Introduction:

Bryophytes are amphibians of the kingdom plantae. Between the two habitats viz. terrestrial and aquatic, there is another traditional habitat represented as swamp areas where water and land meet. It can be well called as amphibious zone. Inhabiting the amphibious zone are the mosses, liverworts and hornworts which collectively constitute a group of non vascular land plants termed as ‘Bryophytes’. Most of the bryophytes are land dwellers which inhabit damp, shaded and humid localities. A few of them, however, live in or float in water. Aquatic habit has been acquired by these plants secondarily. When water dries up they grow equally well on the drying mud. Certain, of course, can withstand long periods of drought. During this period they become almost brittle. With the onset of rainy season the apparently dried, brittle thalli turn green and become active to carry out the normal life functions. Even these apparently xerophytic species grow actively only during the wet weather.

In order to adapt to land environment these sub aerial lives have acquired some features,

* The thick compact, multicellular, thallus like plant body covered with an epidermis is protected to some extent against the drying effects of air. In some species the outermost layer which is exposed to the dry air is coated with a waxy substance called as cutin which reduces rate of water loss as well as total surface area of a compact body is reduced in proportion to its volume which protects them against desiccation.

* Since bryophytes have been adapted for amphibious habitat they have to absorb water from soil and be linked to it for support. For this means, they evolve special hair like structures called the rhizoids which function as absorbing and attaching organ. Sex organs are multicellular and jacketed. The fertilized egg is retained in the archegonium and develops into embryo where it achieves food and water from the parent plant thus protection of reproductive cells from drying and mechanical injury is achieved.

* For absorption of carbon dioxide from the atmosphere for photosynthesis in several liverworts there are numerous pores on the upper surface of the thallus known as air pores.
* The thick-walled, wind disseminated spores and the primitive vascular system in the form of conducting strands are the other adaptations to land habitat.

1. **Salient Features of Bryophytes:**

1) The bryophytes are a small group of primitive land dwellers. They have a leafy or thalloid, green plant body which is small in structure.

2) In their vegetative structure they have become entirely adapted to the land habitat. But for the sexual reproduction water is essential factor.

3) Bryophytes lack the vascular tissues.

4) The sexual reproduction is highly oogamous and the sex organs are jacketed and multicellular.

5) The sperms are biflagellate, which are whiplash type.

6) Female sex organ in the form of an archegonium appears for the first time in the bryophytes in the plant world.

7) The plant body lacks the true roots, stem or leaves. In lower bryophytes plant body is thallus which grows prostrate and attached to substratum by means of delicate, unbranched, unicellular hair-like organs called as rhizoids. While in higher bryophytes the plant body is erect which includes central axis bearing leaf like expansions. It is attached to substratum by branched, multicellular rhizoids.

8) In the life cycle alternation of generation is observed with conspicuous gametophyte which is independent and related with sexual reproduction. Sporophyte is organically attached to the parent gametophyte through out its life. It is dependent upon it partially or completely for its nutrition.

9) The sporogonium is concerned with the production of wind-dissiminated, non-motile, cutinized spores which belong to the category of gonospores or meisopores.
10) The bryophytes are homosporous i.e. the spores in the given species are morphologically of one kind. Spores germinate to produce gametophyte plant either directly or indirectly as a lateral but from the protonema.

11) Water is necessary for fertilization.

12) The fertilized egg is retained in the venter of archegonium.

13) The zygote undergoes repeated division and forms undifferentiated multicellular structure called embryo, at the time venter wall enlarges and forms protective, multicellular envelop, the calyptra.

14) The embryo undergoes division and differentiation and produces sporophyte. Sporophyte is without differentiation into stem and leaves. It is differentiated into foot, seta and capsule. In some bryophytes the seta is absent (Corsina sp.) and rarely both, the foot and the seta (Riccia sp.).

15) Heterologous type of alternation of generation is the characteristic of bryophytes.

Thallose bryophytes vary in size from a length of 20 centimeters and a breadth of 5 centimeters (Monoclea) to less than 1 millimeter in width and less than 1 millimeter in length (male plants of the liverwort Sphaerocarpos). The thallus is sometimes one cell layer thick through most of its width (e.g. liverwort Metzgeria) but may be many cell layered thick and has a complex tissue organization (e.g. liverwort Marchantia). Branching of the thallus may be forked, regularly frond like, digitate, or completely irregular. The margin of the thallus is often smooth but is sometimes toothed; it may be ruffled, flat, or curved inward or downward.

Leafy bryophytes grow up to 65 centimetres (2 feet) in height (the moss Dawsonia) or, if reclining, reach lengths of more than 1 metre (3.3 feet; the moss Fontinalis). They are generally less than 3 to 6 centimetres tall, and reclining forms are usually less than 2 centimetres long. Some, however, are less than 1 millimetre in size (the moss Ephemerum). Leaves are arranged in rows of two or three or more around a shoot or may be irregularly arranged (e.g., the liverwort Takakia). The leafy shoot
may or may not appear flattened. Leaves are usually attached by an expanded base and are mainly one cell thick. Many mosses, however, possess one or more midribs several cells in thickness. Leaves of liverworts are often lobed, while those of mosses are unlobed. Leaves diverge outward from the shoot; rigidity results from water pressure within the cells or from the support of a midrib, when present. The leaves of bryophytes generally lack vascular tissue and are thus not analogous to the leaves of vascular plants. Although most botanists call them leaves for convenience, the technical term for these bryophyte structures is phyllids.

Bryophytes form flattened mats, spongy carpets, tufts, turfs, or festooning pendants. These growth forms are usually correlated with the humidity and sunlight available in the habitat.

2. Distribution and Abundance

Bryophytes are a fascinating group of beautiful plants. Although it is relatively small division of plants, with between 14000 and 21000 species, the interest that they have aroused is out of all proportion to the size either of the plants or of the division. These plants are distributed throughout the world, from polar and alpine regions to the tropics. Water must be present for the completion of their life cycle. Bryophytes do not live in extremely arid sites or in seawater, although some are found in perennially damp environments within arid regions and a few are found on seashores above the intertidal zone. A few bryophytes are aquatic. These are most abundant in climates that are constantly humid and equable. The greatest diversity is at tropical and subtropical latitudes. Bryophytes (especially the moss Sphagnum) dominate the vegetation of peat land in extensive areas of the cooler parts of the Northern Hemisphere.

The geographic distribution patterns of bryophytes are similar to those of the terrestrial vascular plants, except that there are many genera and families and a few species of bryophytes that are almost cosmopolitan. Indeed, a few species show extremely wide distribution. Some botanists explain these broad distribution patterns on the theory that the bryophytes represent an extremely ancient group of plants, while others suggest that the readily dispersible small gemmae and spores enhance wide distribution.
The distribution of some bryophytes, however, is extremely restricted, yet they possess the same apparent dispersibility and ecological plasticity as do widespread bryophytes. Others show broad interrupted patterns that are represented also in vascular plants.

3. Classification of Bryophytes:

It was 1879 when Schimper (cited in Singh, 2006), who for the first time suggested the well defined group of plants under the division Bryophytes. This division was subgrouped into 2 classes viz. Hepaticae and the Musci by Eichler in 1883 (cited in Singh, 2006). Engler (1892 cited in Singh, 2006) subdivided each of these classes into 3 orders viz. Hepaticae- 1. Marchantiales, 2. Jungermanniales, 3. Anthocerotales and Musci- 1. Sphagnales, 2. Andreales, 3. Bryales. Chopra (1981 cited in Singh, 2006) suggested three subdivisions of class bryophyta as Takakiophytina, Hepatophytina and Muscophytina. deBary, ex Janczewski (1872 cited in Singh, 2006), Leitgeb(1879) and Underwood (1894 cited in Singh, 2006) were some of the investigators who pointed out a typical position of Anthocerotales as an order of the class Hepaticae. Finally, Howe (1899 cited in Singh, 2006) reported the class status to the Anthocerotales. Thus Bryophyta is divided into three classes Hepaticae, Anthocerotes and Musci. Eminent hepaticologists like Campbell (1918, 1940 cited in Singh, 2006), Smith (1938, 1955 cited in Singh, 2006), Takhanj (1953 cited in Singh, 2006) supported his classification but Smith, Takhanj, Wardlaw (1955 cited in Singh, 2006) and Schuter (1958 cited in Singh, 2006) proposed the name Anthocerotae for Anthocerotes. New names were proposed by Rothmaler in 1951 which have also been recognised by international code of Botanical Nomenclature. These are Hepaticopsida for Hepaticae, Anthoceropsida for Anthocerotae and Bryopsida for Musci. The modern bryologists classify Bryophyta into following three classes namely Hepaticopsida, Anthocerotopsida (proposed by Proskauer in 1957 cited in Singh, 2006) and Bryopsida. According to Proskauer (loc. cit.) all green algae and green land plants are included under the division Chlorophyta and hence division bryophyta as class Bryopsida which is further divided into three subclasses, Hepaticidae, Anthocerotidae and
**Bryidae.** Thus class Bryopsida contains more than 1,000 genera and more than 18,000 species.

The class Hepaticae is divided into six orders namely Marchantiales, Monocleales, Sphaerocarpels, Metzgeriales, Jungermanniales and Calobryales.

In the present study, plants tested for the allelopathy and pesticidal potential belong to order Marchantiales and also from Anthocerotidae.

**Marchantiales:**

This order comprises 35 genera and more than 420 species which are widely distributed throughout the world. Among the former, the well known Indian members include *Cyathodium, Targionia & Plagiochasma*.

**A. Special features of Marchantiales:**

Gametophytic plant body is dichotomously branched, flat, green, thick and doroventrally thallus with more or less marked midrib. Anatomically thallus is divided into dorsal green region with chlorophyllose cells forming a photosynthetic area, and cells of the remainder of the thallus serving for storage enclosing air chambers with air pores on the dorsal surface; ventral scales often present; rhizoids; sex organs sometimes born on a stalked receptacle; sporophytes with short seta or seta absent; sporangia spherical or elongate, opening by regular or irregular longitudinal lines, a cap like lid; sporophyte often carried up from the thallus surface by elongation of the stalk of a receptacle, with the sporangia hanging downward; occupying a diversity of habitats—some can withstand extended periods of dryness while others are floating or submerged aquatics, and still others grow in humid shaded sites.

At present, order Marchantiales is divided into six families: Ricciaceae, Corciniaceae, Targioniaceae, Monocleaceae, Monocarpaceae, and Marchantiaceae (Singh, 2006). The genera *Plagiochasma* and *Asterella* belong to the family **Rebouliaceae / Marchantiaceae.**

Rebouliaceae includes 6 genera and about 39 species. *Plagiochasma* includes 8 species found in India. Out of which three species *P. articulatum*, *P. appendiculatum* and *P. intermedium* are found at Panahala (Dist. Kolhapur, Maharashtra). The recently investigated member is *P. appendiculatum* for wound healing, antioxidative enzymes
by Nath and Asthana (2001). In the present study *P. intermedium* is investigated.

**a. Plagiochasma intermedium* Ldbg. et G.:

**i) Classification**

Kingdom: Plantae
Division: Chlorophyta
Class: Bryopsida
Subclass: Hepaticidae
Order: Marchantiales
Family: Aytoniaceae
Genus: *Plagiochasma*
Species: *intermedium*

**ii) Distribution:**

*P. intermedium* is distributed ranging from Japan, Korea, Manchuria, China, Formosa, the Philippine islands, Mexico, Guatemala and India. In India, it is found at Pathankot, Ranchi, Lucknow, Panchmarhi, Bhopal, Maharashtra and S. India.

**iii) Habit:** *P. intermedium* grows in dense patches on moist exposed walls (partly shaded) and crevices of rocky area.

**iv) Morphology:**

Thalli are dioecious, forming thick patches. Thallus linear broad, slightly dichotomously branched. Each lobe is strap shaped, dorsal surface green. Margins purple, entire to dentate. Male receptacle at the apex of main thallus, often with an adventitious shoot in front. Female receptacle sessile and on the middle of the dorsal surface. Ventral surface purple, scales multicellular, 1 cell thick, violet, acute at the apex. Rhizoids simple and tuberculate type. Male receptacle shows assimilatory and storage zone with antheridial chambers, some of which contain androgonial mass. Spores brownish, reticulate, with broad, entire, reticulate wings. Elaters branched without spiral bands.
b. *Asterella wallichiana* Lehm. et L.

i) **Classification**

*Asterella* includes 80 species all over the world.

- **Kingdom:** Plantae
- **Division:** Chlorophyta
- **Class:** Bryopsida
- **Subclass:** Hepaticidae
- **Order:** Marchantiales
- **Family:** Aytoniaceae
- **Genus:** *Asterella*
- **Species:** *wallichiana*

ii) **Distribution:**

*A. wallichiana* is one of the most commonly distributed liverworts in India with a range of distribution extending from plains to higher altitudes up to 9,000 ft.

iii) **Habit:** Generally on moist places, sometimes on dry rocks.

iv) **Morphology:**

*A. wallichiana* is the only dioecious species of *Asterella* known from the country. Thallus terrestrial, prostrate, small or medium, green. Male receptacle sessile, naked, cushion like. Female receptacle terminal on the main shoot, stalked perianth, usually ovate or oblong with an abconic apex, dividing longitudinally by many teeth. Spores tetrahedral reticulate – lamellate on the convex side, more or less yellow. Elaters short, simple or furcated mono or bispiral.

Family Targioniaceae includes 5 genera and 6 species.

c. *Targionia hypophylla* L. *sensu stricto*

i) **Classification**

- **Kingdom:** Plantae
- **Division:** Chlorophyta
- **Class:** Bryopsida
- **Subclass:** Hepaticidae
- **Order:** Marchantiales
- **Family:** *Targioniaceae*
Genus: *Targionia*
Species: *hypoPhylla*

ii) Distribution:

*Targionia* is a genus widely distributed in various parts of the world. In India, it grows luxuriantly in many places including eastern and Western Himalayas, hills of south India, Assam and Madhya Pradesh.

iii) Habit: Moist places like moist walls and rocks.

iv) Morphology:
Terrestrial plants, green, prostrate with rough dorsal surface. Black sporophyte on the underside behind apex. Branched elaters with bi and unbranched with tri-spiral thickening. Plant thallose, terrestrial, prostrate and green in colour, long and broad thallus with less frequent ventral shoots and rarely dichotomously branched. Dorsal surface green, margin entire with rough surface. Thallus apex is distinctly notched. Air pores simple conspicuous, slightly elevated, with 3 concentric rings of 8-10 cells each. Scales triangular, delicate appendaged slightly curved with long subulate apex. Smooth and tuberculate rhizoids. Differentiation of thallus with distinct air chambers, filled with green filaments on upperside and parenchymatous storage tissue on lower side. Involucers terminal, ventral, sessile, purple with 5-6 archegonia. Each archigonium consists swollen venter and long slender tubular neck. Neck consists of about 8 neck canal cells with longitudinal rows of 9-10 neck cells. Mouth of neck is covered by cells. Spores reticulate. Elaters branched or unbranched with bi and tri spiral thickening respectively.

d. *Cyathodium cavernarum* (Kunze)
i) Classification:
Family cyathodiaceae includes 5 genera and 14 species.
Kingdom: Plantae
Division: Chlorophyta
Class: Bryopsida
Subclass: Hepaticidae
Order: Marchantiales
Family: *Cyathodiaceae*
Genus: *Cyathodium*
Species: *cavernarum*

**ii) Distribution:**

India, Burma, Jawa, Africa and America. In India Eastern Himalaya, Darjeeling, Khasi Jayanti Hills, shilong; Western Himalaya-Dehradun, Gumkhal, Karan Prayag, Mussoorie; South India-Elephanta caves, Bombay, Khandala, Mahabaleshwar, Malabar hills, Panchgani, Pratapgarh; Central India-Gujarat Madhyapradesh, Gangetic plains, Bareilly, Lucknow; Burma; Jawa; Africa and America.

**iii) Habit:** In moist shady places and mostly on wet walls or crevices in old walls, caves.

**iv) Morphology:**

*C. cavernarum* is a strictly monoecious species. Thalli green to yellowish-green in colour, delicate ribbon like, small dichotomously branched, the resulting branches may be either distinctly separated from one another or repeated dichotomous with little separation of branches may, produce a fan-shaped outline. Dorsal pores more numerous at the anterior end than at the posterior end, large, bounded by 2-3 concentric rings of 4-6 cells each. Rhizoids more or less centrally distributed, all are smooth type. Ventral scales simple, abundant, filamentous on thallus. Male thalli broad, branched, anthredial receptacles lateral-terminal, or the terminal maergi, cushion shaped or disc shaped 0.12mm in diameter. Some times two antheridial receptacles occurring side by side. Archegonial receptacles produced near the margin on the upper parts of the thallus. Involucre globose, deeply cleft in vertical plane into two lips. Black coloured mustcr like sporophyte is present at the notch of the ventral surface. Spores blackish brown isopolar, baculatespinate. Elaters reddish brown, 8-11 in each capsule, bispiral, usually trispiral with one broader and other pointed end.

A hornwort which is investigated in the present investigation is *Anthoceros subtilis* (F- Anthocerotae).
Class Anthoceropsida comprises single order Anthocerotaes which in its turn consists of single family Anthocerotaceae. There are about 5 genera may be recognized, viz. Anthoceros, Phaeoceros, Aspiromirtus, Notothylus, Dendroceros and Megaceros with more than 300 species.

**B. General features of Anthocerotaes** are as followes

1. The gametophyte plant body is a dorsiventral, lobed thallus, simple, without regular dichotomous growth and with or without midrib. There is no any internal differentiation of tissues. The rhizoids are smooth-walled and ventral scales are absent.

2. There are no air chambers or air pores while some species have intercellular cavities which possess mucilage and open by slit-like openings on the lower surface of the thallus. Occasionally these cavities possess a blue green alga Nostoc.

3. Each cell of the thallus usually has a single laminate chloroplast with a conspicuous compound central pyrenoid.

4. The cells lack oil bodies.

5. The antheridia arise on the dorsal side of the thallus from hypodermal cells i.e. are endogenous. The antheridia lie free, either singly or in groups, within closed cavities, the antheridial chambers, beneath the upper surface of the thallus.

6. The archegonia are almost completely embeded in the thallus on the dorsal side.

7. The sporogonium consists of a bulbous foot, a meristematic region and a long cylindrical capsule.

8. The sporogonium has a peculiar property of being able to continue growth throughout the growing season by means of a characteristic intercalary meristem i.e., indeterminate in growth.

9. The wall of the capsule is often rich in chlorophyll.

10. The central collumella is usually distinct and arched over by the dome-shaped elongate archesporium, which is usually derived from the amphithecium.

11. The capsule dehisces basipetally from the top downwards by two valves which being hygroscopic curl back exposing the central column of spores and pseudoelaters.
a. *Anthoceros subtilis* St. Family- Anthocerotae

i) **Classification**

Family anthocerotae includes 21 (Taxa) genera and 9 species in India.

Kingdom: Plantae
Division: Chlorophyta
Class: Bryopsida
Subclass: Hepaticidae
Order: Anthocerotales
Family: Anthocerotae
Genus: *Anthoceros*
Species: *subtilis*

ii) **Distribution:**

India, South Canara, Viatnam. In India : Maharashtra (Purandhar, Lonavala), Karanataka (Mangalore), Kerala.

iii) **Habit:** Terricolous.

iv) **Morphology:**

Plants monoecious. Androecia not found. Female thalli spongy, in various morpho-forms forming rosettes of 6-8mm diameter with deeply dissected apical margin, or narrow at base and fanning out at apex. Mucilage chambers in 1-3 layer. Highest stomatal frequency (20-32 stomata / sq. mm) in all India species of *Anthoceros*. Involucre also spongy, upto 3-4 mm long with nearly smooth mouth. Simple spinulate-biculate sporoderm. Spores brown spinulate-biculate projections, often apically bifurcated. Elaters light brown, thin walled, short, sometimes stout and stumpy.

Bryophytes possess dominant leafy or thalloid plant body representing a phase in evolution of plant migration from water to land. They are in between higher vascular plants and lower thallophytes. Besides traditional biochemical and physiological studies, new and exciting attention has been directed at bryophytes. But we still do not know much about the role of bryophytes and that at the species level. *Plagiochasma,*
Asterella, Cyathodium, Targionia and Anthoceros are dominant bryophytes in Western Ghat region of Maharashtra and grow luxuriantly in rainy season. Generally they are free from attack of any pathogen or insect pest. This observation gives clue that they are immune to any pathogenic attack. The literature survey also supports this statement. It also reveals that they are indicators of heavy metal pollution and also reflects on geometry of a basic type of rock. Besides, they are rich in flavonoids, sterols, terpenoids, lipids and growth stimulating / inhibiting substances. Along with other supporting literature, the question dwelling in mind, ‘why bryophytes are not get affected or infested by any pathogen or pest?’ promoted us to investigate some allelopathic principles and pesticidal potential of this group.

In the present study, the allelopathic effect of above mentioned bryophytes is studied by using their aqueous extracts on germination and seedling growth of wheat and jowar for 24, 48, 72, 96 and 120 h. Qualitative and quantitative analysis of amino acids, polyphenols, lipids and terpenoids in these bryophytes has also been carried out. Other constituents which have been investigated include photosynthetic pigments, carbohydrates, total nitrogen and inorganic constituents including some heavy metals. The antioxidative enzymes have also been attempted.

For convenience and presentation, the thesis is divided into five chapters. CHAPTER I, “Review of literature”, deals with the brief review of literature on ecophysiological studies, mineral elements and chemical investigation of these lower plants. Uses of bryophytes in pollution monitoring, allelopathy, medical and pesticidal properties are also reviewed in general and species specific. CHAPTER II, “Material and Methods”, describes the methodology followed in the present investigation in details. The important findings of the investigation have been critically discussed in the light of relevant and most recent literature available in CHAPTER III, “Results and Discussion.” The scope and significant findings of the present investigation have been briefly summarized in CHAPTER IV “Summary and conclusions” The literature referred in the form of research papers, research articles and reference
books has been listed alphabetically and chronologically in the last part of the thesis, "Bibliography"