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

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Abstract: *Rauvolfia serpentina* (L). Benth. ex Kurz. (Apocynaceae) has long being 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, morpho-taxonomy, 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), Chhota-chand (Hindi), Chivan-amelpodi or Covannamiloori (Tamil), Sarpagandhi, Palalagandhi (Telegu), Sutranabhu, Patalagaruda, Sutranabhi (Kannada), Dhannerna or Dhan-barua (Oriya), Amelpodee (Gujrati), Phlalganni or Phtala-gandi (Telegu), Amalpori, Cuvanna amalpori (Malayalam), Adkai, Chandra (Marathi), Bhungmaraja (Arunachal Pradesh). Ceylon: Acawerya. Java: Akar Tikoes, Poel (or Poeleh) Pandak.

Synonyms: *Ophioxylon serpentinum* L.

Morphology and taxonomy: Santapau (1956) has studied Botanical aspects of this plant. Kattel (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). Diploid autecological and ploidal leaf epidermal characters with emphasis to ecophysiological adaptability were reported by Baruah and Nath (2000).

Perennial from a woody rootstock. Leaves lanceolate or oblanceolate, 13-18×6-8 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; Vollosovich and Butenka, 1970; Ilahi and Akram, 1987a; Mukhopadhyaya *et al*., 1991; Mathur *et al*., 1993; Gupta *et al*., 1950; Roy *et al*., 1994; Ilahi, 1993, 1995; Sarkar *et al*., 1996a, b; Ghosh *et al*., 1998; Rajkarnikar *et al*., 2000; Sehrawat *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*., 2008b; Bhatt *et al*., 2008; Harisaranraj *et al*., 2009) and alkaloid content has been studied (Vollosovich *et al*., 1976; Roja *et al*., 1985; Mathur *et al*., 1987; Ruyter *et al*., 1991; Roja and Heble, 1996; Patil and Jayanthi, 1997). Callus formation was studied by Perveen and Ilahi (1978). Vollosovich *et al.* (1979) have optimized the composition of macrosalts in the culture media. Nutrient medium selection for submerged culturing was studied by Kaukhova *et al.* (1981). Optimization of macronutrient composition for tissue culture was done by Vollosovich *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

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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 colchi-autotetraploids through tissue culture method were reported by Mathur *et al.* (1987). Growth and alkaloid production in multiple shoot culture were reported by Roja *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 Kunakh and Alkhimova (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 Solovyan *et al.* (1994a). Somatic embryogenesis and plant regeneration was reported by Ilahi *et al.* (1995). Somaclonal variation in this plant was reported by Kunakh (1996). Sequential isolation of superoxide dismutase and ajmaline from tissue cultures of this plant was performed by Kirillova *et al.* (2001). Kunakh *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 (Nurcahyani *et al.*, 2008). The influence of different hormone concentration and combination on callus induction and regeneration was studied by Salma *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 Pandey *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 Sarma *et al.* (1997). New alkaloids of the Sarpagine group from hairy root culture have been detected by Sheludko *et al.* (2002a). Isolation and structure elucidation of a new indole alkaloid of the raumacline 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). Rauhimbin und Isorauhimbin from this plant was reported by Hofmann (1954). A chemical investigation of this plant was carried out by Holt and Costello (1954). Reserpinin, another alkaloid was reported by Schlittler *et al.* (1954). Rauhimbin and isorauhimbin were reported by Hofmann (1954). TLC of Rauvolfia alkaloids was performed by Schlemmer and Link (1959). Reserpine analogs were also reported (Agbalyam, 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 Akkhari (1968) have published a review on *Rauvolfia* 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 Rauvolfia were reported by Vollosovich *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 Shimolina *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 Bharadwaj (1988). Expression of enzymatically active cloned strictosidine synthase from *R. serpentina* in Escherichia coli was reported by Kutchan (1989). Biotransformation of ajmaline in plant cell cultures and new indole alkaloids raumacline and N (β)-methyl-raumacline 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 keyintermediate 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 Klushnichenko *et al.* (1994). Alkaloids isolated from somatic hybrid cell cultures of the species combination *Rauvolfia serpentina* x rhazya stricta were reported by Kostenyuk *et al.* (1995). Enzymatic biosynthesis of Raumacline 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 HPLC and HPTLC was performed by Klushnichenko *et al.* (1995). Bacterial biotransformation of 3α(S) strictosidine to the monoterpenoid indole alkaloid vallesiachotamine was reported by Shen *et al.* (1998). Purification, partial amino acid sequence and structure of the product of raucaffricine-O-β-D-glucosidase from plant cell cultures were determined by Warzecha *et al.* (1999). Divergence of the indole alkaloid pattern in two somatic hybrid plant cell subcultures of *Rauvolfia serpentina* x *Rhazya stricta* was mentioned by Sheludko *et al.* (2000). Hydroquinone: O-glucosyltransferase from cultivated Rauvolfia 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 Sreeramu, 2001). 3-Oxo-rhazinilam, a new indole alkaloid from *Rauvolfia 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 Korzhenevskaia (2002) have found the formation of giant and ultramicroscopic forms of *Nostoc muscorum* CALU 304 during cocultivation with Rauvolfia 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 (Azeem *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 raumacline. Functional expression of an ajmaline pathway-specific esterase from Rauvolfia 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). *Rauvolfia 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 polyploidy of this species. Ammal Janaki (1962) has reported tetraploidy in this plant. Increasing root yield of this plant by colchiploidy was reported by Bhaduri and Biswas (1965). Chromosome constitution and alkaloid content were reported by Banerjee and Sharma (1989). In a report on cytotaxonomy of Aapocynaceae 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 Kutchan *et al.* (1988). Homogeneous strictosidine synthase from cell suspension cultures of was reported by Hampp and Zenk (1988). PCR reaction

comparison of the gene for strictosidine synthase from ten Rauvolfia species including *R. serpentina* was reported by Bracher and Kutchan (1992a). Strictosidine synthase from *R. serpentina* and analysis of a gene involved in indole alkaloid biosynthesis were reported by Bracher and Kutchan (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 Kutchan *et al.* (1994). Gerasimenko *et al.* (2002) have reported the heterologous expression of a Rauvolfia cDNA encoding strictosidine glucosidase, a biosynthetic key to over 2000 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 OPA, 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. Pletscher *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 Trcka and Carlsson (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 rauvolfin was obtained from the dried callus of *R. serpentina* by extraction with 0.7 % aqueous ammonium oxalate and it was found to posses 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 maheshvari 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 (Bhatara *et al.*, 1997), mental disorders (Noce *et al.*, 1954), breast cancer (Stanford *et al.*, 1986), human promyelocytic leukemia (Itoh *et al.*, 2005) like diseases. The Unani formulation Pitkriya 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 Mukhaddir (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-lores 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 (Ajmalicine), 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 three 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 arbortristis is mixed with *Rauvolfia serpentina* root juice to treat scabies (Mohanta *et al*., 2006). De-Britto and Mahesh (2007), while exploring the kani tribal botanicalknowledge in agasthiayamalai 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 Khamptis 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 propogated 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 *R. serpentina* reported by different authors.

Conservation status: *Rauvolfia 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 Sastry, 1987, 1988, 1990; Mamgain *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

Abdel-Moty, S.G., S. Sakai, N. Aimi, H. Takayama and M. Kitajima *et al*., 1998. Synthesis of cytotoxic 1-polyhydroxyalkyl-β-carboline derivatives. Eur. J. Med. Chem., 32: 1009-1017.

Agbalyam, S.G., 1961. Synthetic analogs of reserpine. Usp. Khi., 30: 1175-1195.

Ahmad, S., M.N. Amin, M.A.K. Azad and M.A. Mosaddik, 2002. Micropropagation and plant regeneration of *Rauvolfia serpentina* by tissue culture technique. Pak. J. Biol. Sci., 5: 75-79.

Akram, M. and I. Ilahi, 1985a. Biosynthesis of Some Important Alkaloids by Stem Cultures of *Rauwolfia serpentina* Benth. In: Plant Tissue Culture, Ilahi, I. (Eds.). University of Peshawar, Pakistan, pp: 44-45.

Akram, M. and I. Ilahi, 1985b. Bud Differentiation in Root Callus of Regenerated Plantlets of *Rauwolfia serpentina*. In: Plant Tissue Culture, Qureshi, A. and I. John (Eds.). PARC, Islamabad, pp: 18-23.

Akram, M. and I. Ilahi, 1986. Plantlets formation in root callus of *Rauwolfia serpentina*. Pak. J. Bot., 18: 15-19.

Ammal Janaki, E.L., 1962. Tetraploidy in *Rauvolfia serpentina* benth. Curr. Sci., 31: 520-524.

Andreev, I.O., K.V. Spiridonova, V.T. Solovyan and V.A. Kunakh, 2005. Variability of ribosomal RNA genes in *Rauwolfia* species: Parallelism between tissue culture-induced rearrangements and interspecies polymorphism. Cell Biol. Int., 29: 21-27.

Anisuzzaman, M., A.H.M.M. Rahman, M. Harun-Or-Rashid, A.T.M. Naderuzzaman and A.K.M.R. Islam, 2007. An ethnobotanical study of madhupur, Tangail. J. Applied Sci. Res., 3: 519-530.

Anitha, S. and B.D.R. Kumari, 2006. Stimulation of reserpine biosynthesis in the callus of *Rauvolfia tetraphyla* L. by precursor feeding. Afr. J. Biotechnol., 5: 659-661.

Ansari, A.A., 1993. Threatened medicinal plants from Madhaulia forest of Gorakhpur. J. Econ. Bot. Taxonomy, 17: 241-241.

Arend, J., H. Warzecha and J. Stockigt, 2000. Hydroquinone: O-glucosyltransferase from cultivated *Rauvolfia* cells: Enrichment and partial amino acid sequences. Phytochemistry, 53: 187-193.

Azeem, S.W., M.A. Khan and I. Ahmad, 2005. Characterisation of oxidation products of Rauwolfia alkaloids. Pak. J. Pharm. Sci., 18: 33-35.

Badhwar, R.L., G.V. Karira and S. Ramaswami, 1955. *Rauvolfia serpentina*: The wonder drug of India (*Rauvolfia sarpagandha*). Ind. Forester, 81: 258-268.

Badhwar, R.L., G.V. Karira and S. Ramaswami, 1956. Methods of propagation and their effect on root production in *Rauwolfia serpentina*. Ind. J. Pharm., 18: 170-175.

Bailey, P.D., K.M. Morgan, D.I. Smith and J.M. Vernon, 2000. New asymmetric routes to ajmaline and suaveoline indole alkaloids. Perkin Trans. J. Chem. Soc., 1: 3566-3577.

Baksha, R., M.A.A. Jahan, R. Khatun and J.L. Munshi, 2007. *In vitro* rapid clonal propagation of *Rauvolfia serpentina* (Linn.) benth. Bangladesh J. Sci. Indus. Res., 42: 37-44.

Banerjee, N. and A.K. Sharma, 1989. Chromosome constitution and alkaloid content in *Rauwolfiia* L. (Apocynaceae). Cytologia, 54: 723-728.

Baruah, A. and S.C. Nath, 2000. Diploid autecological and ploidal leaf epidermal characters in *Rauvolfia serpentina* benth. with emphasis to ecophysiological adaptability. Adv. Plant Sci., 13: 245-251.

Bedi, Y.S., 1990. Cytology of hardwoods. Proc. Plant Sci., 100: 91-95.

Benjamin, B.D., G. Roja and M.R. Heble, 1993. *Agrobacterium rhizogenes* mediated tranformation of *Rauvolfia serpentina*: Regeneration and alkaloid synthesis. Plant Cell Tissue Organ Cult., 35: 253-257.

Bertler, A., 1961. Effect of reserpine on the storage of catechol amines in brain and other tissues. Acta Physiol. Scand., 51: 75-83.

Bhaduri, P.N. and P.K. Biswas, 1965. Increasing root yield of *Rauvolfia serpentina* by colchiploidy. Sci. Cult., 31: 197-200.

Bharadwaj, K.R., 1988. Quantitative estimation of rutin in *Rauvolfia serpentina* benth. ex Kurz. Curr. Sci., 57: 439-439.

Bhatara, V.S., J.N. Sharma, S. Gupta and Y.K Gupta, 1997. Images in psychiatry. *Rauwolfia serpentina*: The first antipsychotic. Am. J. Psychiatry, 154: 894-894.

Bhatt, R., M. Arif, A.K. Gaur and P.B. Rao, 2008. *Rauwolfia serpentina*: Protocol optimization for *in vitro* propagation. Afr. J. Biotechnol., 7: 4265-4268.

Bhattacharjee, S.K. and P.N Bhaduri, 1959. Floral biology and cytogenetics of diploid and autopolyploid of *R. serpentina* and *R. canescens*. Bull. Bot. Soc. Beng., 13: 86-92.

Bhattacharyya, P.K. and K. Sarkar, 1998. Flora of west champaran district, Bihar. Botanical Survey of India, Calcutta, pp: 534. http://kbd.kew.org/kbd/detailedresult.do?id=334984.

Biswas, K., 1956. Cultivation of *Rauvolfia* in West Bengal. Ind. J. Pharm., 18: 170-175.

Bose, S., 1954. Rauwolfine: A new alkaloid of *Rauwolfia serpentina* benth. J. Ind. Chem. Soc., 1: 47-47.

Bracher, D. and T.M. Kutchan, 1992a. Polymerase chain reaction comparison of the gene for Strictosidine synthase from ten *Rauvolfia* species. Plant Cell Rep., 11: 179-182.

Bracher, D. and T.M. Kutchan, 1992b. Strictosidine synthase from *Rauvolfia serpentina*: Analysis of a gene involved in indole alkaloid biosynthesis. Arch. Biochem. Biophys., 294: 717-723.

Brodie, B.B., K.F. Finer, F.B. Orlans, G.F. Quinn and F. Sulser, 1960. Evidence that tranquilizing action of reserpine is associated with change in brain serotonin. J. Pharmacol. Exp. Ther., 129: 250-256.

Chandra, V., 1954. Vegetative propagation of *Rauwolfia serpentina* (Benth). J. Sci. Indus. Res., 4: 187-195.

Chandra, V., 1957a. Leaf blotch disease of *Rauvolfia serpentina*. Sci. Cult., 23: 99-99.

Chandra, V., 1957b. Chromosome number of *Rauwolfia serpentina*. Curr. Sci., 3: 99-99.

Chatterjee, A. and S. Bose, 1951. A new alkaloid from the root of *Rauwolfia serpentina* benth. Sci. Cult., 17: 139-139.

De Britto, J. and R. Mahesh, 2007. Exploration of kani tribal botanical knowledge in agasthiayamalai biosphere reserve-south India. Ethnobotanical Leaflets, 11: 258-265.

De, J.N., 1965. Some minor plant-fibres of aboriginal usage in the district of Purulia (West Bengal). Bull. Bot. Soc. Bengal, 19: 67-72.

De, J.N., 1967. Further observation on the ethnobotany of Purulia district, West Bengal. Indian For., 95: 551-559.

De, J.N., 1968. Ethnobotany a newer science in India. Sci. Cult., 34: 326-328.

De, J.N., 1979a. Ethnobotanical study of Purulia District, West Bengal, The Eastern anthropologist. Lucknow, 32: 213-218.

De, M., 1979b. Chromosome studies on the genus *Rauvolfia* Linn. (Apocynaceae). Proc. Ind. Sci. Congr. Assoc., 66: 78-79.

De, J.N., 1980. The vegetarian- based tribal economics in the Purulia District West Bengal. Bull. Cult. Res. Inst., 14: 37-42.

Dhar, R., 1965. Variation in alkaloid content and morphology of four geographical races of *Rauvolfia serpentina* benth. Proc. Plant Sci., 62: 242-244.

Dnyansagar, V.R. and S.G. Torne, 1967. Mitosis and karyotype analysis of *Rauvolfia serpentina*. J. Biol. Sci., 10: 7-13.

Dnyansagar, V.R. and S.G. Torne, 1968. Meiotic analysis in *Rauvolfia serpentina* (L.) Benth. ex Kurz. Proc. Natn. Inst. Sci. India, 35: 368-376.

Dutta, P.K., S.B. Choudhury and P.R. Rao, 1962. Germination and chemical composition of *Rauwolfia serpentina* seeds. Ind. J. Pharm., 24: 61-63.

Dutta, P.K., I.C. Chopra and L.D. Kapoor, 1963. Cultivation of *Rauvolfia serpentina* in India. Econ. Bot., 17: 243-251.

Endreb, S., H. Takayama, S. Suda, M. Kitajima, N. Aimi, S. Sakai and J. Stockigt, 1993. Alkaloids from *Rauwolfia serpentina* cell cultures treated with ajmaline. Phytochemistry, 32: 725-730.

Fabricant, D.S. and N.R. Farnsworth, 2001. The value of plants used in traditional medicine for drug discovery. Environ. Health Perspect., 109: 69-75.

Falkenhagen, H. and J. Stockigt, 1993. Enzymatic biosynthesis of vomilenine, a keyintermediate of the ajmaline pathway, catalyzed by a novel cytochrome P 450 dependent enzyme from plant cell cultures of *Rauvolfia serpentina*. Z. Naturforsch. C: Biosci., 50: 45-53.

Falkenhagen, H., I.N. Kuzovkina, I.E. Alterman, L.A. Nikolaeva and J. Stockigt, 1993. Alkaloid formation in hairy roots and cell suspensions of *Rauwolfia serpentina* benth. Nat. Prod. Res., 3: 107-112.

Farooqi, A.A. and B.S. Sreeramu, 2001. Cultivation of Medicinal and Aromatic Crops. University Press, New Delhi, pp: 518.

Gerasimenko, I., Y. Sheludko and J. Stockigt, 2001. 3-Oxo-rhazinilam: A new indole alkaloid from *Rauvolfia serpentina* X *Rhazya stricta* hybrid plant cell cultures. J. Nat. Prod., 64: 114-116.

Gerasimenko, I., Y. Sheludko, X. Ma and J. Stockigt, 2002. Heterologous expression of a *Rauvolfia* cDNA encoding strictosidine glucosidase, a biosynthetic key to over 2000 monoterpenoid indole alkaloids. Eur. J. Biochem., 269: 2204-2213.

Ghani, A., 1998. Medicinal Plants of Bangladesh Chemical Constituents and Uses. Asiatic Society of Bangladesh, Dhaka.

Ghosh, K.C., G.N. Bhattacharya and N. Banerjee, 1998. A high regeneration potential of Rauwolfia serpentina Benth. through shoot tip culture: Chromosome analysis of the regenerants. Perspectives Cytol. Genet., 9: 313-318.

Glynn, J.D., 1955. *Rauwolfia serpentina* (Serpasil) in psychiatry. J. Neurol. Neurosurg. Psychiatry, 18: 225-227.

Goel, M.K., A.K. Kukreja and S.P.S. Khanuja, 2007. Cost effective approaches for *in vitro* mass propagation of *Rauwolfia serpentina* benth. ex Kurz. Asian J. Plant Sci., 6: 957-961.

Goel, M.K., S. Banerjee, K. Shanker and A.K. Kukreja, 2008. Exploring the potential of *Agrobacterium rhizogenes* mediated transformed roots of *Rauwolfia serpentina* for reserpine biosynthesis: One more step towards developing green factories. J. Biotechnol., 136: S168-S168.

Goel, M.K., S. Mehrotra, A.K. Kukreja, K. Shanker and S.P. Khanuja, 2009. *In vitro* propagation of *Rauwolfia serpentina* using liquid medium, assessment of genetic fidelity of micropropagated plants and simultaneous quantitation of reserpine, ajmaline and ajmalicine. Methods Mol. Biol., 547: 17-33.

Gorelova, O.A. and T.G. Korzhenevskaia, 2002. Formation of giant and ultramicroscopic forms of *Nostoc muscorum* CALU 304 during cocultivation with *Rauwolfia* tissues. Mikrobiologiia, 71: 654-661.

Gorelova, O.A. and S. Kleimenov, 2003. The accumulation and degradation dynamics of cyanophycin in cyanobacteria grown in symbiotic associations with plant tissues and cells. Mikrobiologiia, 72: 361-369.

Gupta, J.C., P.K. Roy, G.K. Ray and S.C. Ganguly, 1950. A preliminary note on the excretion of *Rauwolfia* total alkaloids in urine. Ind. J. Med. Res., 38: 67-73.

Habib, S.M. and W.E. Court, 1974. The separation and identification of microquantities of *Rauwolfia* alkaloids. Planta Med., 25: 331-341.

Hampp, N. and M.H. Zenk, 1988. Homogeneous strictosidine synthase from cell suspension cultures of *Rauvolfia serpentina*. Photochemistry, 27: 3811-3815.

Harisaranraj, H., K. Suresh and S. Saravanababu, 2009. Evaluation of the chemical composition *Rauwolfia serpentina* and *Ephedra vulgaris*. Adv. Biol. Res., 3: 174-178.

Hedayatullah, S., 1959. Culture and propagation of *Rauwolfia serpentina* benth. in East Pakistan. Pak. J. Sci. Indus. Res., 2: 118-122.

Hendrian, D.J.M., 1999. Revision of *Rauvolfia* (Apocynaceae) in Malesia. Blumea, 44: 449-470.

Hofmann, A., 1954. Rauhimbin und Isorauhimbin, zwei neue alkaloide aus *Rauwolfia serpentina* benth 2. Mitteilung uber rauwolfia-alkaloide. Helvet. Chim. Acta, 37: 314-320.

Holt, W.L. and C.H. Costello, 1954. A preliminary chemical investigation of *Rauwolfia serpentina*. J. Am. Pharm. Assoc., 43: 144-148.

Holzbauer, M. and M. Vogt, 1956. Depression by reserpine of the noradrenaline concentration in the hypothalamus of the cat. J. Neurochem., 1: 8-11.

Ilahi, I. and M. Akram, 1987a. Leaf callus culture of *Rauwolfia serpentina*. Pak. J. Bot., 19: 217-223.

Ilahi, I. and M. Akram, 1987b. *In vitro* propagation of *Rauwolfia serpentina* through lateral bud culture. Pak. J. Agric. Res., 8: 204-210.

Ilahi, I., 1993. Micropropagation and biosynthesis of alkaloid by *Rauwolfia serpentina* cell culture. Proceedings of the International Plant Tissue Culture Conference, Dec. 19-21, Dhaka, pp: 21-21.

Ilahi, I. and M. Akram, 1993. Enhanced Propagation, Root Production and Alkaloid Biosynthesis by Cultures of *Rauwolfia serpentina*. In: Adapted Propagation Techniques for Commercial Crops of the Tropics, Quynh, N.T. and N. van Hyen (Eds.). Agricultural Publishing House, Ho Chi Minh, Vietnam.

Ilahi, I., 1995. Rapid micro-propagation of *Rauwolfia*. Apam News Lett., 1: 35-36.

Ilahi, I., F. Rahim and M. Jabeen, 1995. Induction of somatic embryos and plant regeneration in *Rauwolfia serpentina* benth. Pak. J. Plant Sci., 1: 255-261.

Ilahi, I., F. Rahim and M. Jabeen, 2007. Enhanced clonal propagation and alkaloid biosynthesis in cultures of *Rauwolfia*. Pak. J. Plant Sci., 13: 45-56.

Itoh, A., T. Kumashiro, M. Yamaguchi, N. Nagakura, Y. Mizushina, T. Nishi and T. Tanahashi, 2005. Indole alkaloids and other constuents of *Rauwolfia serpentina*. J. Nat. Prod., 68: 848-852.

Jadhav, S.N., K.N. Reddy and C.S. Reddy, 2001. Conservation assessment and management planning for medicinal plants of Andhra Pradesh. Medicinal Plants Conservation Center (MPCC) and FRLHT, Hyderabad, India, pp: 1-39.

Jain, S.K. and J.N. De, 1964. Some less known plant foods among the tribals of Purulia (West Bengal). Sci. Cult., 30: 285-286.

Jain, S.K. and J.N. De, 1966. Observations of ethnobotany of Purulia, West Bengal. Bull. Bot. Survey India, 8: 237-251.

Janardhanan, K.K., D. Ganguli and A. Husain, 1964. *Fusarium* wilt of *Rauvolfia serpentina*. Curr. Sci., 30: 313-313.

Jigna, P., N. Rathish and C. Sumitra, 2005. Preliminary screening of some folklore medicinal plants from western India for potential antimicrobial activity. Indian J. Pharmacol., 37: 408-409.

Karim, M.A., W.H. Linnell and L.K. Sharp, 1961. Potential reserpine analogues Part II. 3,4,5-trimethoxybenzoic acid derivatives. J. Phar. Pharmacol., 12: 82-86.

Kataria, V. and N.S. Shekhawat, 2005. Cloning of *Rauvolfia serpentina*-An endangered medicinal plant. J. Sustainable Forestry, 20: 53-65.

Kattel, L.P., 1987. Studies on phyllotaxical morphotypes in *Rauvolfia serpentina* (L.) benth. ex Kurz. J. Plant Anat. Morph., 4: 193-198.

Kaukhova, I.E., A.G. Vollosovich and V.A. Tsigankov, 1981. Nutrient medium selection for submerged culturing in *Rauwolfia serpentina* benth. tissues. Rast. Res., 17: 217-224.

Khatri, C.K., A. Qayum and S.M. Yusuf, 1982. Comparative studies on the effects of reserpine and its derivatives (bromo and dibromo) reserpine on the blood pressure, heart rate and EEG of rabbit. J. Pak. Med. Assoc., 32: 141-144.

Kirillova, N.V., M.G. Smirnova and V.P. Komov, 2001. Sequential isolation of superoxide dismutase and ajmaline from tissue culture of *Rauwolfia serpentina* Benth. Prikl. Biokhim. Mikrobiol., 37: 181-185.

Kirillova, N.V. and V.P. Komov, 2002. Effect of phytohormones on the protein-synthesizing ability of *Rauwolfia serpentina* benth. tissue culture. Applied Biochem. Microbiol., 38: 45-47.

Kirillova, N.V., 2004. Changes in the activity of superoxide dismutase in *Rauwolfia serpentina* benth. Callus cultures grown under standard conditions and heat shock. Prikladnaya Biokhimiya i Mikrobiologiya, 40: 89-93.

Kirtikar, K.R. and B.D. Basu, 1993. Indian Medicinal Plants. 2 Edn., Dehra Dun Publishers. Culcutta, India, pp: 289.

Klushnichenko, V.E., S.Y. Yakimov, T.P. Bychkova, I.N. Kuzovkina, A.N. Vulf'son and A.I. Miroshnikov, 1994. Separation of indole alkaloids from *R. serpentina* and *R. vomitoria* by HPLC and TLC methods. Pharma. Chem. J., 28: 855-859.

Klyushnichenko, V.E., S.A. Yakimov, T.P. Tuzova, Y.V. Syagailo, I.N. Kuzovkina, A.N. Wulfson and A.I. Miroshnikov, 1995. Determination of indole alkaloids from *R. serpentina* and *R. vomitoria* by high-performance liquid chromatography and high-performance thin-layer chromatography. J. Chromatogr. A, 704: 357-362.

Kostenyuk, I.A., O.F. Lyubarets, S. Endre, Y.Y. Gleba and J. Stockigt, 1995. Alkaloids isolated from somatic hybrid cell cultures of the species combination *Rauwolfia serpentina* x *rhazya stricta*. Nat. Prod. Res., 5: 303-307.

Koul, M.L.H., 1964. Natural polyploidy in *Rauwolfia serpentina*. Sci. Res. Banaras Hindu Univ., 2: 100-102.

Kunakh, V.A. and E.G. Alkhimova, 1989. *Rauwolfia serpentina*: *In vitro* culture and the production of ajmaline. Biotechnol. Agric. Forestry, 7: 398-416.

Kunakh, V.A., 1996. Somaclonal Variation in *Rauwolfia*: Biotechnology in Agriculture and Forestry. In: Somaclonal Variation in Crop Improvement, Bajaj, Y.P.S. (Eds.). Vol. 36, Springer-Verlag, New York, pp: 315-332.

Kunakh, V.A., L.P. Mozhylevskaya and S.I. Gubar, 2001. Details of the method for obtaining and productivity of the suspension cultures and cell clones of *Rauwolfia serpentina* benth. *in vitro*. Biotechnology, 4: 9-21.

Kutchan, T.M., N. Hampp, F. Lottspeich, K. Beyreuther and M.H. Zenk, 1988. The cDNA clone for strictosidine synthase from *Rauvolfa serpentine* DNA sequence determination and expression in *Escherichia coli*. FEBS Lett., 27: 40-44.

Kutchan, T.M., 1989. Expression of enzymatically active cloned strictosidine synthase from the higher plant *Rauvolfia serpentina* in *Escherichia coli*. FEBS Lett., 257: 127-130.

Kutchan, T.M., A. Bock and H. Dittrich, 1994. Heterologous expression of the plant proteins strictosidine synthase and berberine bridge enzyme in insect cell culture. Phytochemistry, 35: 353-360.

Lele, C.V. and Ashram, 1968. Die-back disease of *volfia serpentina*sed by *letotrichum dematium*. Ind. Phytopathol., 20: 349-350.

Lutterbach, R. and J. Stockigt, 1992. High-yield formation of arbutin from hydroquinone by cell suspension cultures of *Rauwolfia serpentina*. Helvetica Chimica Acta, 75: 2009-2011.

Ma, X., J. Koepke, A. Bayer, G. Fritzsch, H. Michel and J. Stockigt, 2005. Crystallization and preliminary X-ray analysis of native and selenomethionyl vinorine synthase from *Rauvolfia serpentina*. Acta Cryst., 61: 694-696.

Ma, X., S. Panjikar, J. Koepke, E. Loris and J. Stockigt, 2006. The structure of *Rauvolfia serpentina* strictosidine synthase is a novel six-bladed β-propeller fold in plant proteins. Plant Cell, 18: 907-920.

Madhusudan, K.P., S. Banerjee, S.P. Khanuja and S.K. Chattopadhyay, 2008. Analysis of Hairy root culture of *Rauvolfia serpentina* using direct analysis in real time mass spectrometric technique. Biomed. Chromatogr., 22: 596-600.

Maheshwari, S.K., B.N. Dahatonde, S. Yadav and S.K. Gangrade, 1985. Intercropping of *Rauvolfia serpentina* for higher monetary returns. Ind. J. Agric. Sci., 55: 332-334.

Maheshwari, S.K., O.P. Sharma, S.K. Gangrade and K.C. Trivedi, 1991. Irrigation schedule for sarpagandha (*Rauvolfia serpentina*) in a shallow black soil. Ind. J. Agric. Sci., 61: 169-171.

Mamgain, S.K., A.K. Goel and S.C. Sharma, 1998. Conservation of assessment of some important threatened medicinal plants of India. J. Non-Timber Fore. Prod., 5: 1-9.

Mao, A.A., T.M. Hynniewta and M. Sanjappa, 2009. Plant wealth of northeast India with reference to ethnobotany. Ind. J. Trad. Knowledge, 8: 96-103.

Mathur, A., A.K. Mathur, A.K. Kukreja, P.S. Ahuja and B.R. Tyagi, 1987. Establishment and multiplication of colchi autotetraploids of *R. serpentina* L. Benth ex Kurz. through tissue culture. Plant Cell Tissue Organ Cult., 10: 129-134.

Mathur, A., P.S. Ahuja and A.K. Mathur, 1993. Micro-Propagation of *Panax quiquefoluim*, *Rauwolfia serpentina* and Some other Medicinal and Aromatic Plants of India. In: Adapted Propagation Techniques for Commercial Crops of the Tropics, Quynh, N.T. and N.V. Hyen (Eds.). Agriculture Publishing House, Hochi Minh, Vietnam.

Mehrotra, M.D. and H.S. Thapar, 1990. *Rhizoctonia* leaf spotting and blight of *Rauvolfia serpentina*, a new disease from India. Ind. Forester, 16: 372-374.

Mia, M.M.K., M.F. Kadir, M.S. Hossan and M. Rahmatullah, 2009. Medicinal plants of the Garo tribe inhabiting the Madhupur forest region of Bangladesh. Am. Eurasian J. Sustainable Agric., 3: 165-171.

Mital, SP, M. Kazim, M.A. Kidwai and K.K. Mittal, 1980. Chemotypic Studies in natural populations of *Rauvolfia serpentina* from certail regions of Karnataka State, India. Curr. Sci., 49: 789-790.

Mitra, G.C. and K.N. Kaul, 1964. *In vitro* culture of root and stem callus of *Rauwolfia serpentina* benth. for reserpine. Ind. J. Exp. Biol., 2: 49-51.

Mitra, G.C., 1976. Studies on the formation of viable and nonviable seeds in R. serpentine. Ind. J. Exp. Biol., 14: 54-54.

Mohanta, R.K., S.D. Rout and H.K. Sahu, 2006. Ethnomedicinal plant resources of simlipal biosphere reserve, Orissa, India. Zoo's Print J., 21: 2372-2374.

Mohanty, N.N. and S.K. Addy, 1958. Target spot of *Rauvolfia serpentina*. Sci. Cult., 23: 608-609.

Monachino, J., 1954. *Rauvolfia serpentina*: Its history, botany and medical use. Econ. Bot., 8: 349-365.

Mukhopadhyaya, S., M.J. Mukhopadhyaya and A.K. Shrma, 1991. *In vitro* multiplication and regeneration of cytologically stable platns of Rauwolfia serpentina Benth. through shoot tip culture. Nucleus Calcutta, 34: 170-173.

Muscholl, E. and M. Vogt, 1958. The action of reserpine on the peripheral sympathetic system. J. Physiol., 141: 132-155.

Nayar, S.L., 1956. Experimental propagation and culture of *Rauwolfia serpentina* benth. by seeds. Ind. J. Pharm., 18: 125-126.

Nayar, M.P. and A.R.K. Sastry, 1987. Red Data Book of Indian Plants. Vol. 1, Botanical Survey of India, Calcutta.

Nayar, M.P. and A.R.K. Sastry, 1988. Red Data Book of Indian Plants. Vol. 2, Botanical Survey of India, Calcutta.

Nayar, M.P. and A.R.K. Sastry, 1990. Red Data Book of Indian Plants. Vol. 3. Botanical Survey of India, Calcutta.

Nayar, M.P., 1996. Hot Spots of Endemic Plants in India, Nepal and Bhutan. Tropical Botanical Garden and Research Institute, Thiruvananthapuram, Kerala, pp: 252.

Noce, R.H., D.B. Williams and W. Rapaport, 1954. Reserpine (Serpasil) in the management of mentally ill and mentally retarded. J. Am. Med. Assoc., 156: 821-824.

Nurcahyani, N., Solichatun and E. Anggarwulan, 2008. The reserpine production and callus growth of indian snake root (*Rauvolfia serpentina* (L.) benth. Ex Kurz) culture by addition of Cu2+. Biodiversitas, 9: 177-179.

Obitz, P., S. Endreb and J. Stockigt, 1995. Enzymatic biosynthesis of raumacline. Phytochemistry, 40: 1407-1417.

Padmalatha, K. and M.N.V. Prasad, 2007. Inter and intrapopulation genetic diversity of *Rauvolfia serpentina* (L.) benth. ex Kurz, an endangered medicinal plant, by RAPD analysis. Med. Aromatic Plant Sci. Biotechnol., 1: 118-123.

Pakrashi, S. and B. Akkhari, 1968. *Rauwolfia* alkaloids. Farmatsiia, 17: 64-82.

Pandey, B.P., 1984. Economic Botany. Janta Vedic College, Baraut, India.

Pandey, V.P., J. Kudakasseril, E. Cherian and G. Patani, 2007. Comparison of two methods for *in vitro* propagation of *Rauwolfia serpentina* from nodal explants. Ind. Drugs, 44: 514-519.

Pandey, V.P., E. Cherian and G. Patani, 2010. Effect of growth regulators and culture conditions on direct root induction of *Rauwolfia serpentina* L. (Apocynaceae) benth by leaf explants. Trop. J. Pharm. Res., 9: 27-34.

Pant, K.K. and S.D. Joshi, 2008. Rapid multiplication of *Rauvolfia serpentina* benth. ex. Kurz through tissue culture. Sci. World, 6: 58-62.

Parinitha, M., G.U. Harish, N.C. Vivek, T. Mahesh and M.B. Shivanna, 2004. Ethnobotanical wealth of Bhadra wild life Sanctuary, Karnataka. India J. Traditional Knowledge, 3: 37-50.

Patil, V.M. and M. Jayanthi, 1997. Micropropagation of two species of *Rauwolfia* (Apocyanaceae). Curr. Sci., 72: 961-965.

Pattanaik, C., S. Reddy and K.N. Reddy, 2009. Ethno-medicinal survey of threatened plants in eastern ghats, India. Our Nature, 7: 122-128.

Paul, D., N.K. Paul and P.K. Basu, 2008. Seed germination response of *Rauvolfia serpentna* benth. to certain physical and chemical treatments. J. Bio-Sci., 16: 129-131.

Perveen, R. and I. Ilahi, 1978. Callus formation in *Rauwolfia serpentina*. Pak. J. Bot., 10: 141-148.

Pletscher, A., P.A. Shore and B.B. Brodie, 1955. Serotonin release as a possible mechanism of reserpine action. Science, 122: 374-375.

Polz, L., J. Stockigt, H. Takayama, N. Ushida, N. Aimi and S.I. Sakai, 1990. Biotransformation of ajmaline in plant cell cultures of *Rauwolfia serpentina* benth.: The new indole alkaloids raumacline and N(β)-methyl-raumacline. Tetrahedron Lett., 31: 6693-6696.

Popelak, A., M. Spingler, F. Kaiser, J.D. Achelis and G. Kroneberg, 1953. Neue alkaloide aus *Rauwolfia serpentina*. Naturwissenchaften, 40: 625-625.

Popov, S.V., V.G. Vinter, O.A. Patova, P.A. Markov and I.R. Nikitina *et al*., 2007. Chemical characterization and anti-inflammatory effect of rauvolfin, a pectic polysaccharide of *Rauvolfia* callus. Biochemistry, 72: 778-784.

Raghavan, R.S., 1957. Chromosome numbers in Indian medicinal plants. Proc. Ind. Acad. Sci., 6: 294-298.

Rai, S.K., 2004. Medicinal plants used by meche people of Jhapa district, eastern Nepal. Our Nature, 2: 27-32.

Raj, A.D.S. and S. Sukumaran, 2008. Rare and endemic plants in the sacred groves of akumari district in Tamil Nadu. Ind. J. Forestry, 31: 611-616.

Rajkarnikar, K.M., H.K. Sainju and G.D. Bhatta, 2000. *In vitro* culture of *Rauwolfia serpentina* L. benth. ex. Kurz. Proceedings of Nepal Japan Joint Symposium, pp: 232-234.

Ray, A. and S. Bhattacharya, 2008. Cryopreservation of *in vitro* grown nodal segments of *Rauvolfia serpentina* by PVS2 vitrification. Cryoletters, 29: 321-328.

Roja, P.C., B.D. Benjamin, M.R. Heble and M.S. Chadha, 1985. Indole alkaloids from multiple shoot cultures of *R. serpentina*. Plant. Med., 50: 73-74.

Roja, P.C., A.T. Sipahimalini, M.R. Heble and M.S. Chadha, 1987. Multiple shoot cultures of *R. serpentina*: Growth and alkaloid production. J. Nat. Prod., 50: 872-875.

Roja, G. and M.R. Heble, 1996. Indole alkaloids in clonal propagules of Rauwolfia serpentina Benth. ex. Kurz. Plant Cell Tissue Organ Culture, 44: 111-115.

Rout, S.D., T. Panda and N. Mishra, 2009. Ethno-medicinal plants used to cure different diseases by tribals of mayurbhanj district of North orissa. Ethno-Med., 3: 27-32.

Rout, S.D., S.K. Panda N. Mishra and T. Panda, 2010. Role of tribals in collection of commercial non-timber forest products in Mayurbhanj district, Orissa. Stud. Tribes Tribals, 8: 21-25.

Roy, S.K., M.Z. Hossain and M.S. Islam, 1994. Mass propagation of Rauwolfia serpentina by *in vitro* shoot tip culture. Plant Tissue Cult., 4: 69-75.

Ruppert, M., J. Woll, A. Giritch, E. Genady, X. Ma and J. Stockigt, 2005a. Functional expression of an ajmaline pathway-specific esterase from *Rauvolfia* in a novel plant-virus expression system. Planta, 222: 888-898.

Ruppert, M., X. Ma and J. Stockigt, 2005b. Alkaloid biosynthesis in *Rauvolfia*- cDNA cloning of major enzymes of the ajmaline pathway. Curr. Organic Chem., 9: 1431-1444.

Ruyter, C.M., A. Mahmood, I. Illahi and J. Stockigt, 1991. Investigation of the alkaloid content of *Rauwolfia serpentina* roots from regenerated plants. Planta Med., 57: 328-330.

Saini, S., A. Sattar and M. Alam, 1996. Occurrence of stem rot disease caused by *Rhizopus stolonifer* on periwinkle. Ind. J. Plant Pathol., 14: 1-4.

Salma, U., M.S.M. Rahman, S. Islam, N. Haque, T.A. Jubair, A.K.M.F. Haque and I.J. Mukti, 2008a. The influence of different hormone concentration and combination on callus induction and regeneration of *Rauwolfia serpentina* L. Benth. Pak. J. Biol. Sci., 11: 1638-1641.

Salma, U., M.S.M. Rahman, S. Islam, N. Haque, M. Khatun, T.A. Jubair and B.C. Paul, 2008b. Mass propagation of *Rauwolfia serpentina* L. Benth. Pak. J. Biol. Sci., 11: 1273-1277.

Sankaranarayanan, S., P. Bama, J. Ramachandran, P.T. Kalaichelvan and M. Deccaraman *et al*., 2010. Ethnobotanical study of medicinal plants used by traditional users in Villupuram district of Tamil Nadu. India J. Med. Plants Res., 4: 1089-1101.

Santapau, H., 1956. Botanical aspects of *R. serpentina*. Ind. J. Pharm., 18: 117-126.

Sarkar, K.P., A. Islam, R. Islam, A. Hoque and O.I. Jorarder, 1996a. *In vitro* propagation of *R. serpentina* through tissue culture. Plant Med., 62: 358-359.

Sarkar, K.P., A. Islam, R. Islam, A. Hoque and O.I. Joardar, 1996b. Plant regeneration of *Rauvolfia serpentina* by organogenesis from callus cultures. Plant Tissue Cult., 6: 63-65.

Sarkar, N., S. Rudra and S.K. Basu, 1999. Ethnobotany of Bangiriposi, Mayurbhanj, Orissa. J. Econ. Tax. Bot., 23: 509-514.

Sarma, D., A.K. Kukreja and A. Baruah, 1997. Transforming ability of two *Agrobacterium rhizogenes* strains in *Rauvolfia serpentina* (L.) leaves. Ind. J. Plant Physiol., 2: 166-168.

Saxena, H.O., M. Brahmam and P.K. Dutta, 1988. Ethnobotanical studies in similipal forests of Mayurbhanj district (Orissa). Bull. Bot. Surv. India, 10: 83-89.

Schlemmer, F. and F. Link, 1959. Thin-layer chromatography of rauwolfia alkaloids. Pharm. Ztg., 104: 646-648.

Schlittler, E., H. Saner and J.M. Muller, 1954. Reserpinin, ei neues alkaloid aus *Rauwolfia serpentina*. Experientia, 10: 109-133.

Sehrawat, A.R., U. Sanjogta and A. Punia, 2001. *In vitro* culture and multiplication of *Rauwolfia serpentina*-A threatened medicinal plant. Crop Res., 22: 68-71.

Sen, S. and P.C. Datta, 1990. Use of hormones *in vitro* for alkaloid production in some Apocynaceous drugs. Acta Bot. Sin., 18: 115-117.

Sen, P., M. Dollo, M. Duttachoudhury and D. Choudhury, 2008. Documentation of traditional herbal knowledge of *Khamptis* of arunachal Pradesh. Ind. J. Tradit. Knowledge, 7: 438-442.

Sethi, K.L. and M. Kazim, 1983. Collection and conservation of *Rauvolfia serpentina* genetic resources of South Karnataka and Western Ghats of India. Proceedings of the 5th All India Workshop on Medicinal and Aaromatic Plants, Oct. 83, Solan, Indian, pp: 1-8.

Sethi, K.L., M. Kazim, M.A. Kidwai and S.P. Mital, 1991. Variation of chemo-botanical characters in the indigenous collections of *Rauvolfia serpentina*. Ind. J. Genet. Plant Breed., 51: 134-138.

Shamsi, Y., H. Kumar, S.A. Tamanna and E.A. Khan, 2006. Effect of a polyherbal Unani formulation on chronic urticaria. Ind. J. Tradit. Knowledge, 5: 279-283.

Sharma, S., 1958. Medicinal plants of India. Illustrated Weekly of India, January, pp: 43-44.

Sharma, A.K. and M. De, 1976. Cytotaxonomic studies on medicinal plants of Apocynaceae. Res. Bull. Univ. Calcutta Cytogenetics Lab., 3: 41-42.

Sharma, N. and K.P.S. Chandel, 1992. Low temperature storage of *Rauvolfia serpentina* benth. ex Kurz.: An endangered, endemic medicinal plant. Plant Cell Rep., 11: 200-203.

Sheludko, Y.V. and J.A. Kostenyuk, 1994. Growth dynamics and total alkaloid content in transgenic root culture of *Rauvolfia serpentina* benth. Tsitologiya i Genetika, 28: 35-38.

Sheludko, Y., I. Gerasimenko and O. Platonova, 2000. Divergence of the indole alkaloid pattern in two somatic hybrid plant cell subcultures of *Rauvolfia serpentina* X *rhazya stricta*. Planta Med., 66: 656-659.

Sheludko, Y., I. Gerasimenko, H. Kolshorn and J. Stockigt, 2002a. Isolation and structure elucidation of a new indole alkaloid from *Rauvolfia serpentina* hairy root culture: The first naturally occurring alkaloid of the raumacline group. Planta Med., 68: 435-439.

Sheludko, Y., I. Gerasimenko, H. Kolshorn and J. Stockigt, 2002b. New alkaloids of the sarpagine group from *Rauvolfia serpentina*. hairy root culture. J. Nat. Prod., 65: 1006-1010.

Shen, Z., W. Eisenreich and T.M. Kutchan, 1998. Bacterial biotransformation of 3α(S) strictosidine to the monoterpenoid indole alkaloid vallesiachotamine. Phytochemistry, 48: 293-296.

Sheppard, H. and J.H. Zimmerman, 1960. Reserpine and the levels of serotonin and norepinephrine in the brain. Nature, 185: 40-41.

Shimolina, L.L., T.V. Astakhova and L.A. Nikolafva, 1984. Quantitative determination of total alkaloids in rauwolfia serpentina tissue culture. Rastit. Resur., 20: 137-141.

Shukla, R.S., M. Alam, A. Sattar, Abdul-Khaliq and H.N. Singh, 2006. First report of *Rhizopus stolonifer* causing inflorescence and fruit rot of *Rauvolfia serpentina* in India. EPPO Bull., 36: 11-13.

Siddiqui, S.S. and R.H. Siddiqui, 1931. The alkaloids of *Rauwolfia serpentina*, benth. J. Ind. Chem. Soc., 8: 667-678.

Siddiqui, S.S. and R.H Siddiqui, 1932. The alkaloids of *Rauwolfia serpentina*, benth. J. Ind. Chem. Soc., 9: 539-542.

Siddiqui, S.S. and R.H Siddiqui, 1935. The alkaloids of *Rauwolfia serpentina*, benth. Part II. Studies in ajmaline series. J. Ind. Chem. Soc., 12: 37-37.

Siddiqui, S.S., 1939. A note on the alkaloids *Rauwolfia serpentina*, benth. J. Ind. Chem. Soc., 16: 421-425.

Singh, D.N., 1961. Use of induced rooting in cytological studies. Nature, 189: 420-421.

Singh, D.K., B. Srivastava and A. Sahu, 2004. Spectophotometric determination of *Rauwolfia* alkaloids: Estmation of reserpine in pharmaceuticals. Anal. Sci., 20: 571-573.

Singh, H., 2008. Importance of local names of some useful plants in ethnobotanical study. Ind. J. Tradit. Knowledge, 7: 365-370.

Singh, P.K., V. Kumar, R.K. Tiwari, A. Sharma, C.V. Rao and R.H. Sinhg, 2010. Medico-ethnobotany of chatara block of district sonebhadra, Uttar Pradesh, India. Adv. Biol. Res., 4: 65-80.

Solovyan, V.T., E.V. Spiridonova and V.A. Kunakh, 1994a. Genome rearrangements in cultured *Rauwolfia serpentina* cells. I. The involvement of the multiple genomic sequences. Genetika, 30: 250-254.

Solovyan, V.T., E.V. Spiridonova and V.A. Kunakh, 1994b. Genome rearrangements in cultured *Rauwolfia serpentina* cells. II. Relation to the interspecies variation. Genetika, 30: 399-401.

Solovyan, V.T., V.A. Kunakh, A.V. Vershinin and V.K. Shumny, 1986. The comparison of the DNA homology degree and the number of repeated sequences in intact plant and cultured cells of *Rauwolfia serpentina* benth. Proc. Nat. Acad. Sci., 287: 998-1001.

Spiridonova, E.V., D.M. Adnof, I.O. Andreev and V.A. Kunakh, 2008. Dynamics of genome changes in *Rauwolfia serpentina* callus tissue upon the switch to conditions of submerged cultivation. Cytol. Genet., 42: 101-106.

Sreemantula, S., K.M. Boini and S. Nammi, 2004. Reserpine methonitrate, a novel quaternary analogue of reserpine augments urinary excretion of VMA and 5-HIAA without affecting HVA in rats. BMC Pharmacol., 4: 30-30.

Srivastava, A., A.K. Tripathi, R. Pandey, R.K. Verma and M.M. Gupta, 2006. Quantitative determination of reserpine, ajmaline and ajmalicine in Rawvolfia serpentine by reversed-phase high-performance liquid chromatography. J. Chromatogr. Sci., 44: 557-560.

Stanford, J.L., E.J. Martin, L.A. Brintin and R.N. Hoover, 1986. Rauwolfia use and breast cancer: A case-control study. J. Natl. Cancer Inst., 76: 817-822.

Stockigt, J., A. Pfitzner and J. Firl, 1981. Indole alkaloids from cell suspension cultures of *Rauwolfia serpentina* benth. Plant Cell Rep., 1: 36-39.

Stockigt, J., 1995. Biosynthesis in *Rauwolfia serpentina* Modern Aspects of An Old Medicinal Plant. In: The Alkaloids, Chemistry and Pharmacology, Cordell, G.A. (Eds.). Academic Press, New York, pp: 115-172.

Sultana, S.S., A.N.M. Rubaiyath-Bin-Rahman and S.S. Alam, 2009. Karyotype analysis with orcein and CMA from leaf base cells of *Rauvolfia serpentina* benth. ex Kurz. Bangladesh J. Bot., 38: 111-113.

Tapadar, N., N. Roy and N.K. Sen, 1960. Cytotaxonomical studies on the economic plants of the family Apocynaceae. Caryologia, 3: 367-397.

Tapadar, N. and N. Roy, 1964. Cytotaxonomic studies in apocynaceae and delineation of the different evolutionary tendencies operating within the family. Caryologia, 77: 103-138.

Trcka, V. and A. Carlsson, 1967. Pharmcology of reserpine analogues VI. Reserpine analogs with differential effect on brain monoamines. Acta Pharmacol. Toxicol., 25: 107-112.

Uesato, S., S. Kanomi, A. Iida, H. Inouye and M.H. Zenka, 1986. Mechanism for iridane skeleton formation in the biosynthesis of secologanin and indole alkaloids in *Lonicera tatarica*, *Catharanthus roseus* and suspension cultures of *Rauwolfia serpentina*. Phytochemistry, 25: 839-842.

Vaidya, A.D.B., 2006. Reverse pharmacological correlates of Ayurvedic drug actions. Ind. J. Pharmacol., 38: 311-315.

Vakil, R.J., 1955. *Rauwolfia serpentina* in the treatment of high blood pressure. Circulation, 12: 220-229.

Van der Laan, F.M. and J.C. Arends, 1985. Cytotaxonomy of the apocynaceae. Genetica, 68: 3-35.

Varadarajan, P.D., 1958. Blight and die-back disease of *Rauvolfia serpentina*. J. Biol., 1: 1-4.

Varadarajan, P.D., 1964. Anthracnose disease of *Rauvolfia serpentina* caused by Colletotrichum gloeosporioides. Curr. Sci., 33: 564-565.

Varadarajan, P.D., 1967. Leaf spot and premature defoliation of *Rauvolfia serpentina* under cultivation caused by Curvularia lunata. Ind. Phytopathol., 19: 298-300.

Varchi, G., A. Battaglia, C. Samori, E. Baldelli and B. Danieli *et al*., 2005. Synthesis of deserpidine from reserpine. J. Nat. Prod., 68: 1629-1631.

Vollosovich, A.G. and R.G. Butenka, 1970. Tissue Culture of *Rauwolfia serpentina* as a Resource of Alkaloids. In: Culture of Isolated Organs, Tissues and Cells of Plant, Butenka, R.G. (Eds.). Nauka, Moscow, pp: 253-257.

Vollosovich, N.E., A.G. Vollosovich, T.A. Kovaleva, Z.B. Shamina and R.G. Butenko, 1976. Strains of a *Rauwolfia serpentina* benth. Tissue culture and their productivity. Rast. Res., 12: 578-583.

Vollosovich, A.G., L.A. Nikolaeva, S.G. Duksina and L.K. Kartashova, 1977. Methods for the quantitative determination of the sum of alkaloids in a tissue culture of rauwolfia (*Rauwolfia serpentina* benth). Farmatsiia, 26: 29-32.

Vollosovich, A.G., T.M. Puchinina and L.A. Nikolaeva, 1979. Optimization of the composition of macrosalts for *Rauwolfia serpentina* benth. tissue culture. Rastit. Res., 15: 516-526.

Vollosovich, A.G., T.M. Puchinina and N.A. Listunova, 1982. Optimization of macronutrient composition for *Rauwolfia* tissue culture. Rast. Res., 15: 239-243.

Von Poser, G., H.H. Andrade, K.V. Da Silva, A.T. Henriques and J.A. Henriques, 1990. Genotoxic, mutagenic and recominogenic effects of *Rauwolfia* alkaloids. Mutat. Res., 232: 37-43.

Wachsmuth, O. and R. Matusch, 2002. Anhydronium bases from *Rauvolfia serpentina*. Phytochemistry, 61: 705-709.

Wakhloo, J.L., 1963. Variation in the total alkaloid content of *Rauvolfia serpentina* roots, a consideration from ecological point of view. J. Ind. Bot. Soc., 42: 215-215.

Warzecha, H., P. Obitz and J. Stockigt, 1999. Purifcation, partial amino acid sequence and structure of the product of raucaffricine-O-β-D-glucosidase from plant cell cultures of *Rauwolfia serpentina*. Phytochemistry, 50: 1099-1109.

Yamamoto, O. and Y. Yamada, 1986. Production of reserpine and its optimization in cultured *Rauwolfia serpentina* Benth. cells. Plant Cell Rep., 5: 50-53.

Yamamoto, O. and Y. Yamada, 1987. Selection of a reserpine-producing cell strain using UV-light and optimization of reserpine production in the selected cell strain. Plant Cell Tissue Organ Cult., 8: 125-133.