CHAPTER 38

Chlorophytum borivilianum (Musli): A Promising Alternative to Conventional Reproductive Treatment

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SUMMARY

The use of plants for healing, known as phytomedicine, has ancient roots, and one famous plant in this tradition is *Chlorophytum* (*C.*) *borivilianum*. This plant, also called Musli or Safed Musli (Urdu), is used extensively in traditional medicine and Ayurveda. *C. borivilianum*, has been recognized for its aphrodisiac, immune-modulatory, and antioxidant qualities and is rich in active ingredients such as proteins, polysaccharides, and saponins. Its potential applications in the treatment of ulcers, bacterial infections, and cancer have been highlighted by recent studies. It has antioxidant properties and also the ability to address male infertility. This herb has immune-modulating, reproductive health, and fertility-enhancing properties. Furthermore, it helps to alleviate menstrual symptoms and improve physical features such as vaginal lubrication and drying. It plays a role in areas such as longevity of reproduction, hormonal balancing, and general health. Care should be taken regarding its dosage because it can result in allergic reactions or hormonal imbalances in case of overdose. Due to its ability to improve uterine receptivity, regulate the mensural cycle, and enhance sperm and egg quality, *C. borivilianum* may have ART applications. It has wide economic importance in both international and local markets. In order to improve reproductive health and for patients who are unable to conceive, *C. borivilianum* offers an effective and natural alternative to conventional reproductive treatment.

INTRODUCTION

Phytomedicine is the use of plants to cure illness or prevent disease, a practice that has been around for generations. Herbs may be utilized as an alternative to or in conjunction with conventional treatment, so there's no need to disregard the former. Research into alternative medical practices, such as phytomedicine or ethnomedicine, is not new. For the first time in the 1960s, *Tabebuia* (*T.*) *impetiginosa* (Red Lapacho) drew significant attention as a 'wonder medicine' in Brazil and Argentina. *T. impetiginos* has two major bioactive components: lapachol and betalapachone. The principal anti-tumor component is beta-lapachone, and pro-apoptotic actions were identified in vitro. An endangered geophyte with extensive traditional use and therapeutic value is *Chlorophytum* (*C.*) *borivilianum* (Liliaceae). *C. borivilianum* (Hindi for "white tubers") is the prevalent name for this food item. The root of the *C. borivilianum* plant is given a prominent position in the Ayurveda, Unani, Homeopathic, and Allopathic medical traditions. Traditional *C. borivilianum* usage has been mostly unreported since they have been conveyed orally from one generation to the next in local spoken languages. Recent surveys in various Indian states have shown that the ethnic communities of the Aravali Hills (Meena), Rajasthan (Mizo), Mizorum (Mizo), Maharashtra (Pawra and Thakar), and Madhya Pradesh (Korku and Bharia) have benefited from safed musli's inclusion in their health care system, increasing their health, vitality, and longevity as shown in Fig 1., (Patil, 2003; Meena & Rao 2010; Deshwal & Trivedi 2011; Rai & Lalramnghinglova 2011).

C. borivilianum has been used historically to treat a variety of male sexual disorders and as a general health tonic (Thakur

How to Cite: Asif S, L Saeed, T Umar, M Umar, H Feng, T Adil, AA Khan & S Umer, 2023. *Chlorophytum borivilianum* (musli): a promising alternative to conventional reproductive treatment. In: Complementary and Alternative Medicine: One Health Perspective (Sindhu ZuD, B Aslam, U Uslu & M Mohsin, eds): FahumSci, Lahore, Pakistan, pp: 277-288. ISBN: 978-627-7745-01-1. https://doi.org/10.61748/CAM.2023/038

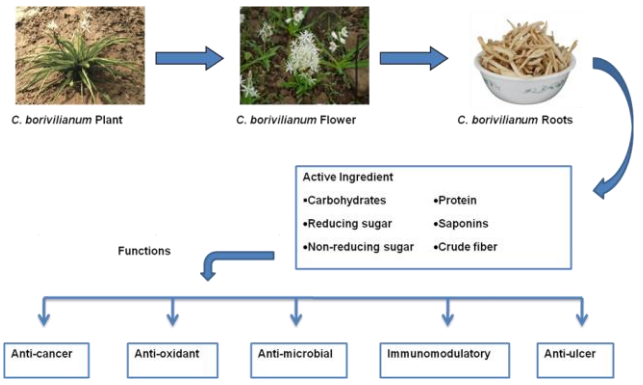

Fig 1. Morphological representation, function and chemical constituents of *C. borivilianum.*

et al., 2009). Such as treating physical weakness and illness, acting as an aphrodisiac and rejuvenator, and enhancing the immune system. It is also believed to possess properties that combat inflammation, microbes, and tumors, and can alleviate symptoms of arthritis, diarrhea, dysentery, gonorrhea, leucorrhea, diabetes, and postnatal complications. It is believed to possess rejuvenating properties and efficacy against sexually transmitted infections. Widely acknowledged for its positive impact on male sexual health, it has gained prominence in both medical and cultural contexts. The noteworthy benefits of these materials include spermatogenic activity, immunomodulation, antioxidant properties, anti-stress effects, and enhanced sexual activity (Kenjale et al., 2007; Kenjale et al., 2008; Thakur & Dixit 2006).Additionally, research has explored its potential in treating female reproductive issues. In Western nations, *C. borivilianum* is gaining popularity for its perceived effectiveness against conditions such as diabetes, hypertension, delayed menopause, rheumatoid arthritis, and chronic leucorrhea (Grover, 2021).

Notably, *C. borivilianum* is the most commercially produced species in the genus, primarily due to its aphrodisiac and immunomodulatory effects. It has recently gained popularity in the West as a natural alternative to "Viagra" because it was mostly used as a medication in India (Thakur et al., 2009). In order to satisfy the growing demand and prevent the reckless exploitation of this wild plant in its natural habitat, a successful farming system has been implemented in certain regions of India.

SCIENTIFIC NAME AND CLASSIFICATION

Scientific name is *Chlorophytum borivilianum.* The term *Chlorophytum* comes from the Greek words for green, chloros, and plant, phyton (Rochford, 1961). Santapau and Fernandes, on the 14th of June, 1954, collected specimens of a new species of *Chlorophytum* from the plains and lower slopes of the Krishnagiri National Park on Salsette Island near Borivali, Bombay, and gave it the scientific name *Chlorophytum borivilianum* (Santapau & Fernandes 1955). Classification of *C. borivilianum* has been given in Tab 1.

Tab 1. Classification of *Chlorophytum borivilianum*

kingdom	**Plantae**
Clade	Angiosperm
Clade	Monocots
Order	Asparagales
Family	Asparagaceases
Sub-family	Agovoideae
Genus	*Chlorophytum*
Species	*C. borivilianum*

Regional names

The common name for *Chlorophytum borivilianum* varies from language to language. Names in several Indian and international languages are provided in Tab 2.

Tab 2. Regional names of *Chlorophytum borivilianum*

Language	**Name**
Hindi	Safed Musli,Hazarmuli,Satmuli
sanskrit	Swetha Musli
Gujrati	Dholi Musali, Ujlimusl
Malyalam	Shedeveli
Marathi	Safed Musli, sufed Musli, Kuli
Tamil	Tannirrvittang, Tannirvittan-Kizhangu, Taniravi Thang, Vipurutti
Telugu	Tsallogadda, Swetha Musli
Garhwali	Jhirna
Bhojpuri	Khairuwa
English	Indian spider plant, spider plant, white musale
French	Chlorophytum medicinal
Arabic	Shaqaqule-hindi, Shaqaqule

Geographical distribution

The *C. borivilianum* was first proposed in India in 1954 from South Africa, where it had first been discovered. The plant *C. borivilianum* is widely distributed and grown in forest areas all over the world. The genus *Chlorophytum* was brought to India from South Africa, and its center of origin is thought to be tropical and subtropical Africa. The species *Chlorophytum borivilianum* rose to prominence in the late 1980s. About 300 different species of rhizomatous plants make up the genus *Chlorophytum*. These plants are mostly found in tropical and subtropical forests throughout the world, with some reaching elevations of up to 1500 meters (Chakraborthy & Aeri 2009; Nayar & Sastry 1987; Oudhia, 2001; Raghavendra et al., 2005). According to Genera Plantarum, 40 species of *Chlorophytum*

are found in Asia, tropical Africa, America, and Australia (Bentham & Hooker 1880). There are 13 species of *Chlorophytum* known to exist in India, of which 6–7 are widely used in the country's traditional medical systems (Nair, 1974; Sheriff, 1972). Conversely, certain *Chlorophytum* species are grown for their decorative qualities (Bordia et al., 1995).

ACTIVE COMPONENTS OF *C. BORIVILIANUM* AND THEIR MECHANISM OF ACTION

Safed musli contains mostly carbohydrates (42%), proteins (8-9%), root fibers (3-4%), and saponins [2-17% (Bordia et al., 1995; Singh & Singh 2007)].*C. borivilianum* contains a variety of useful chemicals, including sugars, proteins, fiber, and medicinal compounds such steroids, saponins, sapogenins, and minerals(Singh & Singh 2007). The dried roots of *Chlorophytum borivilianum* contained 4% saponin. Just 0.18% was found to be sapogenin (hecogenin), whereas 3.80% was found to be sugar moiety. Saponin hydrolysate included galactose (0.73%), glucose (0.76%), xylose (0.74%), arabinose (0.79%), and rhamnose (0.78%). The components of *Chlorophytum borivilianum* are detailed in Tab 3.

Mechanism of action of *C. borivilianum*

C. borivilianum is an ayurvedic aphrodisiac, making it an effective remedy for male impotence. It promotes the production of testosterone, an essential hormone for increasing blood flow to the genitalia, and therefore, strength, by stimulating the adrenal gland. In addition to boosting orgasmic intensity and reviving the reproductive system, it also improves mental health and physical fitness by helping the body fight off stress and depression by increasing testosterone levels. To have an erection, *C. borivilianum* primarily stimulates a man's testosterone production. Adaptogens, like those included in this herbal Viagra, are known to successfully modulate enzyme and hormone levels, ensuring normal genital function (Desale, 2013). Since it may reverse diabetes's negative effects on sperm quality and quantity, *C. borivilianum* root extract may be a viable therapy for male infertility. Root extract also protects against apoptosis that induces oxidative stress in sperm. Our research confirms the therapeutic benefits of *C. borivilianum* root extract on diabetic mice. *C. borivilianum* root powder raised antioxidant enzyme activity and vitamin C levels (Kumar & Mazumder 2012), which may have improved the liver's antioxidant capacity.

Classical basis of *C. borivilianum*

From the 11th century A.D. (Sharma et al., 1999), Shukra, the Ayurvedic counterpart of semen, which includes sperm, seminal fluid, and testosterone, is said to be enhanced by musli and other Shukrala medications. This notion is consistent with the age-old Ayurvedic principle of "similar leads to an increase in similar," which was highlighted by Charak in the second century B.C. In the 2nd Century B.C., *C. borivilianum* dried root tubers, which resemble spermatozoa in form, increase sperm production. It's sticky and white like semen, and it helps boost semen production (Triveni, 1977; Kirtikar, 1991; Sharma et al., 1999).

Contemporary basis of *C. borivilianum*

C. borivilianum main component stigmasterol is structurally identical to that of corticosteroids, and testosterone increases blood levels of these hormones(Kumar & Mazumder 2012).

Anti-cancer

It was discovered that *C. borivilianum* inhibited proliferation and induction of apoptosis in cell lines from humans with breast cancer (Arif, 2005). Deore and Khadabadi evaluated the antiproliferative potential of a methanolic extract and a crude saponin fraction of *Chlorophytum borivilianum* (Deore & Khadabadi 2010).

Saponins have powerful cytotoxic properties. Hence, many researchers have investigated saponins' anticancer potential. The potential effects of different Chlorophytum species on cells from leukemia were investigated (Deore et al., 2015). In vitro, the HL60 leukemia cell line was examined for anticancer properties of numerous Chlorophytum species' methanolic extract and saponins (using the SRB assay technique). HL 60 cell growth was reduced by *C. comosum*'s methanolic extract. Some species' extracts and fractions may be anticancer, but not antileukemia. By summing up the anticancer actions mentioned in the literature, it is clear that the work done is very basic and targeted.

Anti-oxidant

Oxidative processes are essential for optimal bodily function but may damage core cells without antioxidants. Natural antioxidants include vitamins A, C, and E and enzymes like glutathione, catalase, superoxide dismutase, peroxidase, and others. Antioxidant-rich diets lower illness risk and death (Tribble, 1999). In addition, the 1,1-diphenyl-2-picrylhydrazyl (DPPH) test revealed that the plant's methanolic seed extract had excellent free radical scavenging activity, while other antioxidant assays revealed modest inhibitory efficacy (Devi, Singh, Somagond, et al., 2021). According to yet another in vitro investigation, the 125 mg/kg dose of *C. borivilianum* aqueous extract showed excellent antioxidant activity due to the presence of phenolic compounds by reducing the amount of DPPH free radicals and thiobarbituric acid reactive chemicals (Gill et al., 2015).

Tab 3. Active components of *C. borivilianum* and organic analysis of its root powder (Vijaya & Chavan 2009)

Constituents	Value (%)
Saponin	4.4
Total sugar	39.1
Reducing sugar	22.2
Non-reducing sugar	16.9
Total protein	8.5
Water soluble protein	5.8
Crude fiber	5
Saponins	12-17%
Stigmasterol	1.9-3.5%
Sugar	
Arabinose	0.79%
Galactose	3.80%
Glucose	0.73%
Rhamnose	0.78%
Xylose	0.76%
Carbohydrates	35-42%
Reducing sugar	20-25%
Nonreducing Sugar	15-17%
Protein	8-8.5%

Antimicrobial

Compared to antibiotics, ethyl acetate and alcohalic extracts of *Asparagus racemosus*, *Chloro phytum tuberosum*, *Hemi-desmus indicus*, and *Withania somnifera* demonstrated substantial antibacterial activity. Antimicrobial action was identified in Chlorophytum tuberosum's novel bisisoflavanoid [Bis (8-methyl-4'methoxy-7-O-L-rhamnopyranoside) I-5, II5 Bis isoflavone]. Employing the disc diffusion approach, studies have investigated the antibacterial attributes inherent in a callus extract derived from *C. borivilianum* that targets diverse pathogenic microorganisms (Bhat et al., 2018). The extract efficiently inhibited methicillin-resistant *Staphylococcus aureus*, *Candida albicans*, *Bacillus subtilis* B29, *Escherichia coli*, and *Pseudomonas aeruginosa* (Huang et al., 2019).). Evaluating antibacterial activity entails a detailed examination of numerous compounds against a diverse array of microbial pathogens (Bhat et al., 2018). Streptomycin, which served as a control for both gram-positive and gram-negative bacteria, effectively hindered *E. coli* growth to a 12 mm diameter at 250 µg/disc, in contrast to the control sample's 24 mm diameter. Similarly, *B. subtilis* exhibited a 14 mm diameter inhibition effect at the same dosage compared to that of the control, underscoring the inhibitory influence of streptomycin on bacterial development. In the assessment of antifungal efficacy, various compounds were tested against different fungi (Bhat et al., 2018). *Rhizopus stolonifer* exhibited an 8 mm inhibition diameter when exposed to the tested substance, while in the control group, the use of naphthol at a 20.0 ppm dose resulted in a 17 mm inhibition diameter. The test sample against *Aspergillus niger* showed a 7 mm diameter inhibition, whereas the control sample had a 15 mm diameter. Additionally, *Penicillium expansum* displayed a 5 mm inhibition diameter in response to the test chemical, while the control, featuring a naphthol at 20.0 ppm, resulted in an 11 mm diameter. This comparison with the naphthol control suggested the potential antifungal effects of the studied chemicals against the respective fungi.

Immunomodulatory

Enzyme-linked immunosorbent assay was used to assess humoral reaction to sheep red blood cells (RBCs) and antibody levels in Wistar strain albino rats to investigate *C. borivilianum* polysaccharide involvement in immunological function (ELISA). The aqueous plant extract revealed immunomodulatory action. Another research studied the impact of *C. borivilianum* polysaccharide fraction (CBP) on natural killer (NK) cell activity in vitro. NK cell cytotoxic activity against K562 cells was modulated by varying amounts of each *C. borivilianum* fraction in human peripheral blood mononuclear cells (PBMCs) extracted from whole blood on a Ficoll-opaque density gradient. *C. borivilianum* CBP significantly stimulated NK cell activity (Kaur & Kaur 2020).

Anti-ulcer

C. borivilianum root ethanol extract was tested for its ability to reduce stomach acid. At a dose of 100 mg/kg, 50% alcoholic extract showed considerable antiulcer action against ethanol-induced Pylorus ligation-induced stomach ulcers in Sprague-Dawley rats (Rachchh et al., 2005). The alcoholic extract of *C. borivilianum* exhibits therapeutic properties for ulcers. To assess antiulcer activity, a model of stomach ulceration caused by cold stress was chosen. When compared to the control group, the ulcer index is significantly ($p<0.001$) lower after a single oral dose of 200 mg/kg of the alcoholic extracts (Sharma & Chandrul 2017).

IMPACT ON MALE REPRODUCTIVE SYSTEM: EVIDENCE FROM ANIMAL AND HUMAN STUDIES

Safed musli, or *Chlorophytum borivilianum*, is an Ayurvedic herb that has several advantages for male sexual health. According to studies, it can improve sperm motility, boost sperm count and density, treat premature ejaculation, and regulate erectile dysfunction. It can also improve the amount and quality of ejaculation. It is also thought to be a natural energy enhancer and can enhance the quality of semen (Musli, 2013). Several plants have been utilized in Indian traditional herbal therapy to treat male erectile dysfunction, perinatal and postnatal ailments, and sexually transmitted infections (Saxena et al., 2012). Dried plant tubers have also been utilized for these purposes (Haque et al., 2011; Sharma & Mazumdar 2012).

Libido / sexual desire

The aphrodisiacal and spermatogenic properties of *C. borivilianum* have earned it the nicknames "herbal viagra," "desire viagra," and "sex vitalizer" (Devendra et al., 2012; Giribabu et al., 2014; Kenjale et al., 2008; Sharma & Mazumdar, 2012; Thakur & Dixit 2006).

The aphrodisiac properties of this plant have been studied in vitro in rat models. The researchers tested male Wistar albino rats to see if an aqueous extract of *Chlorophytum borivilianum* (C. *borivilianum*) dried roots possesses aphrodisiac and spermatogenic characteristics (Kenjale et al., 2008). The rodents were divided into four groups. Three hours following treatment with distilled water (control group), cannabidiol (CB) at 125 mg/kg/day, cannabidiol (*C. borivilianum*) at 250 mg/kg/day, or sildenafil citrate (Viagra® group) at 4 mg/kg/day, male rats were examined for sexual activity. At 125 mg/kg, CB was shown to have a pronounced aphrodisiac effect, leading to enhanced libido, sexual vitality, and arousal. All aspects of sexual behavior were improved at the higher dosage (250 mg/kg); however, this effect plateaued after 14 days. Both the 125 mg/kg and 250 mg/kg C. *borivilianum* groups showed a dose-dependent increase in sperm count by day 60. They came to the conclusion that Chlorophytum borivilianum root extracts might be used to treat sexual dysfunctions such as premature ejaculation and oligospermia (Kenjale et al., 2008).

In another experiment, aqueous root extract at 250 and 500 mg/kg/day and glibenclamide at 600 g/kg/day were used to treat diabetes in male rats induced by streptozotocin. The experiment lasted for 28 days. Diabetic male rats showed an increase in both normal sperm count and caspase-3 level, but aberrant sperm count, viability, and forwarding motility all decreased. Also, 30 male volunteers aged 20-40 participated in the clinical investigation. The medicine was given in capsule form at 500 mg once a day for 12 weeks, with a placebo utilized as the gold standard. Most participants saw increases in their serum testosterone as compared to those who took a placebo (Giribabu et al., 2014).

Spermatogenesis

Effects of *C. borivilianum* root ethanol extract and sapogenin extracted from the root on sexual activity and spermatogenesis in albino rats. Histological examinations and weight increases in the body and reproductive organs of treated animals showed a substantial anabolic and spermatogenic impact from the administration of 100 mg/Kg and 200mg/Kg of the sapogenin and ethanolic extract, respectively. The therapy had a substantial effect on the animals' sexual behavior, as seen by a decrease in mount latency, intromission latency, ejaculation latency, post-ejaculatory latency, and, as well as an increase in mount frequency and attractiveness to females (Thakur & Dixit 2006).

In another study, Using the Wistar rat as a model, researchers examined the effects of long-term *C. borivilianum* administration on the male reproductive system by measuring sperm cell count, motility, morphology, and abnormalities. There was an increase in sperm count after 54 days of therapy with the test medication at both dosages. The same thing was found in terms of spermatogenesis (Chopra, 1956). *C. borivilianum* steroidal sapogenins were formerly thought to be responsible for the plant's spermatogenic ability. The extract's 75% saponin concentration necessitates more research into its toxicity. When tested on rat striatal synaptosomes, the saponin fraction generated from dried roots inhibited dopamine absorption, resulting in stimulation of the dopaminergic neuron. The enhanced spermatogenic capability of the extract is often attributed to its ability to induce dopaminergic activity.

Sexual dysfunction

Sexual dysfunction (SD) refers to any pattern of sexual behavior or sexual experience that is either aberrant or absent, as a result of a disturbance in the individual's sexual psychology or physiological response. Several symptoms lie under this umbrella term, but erectile dysfunction (ED), difficulty to have sexual relations, and lack of interest all play a role (Chen et al., 2019). The use of Chlorophytum borivilianum goes back around 4000 years, as mentioned in the Hindu epic Srimad Bhagawat. It is part of a select group of Ayurvedic plants called "Vajikaran Rasayana" that are used to improve sexual dynamics, restore youth, and treat sexual dysfunction (Puri, 2002). The Kamasutra's medicine recommendations are based on this principle as well It is mentioned in the Hindu scriptures, Ashwini Kumars, a divine physician, prepared the ‘chyawanprash’ for Chyavanrishi, who married at the age of 80 years, from *C. borivilianum* for improving sexual health (Hooper, 1998).

Testicular impairment in male rats exposed to high temperatures was measured, and the protective effect of certain Ayurveda medicines traditionally used for sexual health was evaluated in an experiment by researchers. The test subjects were male rats whose scrotal sacs were immersed for 15 minutes a day in a water bath kept at 40±2oC for 14 days. Lyophilized aqueous extracts of *Asparagus racemosus Willd., Chlorophytum borivilianum Sant. F., Curculigo orchioides Gaertn., Dactylorhiza hatagirea (D. Don) Soo, and Orchis latifolia Linn* (200 mg/Kg body weight) significantly inhibited the histo-architecture and the overall spermatogenesis profile in rats compared to control. Sexual behavior was also assessed across treatment groups to see how the various interventions affected participants. Mount, ejaculatory latencies, and intromission

were dramatically shortened, and recurrences for the same parameter were considerably recovered, in extract-treated rats exposed to heat compared to the heat-exposed control group alone, indicating a considerable improvement in sexual behavior. Rats in the heat-treated control group had a significant drop in epididymal sperm count, whereas rats in the extracts group had a markedly higher sperm count than rats in the positive control group (Thakur et al., 2008).

Antioxidant activity

Infertility in males can be caused by various factors, including oxidative stress, which can lead to sperm damage and reduced sperm motility. Antioxidants are known to counteract oxidative stress by neutralizing free radicals and protecting cells from damage (Thakur et al., 2009).

There is some research that suggests that *C. borivilianum* may have antioxidant properties, which could potentially be helpful in treating male infertility Fig 2. For example, a study published in the International Journal of Pharmacology found that an extract of *C. borivilianum* had antioxidant activity and was able to reduce oxidative stress in the testes of rats. Roots of C. borivilianum were investigated for their stress-relieving and free-radical-fighting properties by researchers.In rats, it was shown that the conventional medicine (diazepam) was not as efficient as the aqueous extract of *C. borivilianum* (250 mg/kg for 7 days) at lowering plasma glucose, triglyceride, cholesterol, and serum corticosterone levels and at decreasing the ulcer index and adrenal gland weight. It has a little anti-stress effect at 125 mg/kg. The extract demonstrated strong antioxidant ability in an in vitro 1, 1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging experiment and a lipid peroxidation assay. The inhibitory effect of the extract on DPPH free radicals and thiobarbituric acid reactive compounds was dose-dependent. As a result, they hypothesized that it may be utilized to treat conditions brought on by oxidative stress such as infertility (Kenjale et al., 2007) .

In another study, Subfertile Wistar male albino rats were administered a hydromethanolic extract of *C. borivilianum* root; subfertility was caused using cyproterone acetate. By boosting oxidative defense and maintaining homeostasis during the testicular apoptotic process, they found that giving *C. borivilianum* root extract lessened the adverse aberrations brought on by cyproterone acetate. It has been demonstrated that *C. borivilianum* root extract scavenges free radicals, which may

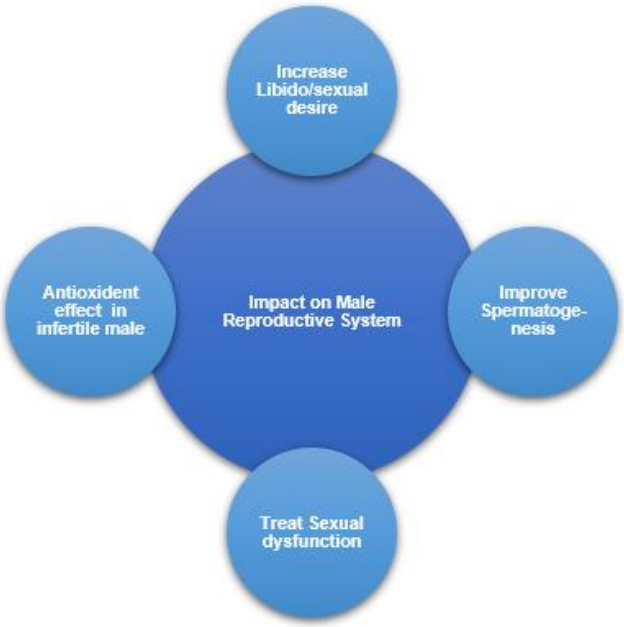

Fig 2. Effects of *C. borivilianum* on the male reproductive system.

be because the plant has a high phenolic component content (Ray et al., 2014).

Further research is required to validate these results and determine the ideal dosage and course of treatment, even though these studies indicate that C. *borivilianum* may be useful in treating male infertility. It's also critical to remember that *C. borivilianum* shouldn't be used in place of medical care and that anyone having issues with conception should see a medical practitioner for a proper diagnosis and course of action.

EFFECT ON FEMALE REPRODUCTIVE HEALTH

To improve women's reproductive health, the plant *C. borivilianum* can be utilized in Ayurvedic medicine. Recent research on its multiple benefits by modern scientists as well as conventional practitioners has focused emphasis on its potential impacts on female fertility. In this context, it is important to recognize the potential consequences of *C. borivilianum* on female reproduction. The information below summarizes the findings from both human and animal studies regarding *C. borivilianum's* potential benefits for female reproductive health.

Impact on female sexual behavior

Previous research has suggested that the neurotransmitter serotonin may have an impact on the sexual behavior of female rats stimulated with hormones (estradiol and progesterone)

(Hull et al., 1999; Olivier et al., 2011). The effects on the sexual behavior of ovariectomized female rats stimulated with progesterone and estradiol were investigated after combined administration of a hydroalcoholic extract of *C. borivilianum* at the rate of 0.1, 0.3, and 0.5 g/kg per day with an antidepressant medication, fluoxetine, at the rate of 10 mg/kg per day for 15 days. The results showed that fluoxetine drastically decreased the rats' involvement in a range of sexual activities as compared to normal rats. However, when the rats were given *C. borivilianum* extract along with fluoxetine, their sexual behavior rose significantly. Accordingly, *C. borivilianum* may be beneficial for women who take antidepressants and have low libido (Vyawahare et al., 2009).

Therapeutic impacts on female reproduction

It has been reported that utilizing *C. borivilianum* for women can help prevent UTIs, decrease heavy menstrual flow, and reduce menopause symptoms, along with several other health benefits (Malabadi & Chalannavar 2020). In an attempt to potentially alleviate the symptoms of leucorrhoea (vaginal discharge), Pedalium murex seeds are commonly administered to females (Bhuker et al., 2022). *C. borivilianum* roots are usually utilized to grind the seeds. The plant's tuberous roots are used as a tonic to overcome fatigue and general weakness, even though the tubers alone may be used to treat leucorrhoea (Bhat et al., 2018). A paste made from roots mixed with water can be beneficial for treating sexual debility in both men and women (Upadhyay et al., 2010). *C. borivilianum* sustains the pregnancy by providing the mother and fetus with essential nutrients. It replenishes the fluids lost by the mother after giving birth in the postpartum period (Grover, 2021).

Broadly speaking, there are several potential health benefits associated with *C. borivilianum* consumption. These include higher energy levels, decreased vaginal dryness, boosted physical strength and stamina, increased vaginal lubrication, higher libido, alleviation of menopausal symptoms, preservation of youthfulness, prevention of urinary tract infections, a decrease in heavy menstrual bleeding, regulation of hormonal imbalances, and promotion of overall well-being and vigor as illustrated in Fig 3., (Sharma & Chandrul 2017).

Enhanced production and antioxidant activity

During the hot and humid weather, the effectiveness of *C. borivilianum* as an immunomodulator was evaluated in a group of eighteen crossbred cattle. The experimental cattle were given three different supplements over the period of ninety days: a control group that received no supplement, *C. borivilianum* at the rate of 40mg and 80mg/kg b.wt daily. It was demonstrated that incorporating *C. borivilianum* into the diet of cows at a dose of 80 mg/kg b.wt. per day was more effective in reducing levels of stress and enhancing immunity by reducing the levels of pro- and anti-inflammatory cytokines. Thereby, it seems that providing *C. borivilianum* in the feed of dairy cows could be a way to alleviate some of the damage caused by extreme temperatures (Devi et al., 2021).

In this study, eighteen cows with different lines were analyzed to determine the effect of adding *C. borivilianum* on their composition, production, and fatty acid profile. In accordance with their body weight and milk production, three groups were established: the control group, Tr. I (first treatment) group; Tr.II (second treatment). Throughout the hot and humid season, two doses of *C. borivilianum* were administered. The first dose was 40 mg/kg b.wt./day, and the second dose was 80 mg/kg b.wt./day. It was discovered that *C. borivilianum* could increase the quantity of milk produced by dairy farm animals. More importantly, it has been found that intake of this plant results in other beneficial effects as well; the SCC (somatic cell count) was reduced and saturated fatty acids relative to unsaturated were decreased. Plasminogen level was increased as well. Therefore, this supplement can keep the health of mammary glands and milk quality in lactating cows (Devi et al., 2021). Accordingly, the root powder of *C. borivilianum* promotes milk production in nursing mothers and lactating cows (Dhoke et al., 2023).

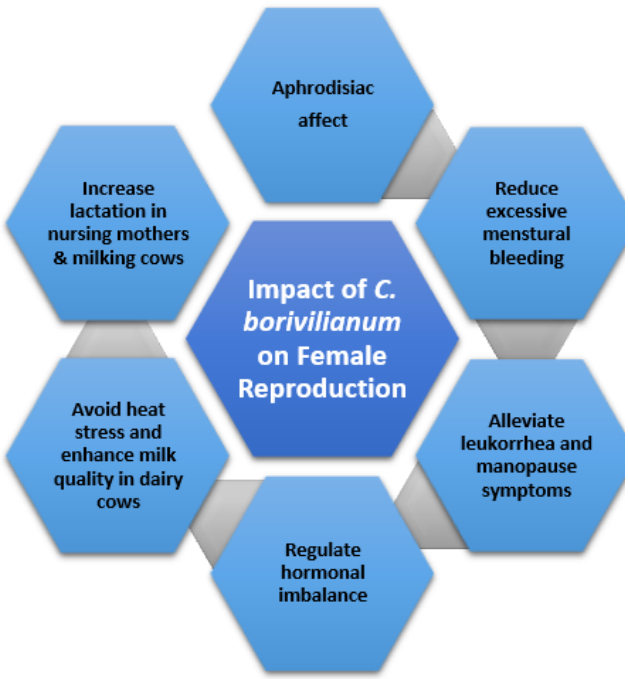

Fig 3. An overview of impact of *C. borivilianum* on the reproductive health of women.

Therefore, it appears to have several health benefits for female animals. It can increase female fertility and improve reproductive health. Its anti-inflammatory and antioxidant properties promote overall health, lowering the risk of diseases. It has also been demonstrated that *C. borivilianum* is helpful in boosting the immune system, which makes female animals more resistant to infections and diseases. *C. borivilianum* has the potential to be an effective safe and natural remedy, benefiting female animals in terms of their general well-being as well as helping restore fertility.

SAFETY AND ADVERSE EFFECTS OF *C. BORIVILIANUM*

The plant *C. borivilianum* is used in traditional Ayurvedic medicine to enhance physical performance, overall well-being, and fertility. But as the herb's profile has improved, concerns have been expressed about its safety and drawbacks. In order to make proper use of *C. borivilianum* and avoid any possible harm, we must understand its safety profile. Safety and side effects of the plant have been investigated in numerous studies, which are reviewed below.

Safety

According to studies, hyperlipidemia affects nearly 1.8 billion people worldwide. Drugs for treating this medical illness are very numerous, yet many of them have unwanted side effects such as liver damage, nausea, and gastrointestinal upset or diarrhea. Herbalists go to great lengths to try an alternative way that lowers side effects and gradually increases overall health. Studies have found that Asparagus racemosus and *C. borivilianum* prevent liver and cardiac tissue from deteriorating. In addition, serum cholesterol levels in normal albino rabbits and diabetic rats were lowered by *C. borivilianum* leaves (Singh & Nain 2022).). Given that synthetic drugs have side effects, it is now common to treat hyperlipidemia with herbal plants such as *C. borivilianum* and Asparagus racemosus.

Consequently, a standardized extract of root was given to male Wistar albino rats for testing as an anti-aphrodisiac and its safety on reproductive organs. After eight weeks of administration, male rats were given 125 and 250 mg/kg extract orally, respectively. *C. borivilianum* enhanced sexual desire in both doses administered, the plant increased male desire; moreover, it stimulated libido and lust during mating. This could help to treat the reproductive dysfunction of males until day 28 of treatment. Moreover, after 54 days of treatment, both preparations increased the sperm count and motility. These combinations can be included in the treatment of oligospermia, or low sperm counts. Moreover, abnormalities of sperm at both concentrations were less than 10 % even after 54 days of treatment. Therefore the use of this formula will not make a man sterile (Das et al., 2016).

Acute oral toxicity was studied to determine safe dose concentrations for the methanolic extract of *Chlorophytum borivilianum* (MECB) root tubers. Several experimental models were employed to examine the psychopharmacological characteristics of the extract and assess its effects on Swiss albino mice and Wister albino rats. Three different dose levels of the MECB (100, 200, and 400 mg/kg of body weight) were proven to be safe (Panda et al., 2011).

An acute toxicity test was conducted on albino mice in accordance with AOT-421 guidelines to assess the safety of the test drug, an alcoholic or aqueous extract of *C. borivilianum* roots. The mice were examined for abnormalities of their skin, fur, eyes, mucus membranes, lacrimation, salivation, incontinence, blood pressure, heart rate, urine, feces, lethargy, ptosis, tremors, and convulsions. The medicine was found to be safe up to a quantity of 2000 mg/kg b.wt (Deore & Khadabadi 2009).

Adverse effects

Several similar studies have been carried out regarding the non-toxic impacts of the root extract of *C. borivilianum*. There

was no recorded harm in terms of disease, morbidity, mortality, or behavior in mice treated with different doses (100, 400, and 800 mg/kg b.wt./day) of the extract for seven days. Mice's tolerance level was 800 mg/kg b.wt./day, as shown by significantly higher levels of superoxide dismutase (SOD) and catalase (CAT), an increase in hepatic reduced glutathione (GSH) and a decrease in lipid peroxidation (LPO) relative to the control group (Kumar et al., 2010; M. Thakur et al., 2009). These findings open up new possibilities for using the extract in different biological research.

The water extract of *Chlorophytum borivilianum (*WECB) is suggested to improve the quantity and quality of semen in healthy adult males aged 20 to 40 years significantly in contrast to placebo when taken for 12 weeks at a dose of 500 mg b.i.d. While a significant effect was not seen, the WECB raised serum testosterone levels in most participants in the study when compared to the placebo. It was considered safe for human consumption as no volunteer experienced any adverse drug reactions (Rath & Panja 2013).

As a herb, *C. borivilianum* is regarded as the perfect aphrodisiac because it doesn't have any of the negative effects that come with chemical-based aphrodisiacs. To prevent negative effects, it must be taken as directed. Increased dosages could disturb the digestive system (Sharma & Mazumdar 2012). The increasing demand for herbal-based medicinal products in the US, Europe, Japan, and other nations has created new markets for *C. borivilianum's* commercial production. Because of its exceptional therapeutic qualities, it is known as "Divya Aushad" in Indian Ayurvedic literature. Over a hundred Ayurvedic medicines contain it as a significant ingredient (Oudhia, 2001). Due to its widespread use and popularity as an aphrodisiac drug-free of adverse effects and addiction issues, it may be a useful treatment for male impotence, especially erectile dysfunction and orgasm.

Because of its high steroidal concentration, the plant *C. borivilianum* is often prescribed as an aphrodisiac. However, although some populations should not consume this plant because they may experience serious adverse effects (for example children and women), others such as the elderly have greater tolerance. Possible adverse effects include hormonal abnormalities and allergy responses (Jay et al., 2021). Therefore, careful use with a medical professional is recommended.

It was discovered that native people used *Chlorophytum tuberosum*, *C. borivilianum*, and *Curcuma longa* as remedies for a wide range of ailments, including arthritis, sore throats, fever, colds, and postpartum and natal issues. A significant portion of them (60–80%) were able to significantly overcome a variety of health issues, including inflammation (69.4%), cold and sore throat (87.5%), physical weakness (66%), joint pain and arthritis (66.6%), and natal and postnatal issues (75%) with no side effects. These results provided compelling evidence for the safe and efficient use of natural compounds by the people living in tribal areas of the Border States of Maharashtra and MP, who have limited access to modern medical facilities, to treat ailments such as inflammation, joint pain, appetite loss, and general weakness (Miraj et al., 2020).

Strong aphrodisiac effects have been demonstrated by *C. borivilianum* roots, which have been observed to increase serum testosterone levels. There is a significant information gap about the proper utilization of these extracts and the right dosage for those with certain medical conditions, such as cardiac patients as well as pregnant or nursing mothers. This is alarming because there isn't much information on heavy metals detected in herbal products. Moreover, inadequate and unreliable data exist about microbiological contaminants that could cause aflatoxins when harvested or stored (Khanam et al., 2013). Therefore, even though *C. borivilianum* appears to have significant health advantages, more research is needed to fully understand its safety profile as well as any potential drawbacks.

APPLICATIONS IN ART

Assisted reproductive technology (ART), is a wide range of medical procedures aimed at assisting those people and couples who are unable to conceive naturally themselves. Low sperm concentration and abnormal mobility, aberrant sperm morphology leads to infertility in males. In the Ayurvedic medical system, *C. borivilianum* has been widely used to help treat male infertility and sexual dysfunction through its ability to increase both spermatozoa numbers and their motility. Thus, ICSI and in vitro fertilization have higher success rates than any of the other ARTs.

C. borivilianum may increase fertility by raising sperm count and quality. Research has demonstrated that *C. borivilianum* contains saponins which can promote the synthesis of testosterone, on which the maturation of sperm cells depends (Grover, 2021; Panda et al., 2011). Furthermore, *C. borivilianum* may enhance the general quality of sperm cells and protect them from damage due to free radicals (Govindarajan et al., 2005; Kaur et al., 2010). Because it's more effective than other plants that only have anti-oxidative capabilities in assisting couples undergoing ART.

Saponins in *C. borivilianum* have also been proven to encourage the release of follicle-stimulating hormone (FSH) and luteinizing hormone (LH), hormones vital for regulating ovulation and menstrual cycle (Behera & Gautam 2017; Devendra et al., 2012; Mahajan et al., 2012). This would stimulate the growth and maturation of normal eggs, increasing

the chances that ART will work. Additionally, *C. borivilianum* might have anti-inflammation effects that could help reduce endometrial inflammation and increase the chances of a successful pregnancy.

Thus, the use of *C. borivilianum* in ART increases both its success rate and pregnancy rates as well. While this natural remedy can indeed be of great help to the infertile, it is still best that one consults a health practitioner before its use. Further research is needed to explore its promise in enhancing fertility.

PUBLIC HEALTH IMPORTANCE

The anti-inflammatory, antioxidant, and immunomodulatory properties, along with its potential benefits for improving reproductive health, have prompted a plethora of research investigations on *C. borivilianum*. The following discusses *C. borivilianum's* potential benefits and importance for public health.

The potential for *C. borivilianum* to improve male reproductive health is considerable. Research has indicated that it may increase both sperm motility and count (Grover, 2021). For infertile couples, this might be helpful. Furthermore, it has been discovered that *C. borivilianum* enhances libido and sexual function (Saini & Ram 2022). These results could positively affect men's general standards of life.

C. borivilianum offers benefits not just for reproductive health but also for anti-inflammatory and antioxidant qualities (Mukim et al., 2023). Among chronic diseases, cancer, diabetes, and heart disease are all significantly influenced by oxidative stress and chronic inflammation. It may help postpone or prevent the development of certain diseases because of its anti-inflammatory and antioxidant effects.

Research has also been done on the potential immunomodulatory effects of *C. borivilianum*. The immune system plays a crucial role in protecting the body from infections and diseases. *C. borivilianum* has been shown in several investigations to support immune system function and strength, which may help prevent infections (Dhoke et al., 2023; Hossain et al., 2022).

One of the top priorities in public health is the development of new and effective cancer treatments. Several studies suggest that *C. borivilianum* may possess anti-cancer characteristics and work well as an adjuvant therapy in the management of cancer (Bhat et al., 2018; Khanam et al., 2013).

Along with its possible uses in cancer treatment, disease prevention, and reproductive health improvement, *C. borivilianum* is also being studied for its anti-anxiety and anti-depressant properties. Mental health issues such as anxiety and depression demand effective treatment alternatives and are becoming an increasing concern for the public. Anxiolytic and antidepressant effects have been revealed by prior studies on *C. borivilianum* (Bhat et al., 2018; Khanam et al., 2013). It may therefore have therapeutic ramifications for particular diseases.

While *C. borivilianum* might offer potential health benefits it is imperative that further research must be conducted to comprehend its mode of action and adverse effects properly. Moreover, one should be highly careful while taking *C. borivilianum* either as a medication or as a supplement. The doctor should be consulted if the consumer has any underlying health condition or taking other medicines as well.

ECONOMIC IMPORTANCE

C. borivilianum is a crop that yields well and carries little risk; it may yield an impressive profit in just one growing season. Among the numerous species in the Chlorophytum genus, *C. borivilianum* is thought to have the maximum commercial significance due to its exceptional saponin content, which may reach as much as 17% (Manjunatha et al., 2004). Since it is classified as agricultural income, revenue from the cultivation of *C. borivilianum* is regarded as tax-free. By adopting proper scientific cultivation methods and carefully selecting planting materials, farmers can enjoy recurrent profits over the years. On average, one acre of *C. borivilianum* can yield 2000-3000 kg of wet *C. borivilianum*, which, after drying and processing, results in about 400-450 kg (20%) of dry *C. borivilianum* In the Indian market, dry *C. borivilianum* sells for around Rs 800 to Rs 1800 per kg, while in the international market, it can fetch more than Rs 3000 per kg. Therefore, one acre of *C. borivilianum* can generate a net income of around Rs. 4-6 lakh (over $10,000). The processed product of *C. borivilianum* in the form of Ayurvedic supplements and formulations commands a high price in both national and international markets.

Pfizer's Viagra has gained worldwide recognition for its ability to act as an aphrodisiac, but due to its synthetic nature, its prescription is limited based on an individual's medical conditions. In contrast, *C. borivilianum* is an herbal alternative known for producing similar effects without any adverse reactions. A potent drug named "Nai Chetna" (new sensation) was introduced by the Gujarat State Forest Development Corporation in 1999 and was featured in The Indian Express Newspaper (Bombay) on December 1, 1999 (Thakur et al., 2009). *C. borivilianum* is the primary ingredient in the drug, which has gained considerable popularity as a substitute for Viagra.

Currently, the commercial demand for the tuberous roots of *C. borivilianum* exceeds the supply, with over 2500 tons per

year of the plant's roots demanded in India (Somanath, 2008). According to a different report, there is a significant disparity between the demand and supply of *C. borivilianum* roots in India, with an estimated demand of 3500 tons per year and a supply of only 500-600 tons annually (Kothari & Singh 2001). It has been estimated that foreign countries have an annual demand for *C. borivilianum* roots ranging from 300 to 700 tons (Chadha, 1995). *C. borivilianum* has significant markets in various countries worldwide, including India, China, France, Italy, Germany, Spain, the UK, Japan, and the USA. Many countries in Europe and the Gulf, along with the US, have been importing the dry roots of *C. borivilianum* for the creation of herbal products and drinks. Nowadays, numerous pharmaceutical and herbal companies sell products containing *C. borivilianum*, which are marketed under various commercial names such as Musli Power Xtra, Foreva, Indian Herbal Viagra, and Eterna (G. S. Thakur et al., 2009).

Currently, the global market demand for roots is estimated to be around 35,000 tons per year, while the production is only approximately 5000 tons per year. This level of production meets less than 15% of the overall demand. Another report suggests that the global demand for roots is almost 50,000 tons per year (Somanath, 2008).

Based on the above data, it is evident that *C. borivilianum* holds significant economic value in both national and international markets. Therefore, the government can promote its trade to generate substantial foreign revenue. However, this would require collaboration between growers, traders, producers, and medical experts to ensure the full commercial potential of the plant is realized.

CONCLUSION

In conclusion, *Chlorophytum borivilianum* (Safed Musli) is a promising alternative to conventional reproductive treatments. Its natural compounds have been found to have various health benefits including, improving male impotence and oligozoospermia; arthritis, diabetes, and as an immune booster. *C. borivilianum* also has potential health benefits for females including, improving reproductive health, exhibiting antioxidant and anti-inflammatory properties, and preventing diseases. Additionally, it has been found to be safe and well-tolerated with minimal side effects. While more research is needed to fully understand its mechanisms of action and potential long-term effects, *C. borivilianum* offers a natural and potentially effective option for individuals struggling with infertility or seeking to enhance their reproductive health.

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