

Pharmacological and Chemical Potential of *Caesalpinia Bonducella*: A Critical Review

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Abstract: *Caesalpinia bonducella* is a thorny shrub widely distributed in tropical regions of India, Srilanka, Pakistan and Andaman & Nicobar. The plant is widely used in Siddha system of medicine to treat Polycystic Ovarian Syndrome. It has been used ethnomedicinally to treat fever, diabetes, tumor, malaria, asthma, ascites and hydrocele. This review provides an overview of morphology, traditional uses, pharmacological activities such as Anti - malarial, anti - tumor, anti - bacterial, anti - diabetic, anti - viral, anti - oxidant, immune - modulatory, anti - convulsant, anti - psoriatic, anti - ulcer and many other activities. The study also provides a brief overview on current trends of *Caesalpinia bonducella*.

Keywords: *Caesalpinia bonducella*, Traditional, Ethnomedicinal, Pharmacological activity, Anti - cancer, Anti – diabetic

1. Introduction

Traditional medicine is now preferred by people, with more than 60% of the total population and about 80% population in developing countries depending directly on traditional system of medicine for their healthcare needs. This is because of the low cost, accessibility and affordability of the traditional system of medicine [1]. Different parts of the plants such as root, stem, bark, leaf, seed, fruit, etc. are used to treat certain diseases and also prevent the symptoms of certain diseases. Modern medicine uses the active compounds alone that are isolated from various parts of the plants, and about 80% of these active components shows good activity in treating those particular disorders, whereas in traditional system of medicine the whole drug is given [2]. *Caesalpinia bonduc* (L.) Roxb (Syn. *Caesalpinia bonducella*) (L.) Fleming, Syn. *Caesalpinia crista* (Linn.), belongs to the family Fabaceae/ Caesalpinaceae. It is widely distributed all over the tropical regions of India, Sri Lanka, Pakistan, Myanmar, Africa and Andaman & Nicobar islands [3]. All parts of the plant have medicinal properties, hence it is considered to be a valuable medicinal plant, which is utilized as a traditional system of medicine [4]. This study was reviewed by electronic database (Google scholar, PubMed, etc.) for medicinal plants that have potent activity against some diseases and common ailments. Various parts of *Caesalpinia bonducella* are used in treating different ailments, hence a pharmacological review on the plant would be of great use for further study about the species. Mostly the seeds of the plant have wider pharmacological activity which is extracted by different solvents and different methods of extraction.

2. History of *Caesalpinia*

The leguminous trees belong to the subclasses Caesalpinaceae, Fabiaceae, and Mimosaceae. They are known for their many hues of green and white. The

leguminosae family is divided into three subfamilies namely the Caesalpinioideae, the Mimosoideae, and the Papilionoideae [5]. The Caesalpinieae are divided into eight informal generic groups. These include the Gleditsia group, the Sclerolobium group, the Peltophorum group, the *Caesalpinia* group, and the Dimorphandrias group. Several studies have been conducted since 1980, which led to the restructuring of some of the informal generic groups within the Caesalpinidae. The genus *Caesalpinieae* has a broad sense of complexity and is characterized by a large number of species [6].

3. Vernacular Names

English – Fever nut, bonduc nut
Hindi - Katkaranj, Gataran, Karanju, Katkaliji
Kannada - Gajaga, Gajjuga, Heggejjuga
Telugu – Gatchakai, Gachakaya
Sanskrit – Lata Karanja
Malayalam – Kazhanchikkuru
Tamil – Kalichikai, Kazharchikkaai [7]

4. Taxonomic Classification

Taxonomical classification of *Caesalpinia bonducella* are tabulated in Table - 1 [8, 9]

Kingdom	Plantae (Plants)
Phylum	Magnoliophyta
Division	Magnoliopsida
Class	Angiospermae
Subclass	Rosidae
Order	Fabales
Family	Fabaceae/ Caesalpinaceae
Genus	<i>Caesalpinia</i>
Species	<i>bonducella</i>

5. Morphological Classification

Various Morphological parts and characters of *Caesalpinia bonducella* are classified as [10, 11]

5.1 Stem: The stem is 5cm in diameter which grows as a vine but flowers and fruits as a shrub. It has numerous spines and the pith is white in color and large in diameter.

5.2 Leaf: Leaves are branched and large up to 30 - 60cm long with petioles and a pair of stipules with a long mucronate point at the base of the leaf. There are 6 - 8 pairs of pinnate with 5 - 7.5cm long stipular spines at the base.

5.3 Leaflet: Leaflets are elliptic - oblong, marginated, mucronate, glabrous above and puberulous at the bottom. Petioloules are very short with hooked spines. Pale golden hairs are present in upper and lower leaf blades. Twigs have straight and recurved spines.

5.4 Flowers: Flowers are dense at the top and loosen up downwards. The pedicels are short in buds. Calyx is fulvous, hairy, 6 - 8mm long with obovate - oblong in shape. Petals are yellow in color, flattened at the base with silky white hairs. Ovary is 1mm long with 2 ovules.

5.5 Fruit: Fruits are inflated pods with rigid spines and short stalks. There are wiry prickles with the shape oblong about 5.0 - 7.5cm. Each pod consists of 1 - 2 seeds.

5.6 Seed: The seed coat is hard, glossy with greenish to grey in color. It has circular and vertical crack markings on the surface which is 1 - 2cm long and oblong in shape. In dried ones, seed kernels are separated from the testa which is about 1 - 11.25 mm thickness and is made of three layers. The outermost layer is thin and brittle, middle layer is the broad and innermost layer is white and papery. The kernels are furrowed, ridged and hard with pale - yellowish white in color, circular to oval in shape. Plumule is cylindrical and straight with a thick radical axis and bitter taste and unpleasant odour.

6. Ethnomedicinal and Traditional Uses

In Ayurveda, *Caesalpinia bonduc* is used in various diseases such as tumour, diabetes, fever, cough, skin diseases, nausea, gout, etc., in Ayurveda. Kuberaksadi vati, Visama Jvaraghi Vati are some of the important formulations of the plant in Ayurveda [12]. Topically, it is used as local applicant to reduce inflammation and pain. Seed oil treats Rheumatoid arthritis and Osteoarthritis. Orally it is used as anti - pyretic, diuretic, nerve tonic, anti - inflammatory agent and to counter ascites, haemorrhoids [13]. In Siddha *Caesalpinia bonduc* is used for treating various conditions and diseases. Kazharchikkai choornam (seed kernel powder) is the major formulation available which treats fever, asthma, malaria, constipation, PCOS, etc. It is used by traditional Siddha physicians in Malabar regions for psoriasis treatment. In Homoeopathy, it is used for the treatment of different ailments of head, eyes, nose, mouth, tongue, abdomen, liver, spleen and for control of mind in homoeopathic system of medicine. It is also approved for the treatment of intermittent fever [14].

7. Pharmacological Activity

7.1 Anti - malarial activity

The seed kernels were extracted with dichloromethane. The phytochemical investigations on the extract showed 44 new diterpenes presence in it. Anti - malarial activity was tested using malarial parasite *P. falciparum* FCR - 3/A2 clone. The extract was found to have inhibitory activity of the growth of the malarial parasite. 8 compounds were found to be more potent out of the 44 compounds. In this, two compounds, Norcaesalpin E and 2 - acetoxy - 3 - deacetoxycaesaldehydric acid were found to be the most potent than the well - known anti - malarial drug Chloroquine [15]. The roots of *C. bonducella* were extracted with dichloromethane by cold maceration method. The extract was subjected to column chromatography to isolate the compound Norcaesalpin - D and its structure was confirmed by spectral analysis and tested against Chloroquine - sensitive, chloroquine - resistant *P. falciparum* and artemisinin - resistant *P. falciparum*. The extract was active against all the above but against the artemisinin - resistant *P. falciparum* it showed much better activity [16]. The seed kernels were extracted successively with n - hexane, ethylacetate and methanol. The extract was purified by various chromatographic processes to yield three new diterpenes, Bonducellpin - E, Bonducellpin - F, Bonducellpin - G and 13 other known compounds. These compounds were tested against the multidrug resistant K1 strain of *Plasmodium falciparum*. All the three compounds showed good anti - plasmodial activity against the parasite with IC₅₀ values of 1.6, 5.8 and 3.8µM respectively [17].

7.2 Hepatoprotective Activity

The leaves of *Caesalpinia crista* were extracted with methanol. The iron overload was carried out to mice by injecting Iron dextran intra - peritoneally. The results showed that DPPH (2, 2 Diphenyl - 1 - picrylhydrazyl) assay exhibited some anti - oxidant activity. Histopathological study showed some hepatocellular necrosis in iron dextran treated mice, and there was reduction in hepatic injuries in drug treated mice. From this, it was found to have some hepatoprotective effect against Iron - overload induced liver toxicity, by increasing anti - oxidant enzymes and chelating iron to excrete from the body [18]. The leaves were extracted with water. Chronic hepatotoxicity was induced by injecting carbon tetra chloride (CCl₄) to the wistar rats. The blood samples are assessed to determine the biochemical and histological parameters. The results showed reduction in the alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), total bilirubin (TB) and prothrombin time (PT) thus further restoring the total protein (TP) and albumin (ALB) in serum. The aqueous extract showed protection against chronic hepatotoxicity [19]. The plant materials were extracted with methanol. Hepatotoxicity was induced to the rats by Gentamicin injection. The weight of the liver and kidney was found to be increased and hepatocellular death was recorded in the Gentamicin treated group. There was a reduction in the necrosis in the rats, and the hepatic damage was treated by the extract. The hepatoprotective nature was due to the Glutathione - mediated detoxification [20].

7.3 Anti - bacterial activity

The seeds of *Caesalpinia crista* were extracted with methanol and two fractions were made with Chloroform & n - butanol. Three compounds were isolated, Octacosane - 12, 15 - diene 2 - Hydroxytridecane - 3, 6 - dienyl pentanoate, 3 - O - methylsuccinic acid 3, O - α - Rhamnopyranoside. All the three compounds had potent activity against *Staphylococcus aureus* with MIC of 64 μ g/mL. The crude methanolic extract was most active than the other fractionated extracts [21]. The seeds of *Caesalpinia bonducella* were extracted with methanol and the triterpenoids were isolated from the extract they were lupeol, lupeol acetate, β - amyryrin, α - amyryrin. These four compounds were tested with various microorganisms such as *B. subtilis*, *E. coli*, *S. aureus*, *M. luteus*, *M. roseus*, *Pseudomonas aeruginosa* and many others with kanamycin as the standard. The ethanolic extract of *C. bonducella* was found to be inhibiting the growth of all the organisms. The inhibiting activity was in the order of Lupeol > α - amyryrin and lupeol acetate > β - amyryrin [22]. The seeds were extracted with methanol, and the extract was fractionated with ethyl acetate and water. The methanol extract, ethylacetate, water fraction and a pure compound Bondenolide was tested for anti - bacterial activity against 10 different organisms by agar well diffusion method. All the four samples showed good activity against *Pseudomonas aeruginosa*. The methanol, ethylacetate extract and bondenolide showed activity against *Klebsiella pneumoniae*, *Escherichia coli* and *Staphylococcus aureus*. The water soluble extract was found to be active against *Corynebacterium diphtheriae*, *Streptococcus pyogenes* and *Shigella flexneri* [23].

7.4 Anti - fungal activity

The seeds were extracted with ethanol, and they were fractionated with n - butanol, ethyl acetate and chloroform. The anti - fungal activity was studied against organisms such as *Candida glabrata* and *Aspergillus flavus*. The crude extract and its fractions were tested with the organisms. There was mild activity in lower concentrations, but the activity was excellent in higher concentrations. The maximum anti - fungal activity was showed by the n - butanol and the chloroform fractions against *Candida glabrata* and *Aspergillus flavus* [24]. The extraction was made with ethanol. Anti - fungal activity was tested against the organisms such as *Aspergillus niger*, *Trichoderma viride*, *Fusarium chlamydosporum*, *Rhizoctonia bataticola* and *Alternaria alternata*. The seed extract was active against all the fungal organisms except against the organism *Trichoderma viride*. The anti - fungal activity was same among all the other organisms [25]. The air - dried seeds were extracted with different solvents such as petroleum ether, benzene, chloroform, ethyl acetate and water. The *in - vitro* anti - fungal activity was performed by agar - diffusion assay method, which determines the fungal mycelium growth inhibition. *C. albicans* and *A. niger* was used as the test organism for anti - fungal activity and griseofulvin was used as the reference drug. The ethyl acetate and petroleum ether extracts were found to be inhibiting the fungal growth at a higher rate compared to others [26].

7.5 Anthelmintic activity

The extraction was made with methanol. *In - vitro* tests were carried out on *Haemonchus contortus* in adult motility assay and their eggs by Egg hatching test. The aqueous methanolic extract showed dose and time dependent Anthelmintic activity by inhibiting the egg hatching. In the *in - vivo* tests the sheep were naturally infected with the nematodes and then treated with the methanolic extract, there was a maximum reduction in the eggs per gram of faeces was recorded [27]. The leaves were extracted with petroleum ether, chloroform and methanol. Anthelmintic activity was studied using adult earthworms such as *Pheretima posthuma* and *Ascaridia galli*. The methanolic extract showed Anthelmintic activity in a dose - dependent manner by giving shortest time of Paralysis (P) and Death (D). Piperazine citrate is used as the standard drug. The Anthelmintic activity observed was found to be produced by the tannins present in the extract [28]. The leaves of the plant were extracted with methanol and the methanolic extract was tested against nematodes *S. obvelata* and Cestode *H. diminuta* for the activity with Praziquantel as the standard drug. The extract showed dose - dependent anthelmintic activity against both leading to paralysis and mortality of the test worms. The *in - vitro* studies showed that, the exposure of the extract to the test worms led to early paralysis and then followed by mortality [29].

7.6 Anti - viral activity

The extraction was made with water. The plants were also extracted with ethanol, methanol and chloroform. Standard viral isolates of *Orthomyxovirus* and *Paramyxovirus* were tested on the hen's eggs. Different dilutions of the extracts were incubated with the standard concentration of the virus. Aqueous and ethanolic extract showed complete inhibitory effect on the growth of *paramyxovirus*. All the extracts except the chloroform extract showed significant inhibitory activity against the *Orthomyxovirus* [30].

7.7 Anti - oxidant activity

The seeds were extracted with ethanol. The total phenolic content was determined by the Folin-Ciocalteu method using gallic acid as the standard. The free radical scavenging activity of the DPPH (2, 2 - Diphenyl - 1 - picrylhydrazyl) was determined by inhibition percentage of the free radical. The radical scavenging ability of the hydroxyl, nitric oxide and super oxide was determined. The ethanol extract showed strong antioxidant activity by inhibiting DPPH, hydroxyl radical, nitric oxide, superoxide anion scavenging and hydrogen peroxide scavenging activities when compared with standard ascorbic acid [31]. The seeds were defatted with ether and then extracted with Chloroform. The anti - oxidant activity was studied by the DPPH radical scavenging activity. The activity was determined by the β - carotene/linoleate model. The results showed that the anti - oxidant activity of the chloroform extract was a bit lesser than that of the standard ascorbic acid and BHA in the β - carotene/linoleate model [32].

7.8 Anti - amyloidogenic activity

The leaves were extracted with water and analyzed for total polyphenol content. The anti - amyloidogenic activity was carried out by Thioflavin - T study and TEM (Transmission Electron Microscopy). The Phase I study shows the inhibition of the aggregate formation of monomers. Phase II study shows the inhibition of the aggregate formation of the oligomers by the extract. Phase III study showed disaggregation of the preformed fibrils. It was found that *C. crista* not only prevents the fibril formation but also disaggregated the formed fibrils. It was concluded that the Anti - amyloidogenic activity may be due to the water soluble polyphenols [33].

7.9 Anti - tumour Activity

The seeds of *Caesalpinia crista* extracted with methanol and the extract was subjected to column chromatography and then further tested for various spectra such as IR, NMR and COSY. The compound was found to be 1α - acetoxy - 5α , 7β - dihydroxycassa - 11, 13 (15) - diene - 16, 12 - lactone. This compound was tested for anti - proliferative activity against mammary adenocarcinoma and human prostate cancer cell lines. It showed a moderate anti - proliferative activity [34]. Two new compounds were isolated from *Caesalpinia bonduc*, and they were found to be diterpenoids and also one compound from *C. pulcherrima*. The structural configurations of the three compounds were determined. They were found to be, 6β - cinnamoyloxy - 7β - acetoxycoumarone - 5α - ol, 6β , 7β - dibenzoyloxy coumarone - 5α - ol and 12 - demethyl neocaesalpin. These compounds were tested for *in vitro* cytotoxic activity on cancer cell lines HL - 60 (Human promyelocytic leukemia) using MTT assay. They were found to be active in concentration dependent manner by decreasing the cell viability [35]. Young twigs and leaves were extracted with ethanol and fractionated with petroleum ether, ethyl acetate and n - butanol. Seven flavonoid compounds were isolated from the extract which was tested on BGC - 823 cell lines with Taxol as the standard drug. All the compounds exhibited cytotoxic activity but 7, 4' - dihydroxy - 3, 11 - dehydrohomoisoflavanone and taxol showed potent cytotoxic activity against the BGC - 823 cells. It is evident that the petroleum ether fraction had the compounds responsible for the cytotoxic action [36].

7.10 Cardio - vascular activity

The aerial parts of the plants were extracted with normal distilled water. Myocardial infarction was induced to the albino rats by intra - peritoneal injection of Doxorubicin. Propranolol was used as the standard drug. After the experiment the blood was collected for various biochemical investigations. Doxorubicin induced rats significantly showed increase in the activities of Troponin - T, nucleic acid; membrane bound enzymes, lipid profiles and decrease in the serum HDL. There was not much alteration in Cholesterol, Triacylglycerols, Phospholipids and Free Fatty Acids in the extract treated animals. This extract also brought back the levels of Lipoproteins like HDL, LDL and VLDL, which were varied, in disease control animals [37].

7.11 Anti - diabetic activity

The seed kernels were extracted with petroleum ether (a). This was again extracted with ethanol (b) and the seed coat was also extracted with ethanol (c). Hyperglycemic effect was induced by intraperitoneal injection of Alloxan to the wistar rats. All the three extracts were found to be acting well in the glucose tolerance test. The extracts markedly reduced the blood glucose levels of the animals, but the extract (b) was found to be more potent and it also reduced the LDL levels and increased the HDL levels. From this, it shows that the extract was found to be anti - diabetic to the alloxan induced hyperglycemia and also anti - hyperlipidemic [38]. The seed coats were extracted with both water and ethanol. Diabetes was induced by injecting Streptozocin in citrate buffer to the rats intra - peritoneally. The animals with blood glucose level below certain level were selected for the experiment with control and standard drug Metformin. The ethanolic extract reduced the blood sugar level more potent than the standard drug. The extract was found to be much active in the type - II diabetes. It also reduced the triglycerides and cholesterol [39]. The seeds were extracted with a mixture solvent of Hydro - methanol. Anti - diabetic activity was tested by inducing Diabetes using Streptozocin. The extract was administered to the rats with Glibenclamide as the standard drug. The Fasting Blood Glucose (FBG) levels were reduced in the extract treated animals similar to that of the standard drug. The extract also stabilized the increased levels of Triglycerides and Total cholesterol in the rats [40].

7.12 Antipyretic and Analgesic Activity

The seeds were extracted with petroleum ether and then extracted again with hot ethanol. Fever was induced to the rats by injecting brewer's yeast in normal saline. The temperature of the animals was tested at regular intervals. The temperature of the drug treated animals was found to be decreased and potent than the standard ASA. The analgesic activity was confirmed by the eddy's hot plate method and the tail flick method [41]. The flowers of *Caesalpinia bonducella* were extracted with ethanol. Fever was induced by brewer's yeast injection, and anti - pyretic activity was tested on rats. Analgesic activity was tested by inducing the pain with capsaicin, and tail - flick test was also performed. Aspirin and Rofecoxib were the standard drug for anti - pyretic and analgesic activity respectively. The flower extract did not show much anti - pyretic and analgesic activity [42]. The seeds of *Caesalpinia bonducella* were distilled with water and the extract is collected to perform the experiment. Analgesic activity was tested by Acetic acid induced writhing and Hot plate test method. Upon treatment with the extract, the animals showed decrease in number of writhing in 20 minutes. In the hot plate test method, there was a increase in the reaction time observed among the drug treated animals. The test was performed along with Indomethacin as the standard drug. It was concluded that the activity might be due to the local synthesis and release of prostaglandins [43].

7.13 Immunomodulatory activity

The seeds were extracted with ethanol, dissolved in water and administered orally to rats to determine the LD50 value. Three major tests were performed, Neutrophil adhesion test for immunostimulant action, Haemagglutinating antibody test to assess the humoral immune response, Delayed hypersensitivity test showed stimulation effect on the T cells. Cyclophosphamide induced the myelosuppression on the animals. The ethanolic extract along with cyclophosphamide normalized the bone marrow activity better than cyclophosphamide alone, which proved it a potent immunostimulant drug [44].

7.14 Neuroprotective activity /Anti - alzheimer

The leaves were extracted with methanol. Neurotoxicity in the brain was induced by injecting aluminium trichloride to the rats. The animals were divided and administered with the methanolic extract with Rivastigmine as the standard drug. The hippocampal and frontal cortex was removed to determine the enzyme activity and lipid peroxidation levels. The various studies showed that the methanolic extract was acting well against the aluminium induced neurotoxicity and it can be used in the treatment of Alzheimer's disease [45].

7.15 Protection against DNA & membrane damage

The leaves were extracted with ethylacetate, methanol and water and the polyphenol content was measured. The ethylacetate and methanol extract was found to be good. Free radicals were used to induce the DNA & membrane damage using hydrogen peroxide. This extract showed better results against RBC hemolysis and DNA damage. The extract exhibited potent Anti - oxidant activity. The compounds DPPH and 2, 2 - azino - bis (3 - ethylbenzthiazoline - 6 - sulfonic acid) are responsible for the activity [46].

7.16 Anti - estrogenic activity

The seeds were extracted with alcohol. Adult female wistar albino rats were used. The control rat showed normal 4 days of the estrous cycle whereas in the drug treated rats the cycle is reduced to 1.5 - 2 days. There was a decrease in the ovary weight recorded and various histological changes such as distortion in the shape and size of follicular antrum, dislocation of primary oocyte, degeneration of cumulus oophorus, detachment of primary oocyte from zona granulosa cells were observed in the drug treated rats [47].

7.17 Anti - convulsant activity

The seeds were extracted with petroleum ether. Male albino mice and wistar rats were grouped separately. The convulsions were induced by PTZ, MES, Strychnine and Picrotoxin. Diazepam was administered as standard drug in all except in MES where phenytoin is used. The lowest dose of the extract did not show much activity, but the medium and higher doses showed potent anti - convulsant activity as that of the standard drug [48].

7.18 Anti - psoriatic activity

The leaves were extracted with hydro alcohol. This extract was further fractionated with n - butanol (CBHAB) and water (CBHAW). The *in - vivo* test was performed by mouse tail test with retinoic acid as the standard drug. Both the extracts showed orthokeratosis and change in epidermal thickness. The *in - vitro* test was performed in the human keratinocyte cell lines. All the extracts showed some anti - proliferative activity in the keratinocyte cells. CBHAW had potent anti - psoriatic, anti - proliferative activity [49].

7.19 Wound healing activity

The seeds were defatted with petroleum ether and extracted with alcohol. This alcoholic extract was fractionated with ether, ethyl acetate, butanone and butanol. All the extract and its fractions were tested for wound healing activity in excision, incision and dead space wound models in albino rats. Ethyl acetate fraction of the extract showed the best wound healing activity among all the extracts [50].

7.20 Anti - ulcer activity

The leaves were extracted with normal distilled water. Female wistar rats were divided into five groups where Omeprazole is given as the standard drug. The extract was given to the animals at three different doses. The ulcer was induced to the animals by pylorus ligation. The gastric contents of the animals were collected to determine the ulcer index. There was a dose - dependent increase in the ulcer index, pH of the gastric fluid and decrease in the gastric volume, free acidity of the drug treated rats [51].

7.21 Diuretic activity

The seeds were extracted with methanol and macerated with distilled water. Adult male wistar rats were divided into six groups with one group receiving the standard drug Furosemide, and other group normal saline, other four groups received the aqueous extract and methanolic extract in two different doses. Both the aqueous and methanol extracts of the seed showed a dose - dependent increase in urine excretion [52].

7.22 Anti - filarial activity

The seed kernels were extracted with water. Anti - filarial activity was determined by testing the extract against *Litomosoides sigmodontis* and *Brugia malayi*. The microfilaricidal, macrofilaricidal and female worm sterilizing efficacy were determined. There was a decrease in the microfilariae count in the *L. sigmodontis* and a good activity against the macrofilariae and female worm sterilizing effect. In *B. malayi* there was a reduction in the microfilariae count and female worm sterilizing ability was good [53].

7.23 Larvicidal activity

The seeds and leaves were extracted with petroleum ether, alcohol and distilled water. The larvicidal activity was tested on the larvae *Culex quinquefasciatus*. The mortality rate of

the larvae was found to be 100% when treated with 1% of the petroleum ether and ethanolic extract of the leaves. The mortality rate decreased to 55% when treated with 2.5% of the aqueous extract and 92.6% when treated with 2.5% of the fixed oil obtained from the seed. It was concluded that the leaves and the seeds possess larvicidal activity [54]. The seeds were extracted with Hexane, Chloroform and Ethyl acetate by maceration. Larvicidal activity was tested on *Spodoptera litura* and studied by the leaf disc no choice method. The larvae were placed on the castor leaf disc and different concentration of the extract was added by leaf dip method. The chloroform extract exhibited high larvicidal mortality whereas the ethylacetate extract showed less larvicidal mortality [55].

7.24 Adaptogenic activity

The seed coats were extracted with ethanol and the kernels with petroleum ether and ethanol. Wistar albino rats were used to determine the adaptogenic activity by cold stress model. The stress was induced by exposing the animals to 4⁰C. The petroleum ether extract, alcoholic extract and seed coat extract was administered with Geriforte as the standard drug. There was a decrease in the blood glucose levels of the stress induced animals. The seed coat extract and the standard drug had the most adaptogenic activity [56].

7.25 Anti - asthmatic activity

The seed kernels were extracted with chloroform. Five new cassane type diterpenoids Norcaesalpinin O, Norcaesalpinin P, Caesalpinin MQ, Caesall O and Caesall P were isolated. Norcaesalpinin - O had moderate inhibitory activity on PDE4 (Phosphodiesterase IV) which is the target protein for asthma, and it had better binding affinity in docking studies. The other known compounds had inhibitory action against NF - KB (Nuclear factor - Kappa light chain enhancer of activated B cells) which shows its anti - inflammatory nature [57].

7.26 Anti - inflammatory activity

The seeds were extracted with ethanol. Wistar albino rats were divided into four groups with the first group as control, second and third group were administered with extract in different doses and the other group was administered with the standard drug Indomethacin. In carrageenan induced paw edema, both the groups, which received the extract, showed potent anti - inflammatory activity, the highest dose was potent. Similarly, in egg albumin induced edema it was very effective in countering the acute inflammation [58]. The seeds were extracted with petroleum ether. Inflammation was induced by carrageenan induced paw edema. The petroleum ether extract was administered to the rats before inducing the paw edema. The extract was found to be acting well against the carrageenan induced edema and concluded that anti - inflammatory action may be due to the presence of Phytosterols [59].

7.27 Anxiolytic activity

The seeds were extracted and tested for anxiolytic activity by various models. In the stair - case model the extract was

treated to the animals and the anxiolytic activity was increased in a dose - dependent manner by increasing the number of steps climbed. In the hole - board model the high dose extract found to be increasing the number and latency of the head dipping of the animals but not the rearings. In the LDT model, there was an increase in the time spent and the crossing in the light compartment and decreased time spent in the dark compartment. From this, it is evident that the seed extract of *C. bonducella* has potent anxiolytic activity [60].

7.28 Skeletal muscle activation

The leaves were extracted with n - hexane. The anterior tibia muscle of the rats was isolated and connected to a transducer. The nerve was stimulated with electrodes to check the isometric contractions. In the drug treated ones there was an increase in the contractile force. The action was similar to the cholinesterase inhibitor Neostigmine in the presence of neuromuscular blocking agent gallamine. The twitch tension of the tibia muscle increased in the extract treated muscle which can be activation in the cholinergic mechanism [61].

7.29 Anti - cataract activity

The seeds were extracted with ethanol. The lenses of the goat eyeballs were removed and incubated in artificial aqueous humor. Cataract was generated by incubating the lenses in high glucose culture. Lenses were divided into six groups with two groups are positive and negative control and one group taking the standard drug Enalapril. Three groups were incubated with the extract drug at three different concentrations. The extract possesses anti - cataract as well as anti - oxidant activity and also slowed down the progression of the cataract [62].

7.30 Anti - mycobacterial activity

The seed, stem wood, stem bark were extracted using n - hexane, methanol, chloroform. The extract was tested against two non - pathogenic mycobacterium species namely *Mycobacteria indicus pranii* and *Mycobacteria madagascariense*. The minimum inhibitory concentration (MIC) is evaluated by the Two - fold serial dilution method. The results showed that the extract had anti - mycobacterial activity [63]. The seed coats were extracted with ethanol and water. Different concentrations of the extract were tested against *Mycobacterium tuberculosis* H37Rv strain by Microplate Alamar Blue Assay (MABA) method with Pyrazinamide as the standard drug. The ethanolic extract had potent anti - mycobacterial activity similar to the standard drug [64].

7.31 Anti - Spermatogenic activity

The seeds were extracted with normal distilled water. Male albino rats were divided into four groups with one as control and the other three groups were administered with the aqueous extract in three different doses. The left and right epididymis were isolated and the sperm suspension is made by cutting off the cauda portion to determine the sperm count. There was a decrease in the sperm density and

average increase in the anti - spermatogenic activity and can be considered as a better drug for birth control programmes [65]. The seeds were extracted with alcohol. Male albino rats were divided into four groups with one as control and the other three administered with different doses of the extract. The morphology of the Cauda epididymis was studied by SEM. The results showed the morphological changes in the head and mid - region of the sperm, disruption of the plasma and acrosomal membrane [66]. The seeds of the plant are extracted with ethanol. Male swiss albino mice are used to study the anti - spermatogenic activity of the extract. Various parameters such as semen analysis which included sperm count, sperm head analysis, testicular oxidative stress were performed. The extract treated mice showed a decrease in the sperm - count with respect to the control groups. This decline in the sperm count is probably due to the non - transformation of spermatids to matured sperm [67].

7.32 Haematological activity

The leaves and stem barks were extracted with petroleum ether, and further extracted with methanol. Haematological parameters such as RBC count, differential leukocyte count, platelet count, etc. were measured to the mice. The extract was administered to the animals at three different doses and normal saline as the control group. Blood was taken and measured for the haematological parameters. There was no change observed in the lowest dose but alterations in the parameters were observed when dose is increased [68]. The seed coats were extracted and tested for various assays by the human platelet rich plasma (PRP). The extract showed a good DPPH scavenging activity and also reduced the lipid peroxidation and the protein carboxylation of the RBC. It also normalized *superoxide dismutase* and *catalase* in the stress induced RBC. The extract showed better anti - platelet activity [69].

7.33 Anti - fertility activity

The seeds were extracted with ethanol. Female wistar albino rats were administered with control and ethanolic extract. There was a decrease in implantation index and increase in resorption index, pre - implantation and post - implantation loss recorded in the seed extract treated rats. There was a decrease in the progesterone levels in the extract treated animals and craniofacial deformities observed in the embryos due to the anti - progesteronic hormonal property [70]. The seeds were extracted with ethanol. Male wistar rats were administered with the extract and paired with female animals. The inseminated female animals were allowed to deliver, and the number of pups was recorded. There was a decrease in the sperm count and motility of the ethanolic extract treated animals, shows their anti - fertility activity [71].

7.34 Aphrodisiac activity

The roots were extracted with water and ethanol. Wistar rats of both sexes were administered with the aqueous and ethanolic extract with Sildenafil as the standard drug. The sexual behaviors of the animals were studied by frequency of sniff, frequency of goes up, latent time of goes up. The

ethanolic extract showed good effect by decreasing the latent time of goes up while the aqueous extract increased the frequency of goes up. The results showed the sexual behavior in the rats increased in the dose dependent manner [72]. The roots of *Caesalpinia bonducella* were extracted with hexane, ethanol, ethyl acetate and methanol. Male wistar rats were used for determining the activity with Sildenafil citrate as the standard drug. Animals were separated into different groups and administered with the extract, standard drug and control group. The parameters such as Intromission frequency and latency, Mount frequency and latency were observed on the rats. There was an increased sexual behavior activity observed in the ethanolic extract treated animals. The ethanolic extract showed increase in testosterone levels which conclude that *Caesalpinia bonducella* had aphrodisiac activity [73]

7.35 Anti - feedant and Ovicidal activity

The leaves were extracted with methanol. Six compounds isolated from the extract and the crude extract was tested against *Tuta absoluta*. Compared to the isolated compounds, the extract showed good anti - feedant and ovicidal activity. The most active component which led to the activity was found to be Neocaesalpin L. The study shows that cassane - type diterpenes and flavonoids constituents have significant anti - insect activities [74]. The seed kernels were extracted successively with hexane and methanol. The methanolic extract was partitioned with ethylacetate and water. The cake obtained from the hexane and methanol extract was suspended in distilled water, and extracted with butanol. The different extracts were tested against 3rd instar of the insect *Helicoverpa armigera*. All the extracts had little to high activity against the insects. The methanolic extract was the most effective by affecting the survival of the larvae and the aqueous extract was the least effective [75].

7.36 Anti - diarrheal activity

The leaves were extracted with methanol and fractioned with chloroform, petroleum ether and ethyl acetate. Diarrhea was induced to the rats by injecting castor oil to them. Animals were administered with the methanolic extract and its fractions in different doses with Loperamide as the standard drug. All the extract showed better activity against the castor oil induced diarrhoea. Ethyl acetate fraction showed the best Anti - diarrheal activity [76].

7.37 Irritant activity

The seeds were extracted with methanol and partitioned with ethyl acetate and water. The aqueous extract was again shaken with n - butanol. The extract was subjected to column chromatography and four compounds α - Amyrin, β - Amyrin, Lupeol and Lupeol acetate were isolated. The animals were treated with the extracts. The ears of the mice were checked for the redness and also tested for chronic irritant effects. The number of animals in red ears was noted as the irritant units (IU) which show the irritant action [77].

Conflict of interest

The author declares no potential conflict of interest.

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