CHAPTER 1

SILVER NANOPARTICLES AND MORINGA OLEIFERA

1.1. INTRODUCTION

Nanotechnology is an important field of modern research dealing with design, synthesis, and manipulation of particles structure ranging from approximately 1-100 nm in one dimension. Remarkable growth in this up-and-coming technology has opened novel fundamental and applied frontiers, including the synthesis of nanoscale resources and exploration or utilization of their exotic physicochemical and optoelectronic properties. Nanotechnology is rapidly gaining importance in a number of areas such as health care, cosmetics, food and feed, environmental health, mechanics, optics, biomedical sciences, chemical industries, electronics, space industries, drug-gene delivery, energy science, optoelectronics, catalysis, reorography, single electron transistors, light emitters, nonlinear optical devices, and photo electrochemical applications [1, 2]. Nanomaterials are seen as answer to many technological and environmental challenges in the field of solar energy conversion, catalysis, medicine, and water treatment. In the context of global efforts to reduce dangerous waste, the continuously increasing demand of nanomaterials must be accompanied by green synthesis methods.

Nanotechnology is fundamentally changing the way in which materials are synthesized and devices are fabricated. Incorporation of nanoscale building blocks into functional assemblies and further into multifunctional devices can be achieved through a “bottom-up approach”. Research on the synthesis of nanosized material is of great interest because of their unique properties like optoelectronic, magnetic, and mechanical, which differs from bulk [3].
1.2. NANOPARTICLES

The term “nanoparticles” is used to describe a particle with size in the range of 1nm-100nm, at least in one of the three possible dimensions. In this size range, the physical, chemical and biological properties of the nanoparticles changes in fundamental ways from the properties of both individual atoms/molecules and of the corresponding bulk materials. Nanoparticles can be made of things of diverse chemical nature, the most common being metals, metal oxides, silicates, non-oxide ceramics, polymers, organics, carbon and biomolecules. Nanoparticles exist in several different morphologies such as spheres, cylinders, platelets, tubes etc. Generally the nanoparticles are planned with surface modifications tailored to meet the needs of specific applications they are going to be used for. The vast diversity of the nanoparticles (Fig. 1.1.) arising from their wide chemical nature, shape and morphologies, the medium in which the particles are present, the state of dispersion of the particles and most importantly, the numerous possible surface modifications the nanoparticles can be subjected to make this an important active field of science now-a-days.
Fig. 1.1. Various features contributing to the diversity of engineered nanoparticles

1.3. TYPES OF NANOPARTICLES

Nanoparticles can be broadly grouped into two, namely, organic nanoparticles which include carbon nanoparticles (fullerenes) while, some of the inorganic nanoparticles include magnetic nanoparticles, noble metal nanoparticles (like gold and silver) and semi-conductor nanoparticles (like titanium oxide and zinc oxide). There is a growing interest in inorganic nanoparticles i.e. of noble metal nanoparticles (Gold and silver) as they provide superior material properties with functional versatility. Due to their size features and advantages over available chemical imaging drug agents and drugs, inorganic particles have been examined as potential tools for medical imaging as well as for treating diseases. Inorganic nonmaterial have been widely used for cellular delivery due to their versatile features like wide availability, rich functionality, good compatibility, and capability of targeted drug delivery and controlled release of drugs [4].
1.4. SILVER NANOPARTICLES

Silver nanoparticles are dominant among the most important and entrancing nanomaterials among a few metallic nanoparticles that are engaged with the biomedical applications. They show excellent antibacterial, antifungal, anti-inflammatory and antiviral properties liberally or either after reacting with specific elements to impart such functional properties [5]. To an extent, the silver nanoparticles can be used against a broad variety of infections [6]. The use of silver nanoparticles is not limited to the medical field only; they have been also used as self-cleaning, UV protection, refining durability and opto-electronics. Silver is stable in pure water and air environments but the surrounding of ozone, hydrogen sulfide or sulfur if present in air or water may bring about silver tarnishing because of the formation of silver sulfide [7]. Apart from conventional Ag$^+$, silver exists in three other oxidation states: Ag$^0$, Ag$^{2+}$, Ag$^{3+}$. However, the last two are unstable and rarely found in the sea-going condition. Silver has many isotopes but with molecular weight 107 is the most usually existing. Even though strong poisonous quality of silver in the condition is subject to the accessibility of free silver particles, analyses have appeared that these convergences of Ag$^+$ particles are too low to lead toxicity. Metallic silver appears to posture the insignificant hazard to wellbeing, while solvent silver mixes are all the more promptly consumed and can possibly distribute unfriendly effects [8]. The decrease in the degree of silver to nano-sized silver expands its capacity to control microscopic organisms and growths. Because of the extensive surface region of nanomaterials prompt the expanded contact with microbes and growths which builds its affectivity. Nano-silver, when in contact with microorganisms and their growth, unfavorably influences the cell digestion of the electron exchange structures and cause the substrate movement in the microbial cell film [9]. Microscopic organisms and growths causes’ irritation, contamination, smell,
wounds, the utilization of nano-silver subdue the expansion of microscopic organisms and parasites [10]. Nano-silver have been generally utilized because of its antibacterial microbial movement for the advancement of items containing silver incorporate nourishment contact materials, (for example, containers, bowls and cutting sheets), scent safe materials, gadgets and family unit apparatuses, beautifying agents and individual care items, therapeutic gadgets, water disinfectants, room splashes, children’s toys, newborn child items and health supplement [11].

1.5. SYNTHESIS OF SILVER NANOPARTICLES

The nanoparticles of silver can be synthesized by various physical, chemical, biological and other methods. The most prevalent chemical methodologies contain the chemical reduction by using a range of several inorganic and organic reducing agents, physicochemical reduction, radiolysis and electrochemical methods [12]. The vast majority of these techniques are still in the development stage as well experienced some complications in silver nanoparticles stability and accumulation, morphology, size and size distribution [13]. Moreover, for the produced silver nanoparticles, the extraction and purification are still significant concerns for further applications. Besides, silver nanoparticles prepared through biological, irradiation and Tollen’s method and in presence of polyoxomerales and polysaccharides method can also be incorporated into functional materials [14].

In the biological method, the synthesis of silver nanoparticles takes place through the reduction of the silver ion by the help of micro-organisms extracts [15]. The extracts of the micro-organisms at a time can behave as both the capping agents as well as reducing agent. The preparation of silver nanoparticles by using polysaccharides along with water as the capping agent is recognized as polysaccharide technique [16]. The nanoparticles of silver can also be synthesized by using numerous
irradiation methods like UV-irradiation, microwave, gamma rays and through sonochemical methods [17]. These nanoparticles can also be fabricated by the Tollens method and polyoxomerales procedures. The stable spherical silver nanoparticles with a diameter 0.5–150 nm are also created at the several concentration of silver nitrate using the biosynthesis procedure [18]. These methods have many advantages than chemical, physical and the microbial synthesis because in this procedure no hazardous chemicals are being used. Fundamentally, the green synthesis is considered to be an environmental friendly as well the cost effective substitute to the physical and chemical procedures. The plant extract is the most common reducing agent in the green synthesis [19]. Generally, the silver ions face reduction in aqueous solution to produce different nanometer diameter sized colloidal silver. Herein, the silver ions also get reduced to silver atoms which then rise into the oligomer clusters. Later these clusters support to advance the colloidal silver particles.

Fabrication of silver nanoparticles follows the three chief principles that are, the selection of solvent medium, and selection of environment friendly reducing agent along with the choice of the harmless substances to stabilize the nanoparticles of silver. A huge collection of secondary metabolites is created in plants that have the redox capability for the biosynthesis of silver nanoparticles. So, the silver nanoparticles are produced from Ag\(^+\) ion by the bio reduction by the help of plant metabolites [20]. The uniform silver nanoparticles of controlled size can also be synthesized by using the micro emulsion procedures [21]. The nanoparticles preparation in the two-phase aqueous organic schemes is centered onto the preliminary spatial split-up of the reactants of metal precursor and reducing agent into the two immiscible segments. The interface between the two fluids and the strength of inter-phase transference between the two phases, which is intermediated by the quaternary alkyl-ammonium salt,
influence the level of interactions between the metal precursors and the reducing agents. The metal clusters formed at the interface are stabilized, due to their coated surface with stabilizer molecules arising in the non-polar aqueous medium, and shifted to the organic medium by the inter-phase transporter [22]. The major drawbacks of this process are the use of highly poisonous organic solvents. Consequently, the large amounts of surfactant and the organic solvent must be disconnected and removed from the final product. On the other hand, the colloidal nanoparticles prepared in no aqueous media for conductive inks are well-dispersed in a low vapor pressure organic solvent, to readily wet the surface of polymeric substrate without any accumulation [23]. The nanoparticles of silver can be produced through the wide range of the irradiation methods [24]. The silver nanoparticles of well-defined shape and size can be produced by the laser irradiation of the surfactant along with an aqueous solution of the silver salt. Moreover, laser is being used in the photo-sensitization synthetic method of producing the silver nanoparticles by using benzo-phenone. At the short irradiation periods, the low laser powers formed the nanoparticles of about 20 nm, whereas an improved irradiation power created the silver nanoparticles of the size about 5 nm. Mercury lamp and laser can be used as the light sources for the production of the silver nanoparticles. In the visible light irradiation method, the photo-sensitized growth of silver nanoparticles using thiophene (sensitizing dye) and silver nanoparticle formation by illumination of [Ag(NH$_3$)$_2$]$^+$ in ethanol are being used [25].

Among all available methods, the basic route for the syntheses of nanoparticles is defined by keeping in mind the parameters like availability of chemicals, natural extract and available instruments, the demanded size and shape of nanoparticles and most importantly the use of nanoparticles in a particular application. The solvent-free synthesis of oleophobic nanoparticles from silver nitrate and oleyl amine was prepared
The direct heating of reaction mixture for 20 min at 165°C yielded the nanoparticles of average 68 nm upon dispersal in ethanol. The ultra-refined nanoparticles were incorporated in the polymerization of dicyclopentadiene and polymers were evaluated against their activity for microbes. Another example constitutes the manufacturing of fluff pulp using sonochemically impregnated silver nanoparticle and the materials was compared for their antimicrobial properties against the conventionally used sodium borohydride reducing agent [18].

1.6. ANTIMICROBIAL PROPERTIES OF SILVER NANOPARTICLES

Both, the Gram-positive and Gram-negative microorganisms are successfully killed by nanosilver, so it can call as executing agent including the anti-toxin safe strains [27]. Gram-negative microscopic organisms are the microbes which hold the shade of the stain even in the wake of washing with liquor acetone or alcohol as well include genera, for example, Salmonella Acinetobacter, Escherichia, Vibrio and Pseudomonas [28]. The Acinetobacter species are related with nosocomial diseases, i.e., contaminations that are the consequence of treatment in a doctor's facility or a human services benefit unit, however auxiliary to the patient’s unique condition. Gram-positive microscopic organisms are those which lose the shade of the stain after wash with liquor or acetone and incorporate some outstanding genera, for example, Staphylococcus, Listeria, Bacillus, Enterococcus, Streptococcus and Clostridium [29]. Antitoxin safe microbes are the microscopic organisms that are not controlled or murdered by anti-toxins which incorporate strains, for example, Staphylococcus aureus, and Enterococcus faecium, methicillin-safe and vancomycin-safe [30]. To improve the antibacterial action of different antibiotics, penicillin G, amoxicillin, erythromycin, clindamycin and vancomycin against Staphylococcus aureus and Escherichia coli, the silver nanoparticles assumes to be an extremely evident part. The antimicrobial
movement of silver nanoparticles relies upon their size and Gram-positive microorganisms [31]. The little-sized nanoparticles with a vast surface range to volume proportion give a more effective intends to antibacterial action even at low fixation. Additionally, the antimicrobial action of silver nanoparticles relies on the fixation and shape [32]. The diverse shapes silver nanoparticles of circular, pole formed, truncated triangular nano-plates have been created by manufactured progressions [30]. Because of their expansive surface zone to volume proportions, truncated triangular silver nano-plates show the most grounded antibacterial action [33] (Fig. 1.2.).

Fig. 1.2. Silver nanoparticles rupturing the cell membrane

1.6.1. Factors affecting the antimicrobial activity of silver nanoparticles

Silver nanoparticles are right now utilized as a part of the type of colloids, comprising mostly of diffused nano-metric silver particles, a stabilizing element and also act as a solvent [34]. Biological action of silver nanoparticles relies upon the morphology and physicochemical properties of the nanoparticles, and in addition the particular qualities of microorganisms which are dealt with by silver nanoparticles [35]. One can recognize various elements influencing the antimicrobial action, for example,
shape, size and zeta (ζ) potential of the metal particles which impact the surface properties of the particles and the stabilizer, the pH of the suspension, ionic quality contaminants and so forth [36].

1.6.2. Mechanism of antimicrobial activity of silver nanoparticles

Usually it is broadly recognized that the main antibacterial effect of silver nanoparticles or silver nanoparticles-based materials is due to the partial oxidation of nanoparticles and due to the release of the silver ions (Ag⁺) [37]. Later on the oxidation takes place, resulting the following actions that can happen either separately or simultaneously;

1. The uptake of the free silver ions (Ag⁺) followed by the interference of ATP production and DNA replication
2. Silver nanoparticles and silver ions (Ag⁺) interaction takes place with the bacterial proteins, by disrupting the synthesis of protein
3. Silver nanoparticles directly damage the cell membranes, interacting with the peptidoglycan wall cell and the plasmatic membrane causing cell-lysis [38].

1.7. APPLICATION OF SILVER NANOPARTICLES

Silver nanoparticles are of particular interest in the modern research of nanotechnology due to its unique properties, which can be incorporated into a wide range of extensive applications such as antiseptic agents in medical industry, cosmetics, food packaging, bioengineering, electrochemistry, catalysis, and environmental uses. As compared to their bulk materials, noble nanoparticles exhibit different catalytic activities, and therefore nano catalysis recently has gained much attention in such a way of using nanoparticles as catalysts in various types of processes. For instance, gold,
silver, platinum, and metal ions are well-known catalysts in the process of decomposition of \( \text{H}_2\text{O}_2 \) to oxygen [39]. In the study of [40], catalytic potential of silver nanoparticles was observed to be better than that of gold and platinum nanoparticles in the emission system of chemiluminescence from luminol–\( \text{H}_2\text{O}_2 \). Moreover, catalysis of the reduction of dyes by sodium borohydride (NaBH\(_4\)) can be enhanced by using silver nanoparticles immobilized on silica spheres. In the absence of silver nanoparticles as catalysts, the rate of reaction was almost stationary showing very little or even no reduction of the dyes occurred [41] (Fig. 1.3).

Due to the significant antimicrobial properties of silver nanoparticles against wide ranging microorganisms, numerous medical applications impregnated with silver nanoparticles such as catheters and cardiovascular and bone implants have been recognized for hindering the formation of biofilm and lowering the risk of pathogenic invasion [41]. Typically, ultrahigh molecular weight polyethylene has been widely used as an insert for artificial joint replacement, but its application is somehow limited due to its high susceptibility to wear and tear [42]. Yet, the drawback of wear and tear of the polymer is significantly abridged by the addition of silver nanoparticles. In addition, with the excellent antibacterial properties of silver nanoparticles, it is also loaded with polymethyl methacrylate broadly as bone cements that are broadly used as synthetic joint replacement [43]. In 2010, Xing et al. deduced that (poly-(-3-hydroxybutyrate-co-3-hydroxyvalerate) PHBV nanofiber scaffolds containing silver nanoparticles have the tendency of aiding in bone and skin tissue regeneration from their extensive study on both osteoblast (bone cells) and fibroblast (skin cells) cultured on such scaffolds. Hence, the risk associated with implantation surgery can be overcome by fabricating the surface of structure of the bone implants devices and scaffolds with silver nanoparticles [44].
Furthermore, silver nanoparticles are also applied in nano-crystalline dressings for the therapy of wound or hospital-acquired infections, minimizing the inflammatory response [45]. For instance, the classical surgical meshes are used to bridge severe wounds and for tissue therapy, but it is highly vulnerable to pathogenic invasions. Thus, the effectiveness of these meshes is enhanced with the impregnation with silver nanoparticles. With the plasmonic properties of silver nanoparticles, it can be widely applied in bio-imaging for monitoring dynamic events over an extended period of time without undergoing photo-bleaching as compared to common fluorescent dyes. Therefore, the conjugation of cells to the target cells leads to the conversion of light energy to thermal energy and then resulted in thermal ablation of the target cells, aiding in destroying unwanted or damaged cells [46]. In addition, the plasmonic properties of silver nanoparticles can be exploited for bio-sensing, which can effectively detect wide ranging of proteins that typical biosensors do not. With this unique capability, silver nanoparticles are broadly employed for detecting various abnormalities and diseases in human body system, e.g., tumor cells or cancer. The plasmonic properties of silver nanoparticles are somehow dependent on its size, shape, and the dielectric potential of surrounding medium [42].
In recent years, silver nanoparticles are widely applied in chemical industry as an additive to cosmetics, because silver nanoparticles satisfy the requirements of excellent antiseptic properties, as a safe preservative additive, and also as a constituent for the skin therapy, e.g., treatment of acne [47]. In addition to the applications of silver nanoparticles in medical and environmental protection field, silver nanoparticle-coated paper could also serve a critical role in food preservation in which provides a reservoir for slow releasing of ionic silver from the surface to the bulk to prevent microbial growth in the food as well as to prevent growth of pathogens on the surface itself [48]. Owing to the excellent antimicrobial activity of silver nanoparticles, developing antibacterial coatings on surfaces has drawn much interest for human health and environmental protection in the paint coating industry. The green synthesis techniques demonstrated the metallic nanoparticle-embedded paints using common household
paint in a single step. Through the naturally occurring oxidative drying process in oils that involves free-radical exchange, reduction of metal salts and dispersion of metal nanoparticles in the oil media were successfully done without the use of any external chemical reducing or stabilizing agents. The resulting well-dispersed metal nanoparticles in oil dispersions can then be directly used on different surfaces such as wood, glass, steel, and different polymer surfaces, and also exhibit excellent bactericidal properties against gram-positive and gram-negative bacteria, especially silver nanoparticle-embedded paints [49].

1.8. IMPORTANCE OF BIOSYNTHESIS

Chemical and physical syntheses of nanoparticles are unable to be expanded easily to large scale production due to several drawbacks such as the presence of toxic organic solvents, production of hazardous by-products and intermediate compounds, and high energy consumption. This could lead to an increase in the particle reactivity and toxicity, which might harm human health and environment due to the composition ambiguity and lack of predictability. Therefore, this leads to biological methods which could be more eco-friendly and does not cause any harm to human and domestic animals health.

1.9. BIOSYNTHESIS USING MORINGA OLEIFERA

The plants have always been vital for mankind irrespective of the era and area all over the globe since the beginning of life. These were, are and will remain ever beneficial from nutritional, social, cultural, religious, environmental and human’s health etc. *Moringa oleifera* commonly known as Moringa, drumstick tree, horseradish tree, ben oil tree, or benzoil tree is the only genus in the family Moringaceae. The plant is native to northwestern India and widely cultivated in tropical and subtropical areas
It is the most widely cultivated species of the genus *Moringa*, and its young seed pods and leaves are used as vegetables. All parts of the *Moringa* tree are edible and have long been consumed by humans [51]. *Moringa* is used worldwide in the traditional medicine, for various health conditions, such as skin infections, anemia, anxiety, asthma, blackheads, blood impurities, bronchitis, catarrh, chest congestion, cholera, infections, fever, glandular, swelling, headaches, abnormal blood pressure, hysteria, pain in joints, pimples, psoriasis, respiratory disorders, scurvy, semen deficiency, sore throat, sprain, tuberculosis, for intestinal worms, lactation, diabetes, and pregnancy [52-54]. In many regions of Africa, it is widely consumed for self-medication by patients affected by diabetes, hypertension, or HIV/AIDS [55]. Moringa oil has tremendous cosmetic value and is used in body and hair care as a moisturizer and skin conditioner. It has been shown that aqueous, hydroalcohol, or alcohol extracts of *Moringa oleifera* leaves possess a wide range of additional biological activities including antioxidant, tissue protective (liver, kidneys, heart, testes, and lungs), analgesic, antiulcer, antihypertensive, radioprotective, and immunomodulatory actions [56]. Phytochemical analyses have shown that *Moringa oleifera* is a rich source of potassium, calcium, phosphorous, iron, vitamins A and D, essential amino acids, as well as known antioxidants, such as β-carotene, vitamin C, and flavonoids [57,58].

### 1.9.1. Botanical Description

*Moringa oleifera* is a small deciduous tree with sparse foliage (Fig. 1.4). The tree grows to 8m in height, and has a smooth, dark gray bark with thin yellowish slashes; its crown is wide, open, typically umbrella-shaped, and usually has a single stem. The leaves are alternate, large, with opposite pinnae, spaced about 5 cm apart up the central stalk, usually with a second lot of opposite pinnae, and bears leaflets in
opposite pairs. Leaflets are dark green above and pale on the undersurface, and variable in size and shape, but often rounded elliptic, and up to 2.5 cm long.

![Moringa oleifera plant](image)

**Fig. 1.4. Moringa oleifera plant**

Flowers are produced throughout the year, in loose axillary panicles up to 15 cm long, and possess a very sweet smell. The fruit is large and distinctive, light brown, up to 90 cm long and 12mm broad, slightly constricted at intervals, gradually tapering to a point, three- or four angled, with two grooves on each face. It splits along each angle to expose the rows of rounded blackish oily seeds, each with three papery wings [50].

### 1.10. MEDICINAL USES OF MORINGA OLEIFERA

In the literature, there are some studies showing the uses of MO parts like bark, sap, root, leaves, seed, oil and flower for health treatments, and some of these parts are detailed discussed below:

1. **Root:** Antilithic, rubefacient, vesicant, carminative, anti-fertility, anti-inflammatory, stimulant in paralytic afflictions; act as a cardiac/circulatory
tonic, used as a laxative, abortifacient, treating rheumatism, inflammations, articular pains, lower back or kidney pain and constipation [58-61].

2. Leaves: Purgative, applied as poultice to sores, rubbed on the temples for headaches, used for piles, fevers, sore throat, bronchitis, eye and ear infections, scurvy and catarrh; leaf juice is believed to control glucose levels, applied to reduce glandular swelling (Fig. 1.5) [58,60,62,63].

![Fig. 1.5. Leaves of Moringa oleifera](image)

3. Stem bark: Rubefacient, vesicant is used to cure eye diseases and for the treatment of delirious patients, prevent enlargement of the spleen and formation of tuberculous glands of the neck, to destroy tumors and to heal ulcers. The juice from the root bark is put into ears to relieve earaches and also placed in a tooth cavity as a pain killer, and has anti-tubercular activity (Fig. 1.6) [64, 65].
4. Gum: Used for dental caries, and is astringent and rubefacient; Gum, mixed with sesame oil, is used to relieve headaches, fevers, intestinal complaints, dysentery, asthma and sometimes used as an abortifacient, and to treat syphilis and rheumatism [66].

5. Flower: High medicinal value as a stimulant, aphrodisiac, abortifacient, cholagogue; used to cure inflammations, muscle diseases, hysteria, tumors, and enlargement of the spleen; lower the serum cholesterol, phospholipid, triglyceride, VLDL, LDL cholesterol to phospholipid ratio and atherogenic index; decrease lipid profile of liver, heart and aorta in hypercholesterolaemic rabbits and increased the excretion of faecal cholesterol (Fig. 1.7) [60,65-67].
6. Seed: Seed extract exerts its protective effect by decreasing liver lipid peroxides, antihypertensive compounds thiocarbamate and isothiocyanate glycosids have been isolated from the acetate phase of the ethanolic extract of Moringa pods (Fig. 1.8) [68, 69].

![Fig. 1.8. Seeds of Moringa oleifera](image)

7. Pod: The leaves, fruits, roots and seeds are useful to treat: anemia, anxiety, asthma, paralysis strokes, bronchitis, catarrh, cholera, chest congestion, conjunctivitis, sperm deficiency, milk deficit in lactating mothers, diabetes, diarrhea, erectile dysfunction, painful joints, headaches, sore throat, scurvy, sprains, pimples, fever, gonorrhea, gland swelling, high blood pressure, hysteria, impurities in the blood, skin infections, sores, malaria, earache, intestinal parasitism, poisonous bites, bladder and prostate troubles, psoriasis, breathing disorders, cough, tuberculosis, abdominal tumors, ulcers, etc. (Fig. 1.9) [52].
1.11. CONCLUSION

The parts of MO present lots of health benefits, including anti-convulsant, antioxidant (for cardiovascular diseases), anti-diabetic, anti-nephroticity, anti-gram-positive and gram-negative bacterial, anti-ulcer, anti-mutagenic, anti-urilhiatic, anti-tumor, anti-inflammation and anti-hypertensive potential. Each part (leaf, root, seed and pod) present its benefits, establishing the good reputation of MO plant and clarifying the surname “miracle tree”.