ANTI-INFLAMMATORY ACTIVITY

6.1 General Introduction

Man depends upon plants for his entire essentials requirement like food, clothing and shelter. Plants are also an important source of fine chemicals, which find their application in pharmaceutical industries across the globe (Singh, 1988). Plants have been the traditional source of raw materials and finished medicinals, since many centuries. A rich heritage of knowledge on preventive and curative medicines is available in ancient scholastic works. This is included in the Atharva Veda, Charak Samhita, Sushruta Samhita, etc (WHO Regional Office for the Western Pacific, 1993; Pushpaganda, 1995).

Since disease, decay and death co-existed with life, the study of disease and its treatment must have also been contemporaneous with the dawn of human intellect (Kirtikar and Basu, 1991). In India, the Science of Ayurveda has provided a system of medical treatment. Most of the remedies for treating illnesses are being taken from plants. During the last few decades, much work has been done in the field of these natural products.

It is reported that in the modern times 41% prescriptions in U.S.A. and 90% in Europe for treating various ailments contain constituents from natural products. This shows an increasing trend of using natural products (Shah, 1982). Moreover, natural products have also served as lead molecules for the development of novel synthetic drugs. For example atropine for tropicamide, quinine for chloroquine, cocaine for procaine and tetracaine, etc.
India is a vast country, which often referred as a subcontinent for ‘Emporium of Medicinal Plants’ due to the occurrence of several thousand medicinal plants in different bioclimatic zones. Ayurveda and Siddha systems of medicine, which are the traditional heritage of India include many time tested medicinal plant drugs for various diseases to which there is no answer in modern medicine till today. The demands for Ayurvedic drugs or phytomedicines are increasing day by day globally (Yoganarasimham, 2000).

The development of the science of phyto pharmaceuticals and the hope for remedies for chronic diseases has generated new enthusiasm among researchers to develop herbal medicines. Quite a considerable amount of work has been put for the study potential of herbal medicines. Modern science has accepted the plant kingdom as a source of new bio dynamic constituents.

Scientific investigation regarding some folk medicines has resulted in bonafide drugs. Natural products have also been incorporated into many modern formulations. The most important drugs that have come from plant sources into clinical use are cinchona, opium, ergot, rauwolfia, etc. All were known to be healers in traditional medicine before their introduction to modern medicine. As the medicinal value of Indian traditional medicine cannot be ignored, researchers are gradually becoming interested in identification of active principles in their extracts with intensive follow-up study of their mechanisms of action.
6.2 Introduction to Inflammation

The word inflammation comes from the Latin word “inflammare” which means state of being inflame or heat associated with redness and swelling. This is a complex, integrated host response found only in vertebrates. The inflammatory response has two facets:

i) inflammation and ii) repair.

Inflammation serves to destroy, dilute, or wall off the injurious agent and the tissue cells that may have been destroyed later. The second factor of the inflammatory response sets into motion. It is a complex series of events, which helps to heal and reconstitute the damaged tissue.

Repair begins during the active phase of inflammation, but reaches completion usually after the injurious influence has been neutralized. Destroyed cells and tissues are repaired thereby. Both inflammation and repair generally serve useful purpose. Without inflammation, bacterial infections would remain unencountered, wounds would never heal, and injured tissues and organs might be permanently defected. But inflammation may be potentially harmful. Inflammatory reactions underlie the genesis of crippling rheumatoid arthritis, life threatening sensitivity reaction, and some forms of fatal glomerular diseases.

6.3 History of inflammation (Spector et al., 1968; Movit et al., 1971)

“Inflammation” was known as ‘phlogosis’ to the Greeks and as inflammation to the Romans. Nearly 2000 years ago Cornelous Celsius, a Roman doctor first described the four main signs of inflammation: rubor,
tumor, calor and dolor. Galen in third century A.D. defined inflammation as a reaction of the body against injury.

Subsequently, Julius Colinteim in 1873 emphasized the role of vessels in the inflammatory process and Metchnikoff in 1892 emphasized mainly on the migration of Leucocytes and on phagocytosis. According to Rocha a Silva (1978), all the views developed by these eminent persons, with the four signs of Celsius in the background constituted ‘master leads’ to understand the whole pattern developed by the body to fight against aggression.

In late 19th Century, the science of immunology had been developed with the pioneering contributions from Jenner, Pasteur, Land Steiner, and so on. Thereafter, conclusive evidences have accumulated regarding body fluids and blood serum, which have a protective effect against a variety of invasive micro organisms. Lewis, 1927, proposed that either histamine or H - substances might be released from the skin in many forms of injury.

During 1930’s Henry Dale tried to explain the process of inflammation as an auto pharmacological phenomenon. According to him, most pathophysiological events of inflammation are mediated by the release of acetylcholine, catecholamine, histamine, etc. In 1940’s by Menkin ,Rocha a Silva with their co workers in the fifties demonstrated the role of the leukotrienes and kinins, in the process of inflammation. In the late sixties and seventies there came the prostaglandin phase. On the other hand, in sixties, Florey and Majno with their associates studied the ultra structural alterations
of the vessels during inflammatory processes with the help of electron microscope.

6.4 Pathophysiology of inflammation

Physical agents, chemical agents, infections and immunological reactions may bring about injury in its turn causes inflammation. Essentially there are two categories of inflammation: i) acute and ii) chronic.

Figure 6.1: Physiology of inflammation

6.5 Acute inflammation

The classical signs of acute inflammatory reaction are warmth, redness, pain, swelling and loss of function. Zweifach reviewed the vascular changes and phenomena which occur in acute inflammation after injury (Anonymous, 1975). They are as follows:
6.5.1 Active hyperaemia

Immediately after the injury, the arterioles of the injured tissue contract followed by relaxation. As a result of that, the capillary network and post capillary venules become engorged with rapidly flowing blood, which warms the normal skin. It also causes redness. In the area of engorged microcirculation, blood flows rapidly at first, later it becomes progressively slower and there might be a temporary static of blood.

6.5.2 Exudation of Protein - rich fluid

After the onset of active hyperaemia, the protein-rich fluid escapes from the blood vessels into the surrounding tissue and forms interstitial oedema. The inflammatory exudates are much richer in plasma proteins than normal extra cellular fluids indicating the increased permeability of the vessels to macro molecules. The increased leakage of fluid and electrolytes in acute inflammation is explained by the increased hydrostatic pressure of blood in small vessels in active hyperaemia. Exudation of plasma proteins from small vessels in acutely inflamed tissue requires an increase in permeability of endothelium. This is provided by the reversible opening up of relatively large gaps between endothelial cells.

6.5.3 Emigration of Leukocytes

One of the major hallmark of the inflammation is the migration of leukocytes (principally neutrophil and monocytes) derived from the blood in the injured area. In normal blood flow, the red blood cells and white blood cells in the microvessels flow mainly in the central column of blood separated
from the vessel wall by a clear layer of plasma (Axial streaming). In
inflammation, when slowing of flow ensues, the axial streaming disappears,
the leukocytes in the venules passes into the peripheral stream, make contact
with vascular endothelium and thereby get arrested on it, eventually forming
a continuous layer.

The adhesion may be due to neutralization of negative charges or
reduction of charge density of the leukocytes. Divalent ions also play an
important role and the chemostatic factors increase the adherence of
neutrophils to endothelial cells. The marginated polymorphs extend between
the junctions of the two endothelial cells and thereby disrupt it, then squeeze
through it and the intercellular junction reforms rapidly.

Neutrophils migrate earlier and more rapidly than monocytes.
Eosinophils accumulate mainly in immunologic inflammatory reaction. The
neutrophil polymorphs are actively phagocytic but the migrated monocytes
are not so, although they become more active when they change into
macrophage. The process is similar for both. The particle to be ingested
becomes attached to the surface of the leukocytes and a process known as
‘opsonisation’ occurs. Opsonin coats the foreign matter in such a way that
leukocytes recognize it as a foreign body. The limiting membrane of the
phagocytic vacuole fuses and then there is a discharge of the granule content
into this phagolysosome.

The leukocytes become progressively degranulated and during this
degranulation, there is some leakage of hydrolytic enzyme and some
metabolic product into the external medium. Phagocytosis is an energy dependent process that stimulates numerous intercellular events including increased oxygen consumption, glycogenolysis, increased glucose oxidation and hydrogen peroxide production. The hydrogen peroxide produced within the phagolysosome is important in bacterial killing, which is the ultimate step in phagocytosis.

6.5.4 Consequences of acute inflammation

a) After termination of the injury, the blood flow and vascular permeability becomes normal. Pavementing of leukocytes ceases, Cells and tissue debris are digested by the enzymes. Migrated polymorphs die and macrophages are drained. In short, normalization of the tissue is restored.

b) In certain inflammatory conditions (due to pyrogenic bacteria), severe local toxic injury forms abscess in the tissue which is filled with inflammatory exudates rich in polymorphs, bacteria and fragments of necrotic tissue. Here, return to normal state is no longer possible since the tissue has been destroyed and the abscess becomes enclosed in a wall of granulation tissue, which eventually matures to real tissue.

c) Some acute inflammatory lesions do not subside. So the return to normalcy is hampered. Formation of granulation tissue with consequent fibrosis or scarring is very common. It complicates acute inflammation and there is necrosis to tissue or excessive fibrin
deposition and when acute inflammation persists. It becomes a chronic one.

6.6 Chronic inflammation

Chronic inflammation is also characterized by pain, redness and swelling, but it does not subside in a period of days, but may instead have a relentless damaging course of several weeks, months or years, and may have far reaching effects on the well being of the host. A chronic inflammation is caused by the persistence of an irritant, which may be of biologic, physical, or chemical nature.

6.6.1 The histological marks of chronic inflammation

The irritant remains at the site due to inability of macrophages to digest it. The cycle of cellular infiltration, necrosis and fibrosis will continue as long as the irritant remains.

i) **Infiltration of mononuclear cells, macrophages, lymphocytes and plasma cells:**

When monocytes reach the extra-vascular tissue, they are transformed into much larger macrophages. Macrophages then undergo activation. In acute inflammation, if the injurious agent is not eliminated, macrophages persist for longer time.

ii) **Proliferation of fibroblasts and small blood vessels:**

The complete mechanism given above is not fully clear but the factors derived from activated macrophages have been implicated in both fibroblasts and new vessel growth. Continued fibroblastic proliferation results in increased deposition of collagen, which causes scar formation.
with resultant deformities, adhesion between serosal surfaces, permanent fibrous replacement of damaged parenchyma and may result in permanent damage to tissue.

Chronic inflammation is more proliferative than an exudative one and necrosis commonly occurs and reoccurs. Formation of granulation tissue and connective tissue takes place. Thus, increasing amount of fibrous tissue will characterize a persistent, long term chronic process. Two types of chronic inflammation have been characterized; i) granulomatous and ii) basal.

Granulomas are small collections of inflammatory cells, principally modified macrophages, surrounded by a rim of lymphocytes. These modified macrophages are derived from monocytes and are known as epitheloid cells. Another feature of the granuloma is the presence of Langhans or foreign body type giant cells, which are formed by the coalescence and fusion of macrophages. Giant cells are associated with the presence of large amounts of indigestible materials and they often conglomerate around a foreign body. Fibroblasts, plasma cells and at times neutrophils can also be seen in a granuloma. Basal chronic inflammation is not highly cellular and produces relatively smaller lesions.

6.7 Cell Biology of Inflammation (Willoughby et al., 2000)

Inflammation is a critically important mechanism utilized by all tissues of the body as a primary defense against infection.

6.7.1 Accumulation of inflammatory Cells: The first stage of inflammation involves the accumulation of inflammatory cells in the micro
vasculature in response to the initial infection either driven by molecules released from the organisms themselves or via generation of chemoattractants and chemokines from resident tissue cells, pulmonary capillaries or systemic venular endothelium. This represents one area of investigation.

6.7.2 Activation pathways: Once arrived, inflammatory cells contribute to the destruction of the infectious organism and the inflammatory process primarily by secretion of preformed and newly synthesized constituents. The biochemical and morphologic mechanisms involving activation and secretion from neutrophils and macrophages (both to the cell exterior as well as into the phagosome), with a particular emphasis on cell priming (i.e. mechanisms of sequential cooperative stimulation) and the signal pathways involved particularly those mediated through p38 MAP kinase should be considered.

6.8 Recognition and removal of Apoptotic cells:

Under normal circumstances, inflammatory cells are removed from the lesions during resolution of the inflammation. This follows programmed cell death (apoptosis) involving DNA fragmentation, nuclear alterations and changes in surface membranes without cell lysis which leads to recognition and phagocytosis by mature macrophages and adjacent tissue cells.

The processes appear highly abundant involving at least six different classes of receptors. The recognition and uptake of apoptotic cells also result in active suppression of pro-inflammatory cytokine, chemokine and
eicosanoid production by macrophages, presumably also contributing to resolution, but perhaps in inadvertently enhancing opportunities for intracellular viral or bacterial pathogens in excess, leading to fibrosis.

6.9 Macrophage Maturation:

Maturation of macrophages under the influence of different inflammatory stimuli results in ‘phenotypes’ that are characterized by the synthesis of specific protein markers, including new receptors for removal of apoptotic cells. The mechanisms of control of these pathways and their contribution to inflammatory cell clearance and/or progress of injury are yet another area of study.

Particular emphasis is on the generation of anti-inflammatory macrophages that are actively secreting suppressive mediators such as THFb, their potential induction by oxidized phospholipids or activators of PPARs and they have role in p38 MAP kinase inhibition.

6.10 Inflammatory Mediators:

Finally, the complex elements of inflammation are orchestrated by the actions of a network of ‘mediators’. Of particular interest are lipid mediators, including the alkyl phospholipids, platelet activating factor (PAF) or oxidatively chain-shortened phospholipid analogues of PAF and the broad spectrum of arachidonate derivatives (eicosanoids). The coordinate production of these by inflammatory cells, the role of cooperation between cell types in their synthesis, the mechanisms of their secretion (release) and their interactive roles in inflammation are under investigation still.
6.10.1 Phospholipase A\(_2\):  

Arachidonic acid (AA) is a common precursor for eicosanoids such as prostaglandins, leukotrienes, etc from membrane phospholipids. AA release is catalysed by a membrane associated enzyme, PLA\(_2\), which is also responsible for the production of platelet activating factor and other proinflammatory mediators (Chilton et al., 1984).

6.10.2 Cyclo-oxygenases:

Cyclo-oxygenase (COX) pathway leads to the formation of PGs, thromboxanes and prostacyclins, a family of autocrine and paracrine mediators that contribute to many physiological and pathophysiological responses (see Fig.4.2). Cyclooxygenase (COX; Prostaglandin endoperoxide synthase catalyzes two separate enzyme reactions.
i) The bisoxygenation of arachidonic acid at carbon 11 and 15 (cyclooxygenase activity) and ii) the subsequent bi-electron reduction at 15-hydroperoxy group of PGG$_2$ (Peroxidase activity) to form another endoperoxide derivative, PGH$_2$ (Smith et al., 1996). These two reactions occur at distinct but structurally and functionally interconnected sites.

6.10.3 5-Lipoxygenase:

Lipoxygenase (LOX) pathway leads to the formation of hydroperoxyeicosatetraenoic acid (HPETEs), leukotrienes (LTs) and lipoxins from arachidonic acid. Among these LTs are the most potent biologically active compounds.

LOXs have been classified based on their positional specificity of arachidonate oxygenation (Yamamota, 1992).
6.10.4 Platelet activating factor (PAF):

PAF is an extraordinarily potent mediator of endotoxic shock and inflammation (Hosford et al., 1990). It exerts its biological effects by activating the PAF receptor, accordingly stimulating protein kinase C and increasing intracellular Ca++. 

6.10.5 Myeloperoxidase (MPO):

Myeloperoxidase is the most abundant protein stored in azurophilic granules of neutrophils (polymorphonuclear leukocytes) which constitutes 5% and plays a central role in microbial killing and inflammatory tissue damage (Burner et al., 1999). MPO catalyses the reaction of hydrogen peroxide and chloride at plasma concentration levels, thereby producing oxidative toxic products such as hypochlorous acid (HOCl) and free radical hydroxyl ion (Ramos et al., 1995).

6.10.6 Neutrophil elastase:

NE, a neutrophil granule serine protease, is a key enzyme in tissue injury. The enzyme is a single chain polypeptide with a strong basic isoelectric pH (10 to 11) (Janoff, 1985).

6.10.7 Inducible Nitric Oxide Synthase:

Cells synthesize nitric oxide (NO) by utilizing inducible nitric oxide synthase (iNOS), which converts L-arginine to L-citrulline and NO. NO plays an important role to induce apoptosis and necrosis (Sandowska-Krowicka et
al., 1988) associated with chronic inflammatory process such as asthma and rheumatoid arthritis.

6.10.8 Cytokines:

Interleukins (ILs), tumour necrosis factor (TNF), interferons, platelet-derived growth factor (PDGF), granulocyte-macrophage-colony-stimulating factor (GMCSF) and chemokines are collectively known as cytokines and are mediators of the immune system.

Cytokines, particularly IL-1 and TNF-α have been implicated as important mediators of inflammation and joint destruction in rheumatoid arthritis (Arend and Dayer, 1990).

6.11 EXPERIMENTAL MODELS USED FOR TESTING OF ANTI-INFLAMMATORY ACTIVITY (Robert Turner, A. 1965)

The inflammatory process involves a series of events that can be elicited by numerous stimuli, e.g. infectious agents, ischemia, antigen-antibody interactions, chemical, thermal or mechanical injury. The response is accompanied by the clinical signs of erythema, oedema, hyperalgesia and pain inflammatory responses which occur in three distinct phases, each apparently mediated by different mechanisms given as under.

- An acute, transient phase, characterized by local vasodilation and increased capillary permeability.
- A Sub-acute phase, characterized by infiltration of leukocytes and phagocytic cells.
A chronic proliferative phase in which tissue degeneration and fibrosis occur.

In vivo methods for testing acute and sub-acute inflammation are:

- UV - erythema in guinea pigs
- Vascular permeability
- Oxazolone induced ear oedema in rats and mice
- Croton oil induced ear oedema in rats and mice
- Paw oedema in rats.

6.12 Paw oedema can be induced by chemical agents

Inflammogens

- Increase vascular permeability and cause fluid accumulation
  Eg: histamine, serotonin, dextran, eggwhite
- Cause fluid accumulation by damaging the tissue
  Eg.: formalin, kaolin

- Pleurisy tests
- Granuloma pouch technique
- Hyaluronidase Inhibition

The proliferative phase is measured by methods for testing granuloma formation, such as

- Cotton wool granuloma
- Glass rod granuloma
- PVC sponge granuloma
6.13 Experimental Models for Evaluation of Anti-Inflammatory Activity

The various models available for testing anti-inflammatory activity with reasonable accuracy, minimum time and test compound consumption are described below:

6.13.1 Acute models of inflammation

6.13.1.1 Carrageenan induced oedema model (Nasrin et al., 2005)

Acute hind paw oedema was induced either in mice or in rats by injecting 0.05 ml to 0.1 of 1 % w/v carrageenan which reaches a peak level at 3-5 hrs of carrageenan injection. Although oedema can be induced by many other phlogistic agents like dextrin, formaldehyde, 5-hydroxytryptamine, histamine, bradykinin and prostaglandin E₁ etc., for routine screening, acute carrageenan induced oedema test was employed.

6.13.1.2 U.V.light induced erythema model (Iracema et al., 2005)

Exposure to U.V. radiation also induce acute erythema which is used as model for anti-inflammatory activity testing.

6.13.2 Chronic models of inflammation

6.13.2.1 Cotton pellet method (Victor et al., 2005; Gupta et al., 2005).

Chronic inflammation was induced by the implantation of sterile cotton pellets (50 mg ± 1 mg) on the back or axilla of the rats asceptically. The peak effect was reached within 7 days.

6.13.2.2 Granuloma pouch method (Perez-Garcia et al., 2005; Isabel et al., 2004).

Pouch on the back of the rat was produced by injecting 20 ml of air and 1.0 ml of 1% croton oil in olive oil or 0.5ml of turpentine oil in the
subcutaneous tissues in between the shoulder blades. The effect was seen after 7 days.

**6.13.2.3 Formaldehyde induced arthritis** (Moura et al., 2005; Eun Mi et al., 2003).

Arthritis was induced by injecting 0.1 ml of 2 % formaldehyde solution into the subplanta region of one of the hind paws of rat on the first and third day of the 10 days experiment.

**6.13.2.4 Adjuvant induced arthritis** (Lilly et al., 2005; Fan et al., 2005).

Chronic arthritis in rats was induced by injection of 0.5 mg of heat killed Mycobacterium tuberculosis (Difco) suspended in 0.1 ml of liquid paraffin into one of the hind paws. The effect was observed till 21 days of irritant injection.

**6.14 Plants with anti-inflammatory activity**

Inflammatory diseases including different types of rheumatic diseases are very common throughout the world. Although rheumatism is one of the oldest known diseases of mankind and affects a large population of the world, there have been no substantial progress has been made in achieving a permanent cure. The greatest disadvantage of the presently available potent synthetic drugs lie in their toxicity and reappearance of symptoms after discontinuation of treatment. The research of screening and development of drugs for their anti-inflammatory activity is therefore, an unending problem and there is need of finding out antirheumatic drugs from indigenous plants.

The literature survey reveals that plant species of about 96 genera belonging to 56 families have exhibited anti-inflammatory activity. Some of
the plant sources used in traditional systems of medicine with pharmacologically/therapeutically proven anti-inflammatory and antirheumatic claims are mentioned in the table no 6.1.

**Table: 6.1 Some plants with anti-inflammatory activity** *(The Useful plants of India, 1988; The Medicinal Plants of India, 1987; The Wealth of India, 1952).*

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Trade names in India</th>
<th>Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aconitum napellus</td>
<td>Aconite</td>
<td>Ranunculaceae</td>
</tr>
<tr>
<td>Alpinia officinarum</td>
<td>Rasna</td>
<td>Zingiberaceae</td>
</tr>
<tr>
<td>Azadirachta indica</td>
<td>Neem</td>
<td>Meliaceae</td>
</tr>
<tr>
<td>Balanites roxburghii</td>
<td>Gari</td>
<td>Simarubicae</td>
</tr>
<tr>
<td>Boerhaavia diffusa</td>
<td>Punarnava</td>
<td>Nyctaginaceae</td>
</tr>
<tr>
<td>Boswellia serrata</td>
<td>Salaiguggal</td>
<td>Burseraceae</td>
</tr>
<tr>
<td>Colchicum autumnale</td>
<td>Colchicum</td>
<td>Liliaceae</td>
</tr>
<tr>
<td>Commiphora mukul</td>
<td>Guggulu</td>
<td>Burseraceae</td>
</tr>
<tr>
<td>(Balsamodendron mukul)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curcuma longa</td>
<td>Turmeric</td>
<td>Zingiberaceae</td>
</tr>
<tr>
<td>Delonix elata</td>
<td>Vatanarayana</td>
<td>Leguminosae</td>
</tr>
<tr>
<td>Glycyrrhiza glabra</td>
<td>Liquorice</td>
<td>Leguminosae</td>
</tr>
<tr>
<td>Hedychium spicatum</td>
<td>Karpur kacheri</td>
<td>Zingiberaceae</td>
</tr>
<tr>
<td>Heliotropium curassavicum</td>
<td>Haatisura</td>
<td>Boraginaceae</td>
</tr>
<tr>
<td>Hemidesmus indicus</td>
<td>Margabi</td>
<td>Asclepiadaceae</td>
</tr>
<tr>
<td>Hibiscus rosa sinensis</td>
<td>Jassoon</td>
<td>Malvaceae</td>
</tr>
<tr>
<td>Indigofera aspalathodes</td>
<td>Hakna</td>
<td>Febaceae</td>
</tr>
<tr>
<td>Inula recemosa</td>
<td>Poshkar</td>
<td>Compositaceae</td>
</tr>
<tr>
<td>Iris kashmiriana</td>
<td>Padma-pushkara</td>
<td>Iridaceae</td>
</tr>
<tr>
<td>Lawsonia inermis</td>
<td>Hena</td>
<td>Lythraceae</td>
</tr>
<tr>
<td>Leucas aspera</td>
<td>Hulkusha</td>
<td>Labiatae</td>
</tr>
<tr>
<td>Mammea longifolia (Vitexin)</td>
<td>Nagkesar</td>
<td>Guttiferae</td>
</tr>
<tr>
<td>Moringa oleifera</td>
<td>Sahinjan</td>
<td>Moringaceae</td>
</tr>
<tr>
<td>Morus alba</td>
<td>Tutri</td>
<td>Moraceae</td>
</tr>
</tbody>
</table>
Myrtus communis
Nepeta hindostana (Nepitrin)
 Nerium indicum (Plumieride)
Nigella sativa
 Nyctanthes arbor-tristis
Nympheaa stellata
 Operculina turritum
Ougenia oojineensis
Paederia foetida
Peltophorum
 pterocarpum (Berginina)
Phyla nodiflora
Piper longum
Pluchea lanceolata
Premna herbacea
Prosopos spicigera
Psoralea coryl Tribute
(bavachinine)
Pterocarpus santalinus
Randia dumetorum
Salvadora pereca
Teramnus labialis
Tinospora malbarica
Urena lobata
Vandal roxburgii
Verbena officinalis
Vitex negundo
Withania somnifera

Baragasha
Billilotan
Kaner
Kalonji
Seoli
Nilkamal
Nakpatra
Sandan
Gandhali
Kondachinta
Jalapeepala
Pippali
Rasna
Bhumjambu
Shami
Bakuchi
Raktachandana
Mainphal
Brihatpilu
Mashaparni
Sudarsana
Vanabhenda
Rasna
Karaita
Nirgundis
Ashwagandha

Myrtaceae
Labbiatae
Apocynaceae
Ranunculaceae
Oleaceae
Nympheaceae
Convolvulaceae
Febaceae
Rubiaceae
Caesalpiniaceae
Verbenaceae
Piperaceae
Compositae
Verbenaceae
Leguminosae
Leguminosae
Leguminosae
Verbenaceae
Rubiaceae
Salvadoraceae
Leguminosae
Menispermaceae
Malvaceae
Orchidaceae
Verbenaceae
Verbenaceae
Solanaceae
6.15 Treatment of inflammation

For the treatment of inflammation Non Steroidal Anti-Inflammatory Drugs (NSAIDs) (Nabumetone, Nimesulide, Etodolac etc.,) are commonly used. Most commonly used drugs are:

- Salicylates: Aspirin
- **Propionic acid derivatives:** Ibuprofen, Ibuprofen + Paracetamol Combination. Flurbiprofen, Ketoprofen Naproxen, Fenamates and Mefenamic acid
- **Pyrazolones:** Phenylbutazone and Oxyphenbutazone
- **Indole derivative:** Indomethacin
- **Arylacetic acid derivatives:** Diclofenac sodium, Diclofenac potassium Diclofenac + Paracetamol Combination, Combination preparation of diclofenac and serratiopeptidase
- **Oxicam derivatives:** Piroxicam, Tenoxicam and Meloxicam
- **Pyrrole-Pyrrole Derivatives:** Ketorolac
- **Para aminophenol derivative:** Paracetamol

**Others:** Celecoxib, Rofecoxib, Valdecoxib and Nimesulide, Combination preparation of Nimesulide, Nabumetone and
Figure: 6.4 Some important NSAIDs with their structures are represented

Nabumetone

Nimesulide

Meloxicam

Celecoxib

Naproxen

Ibuprofen

Dup 697

Etodolac

Aspirin

Rofecoxib
6.16 Selection of Animals

Wistar albino rats of either sex weighing between 150-200 g were obtained from National Institute of Nutrition, Hyderabad, Andhra Pradesh, India. The animals were housed under standard environmental conditions (temperature of 25 ± 2°C with an alternating 12h light-dark cycle and relative humidity of 50 ±15%), one week before the start and also during the experiment as per the rules and regulations of the Institutional Animal Ethics committee and of the Regulatory body of the government (Regd no. 516/ 01/ A/ CPCSEA). They were fed with standard laboratory diet (supplied by Ratan Brothers, India) and water ad libitum during the experiment.

6.17 Experimental Protocol

The rats were given doses orally with extracts at different dose levels 18 h and 2 h prior to the induction of carrageenan subcutaneously (SC) into the subplantar tissue of the hind paw of each rat, 0.1 ml of 1% carrageenan suspension.

The drug effects were estimated by comparing the maximal oedema response during 6 h in the drug as extract treated group with that of vehicle treated group as control. Group I normal rats treated with Drug vehicle (1% Sodium CMC) and served as normal control and Group II rats were treated with Indomethacin 2.5x10^-5 moles/ kg b.wt (5 mg/ kg). All the doses were administered orally according to the body weight of the animals.
6.18 Evaluation of Model

To evaluate this model, the percentage increase in paw thickness was plotted against the time (Hour) and the maximal oedema response induced during the 6 hr was determined. The results showed the ability of the model in detecting that the time course changes in the paw size was associated with carrageenan induced rat paw oedema. The paw oedema was constantly increased during 4 hr and reached peak of oedema at 4th hour. At the 5th and 6th hour, the oedema was gradually reduced.

Figure:6.5 Progression of the carrageenan-induced rat paw oedema over 6 hr as monitored with Zeitlin’s apparatus
6.19 Effect of hydro-alcoholic extract of Cleome chelidonii root on Carrageenan-induced rat paw oedema

6.19.1 Aim

To evaluate the anti-inflammatory activity of hydro-alcoholic extract of Cleome chelidonii root.

6.19.2 Materials and Methods

Wistar albino rats of either sex (150-200 g, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness, were used.

The hydro-alcoholic root extract of C. chelidonii at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema induced by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.6.

The extracts were administered orally in the following order:

- **Group-III** Received hydro-alcoholic crude extract of C. chelidonii seeds 100 mg/ kg
- **Group-IV** Received hydro-alcoholic crude extract of C. chelidonii seeds 200 mg/ kg
- **Group-V** Received alcoholic crude extract of C. chelidonii seeds 400 mg/ kg
6.19.3 Results:

Table 6.2 shows that the Indomethacin and hydro-alcoholic extract of C. chelidonii root at doses 100, 200 & 400 mg/kg significantly inhibited the maximal oedema response and the percentage inhibition was found to be 62.92±1.5, 37.41±0.8, 44.65±1.2 and 50.28±1.2% respectively during the 6 hr of the carrageen-an-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 45.71±0.8, 47.81±1.3 and 51.25±1.1% (Figure 6.6) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.19.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the hydro-alcoholic root extract of C. chelidonii produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group III</td>
<td>37.41±0.8***</td>
<td>45.71±0.8***</td>
</tr>
<tr>
<td>Group IV</td>
<td>44.65±1.2***</td>
<td>47.81±1.3***</td>
</tr>
<tr>
<td>Group V</td>
<td>50.28±1.2***</td>
<td>51.25±1.1***</td>
</tr>
</tbody>
</table>

Table 6.2. Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the hydro-alcoholic extract of C. chelidonii root and Indomethacin. ***P<0.001.
Fig.6.6 Effect of the hydro-alcoholic root extracts of C.chelidonii, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^{-5} moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.20 Effect of methanolic extract of Cleome chelidonii root on carrageenan-induced rat paw oedema

6.20.1 Aim

To evaluate the anti-inflammatory activity of methanolic root extract of Cleome chelidonii.

6.20.2 Materials and Methods

Wistar albino rats of either sex (150-200 gm, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness, were used.

The methanolic extract of C. chelidonii root at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema induced by carrageenan injection and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.7.

The extracts were administered orally in the following order

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group-VI</td>
<td>Received methanolic root extract of C. chelidonii 100 mg/ kg</td>
</tr>
<tr>
<td>Group-VII</td>
<td>Received methanolic root extract of C. chelidonii 200 mg/ kg</td>
</tr>
<tr>
<td>Group-VIII</td>
<td>Received methanolic root extract of C. chelidonii 400 mg/ kg</td>
</tr>
</tbody>
</table>
6.20.3 Results:

Table 6.3 shows that the Indomethacin and methanolic extract of C. chelidonii significantly inhibited the maximal oedema response and the percentage inhibition was found to be 62.92±1.5, 38.91±0.5, 47.76±1.1 and 53.39±1.2% respectively during the 6 hr of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 47.15±1.2, 49.68±0.5 and 53.32±0.6% (Figure 6.7) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.20.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the methanolic extract of C. chelidonii root produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group VI</td>
<td>38.91±0.5***</td>
<td>47.15±1.2***</td>
</tr>
<tr>
<td>Group VII</td>
<td>47.76±1.1***</td>
<td>49.68±0.5***</td>
</tr>
<tr>
<td>Group VIII</td>
<td>53.39±1.2***</td>
<td>53.32±0.6***</td>
</tr>
</tbody>
</table>

Table 6.3.Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the methanolic root extract of C. chelidonii and Indomethacin. ***P<0.001.
Fig. 6.7. Effect of methanolic extracts of C. chelidonii root, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^{-5} moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.21 Effect of ethyl acetate extract of C. chelidonii root on carrageenan-induced rat paw oedema

6.21.1 Aim

To evaluate the anti-inflammatory activity of ethyl acetate root extract of C.chelidonii.

6.21.2 Materials and Methods

Wistar albino rats of either sex (150-200 gm, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness, were used.

The ethyl acetate extract of C. chelidonii root at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema induced by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.8.

The extracts were administered orally in the following order

Group-IX Received ethyl acetate root extract of C. chelidonii 100 mg/ kg
Group-X Received ethyl acetate root extract of C. chelidonii 200 mg/ kg
Group-XI Received ethyl acetate root extract of C. chelidonii 400 mg/ kg
6.21.3 Results:

Table 6.4 shows that the Indomethacin and ethyl acetate extract of C. chelidonii root significantly inhibited the maximal oedema response and the percentage inhibition was found to be 62.92±1.5, 34.92±1.1, 43.08±0.6 and 48.65±1.3% respectively during the 6 h of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 44.1±1.2, 46.04±0.5 and 49.45±1.2% (Figure 6.8) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.21.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the ethyl acetate extract of C. chelidonii root produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group IX</td>
<td>34.92±1.1***</td>
<td>44.1±1.2***</td>
</tr>
<tr>
<td>Group X</td>
<td>43.08±0.6***</td>
<td>46.04±0.5***</td>
</tr>
<tr>
<td>Group XI</td>
<td>48.65±1.3***</td>
<td>49.45±1.2***</td>
</tr>
</tbody>
</table>

Table 6.4.Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the ethyl acetate root extract of T. C. chelidonii and Indomethacin. ***P<0.001.
Fig.6.8. Effect of ethyl acetate extracts of C. chelidonii root, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^{-5} moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.22 Effect of hexane extract of C. chelidonii root on carrageenan-induced rat paw oedema

6.22.1 Aim

To evaluate the anti-inflammatory activity of hexane extract of C. chelidonii root.

6.22.2 Materials and Methods

Wistar albino rats of either sex (150-200 gm, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness, were used.

The hexane extract of C. chelidonii root at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema induced by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.9.

The extracts were administered orally in the following order:

- **Group-XII**: Received hexane root extract of C. chelidonii 100 mg/ kg
- **Group-XIII**: Received hexane root extract of C. chelidonii 200 mg/ kg
- **Group-XIV**: Received hexane root extract of C. chelidonii 400 mg/ kg
6.22.3 Results:

Table 6.5 shows that the Indomethacin and hexane extract of C. chelidonii root significantly inhibited the maximal oedema response and the percentage inhibition was found to be 62.92±1.5, 32.58±1.2, 36.92±1.1 and 44.17±1.2% respectively during the 6 h of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 41.55±1.2, 42.66±1.4 and 46.23±1.5% (Figure 6.9) respectively over 6 h when compared to the control group treated with drug vehicle.

6.22.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the hexane extract of C. chelidonii root produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group XII</td>
<td>32.58±1.2***</td>
<td>41.55±1.2***</td>
</tr>
<tr>
<td>Group XIII</td>
<td>36.92±1.1***</td>
<td>42.66±1.4***</td>
</tr>
<tr>
<td>Group XIV</td>
<td>44.17±1.2***</td>
<td>46.23±1.5***</td>
</tr>
</tbody>
</table>

Table 6.5. Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the hexane extract of C. chelidonii root and Indomethacin. ***P<0.001.
Fig. 6.9. Effect of hexane extracts of C. chelidonii root, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^{-5} moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.23 Effect of hydro-alcoholic extract of Gynandropsis gynandra on carrageenan-induced rat paw oedema

6.23.1 Aim

To evaluate the anti-inflammatory activity of hydro-alcoholic extract of Gynandropsis gynandra whole plant.

6.23.2 Materials and Methods

Wistar albino rats of either sex (150-200 g, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness, were used.

The hydro-alcoholic extract of Gynandropsis gynandra at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.10.

The extracts were administered orally in the following order:

- **Group-XV** Received hydro-alcoholic extract of Gynandropsis gynandra whole plant 100 mg/ kg
- **Group-XVI** Received hydro-alcoholic extract of Gynandropsis gynandra whole plant 200 mg/ kg
- **Group-XVII** Received hydro-alcoholic extract of Gynandropsis gynandra whole plant 400 mg/ kg
6.23.3 Results:

Table 6.6 shows that the Indomethacin and hydro-alcoholic extract of Gynandropsis gynandra significantly inhibited the maximal oedema response and the percentage inhibition was found to be 62.92±1.5, 23.68±1.4, 31.09 ±2.1 and 34.63±2.4% respectively during the 6 h of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 34.5±1.1, 39.94±1.5 and 44.82±2.1% (Figure 6.10) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.23.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the hydro-alcoholic extract of Gynandropsis gynandra produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group XV</td>
<td>23.68±1.4***</td>
<td>34.5±1.1***</td>
</tr>
<tr>
<td>Group XVI</td>
<td>31.09±2.1***</td>
<td>39.94±1.5***</td>
</tr>
<tr>
<td>Group XVII</td>
<td>34.63±2.4***</td>
<td>44.82±2.1***</td>
</tr>
</tbody>
</table>

Table 6.6. Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the alcoholic crude extract of G. gynandra and Indomethacin. ***P<0.001.
Fig.6.10. Effect of the hydro-alcoholic extracts of G. gynandra, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^{-5} moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.24 Effect of methanolic extract of *Gynandropsis gynandra* on carrageenan-induced rat paw oedema

6.24.1 Aim

To evaluate the anti-inflammatory activity of methanolic extract of *Gynandropsis gynandra* whole plant.

6.24.2 Materials and Methods

Wistar albino rats of either sex (150-200 gm, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness, were used.

The methanolic extract of *Gynandropsis gynandra* at different doses were administered p.o in sodium carboxyl methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.11.

The extracts were administered orally in the following order

- **Group-XVIII**: Received methanolic extract of *Gynandropsis gynandra* whole plant 100 mg/ kg
- **Group-XIX**: Received methanolic extract of *Gynandropsis gynandra* whole plant 200 mg/ kg
- **Group-XX**: Received methanolic extract of *Gynandropsis gynandra* whole plant 400 mg/ kg
6.24.3 Results:

Table 6.7 shows that the Indomethacin and methanolic extract of Gynandropsis gynandra significantly inhibited the maximal oedema response and the percentage inhibition was found to be 62.92±1.5, 29.52±1.1, 34.62±1.2 and 38.66±1.5% respectively during the 6 h of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 39.15±1.5, 43.02±2.1 and 46.86±2.1% (Figure 6.11) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.24.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the methanolic extract of Gynandropsis gynandra whole plant produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group XVIII</td>
<td>29.52±1.1***</td>
<td>39.15±1.5***</td>
</tr>
<tr>
<td>Group XIX</td>
<td>34.62±1.2***</td>
<td>43.02±2.1***</td>
</tr>
<tr>
<td>Group XX</td>
<td>38.66±1.5***</td>
<td>46.86±2.1***</td>
</tr>
</tbody>
</table>

Table 6.7.Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the methanolic extract of G.gynandropsis and Indomethacin. ***P<0.001.
Fig. 6.11. Effect of methanolic extracts of *G. gynandra*, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^{-5} moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.25 Effect of ethyl acetate extract of *Gynandropsis gynandra* on carrageenan-induced rat paw oedema

6.25.1 Aim

To evaluate the anti-inflammatory activity of ethyl acetate extract of *Gynandropsis gynandra*.

6.25.2 Materials and Methods

Wistar albino rats of either sex (150-200 gm, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness, were used.

The ethyl acetate extract of *Gynandropsis gynandra* at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.12.

The extracts were administered orally in the following order:

- **Group-XXI**: Received ethyl acetate extract of *Gynandropsis gynandra* whole plant 100 mg/ kg
- **Group-XXII**: Received ethyl acetate extract of *Gynandropsis gynandra* whole plant 200 mg/ kg
- **Group-XXIII**: Received ethyl acetate extract of *Gynandropsis gynandra* whole plant 400 mg/ kg
6.25.3 Results:

Table 6.8 shows that the Indomethacin and ethyl acetate extract of Gynandropsis gynandra whole plant significantly inhibited the maximal oedema response and the percentage inhibition found to be 62.92±1.5, 17.81±0.5, 22.95±1.2 and 28.9±1.4% respectively during the 6 h of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 30.5±1.2, 35.22±1.1 and 39.84±1.5% (Figure 6.12) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.25.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, whereas the ethyl acetate extract of Gynandropsis gynandra whole plant produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group XXI</td>
<td>17.81±0.5***</td>
<td>30.5±1.2***</td>
</tr>
<tr>
<td>Group XXII</td>
<td>22.95±1.2***</td>
<td>35.22±1.1***</td>
</tr>
<tr>
<td>Group XXIII</td>
<td>28.9±1.4***</td>
<td>39.84±1.5***</td>
</tr>
</tbody>
</table>

Table 6.8.Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the ethyl acetate extract of G. gynandra and Indomethacin. ***P<0.001.
Fig.6.12. Effect of ethyl acetate extracts of G. gynandra, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^{-5} moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.26 Effect of hexane extract of Gynandropsis gynandra whole plant on carrageenan-induced rat paw oedema

6.26.1 Aim

To evaluate the anti-inflammatory activity of hexane extract of Gynandropsis gynandra.

6.26.2 Materials and Methods

Wistar albino rats of either sex (150-200 gm, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness, were used.

The hexane extract of Gynandropsis gynandra at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema by carrageenan injection and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.13.

The extracts were administered orally in the following order:

Group-XXIV Received hexane extract of Gynandropsis gynandra whole plant 100 mg/ kg

Group-XXV Received hexane extract of Gynandropsis gynandra whole plant 200 mg/ kg

Group-XXVI Received hexane extract of Gynandropsis gynandra whole plant 400 mg/ kg
6.26.3 Results:

Table 6.9 shows that the Indomethacin and hexane extract of Gynandropsis gynandra significantly inhibited the maximal oedema response and the percentage inhibition was found to be 62.92±1.5, 16.2±0.5, 21.11±1.2 and 26.41±1.5% respectively during the 6 hr of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 28.23±1.2, 32.86±1.4 and 37.09±2.1% (Figure 6.13) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.26.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the hexane extract of Gynandropsis gynandra produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group XXIV</td>
<td>16.2±0.5***</td>
<td>28.23±1.2***</td>
</tr>
<tr>
<td>Group XXV</td>
<td>21.11±1.2***</td>
<td>32.86±1.4***</td>
</tr>
<tr>
<td>Group XXVI</td>
<td>26.41±1.5***</td>
<td>37.09±2.1***</td>
</tr>
</tbody>
</table>

Table 6.9. Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the hexane extract of G. gynandra and Indomethacin. ***P<0.001.
Fig. 6.13. Effect of hexane extracts of G. gynandra, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^-5 moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.27 Effect of hydro-alcoholic extract of Heliotropium indicum on carrageenan-induced rat paw oedema

6.27.1 Aim

To evaluate the anti-inflammatory activity of hydro-alcoholic extract of Heliotropium indicum.

6.27.2 Materials and Methods

Wistar albino rats of either sex (150-200 g, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness were used.

The hydro-alcoholic extract of Heliotropium indicum at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.14.

The extracts were administered orally in the following order:

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXVII</td>
<td>Received hydro-alcoholic extract of Heliotropium indicum 100 mg/ kg</td>
</tr>
<tr>
<td>XXVIII</td>
<td>Received hydro-alcoholic extract of Heliotropium indicum 200 mg/ kg</td>
</tr>
<tr>
<td>XXIX</td>
<td>Received hydro-alcoholic extract of Heliotropium indicum 400 mg/ kg</td>
</tr>
</tbody>
</table>
6.27.3 Results:

Table 6.10 shows that the Indomethacin and hydro-alcoholic extract of Heliotropium indicum significantly inhibited the maximal oedema response and the percentage of inhibition was found to be 62.92±1.5, 30.84±0.8, 34.22±1.2 and 36.24±1.4% respectively during the 6 hr of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 40.53±1.5, 44.27±1.4 and 47.81±1.5% (Figure 6.14) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.27.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the hydro-alcoholic extract of Heliotropium indicum produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group XXVII</td>
<td>30.84±0.8***</td>
<td>40.53±1.5***</td>
</tr>
<tr>
<td>Group XXVIII</td>
<td>34.22±1.2***</td>
<td>44.27±1.4***</td>
</tr>
<tr>
<td>Group XXIX</td>
<td>36.24±1.4***</td>
<td>47.81±1.5***</td>
</tr>
</tbody>
</table>

Table 6.10.Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the alcoholic crude extract of H.indicum and Indomethacin. ***P<0.001.
Fig. 6.14. Effect of the alcoholic crude extracts of *H. indicum*, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^{-5} moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.28 Effect of methanolic extract of Heliotropium indicum on carrageenan-induced rat paw oedema

6.28.1 Aim

To evaluate the anti-inflammatory activity of methanolic extract of Heliotropium indicum.

6.28.2 Materials and Methods

Wistar albino rats of either sex (150-200 gm, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness were used.

The methanolic extract of Heliotropium indicum at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.15.

The extracts were administered orally in the following order

<table>
<thead>
<tr>
<th>Group</th>
<th>Dosage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group-XXX</td>
<td>100 mg/kg</td>
<td>Received methanolic extract of Heliotropium indicum 100 mg/kg</td>
</tr>
<tr>
<td>Group-XXI</td>
<td>200 mg/kg</td>
<td>Received methanolic extract of Heliotropium indicum 200 mg/kg</td>
</tr>
<tr>
<td>Group-XXII</td>
<td>400 mg/kg</td>
<td>Received methanolic extract of Heliotropium indicum 400 mg/kg</td>
</tr>
</tbody>
</table>
6.28.3 Results:

Table 6.11 shows that the Indomethacin and methanolic extract of Heliotropium indicum significantly inhibited the maximal oedema response and the percentage of inhibition was found to be 62.92±1.5, 33.73±0.8, 37.45±1.2 and 41.45±1.5% respectively during the 6 hr of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 40.92±1.6, 45.35±1.5 and 49.51±1.5% (Figure 6.15) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.28.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the methanolic extract of H.indicum produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group XXX</td>
<td>33.73±0.8***</td>
<td>40.92±1.6***</td>
</tr>
<tr>
<td>Group XXXI</td>
<td>37.45±1.2***</td>
<td>45.35±1.5***</td>
</tr>
<tr>
<td>Group XXXII</td>
<td>41.45±1.5***</td>
<td>49.51±1.5***</td>
</tr>
</tbody>
</table>

Table 6.11. Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the methanolic extract of H.indicum and Indomethacin. ***P<0.001.
Fig. 6.15. Effect of methanolic extracts of *H. indicum*, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^-5 moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.29 Effect of ethyl acetate extract of Heliotropium indicum on carrageenan-induced rat paw oedema

6.29.1 Aim

To evaluate the anti-inflammatory activity of ethyl acetate extract of Heliotropium indicum.

6.29.2 Materials and Methods

Wistar albino rats of either sex (150-200 gm, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness were used.

The ethyl acetate extract of Heliotropium indicum at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.16.

The extracts were administered orally in the following order

<table>
<thead>
<tr>
<th>Group</th>
<th>Received ethyl acetate extract of Heliotropium indicum</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXXIII</td>
<td>100 mg/ kg</td>
</tr>
<tr>
<td>XXXIV</td>
<td>200 mg/ kg</td>
</tr>
<tr>
<td>XXXV</td>
<td>400 mg/ kg</td>
</tr>
</tbody>
</table>
6.29.3 Results:

Table 6.12 shows that the Indomethacin and ethyl acetate extract of Heliotropium indicum significantly inhibited the maximal oedema response and percentage inhibition was found to be 62.92±1.5, 23.6±0.5, 28.36±1.2 and 32.26±1.5% respectively during the 6 hr of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 35.45±1.5, 39.91±1.2 and 43.51±1.5% (Figure 6.16) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.29.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the ethyl acetate extract of Heliotropium indicum produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group XXXIII</td>
<td>23.6±0.5***</td>
<td>35.45±1.5***</td>
</tr>
<tr>
<td>Group XXXIV</td>
<td>28.36±1.2***</td>
<td>39.91±1.2***</td>
</tr>
<tr>
<td>Group XXXV</td>
<td>32.26±1.5***</td>
<td>43.51±1.5***</td>
</tr>
</tbody>
</table>

Table 6.12.Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the ethyl acetate extract of Heliotropium indicum and Indomethacin. ***P<0.001.
Fig. 6.16. Effect of ethyl acetate extracts of H. indicum, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^{-5} moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
6.30 Effect of hexane extract of Heliotropium indicum on carrageenan-induced rat paw oedema

6.30.1 Aim

To evaluate the anti-inflammatory activity of hexane extract of Heliotropium indicum.

6.30.2 Materials and Methods

Wistar albino rats of either sex (150-200 gm, n=6), Carrageenan, Sodium CMC and the Zeitlin Isotonic Lever (Appendix A, Figure A) for measuring paw thickness were used.

The hexane extract of Heliotropium indicum at different doses were administered p.o in sodium carboxy methyl cellulose suspension 18 hr and 2 hr prior to the induction of oedema by carrageenan and monitored the oedema progression as described in Appendix A. The maximal oedema response and the area under the time-course (AUC) as total oedema response are shown in Figure 6.17.

The extracts were administered orally in the following order:

Group-XXXVI Received hexane extract of Heliotropium indicum 100 mg/ kg
Group-XXXVII Received hexane extract of Heliotropium indicum 200 mg/ kg
Group-XXXVIII Received hexane extract of Heliotropium indicum 400 mg/ kg
6.30.3 Results:

Table 6.13 shows that the Indomethacin and hexane extract of Heliotropium indicum significantly inhibited the maximal oedema response and percentage inhibition was found to be 62.92±1.5, 19.43±0.5, 24.64±1.2 and 29.58±1.5% respectively during the 6 hr of the carrageenan-induced rat paw acute inflammation. The total oedema response (AUC) was inhibited by 68.4±1.2, 34.43±1.8, 36.86±1.5 and 40.11±1.5% (Figure 6.17) respectively over 6 hr when compared to the control group treated with drug vehicle.

6.30.4 Discussion:

The results suggested that the standard drug Indomethacin significantly inhibited paw oedema compared to drug vehicle, where as the hexane extract of Heliotropium indicum produced significant effect in reducing paw oedema at all three doses of 100, 200 & 400 mg/ kg.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage inhibition of the maximal paw oedema during 6 hours</th>
<th>Percentage inhibition of total AUC paw oedema during 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Group II</td>
<td>62.92±1.5***</td>
<td>68.4±1.2***</td>
</tr>
<tr>
<td>Group XXXVI</td>
<td>19.43±0.5***</td>
<td>34.43±1.8***</td>
</tr>
<tr>
<td>Group XXXVII</td>
<td>24.64±1.2***</td>
<td>36.86±1.5***</td>
</tr>
<tr>
<td>Group XXXVIII</td>
<td>29.58±1.5***</td>
<td>40.11±1.5***</td>
</tr>
</tbody>
</table>

Table 6.13.Percentage inhibition of Carrageenan induced paw oedema in rats by prophylactic treatment with the hexane extract of H.indicum and Indomethacin. ***P<0.001.
**Fig. 6.17.** Effect of hexane extracts of *H. indicum*, at 100, 200 & 400 mg/kg along with Indomethacin (2.5x10^-5 moles/kg body wt) on A) the maximal and B) the total paw oedema in carrageenan induced rats.
General Discussion:

The most widely used test to evaluate anti-inflammatory activity of any new compound is by testing its caliber in reducing the irritant induced oedema in experimental animals (Winter et al., 1962). The development of oedema in the paw of the rat after the injection of carrageenan has been described as biphasic event.

The initial phase which occurs between 0 and 2.5 hr has been attributed to the action of histamine, serotonin and bradykinin on vascular permeability (Vinegar et al., 1987). The oedema volume reaches its maximum approximately 3h post treatment and then begins to decline. The late phase, which is also a complement dependant reaction, has been shown to be a result of over production of prostaglandins in tissues (Di Rosa, 1974).

The methanolic extracts of *C. chelidonii* root exhibited good anti-inflammatory activity when compared to the whole plant extracts of *G. gynandra* and *H. indicum*. Pharmacological investigations clearly indicated that anti-inflammatory activity in many plants have been attributed to their flavanoid and sterol contents. Several flavanoids isolated from the medicinal plants have been discovered to possess significant anti-inflammatory activity (Duke, 1992).

Literature review reports the presence of flavanoids, triterpenoids, phytosterols and alkaloids in *C. chelidonii*, *G. gynandra* and *H. indicum*. These compounds may be responsible for the anti-inflammatory activity. The results clearly indicated that the pretreatment with the selected plant extracts and
indomethacin suppressed the increase in paw oedema produced by the phlogistic agent. Among the selected three plant extracts, the methanolic extracts produced significant reduction of paw oedema.

Hydro-alcoholic, Methanolic extracts from the three selected species had produced significant activity at the lower to higher doses, where as the ethyl acetate and hexane extracts produced good reduction at the maximum dose. The methanolic root extract of C. chelidonii produced significant (P<0.001) reduction dose dependently at 100, 200 & 400 mg/kg when compared to drug vehicle treated control group.

The hydro-alcoholic and methanolic extract of G. gynandra whole plant at three different doses produced significant (P<0.05) reduction dose dependently at 100,200 and 400 mg/kg when compared to drug vehicle treated control group. The ethyl acetate and hexane extracts of G. gynandra tested, at the doses 100,200 and 400 mg/kg were exhibited significant (p<0.001) activity, where as both the extracts at a dose of 400 mg/ kg exhibited a highly significant (p<0.001) effect when compared to drug vehicle treated control group.

The hydro-alcoholic and methanolic extract of H.indicum at three different doses produced significant (P<0.001) reduction at 100,200 and 400 mg/kg when compared to drug vehicle treated control group. The ethyl acetate and hexane extracts of H.indicum tested, at the doses 100,200 and 400 mg/ kg have exhibited significant (p<0.001) activity, where as the dose 400
mg/kg exhibited a highly significant (p<0.001) effect when compared to drug vehicle treated control group.

The percentage inhibition of the maximal paw oedema during 6 hr for the hydro-alcoholic extracts of C.chelidonii, G. gynandra and H.indicum at 400 mg/kg were in the following order C.chelidonii > H.indicum > G. gynandra.

The percentage inhibition of the maximal paw oedema during 6 hr for the methanolic extracts of C.chelidonii, G. gynandra and H.indicum at 400 mg/kg were in the following order C.chelidonii > H.indicum > G. gynandra.

The percentage inhibition of the maximal paw oedema during 6 hr for the ethyl acetate extracts of C.chelidonii, G. gynandra and H.indicum at 400 mg/kg were in the following order C.chelidonii > H.indicum > G. gynandra.

The percentage inhibition of the maximal paw oedema during 6 hr for the hexane extracts of C.chelidonii, G. gynandra and H.indicum at 400 mg/kg were in the following order C.chelidonii > H.indicum > G. gynandra.

The results clearly indicated that the pretreatment with the selected plant extracts and indomethacin have contained the increase in paw oedema due to the phlogistic agent. Among the selected three plant extracts methanolic extracts of C.chelidonii, G. gynandra and H.indicum produced highly significant reduction of paw oedema than hydro-alcoholic, ethyl acetate and hexane extracts.