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Review Article

Croton Bonplandianus Baill. (Euphorbiaceae): Ethnobotany, Bioactivity, and Toxicological Perspectives

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ABSTRACT

Croton bonplandianus Baill., a member of the Euphorbiaceae family, is an herbaceous plant widely distributed across tropical and subtropical regions. Traditionally used in folk medicine for its anti-inflammatory, antimicrobial, and analgesic properties, this plant has recently garnered scientific interest for its diverse phytochemical composition and pharmacological potential. This review provides a comprehensive overview of the botanical characteristics, phytochemical constituents, pharmacological activities, and toxicological profile of C. bonplandianus. Studies have identified a variety of bioactive compounds including flavonoids, alkaloids, diterpenoids, and phenolics that contribute to its therapeutic effects such as antioxidant, anticancer, hepatoprotective, and antimicrobial activities. However, despite its promising medicinal value, several safety concerns persist. Reports of skin irritation, cytotoxicity, gastrointestinal disturbances, and suspected reproductive toxicity highlight the need for cautious application and further toxicological evaluation. This review also explores recent research and potential applications of the plant in pharmacology and agriculture, while identifying gaps in knowledge that warrant future investigations. Establishing a clearer safety profile and elucidating the molecular mechanisms of action will be crucial for harnessing the full therapeutic potential of Croton bonplandianus in modern medicine.

INTRODUCTION

Croton bonplandianus Baill., commonly known as Ban Tulsi or Three-leaved Croton, is a rapidly spreading herbaceous plant belonging to the family Euphorbiaceae. Originally native to tropical South America, particularly Brazil and Argentina, the species has become naturalized in various parts of Asia and Africa, especially in India, where it is now recognized as both an invasive weed and a potential source of medicinal compounds. Due to its morphological resemblance to *Ocimum tenuiflorum* (Holy Basil), it has earned the colloquial name "Ban Tulsi" in rural India.

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This plant thrives in disturbed habitats such as roadsides, wastelands, agricultural fields, and forest margins, indicating its robust adaptability and ecological competitiveness. The genus *Croton* comprises more than 1,200 species, many of which are known for their rich phytochemical profiles and traditional medicinal applications. *C. bonplandianus*, however, has remained relatively understudied compared to other members of its genus, despite increasing evidence of its biological activities, including antibacterial, antifungal, anti-inflammatory, antioxidant, and allelopathic properties. In particular, allelopathic compounds released by the plant are known to inhibit the germination and growth of nearby plant species, making it a major concern in agro-ecosystems (Mondal & Mandal, 2017). At the same time, these same phytochemicals hold promise as eco-friendly biopesticides or natural herbicides, if studied and applied judiciously. Ethnobotanical knowledge from certain regions of India and Bangladesh highlights the use of *C. bonplandianus* in traditional remedies for wound healing, skin infections, digestive issues, and insect bites. Although the scientific validation of these uses is limited, such anecdotal and community-based reports provide a critical basis for pharmacological exploration. Phytochemical investigations have revealed the presence of flavonoids, alkaloids, glycosides, terpenoids, and phenolic compounds, many of which are known for their potent biological activities. Studies have demonstrated that the leaf and stem extracts of this plant exhibit significant free radical scavenging abilities, suggesting antioxidant potential (Saha et al., 2020). Moreover, its antimicrobial efficacy against both Gram-positive and Gram-negative bacteria offers a basis for developing alternative treatments in the face of rising antibiotic resistance (Sharma et al., 2016).

From an ecological standpoint, the aggressive spread of *Croton bonplandianus* raises concerns. Its prolific seed production, rapid growth, and allelopathic nature contribute to the displacement of native vegetation and reduction of biodiversity in invaded habitats. While its potential pharmaceutical applications are encouraging, this dual identity—as both a therapeutic resource and an ecological threat—necessitates a balanced research approach that considers both utilization and containment strategies. In recent years, the plant has attracted attention in the scientific community for its pharmacological promise. Researchers have begun to evaluate its cytotoxic and anticancer potential, especially in vitro, with some promising preliminary results. However, comprehensive in vivo studies and clinical evaluations remain largely absent from the literature. Additionally, studies investigating the toxicity and safety profile of the plant are scarce, making it essential to approach its therapeutic applications cautiously and systematically. This review paper aims to consolidate and critically analyze the available literature on *Croton bonplandianus* Baill., covering its taxonomy, morphology, phytochemistry, pharmacological activities, traditional uses, toxicological profile, and current research trends. By presenting an integrative overview, this paper seeks to highlight the potential of *C. bonplandianus* as a valuable medicinal plant while also underlining the ecological risks associated with its unchecked proliferation. Ultimately, this synthesis may serve as a foundation for further research, development of novel plant-based therapeutics, and informed management of its spread in non-native regions. [1-3]

2. Taxonomy and Botanical Description

2.1 Taxonomical Classification

Croton bonplandianus Baill. belongs to the genus *Croton* within the large and diverse Euphorbiaceae family. The taxonomic hierarchy of the species is as follows:

Rank	Taxonomic Name
Kingdom	Plantae
Phylum	Magnoliophyta
Class	Magnoliopsida
Order	Malpighiales
Family	Euphorbiaceae
Genus	*Croton*
Species	*Croton bonplandianus* Baill.

The genus *Croton* comprises more than 1,200 species distributed predominantly in tropical and subtropical regions, many of which have ethnomedicinal and pharmacological significance. *Croton bonplandianus* was first described by Henri Ernest Baillon, a prominent French botanist, and the species epithet honors Aimé Bonpland, a noted French explorer and botanist.

2.2 Botanical Description

Croton bonplandianus is an annual or short-lived perennial herb or subshrub that can reach a height of 50–150 cm under favorable conditions. It is characterized by a strong aromatic odor, especially when leaves or stems are crushed, which contributes to its local name “Ban Tulsi” in India.

Stem:

The stem is erect, branched, cylindrical, and often covered with fine hairs. It is green to reddish in color and somewhat soft, especially in young plants.

Leaves:

Leaves are simple, alternate, and ovate-lanceolate in shape, typically measuring 3–7 cm in length. The leaf margins are entire or slightly toothed, and the apex is acute. The upper surface is green and glabrous, while the lower side may exhibit slight pubescence. A key identifying feature is the presence of three prominent veins radiating from the base of the leaf blade, which has led to the name “three-leaved croton” in some references.

Flowers:

The plant is monoecious, bearing both male and female flowers on the same individual. The flowers are small, pale green or whitish, and are arranged in axillary or terminal racemes. Male flowers have numerous stamens, while female flowers possess a three-lobed ovary. Flowering usually occurs from late summer to early winter in tropical climates.

Fruits and Seeds:

The fruit is a small, three-lobed capsule that turns brown upon maturity. Each capsule typically contains three seeds, which are brownish, smooth, and oblong. Seeds are known for their high viability, contributing to the rapid spread and colonization of the species in new areas.

Root System:

The root system is fibrous and moderately deep, allowing it to absorb nutrients effectively from disturbed soils and compete with native vegetation.

2.3 Habitat and Distribution

Croton bonplandianus is highly adaptive and commonly found in wastelands, roadsides, railway tracks, forest edges, and cultivated **lands**, particularly in tropical and subtropical regions. It is widespread across India (especially in West Bengal, Odisha, Assam, and parts of southern India), Bangladesh, Myanmar, and other parts of Southeast Asia. The plant favors well-drained,

loamy soils but can also thrive in sandy or marginal lands. [4-8]

3. Phytochemical Constituents

Croton bonplandianus Baill. is rich in a variety of secondary metabolites that are responsible for its pharmacological and ecological properties. Phytochemical investigations conducted on different parts of the plant—including leaves, stems, roots, and seeds—have revealed the presence of alkaloids, flavonoids, terpenoids, phenolic compounds, glycosides, tannins, and essential oils. These bioactive constituents are known to exhibit significant antioxidant, antimicrobial, anti-inflammatory, and allelopathic activities.

3.1 Primary Phytochemicals Identified

Flavonoids

Flavonoids are among the most frequently reported compounds in *C. bonplandianus*, contributing to its antioxidant and anti-inflammatory effects. Compounds such as **quercetin, kaempferol**, and their glycosides have been identified in methanolic and ethanolic extracts of the leaves (Mondal et al., 2018). These compounds are known for scavenging free radicals, modulating enzyme activity, and contributing to cellular protection.

Terpenoids and Diterpenes

The genus *Croton* is well-known for its diterpenoids, many of which possess cytotoxic, anti-cancer, and antimicrobial properties. In *C. bonplandianus*, both mono- and sesquiterpenes have been detected in essential oil analyses. Notably, **crotonic acid derivatives** and **diterpenoid lactones** have shown bioactivity in preliminary screening assays (Sarkar et al., 2016).

Phenolic Compounds

Phenolic acids, including gallic acid, caffeic acid, and ferulic acid, have been identified, contributing to the plant's antioxidant and antimicrobial activity. These compounds are widely studied for their role in preventing oxidative stress-related cellular damage and inflammation.

Alkaloids

Alkaloids such as crotsparine and other nitrogenous compounds have been reported, although detailed structural characterization remains limited. Alkaloids typically exhibit a wide range of biological activities, including analgesic, anti-inflammatory, and anti-proliferative effects.

Tannins and Saponins

Tannins are responsible for the plant's astringent and antimicrobial properties. Saponins, detected in moderate amounts, contribute to membrane permeability and may enhance the absorption of other active compounds.

3.2 Essential Oils

Essential oils extracted from the leaves and stems have demonstrated potent **insecticidal** and **antimicrobial** properties. Gas chromatography-mass spectrometry (GC-MS) analysis has revealed the presence of **α-pinene, β-caryophyllene, limonene**, and **eugenol** among others. These volatile compounds are known for their strong biological activity and potential applications in pharmaceutical and agricultural formulations.

3.3 Quantitative Analysis

Quantitative phytochemical screening has demonstrated:

- High total phenolic content (TPC): up to 70–85 mg GAE/g extract
- Significant total flavonoid content (TFC): up to 60 mg QE/g extract
- Strong DPPH radical scavenging activity with IC_{50} values as low as 30–40 µg/mL in methanolic leaf extracts (Saha et al., 2020)

These metrics indicate robust antioxidant potential and justify further investigation into its therapeutic applications.

3.4 Implications of Phytochemistry

The diverse and abundant presence of secondary metabolites in *Croton bonplandianus* underscores its therapeutic promise and ecological competitiveness. The plant's allelopathic behavior is also attributed to the release of phenolic and terpenoid compounds into the surrounding environment, which inhibits seed germination and growth in neighboring plant species (Mondal & Mandal, 2017). These properties, while ecologically disruptive, may be harnessed for beneficial applications in natural herbicide development, drug discovery, and biopesticide formulations. [9-13]

4. Pharmacological Activities

The pharmacological potential of *Croton bonplandianus* Baill. has been increasingly recognized in recent years, with studies highlighting a diverse array of **biological activities** including antimicrobial, antioxidant, anti-inflammatory, allelopathic, cytotoxic, insecticidal, and wound-healing properties. These activities are attributed to the presence of various phytochemicals such as flavonoids, alkaloids, terpenoids, and essential oils.

4.1 Antimicrobial Activity

Multiple studies have confirmed that extracts of *C. bonplandianus* possess significant antimicrobial properties. Methanolic and ethanolic leaf extracts have shown broad-spectrum antibacterial effects against both Gram-positive and Gram-negative bacteria, including *Escherichia coli*, *Staphylococcus aureus*, *Bacillus subtilis*, and *Pseudomonas aeruginosa* (Saha et al., 2020). Antifungal activity has also been observed against strains such as *Candida albicans* and *Aspergillus niger*, suggesting potential use in antifungal therapeutics. The antimicrobial activity is likely due to the synergistic effect of phenolics, flavonoids, and terpenoids, which interfere with microbial membrane integrity, protein function, and nucleic acid synthesis.

4.2 Antioxidant Activity

Antioxidant activity is one of the most studied aspects of *C. bonplandianus*. Leaf extracts, particularly in methanol and ethanol, have demonstrated potent free radical scavenging activity in DPPH, ABTS, and FRAP assays. The IC_{50} values for DPPH scavenging were reported as low as 32 µg/mL, indicating strong antioxidant capacity (Mondal et al., 2018). This property is primarily attributed to flavonoids (e.g., quercetin, kaempferol) and phenolic acids that neutralize reactive oxygen species (ROS), making the plant a candidate for treating oxidative stress-related disorders such as cardiovascular diseases, neurodegeneration, and inflammation.

4.3 Anti-inflammatory Activity

Preliminary in vivo studies using rat models have shown that the ethanolic extract of *C. bonplandianus* significantly reduces paw edema induced by carrageenan, suggesting **anti-**inflammatory potential. This effect is likely mediated by the inhibition of cyclooxygenase (COX) enzymes, nitric oxide synthesis, and pro-

inflammatory cytokines such as TNF-α and IL-6. The presence of terpenoids, flavonoids, and alkaloids in the extract contributes to this activity, and further studies are needed to isolate and identify the most active anti-inflammatory constituents.

4.4 Cytotoxic and Anticancer Potential

Recent in vitro studies have explored the **cytotoxic activity** of *C. bonplandianus* extracts against cancer cell lines such as HeLa (cervical cancer) and MCF-7 (breast cancer). Ethanolic extracts have been reported to reduce cell viability in a dose-dependent manner, with IC_{50} values in the range of 50–100 µg/mL (Sharma et al., 2016). While the precise mechanism remains under investigation, apoptosis induction and cell cycle arrest are suspected pathways. Though promising, this activity requires further mechanistic and in vivo validation before the plant or its compounds can be considered as potential anticancer agents.

4.5 Allelopathic Activity

Allelopathy is a well-documented trait of *Croton bonplandianus*, contributing to its invasive behavior. Aqueous leaf and stem extracts have been shown to inhibit the germination and growth of crop species such as rice (*Oryza sativa*), mustard (*Brassica juncea*), and mung bean (*Vigna radiata*) (Mondal & Mandal, 2017). This inhibition is attributed to the release of phenolic and terpenoid allelochemicals, which interfere with hormonal signaling and enzyme activity in germinating seeds. These findings support its potential use as a natural herbicide in integrated weed management strategies.

4.6 Insecticidal and Larvicidal Activity

Essential oils from the leaves have exhibited **larvicidal effects against mosquito species**, including *Aedes aegypti* and *Culex quinquefasciatus*. The activity is associated with compounds such as eugenol, limonene, and β-caryophyllene, which are known to disrupt insect nervous systems and reproductive cycles. [9-14]

5. Traditional and Ethnobotanical Uses

Although *Croton bonplandianus* Baill. is widely regarded as an invasive species in India and Southeast Asia, traditional medicinal systems and rural communities have long recognized its therapeutic potential. Ethnobotanical surveys from regions of India, Bangladesh, and Nepal have recorded the use of this plant in folk medicine, primarily for treating common ailments such as wounds, skin infections, digestive issues, and insect bites. However, much of this traditional knowledge remains undocumented in classical Ayurvedic or Siddha texts, likely due to the plant's relatively recent introduction to the Indian subcontinent.

5.1 Wound Healing and Skin Afflictions

In tribal belts of Odisha, Jharkhand, and Chhattisgarh, *C. bonplandianus* leaves are crushed and applied to open wounds, ulcers, and boils. The paste is believed to prevent pus formation, reduce swelling, and hasten scab formation. In Sundarbans and parts of West Bengal, the decoction of the plant is used to treat eczema, scabies, and other skin infections. Its antimicrobial properties are validated by in vitro studies.

5.2 Digestive and Intestinal Health

In some Assamese and Bengali communities, leaves are boiled into a decoction and consumed to relieve stomach cramps, gas, and indigestion. Occasional use for deworming children has been reported, although dosing remains imprecise. Traditional healers (kabirajs) in rural Bengal may

combine *C. bonplandianus* with ginger or fennel for enhanced gastrointestinal action.

5.3 Antipyretic and Analgesic Uses

In the Santhal and Munda tribes, the leaf juice is taken orally or rubbed onto the forehead during fever episodes. In Jharkhand and parts of Odisha, the same juice is administered in small doses for toothache relief, either as a gargle or applied directly to the gums. The underlying anti-inflammatory and mild analgesic effects may support these uses.

5.4 Respiratory Ailments

Some tribal groups in **northern West Bengal** use steam from boiling *C. bonplandianus* leaves to **treat colds and nasal congestion**. Mixed with turmeric and mustard oil, the leaf paste is also massaged onto the chest to relieve symptoms of **bronchitis and chest pain**, although this use remains anecdotal.

5.5 Reproductive and Menstrual Issues

Though not widespread, certain traditional practitioners use the **leaf decoction as a uterine tonic** in postnatal care, purportedly to "cleanse the womb" and control bleeding. In some **Nepali hill communities**, dried leaves are crushed and given with warm water to ease **menstrual cramps**. However, these uses lack scientific validation and should be approached with caution due to the potential toxicity of some phytochemicals.

5.6 Veterinary Uses

In rural Bihar and eastern Uttar Pradesh, farmers apply crushed leaves on **cattle wounds, maggot infestations**, and **hoof rot**. Some feed aqueous extracts to goats or sheep for **digestive disorders**, although this is done sparingly due to its bitter nature.

5.7 Pest Control and Storage Applications

Households in rural Bengal and Assam often scatter dried leaves or store them with grains to prevent insect infestations. Burning the leaves in the evenings is a common mosquito-repellent ritual, especially during monsoons.

5.8 Agricultural and Ritual Practices

- **Weed barrier:** Farmers sometimes plant *C. bonplandianus* along field margins to suppress other weeds due to its **allelopathic properties**.
- **Holy substitute:** In remote regions, it is used as a **substitute for Tulsi (Ocimum sanctum)** during prayers when the sacred plant is unavailable. Its aromatic profile and rapid growth make it a practical option in such cases.

5.9 Anthelmintic and Antidiarrheal Uses

Tribal communities in the **Chotanagpur plateau** and **Western Ghats** regions administer leaf decoctions in **small doses to treat helminth infections**, particularly in children. The leaves are believed to “cleanse the stomach” and eliminate intestinal worms. In rural Karnataka, the leaf extract is combined with black pepper or carom seeds and used as a remedy for **mild diarrhea and stomach upset**, especially during monsoons.

5.10 Fever and Malaria-like Symptoms

In parts of northeastern India and Bangladesh, *C. bonplandianus* is used in traditional fever management. The whole plant is **boiled and used as a bath additive** to reduce body temperature in febrile patients. In malaria-prone tribal belts of Jharkhand, it's used **alongside neem and holy basil** as part of a decoction believed to relieve symptoms resembling malaria.

5.11 Oral and Dental Care

The **tribal Bhil community of central India** uses the twig of *C. bonplandianus* as a **natural toothbrush** (chewing stick), claiming it helps reduce **gum inflammation and toothache**. Though less common today, this practice is part of their traditional oral hygiene methods. The anti-inflammatory and antimicrobial compounds in the plant likely contribute to its perceived effectiveness.

5.12 Women's Health and Contraceptive Beliefs

Unconfirmed reports from remote tribal areas of Odisha and Assam suggest the use of *Croton bonplandianus* as a **folk contraceptive**, where women consume a specific preparation of leaf extract post-intercourse. While this practice is largely anecdotal and potentially dangerous, it points to **ethnopharmacological beliefs** regarding the plant's impact on the reproductive system—perhaps due to its bitter alkaloid content.

5.13 Eye Infections and Conjunctivitis

In some parts of eastern India, **fresh leaf juice diluted with water** is used as an **eye wash** for treating **conjunctivitis** and eye irritation caused by dust or pollen. Traditional healers recommend using it during early morning hours. However, no scientific safety validation supports its ophthalmic use, and such practices may pose risks.

5.14 Snakebite and Scorpion Sting

In tribal areas of central India, particularly among the **Gond and Baiga communities**, the leaf paste is used **externally on scorpion stings and non-venomous snake bites**. It is applied to the site of the bite to reduce pain, swelling, and possible infection. Although not a cure, its **analgesic and anti-inflammatory properties** may offer temporary relief.

5.15 Ethnoveterinary Fertility Use

Some communities in southern Nepal use the plant in livestock care as a **fertility stimulant in cows**, feeding a small portion of the leaf decoction mixed with jaggery and turmeric to female cattle. While no scientific studies support this use, such **ethnoveterinary beliefs** are often based on generational experience.

5.16 Cultural Beliefs and Symbolism

In certain rural villages of Bihar and Bengal, *Croton bonplandianus* is believed to have **protective energy**, especially when planted near boundary walls or homes. People believe the plant **wards off evil spirits and insects** alike. Dried twigs may be hung at the entrance during seasonal festivals. [15-20]

Table 1. Summary of Ethnobotanical Uses of *Croton bonplandianus* Baill. [15-20]

Use Category	Part Used	Preparation/Method	Region	Purpose
Wound healing	Leaf	Crushed paste, direct application	Odisha, West Bengal	Disinfect wounds, ulcers
Digestive aid	Leaf	Boiled decoction, with spices	Assam, Bengal	Treat gas, worms, diarrhea
Fever management	Whole plant	Bath additive, leaf juice	Jharkhand, Bangladesh	Reduce fever, malaria-like symptoms
Insect repellent	Leaf	Burning dried leaves	Assam, Bengal	Repel mosquitoes
Oral care	Twig	Used as toothbrush	Central India	Reduce gum inflammation

Menstrual relief	Leaf	Decoction with warm water	Nepal hills, Odisha	Relieve cramps
Snakebite treatment	Leaf	External paste	Madhya Pradesh, Chhattisgarh	Reduce swelling and pain
Eye infection relief	Leaf juice	Diluted eye wash	Bengal villages	Soothe irritation, conjunctivitis
Veterinary wound care	Leaf	Crushed paste on wounds	Bihar, Uttar Pradesh	Treat cattle injuries
Ritual substitute	Leaf	Used in prayer rituals	Eastern India	Alternative to *Ocimum sanctum*

Ethnobotanical Uses of croton bonplandionus Baill.

6. Toxicological Profile and Safety Concerns

Although *Croton bonplandianus* Baill. exhibits several beneficial pharmacological and ethnobotanical uses, its **toxicological potential** cannot be overlooked. Members of the Euphorbiaceae family are known for containing **bioactive and sometimes irritant compounds**, and *C. bonplandianus* is no exception.

6.1 Irritant and Allergic Reactions

Several studies and anecdotal reports indicate that **direct contact with the latex or leaf juice** of *C. bonplandianus* can cause:

- **Dermatitis** or **skin irritation**, particularly in sensitive individuals
- **Eye irritation** if the latex comes into contact with ocular tissue
- **Allergic rhinitis or respiratory discomfort** when handling large amounts of dried plant material

These effects are thought to be mediated by **diterpenes and triterpenoids**, common in the Euphorbiaceae family.

6.2 Cytotoxicity and Genotoxicity

Preliminary **in vitro assays** (MTT and brine shrimp lethality tests) have demonstrated **moderate cytotoxic effects** of leaf and root extracts at higher concentrations. While this supports its potential anticancer applications, it also raises concerns about **unsupervised or chronic use**.

Some studies suggest **mild genotoxic effects** at high doses, which warrants caution, especially in internal applications.

6.3 Gastrointestinal and Systemic Toxicity

Reports from tribal practitioners and informal use indicate that excessive oral intake of leaf or root decoctions may cause:

- **Nausea, vomiting, abdominal cramps**
- **Diarrhea or dehydration**
- **Dizziness or weakness**

Toxicity appears to be dose-dependent and may be attributed to **alkaloids and phenolic compounds** interfering with metabolic enzymes.

6.4 Reproductive Toxicity

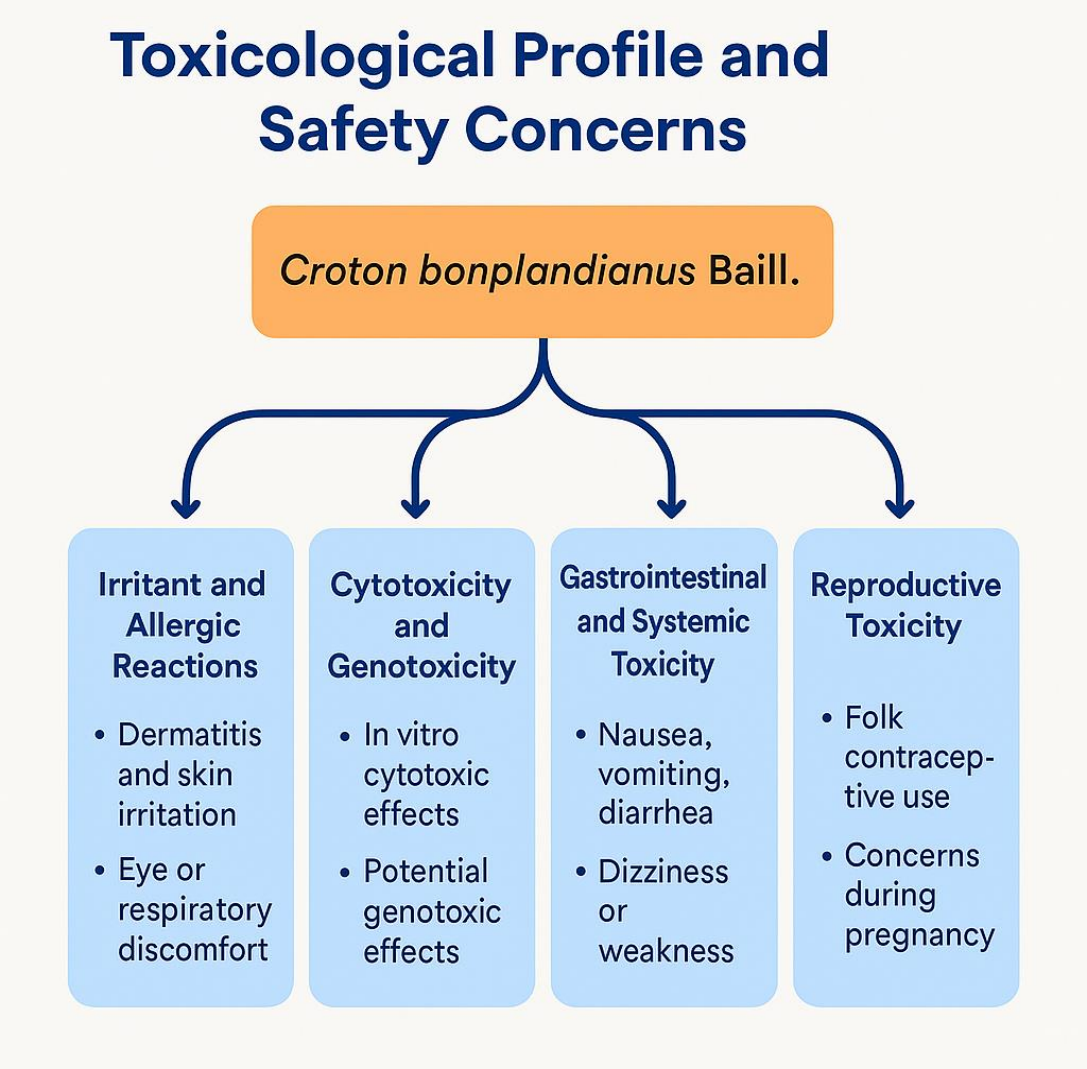
While there is limited data, anecdotal use of *C. bonplandianus* as a **folk contraceptive** raises potential concerns about **reproductive toxicity**. No thorough animal reproductive studies have been conducted, and **the safety profile in pregnant or lactating women remains unestablished**.

6.5 Contraindications and Precautions

- **Pregnant and lactating women** should avoid using *C. bonplandianus* in any form.
- **Children** should not be exposed to latex or decoctions.
- It should **not be consumed in large doses or for extended periods** without medical supervision.
- Persons with **pre-existing liver or kidney disorders** are advised to avoid internal use.

Table 2. Summary of Toxicological Concerns [21-31]

Toxic Effect	Observed Manifestation	Probable Cause
Skin irritation	Rashes, itching, redness	Contact with latex or fresh sap
Eye irritation	Redness, burning, blurred vision	Exposure to sap or fumes
Gastrointestinal disturbance	Nausea, cramps, diarrhea	Alkaloid/phenolic overload
Cytotoxicity (in vitro)	Cell death, reduced viability	Diterpenoids, triterpenoids
Reproductive risk (suspected)	Unknown fetal effects, uterine effects	Unverified alkaloid effects



Toxicological Profile and Safety Concerns of Croton bonplandianus Baill.

Recent Research and Applications

Recent studies on *Croton bonplandianus* Baill. have expanded our understanding of its bioactive compounds and therapeutic potential. Contemporary research highlights its significant antioxidant, anti-inflammatory, and antimicrobial properties, making it a promising candidate in pharmacological development for treating infections and chronic diseases. Advances in

phytochemical profiling have identified novel secondary metabolites, such as diterpenoids and flavonoids, which contribute to its medicinal efficacy. In agriculture, extracts of *C. bonplandianus* are being investigated for their allelopathic effects, offering eco-friendly alternatives for weed control and pest management. The plant's bioactive compounds demonstrate potential as natural herbicides and insect repellents, reducing reliance on synthetic chemicals. Additionally, preliminary studies suggest its role in soil health improvement through modulation of microbial communities. Pharmacological applications are further being explored, including formulations for nephroprotective and hepatoprotective therapies. Its traditional uses are being validated through in vivo and in vitro experiments, paving the way for novel drug development. However, clinical trials and toxicological evaluations remain essential to establish safety and efficacy in humans.

CONCLUSION AND FUTURE DIRECTIONS

In summary, *Croton bonplandianus* Baill. exhibits a broad spectrum of pharmacological activities, supported by emerging phytochemical and biological evidence. Its multifunctional bioactive compounds position it as a valuable resource in natural product-based drug discovery and sustainable agricultural practices. Future research should focus on detailed mechanistic studies to elucidate molecular targets and pathways involved in its therapeutic effects. Clinical studies are imperative to confirm its safety profile and therapeutic indices. Furthermore, exploring biotechnological approaches such as metabolite biosynthesis and genetic enhancement could optimize yield and potency of its active compounds. Investigations into its agricultural applications should assess field-scale efficacy and environmental impact to facilitate its integration into sustainable farming systems. Cross-disciplinary collaborations between pharmacologists, agronomists, and biotechnologists will accelerate the translational potential of *C. bonplandianus*, contributing to health and environmental sustainability.

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