Original Article

An Overview on the Ethnophytopathological Studies of *Cassia alata* - an Important Medicinal Plant and the Effect of VAM on its Growth and Productivity

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Abstract

Traditional medicine comprises medical knowledge system that develops over generations within various societies before the era of modern medicine. It includes herbal, ayurveda, and acupuncture. In some Asian and African countries upto 80% of the population relies on traditional medicines or practices and can have negative or dangerous effect, therefore further research is needed to ascertain the efficacy and safety. Here we have selected an important medicinal plant, *Cassia alata* for a comprehensive review on ethnophytopathology of this plant and the effect of vesicular arbuscular mycorrhizal fungi on its growth and productivity. This plant is found widely in tropical regions, sometimes cultivated for medicinal purposes. Fresh or dried leaflet of *C. alata* has been used as folk medicines and its different parts are used in ayurvedic medicine as well as home remedies for common ailments in the treatment of constipation, stomach pain, ringworm and skin disease [1, 2, 3, 4, 5]. Sequential extraction using solvents viz. petroleum ether, chloroform, ethanol, methanol and water of leaves of the plant have been proved to possess antibacterial property [6] and found to be effective against some clinical isolates of Gram-positive and Gram-negative bacteria viz., *Vibrio cholerae, Bacillus subtilis, Staphylococcus aureus, Streptococcus sp., Escherichia coli* as well as against a few fungi which are mostly dermatophytes causing skin infection in human beings like, *Aspergillus niger, Aspergillus flavus, Aspergillus candidus, Penicillium patulum, Candida albicans* and *Rhizopus stolonifer* [5] and *Trichophyton mentagrophytes var interdigitale, T. Mentagrophytes var. mentogrophytes, T. rubrum* and *Microsporum gypseum* and *Microsporum canis* [7]. Phytochemical screening of extract of this plant has been performed for constituents like, alkaloids, flavonoids, tannins, anthraquinones, saponins and volatile oils which are responsible for exerting antimicrobial activity [8,9]. Results were compared to commercial antibiotics like, chloramphenicol, penicillin, ciprofloxacin and flucanazole. Histological examination on the liver cells suggests that the extract contributes to mild hepatocyte degeneration [10]. The significance of VAM for enhancement of plant growth, vigour and yield is gradually appreciated. Association of VAM fungi in this plant has been studied by Chatterjee *et al*.2010.

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key words-*Cassia alata*, VAM, Antimicrobial activity

Introduction:

Demands of traditional herbal medicines are increasing day by day not only by the developing countries but also by the developed countries throughout the world. The demand is due to the increased acceptance of ayurveda and traditional herbal medicines, because of having their no side effects, and as such modern people relies more on drug resources of plant origin. So studies on the ethno-botany, ethnophytopathology and ethnomedicinal uses of our wild medicinal plants and investigations regarding enhanced productivity of medicinal plants is one of the frontier areas of modern research. Ethnobotany is the study of the relationship between people and plants. This interdisciplinary field includes studying plants as wild foods and as agricultural crops. Ethnophytopathology is might be considered a reworking of the classic plant pathological concept of the disease triangle, i.e. the relationships between pathogens, the environment, and society [11].

Many species of *Cassia* possess anti-tumours, laxative, emetic, astringent, anti-pyretic and anti-oxidant properties. *Cassia alata* commonly known as ‘dadmari’ / ‘candlebrush’ having very high medicinal values like – antimicrobial property particularly against fungal dermatophytes and traditionally being used in the treatment of skin infections in man [4, 5]. Leaf extract is also credited
for the treatment of constipation, inguinal hernia, intestinal parasitosis, syphilis and diabetes [1, 2, 3]. Leaf extract is a good antioxidant and the compound obtained from has been identified as a flavonol compound and named as ‘Kaempferol’ [12].

The symbiotic association between fungi and the roots of higher plants comes under the general name ‘mycorrhiza’ which literally means fungus-root. Vascular arbuscular mycorrhizal fungi (VAM) or most commonly arbuscular mycorrhizal fungi (AM) are ubiquitous in their distribution and occur abundantly. Population of fungal and bacterial microflora of the rhizosphere soil of Cassia alata has been studied, before and after application of a VAM fungus Glomus fasciculatum in the form of root cuttings of Zea mays and VAM rich soil. It was recorded that the soil without VAM inoculation exhibited some resident VAM fungi but the number of spores were much lesser than that in VAM inoculated soil. The resident VAM fungi were still present even after the application of Glomus fasciculatum in pot culture. Diversity of fungal population other than VAM was more in the rhizosphere soil not inoculated with Glomus fasciculatum. However, diversity of bacterial population was more in VAM inoculated soil than the non-VAM-inoculated soil. It was noticed that the VAM-inoculated soil exhibited more diversity and population density of some plant growth promoting rhizobacteria (PGPR) like Bacillus sp, Pseudomonas fluorescence, Rhizobium sp, Azotobacter sp, etc. Majority of land plants have the dynamic association of VAM fungi and about 80% of the total land plants are associated with vascular arbuscular mycorrhizal fungi [13]. Survey on VAM association in different medicinally important angiosperms [14] and pteridophytes [15] has been done. It represents one of the nature’s best gift to the mankind. The significance of VAM in augmenting food production is increasingly appreciated. VAM fungi are responsible for enhanced uptake of mineral nutrients specially phosphorus from the soil by the host plants and thereby enhancing growth and vigor of the host plant. VAM fungi are reported to enhance the IAA production and IAA metabolism in the host plants and thereby enhancing growth and vigor of the host [16, 17]. That is why they are referred as biofertilizers and can be substantiated for substantial amounts of chemicals fertilizers [17]. Another impact of VAM fungi on the host plants is to provide protection to the hosts against pathogenic attack. [18, 19]. They also enhance the tolerance limit of the plants to different types of stresses like, salinity stress, drought stress etc. So, the purpose of present review is to study the ethnobotanical and ethnophytopathological investigation on Cassia alata with special reference to its antifungal and antibacterial activity, antioxidant properties and assessment of VAM association and effect of VAM infection in this plant.

Taxonomy and Systematic Position:
Family: Fabaceae
Genus: Cassia
Species: alata
Synonym: Senna alata, Herpetica alata, Cassia bracteata, Cassia herpetica.
Common names: guava, amana-putir-i, bajagua, bois d'artre, candlebush, senna, candlesticks, Christmas-candle, daoen koepang, dartres, dates jaunes, emperor's candlesticks, empress-candleplant, fleur a dartres, fleur St Christophe, fleur dartre, fleur palmiste, gelenggang, guacamaya francesa, herbe a dattes, ketepeng kebo, ketepeng tijna, ketepeng, ketepeng badak, ki manila, ludanggan, mata-pasto, matupa, mocot retama, ringworm senna, ringworm bush, ringworm shrub, seven-goldencandlesticks.

Guajava is a beautiful flowering shrub that grows about 1 to 2 m in height. It produces pretty yellow flowers in a column that resemble yellow candlesticks - earning its common name candles. The persistent shrub can grow up to six feet tall (one to two meters) and consists of yellow waxy, erect spikes that may bear resemblance to big, golden candles prior to full blossoming. The bilateral leaves are substantial, alternately arranged and folds upon itself during nighttime. In addition, around eight to twenty oblong-elliptically shaped leaflets measuring about two to four inches embrace the leaves. The trunk or branches grow generally upright with no thorns but is thin and easily damaged [20]. Its flowers are made up of oblong sepals while the fruits are smooth, winged and tetragonal. Moreover, the fruit is a pod measuring up to six to twelve inches and brown while the seeds are square in form and tiny [20].
with about 4cm in diameter is arranged in an inflorescence column that resembles yellow candlesticks. Flowers are petals because of the indistinguishableness of the petals and sepals [21] and pseudo-papilionaceous (common among all sub-family members of Caesalpinioideae) [23]. There are two sets of sepals once a young bud is maturing and the outermost layer falls off as the flower matures and opens up. The flowers are actually hypogynous but are appears to be perigynous because of the hypanthium; a floral structure consisting of the bases of the sepals, petals, and stamens fused together (a characteristic evident among members of family Fabaceae). C. alata L. is a perfect and complete flower. Each flower has two long banana-shaped anthers (which are tetrasporangiate), 3 projections from its stigma, 4 stamens that serve as the exit point of pollen, a nectar, and a long pointed stalk that will eventually become the fruit pod of the future seeds known as the Gynophore.

[24] have observed that the Pollen grains of C. alata are 27µm polar length and 26µm in equatorial length in 3000x magnification through Scanning Electron Microscope. It is tricolpate with a prolate spheroidal shape. Membrane of pollen grains are smooth with the 2µm thick exine and a finely articulate sexine with granulate muri and lumina. Anthers dehisce and pollen are viable during early morning or mid-day as an evolutionary technique to increase plant–pollinator interaction success. Receptacle houses unicarpellate ovary but forms a fruit separate from the receptacle. Other organs found in the receptacle are vascular bundles, style extension towards the ovary and other various parts of the ovary itself (e.g. placenta, locules, etc.). Placentation of the flower is lateral or marginal. The ovule type is amphitropous. The egg cell’s development is a monosporic polygonum 7-8n type. An axis of produces 4-winged pods (i.e. legume) which grows at about 6-12 inches containing 50-60 flattened, triangular seeds. At a young age, the pods are green, but eventually harden and turn brown as they mature. [21, 22].

**Distribution:**
It is native to the Amazon Rainforest and can be found in Peru, Brazil, French Guiana, Guyana, Suriname, Venezuela and Colombia. Due to its beauty, it has been cultivated around the world as an ornamental plant and has naturalized in many tropical regions in the world including tropical Africa, tropical Asia, Australia, Mexico, the Caribbean islands, Melanesia, Polynesia, Hawaii and widely distributed throughout the different parts of India like, Chattisgarh, Maharashtra, West Bengal, Andhra Pradesh etc.

**Tribal and Ethnomedicinal Uses:**
The Tikuna Indians of the Amazon prepare a decoction of the flowers as a purgative and one cup is taken each morning. In Cuba, the plant is named ‘Guacamayafraçnese’ and it is used for herpes ulcers and other skin infections, as a diuretic and as a laxative. In Peruvian herbal medicine systems the plant is called ‘Retama’ and the flowers are prepared in an infusion to treat urinary infections and used to increase urination; the leaves and stems are prepared in a decoction for ascaries, herpes ulcers, ringworm, and other skin infections and the root, leaves, wood and flowers are decocted for a remedy against intestinal parasites and hepatitis. Interestingly, the flowers are used as a diuretic (to increase urination), while the leaves are believed to be anti-diuretic. In Brazil, the plant is called guava or mata-pasto. An infusion of the bark and roots is used for hydropsy, skin eruptions and fever. The leaves are considered emmenagogues (herbs which stimulate blood flow in the pelvic area and uterus; some stimulate menstruation. Women have used plants such as mugwort, parsley and ginger to prevent or terminate early pregnancy (abortifacient). Others use emmenagogues to stimulate menstrual flow when menstruation is absent for reasons other than pregnancy, such as hormonal disorders or conditions like oligomenorrhea (infrequent or light menses) and diuretic and are prepared in extracts or capsules for liver problems, anemia, dyspepsia, menstrual problems, and high fevers. The leaves are juiced and mixed with lemon juice and applied to the skin for dermatitis and taken internally for syphilis [25].

**Traditional Herbal Medicinal uses:**
Leaves or sap are used to treat fungal infections such as ringworm. They contain a fungicide, chrysophanic acid.

**Molecular Structure**

Because of its anti-fungal properties, it is a common ingredient in soaps, shampoos and lotions in the Philippines. The effectiveness of this plant against skin diseases is confirmed by modern scientific studies. Other chemicals contained in the plant includes saponin which acts as a laxative and expels intestinal parasites. In Africa, the boiled leaves are used to treat high-blood pressure. In South America, besides skin diseases, it is also used to treat a wide range of ailments from stomach problems, fever, asthma to snake bite and vesicular diseases like, syphilis, gonorrhea etc. [6].

**Worldwide Ethnomedicinal Uses:**
- **Africa** - as an abortifacient, laxative, for parturition, scurvy.
- **Brazil** - for anemia, constipation, dermatitis, dyspepsia, fevers, hydropsy, liver problems, menstrual disorders, skin problems, venereal disease, as a diuretic, emmenagogues, laxative and as a purgative.
- **Cuba** - as a diuretic, diaphoretic, laxative, against herpes, skin infections.
- **Ghana** - as an abortifacient, insecticide, purgative, vermifuge, for ascites, crav-craw, dhobeyitch, eczema, gonorrhea, herpes, leprosy, mycosis, parturition, ringworm, shingles, skin problems, sores, wounds.
- **Part Used:** Leaves, Bark, Stem, Root, Pod, Seed, etc.
- **Haiti** – as a depurative, diaphoretic, insecticide, tonic, vulnerary, for amygdaletis, herpes, itch, meases, psoriasis, sore (throat), tonic, skin problems, prurigo, sores, wounds etc.
- **Java** - for herpes, itch, ringworm, scabies, syphilis, as a larvaecide etc.
- **India** - as a antidote, bactericide, diuretic, fungicide,
insecticide, pesticide, purgative, vermifuge, for asthma, bronchitis, constipation, dysentery, eczema, herpes, intestinal parasites, rheumatism, skin disorders, snakebite, stomachache, venereal diseases etc.

**Mexico** - as a diaphoretic, diuretic, insecticide, purgative; for fever, rheumatism, ringworms, skin infections, snakebite, syphilis etc.

**Peru** - as a diuretic, insecticide, laxative, vermifuge, for acaries, hepatitis, herpes, intestinal parasites, ringworm, skin problems, snakebite, urinary infections etc.

**Samoa** - as a purgative, for ringworms, skin problems, snakebite etc.

**Trinidad** as a bactericide, laxative, vermifuge, for diarrhea, eczema, herpes, venereal diseases, vitiligo etc.

**Venezuela** as a diuretic; for itch, skin problems.

**Elsewhere** - as an antiseptic, bactericide, diuretic, fungicide, insecticide, pesticide, purgative, vermifuge, for asthma, bronchitis, constipation, dysentery, eczema, herpes, intestinal parasites, rheumatism, skin disorders, snakebite, stomachache, venereal diseases etc.

**Phytochemicals Present in Cassia alata and Phytochemical Assay:**

Guajava, like most *Cassia* and *Senna* plants, contain a group of chemicals called *anthraquinones*. These chemicals are well known for their laxative effect. Guajava leaves also contain a chemical called adenine which has been documented as an effective platelet aggregating inhibitor (reduces sticky blood and arterial plaque). Other chemicals in guajava include chryssoeriol-7-O-(2"-O-beta-D-mannopyranosyl)-beta-D-Dallopyparside, kaempferol, kaempferol 3-O-gentiobioside, naringenin, quercetin, and rhamnetin-3-O-(2"-O-beta-D-mannopyranosyl)-beta-D-allopyranoside [25]. Extracts of *Senna alata* were investigated for antioxidant phenolic compounds using High Performance Liquid Chromatography (HPLC). The dried aerial plant parts were macerated into powder and extracted in different organic solvent systems consisting of methanol, hexane, chloroform, ethyl acetate, butanol and water. Each extract was dried under reduced pressure using a rotary evaporator, freeze-dried and stored at a temperature of 4°C. The extracts were then subjected to high performance liquid chromatography studies. Two major phenolic compounds Naringin and Apigenin, were identified in some of the fractions of *Senna alata*. The presence of these flavonoids in *Senna alata* may explain its wide use in ethnomedicine practice for the treatment of hypertension, sickle cell anemia and diabetes in Southwestern Nigeria.

Phenols are a class of low molecular weight secondary metabolites found in most land plants. These compounds are of great importance in foods and drinks because they are responsible for their organoleptic properties. Polyphenols such as anthocyanins, add colour to food which may be purple, black or red [26] and this is desirable in red wines. Phenolic compounds are the largest group of phytochemicals and accounts for most of the antioxidant activity in plants or plant products [27]. Phenolic substances such a flavonols, naringin, apigenin, myricetin, coumarins and caffeic acids are known to posses antioxidant properties which play important roles in protecting foods, cells and organs from oxidative degeneration and are considered as antioxidants [28]. Antioxidants are able to scavenge free radicals and thereby prevent free radicals from causing damage. Reports indicate that diets rich in phenolic compounds play pivotal role in the prevention of various diseases associated with oxidative stress such as cancer, cardiovascular and neurodegenerative diseases etc. [29,30]. In addition, phenols constitute the active substances found in many medicinal plants with important pharmacological activities and modulate the activities of a wide range of enzymes and cell receptors [31]. Therefore, the isolation and identification of these compounds are of great interest and importance because of their role in drug development and in management of many chronic diseases. *Senna alata* Linn. Roxb. (Leguminosae) synonym *Cassia alata* Linn. commonly referred to as Asunwon oynibo by the Yoruba ethnic stock in Southwestern Nigerian, is indigenous to Africa. In Cameroon, the leaves and stem bark of *S. alata* are used to treat hepatitis, skin diseases, jaundice, gastroenteritis, eczema and ringworm. The young leaves are used in rural areas of Nigeria to treat constipation and food poisoning [32]. In Northern Nigeria, the root, stem and leaves are used to treat burns, wounds, skin infection, diarrhea and upper respiratory tract infection [33]. The bioactivity of the plant include antibacterial, antifungal, antimicrobial, diuretic, analgesic and choleretic [20]. There are reports on the antioxidant activity of the leaves of this plant. [34] reported that *Senna alata* was able to induce antioxidant effects in the serum of rats exposed to carbon tetrachloride (CCL4) with a concentration-dependent decrease in alanine aminotransferase (ALT) and aspartate aminotransferase (AST). In this study, High Performance Liquid Chromatographic (HPLC) analysis coupled to an UV (Ultra violet) detector was done to identify and determine the phenolic contents of fractions of *Cassia alata*.

**Biological Activities and Clinical Research:**

Guajava has demonstrated effective broad spectrum antibacterial, antifungal, and antifungal activities in several laboratory studies over the years. Researchers in Malaysia reported their findings in 2002 stating: Based on the current findings, it can be concluded that this plant has antimicrobial activity, which is as potent as standard antimicrobial drugs against certain microorganisms. Japanese researchers in 2003 reported that a leaf extract evidenced anti-inflammatory activity. In animal studies conducted in the Philippines in 2002, Guajava leaves were reported to possess pain-relieving, anti-inflammatory, antimutagenic, and hypoglycemic actions. In 1994 a 10-year human study was published in India which indicated that a Guajava leaf extract can be reliably used as a herbal medicine to treat *Pityriasis versicolor* (a type of skin fungus) without side effects (20th of January 2006, Guardian newspapers). Another clinical trial on human being was conducted in 1990 by Damodaran and Venkataraman to study the therapeautic efficacy of Cassia alata Leaf extract against *Pityriasis versicolor*, Ethnopharmacol. 42:19-23, 1994 study. According to results obtained, the choleretic activity of the plant at 15
mg/kg was better than the control used but in higher doses, the plant tended to inhibit bile secretion (Tropical Plant). The leaves are reported to be useful in treating convulsion, gonorrhea, heart failure, abdominal pains, oedema and is also used as a purgative. A study in Malaysia reported that ethanolic extract of the Senna plant showed high activity against dermophytic fungi: Trichophyton mentagrophytes var. interdigitale, T. mentagrophytes var. mentagrophytes, T. rubrum and Microsporum gypseum (MIC: 125mg/ml) and Microsporum canis (MIC: 25mg/ml). Several studies have been conducted to provide scientific basis for the efficacy of plants used in herbal medicine. It has been observed that antimicrobial activity of the plants is associated with the presence of some chemical components such as phenols, tannis, saponins, alkaloids, steroids, flavonoids and carbohydrates. In this study the methanolic, ethanolic and petroleum ether extracts of the leaves of Cassia alata were investigated for antibacterial and antifungal activity. The phytochemical components were also investigated as a scientific assessment of the claim of therapeutic potency. [5] have investigated the antifungal and antibacterial activity of Cassia alata and have got positive results.

**Table: 2 Antimicrobial activity of Cassia alata on some selective fungal pathogens**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Test fungi</th>
<th>Colony diameter of the fungal Pathogen (c.m.)</th>
<th>% Growth inhibition of the fungal pathogen *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassia alata</td>
<td>Aspergillus niger</td>
<td>2.7</td>
<td>70.00±0.04</td>
</tr>
<tr>
<td></td>
<td>Aspergillus flavus</td>
<td>3.2</td>
<td>64.45±0.04</td>
</tr>
<tr>
<td></td>
<td>Aspergillus candidus</td>
<td>2.5</td>
<td>72.22±0.02</td>
</tr>
<tr>
<td></td>
<td>Candida albicans</td>
<td>4.0</td>
<td>55.56±0.01</td>
</tr>
<tr>
<td></td>
<td>Rhizopus stolonifer</td>
<td>2.2</td>
<td>75.00±0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0</td>
<td>66.67±0.09</td>
</tr>
<tr>
<td>Fluconazole antibiotic (100 µl at a dose of 5 µg/ml)</td>
<td>Aspergillus niger</td>
<td>0.5</td>
<td>94.44±1.26</td>
</tr>
<tr>
<td></td>
<td>Aspergillus flavus</td>
<td>0.5</td>
<td>94.44±1.10</td>
</tr>
<tr>
<td></td>
<td>Aspergillus candidus</td>
<td>1.0</td>
<td>88.89±2.12</td>
</tr>
<tr>
<td></td>
<td>Penicillium patulum</td>
<td>1.7</td>
<td>81.11±0.65</td>
</tr>
<tr>
<td></td>
<td>Candida albicans</td>
<td>1.3</td>
<td>85.56±0.83</td>
</tr>
<tr>
<td></td>
<td>Rhizopus stolonifer</td>
<td>0</td>
<td>100±0.12</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>9.0</td>
<td>-</td>
</tr>
</tbody>
</table>

Data are the mean values of five replicates
CD at 5% → 1.16
Adopted from Chatterjee et al., 2010

**Table: 3 Antibacterial activity of the phytoextracts of Cassia alata against some pathogenic bacteria**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Name of the bacteria</th>
<th>Growth status *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassia alata</td>
<td>Vibrio cholerae</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Bacillus subtilis</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus aureus</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Streptococcus sp.</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli</td>
<td>+</td>
</tr>
<tr>
<td>Ciprofloxacin antibiotic (100 µl at a dose of 5 µg/ml)</td>
<td>Vibrio cholerae</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Bacillus subtilis</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus aureus</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Streptococcus sp.</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli</td>
<td>++++</td>
</tr>
<tr>
<td>0.1% (v/v) Tween-20 in phosphate buffer saline (pH 7.2)</td>
<td>Vibrio cholerae</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Bacillus subtilis</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus aureus</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Streptococcus sp.</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli</td>
<td>G</td>
</tr>
</tbody>
</table>

* Data are the mean values of five replicates
CD at 5% → 1.82
+ = 5-10 mm diameter of zone of inhibition, ++ = 10-20 mm diameter of zone of inhibition
+++ = 20-30 mm diameter of zone of inhibition, ++++ = 30-40 mm diameter of zone of inhibition
+++++ = 50-70 mm diameter of zone of inhibition, +++++ = 70-95 mm diameter of zone of inhibition
G = Growth of bacteria around the Tween-20 control well
Adopted from Chatterjee et al., 2010

**VAM Association in the Plant Cassia alata:**
VAM association in Cassia alata was determined by [5] and this is the first report of VAM association in C. alata. During surveys, soil types, soil nutrient levels like nitrogen and phosphorus content of the soil and pH of the soil were taken into consideration to determine the effects of these soil parameters on root colonization by VAM fungi. Seasonal variations were also taken into account.
References:


Table: 4 VAM association in Cassia alata with special reference to soil character

<table>
<thead>
<tr>
<th>Name of the plant</th>
<th>Season of collection of the roots</th>
<th>Presence or absence of mycorrhizae</th>
<th>Mycorrhizal infection*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassia alata</td>
<td>Summer</td>
<td>+</td>
<td>Vesicles + Arbuscles % Root colonization</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name of the plant</th>
<th>Soil type</th>
<th>Soil nutrient / soil nutrient character (mg/kg soil)</th>
<th>No. of spores /10 gm soil*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassia alata</td>
<td>Open grass land soil</td>
<td>Phosphorus (mg)</td>
<td>Nitrogen (mg)</td>
</tr>
<tr>
<td></td>
<td>Forest soil</td>
<td>0.58±1.78</td>
<td>86.75±4.11</td>
</tr>
</tbody>
</table>

*Data are the mean values of five replicates + Indicates presence of mycorrhizae (Chatterjee et al., 2010)
Lumpur, Malaysia, pp: 654-659.


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