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Scope and Potential for Cultivation of *Acacia senegal* (Gum Arabic) in Kota Stone Mine Spoils Dumped Sites in Rajasthan

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Gum Arabic is the natural gum exuded by various species of Acacia. The main source of commercial gum arabic is *Acacia senegal* L.willd. The trees are native of North Africa and grow mainly in the sub. Sahara or Sahel zone of Africa and also in Australia, India and South America. *A. senegal* is a small sized thorny tree (4 - 5 m height). The main producing and exporting countries in the 'gum arabic belt' include Cameroon, Chad, Mali, Nigeria and Sudan. Sudan dominates the world gum trade with a market share of about 60%.Acacia senegal is an excellent species for desert afforestation due to sand sune stabilization gully stabilisation and ravine rehabilitation for it slope stabilizing, nitrogen-fixing, and drought-tolerant properties. Its ability to restore degraded lands, improve soil fertility, control erosion, and promote biodiversity makes it a valuable tool in rehabilitating mines, ravines and other degraded landscapes. *A.senegal* gum, known as Gum Arabic (Gond), is a natural, edible gum derived from the sap of Acacia trees, widely used in India as a thickener, stabilizer, and pre-biotic fiber in food, cosmetics, and pharmaceuticals. It is primarily harvested in dry areas like Rajasthan, Gujarat, and parts of Punjab. The gum is harvested from *A. senegal* trees found in the rocky hills of Southeast Punjab, Northern Aravalli hills, and dry regions of Rajasthan and Gujarat. In India, it is commonly available as powder or crystals for prices ranging between ₹170–₹500 per kg depending on quality and quantity. It is highly valued for the gum it produces (known as Gum arabic), which is a natural product used in a wide range of industries, from food and pharmaceuticals to cosmetics and paints.

Description and Distribution of the Gum Arabic Tree

The gum arabic tree (*Acacia senegal*) is a leguminous tree native to the semi-arid and arid regions of Africa and parts of Asia. Acacia trees are grown from seedlings which are planted when they reach the height of 15-20 cm. Gum production can begin when the trees are 5 years old,although gum may be tapped from the trees after 3 years. However, the quality and yield are consistent only after 5 years. *A. senegal* is a natural, edible gum derived from the sap of Acacia trees, widely used in India as a thickener, stabilizer, and pre-biotic fibre in food, cosmetics, and pharmaceuticals. It is primarily harvested in dry areas like Rajasthan, Gujarat, and parts of Punjab. In India, it is commonly available as powder or crystals for prices ranging between ₹170–₹500 per kg depending on quality and quantity. It is highly valued for the gum it produces (known as Gum arabic), which is a natural product used in a wide range of industries, from food and pharmaceuticals to cosmetics and paints.

A. Distribution of Acacia senegal

A. senegal is predominantly found in the tropical and subtropical regions of Africa, but it also extends into parts of Asia. It thrives in regions that have seasonal rainfall, long dry periods, and moderate to high temperatures.

i. Native Distribution

a.Africa: *A. senegal* is most commonly found in the Sahel region, a semi-arid zone located just south of the Sahara Desert. It also occurs in parts of West Africa, Central Africa, and East Africa. Sudan, Chad, Mali, Senegal, Ethiopia, and Niger are some of the main producing countries of gum arabic. It is commonly found in countries like Sudan (the largest producer of gum arabic), Chad, Mali, Mauritania, Senegal and parts of Nigeria and Ethiopia. In East Africa, the tree grows in the Somali-Masai biome, which includes parts of Kenya, Somalia, and Ethiopia.

b.Asia: *A. senegal* is also found in parts of India and Pakistan, particularly in areas with arid and semi-arid climates. The important tree is commonly planted in the Thar Desert of India and Pakistan for soil stabilization and gum production.

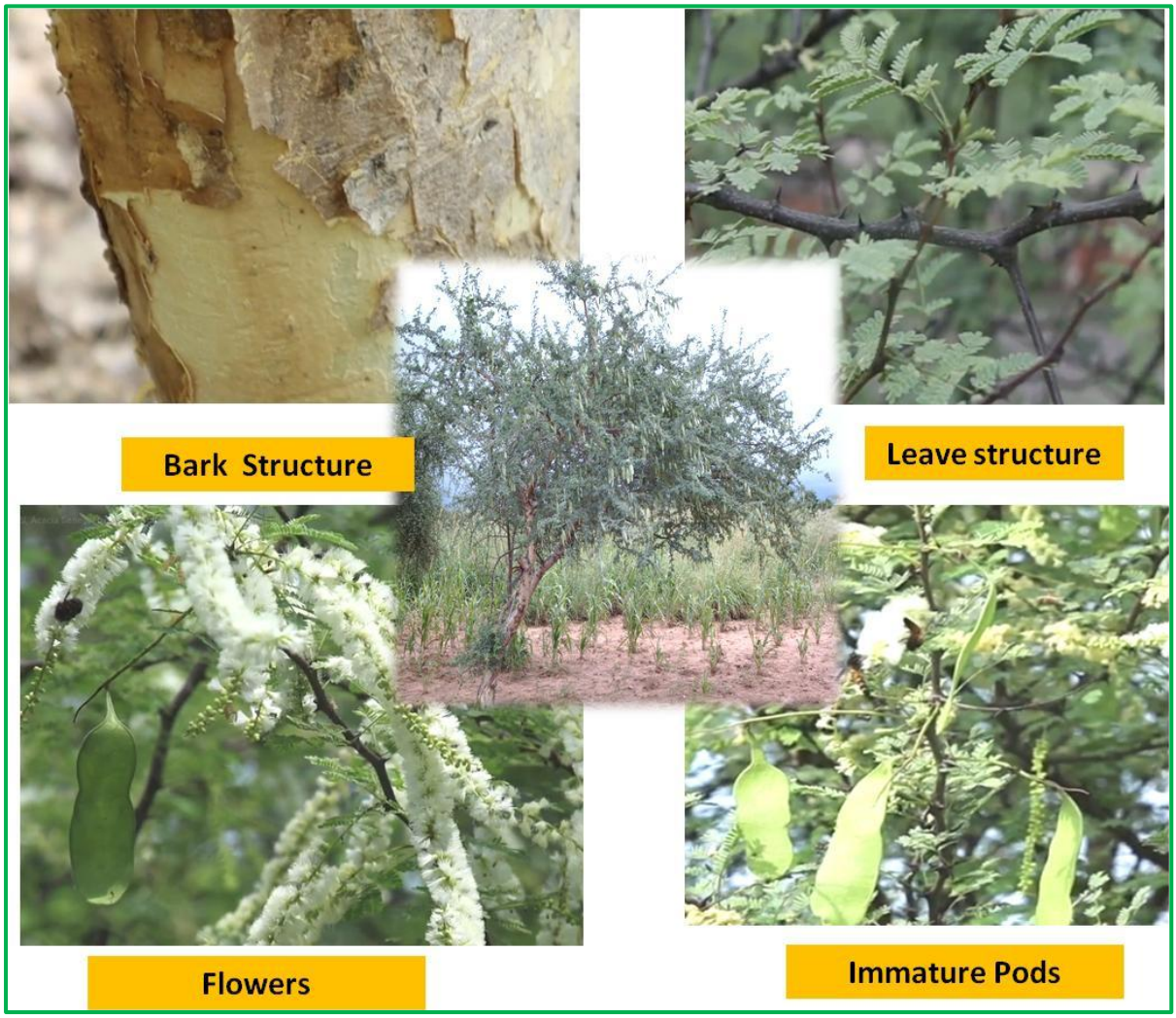

Photo.1. Basic features of Acacia senegal (Gum Arabic Tree)

B. Botanical Description of *Acacia senegal*

A. senegal is a small to medium-sized tree that typically grows in dry, savanna, and semi-desert regions. It is well-adapted to arid climates and is an essential species for sustainable land management, especially in areas affected by soil degradation and erosion.

i) Height: Typically grows to a height of 3 to 7 meters (10 to 23 feet), although under ideal conditions, it can reach up to 10 meters (33 feet). ***ii) Trunk:*** The tree has a relatively slender trunk with a greyish or pale bark (Photo.1). The bark is often cracked and rough. ***iii) Leaves:*** Acacia senegal has feathery, pinnate leaves, which are compound and consist of numerous

small leaflets. These leaves are adapted to conserve moisture, making them suited for dry environments. ***iv) Flowers:*** The tree produces small, creamy-yellow or white flowers that grow in dense clusters. The flowers are highly aromatic and have a pleasant scent. ***v)Pods:*** After flowering, the tree produces flat, curved seed pods that are typically around 5–10 cm long and contain seeds that are dispersed by wind and animals (Photo.1). ***vi) Thorns:*** Acacia senegal often has sharp thorns on its branches, which provide a form of defence against herbivores.

C. Climate and Habitat

Climate: *A. senegal* is suited to semi-arid to arid climates with low to moderate rainfall (usually between 200–700 mm annually). It grows well in areas with hot temperatures and can tolerate drought conditions.

Soil: It grows best in well-drained soils, ranging from sandy soils to light clay. The tree is adapted to poor soils and is highly drought-tolerant, making it suitable for land restoration projects in degraded areas.

Elevation: It is typically found at elevations ranging from sea level up to about 1,500 meters in some areas, although it is most abundant in lowland regions.

Rainfall and Temperature: *A.senegal* thrives in regions with a distinct dry season, where it experiences long periods of water stress. However, it requires some amount of seasonal rainfall for regeneration, especially during the growing season.

d. Gum Extraction Procedures

The tree is particularly known for the gum arabic it produces. This gum is exuded from the tree's bark when it is cut or tapped. The gum is collected and dried into transparent, light amber-coloured pieces. The gum is a complex mixture of polysaccharides and glycoproteins, which makes it highly soluble in water and useful as an emulsifier and stabilizer in various products.

Gum Tapping, Harvesting & Collection

Tapping Season

Best Time for Tapping: During the dry season, usually between November to April in regions with distinct wet and dry seasons. Tapping is typically done during the morning hours to minimize heat exposure, which can lead to premature drying of the gum.

Tools & Preparation

Tapping Knife or Scraper: A sharp, specialized tool used to make a clean cut into the bark.

Clean Cloth/Spatula: To wipe off excess gum and prevent contamination.

Collection Vessel: To catch the gum, usually a small container or a traditional gourd.

Protective Gloves: To avoid injury from the spines and to keep the tapping area free from contamination

Tapping Process

Identification of Suitable Trees:

- Trees should be at least 5-7 years old.
- Select healthy trees with a straight trunk and good-sized diameter.
- Trees should be free of significant pest or disease damage.

D.Tapping Location

Usually mature trees, 4.5-6 m high and 5-25 years old, are tapped by making incisions in the branches and stripping away bark. The gum starts to collect in the wound within 3-8 weeks, but this depends on the weather conditions.

- Tapping is done on the main stem or larger branches where the bark is smooth.
- Avoid tapping the root collar area to prevent damaging the tree's growth.
- Select areas that are free from insect infestation or fungal growth.

Making the Cut: Vertical cuts: First, a vertical cut (about 6–10 cm) is made into the bark to a depth of 2–3 cm (depending on tree size).Horizontal cut: A second horizontal cut is made at the bottom of the vertical cut, creating a small "V" or "U" shape. This ensures the gum flows downward and is collected easily. The cuts should be shallow and not too deep (to avoid

harming the tree) but sufficient enough to allow gum exudation. Tapping height: The cuts should be made at a height of 1–2 meters above the ground.

E.Period of harvesting/collection:

Collection of gum arabic takes place at intervals during the dry season from November to May. During the rainy season no gum is formed since the trees are in full bloom. Efforts are now being made to improve gum yield by treatment of tree wounds with chemical irritant and injection of hormones.

F.Gum Yield: A tree, on an average, may yield 250 grams of gum arabic per annum, although production may range from a few grams to as high as 10 kg. The highest yields are observed on individuals aged from 7 to 12 years. A young nee usually yield 200-700g annually. In general, the higher the average temperature, the higher is the yield of gum. Damaged trees give larger yield of gum. Gum yields are improved by natural factors that lessen the vitality of the trees such as hot weather, poor soil, lack of moisture, etc.

Collection: Gum droplets are about 0.75-3 cm in diameter, and they gradually dry and harden on exposure to the atmosphere. These gum tears are manually collected.

- ❖ Gum begins to ooze out within 24 hours after the cut.
- ❖ The gum is collected as it hardens. It may take up to 3–4 weeks for full gum exudation.

After 1–2 weeks, a second tapping can be done on the same tree if the first cut is drying up. Tapping should be done in moderation to prevent excessive damage to the tree. The gum is scraped off gently from the stem into collection containers. Gum tapping can be done over several years on a single tree, but it's crucial to rotate trees to avoid exhaustion of the tree's gum-producing capacity.

Post-Tapping Care: Wound healing: Care should be taken not to damage the cambium layer. The wound should heal naturally, and no further tapping should be done on the same tree for the next 3–4 months .Resting the tree: Adequate resting time is essential for the tree to replenish its gum-producing capacity.

Gum Formulations and Uses:

Gum Formulations

Gum arabic is a highly versatile natural product and can be used in various formulations, including:

1. Powder Form: Ground into fine powder after collection, it is commonly used in the food industry (e.g., as an emulsifier in beverages, confectioneries, and dairy products).

2. Solution Form: Gum arabic is often dissolved in water (a 10–30% concentration), used as a stabilizing agent in emulsions for cosmetics, paints, and inks solubility: It dissolves in both hot and cold water, producing a thick, sticky solution that can be used in many industrial applications.

3. Syrup Form: For medicinal purposes or as a binding agent in pharmaceutical tablets and syrups. Acacia gum syrup is also used as a soothing agent for throat infections.

4. Gum Coating: Used in coating pills and capsules to make them easier to swallow, and also as a binder in tablet formulations.

5. Cosmetic & Pharmaceutical Formulations:

Skin Care: Used as a hydrating agent in moisturizers and lotions .*Hair Care:* Used in conditioners and shampoos for its film-forming and stabilizing properties. *Pharmaceuticals:* Used to manufacture suspensions, emulsions, and syrups due to its adhesive properties.

Major Research Outcomes with *Acacia senegal* under Indian Condition

Acacia senegal has been the focus of a significant amount of scientific research due to its ecological, economic, and industrial importance, particularly for its gum arabic production. Research outcomes have explored various aspects of the tree's biology, physiology, environmental impact, and commercial applications. Here's a summary of key findings and research outcomes associated with *Acacia senegal*:

a. Agroforestry and Land Reclamation

Acacia senegal has been tested in agroforestry systems and land reclamation projects in the Thar Desert and Rajasthan, where desertification and soil degradation are major challenges.

Studies in Rajasthan have shown that *A. senegal* helps improve soil fertility, increase water retention, and stabilize sandy soils in semi-arid and arid regions (Fig.1). Its drought tolerance has made it a viable option for land restoration in dryland areas. It has been identified as a potential species for sand dune stabilization in north-western India, where it can reduce wind erosion and restore vegetative cover.

b. Drought Resistance and Water Management

Studies have examined *A. senegal's* suitability for planting in water-scarce regions of India, especially as part of soil moisture conservation efforts. In Rajasthan, research has found that *A. senegal* is capable of withstanding the harsh conditions like Thar Desert, hence it is showing resilience to low water availability and high temperatures of kota mine dump sites. The species is being studied for its role in watershed management and water conservation through the improvement of soil water retention and groundwater recharge.

Sustainability and Land Restoration:

Acacia senegal is increasingly being used in agroforestry and land reclamation projects to restore degraded lands and combat desertification in sub-Saharan Africa and other arid regions. It is often planted in soil stabilization programs and mine spoil rehabilitation projects due to its ability to withstand harsh conditions while improving soil fertility.

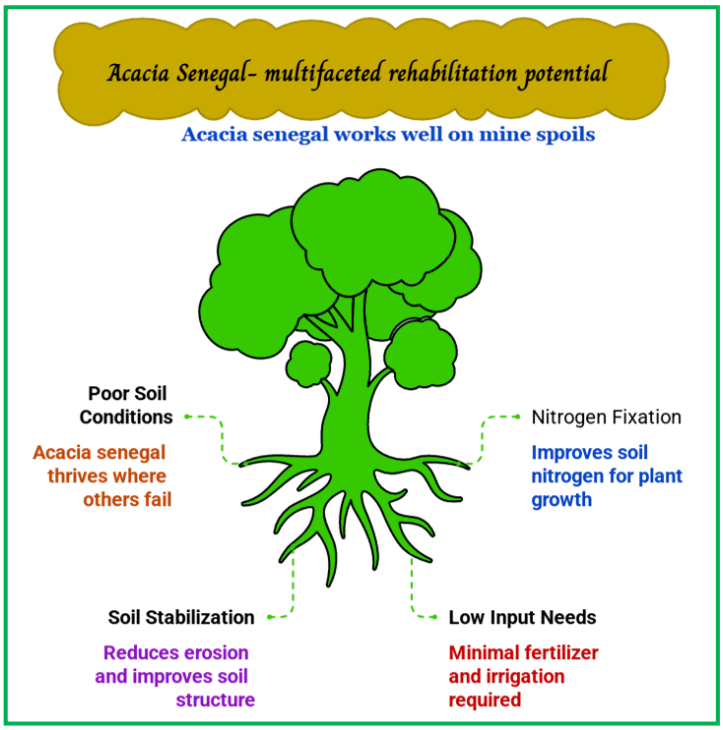

Fig. 1. Ability of *Acacia senegal* on degraded lands

a. Soil Fertility and Nitrogen Fixation

A. senegal is a leguminous species, meaning it can fix atmospheric nitrogen into the soil through a symbiotic relationship with rhizobium bacteria. This is particularly important in arid and semi-arid regions where soil fertility is low. Studies in Sudan and Chad show that the tree significantly improves soil quality by increasing nitrogen levels, which enhances soil fertility for subsequent crops. In West Africa, research found that *A. senegal* could restore degraded soils and increase soil organic matter, vital for improving long-term soil productivity (Fig.1).

b. Erosion Control and Land Stabilization

A. senegal is widely used for soil erosion control in arid and semi-arid regions. The root system of the tree helps stabilize the soil, preventing further erosion in gullies, ravines, and mined areas. Studies in Sudan and Mali have demonstrated the effectiveness of Acacia senegal in stabilizing sandy and eroded soils. *A. senegal* plays a vital ecological role in the environments where it is found, especially in semi-arid and degraded landscapes. As a nitrogen-fixing plant, it helps improve the fertility of nutrient-poor soils, which is crucial in semi-arid regions prone to soil degradation. The tree's extensive root system helps to bind soils and prevent erosion, which is common in ravines, mining sites, and overgrazed land. The tree provides habitat and food for various wildlife, including insects, birds, and small mammals (Fig.2). Its flowers attract pollinators like bees, while its leaves serve as a food source for herbivores. It is often incorporated into agroforestry systems where it helps stabilize soils, improve soil health, and support agricultural productivity in semi-arid regions.

Income Generation: *Acacia senegal* is of considerable economic importance due to the gum arabic it produces, which is in high demand globally for various applications. In countries

where *A. senegal* is grown, especially in Sudan and Chad, it provides a significant source of income for local communities through the collection and sale of gum arabic. The export of gum arabic contributes to the economy of several African nations, with Sudan being the largest global supplier.

a.Gum Production: The gum's non-toxic nature and biodegradability make it an eco-friendly alternative to synthetic additives. In India, it is commonly available as powder or crystals for prices ranging between ₹170–₹500 per kg depending on quality and quantity. It is highly valued for the gum it produces (known as Gum arabic), which is a natural product used in a wide range of industries, from food and pharmaceuticals to cosmetics and paints. Gum arabic is used in industries such as food and beverages, pharmaceuticals, cosmetics, paints, inks, and textiles. The food industry is the largest consumer of gum arabic, using it as a stabilizer, emulsifier, and thickening agent in products like soft drinks, candies, and ice cream. It is also used as a binder in pharmaceutical tablets and a coating agent for pills and capsules.

b. Seed -Traditional recipe and Income generation: *Acacia senegal* produces light brown, papery, dehiscent pods (7.5–18 cm long) containing 5–15 flat, olive-brown seeds, 8–12 mm in diameter. *A.senegal* seeds are primarily used for human consumption, particularly in regions like Rajasthan, where they are consumed directly.. ***Rajasthani Panchkuta Receipe*** contains five main ingredients – Ker, Khejri pods as Sangri, Mango powder, Gunda (Lasoda) and Kumta seeds, hence the name Panchkutta. Hence, *A. senegal* seed is important component and utilized in traditional diets, often in arid regions. Studies indicate that seed extracts can help reduce cholesterol (TC, LDL-C, VLDL-C) and triglycerides. They are rich in phytochemicals, including polyphenols and flavonoids, and research suggests their extracts have potential antiatherosclerotic and cardioprotective properties. Hence, seeds are traditionally used as a component dry vegetable in their traditional panchkutta receipe in especially in western Rajasthan

Animal Fodder: Leaves, pods, and seeds are consumed by sheep, goats, and camels while the pods and leaves serve as livestock fodder. Gum arabic tree leaves are of good nutritional value, with a protein content ranging from 15 to 33% of DM when the leaves are fresh. The leaves are also relatively low in fibre (crude fibre 14-25% of DM). The pods are also rich in protein but with a higher fibre content.

Biodiversity and Ecosystem Restoration

As a pioneer species, *A. senegal* facilitates the restoration of native vegetation by providing shelter and nutrients for other species. Research from the Sahel region indicates that *A. senegal* provides a habitat for pollinators and small herbivores, thus contributing to the overall biodiversity of the region (Fig.2). In Ethiopia, studies have shown that the species can improve plant diversity and help reforest degraded lands in dryland ecosystems.

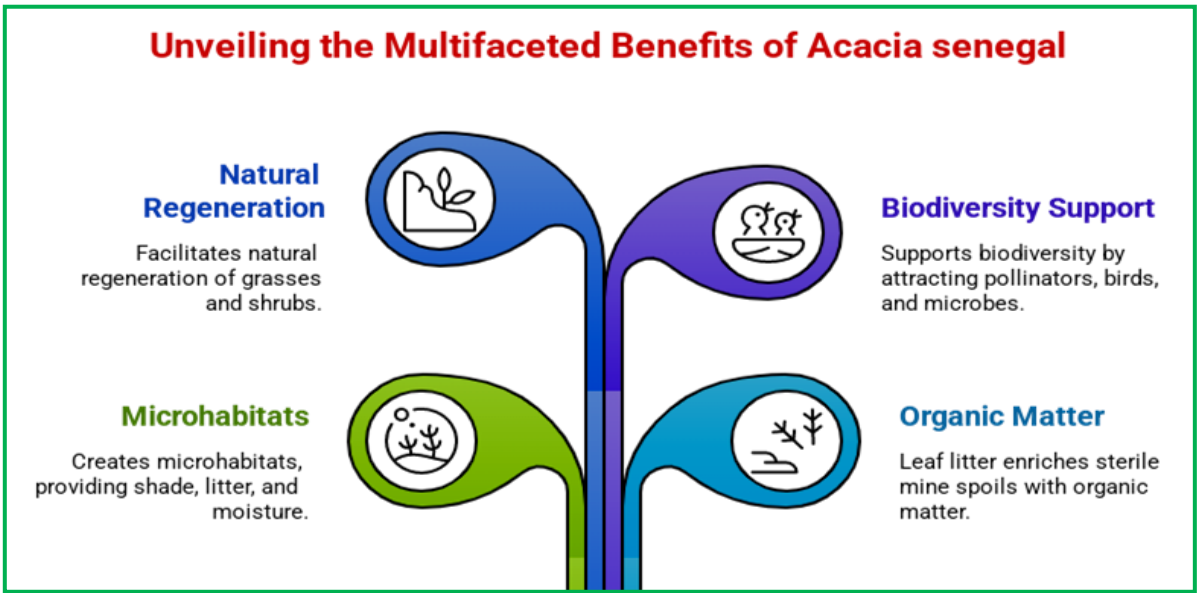

Fig.2. *Acacia senegal* - Important for soil resource conservation beyond gum and seed

a. Potential for Phyto-remediation and *Climate Change Mitigation*

It has been included in phyto-remediation studies in India, particularly in regions where soil contamination due to mining or industrial activities has become a problem. Studies in Uttarakhand and Jharkhand have indicated that it can absorb heavy metals from contaminated soils, thus contributing to environmental restoration efforts in polluted regions.

Acacia senegal is well-suited to the arid and semi-arid climates, making it a species of interest for climate change mitigation efforts, especially in desertification-prone areas. In West Africa, research has shown that the species can help reduce carbon emissions by promoting carbon sequestration in degraded soils. Studies indicate that Acacia senegal has a high resilience to drought and temperature fluctuations, making it a potential tool for increasing ecosystem resilience to climate change.

b. Rehabilitation of stone mine spoil area with *Acacia senegal*

Some research has focused on the potential of *Acacia senegal* to absorb and accumulate heavy metals from contaminated soils, a process known as phyto-remediation. Studies in India and Africa have found that *A. senegal* can tolerate soils contaminated with lead, cadmium, and zinc, suggesting that it may be useful for remediating polluted areas. Research in India suggests that its ability to absorb heavy metals from the soil can be improved through soil amendments and specific planting techniques.

***Photo. 2. Acacia senegal* – Block plantation in Kota Stone mine spoil areas in Rajasthan**

Our basic species exploration survey on post rehabilitation minedout area has been indicated that A.*senegal* adaptability and suitability for mine spoil rehabilitation (Photo.2). The high potential and ample feasibility to use of *A.senegal* for mine spoil waste rehabilitation is a promising approach to restore degraded mining sites, especially in arid and semi-arid regions. The tree's adaptability to harsh environments, ability to fix nitrogen, and drought tolerance make it a suitable species for phyto-remediation and soil restoration in mining areas. The leaf litter from *A. senegal* enriches the soil with organic material, improving soil structure and water retention capacity. Once trees mature (around 5–7 years), gum arabic can be harvested, providing economic benefits to local communities engaged in rehabilitation efforts. In the Sahel region, *A senegal* has been used to rehabilitate degraded

soils, both as a gum production species and for agroforestry projects in disturbed mining regions. Trees like *A.senegal* help in carbon sequestration, contributing to climate change mitigation while rehabilitating degraded sites. This species can help stabilize soils, restore vegetation, and improve the ecological health of degraded landscapes.

Challenges and Threats

Despite its resilience, *Acacia senegal* also faces several challenges:

- Over-exploitation: Over-harvesting of gum arabic can lead to tree depletion, especially in regions with high demand for the gum.
- Climate Change: Changes in rainfall patterns and increasing temperatures can impact the growth and gum production of the tree, especially in regions where rainfall is becoming increasingly unpredictable / quantity fluctuations in plantation failure and quality gum production.
- Pests and Diseases: It can be affected by pests like termites and scale insects, which can damage the bark and reduce gum production.
- Land Degradation: Despite its ability to thrive in poor soils, *Acacia senegal* can still struggle in extremely degraded or polluted soils.

Conclusion

Acacia senegal is a vital species in semi-arid and arid regions of Africa and parts of Asia, providing significant ecological, economic, and commercial benefits. It plays a crucial role in soil restoration, erosion control, and biodiversity enhancement in degraded landscapes in India. Its gum is an essential natural resource with diverse industrial applications, making it a valuable species for both research on *Acacia senegal* in India and the World. In India, *Acacia senegal* has shown promise in Desertification, soil reclamation and dryland afforestation including mine spite areas, particularly in regions like Rajasthan and Gujarat. Though gum arabic production in India is still limited, ongoing research is exploring ways to improve its yield and quality under Indian climatic conditions. Additionally, the species' ability to tolerate drought and heavy metals positions it as a useful species for land reclamation and phyto-remediation. Viable productive utilization of Kota stone mine waste dumping sites enviably needs to be include *Acacia senegal* as a suitable multipurpose trees (MPTs) for large scale afforestation which might useful for gum extraction, seed production and fodder purposes which is always desirable.