International Journal of Noni Research

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REVIEW

ORIGINAL ARTICLE

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Review on the current scenario of Noni research: Taxonomy, distribution, chemistry, medicinal and therapeutic values of *Morinda citrifolia*

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Introduction

Plants are the reservoirs of a large number of imperative organic compounds and they have long been used as the sources of medicines. Dependence on plants is prevalent in developing countries where the traditional herbal medicine plays a major role in health care and in the treatment of many infectious diseases. The rural population of a country is more disposed to traditional ways of treatment because of its easy availability and cheaper cost. Herbal therapies although still an unwritten science is well established in some cultures and tradition and have become a way of treatment in almost 80% of the people in rural areas, especially those in Asia, Latin America and Africa.

Natural products of folk medicine have been used for centuries in every culture throughout the world. Scientists and medical professionals have shown increased interest in this field as they recognized the true health benefits of these remedies. While searching for food, the ancient found that some foods had specific properties of relieving or eliminating certain diseases and maintaining good health. It was the beginning of herbal medicine. The same story occurred in Polynesia. Among the medicinal plants discovered by the ancestors of Polynesians, Noni (*Morinda citrifolia*) is one of the important traditional folk medicinal plants that have been used for over 2000 years in Polynesia. It has been reported to have a broad range of therapeutic and nutritional value. The ancestors of Polynesians are believed to have brought many plants with them, as they migrated from Southeast Asia 2000 years ago (Tabrah and Eveleth, 1966; Gerlach, 1996). Of the 12 most common plants they brought, Noni was the second most popular plant used in herbal remedies to treat various common diseases and to maintain overall good health (Krauss, 1993; Gerlach, 1996).

Morinda citrifolia fruit has long history of use as a food in tropical regions throughout the world. Documentation of the consumption of the fruit as a food source precedes the twentieth century. Captain James Cook of the British Navy noted in the late 1700's that the fruit was eaten in Tahiti. An 1866 publication in London explained that *M. citrifolia* fruit was consumed as a food in the Fiji Islands. Later publications described the use of this fruit throughout the Pacific Islands, Southeast Asia, Australia and India. In Roratonga, the natives often ate the fruit. Australian Aborigines were very much fond of this fruit. In Samoa, Noni fruit was common fare and in Burma it was cooked in curries or eaten raw with salt. In 1943, Merrill described *M. citrifolia L.* as an edible plant in a technical manual of edible and poisonous plants of the Pacific Islands, in which the leaves and fruits were used as emergency food. In 1992, Abbott reported that Noni had been used as food, drink, medicine and dye.

The medicinal properties of *M. citrifolia* such as anticancer, antitumour, antidiabetics, antiageing, antimicrobial, etc. have fully been studied scientifically in abroad as a result several commercial products of Noni are available at present.

Noni is commonly referred to the species *M. citirfolia* and is also called as Indian Mulberry. It is also known in different names locally as Cheese Fruit, Forbidden Fruit, Headache Tree, Hog Apple, Mona, Mora de la India, Nino, Nona, Nono, Nonu, Nuna, Pain Bush, Pain Killer Tree, Pinuela, Wild Pine, etc. in various parts of the world. Noni is an evergreen tree found growing in open coastal regions at sea level (*Fig. 1*) and in forest areas up to about 1300 feet above sea level. It is often found growing along lava flows. Noni is identifiable by its straight trunk, large, bright green and elliptical leaves, white tubular flowers and its distinctive, ovoid, "grenade-like" yellow fruit.

The fruit can grow in size up to 12 cm or more and has a lumpy surface covered by polygonal-shaped sections (*Fig. 2*). The seeds, which are triangular shaped and reddish brown, have an air sac attached at one end, which makes the seeds buoyant. The mature Noni fruit has a foul taste and odour.

Fig. 1. Habit of *M. citrifolia*

Fig. 2. Fruit of *M. citrifolia*

Distribution of *Morinda*

The genus *Morinda* is present worldwide predominantly in tropical countries. It occurs in Africa, Australia, Barbados, Cambodia, Caribbean, Cayman Islands, Cuba, Dominican Republic, El Salvador, Fiji, Florida, French West Indies, Guadeloupe, Guam, Haiti, Hawaii, India, Jamaica, Java, Laos, Malaysia, Marquesas Islands, Philippines, Polynesia, Puerto Rico, Raratonga, Samoa, Seychelles, Solomon Islands, Southeast Asia, St. Croix, Surinam, Tahiti, Thailand, Tonga, Trinida and Tobago and Vietnam.

Survey of *Morinda* in south India indicated that 12 different species or varieties of *Morinda* are distributed throughout TamilNadu and Kerala. However, the species *M. tinctoria* is present abundantly in most parts of TamilNadu and in some parts of Kerala. To our surprise, *M. citrifolia* is not recorded in the study area of TamilNadu whereas it is profusely distributed in most part of the Kerala especially coastal region and also in the Mangalore area of Karnataka. Recently we recorded the presence of an unidentified *Morinda* species with large and leathery leaves in the Dhandakaranya forest area of Malkanagiri district in Orissa.

Taxonomy of *Morinda*

Family: Rubiaceae
Common name: Nuna, Noni, Cheese fruit, Koonjerung, Tokoonja, Great Morinda.

Derivation of the name *Morinda*: From Latin M*orus*, Mulberry and *indicus*, Indian referring to the similarity of the fruit to the Mulberry, *Morus indica*.

General description of the genus *Morinda*

Plant: Woody vines, lianas, shrubs, medium-sized trees or tall canopy trees; raphides present; auciliary thorns absent.

Stipules: Interpetiolar, free at base or interpetiolar, connate at base or sheathing (not splitting on one side), oblong or ligulate, spatulate or bifid, sheathing at base, with two small (non-foliose) lobes each side, persistent.

Leaves: Opposite or whorled, rarely ternate, 3 per node, long or short-petiolate; blades ovate, broadly elliptic, oblong or oblanceolate, chartaceous or stiffly chartaceous; *foliar pellucid glands* absent; *domatia* sparse or dense tufts of hairs or absent.

Inflorescence: Axillary or terminal, simple panicle or umbellate heads, not frondose, globose, not subtended by bracts.

Flowers: Bisexual, protandrous.

Calyx: Tubular, urceolate or hemispheric, extremely reduced, with small lobes or short tubular, caducous; lobes absent (calyx truncate or undulate) or 4 to 7, broadly triangular, minute. *Calycophylls* absent.

Corolla: Tube, more or less funnel shaped, hypocrateriform or narrowly infundibuliform, actinomorphic, white to cream-white; tube externally glabrous, internally glabrous or pubescent; without a pubescent ring inside; orifice annular thickening absent; lobes 4 to 7, valvate in bud, lanceolate or oblong, margin entire, obtuse or acute at apex.

Stamens: Alternate to the corolla lobes, included, partially exerted (only tips exerted) or exerted just beyond the corolla; anthers narrowly oblong or elongate, round at base, with acuminate extensions at apex, dehiscing by longitudinal slits, dorsifixed near the middle; filaments attached at the middle of the corolla tube, free at base, slender, long, shorter than corolla tube, equal, glabrous.

Style: Exerted just beyond the corolla, terete throughout, not fleshy or terete, not fleshy, capitate, glabrous; lobes absent or 2, ovate, oblong or linear, stigmatic surface located at style apex. exert

Ovary: Inferior, 2- or 4- locular, narrowly obovoid; placenta reduced, ovules basally inserted, 1 per locule.

Fruit: Densely clustered globose syncarp, fleshy.

Seeds: Vertical, medium-sized, ovoid to obovoid or reniform; wings absent.

Chemical properties of *Morinda*

A number of major compounds have been identified in the Noni plant such as scopoletin, octoanoic acid, potassium, vitamin C, terpenoids, alkaloids, anthraquinones (such as nordamnacanthal, morindone, rubiadin, andrubiadin-1-methyl ether, anthraquinone glycoside), β-sitosterol, carotene, vitamin A, flavones glycosides linoleic acid, alizarin, amino acids, acubin, L-asperuloside, caproic acid, caprylic acid, ursolic acid, rutin and a putative proxeronine. (Levand and Larson, 1979; Farine *et al.,* 1996; Peerzada *et al.,* 1990; Budhavari *et al.,* 1989; Moorthy and Reddy, 1970; Daulatabad *et al.,* 1989; Balakrishnan *et al.,* 1961; Legal *et al.,* 1994; Singh and Tiwari, 1976; Simonsen, 1920; Heinicke, 1985). The dominant substances in the fruit are fatty acids, while the roots and bark contain anthraquinone. The seed of *M. citrifolia* contains 16.1% Oil. The main fatty acid components of the oil were linoleic (55%), Oleic (20.5%), Palmitic (12.8%), Ricinoleic (6.8%) and Stearic (4.9%) (Dualatabad *et al.,* 1989; Seidemann, 2002).

A research group led by Chi-Tang Ho at Rutges University in the USA is searching for new novel compounds in the Noni plant. They have successfully identified several new flavonol glycosides, and iridoid glycoside from the Noni leaves, trisaccharide fatty acid ester, rutin and an asperolosidic acid from the fruit. Two novel glycosides and a new unusual iridoid named citrifoliniside have been shown to have inhibiting effect on AP-1 trans activation and cell transformation in the mouse epidermal JB6 cell lines (Wang *et al.,* 1999; Sang *et al.,* 2001a and b; Liu *et al.,* 2001; Wang *et al.,* 2000). Further, 23 different phytochemicals were found in Noni besides, 5 vitamins and 3 minerals (Duke, 1992).

General use of *Morinda*

The species of *Morinda* especially *M. citrifolia* has been reported to have a broad range of health benefits for cancer, infection, arthritis, asthma, hypertension, and pain (Whistler, 1992). The roots, stems, bark, leaves, flowers, and fruits of the Noni are all involved in various combinations in almost 40 known and recorded herbal remedies (Bruggnecate, 1992). Additionally, the roots were used to produce a yellow or red dye for tapa cloths and fala (mats), while the fruit was eaten for health and food (Aragones *et al.,* 1997).

Medicinal use of *Morinda*

The Polynesians utilized the whole Noni plant for herbal remedies. The fruit juice is in high demand in alternative medicine for different kinds of illnesses such as arthritis, diabetes, high blood pressure, muscle aches and pains, menstrual difficulties, headaches, heart disease, AIDS, cancers, gastric ulcer, sprains, mental depression, senility, poor digestion, arteriosclerosis, blood vessel problems, and drug addiction. Scientific evidence of the benefits of the Noni fruit juice is limited but there is some anecdotal evidence for successful treatment of colds and influenza (Solomon, 1999). Allen and London (1873) published one of the earliest articles on the medicinal benefits of Noni in which they reported the ethnobotanical properties of Noni and the use of fruit. Abbott (1985), a former botanical chemist at the University of Hawaii, stated the use of Noni for diabetes, high blood pressure, cancer, and many other illnesses (Abbott, 1985; Dixon *et al.,* 1999). Noni was a traditional remedy used to treat broken bones, deep cuts, bruises, sores and wounds (Bushnell *et al.,* 1950). Morton (1992) gave numerous references for medicinal uses of Noni. In addition, Polynesians are reported to treat breast cancer and eye problems.

Biological properties of Noni

Antimicrobial activity

Several anthraquinone compounds in Noni roots are all proven antibacterial agents. These compounds have been shown to fight against infectious bacterial strains such as *Pseudomonas aeruginosa, Proteus morgaii, Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Salmonella* sp. and *Shigella* sp. (Mohtar *et al.,* 1998; Jayasinghe *et al.,* 2002). These antibacterial elements within Noni are responsible for the treatment of skin infections, colds, fevers, and other bacterial-caused health problems (Atkinson, 1956, Ancolio *et al.,* 2000). Bushnell reported on the antibacterial properties of some plants found in Hawaii, including Noni. He further reported that Noni was traditionally used to treat broken bones, deep cuts, bruises, sores and wounds. Extracts from the ripe noni fruit exhibited antibacterial properties against *P. aeruginosa, M. pyrogenes, E. coli, Salmonella typhosa, Salmonella montevideo, Salmonella schottmuelleri, Shigella paradys* (Bushnel *et al.,* 1950).

Leach *et al.* (1988) demonstrated that acetone extracts of *M. citrifolia* showed antibacterial activity. The wide spread medicinal use of these plants would suggest that they do contain pharmacologically active substance and alternative methods of extraction and screening should be carried out to find the major bioactive components in the plants for the purpose of new drug development. Locher *et al.* (1995) reported that selected plants including *M. citrifolia* have a history of use in Polynesian traditional medicine for the treatment of infectious disease. The scopoletin, a health promoter of Noni inhibit the activity of *E. coli* that is commonly associated with outbreaks resulting in hundreds of serious infection and even death. Noni also helps stomach ulcer through inhibition of the bacterium *H. pylori* (Umezawa, 1992).

Another species of *Morinda* namely *M. tinctoria* have excellent antimicrobial activity against various human and plant pathogenic bacteria, and fungi. The chloroform fruit extract of *M. tinctoria* exhibited high antimicrobial activity against the human pathogens such as *Pseudomonas aeruginosa, Staphylococcus aureus, Escherichia coli* and *Candida albicans*. Further the same extract also significantly inhibited the spore germination and mycelial growth of plant pathogenic fungi *viz., R. solani, B. oryzae, F. oxysporum* and *C. lunata* (Surendiran, 2004).

A compound isolated from Noni roots named 1-methoxy-2-formyl-3-hydroxyanthraquinone suppressed the cytopathic effect of HIV infected MT-4 cells, without inhibiting cell growth (Umezawa, 1992).

Noni has been found to kill *Mycobacterium tuberculosis*. A concentration of extracts from Noni leaves killed 89 of the bacteria in a test tube, almost as effective as a leading anti-TB drug, Rifampicin, which has an inhibition rate of 97% at the same concentration. Although there had been anecdotal reports on the native use of Noni in Polynesia as a medicine against tuberculosis, this is the first report demonstrating the antimycobacterial potential of compounds obtained from the Noni leaf (American Chemical Society, 2000).

Antitumour and anticancer activities

The anticancer activity from alcohol-precipitate of Noni fruit juice (Noni-ppt) on to lung cancer in c57 B1/6 mice has been presented in the 83 Annual Meeting of American Association for Cancer Research. The noni-ppt significantly increased the life of mice up to 75% with implanted Lewis lung carcinoma as compared with the control mice (Hirazumi *et al.,* 1994). It was concluded that the Noni-ppt seems to suppress tumor growth directly by stimulating the immune system (Hirazumi *et al.,* 1996). Improved survival time and curative effects occurred when Noni-ppt was combined with sub optimal doses of the standard chemotherapeutic agents such as adriamycin (Adria), cisplatin (CDDP), 5-flourouracil (5-FU) and vincristine (VCR), suggesting important clinical application of Noni-ppt as a supplemental agent in cancer treatment (Hirazumi and Furusawa, 1999). These results indicated that the Noni-ppt might enhance the therapeutic effect of anticancer drugs. Therefore, it may be a benefit to cancer patients by enabling them to use lower doses of anticancer drugs to achieve the same or even better results.

Wang *et al.* (2002) demonstrated that the cytotoxic effect of Tahitian Noni

Juice (TNJ) on cultured leukemia cell line at various concentrations. They also observed the synergistic effects of TNJ with known anticancer drugs. At a sub-optimal dose, both prednisolone and TNJ could induce apoptosis. When the dose of prednisolone was fixed, the dose of TNJ increased. Therefore TNJ is able to enhance the efficacy of anticancer drugs such as predinosolone. When a single dose of taxol induced a lower percentage of apoptosis in leukemia cells, TNJ enhanced the rate of apoptosis.

Hiramatsu *et al.* (1993) reported the effects of over 500 extracts from tropical plants on the K-Ras-NRK cells. Damnacanthal, isolated from Noni roots is an inhibitor of Ras function. The Ras oncogene is believed to be associated with the signal transduction in several human cancers such as lung, colon, pancreas, and leukemia. Two glycosides extracted from Noni-ppt were effective in inhibiting cell transformation induced by TPA or EGF in the mouse epidermal JB6 cell line. The inhibition was found to be associated with the inhibitory effects of these compounds on AP1 activity. The compounds also blocked the phosphorylation of c-Jun, a substrate of JNKs, suggesting that JNKs are the critical target for the compounds in mediating AP1 activity and cell information (Liu *et al.,* 2001).

Insecticidal activity

An ethanol extract of the tender Noni leaves induced paralysis and death of the human parasitic nematode worm, A*scaris lumbricoides* within a day (Raj, 1975). Noni has been used in the Philippines and Hawaii as an effective insecticide (Morton, 1992; Murdiatia *et al.,* 2000).

Analgesic activity

Younos *et al.* (1990) tested the analgesic and sedative effects of the Noni extract and observed a significant dose-related central analgesic activity in the treated mice. The analgesic efficacy of the Noni extract is 75% as strong as morphine with free of side effects. The TNJ was tested for its analgesic properties by the twisted method animal model using mice. Clearly the analgesic effect of TNJ in mice showed a dose-dependent manner. The analgesic effects of each TNJ group are statistically significant compared with that in the control group. Data from this experiment have clearly indicated that the TNJ was able to make the animals tolerate more pain.

Immunological activity

An alcohol extract of Noni fruit at various concentrations inhibited the production of tumor necrosis factor-alpha (TNA-α), which is an endogenous tumor promoter. Therefore, the alcohol extract may inhibit the tumor promoting effect of TNF-α (Hokama, 1993). Hirazumi and Furusawa (1999) found that Noni-ppt contains a polysaccharide-rich substance that inhibited toxic effects in adapted cultures of lung cancer cells, but could activate peritoneal exudate cells to impart profound toxicity when co-cultured with the tumor cells. This suggested the possibility that Noni-ppt may suppress tumor growth throughout the activation of host immune system. Noni-ppt was also capable of stimulating the release of several mediator from murine effector cells, including TNF-α, interleukin-1 beta (IL-1β), IL-10, IL-12, interferon-gamma (IFN-γ) and nitric oxide (NO) (Hirazumi and Furusawa, 1999). Hokama (1993) separated ripe noni fruit juice into 50% aqueous alcohol and precipitated fractions that stimulated the BALB/c thymus cells in the (^{3}H) thymidine analysis. It is suggested that inhibition of Lewis lung tumors in mice, in part, may have been due to the stimulation of the T-cells immune response. Wang *et al.* (2002) observed that the thymus in animals treated with TNJ was enlarged. The wet weight of the thymus was 1.7 times that of control animals at the seventh day after drinking 10% TNJ in drinking water. The thymus is an important immune organ in the body, which generates T cells, involved in the ageing process and cellular immune functions. TNJ may enhance immune response by stimulating thymus growth, and thus affecting anti-ageing and anticancer activities, and protecting people from other degenerative diseases.

Allergenicity and toxicity

Studies sponsored TNJ *Morinda* Inc, marker of TNJ were focused to investigate the acute toxicology of TNJ. About 15000 mg/kg was administered via gavage and the animals were observed and no adverse clinical signs were noted. No signs of gross toxicity were seen in the organs after necropsy. Two studies using guinea pigs were performed to assess the allergenic risk of TNJ. Both study designs included an induction phase and a rest period, followed by a challenge with TNJ. Results of this study have revealed that there were no allergic reactions to TNJ (Kaabeer, 2000).

Similarly a 13-week oral toxicity study in rats indicated that the No-Observable-Adverse Effect Level (NOAEL) was above 20 ml of 4 times concentrated TNJ/kg/day. This is equivalent to 80 ml TNJ kg/day. Perceptively, this amount is 8% of the animal's body weight (Sang *et al.*, 2001a and b). The major ingredients in TNJ, Noni fruit, have been safely consumed in other parts of the world for several hundred years (Whistler, 1992; Bruggnecate, 1992; Seemann and Flora, 1866; Dengener, 1973; Rock, 1913; Stone, 1970; Sturtevant, 1919; Terra, 1996; Turbott *et al.,* 1949; Uhe, 1974; Wilder, 1934; Yuncker, 1943). TNJ is demonstrated to be safe for human consumption through extensive chemical, microbiological, and toxicological analysis and evaluation.

Antioxidant activity

In general consuming fruits and vegetables reduces free radicals-induced oxidative damage and the consequent lipid peroxidation and therefore reduce the cancer risk (Wang and Leiher, 1995; Diplock *et al.*, 1998). It is believed that fruits and vegetables are major sources for antioxidants (Weisburer *et al.,* 1997; Nishikimi *et al.*, 1972). Noni is a medicinal plant that helps the human in different health conditions. It was believed that the Noni fruit juice contained significant level of antioxidants. This has been proved scientifically by the analysis of TNJ. The study was designed to measure how the TNJ scavenged super oxide anion radicals (SAR) and quenched lipid peroxides (LPO) by TNB assay and LMB assay, respectively (Auerbach *et al.*, 1992; Wang and Su, 2001). SAR scavenging activity was examined *in vitro* by *Tettrazolium nitroblue* (TNB) assay. The SAR scavenging activity of TNJ was compared to that of three known antioxidants; vitamins C, grape seed powder, and pyncogenol at the daily dose per serving level recommended by US RDA's or manufacturer's recommendations. Under the experimental conditions the SAR scavenging activity of TNJ was shown to be 2.8 times that of vitamin C, 1.4 times that of pyncogenol and 1.1 times that of grape seed powder. Therefore TNJ has a great potential to scavenge reactive oxygen free radicals (Wang and Su, 2001).

Anti-inflammatory activity

Evidences are indicating that COX-2 inhibitors may be involved in breast, colon, and lung cancer development (Yau *et al.,* 2002; Takahashi *et al.,* 2002; Langman *et al.,* 2000). Research on anti-inflammatory has shown that the selectivity of COX-2 inhibition of TNJ is comparable with that of Celebrex. The discovery of the selective COX-2 inhibition of TNJ is very significant since TNJ is a natural fruit juice without side effects this is the first scientific evidence for a strong anti- inflammatory activity in TNJ, which may also be one of the mechanisms of cancer prevention (Zhang *et al.,* 1994). The anti-inflammatory activity was observed in an acute liver injury model in female SD rats induced by CCl4. A decrease in inflammatory foci and lymphocyte surrounding central vein areas were observed at 6 h post CCl4 administration in animals pre treated with 10% TNJ for twelve days in drinking water compared with CCl4 without TNJ (Wang *et al.,* 2001).

Research from this clinical trials indicated that cigarette-smoke is not only involved in cancer but also involved in pulmonary, heart and other degenerative diseases. However, drinking TNJ was beneficial for the prevention of heart, lung, and brain diseases as well as delaying the ageing processing, and maintaining overall good health.

Wound healing activity

It is well established that the *Morinda* leaf and fruit extracts are effective in healing the wounds. Surendiran (2004) studied the wound healing property of *M. tinctoria* using the animal model. The application of chloroform fruit extract of *M. tinctoria* topically on the excision wound surface of two different doses accelerated the wound healing process by decreasing the surface area of the wound. The fruit extracts of *M. tinctoria* at 20 mg/ml significantly healed the wound in rats within 15 days where complete healing was observed against 60% in untreated control. On day 3, all the treated animals exhibited considerable increase in the percentage of wound contraction as compared to control. The wound contraction was significantly increased in the subsequent days due to treatment of fruit extract at 10 and 20 mg/ml as compared to control.

Conclusions

The nutritive and medicinal values of the *Morinda* spp. have been clearly established with the research outcome that was completed in different laboratories in abroad. In India, the awareness on the importance of Noni has just come with the public and also with the scientific community. Hopefully furthermore useful and vital information will be emerged out of the research activities initiated on this wonder tree, Noni. Since the already published literature of various animal studies and clinical trials has clearly proved beyond doubt for its medicinal importance and nutritional significance, it will be in the limelight in both researches as well as in alternative medical arena in the coming days.

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Effect of growth regulators in rooting of stem cuttings of *Morinda citrifolia* var *citrifolia* in Bay Islands

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Abstract : The experiment was carried out to study the response of growth regulators on root formation of *Morinda citrifolia*. The soft wood and semi hard wood cuttings were treated with different concentrations by quick dip method using IBA (Indole butyric acid) and NAA (Naphthalene acetie acid) separately and in combination (1:1). The results have clearly indicated that 400 ppm of IBA has given maximum percentage of rooted cuttings.

Introduction

Noni, *Morinda citrifolia* Linn. and is also known as Indian Mulberry, is one of the important fruit plants of Rubiaceae family. Locally known as Lorang, Burmaphal, Pongeephal and Suraogi by the tribals of Andaman and Nicobar Islands (Singh *et al.*, 2005a). Indigenous to South East Asia, and was domesticated and cultivated by Polynesians, first in Tahiti and the Marquesas and eventually in the Hawaiian Islands. Today, Noni grows in most regions of the South Pacific, India, the Caribbean, South America and the West Indies. Noni's broad proliferation gives testimony to its value to traditional cultures. In Andaman and Nicobar Islands, it is widely found throughout the coastal region and along the fences and the roadside. Due to its adaptability to wide range of environmental conditions, the Noni plant grows even in infertile, acidic, alkaline, sea inundated land and also prefers to grow even in the dry and wet areas. The tropical humid climate is very much suitable for its cultivation. It can also be called as Kalpavriksha as its every part has commercial importance.

The interesting fact is that the tribes i.e. Nicobari tribes of these islands have very long association with this plant, as they have been using different parts as medicine for different purposes. They consume this fruit raw with salt as well cooked as vegetable. Nicobarese mix the leaves of *Tylophora tenuissima* with *Morinda citrifolia* leaves, crush them, mix with water and take as febrifuge and apply on body to relieve pain. Equal quantities of *Alchornea rugosa* (Lour.) and leaves of *Morinda citrifolia* are ground into paste with little water and given internally by the Nicobarese as a cure for chest pain. A mixture containing leaves of *Colubrina* *asiatica* (Linn.), *Ficus ampelas* and *Morinda citrifolia*, boiled in coconut oil and pig fat were used in bandages to treat fracture. The leaves and fruits are eaten by the Nicobarese and Shompen tribals and pulp of the fruit is used for cleaning hair. The roots and leaves in combination with several other ingredients and coconut milk are made into paste to treat bone fracture. The leaves made into paste with the leaves of *Tylophora tenuissima* and coconut oil are rubbed on body by them for relieving pain during fever (Dagar and Singh, 1999).

The *Morinda citrifolia* is gaining popularity among the farmers and local communities due to its good market value, and is also gaining more significant importance because of tolerant to salinity and brackish water (Singh *et al.*, 2005b). *Morinda citrifolia* is naturalized in almost all parts of the islands, as it grows in dry to wet and in sea level of about 1500 feet elevation. The production of large number of saplings from the limited elite pedigree tree could be possible within a short period and could meet growing demand by the farmers. The true to the pedigree plants thus produced in the country can enhance the foreign exchange earning capacity. Though it has greater demand hitherto, no efforts on its propagation have been made owing to its hollow nature of stem. Its domestication is possible only by standardizing the propagation techniques.

The primary disadvantage of seed propagation is that it takes more time for germination and also variation in fruits, whereas, stem cuttings can be rooted early and with no variations in fruits. In order to overcome the problem with seeds, vegetative propagation could be tried as potential means of propagation of quality planting stock. The goal of vegetative propagation is to get the best planting stock with highest genetic quality material (Hartman and Kester, 1983; Nanda, 1970; Wright, 1975). For making plants through cuttings, it is essential to know the proper techniques for vegetative propagation of this crop. Auxins like Naphthalene acetic acid and Indole butyric acid have been reported to show quick and better rooting in vegetative propagation of many fruit crops viz. guava, grapes, ber, custard apple, (Shanmugavelu, 1987; Singh and Singh, 1973; Banker, 1989; Dhua *et al.*, 1982). For getting better, quick and more number of rooted cuttings it is necessary to see the effect of different hormones on the success and establishment of cuttings. Present investigation was carried out to find out the type of cutting and effective concentration of growth regulators for proper rooting and establishment as a healthy plant.

Materials and Methods

The present experiment was conducted during March-June, 2005 at Central Agricultural Research Institute, Port Blair which is located between 6°45' and 13° 41'N latitudes and 92°12' and 93°57'E longitudes in the North–South direction in the Bay of Bengal. The soft wood and semi hard wood cuttings of 20 cm long and 2.0 to 3.0 cm in diameter from two year old shoots of approximately 20 years old trees located near the Institute was used for the study. Soft wood cuttings (with a pair of leaves on the tip) and semi hard wood cuttings (with no leaf on stem) were taken and dipped for 15 seconds in 2000, 4000 and 6000 ppm solutions of IBA and NAA separately and in combination (1:1) while cuttings under control were treated with distilled water. These were replicated in quadruplicate under each of these concentrations. Twelve weeks after planting of the cuttings, observations on various parameters were recorded. The rooted cuttings were transplanted on the same day after the root studies and a further observation in respect of percentage of survival was recorded.

Results and Discussion

The results presented in Table 1 clearly show that the cuttings treated with 2000, 4000 and 6000 ppm of IBA and NAA separately and in combinations promoted root and shoot growth and establishment. Percentage of rooting, number of primary roots, length of longest primary root and length of basal portion of cuttings showing roots were significantly high over control when the cuttings were dipped in 4000 ppm IBA. Nevertheless, it was significantly more effective compared to 2000 ppm IBA. Similar differences were also noted among the concentrations of NAA and combination of IBA and NAA where 4000 ppm was more effective than 2000 and 6000 ppm of same growth regulator.

Table 1. Effect of different levels of growth regulators on root formation in the cuttings of *Morinda citrifolia*

Treatments	Rooting (%)	No. of primary roots	Length of the primary roots (cm)	Diameter of the thickest root (cm)
IBA				
2000 ppm	66.87	13.27	11.58	0.09
4000 ppm	93.12	18.25	17.55	0.50
6000 ppm	75.00	13.88	14.14	0.06
NAA				
2000 ppm	64.37	15.32	14.48	0.07
4000 ppm	73.13	17.22	16.96	0.03
6000 ppm	73.75	12.76	15.21	0.04
IBA+NAA				
2000 ppm	65.62	13.34	13.41	0.03
4000 ppm	76.62	14.94	15.57	0.03
6000 ppm	69.37	14.14	15.02	0.03
Control	33.12	10.08	11.44	0.02
C.D at 5%	3.68	1.15	1.41	NS

Continued in next page

Continued Table 1

Length of basal portion of cutting	Secondary rooting (%)			Callus production (%)				Cuttting establish-ment (%)
	Profuse	Countable	Nil	Profuse	Moderate	Poor	Nil	
12.67	8.75	90.37	0.87	27.75	55.19	15.12	10.0	47.79
18.73	53.27	46.72	0.00	62.0	21.65	14.56	1.76	72.35
15.22	35.4	64.32	0.26	36.25	42.4	17.75	3.59	58.34
15.54	47.84	59.00	0.15	32.5	42.28	20.35	48.7	48.37
18.15	47.41	52.06	0.52	41.5	22.15	25.35	70.7	58.35
16.48	37.25	62.4	0.34	36.25	27.86	27.97	7.85	53.4
15.2	59.14	40.55	0.3	30.00	59.14	6.60	4.25	43.42
16.6	57.59	41.76	0.34	52.62	19.26	17.82	10.29	49.4
16.12	48.29	51.52	0.18	23.30	27.25	28.00	21.45	55.92
13.09	0.00	99.00	1.00	12.86	39.41	34.50	13.22	37.1
1.15	16.22	0.62	0.13	0.05	14.9	0.61	0.68	0.78

Combination of IBA and NAA synergetically promoted secondary root to form profuse network and 4000 ppm IBA proved to be the next best. However, profuse callusing was obtained by the use of 4000 ppm IBA. This trend was confirmed with the work reported by Cameron and Rook (1974), Nanda (1970) and Banker (1989). However, high level of auxins associated with comparatively reduced root growth would have retarded the carbohydrate metabolisation and caused nutritional imbalance as suggested by Spiegel (1954) and Nanda *et al.* (1974). IBA translocates poorly and remains near the site of application, and so it was found to be one of the best rooting stimulator.

The performance of soft wood cuttings with respect to percentage of rooting, number of primary roots, percentage of secondary rooting and callus production was significantly superior over semi hard wood cuttings (Table 2). However, not much difference was recorded in length, diameter of the root and establishment of the cuttings. The superiority of the soft wood over semi hard wood cuttings in respect of rate and degree of rooting, growth of the roots and shoots shows that the region of the mother shoot is a major factor in regeneration through stem cutting. These results are in conformity with those of Garner and Hatcher (1958) who found that the young and juvenile shoot portion were superior to mature forms in the regeneration of cuttings in the species they worked with. The marked superiority of soft wood cuttings lies in their ability to form missing parts very readily and profusely as noted by the production of callus and roots on the cuttings. On the other hand, in the case of semi hard wood cuttings, these processes were very slow and that too in relatively small percentage.

Table 2. Effect of growth regulators on root formation in soft and semi hard wood cuttings of *Morinda citrifolia*

Parameters	Type of cuttings		C.D at 5%
	Soft wood	Semi hard wood	
Rooting (%)	71.75	66.25	1.61
No. of primary roots	15.32	13.32	0.51
Length of longest root in (cm)	14.69	14.39	NS
Diameter of the thickest root (cm)	0.12	0.06	NS
Length of basal portion of cuttings showing root (cm)	16.01	15.56	NS
Secondary rooting (%)			
(a) Profuse	48.32	29.23	7.25
(b) Countable	57.29	70.25	0.27
(c) Nil	0.38	0.42	NS
Callus production (%)			
(a) Profuse	37.35	33.78	0.29
(b) Moderate	33.46	37.86	NS
(c) Poor	21.96	19.52	0.27
(d) Nil	7.21	8.82	0.29
Cuttings establishment (%)	90.00	98.10	0.28

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The effect of growth regulators and its combination with nicking on the germination of Indian Mulberry (*Morinda citrifolia L.*)

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Key words : *Morinda citrifolia,* Gibberllic acid, Indole acetic acid, Indole butyric acid, nicking, germination.

Abstract : A study was carried out to investigate the effect of growth regulators and its combination with nicking on the germination of Indian Mulberry (*Morinda citrifolia L.*). Seeds were nicked first and then treated with growth regulators. Treated seeds were sown in poly bags (with the size of 20 x 15 cm) under open condition for germination. 100 seeds of *M. citrifolia* in each treatment with three replications were used. The highest germination was recorded in treatments where the seeds were nicked and then treated with Gibberllic acid (GA) at 1000 ppm for a period of 24 h. Germination was observed to be enhanced by nicking and GA treatment and poor response was observed in control. Results of this study may serve as an useful information in the production and improvement of the tree species, as knowledge on seed germination requirements are a critical factor in seedlings production.

Introduction

Indian Mulberry (*Morinda citrifolia* L.) described as wonder, sacred and miracle tree brought from paradise have powerful abilities to help with variety of health enhancing properties. This is commercially called as Noni, which grows widely in tropic and sub tropic region where it is relatively wet from about 1500 MSL (Nelson, 2003). It can be found in coast, in open low land, grass lands and disturbed forests of the dry areas. Noni is commercially propagated through seeds because of its deep root nature and high resistance to pests and diseases. In field, the growth and management of Noni is in the hands of local farmers. Nursery phases are an important part of the operation in the cultivation of many tropical tree crops. Keeping the seedlings growing in the nursery until they are big enough, tougher and more vigorous save seeds, space, water and reduces the risk of damage or loss of the plant

(Ayodele, 1997). Noni seeds are reddish-brown, oblong-triangular, and have a conspicuous air chamber which makes them buoyant and hydrophobic. The durable, water-repellant, fibrous seed coat is very tough, relatively thick, and covered with cellophane-like parchment layers. Noni seeds require hot, wet conditions for optimum germination. Untreated seeds require several months to a year before natural germination takes place, but their germination can be reduced to a month or so by using some growth regulators and scarification technique (like Nicking - a form of seed scarification which can reduce the time required for Noni seeds to germinate. A small opening is created at the tip of the seed, near the embryo, which allows water and air to get contact with the embryo). So this study is therefore designed with the effect of growth regulators and its combination with nicking on the seed germination of *M. citrifolia.*

Materials and Methods

The experiment was carried out at Centre for Organic Indian Noni (COIN), TamilNadu, India. Noni fruits (fully ripened, soft and white coloured fruits naturally fallen on to the ground) were collected and brought from Kottayam district of Kerala. The pulp of the Noni fruit was separated from the seeds. After the pulp separation, the Noni seeds were dried under the sun for 2 h with occasional stirring and shade dried for another 24 h.

The shade dried seeds were nicked first and then treated with growth regulators. The treated seeds were sown in polybags filled with 1:1:1 ratio of soil media which contains red soil, sand and farmyard manure respectively. Uniform sizes (20 x 15 cm) of polybags were used with a capacity of 1.5 kg of soil media.

Details of Experiment

The experimental design followed was Completely Randomized Block Design (CRBD). There were seven treatments with three replications each. Each treatment carried 100 seeds. The dependent variables were measured at 3, 6 and 9 weeks after sowing. The treatments were as follows

T1 - Control
T2 - Seeds treated with GA at 1000 ppm for 24 h
T3 - Seeds treated with Indole acetic acid (IAA) at 1000 ppm for 24 h
T4 - Seeds treated with Indole butyric acid (IBA) at 1000 ppm for 24 h
T5 - Nicking + T2
T6 - Nicking + T3

T7 - Nicking + T4

T8 - Nicking alone

The data were subjected to the Analysis of Variance (ANOVA). If there were significant differences among treatments, means separation was done using the Duncan's Multiple Range Test (Steel and Torie, 1980).

Results and Discussion

The data on the effect of various treatments on the seed germination are presented in Table. The percentage of seed germination showed variations among the treatments. T5 (Nicking + GA at 1000 ppm for 24 h) treatment registered the germination of 27% and 81% at the end of 3rd and 9th week after sowing respectively. All other treatments were found to be comparable with each other. It was observed that *M. citrifolia* seed germination was highest in T5. This might be due to scarification (Nicking) which allowed the seed to imbibe causing the seed coat to rupture, hence speeding up normal and uniform germination in a shorter time and at the same time GA could have enhanced the elongation of the radicle and pushed through the endosperm and nicked seed coat. Even the T8 (Nicking alone) treatment

Table. Effect of growth regulators and its combination with nicking on the seed germination of the *Morinda citrifolia*

Treatments	Per cent germination		
	3 WAS	6 WAS	9 WAS
T1	0c	14c	33c
T2	15b	36b	58b
T3	5bc	27bc	37bc
T4	5bc	32bc	52b
T5	27a	63a	81a
T6	8c	25bc	46bc
T7	9bc	27bc	53b
T8	7bc	29bc	56b

WAS-Weeks after sowing

Mean in a column with similar letters are not significantly different at 5% level of probability according to the Duncan Multiple Range Test.

was found to be comparable with GA treatment. Pandey and Sinha (2001) reported that GA induced the synthesis of α-amylase and other hydrolytic enzymes during the early stages of seed germination. Railton (1982) also found the accelerating effect of GA in seed germination of *Morus indica*. Kale

(2001) however, rightly stated that hard coated seeds often gave poor germination but this does not mean that the seed is of low quality because the hard seed coat condition can be broken allowing germination. So nicking alone has also got comparable percentage of germination. The germination percentage of the seeds treated with IAA and IBA were low when compared to GA treatment. This might be due to the seeds not withstanding more concentration of IAA and IBA. Sircar (1971) worked on *Crotolaria juncea* with IBA and IAA in the range of 1000-2000 ppm and noted delay and decrease in the percentage of germination.

The results obtained will be useful in commercial rapid seedling production in large scale which would be essential for anti-desertification. This information could ultimately help in the sustainable development of arid zones.

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S. Vezhavendan
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An approach to obtain true Noni through cuttings

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Keywords : *Morinda citrifolia,* tip cutting, semi hard wood, hard wood, propagation

Abstract : Cutting is a method to propagate Noni by the use of detached plant parts which when placed under favourable conditions develop into a complete plant resembling in all characteristics to the parent from which it was taken. Next to seeds this is the method commonly used in Noni which is also very quick and economical. A study was conducted at COIN (Centre for Organic Indian Noni, TamilNadu, India) to develop a standard vegetative propagation technique through cuttings. Among the different types (Tip, Semi hard wood and Hard wood cutting) with different number of nodes (2, 3 and 4), Hard wood cuttings with 4 nodes performs better and gives more success percentage and healthy planting material.

Introduction

Noni is a wonder crop expecting our respect to become a commercial orchard crop under cultivation. Noni, commonly – Indian Mulberry and scientifically *Morinda citrifolia* L. belongs to the coffee family Rubiaceae. Plants naturalized to the tropics, subtropics especially under ever green (rain) forest climate. Different genotypes (Species and Botanical varieties) and ecotypes varying in yield and quality parameters are there all over the world. To convert this wild crop into domestic crop we have to find an elite plant and it should be multiplied vegetatively to maintain its parent's nature. Cuttings are the very common, easy and cheapest method of vegetative propagation.

Healthy parent plant, part of stem, size of the stem, length of cuttings, number of nodes, rooting media, growing structure are considered to influence success percentage and production of healthy plantlets. In this experiment we mainly considered types of cuttings and number of nodes.

Materials and Methods

In order to find specific type of stem cutting and number of nodes per cutting required, a field experiment was conducted at Centre for Organic Indian Noni, TamilNadu, India.

Preparation of cuttings : Cuttings of 15-20 cm length with uniform pencil thickness were selected and prepared from an ideal mother plant. Selected cuttings were carefully prepared by giving a slanting cut (45°) at the bottom to expose more cambial area to absorb more moisture and form roots. Bottom cuts were given just immediate to the nodes and planted in slanting position.

Rooting media and growing condition : Using a mixture of sand and vermicompost (1:1) raised beds were prepared under 50% shade net with poly tunnels.

Planting of cuttings : Prepared cuttings were planted at 10-15 cm apart with half portion of cutting inside the soil and taken care that the lower buds were not damaged. The soil was thoroughly pressed around the cuttings and watered regularly to keep it moist.

Experimental design : Experimental design followed was Completely Randomized Block Design (CRBD). There were nine treatments with three replications. Each treatment was with 100 numbers of cuttings.

Treatment details : Three different types of cuttings with 3 different node numbers were used. The treatment details are presented in Table 1.

Table 1. Details of treatment

Treatments	Type of cutting	Number of nodes
T1	Tip cutting	2
T2	Tip cutting	3
T3	Tip cutting	4
T4	Semi hard wood	2
T5	Semi hard wood	3
T6	Semi hard wood	4
T7	Hard wood	2
T8	Hard wood	3
T9	Hard wood	4

Results and Discussion

The results on success percentage in relation to type of cuttings and number of nodes revealed significant differences among treatments (Table 2).

It was observed that the success percentage was maximum (82%) in T 9 (Hardwood cuttings with 4 nodes) and the minimum (2%) in T 1 (Tip cuttings with 2 nodes). Type of cuttings influenced more effectively than number of nodes. Type of cuttings are influenced by the factors like nutritional status of stem, age of the plant, etc. Hard wood stems with high amount of carbohydrate and less Nitrogen lead to better success. According to Kumar (2000) factors influencing shoot and root growth in cuttings are food supply (ratio of carbohydrate to nitrogen in the stems), age of the plant, type of cuttings and environmental conditions (water, temperature, relative humidity, light and rooting media).

Noni is the perennial plant, in which stored energy is more in hard wood stem than in other parts. This is the plant with typical hollow stem, which is weaker and with less cambial tissue wherever the stem is not well matured. Cambium is the primary tissue for the development of vascular tissue and root system. So the hard wood stem is with less hollow and with more cambial tissue when compared to soft wood and tip cuttings. Stored energy is more in hard wood cuttings to enhance shoot sprout and root initiation.

Gill *et al*. (1998) reported that very common type of cutting propagation in perennial plant is hard wood cutting. Hard wood cuttings are prepared from the trees when tissues are fully mature. The shoots of about one year old or more can easily be used for preparing hard woodcuttings. It is now recognized

Table 2. Per cent success in different treatments

Treatments	Days after planting					Transplanted successfully to polybags (%)
	10	20	30	40	45	
T1	58	25	3	2	2	2
T2	64	26	6	5	5	5
T3	67	28	7	7	7	7
T4	72	34	14	12	12	12
T5	82	56	38	34	34	34
T6	78	57	41	40	40	40
T7	86	69	61	58	58	58
T8	87	76	74	73	73	73
T9	92	84	82	82	82	82

that the nutrition–status of stock plants exerts a strong influence on the development of roots and shoots from the cutting. Cuttings from plants with high C/N ratio produce more roots but feeble shoots as against those containing ample carbohydrate and higher nitrogen that produce fewer roots but stronger shoots. Cuttings from succulent stems with very low carbohydrate and high nitrogen do not succeed (Singh, 2000).The type of stem cutting is arbitrary, but 20 to 40 cm cuttings are manageable and effective in Noni (Nelson, 2003).

The results of the above study revealed that the hard wood cuttings with four nodes are the best method to propagate Noni through cuttings. This can be applied at field level for mass multiplication of ideal true to type plants through stem cuttings.

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Influence of Gibberllic acid on seed germination in Noni (*Morinda citrifolia* Linn.) of Andamans

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Key words : *Morinda citrifolia,* Gibberllic acid, concentration, duration, germination

Abstract : Freshly extracted seeds of Noni (*Morinda citrifolia* Linn.) were soaked in water and Gibberllic acid (GA) solutions of 400, 600, 800, 1000 and 1200 ppm concentrations for 12, 24 and 36 h and were sown in pots for germination. GA at 800 ppm followed by 1000 and 1200 ppm induced significantly higher percentage of germination (91.06, 87.9 and 80.4% respectively) against water treatment (56.4%). Soaking for 24 h was best in this respect. Every increase in concentration of GA significantly decreased the time taken for germination (58.3 to 9.0 days), increased the height of seedlings (16.05 to 19.23 cm) and number of leaves per plant (9.24 to 13.10). Similarly, more duration of soaking was better for these traits. However, survival of seedling was adversely affected by GA treatments at all the concentrations and duration.

Introduction

Seeds are programmed to germinate at specific temperature and moisture conditions to insure that the seedlings will survive. If germination mix is too wet the seeds can rot before the plant has broken through the surface. If soil temperature is too warm or too cold, the seeds will just sit. In some cases the dormancy lock will be broken only if the required temperature fluctuations have been achieved for a specific period of time. The temperature coding for some seeds is so complex, that no one has succeeded in artificially breaking the dormancy code. Incomplete pollination results in a high proportion of empty seeds. They look like seeds, but there is no embryo or one, which is only partly developed. Some plants require 15 to 20 visits to each flower by a pollinator in order to produce a good seedpod or fruit. Even then, the seeds have to be collected after they have fully ripened. This is a common problem in the collection and cleaning of seed.

Nelson (2002) reported that the primary disadvantage of seed propagation in *Morinda citrifolia* is that without seed treatment, germination takes 6-12 months or more, whereas stem cuttings can be rooted in approximately 1-2 months. He further reports that the disadvantage of producing plants vegetatively from cuttings is that they may not be as strong and disease resistant as seedling and the trunk and branches may split and break during the first year of fruit production.

Gibberlic Acid has been reported to improve seed germination and seedling growth in many crops (Abdalla *et al.* 1978, Singh *et al.* 1979 and Chaudhari & Chakrawar, 1981). Present studies were, therefore taken up to study its effect on germination of *Morinda citrifolia* seeds.

Materials and Methods

The experiment was conducted during April – July 2005 in the division of Horticulture and Forestry at CARI, Port Blair. Noni seeds were collected from the sound and fully ripened fruits that were fallen on the ground from a mother plant (located near the institute) aged approximately 20 years. The seeds were extracted and washed with distilled water. They were then soaked in water (serving as control), 400, 600, 800, 1000 and 1200 ppm concentrations of GA (symbolically represented by C_0, C_1, C_2, C_3, C_4, C_5 and C_6 respectively) separately for 12, 24 and 36 h (represented by D_1, D_2 and D_3 respectively). Thus there were eighteen treatment combinations which were replicated thrice. A pot sown with 25 seeds worked as a unit and sowing was done on 2nd April 2005. Pots were regularly irrigated as it was kept under protected house (top covered with PVC sheet) and observed to record the date of first germination. After completion of germination total number of germinated seeds were counted to work out the per cent germination. After a month of last germination total number of surviving seedlings was also recorded to calculate the per cent survival. Plant height and number of leaves were counted at this stage to assess the plant vigour.

Results and Discussion

It is apparent from Table 1 that seed soaking in GA 800 ppm resulted in significantly maximum germination (91.06%), which, however, did not vary significantly from GA 1000 ppm. On the other hand, minimum germination (56.4%) was recorded under water treatment. Shant and Rao (1973) also reported 66.64% germination in the seeds of acid lime. Singh *et al* (1979) also obtained highest germination of 61.3% in citrus Jambhiri by treatment with GA.

Results further elucidate that soaking for 24 h gave the best (78.75%) germination. Similar results have been reported by Singh *et al.* (1979). Interaction results from the same Table corroborate the above said results by recording maximum germination (100%) in the treatment where seeds were soaked for 24 hours at 800 ppm.

Table 1. Effect of seed soaking on per cent seed germination in *Morinda citrifolia*. in different concentrations of GA at different duration

	C_0	C_1	C_2	C_3	C_4	C_5	Average
D_1	53.30	60.0	73.3	86.6	86.6	77.3	72.8
D_2	57.3	61.3	76.6	100	90.6	86.6	78.73
D_3	58.6	61.3	77.3	86.6	86.6	75.3	74.6
Average	56.4	60.9	65.7	91.06	87.9	80.4	

CD (5%)C = 1.526D= 2.158CxD = 3.293

D-Duration ; C-Concentration

Table 2. Effect of seed soaking on time taken for germination (days) in different concentrations of GA at different duration

	C_0	C_1	C_2	C_3	C_4	C_5	Average
D_1	61.00	40.30	36.30	30.0	28.30	24.0	36.60
D_2	59.0	37.60	34.30	26.30	24.0	21.0	33.70
D_3	55.0	34.60	31.30	24.30	11.0	9.0	27.53
Average	58.30	37.5	33.9	26.2	21.30	18.0	

CD (5%) C=0.568 D=0.803CxD=0.456

Table 3. Effect of seed soaking on the percentage of survival in different concentrations of GA at different duration

	C_0	C_1	C_2	C_3	C_4	C_5	Average
D_1	94.30	92.60	91.0	90.30	89.30	88.0	90.92
D_2	99.0	94.30	92.6	90.60	90.60	88.30	92.57
D_3	99.0	94.0	92.0	90.0	87.60	87.0	91.60
Average	97.43	93.63	91.87	90.30	89.16	87.77	

CD (5%)C = 1.038 D= 0.735CxD = 0.762

Table 4. Effect of seed soaking on average height of plant (cm) in different concentration of GA at different duration.

	C_0	C_1	C_2	C_3	C_4	C_5	Average
D_1	16.01	16.27	16.93	17.10	17.49	18.90	17.10
D_2	16.00	15.57	17.20	17.60	17.92	19.23	17.25
D_3	16.13	16.61	17.34	17.69	18.16	19.48	17.57
Average	16.05	16.15	17.16	17.46	17.86	19.53	

CD (5%)C = 0.115 D= 0.081C x D = 0.0093

Table 5. Effect of seed soaking on number of leaves per plant in different concentrations of GA at different duration.

	C_0	C_1	C_2	C_3	C_4	C_5	Average
D_1	9.47	10.48	11.36	11.97	12.47	12.76	11.42
D_2	9.08	10.59	11.60	11.97	12.56	12.95	11.46
D_3	9.18	10.60	11.68	12.45	12.91	13.59	11.74
Average	9.24	10.56	11.55	12.13	12.65	13.10	

CD (5%)C = 0.065 D= 0.046CxD = 0.002

Data presented in Table 2 further indicate that significant earliness in germination was induced by every concentration of GA and duration of soaking. Thus minimum germination time (9.00 days) was taken by seed soaked in 1200 ppm GA for 36 h. Maximum germination time (61.0 days) was noted in the seeds soaked in water for 12 hours. No previous data is available on these lines to support or contradict these findings. However, Rajput and Haribabu (1985) noted that seeds of different citrus species take 2 -3 weeks to germinate and thus confirm to the present findings to some extent.

Results (Table 3) show that water treatment accounted for highest percentage of survival of the seedlings (97.43%), which was significantly reduced, by all GA treatments. Every increase in concentration of GA reduced the survival percentage, which varied significantly. On the other hand, 24 h soaking gave significantly more percentage of survival (92.57%) than 12 or 36 h soaking, which were statistically at par to one another. Interaction results indicate that 12 h soaking was better for all the solutions.

Table 4 and 5 reveal that seed treatment by GA significantly increased the height of seedlings (19.53 cm) and number of leaves per seedlings (13.10). Every increase in concentrations of GA increased the height of seedlings and number of leaves thereon, significantly. The interaction also increased the number of leaves per seedlings (13.59 cm) and was noted in 1200 ppm GA for 36 h. These findings are in agreement with those reported by Babu and Lavania (1985) in lemon.

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The effect of hot water and sulphuric acid on the seed germination of *Morinda citrifolia* L.

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Key words : *Morinda citrifolia,* Gibberllic acid, concentration, duration, germination

Abstract : An experiment was conducted to study the effect of hot water and sulphuric acid on seed germination of *Morinda citrifolia.* The seeds were treated with sulpuric acid at concentrations of 50% and 100% for a period of 5 and 10 min. In the case of hot water treatment seeds were soaked in hot water at 40ºC, 50ºC and 60ºC for a period of 24 h. The results clearly showed that the treatment with hot water at 40ºC for a period of 24 h and treatment with sulphuric acid at a concentration of 50% for 5 min. was able to overcome the seed dormancy.

Introduction

Indian Mulberry (*Morinda citrifolia*) belongs to family Rubiaceae and is commercially called as Noni. The genus *Morinda* consists of more than 80 species (Johanssen, 1994). Noni plant is a small evergreen tree found growing in open coastal regions and in forest areas at about 1300 feet above mean sea level. It's identifiable by its straight trunk, large, bright green elliptical leaves with white tubular flowers, and its distinctive, ovoid, "grenade-like" yellow fruit. The fruit can grow in size up to 12 cm or more and has a lumpy surface covered by polygonal-shaped sections. The seeds, which are triangular shaped and reddish brown, have an air sac attached at one end, which makes the seeds buoyant and hydrophobic. The mature Noni fruit has a foul taste and odour. *Morinda citrifolia* is not considered to be at risk in the wild. Elkins (2002) reported that all parts of the plant have traditional and /or modern uses - root and bark (dye and medicine), trunk (fire wood and tools), leaves and fruits (food and medicine). So the tree has attained significant economic importance worldwide in recent years through a variety of health and cosmetic products made from leaves and fruits (Morton, 1992). The Noni seeds have a problem of seed dormancy/hard seed coat (water repellant) thus limiting its commercial cultivation. So untreated seeds need several months to a year before natural germination takes place but their germination can be reduced to a month by using heat or chemical scarification. Therefore, the objective of this study was to investigate the effect of hot water and sulphuric acid on the seed germination of *Morinda citrifolia.*

Materials and Methods

The experiment was conducted at Centre for Organic Indian Noni (COIN) having hot and dry humid climate. One month old seeds were obtained from a local farmer at Mangalore in Karnataka, India.

Seeds were sown in polybags filled with soil media containing red soil, sand and vermicompost in the ratio of 1:1:1 respectively. Uniform size (20 x 15 cm) of polybags was used with a capacity of 1.5 kg of soil media. 100 seeds were used for each treatment.

Sulphuric acid seed treatment was carried out to find the right concentration and duration of soaking on seed germination. Sulphuric acid with two concentrations (100% and 50 %) for a period of 5 and 10 min. were used. Sulphuric acid treated seeds were rinsed several times with clean water and tested for germination. The effect of hot water was carried out at three different temperatures (40°C, 50°C and 60°C) for a period of 24 hours and then tested for seed germination. A Completely Randomized Block Design (CRBD) with three replications were used, while the dependent variables were measured at 21, 28, 35 and 42 days after sowing. The details of treatments are given below

T1 - Control
T2 - Hot water treatment (40°C) for 24 h
T3 - Hot water treatment (50°C) for 24 h
T4 - Hot water treatment (60°C) for 24 h
T6 - Sulphuric acid treatment at 100% concentration for 5 min.
T7 - Sulphuric acid treatment at 100% concentration for 10 min.
T8 - Sulphuric acid treatment at 50% concentration for 5 min.
T9 - Sulphuric acid treatment at 50% concentration for 10 min.

The data was subjected to the analysis of variance (ANOVA) and where there were significant differences among treatments, mean separation was done using the Duncan's Multiple Range Test. (Steel and Torie, 1980)

Results and Discussion

Treating *Morinda citrifolia* seeds with hot water (40°C and 50°C) for a period of 24 h and with 50% sulphuric acid for 5 and 10 min. had significantly increased the germination compared to control and other treatments (Table.) The seeds soaked in hot water at 40°C and 50°C for a period of 24 h significantly showed maximum germination than the other treatments throughout the observation period. After 42 days of sowing, the seeds treated with hot water (40°C) for a period of 24 h had highest germination percentage (61%) compared to all other treatments, and was also on par with the seeds treated with sulphuric acid for 5 min. But over all, the seeds treated with hot water at 40°C for a period of 24 h and 50% of sulphuric acid treated for 5 min. recorded the highest percentage of germination (61% and 59% respectively).

Table. Effect of hot water and sulphuric acid on the percentage of seed germination of *Morinda citrifolia*

Treatments	Per cent seed germination			
	21 DAS	28 DAS	35 DAS	42 DAS
T1	0c	0c	3c	16c
T2	4a	20a	43a	61a
T3	0c	13b	25b	43b
T4	0c	3c	16bc	26c
T5	0c	2c	17bc	23c
T6	0c	2c	9c	14c
T7	2b	15c	38b	59a
T8	0c	5c	17bc	24c

DAS - Days after sowing

Mean in a column with similar letters are not significantly different at 5% level of probability according to the Duncan Multiple Range Test.

Dormancy is a condition where seed will not germinate even when the environmental conditions (water, temperature and aeration) are permissive for germination (Hartmann, 2002). Seed dormancy prevents immediate germination but also regulates the time, condition and place for germination to occur. In nature, different kinds of primary dormancy have evolved to aid in survival of species by programming the time of germination at a particular favorable period in the annual cycle (Alwater, 1980 and Baskin and Baskin, 1998). Seed dormancy is an evolutionary adaptation to delay germination after the seed has been shed from the plant.

The result of the present study showed that hot water treatment (40°C) and concentrated sulphuric acid for 5 min. enhanced the germination of Noni seeds and thereby reveals that the type of dormancy in *Morinda citrifolia* seed is physical dormancy (seed coat dormancy). Seed with physical dormancy fail to germinate because the seed will be impermeable to water (Hartmann, 2002). Physical dormancy is most often caused by a modification of seed covering, especially the outer integument layer of the seed that may become hard, fibrous and mucilagenous during dehydration and ripening. The seed coat hardens and become impervious to water. Germination can be induced by any method that can soften or scarify the seed coat. This implies that hot water and concentrated sulphuric acid scarified the *Morinda* seed and promoted water imbibition by the seed that helped in seed germination.

Soaking the seeds in hot water at more than 40°C would have affected the embryo of the seed. Similar study was reported by Nelson (2001). Exposing the seed for more than 5 min. in 50% and 100% sulphuric acid decreased the germination capacity because sulphuric acid being corrosive might have damaged the seeds. A similar result was obtained by Awodola (1994).

From this result, it can be concluded that hot water treatment (40°C) and sulphuric acid treatment (50%) for not more than 5 min. overcame the seed dormancy in *Morinda citrifolia*. Although Sulphuric acid treatment increased the germination, the time for which the seed should be soaked in acid is important. Seed soaked for more than 5 min. may lead to decrease in germination due to embryo damage by the acid. From the farmers point of view, hot water treatment is the best one as some farmers may not have access to or do not know how to handle the sulphuric acid.

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Indian Noni Research Foundation
Healthy People, Healthy Nation

With the mission of educating the people, the Indian Noni Research Foundation, a non-profit organisation dedicates itself to love and care for *Morinda citrifolia.,* through research and development. Learning from the wisdom of the simple people, INRF aims at working with everyone to conserve and improve Noni towards sustainable human and ecological health. It will share the Noni's past glory, ethnobotany, history, science, benefits and its multiple uses with all. The INRF also serves as a facilitatory body for all Noni farmers, industries and consumers to establish a sustainable Noni economy network. The INRF collectively represents the interests of all people in the Noni research and industry. It is an independent body and committed to exclusive Noni research and development. The INRF website, journals and news letters are established to provide a non-biased forum for the researchers, consumers and industries to publicise their research findings and experiences with *Morinda* species.

INRF believes that this synergistic effort of scientists and people of 'Noni Solidarity' would empower millions of ordinary masses to find their dignity and economic freedom, more naturally. This will lead to the realization of our vision "Healthy people, Healthy nation" in India and rest of the world.

Our Programmes Focus on

- Conserving the *Morinda* species in India and rest of the world from its degradation.
- Organising "Noni Biodiversity Action Network" (NBAN) to save endangered (Red listed) *Morinda* species in the above regions.
- Developing Bioinformatics database on *Morinda* species existing in India and rest of the world and record all Indigenous Technical Knowledge about it.
- Supporting the research and development programmes on discovering the multiple potential of *Morinda* species in fields like pharmaceutical, nutraceutical, cosmetology, dye, agriculture, etc.
- Sharing the cutting edge action-programmes and research findings with researchers, farmers, consumers, food industry leaders, health - drug industry leaders, students and masses.
- Connecting the *Morinda* species researchers in India and rest of the world.
- Promoting the Indian Noni for health regenerative systems and processes through clinical studies & biotechnological research.
- Developing "Noni Villages" for Noni based socio-economic development of people at the grass-root level.
- Monitoring and encouraging quality *Morinda* products in the Market.
- Regenerating the glory of Indian Noni

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