**Rauvolfia serpentina** (L.) Benth. ex Kurz.-A Review

1Abhijit Dey and 2J.N. De

1Department of Botany, Presidency College, 86/1, College Street, Kolkata-700073, West Bengal, India
2Retired Reader in Botany, Charuchandra College, Kolkata, India

**Abstract:** *Rauvolfia serpentina* (L.) Benth. ex Kurz. (Apocynaceae) has long been used in India for the treatment of snakebites and mental illness. It also controls hypertension and reduces blood pressure. The present review deals with the enormous amount of studies undertaken in different aspects of this plant in the areas of tissue culture, phytochemistry, pharmacology, molecular biology, chromosomal constituents, morphotaxonomy, medicine and ethnobotany.

**Key words:** *Rauvolfia serpentina*, sarpagandha, snakebites

**INTRODUCTION**

*Rauvolfia serpentina* (L.) Benth. ex Kurz. (Apocynaceae) commonly known as Sarpagandha is an important medicinal plant of Indian subcontinent and South East Asian countries. The plant grows generally in the region with annual rainfall of 200-250 cm and up to an altitude of 1000 m and favours deep fertile soil rich in organic matter. Poor seed germination rate, over exploitation and loss of habitat are the major causes of decline of this species from its natural habitat. It is found in Bangladesh, Bhutan, China, Indonesia, India, Lao PDR, Malaysia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and Viet Nam.

**Vernacular names:** India: Naakuli, Candrika, Chandramarah (Sanskrit), Chandra (Bengali), Chhotachand (Hindi), Chivan-amelpodi or Covannamiloori (Tamil), Sarpagandhi, Palalagandhi (Telegu), Sutranabhi, Patalagaruda, Sutranabhi (Kannada), Dhannema or Dhan-barua (Oriya), Anmelpodee (Gujrat), Phalagannu or Phalta-gandi (Telegu), Amalpori, Cuvanna amalpori (Malayalam), Adkai, Chandra (Marathi), Bhungmaraja (Arunachal Pradesh). Ceylon: Aceawerya. Java: Akar Tikoes, Poel (or Poeleh) Pandak.

**Synonyms:** *Ophioxylon serpentinum* L.

**Morphology and taxonomy:** Santapau (1956) has studied Botanical aspects of this plant. Kettel (1987) has reported phyllotaxical morphotypes. Variation of chemo-botanical characters in the indigenous collections of this plant was reported by Sethi *et al.* (1991). Revision of *Rauvolfia* (Apocynaceae) in Malesia was reported by Hendrian (1999). Diplod coteugological and ploid leaf epidermal characters with emphasis to ecophysiological adaptability were reported by Barynah and Nath (2000).

Perennials from a woody rootstock. Leaves lanceolate or oblanceolate, 13-18x6-8 cm, acute or acuminate, shining. Calyx lobes lanceolate. Corolla white; tube swollen above the middle; lobes elliptic-oblong. Drupes 0.5-0.7 cm across, purplish black (Bhattacharyya and Sarkar, 1998).

**Tissue culture and transformation studies:** Propagation of *R. serpentina* through tissue culture has previously been described (Mitra and Kaul, 1964; Volosiovec and Butenka, 1970; Ilahi and Akram, 1987a; Mukhopadhyaya et al., 1991; Mathur *et al.*, 1993; Gupta *et al.*, 1980; Roy *et al.*, 1994; Ilahi, 1993, 1995; Sarkar *et al.*, 1996a, b, Ghosh *et al.*, 1998; Rajkumar et al., 2000; Sehrват et al., 2001; Ahmad *et al.*, 2002; Kataria and Shekhawat, 2005; Pandey et al., 2007; Ilahi et al., 2007; Baksha et al., 2007; Goel et al., 2007; Pant and Joshi, 2008; Salma et al., 2008; Bhatt et al., 2008; Harisaranraj et al., 2009) and alkaloid content has been studied (Volosiovec *et al.*, 1976; Roja *et al.*, 1985; Mathur *et al.*, 1987; Ruyter *et al.*, 1991; Roja and Heble, 1996; Patil and Jayanti, 1997). Callus formation was studied by Perveren and Ilahi (1978). Volosiovec *et al.* (1979) have optimized the composition of macromsalts in the culture media. Nutrient medium selection for submersed culturing was studied by Kaukhova *et al.* (1981). Optimization of macronutrient composition for tissue culture was done by Volosiovec *et al.* (1982). Biosynthesis of some important alkaloids by stem cultures of this species was reported by Akram and Ilahi (1985a). Bud differentiation in root callus
of regenerated plantlets of *R. serpentina* was reported by Akram and Ilahi (1985b). Plantlets formation in root callus was reported by Akram and Ilahi (1986). Production of reserpine and its optimization in cell culture were reported by Yamamoto and Yamada (1986). Selection of a reserpine-producing cell strain using UV-light and optimization of production of reserpine in the selected cell strain were reported by Yamamoto and Yamada (1987). Establishment and multiplication of colchis-autotetraploids through tissue culture method were reported by Madur et al. (1987). Growth and alkaloid production in multiple shoot culture were reported by Koja et al. (1987). Leaf callus culture was reported by Ilahi and Akram (1987b). *In vitro* culture of the plant and the production of ajmaline were studied by Kurak and Alkimova (1989). Sen and Datta (1990) have used hormones *in vitro* for alkaloid production from this plant. Enhanced propagation, root production and alkaloid biosynthesis by cultures of this plant were reported by Ilahi and Akram (1993). Genome variation in cultured cells of *R. serpentina* was reported by Soloyan et al. (1994a). Somatic embryogenesis and plant regeneration was reported by Ilahi et al. (1995). Somaclonal variation in this plant was reported by Kurak (1996). Sequential isolation of superoxide dismutase and ajmaline from tissue cultures of this plant was performed by Kirillova et al. (2001). Kurak et al. (2001) have studied the method for obtaining and productivity of the suspension cultures and cell clones. Effect of phytohormones on the protein-synthesizing ability of *R. serpentina* tissue culture was reported by Kirillova and Komov (2002). Changes in the activity of superoxide dismutase in callus cultures grown under standard conditions and heat shock was reported by Kirillova (2004). Addition of copper was found to enhance the reserpine production in callus culture (Nurahyani et al., 2008). The influence of different hormone concentration and combination on callus induction and regeneration was studied by Sama et al. (2008a). *In vitro* propagation of *R. serpentina* using liquid medium was reported by Goel et al. (2009). Effect of growth regulators on direct root induction from leaf explants were studied by Pankey et al. (2010).

Benjamin et al. (1993) have reported Agrobacterium rhizogenes mediated transformation in *R. serpentina*. Alkaloid formation in hairy roots and cell suspensions was reported by Falkenhagen et al. (1993). Growth dynamics and total alkaloid content in transgenic root culture was studied by Sheludko and Kostenyuk (1994). Transforming ability of two *A. rhizogenes* strains in *R. serpentina* leaves were studied by Sama et al. (1997). New alkaloids of the Sarpgine group from hairy root culture have been detected by Sheludko et al. (2002a). Isolation and structure elucidation of a new indole alkaloid of the raumacine group from hairy root culture was reported by Sheludko et al. (2002b). Potential of *A. rhizogenes* mediated transformed roots for reserpine biosynthesis was explored by Goel et al. (2008). Hairy root culture of this plant using direct analysis in real time mass spectrometric technique was analyzed by Madhusudan et al. (2008).

**Phytochemistry:** The alkaloids of *R. serpentina* were reported by Siddiqui and Siddiqui (1931, 1932, 1935) and Siddiqui (1939). Chatterjee and Bose (1951) have reported a new alkaloid from the roots of this plant. New alkaloids from this plant were reported by Popelak et al. (1953). Another alkaloid, Rauwolfine was described by Bose (1954). Rauhinbin and Isorauhinbin from this plant was reported by Hofmann (1954). A chemical investigation of this plant was carried out by Holt and Costello (1954). Reserpine, another alkaloid was reported by Schillter et al. (1954). Rauhinbin and isorauhinbin were reported by Hofmann (1954). TLC of Rauwolfia alkaloids was performed by Schlemmer and Link (1959). Reserpine analogs were also reported (Agbalam, 1961; Karim et al., 1961). Variation in alkaloid content from ecological point of view (Wakhloo, 1963) and of different geographical races (Dhar, 1965) and chemotypic studies of natural populations from certain regions of Karnataka, India (Mital et al., 1980) were also studied. Pakrashi and Akkari (1968) have published a review on Rauwolfia alkaloids. The separation and identification of microquantities of alkaloids were performed by Habib and Court (1974). Methods for the quantitative determination of the sum of alkaloids in tissue culture of Rauwolfia were reported by Volosovich et al. (1977). The indole alkaloid patterns of cell suspension and tissue cultures have been investigated (Stockigt et al., 1981; Stockigt, 1995). Quantitative determination of total alkaloids in this plant in tissue culture was reported by Shimolins et al. (1984). Mechanism for iridane skeleton formation in the biosynthesis of secologanin and indole alkaloids in suspension cultures of *R. serpentina* were reported by Uesato et al. (1986). Quantitative estimation of Rutin in this plant was reported by Bhardwaj (1988). Expression of enzymatically active deonized strictosidine synthase from *R. serpentina* in Escherichia coli was reported by Kutchan (1989). Biotransformation of ajmaline in plant cell cultures and new indole alkaloids raumacine and N (B)-methyl-raumacine were reported by Polz et al. (1990). Lutterbach and Stockigt (1992) have reported high-yield formation of arbutin from hydroquinone by cell suspension cultures. Alkaloids from cell cultures treated with ajmaline were reported by Endreb et al. (1993). Falkenhagen and
Stockigt (1993) have reported enzymatic biosynthesis of vomilenine, a key intermediate of the ajmaline pathway, catalyzed by a novel cytochrome P 450 dependent enzyme from plant cell cultures. Separation of indole alkaloids by HPLC and TLC methods were reported by Klushchienko et al. (1994). Alkaloids isolated from somatic hybrid cell cultures of the species combination Rauwolfia serpentina x rhazya stricta were reported by Kosteryuk et al. (1995). Enzymatic biosynthesis of Raumachine in cell suspension cultures was reported by Obitz et al. (1995). Stockigt (1995) has discussed the modern aspects of biosynthesis in R. serpentina. Determination of indole alkaloids from R. serpentina and R. vomitoria by HFLC and HPTLC was performed by Klushchienko et al. (1995). Bacterial biotransformation of 3α(S) strictosidine to the monoterprenoid indole alkaloid vallesiaichotamine was reported by Shen et al. (1998). Purification, partial amino acid sequence and structure of the product of raucaffrinose-0-B-D-glucosidase from plant cell cultures were determined by Warzeka et al. (1999). Divergence of the indole alkaloid pattern in two somatic hybrid plant cell subcultures of Rauwolfia serpentina x Rhazya stricta was mentioned by Sheludko et al. (2000). Hydroquinone: O-glucosyltransferase from cultivated Rauwolfia cells, enrichment and partial amino acid sequences was reported by Arend et al. (2000). The biosynthetic interconversion of members of the ajmaline family emphasises the fact that advanced intermediates can often be exploited in the synthesis of several alkaloids and analogues (Bailey et al., 2000). The alkaloid content varies from 1.4-3%, depending on location, season and soil conditions (Farooqi and Sereramu, 2001). 3-Oxorhazinilam, a new indole alkaloid from Rauwolfia serpentina x rhazya stricta hybrid plant cell cultures was reported by Gerasimenko et al. (2001). Anhydronium bases from this plant were reported by Wachsmuth and Matusch (2002). Novel alkaloids such as vomilenin, perkin, 17-o-acetylajmaline and 17-o-acetylnorajmaline were also produced by tissue cultures of R. serpentina (Ahmad et al., 2002). Gorelova and Korzhenevskaya (2002) have found the formation of giant and ultramicroscopic forms of Nostoc muscorum CALU 304 during cocultivation with Rauwolfia tissues. Gorelova and Kleimenov (2003) have reported the accumulation and degradation dynamics of cyanophycin in cyanobacteria (N. muscorum CALU 304) grown in symbiotic associations with the R. serpentina callus. Evaluation of chemical composition (Harisaranraj et al., 2009); Spectrophotometric determination of alkaloids (Singh et al., 2004) and characterization of oxidation products of alkaloids (Azeeem et al., 2005) were also reported. Indole alkaloids and other constituents of this plant were analyzed with NMR by Itoh et al. (2005). Deserpidine which differs from reserpine only by the absence of a methoxy group at C-11, was synthesized from Reserpine (Varchi et al., 2005). Biotransformations in R. serpentina cell cultures fed with ajmaline produce a range of alkaloids including suaveoline and raumachine. Functional expression of an ajmaline pathway-specific esterase from Rauwolfia in a novel plant-virus expression system was reported by Ruppert et al. (2005a). Crystallization and preliminary X-ray analysis of native and selenomethionyl vinorine synthase from R. serpentina were done by Ma et al. (2005). The Structure of R. serpentina Strictosidine Synthase is a novel six-bladed β-propeller fold in plant proteins was reported by Ma et al. (2006). Quantitative determination of reserpine, ajmaline and ajmalicine in this plant by reversed-phase HPLC was reported by Srivastava et al. (2006). Quantitation of Reserpine, Ajmaline and Ajmalicine from the plant by HPLC was reported by Goel et al. (2009).

Chromosome analysis: 2n = 22 (Dnyansagar and Torne, 1967; Bhattacharjee and Bhaduri, 1959; Tapadar et al., 1960; Tapadar and Roy, 1964; Koul 1964; Mukhopadhyaya et al., 1991), 2n = 24 (Chandra, 1957b), 2n = 20 (Singh, 1961; Raghavan, 1957; Sultana et al., 2009), 2n = 44 (Koul, 1964). n = 11 was reported by Dnyansagar and Torne (1968), Sharma and De (1976) De (1979) and Bedi (1990). Rauwolfia serpentina might be considered as an advanced species in respect of chromosomal length and primitive on the basis of centromeric type (Sultana et al., 2009). They have also used CMA-banding technique to indicate the GC-rich regions of the chromosomes. Koul (1964) has reported the presence of different cytotypes and polyplody of this species. Annum Janaki (1962) has reported tetraploidy in this plant. Increasing root yield of this plant by colchicine was reported by Bhaduri and Biswas (1965). Chromosome constitution and alkaloid content were reported by Banerjee and Sharma (1989). In a report on cytology of Apocynaceae by Van der Laan and Arends (1985), it was mentioned that 60% of the assessed genera were having the basic No. x = 11.

Molecular biological analysis: The comparison of the DNA homology degree and the number of repeated sequences in intact plant and cultured cells of this plant was determined by Solovyan et al. (1986). The cDNA clone for strictosidine synthase from R. serpentina and DNA sequence determination and expression in E. coli was reported by Kuchan et al. (1988). Homogeneous strictosidine synthase from cell suspension cultures of was reported by Hampp and Zenk (1988). PCR rea
comparison of the gene for strictosidine synthase from ten Rauvolfia species including *R. serpentina* was reported by Bracher and Kutechan (1992a). Strictosidine synthase from *R. serpentina* and analysis of a gene involved in indole alkaloid biosynthesis were reported by Bracher and Kutechan (1992b). Genome rearrangements in cultured *R. serpentina* cells, the involvement of the multiple genomic sequences and relation to the interspecies variation were reported by Solovyan et al. (1994b). Heterologous expression of the plant proteins strictosidine synthase and berberine bridge enzyme in insect cell culture was reported by Kutechan et al. (1994). Gerasimenko et al. (2002) have reported the heterologous expression of a Rauvolfia cDNA encoding strictosidine glucosidase, a biosynthetic key to over 200 monoterpenoid indole alkaloids. Alkaloid biosynthesis in Rauvolfia-cDNA cloning of major enzymes of the ajmaline pathway was reported by Ruppert et al. (2005b). Variability of ribosomal RNA genes in this species and parallelism between tissue culture-induced rearrangements and interspecies polymorphism was studied by Andreev et al. (2005). Inter- and intra-population genetic diversity of the plant species from six localities of Andhra Pradesh (India) by RAPD analysis was performed by Padmalatha and Prasad (2007). Dynamics of genome changes in callus tissue upon the switch to conditions of submerged cultivation was reported by Spiridonova et al. (2008). RAPD analysis of different samples of this plant was also performed by Goel et al. (2009) using CPA, OPB and MAP series of primers.

**Pharmacology:** Use of *R. serpentina* (Serpasil) in psychiatry was reported by Glynn (1955). Holzbauer and Vogt (1956) have reported depression by reserpine of the noradrenaline concentration in the hypothalamus of cat. Plotscher et al. (1955) have reported serotonin release as a possible mechanism of reserpine action. Muscholl and Vogt (1958) have noted the action of reserpine on the peripheral sympathetic system. Brodie et al. (1960) have found evidence of tranquilizing action of reserpine, which is associated with change in brain serotonin. Reserpine and the levels of serotonin and norepinephrine in the brain were discussed by Sheppard and Zimmerman (1960). Effect of reserpine on the storage of catecholamines in brain and other tissues was reported by Bertler (1961). Reserpine analogs with differential effect on brain monoamines were reported by Treka and Carlson (1967). Comparative studies on the effects of reserpine and its derivatives (bromo and dibromo) reserpine on the blood pressure, heart rate and EEG of rabbit were made by Khatri et al. (1982). The inter-generic somatic hybrid cell culture of *R. serpentina* and *Rhazya stricta* has showed cytotoxic activity against human promyelocytic leukemia cells HL 60 and/or human diploid embryonic lung fibroblast cells (Abdel-Moty et al., 1998). Reserpine methonitrate, a novel quaternary analogue of reserpine augments urinary excretion of VMA (vanillylmandelic acid) and 5-HIAA (5-hydroxyindoleacetic acid) without affecting HVA (homovanillic acid) in rats, was reported by Sreemantula et al. (2004). Ethanolic extract of this plant was found to inhibit some bacterial strains to some extent while the aqueous extract did not show any activity (Jigna et al., 2005). The pectic polysaccharide named rauvofixin was obtained from the dried callus of *R. serpentina* by extraction with 0.7 % aqueous ammonium oxalate and it was found to possess some anti-inflammatory effect (Popov et al., 2007).

**Medicinal uses:** This plant was first mentioned by Sushruta in 600 BC. The Rauvolfia root has been used since the pre-Vedic period as a drug in India, known at that time as the Sarpagandha root, to treat snake bites and fever. The root was continuously applied during the subsequent vedic and ayurvedic periods. The plant is mentioned in ancient literature including the works of Charaka (1000-800 BC) where it was said to be used against snake bites and insect stings (Pandey, 1984). Rauvolfia can be regarded as a typical drug of Ayurvedic medicine. It belongs to a small group of plants deserving attention as a traditional medicinal plant since 3000 years (Ruppert et al., 2005b). The ayurvedic preparations of *R. serpentina* are Sarpagandha ghanavati, Sarpagandha yoga, sarpagandha churna and maheshvati vati, among others (Vaidya, 2006). Its roots are used as a valuable remedy for high blood pressure, insomnia, anxiety, excitement, schizophrenia, insanity, epilepsy, hypochondria and other disorders of the central nervous system (Monachino, 1954; Kirtikar and Basu, 1993). Alkaloids of this plant have a great medicinal importance to treat cardiovascular diseases (Anitha and Kumari, 2006), high blood pressure (Vakil, 1955), hypertension (Von Poser et al., 1990), arrhythmia (Kirillova et al., 2001), various psychiatric diseases (Bhatura et al., 1997), mental disorders (Noce et al., 1984), brain cancer (Stanford et al., 1986), human promyelocytic leukemia (Itoh et al., 2005) like diseases. The Unani formulation Pitkiriya capsule contains arsol (Rauvolfia serpentina) (Shamsi et al., 2006). It acts as Musakkin-wo-Munawwim (sedative and hypnotic), Mudir (Diuretic), Musakkin-e-Asab (nervine sedative) and Mukhaadid (anesthetic).

**Ethnobotanical uses:** In the vast rural areas of India, at the first signs of insomnia, melancholia, schizophrenia or more
violent mental disorders, used to soak the roots of the plant in rose water and administer it (Sharma, 1958). One of the authors of this review has worked on Ethnobotanical aspects of Purulia District, West Bengal, India (De, 1965, 1967, 1968, 1979a, b, 1980; Jain and De, 1964, 1966) and found out the use of Tylophora sp. against snake-bite (Jain and De, 1966). Use of Rauvolfia serpentina and Tylophora indica against snake-bite was also reported (Parinitha et al., 2004; Sankaranarayanan et al., 2010). There are many folk-lore about this plant. One of which is that a mongoose would first chew upon its leaves to gain power before combating a cobra. According to another, it’s freshly ground leaves when applied to the toes could serve as an antidote for snake poison. A third one is that, the mentally challenged person is relieved of his insanity if he eats the root (Pandey, 1984). This plant was found to be used very commonly by tribes indicating the authenticity of their usefulness (Saxena et al., 1988; Sarkar et al., 1999). The inhabitants of Macassar use the petioles as an antidote for infusion, decoction and extracts of the roots are employed to increase uterine contractions for expulsion of fetus, to treat painful affections of bowels, diarrhea, dysentery, cholera and colic (Ghani, 1998). Ethnomedical use of this plant to treat circulatory disorders (Ajamalicine), as antihypertensive and tranquilizer (Reserpine, Deserpidine and Rescinnamine) was reported by Fabricant and Farnsworth (2001). Young shoot extract of this plant (ca 10 mL) is given three times daily to cure pneumonia in early stage by the Meche People of Jhapa District, Eastern Nepal (Rai, 2004). Juice extracted from the leaves along with the juice of Andrographis paniculata and Azadirachta indica with honey to cure malaria. In case of snake-bite, juice extracted from leaves taken twice a day for 3 days. Fifteen grams of roots along with roots of Cassia tora and Holarrhena pubescens paste applied twice a day for two days. Juice extracted from leaves of Andrographis paniculata and Nyctanthes arbor-tristis is mixed with Rauvolfia serpentina root juice to treat scabies (Mohanta et al., 2006). De-Britto and Mahesh (2007), while exploring the kan tribal botanical knowledge in agasthiyamalai biosphere reserve, South India, have reported that the leaves and the flowers of this species are consumed to treat Asthma. Local people of Madhupur, Tangail, Bangladesh use Rauvolfia serpentina (Locally called Do-grek-mi) root and leaf paste to make pills and sun dried to use in malarial fever; the root juice is used during the time of liver pain; the fresh leaf juices are used to prevent eye inflammation (Anisuzzaman et al., 2007). Rural people of Kanyakumari district, India, use the decoction of roots during labour and juice of leaves for removal of opacities of the eye cornea (Raj and Sukumaran, 2008). Roots are chewed for stomach pain and fever by Khampits of Arunachal Pradesh, India (Sen et al., 2008). Singh (2008) has reported the ethnomedical use of this plant against snake bite. Garo tribe inhabiting the Madhupur forest region of Bangladesh uses this plant to treat malaria, spleen diseases. A paste of root and black pepper is administered in malaria (dose only equal to 4-5 ratis, 1 rati = 1 tola = 11.66 g) (Mia et al., 2009). Pattanaik et al. (2009) has reported the use of this plant (Known as Patalgaruda locally) by the local people of Eastern Ghats, India against snakebite. Juice of tender leaves is given on empty stomach pain by the tribals of Mayurbhanj district of north Orissa, India. Root powder is mixed with black pepper and one tea spoonful is taken with a cup of water twice day for two days (Rout et al., 2009). Rout et al. (2010) have reported the use of R. serpentina while discussing the role of tribals in collection of commercial non-timber forest products in Mayurbhanj district, Orissa, India. The plant is used as an antidote to snake bite, in insomnia, high blood pressure and madness in Chatara block of district Sonebhadra, Uttar Pradesh, India (Singh et al., 2010).

**Propagation and cultivation:** Chandra (1954) has reported vegetative propagation of this plant. Cultivation of Rauvolfia in India was reported by many authors (Biswas, 1956; Dutta et al., 1963; Badhwar et al., 1955). Hedayatullah (1959) has reported culture and propagation of this plant. Nayar (1956) has reported propagation and culture of this species by seeds. Methods of propagation and their effect on root production were reported by Badhwar et al. (1956). Germination and chemical composition of the seeds were reported by Dutta et al. (1962). The cultivation of this plant is very difficult for various reasons, one being formation of a large proportion of non-viable seeds (Mitra, 1976). The plant is vegetatively propagated by root cutting because of poor seed viability and low germination percentage that may be due to the presence of cinnamic acid and derivatives in the seed (Mitra, 1976). Intercropping of R. serpentina for higher monetary returns was reported by Maheshwari et al. (1985). Irrigation schedule in a shallow black soil was reported by Maheshwari et al. (1991). Low temperature storage of this plant was reported by Sharma and Chandel (1992). Paul et al. (2008) have treated the seeds by scarification and with hot water, sulphuric acid and hydrochloric acid to break dormancy. Cryopreservation of in vitro grown nodal segments of the plant by PVS2 vitrification was reported by Ray and Bhattacharya (2008).
Diseases: Stem rot (Saini et al., 1996); Blight and die-back (Varadarajan, 1958); Leaf blotch (Chandra, 1957a); taget spot (Mohanty and Addy, 1958); Fusarium wilt (Janardhanan et al., 1964); anthracnose (Varadarajan, 1964); Leaf spot and premature defoliation under cultivation caused by Curvularia lunata (Varadarajan, 1967). Die back (Lele and Ashram, 1968); Rhizoctonia leaf spotting and blight (Mehrotra and Thapar, 1990); inflorescence and fruit rot (Shukla et al., 2006) by Rhizopus stolonifer are the different diseases of *Rauwolfia serpentina* reported by different authors.

Conservation status: *Rauwolfia serpentina* is threatened with extinction in India due to indiscriminate collection and over exploitation of natural resources for commercial purposes to meet the requirement of the pharmaceutical industry, coupled with limited cultivation (Nayar and Sastri, 1987, 1988, 1990; Mangain et al., 1998; Singh et al., 2010). Collection and conservation of this plant from south Karnataka and Western Ghats of India were reported by Sethi and Kazim (1983). Ansari (1993) has stated that genetic erosion has affected the species greatly and populations left in India have very poor alkaloid content. It was found to be endangered in Southern Western Ghats of India (Nayar, 1996). It has been categorized as globally endangered (Jadhav et al., 2001). Raj and Sukumaran (2008) have reported this species as endangered and threatened in Kanyakumari district, India. The plant was described as critically endangered in the Northeast India (Mao et al., 2009).

REFERENCES


