal excreta as well as human refuse. The developed method should be target-specific and non-hazardous to human interaction in accordance to the observed occurrences of this species in human dwellings. A direct and effective exterminating method has not been developed yet. Hence there is immense scope to study about this species and its biological weaknesses.

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