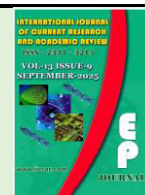




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Green Synthesis of Copper and Zinc Nanoparticles from Different Varieties of Banana Starch and Evaluation of Their Antifungal Activity against *Fusarium oxysporum cubense*

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Abstract

Soil borne diseases which are caused to various plants include a wide variety of soil microbes like fungi and bacteria, among which *Fusarium wilt* is one such disease caused by *Fusarium oxysporum cubense* in banana plants. Wilt disease or the panama disease of plant is among the most destructive disease of banana in the tropics and even the control methods like field sanitation, soil treatments and crop rotations have not been a long term control for this disease. An alternative method of treating *Fusarium oxysporum* was adopted by using various banana parts mainly its peel, pulp sap and its latex of varieties such as Robusta (B1) *Musa acuminata* Colla (AAA), Etha (B2) *Musa x paradisiaca* (AAB), Poovan (B3) *Musa x paradisiaca* (AAB), Sundari (B4) *Musa acuminata* Colla (AA), Njalipoovan (B5) *Musa acuminata* Colla (AB), Palayamkoda (B6) *Musa x paradisiaca* (AAB), Kannan (B8) *Musa acuminata* Colla (AAA), Pachakadali (B9) *Musa acuminata* Colla (AAA). Nanoparticles are small particles with a dimension of 10^{-9} and 10^{-10} . Green synthesis is a new method developed for the synthesis of nanoparticles which is small in size, large surface area and eco- friendly. Leaf extracts of these plants were used for synthesis of copper and zinc nanoparticles, as nanoparticles are powerful antimicrobial agents. The results shows that dry skin and fruit extracts of Palayamkoda, Njalipoovan, Etha, Pachakadali with solvents, propane, ethanol, methanol and acetone and the fresh extract latex and sap of Palayamkoda and Poovan with solvents isopropanol, ethanol, methanol with 1/10 and 1/50 dilution are used for the synthesis of copper and zinc nanoparticles. Copper and zinc nanoparticle shows greater antifungal activity than copper sulphate and zinc sulphate, respectively and dry extract. The maximum zone of inhibition was at 50 and 100 μ l for all the test plates. This indicates that the zone of inhibition increases with as the concentration of nanoparticles increased. An overall result showed that ethanol, methanol and isopropanol could be used as a good solvents and skin of Njalipoovan and Etha could be used for controlling the *Fusarium oxysporum cubense* under invitro conditions.

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Introduction

Noble metal nanoparticles chemistry is a domain in rapid expansion, as those objects lead to interesting applications in the fields of catalysis, biosensing,

electronics and optics. Because of their structure, intermediate between that of molecules and of bulk material, they enable to bridge the gap between molecular chemistry and surface science. In particular, their optical properties, known since antiquity, have

already shown a part of their potential and further major discoveries can reasonably be expected. Their most insightful optical properties rely on a strong absorption in the visible spectrum, called the plasmon band, that colloidal solutions of gold, silver or copper feature.

Nanotechnology is an emerging field of science. It has increased applications in diverse area for the development of new materials at nanoscale levels (Paul *et al.*, 2015). Nano-technology mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or one molecule (Prasad *et al.*, 2008). Nanoparticles has 1-100 nm in size and they possess novel physical and chemical properties (Sajeshkumar *et al.*, 2015a; Sajeshkumar *et al.*, 2015b). Nanoparticles bear antibacterial properties (Hajipour *et al.*, 2012).

Nanoparticles play important role in fighting against disease causing microbes. Nanoparticles are very minute particles. Due to large surface volume ratio; renewable surface and varying micro electrode potential values nanoparticles are largely used as catalysts also (Din and Rehan, 2017). There are different types of nanoparticles including; silver, copper, zinc (metal nanoparticles).

Nowadays humans face dangers infections due to pathogenic microbes. Nanoparticles can overcome this problems. Nanoparticles have antibacterial property. Metal nanoparticles such as silver, copper and zinc has inhibitory effect on microorganisms.

Nanotechnology is an emerging field which makes an impact on human life such as health, food, chemical and energy industries, environmental and space industries etc. Various methods to synthesize nanoparticles include sol gel method, chemical reaction, solid state reaction and co precipitation. Another method used is the green synthesis method which is one of the most appropriate method used in recent years. This method have several advantages namely low cost, simple, use of less toxic materials, most important is eco-friendly. The metal nanoparticles such as Ag, Cu etc., are found to have antibacterial and antifungal activity. This effect of metal nanoparticles has been attributed to their small size, and high surface to volume ratio, which allow them to interact closely with microbial membranes and it is not merely due to the release of metal ions in solutions. The antibacterial and antifungal properties of the metal nanoparticles find applications in various fields such as medical instrument, and devices, water treatment and food processing. Some of the methods to prepare

nanoparticles is by using the methods such as thermal reduction, vacuum vapor deposition, microwave irradiation methods, chemical reduction, and laser ablation. All these methods use oxygen-free atmosphere to synthesize copper, zinc or aluminium nanoparticles because it easily oxidizes. Nanoparticles have various applications in optoelectronics, nanodevices, nanoelectronics, nanosensors, information storage etc. Among various metal particles, copper nanoparticles have attracted more attention because of their catalytic, optical, electrical and antifungal/antibacterial applications (Ramyadevi *et al.*, 2012).

Soil borne diseases which are caused to various plants include a wide variety of soil microbes like fungi and bacteria, among which *Fusarium wilt* is one such disease caused by *Fusarium oxysporum cubense* in banana plants. A decrease in the pathogen growth in soil is manipulated through agro-ecosystem, which focuses on the depletion of various soil borne diseases in banana plants (Shen *et al.*, 2019). Bananas are an important source of living for farmers across wet tropics and subtropics, including various countries like Americas, Africa, Southeast Asia and the Pacific. Although it is a commercial crop in the world, but it is considered that 87% of the banana production is for local food consumption (Langhe, *et al.*, 2009).

Wilt disease or the panama disease of plant is among the most destructive disease of banana in the tropics and even the control methods like field sanitation, soil treatments, crop rotations and organic amendments have not been a long term control for this disease. Many potential biocontrol agents can be developed against *Fusarium oxysporum cubense* by understanding the interactions between the biocontrol and fungal pathogen (Getha and Vikineswary, 2002). Bananas are rich sources of both simple and complex carbohydrates, and of the vitamins ascorbic acid, B6, carotene, niacin, riboflavin, and thiamin. They are also excellent sources of potassium. Moreover, bananas are easily digestible, offering access to food energy faster than apples and meats.

The reddish brown discoloration of the xylem, develops in feeder roots, the initial sites of infection shows the first internal symptom. Vascular discoloration progresses to the rhizome, is most prominent where the stele joins the cortex. The younger leaves wilt and collapse until the entire canopy consists of dead or dying leaves. *F. oxysporum* cannot be morphologically distinguished easily. There colonies grow 4-7 mm on potato dextrose

agar at 25°C With abundant white to purple mycelium. (Ploetz, 2005) Both pathogenic and nonpathogenic strains of *F. oxysporum* are found in agricultural soils throughout the world, and it is these populations that have received the most attention from researchers. It is not a pathogen of plants in native situations and the grasslands often support large populations of *F. oxysporum*, yet grasses, whether cultivated or native, are not known to be hosts to pathogenic strains of this fungus. Moreover understanding the evolution of pathogens in *F. oxysporum* species will ultimately require a detailed characterization of the relationships between diverse pathogenic and nonpathogenic forms in this species (Gordon and Martyn, 1997).

Biological evolution and nomenclature

Banana is widely cultivated over 130 countries along the tropics and sub tropics (Mohapatra *et al.*, 2010). Original bananas were seeded and mostly non edible forms. The slow decline in seed fertility, increases in parthenocarpy as well as human selection of characters (pulpiness, fruit colour and taste) may leads to the evolution of edible banana varieties (Uma *et al.*, 2005a; Uma *et al.*, 2005b). Most of the edible bananas present now a days are derived solely from *Musa accuminata* Colla or *Musa balbisiana* Colla or a hybrid between the two wild diploid species. These two diploid ancestral parents contribute to A and B genomes respectively and considered as the Adam and Eve of present day bananas (Uma *et al.*, 2005a; Uma *et al.*, 2005b; Mohapatra *et al.*, 2010; Simmonds and Shepherd, 1955). The banana plant seems to be originated from India as well as eastern Asian regions (Malaysia and Japan). Polyploidy, hybridization and various combinations of A and B genome has resulted in the development and emergence of broad spectrum of genomic groups; diploid (AA, AB, BB), triploid (AAA, AAB, ABB, BBB) and tetraploid (AAAA, AAAB, ABAB, ABBB) varieties of banana.

Various other varieties also co-evolved or exist naturally with theses genomes and have slightly different nomenclatures (Simmonds, 1962; Robinson, 1996). Three common species of *Musa* (*M. cavendishi*, *M. paradisiaca* and *M. sapientum*) are widely cultivated across the world. *Musa cavendishi* is the pure triploid acuminate (AAA) is also known as desert banana characterized by sweeter and less starchy than *M. paradisiaca*. *Musa sapientum* is known as the true banana could be eaten raw when fully mature. Both *M. paradisiaca* and *M. sapientum* belongs to AAB group characterized by higher starch content compared to pure

acuminate group (Mohapatra *et al.*, 2010; Stover and Simmonds, 1987). Cooking bananas falls under ABB and BBB genome with prominent *M. bulbisiana* genes. A great diversity of dessert banana exist due to plant size and various morphological characters. Productivity is high for Cavendish bananas and giant French plantains (>30 t/ha/yr).

Indian production scenario

Banana is the second most important fruit crop in India after mango, good export potential and popular among all classes of people due to its year round availability, affordability, varietal range and nutritional properties. Out of more than 50 varieties of banana cultivated across India, around 20 are commonly grown in various Indian States (Duran *et al.*, 2007).

Musa (banana)

The bispecific origin of edible banana first mentioned by Kurz (1867) and experimentally proved by Simmonds and Shepherd (1955) by cross the two parent varieties; *M. acuminate* and *M. bulbisiana*. Supported by morphological and cytological evidences, it was assumed that the edible bananas were evolved from the two ancestors in five main stages. The triploids were formed by the fertilization of diploid egg cell with haploid pollen leads to the formation of triploids as a main step in the banana evolution process. The triploids were popular among farmers and breeders due to many beneficial traits especially sturdiness, robustness and pulpiness. Parthenocarpy, sterility, polyploidy and vegetative propagation for perpetuation of useful traits has played a major role in the evolution of current banana varieties (Uma *et al.*, 2005b).

The generic name *Musa* is rooted in Sanskrit word Moca or may have derived from Arabic word Mauz, Mouz or Mauwz, which is used for banana (De Candolle, 1886; Nayar, 2010; Hakkinen *et al.*, 2013). The Arabic name for banana 'Mauz' is also mentioned in Rheede's 'Hortus Malabaricus'.

The earliest scientific classification of banana was made by the famous taxonomist Linnaeus in 1783. According to his classification, all dessert banana were known as *Musa sapientum*; which is sweet during ripening and consumed fresh. The name *Musa paradisiaca* was assigned to the plantain group which are cooked and consumed while starchy. These two apparent species are not species at all, but considered to be closely related

interspecific triploids hybrids of the AAB group. The modern method of classifying edible bananas was devised by Simmonds and Shepherd (1955), most modern edible bananas originally come from two wild species, *Musa acuminata* Colla (A genome) and *Musa balbisiana* Colla (B genome). The classification proposed by Simmonds and Shepherd (1955) based on the relative contribution of the parent character to the constitution of the cultivar and to the ploidy or chromosome number of the cultivar. The original characters used by Simmonds and Shepherd (1955) were amended and updated by many taxonomists (Purseglove, 1972; Stover and Simmonds, 1987; Valmayor *et al.*, 1991).

By using 15 separate characters, with strong diagnostic differences between the two ancestors, the contribution of the two species could be clearly distinguished. For each character in which a cultivar agreed completely with wild *acuminata*, a score of 1 was given, and for each character in which the cultivar agreed with *balbisiana*, a score of 5 was given. The intermediate expression of the character were assigned as score of 2, 3 or 4, according to intensity.

Concerning ploidy, edible bananas belonging to the section *Eumusa* have 22, 33 or 44 chromosomes. The basic haploid number is 11, thus cultivars can only be diploid, triploid or tetraploid. Of the 200-300 clones which are thought to exist, more than half are triploids, with the remaining being mostly diploids. Tetraploid clones are very rare. The planted area of triploid bananas is more than 100 times greater than that of diploids. Triploids are hardier, more vigorous and easier to grow. Morphologically, triploids and tetraploids are larger and more robust than diploids. Also leaf thickness and cell size increases with increasing ploidy.

The scoring technique based on 15 plant characters allows for a range of total score from 15 (pure *Musa acuminata*) to 75 (pure *Musa balbisiana*). Scores in between would be based on the relative contribution of the two species plus the level of ploidy in the interspecific hybrid. Simmonds and Shepherd (1955) and Stover and Simmonds (1987) used the groups and scores to classify a range of edible bananas. Silayoi and Chomchalow (1987) classified 137 accessions in the Thai banana gene bank on the same basis. Recognizing some deficiencies, they later modified the classification.

The main difference between these two classification is the introduction of almost pure *balbisiana* clones in the

Thai grouping, which did not appear in the original classification. Espino and Pimental (1990) used isozyme technology to differentiate clones of pure *acuminata*, pure *balbisiana* and their hybrids from one another. They found broad bands of malate dehydrogenase activity which were unique to pure *balbisiana*, and other bands which indicated an *acuminata* genome. They concluded that BB and BBB cultivars were unique and distinct from hybrid ABB clones. The cooking plantain Saba (BBB) is very close to pure *balbisiana* (73 to 75 points).

Valmayor *et al.* (1991) endorsed the continued adaptation of Simmonds and Shepherd's classification scheme with amendments to accommodate South-east Asian varieties.

All banana taxonomist agree that no single scientific name can be given to all the edible bananas. *Musa acuminata* could be applied to the pure, seedless diploid (AA) and triploid (AAA) forms of dessert bananas such as Pisang Mas and Grand Nain respectively. Similarly *Musa balbisiana* could be applied to the pure seedless diploid (BB) and triploid (BBB) forms of cooking bananas such as Abuhon and Saba respectively.

However, the many hybrids cannot carry a specific name due to their mixed composition and differences in ploidy. To avoid confusion, it is internally accepted that all banana cultivars should be referred to by genus *Musa* followed by a code denoting the genome subgroup and ploidy level, followed by subgroup name (if any), followed by the popular name of the cultivar.

Musa AAA (Cavendish subgroup) Grand Nain
Musa (AAB) (plantain subgroup) Horn
Musa BBB Saba
Musa AB Ney Poovan

The significance of somatic mutations in bananas is very great because of the number of clones has gradually increased in this way. Many somatic mutations have remained unrecognized, especially when morphological changes has been small. Some better known somatic mutants have been selected, utilized and names are Extra Dwarf Cavendish from Giant Cavendish; Williams from Giant Cavendish; Highgate from Gros Michel; Cocos from Gros Michel; Dwarf French Plantain from French Plantain; Sliver Bluggoe from Bluggoe and Green Red from Red. The natural rate of somatic mutations are very low with banana propagated conventionally. The levels are significantly increased during propagation by *in vitro* techniques and considered as somoclonal variations.

Green synthesis of nanoparticles

Synthesis of nanoparticles using biological methods is referred as greener synthesis of nanoparticles. Green synthesis provides advancement over chemical and physical method as it is cost effective, environment friendly, and safe for human therapeutic use (Kumar *et al.*, 2009). Metals like silver, copper and zinc has inhibitory effect on microbes. Biological synthesis of metallic nanoparticles is inexpensive single step and eco-friendly methods. The plants and seeds are used successfully in the synthesis of various greener nanoparticles such as copper, silver, and zinc oxide (Kuppusamy *et al.*, 2014; Mishra *et al.*, 2014).

Application of nanoparticles

Nanoparticles has various applications. Nanoparticles have been used for constructing electrochemical and biosensors (Luo *et al.*, 2006). Metal nanoparticles embedded paints have good antibacterial activity (Kumar *et al.*, 2008). Current research is going on regarding the use of magnetic nanoparticles in the detoxification of military personnel in case of biochemical warfare (Salata, 2004). One of the major opportunities for nanoparticles in the area of computers and electronics is their use in a special polishing process, chemical-mechanical polishing or chemical mechanical planarization, which is critical to semiconductor chip fabrication (Elechguerra *et al.*, 2005).

Magnetic nanoparticles are also used in targeted therapy where a cytotoxic drug is attached to a biocompatible nanoparticle for tumour cell treatment (Pankhurst *et al.*, 2003). Porous nanoparticles have been used in cancer therapy. Bioremediation of radioactive wastes from nuclear power plants and nuclear weapon production such as uranium has been achieved using nanoparticles (Duran *et al.*, 2007).

Copper nanoparticles

Copper nanoparticles have high optical, catalytic, mechanic and electrical properties. They are cheap high yielding and have short reaction time under normal reaction condition. Copper nanoparticles have antimicrobial activities against various bacterial and fungal strain from any researchers (Patravale *et al.*, 2004).

It is used in various fields including agricultural, industrial, engineering and technical fields. Effective anti-bacterial activities are exhibited by copper

nanoparticles. They are cost effective and have efficient bio synthesize techniques. Copper nanoparticles have less cost than silver and gold nanoparticles.

Zinc nanoparticles

Zinc nanoparticles have wide application; various synthetic methods have been employed to produce ZnNps (Chen *et al.*, 2007). Zinc nanoparticles can produced from zinc oxide and zinc sulphate. Zinc nanoparticles has several medicinal uses, which harm skin, stomach, intestine and lymphatic system and they probably induces tumours. Zinc nanoparticles has antibacterial effect on microbes, and it mainly depends up on the size and the presence of visible light. Zinc nanoparticles are used in the optical devices, sensors, catalysis, biotechnology, DNA labelling, drug delivery, medical, chemical and biological sensors (Devasenan *et al.*, 2016).

Antimicrobial activity

Anti-microbial agent is a substance that kills microorganisms or stops their growth. Anti-microbial medicines are grouped according to the micro-organisms they act. Antibiotic are used against bacteria, antifungal are used against fungi. They are also classified on the basis of their function. The agents that kill microbes are called microbicidal; those that merely inhibit their growth are called biostatic (Al Juhaiman *et al.*, 2010). The use of anti-microbial agents for the treatment of infection is known as anti-microbial therapy. The use of antimicrobial medicines for the prevention of infection is known as antimicrobial prophylaxis.

Antifungal activity

Antifungals are used to treat fungal infections. The drug toxicity to humans and other animals from antifungals is generally high. They comprise a large and diverse group of drugs used to treat fungal infections. The mechanism of action of the antifungals include inhibition of fungal membrane and cell wall synthesis, alterations of fungal membranes, effects of microtubules and inhibition of nucleic acid synthesis. Antifungal activities potentially offer solution to the problem of antibiotic resistance. The antifungal medication is also called as antimycotic medication, a pharmaceutical fungicide used to treat and prevent mycosis and serious systematic infections. They are made to acts against plants, animals and humans. The modern era of antifungal therapy by the introduction of oral griseofulvin and tropical chlormidazole in 1958 and

the subsequent introduction of IV AmB in 1960. Antifungal creams, liquids and sprays are used to treat fungal infections.

Agar well diffusion

Agar well diffusion test is used for antifungal assay. The well that cut on the solidified agar act as pour for loading sample. The agar that is inoculated with test organism after overnight incubation may show zone of inhibition. The sample that is diffused in the agar inhibits the growth of microbes.

Objectives

Synthesis of copper and zinc nanoparticles using starch of different varieties of banana such as Robusta (B1) Musa acuminate Colla (AAA), Etha (B2) Musa x paradisiaca (AAB), Poovan (B3) Musa x paradisiaca (AAB), Sundari (B4) Musa acuminate Colla (AA), Njalipoovan (B5) Musa acuminate Colla (AB), Palayamkodan (B6) Musa x paradisiaca (AAB), Kannan (B8) Musa acuminate Colla (AAA), Pachakadali (B9) Musa acuminate Colla (AAA) and fresh extract of latex and sap from banana variety such as Palayamkodan (B6) Musa x paradisiaca (AAB), Robusta (B1) Musa acuminate Colla (AAA) and Poovan (B3) Musa x paradisiaca (AAB), across Kerala and determination of the antifungal properties of these nanoparticles against *Fusarium oxysporum cubense*.

Scope of the study

The study would enlighten the medical and pharmaceutical applications various green synthesised nanoparticles applications against *Fusarium oxysporum cubense* which could be further explored.

Copper nanoparticles widely used due to their superior, optical, electrical, antifungal/antibacterial and biomedical applications. Copper nanoparticles have superior antibacterial activity as compared to silver nanoparticles. Because copper is highly toxic to microorganisms (Singh, 2017).

The antimicrobial activity mainly tested for drug discovery and prediction of therapeutic outcome. Agar disc diffusion and agar well diffusion are two methods used to evaluate antimicrobial activity (Balouiri *et al.*, 2016).

Plant morphology

In the publications of Simmonds (1962), Barker and Steward (1962), Purseglove (1972), Morton (1987), Ross (1987), Simmonds and Weatherup (1990), Espino *et al.*, (1992), Karamura and Karamura (1995), Rieger (2006), Pillay and Tripathi (2007); detailed morphological description of banana plant is provided.

Banana plant is a perennial monocotyledon with an approximate height of about 2-9 m. The part above the ground is called pseudostem (false stem), which is composed of concentric layers of leaf sheath and the part below the ground is called corm (also known as true stem). The meristem of apical bud initially gives rise to leave before it elongates to the pseudostem. Each pseudostem produces inflorescence only once. According to Barker and Steward (1962), leaves around the Musa gets tightly rolled from the centre of the pseudostem in a clockwise manner. The petiole is formed as the leaf sheath taper on the both sides. The can be erect, intermediate or dropping on the basics of the Musa sp.

According to Méndez *et al.* (2003), the biochemical composition of the fruit depends on its cultivator, abiotic factors, like climate, method of cultivation and the nature of soil. The fruit contains high level of potassium whereas the level of vitamin A is low.

Banana doesn't exist any toxic properties but it contains high levels of biogenic amines. The intake of high amount of banana can cause endomyocardial fibrosis (Foy and Parratt, 1960).

Musa accuminata

Stools are moderate in which pseudostem attains a height of 3-8 m, is slenderer than of cultivated banana. Presence of brown black blotches marked on pseudostem. Its petiole canal is erect in position, with short hairy peduncle of about 1 cm. Ovules are arranged in 2 regular rows in each of the locules.

The shape of the bract is lanceolate, after the opening of the bracts it roll back and its colour varies from reddish-purple to pink purple. Usually one Bract falls daily, prominent scars are present on its bract. Presence of creamy white male flower with rich yellow or orange stigma is an important feature. The approximate length of the fruit varies from 8-13 cm with dull black smooth seeds.

Musa balbisiana

Stools are free in which the pseudostem attains an average height of 6-7 m and is robust in nature. Presence of green or yellowish green blotches often black blotches in its upper part. Its petiole margins are curved inside with long hairy of about 1-2 cm. Ovules are arranged in Four irregular locules. The bracts lift up without rolling them back. The colour of the bract varies from crimson purple to bright crimson purple. Scarcely prominent scars are present on the bract. The colour of the male flower is variably flushed with pink within it, with cream or pale-yellow stigma. The length of the fruit is 7-15 cm long with black seeds. For the growth of the plant it requires nutrients, both macronutrients and micronutrients are essential. Macronutrients are those which are required in large amounts and in large quantities. These include nutrients like nitrogen, phosphorous, potassium, magnesium, calcium, and sulphur. The chief promoter for the growth of the plant is nitrogen, which induces the growth of the pseudostem and leaves. For the production of healthy rhizome and a strong root system phosphorus play an important role. Potassium stimulates the early shooting and helps in significantly shortening the time required for fruit maturity. Nutrients that are required in very small quantities are called micronutrients, it includes boron, iron and zinc. The deficiency boron results in the reduction in weight and size of the bunch, which affects the filling of the bunch. Iron deficiency are commonly seen in the plants that are grown in alkaline soils. Plants that are grown on zinc deficient soils are found to be zinc deficient. Symptoms like narrow pointed and chlorite young leaves etc due to zinc deficiency.

Taxonomical classification (*Musa acuminata*; banana)

Kingdom: Plantae -- planta, plantes, plants, vegetal
 Subkingdom: Tracheobionta
 Superdivision: Spermatophyta
 Division: Magnoliophyta
 Class: Liliopsida
 Order: Zingiberidae
 Family: Musaceae
 Genus: *Musa* L
 Species: *Musa acuminata*

Hypothesis

The current research work is based on the following hypothesis

1) Extracts of banana fruit of different banana varieties (Robusta (B1) *Musa acuminata* Colla (AAA), Etha (B2) *Musa x paradisiaca* (AAB), Poovan (B3) *Musa x paradisiaca* (AAB), Sundari (B4) *Musa acuminata* Colla (AA), Njalipoovan (B5) *Musa acuminata* Colla (AB), Palayamkodan (B6) *Musa x paradisiaca* (AAB), Kannan (B8) *Musa acuminata* Colla (AAA), Pachakadali (B9) *Musa acuminata* Colla (AAA)), could be used as antifungal agents.

2) These banana extracts could be used in formulating nanoparticles (copper and zinc) and their antifungal activity vary widely.

Materials and Methods**Study area**

Kerala state covers an area of 38,863 km² with a population density of 859 per km² and spread across 14 districts. The climate is characterized by tropical wet and dry with average annual rainfall amounts to 2,817 ± 406 mm and mean annual temperature is 26.8°C (averages from 1871-2005; Krishnakumar *et al.*, 2009). Maximum rainfall occurs from June to September mainly due to South West Monsoon and temperatures are highest in May and November.

Sample collection

Samples of Robusta (B1), Etha (B2), Poovan, Sundari (B4), Njalipoovan (B5), Palayamkodan (B6), Kannan (B8), Pachakadali (B9) were collected from Ramapuram, Kottayam district of Kerala State, India.

The skin and fruit of banana varieties were thoroughly cleaned using double distilled water. The samples were chopped, dried in hot air oven at 60°C for 48 hrs and then powdered; stored in air tight polyethylene zipper bag for analysis.

Extraction method**Dried extraction**

About 1 g of dried samples are taken in a test tube to which 9 ml of distilled water, propane, hexane, acetone or methanol is added. The mixture is mixed well and is kept for half an hour. It is then filtered using a filter paper into a container which is then stored at 4°C for further use. The obtained dried leaf extract shows different colour in different solvents.

Synthesis of nanoparticles

Copper nanoparticles

The stock solution is prepared by dissolving 2.49 g of Copper sulphate (CuSO_4) in 100 ml of DH_2O . Add 9ml of the 100mM CuSO_4 solution to 1ml of the leaf extract and is allowed to react in room temperature. The copper nanoparticles will be formed after 2-3 hours.

Zinc nanoparticles

The stock solution is prepared by dissolving 2.87g of Zinc sulphate (ZnSO_4) in 100ml of DH_2O . Add 9ml of the 100mM ZnSO_4 solution to 1ml of the leaf extract and is allowed to react in room temperature. The Zinc nanoparticles will be formed after 2-3 hours.

Test microorganisms

Fusarium oxysporum cubense is a fungal plant pathogen that causes Panama disease of banana (*Musa spp.*), also known as fusarium wilt of banana. The test organism were obtained from the department of Pathology, Indian Council of Agricultural Research (ICAR), New Delhi.

Solvents

Distilled water

The water that has been boiled into vapour and condensed back into liquid in a separate container. Impurities in the original water that do not boil below or at the boiling point of water remain in the original container. Thus, distilled water is one type of purified water. It goes through a distillation process.

Isopropanol

It is a three-carbon alkane with the molecular formula C_3H_8 . Its boiling point is -42°C and its melting point is 188°C and has a molecular mass of 44.1 g/mol.

Hexane

It is an alkane of six carbon atoms, with the chemical formula C_6H_{14} . They are colorless liquids, odorless when pure, with boiling points between 50 and 70°C (122 and 158°F). It is a good solvent if trying to dissolve a non-polar compound. It is highly flammable and its vapours can be explosive.

Acetone

It is an organic compound with the formula $(\text{CH}_3)_2\text{CO}$. It is a colorless, volatile, flammable liquid and is the simplest and smallest ketone. It is a good solvent for many plastics and some synthetic fibers and used for thinning polyester resin, cleaning tools etc.

It is used as one of the volatile components of some paints and varnishes.

Methanol

It is the simplest alcohol, consisting of a methyl group linked to a hydroxyl group. It is a light, volatile, colorless, flammable liquid with a distinctive odour.

It is however far more toxic than ethanol. At room temperature, it is a polar liquid. It can be used as an antifreeze, solvent, fuel, and as a denaturant for ethanol.

Characterization of nanoparticles

UV-Vis spectroscopy

The periodic scans of the optical absorbance between 345 and 700 nm with a UV- Vis spectrophotometer (Model 118, Systronics, Mumbai, India) at a resolution of 1 nm were performed to investigate the reduction rate of green synthesised nanoparticles. Deionised water was used to adjust the baseline.

The reduction of Cu^{2+} and Zn^{2+} was monitored periodically by using a UV- Vis Spectrophotometer and the UV- Vis spectra of the reaction solutions were measured in the range of 375–760 nm.

SEM-EDX analysis

SEM-EDX Analysis was carried out in instrument JSM 6390 with acceleration voltage 20 kV. SEM reveals information about the sample including external morphology, chemical composition and crystalline structure and orientation of materials making up the sample. SEM provides detailed high-resolution images of the sample by rastering a focused electron beam across the surface and detecting secondary or back scattered electron signal. The EDX spectrum of the silver nanoparticles was performed to confirm the presence of elemental silver signal and provides quantitative compositional information.

Antifungal assay

Antifungal assay was performed by agar well diffusion method. Active cultures of *Fusarium oxysporum cubense* were aseptically swabbed on Potato Dextrose Agar (PDA) plates using sterile cotton swabs. Wells of 7 mm diameter were made in the inoculated plates using sterile syringe (with front end cut and polished) and wells are filled with 50, 100 and 150 µl of nanoparticle solution, control (stock solution) and sample (fresh and dry leaf extracts). The plates were incubated at 25°C for 72 hours after which the diameter of zones of inhibition were measured on regular intervals (24, 48 and 72 hrs).

Statistical analysis

The results were analyzed and descriptive statistics were done using SPSS 12.0 (SPSS Inc., an IBM Company, Chicago, USA) and graphs were generated using Sigma Plot 7 (Systat Software Inc., Chicago, USA).

Results and discussion

Synthesis of nanoparticles

Nanoparticles were synthesized from the dry skin and fruit extract, fresh sap and latex from banana varieties such as Robusta (B1), Etha (B2), Poovan (B3), Sundari (B4), Njalipoovan (B5), Palayamkodan (B6), Kannan (B8), Pachakadali (B9) using solvents like distilled water, isopropanol, hexane, methanol and acetone.

Copper nanoparticles

Copper nanoparticles were synthesized from the dry skin and fruit extract, fresh sap and latex from banana varieties such as Robusta (B1), Etha (B2), Poovan (B3), Sundari (B4), Njalipoovan (B5), Palayamkodan (B6), Kannan (B8), Pachakadali (B9). Dry peel and fruit extracts was added to 100Mm copper sulphate solution and kept to reaction to take place.

A colour change was observed from blue to pale yellow. This occurred due to the reduction of copper ions present in the solution.

Copper nanoparticles were synthesized from banana latex and sap extract of various banana varieties such as Robusta, Poovan, Palayamkodan. Fresh sap and latex extract were added to 100Mm copper sulphate solution and kept to reaction to take place.

Zinc nanoparticles

Zinc nanoparticles were synthesized from the dry skin and fruit extract, fresh sap and latex from banana varieties such as Robusta (B1), Etha (B2), Poovan (B3), Sundari (B4), Njalipoovan (B5), Palayamkodan (B6), Kannan (B8), Pachakadali (B9). Dry peel and fruit extracts were added to 100Mm zinc sulphate solution and kept to reaction to take place. A colour change was observed from colourless to pale brown. This occurred due to the reduction of zinc ions present in the solution.

Zinc nanoparticles were synthesized from banana latex and sap extract of various banana varieties such as Robusta, Poovan, Palayamkodan. Fresh sap and latex extract were added to 100Mm zinc sulphate solution and kept to reaction to take place. A colour change was observed from colourless to pale brown.

Characterization of nanoparticles

Copper nanoparticles-UV spectroscopy

Synthesized copper nanoparticles were characterized by UV-VIS spectrophotometry. The maximum peak was found to be at 435 nm for the skin extracts of Njalipoovan, Etha, Pachakadali, Kannan, Sundari, Poovan with distilled water and methanol and 680nm with ethanol solvent extracts. The intensity of the peak was increased with time until the reduction completes.

The maximum peak was found to be at 435 nm for the pulp extracts of Njalipoovan, Etha, Palenkodan, Poovan with distilled water, methanol, acetone and 680nm with ethanol solvent extracts.

The maximum peak was found at 435 nm for latex and sap extracts of palenkodan with isopropanol and undiluted solution where as for latex and sap extract of poovan the maximum peak was found to be at 680nm isopropanol, acetone and undiluted solvent extracts.

Zinc nanoparticles-UV spectroscopy

Synthesized zinc nanoparticles were characterized by UV-VIS spectrophotometry. The maximum peak was found to be at 385nm for the skin extracts of Palenkodan, Njalipoovan and Etha with distilled water, methanol, ethanol and 560nm with acetone solvent extract. The intensity of the peak was increased with time until the reduction completes.

The maximum peak was found to be at 385 nm for the pulp extracts of Palenkodan, Njalipoovan and Etha with distilled water, methanol, ethanol and 560nm with acetone solvent extract. The maximum peak was found at 385 nm for latex and sap extracts of palenkodan with isopropanol and undiluted solution where as for latex and sap extract of poovan the maximum peak was found to be at 560 nm isopropanol, acetone and undiluted solvent extracts.

The SEM-XRD analysis proved the effective formation of copper and zinc nanoparticles in all the samples.

Antifungal assay

The dry skin and fruit extract and also from fresh sap and latex from banana varieties such as Robusta (B1), Etha (B2), Poovan (B3), Sundari (B4), Njalipoovan (B5), Palayamkodan (B6), Kannan (B8), Pachakadali (B9) using solvents like distilled water, isopropanol, ethanol, methanol and acetone showed the growth inhibitory effects against *Fusarium oxysporum cubense*.

Robusta (B1) Musa acuminata Colla (AAA)

The copper nanoparticles formed from the liquid sap and latex extracts with solvents distilled water, isopropanol, acetone, ethanol had a better zone of inhibition than the zinc nanoparticles. However the extract with methanol forming zinc particles had a better zone of inhibition than copper nanoparticles. The highest inhibitory zone was showed by the Cu nanoparticles formed from methanol, acetone and ethanol, its action remained for more than 72 hours. The zone of inhibition showed by *Fusarium oxysporum cubense* by copper nano particles formed by liquid sap and latex extracts in solvents distilled water, methanol, acetone, ethanol in 50 micro litre solution was 0.2, 0.4, 0.4, 0.5 cm respectively; from 100 micro litre solution was 0.4, 0.6, 0.6, 0.4 cm respectively; from 150 micro litre solution was 0.9, 1, 1.1, 1.3 cm respectively. The zone of inhibition showed by *Fusarium oxysporum cubense* by zinc nano particles formed by liquid sap and latex extracts in solvents distilled water, methanol, acetone, ethanol in 50 micro litre solution was 0.1, 0.2, 0.4, 0.3 cm respectively; from 100 micro litre solution was 0.2, 0.3, 0.8, 0.4 cm respectively; from 150 micro litre solution was 0.5, 0.6, 1.3, 1cm respectively.

Etha (B2) Musa x paradisiaca (AAB)

The copper nanoparticles formed from the dry extracts with solvents methanol, propane, acetone, ethanol with

1/10 and 1/50 dilution had a better zone of inhibition than the zinc nanoparticles. The highest inhibitory zone was showed by the Cu nanoparticles formed from methanol, acetone and ethanol, its action remained for more than 72 hours.

The zone of inhibition showed by *Fusarium oxysporum cubense* by copper nano particles formed by dry extracts in methanol, propane, acetone, ethanol in 50 micro litre solution in 1/10 dilution and 1/50 dilution was 0.3, 0.4, 0.6, 0.9 and 0.4, 0.6, 0.8, 1 cm respectively; from 100 micro litre solution in 1/10 dilution and 1/50 dilution was 0.6, 0.7, 0.8, 0.9, 0.9 and 0.7, 0.9, 0.9, 1 cm respectively; from 150 micro litre solution in 1/10 dilution and 1/100 dilution was 0.9, 1, 1.1, 1.3 and 1, 1, 1.2, 1.4 cm respectively.

The zone of inhibition showed by *Fusarium oxysporum cubense* by zinc nano particles formed by dry extracts in methanol, propane, acetone, ethanol in 50 micro litre solution in 1/10 dilution and 1/50 dilution was 0.1, 0.2, 0.4, 0.6 and 0.1, 0.3, 0.4, 0.4 respectively; from 100 micro litre solution in 1/10 dilution and 1/50 dilution was 0.2, 0.5, 0.4, 0.8, 0.7 and 0.3, 0.6, 0.7, 0.8 cm respectively; from 150 micro litre solution in 1/10 dilution and 1/100 dilution was 0.4, 0.8, 1, 0.9 and 0.8, 0.9, 1, 1.1cm respectively.

Poovan (B3) Musa x paradisiaca (AAB)

The copper nanoparticles formed from the dry extracts with solvents methanol, propane, acetone, ethanol had a better zone of inhibition than the zinc nanoparticles. The highest inhibitory zone was showed by the Cu nanoparticles formed from methanol, acetone and ethanol. The copper nanoparticles formed from the liquid sap and latex extracts with solvents distilled water, propane, acetone, ethanol with 1/10 and 1/50 dilution had a better zone of inhibition than the zinc nanoparticles. However the extract with methanol forming zinc particles had a better zone of inhibition than copper nanoparticles; its action remained for more than 72 hours.

The zone of inhibition showed by *Fusarium oxysporum cubense* by copper nano particles formed by liquid sap and latex extracts in solvents distilled water, propane, acetone, ethanol in 50 micro litre solution in 1/50 dilution was 0.2, 0.5, 0.7, 0.7 respectively; from 100 micro litre solution in 1/50 dilution was 0.5, 0.9, 0.9, 0.9 respectively; from 150 micro litre solution in 1/50 dilution was 0.9, 1.1, 1.1, 1.2 cm respectively.

Figure.1 Map of Kerala showing the sample collection point.

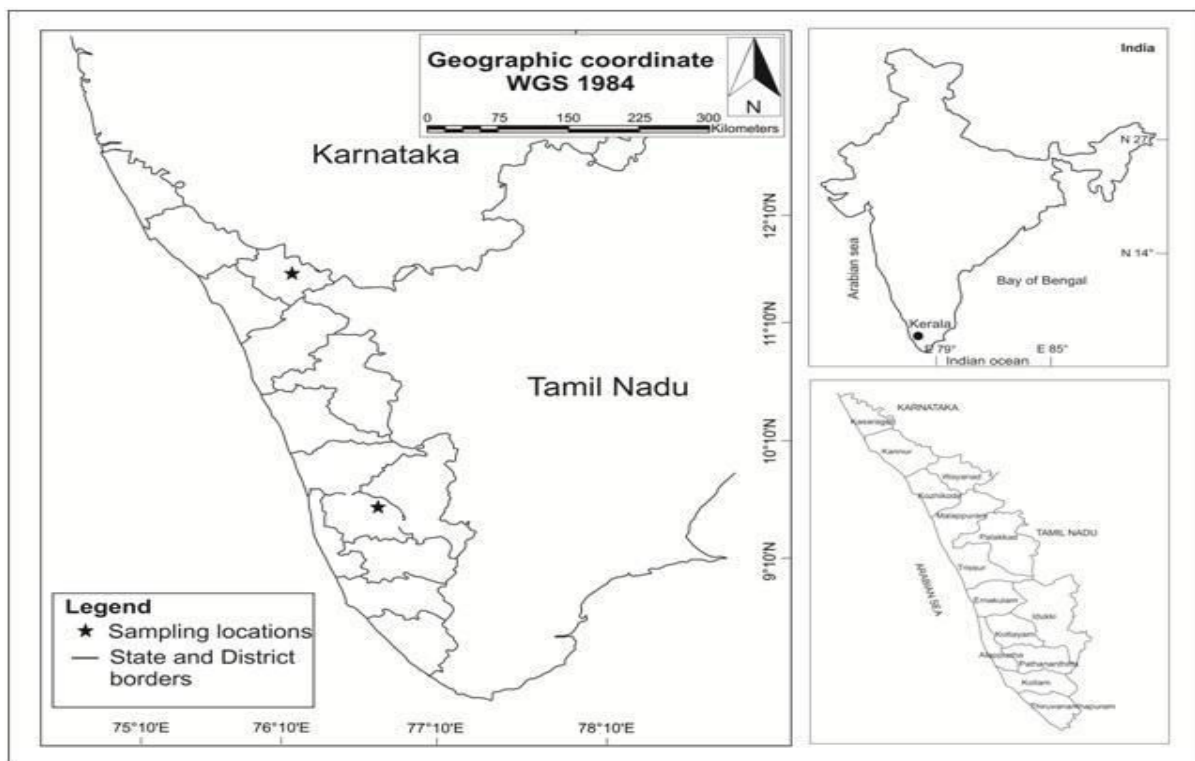


Figure.2 The evolution of the banana complex: A, *M. acuminata*; B, *M. balbisiana*. Genotypes known to occur naturally are encircled, those known only from experiment are not encircled (adopted from Simmonds and Shepherd, 1955).

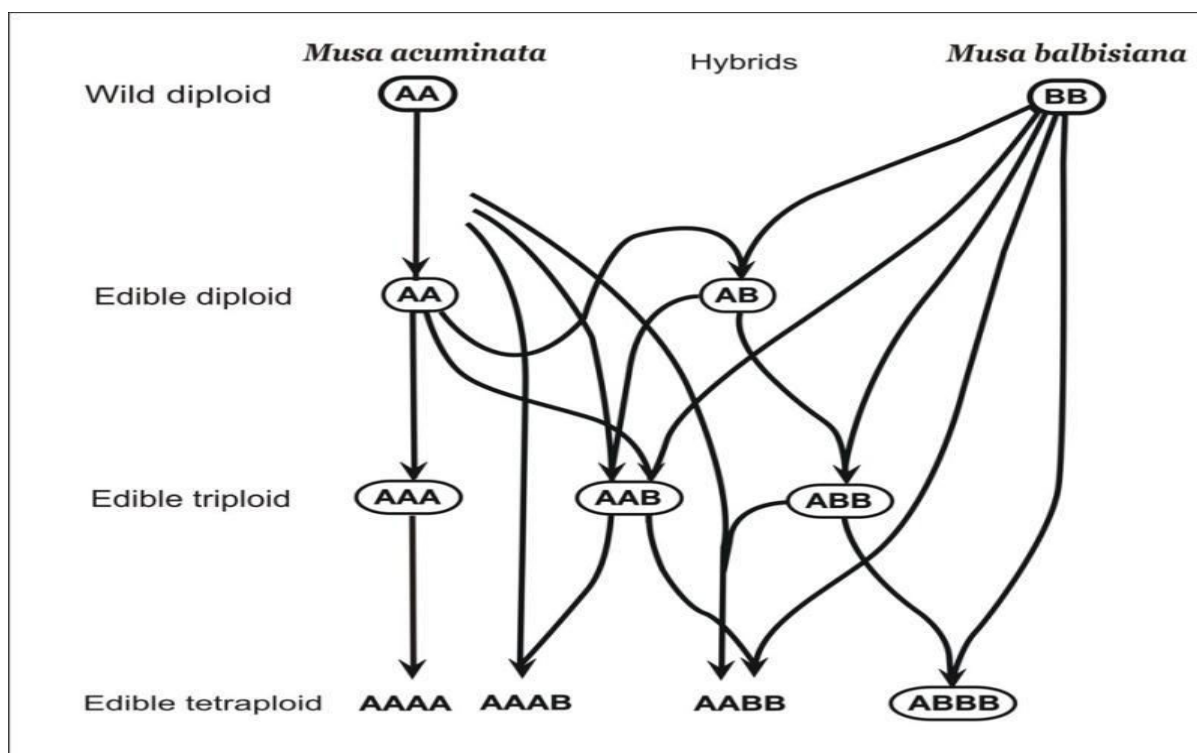


Figure.3 Description of pseudostem/suckers of banana. Modified after: IPGRI, 1984.

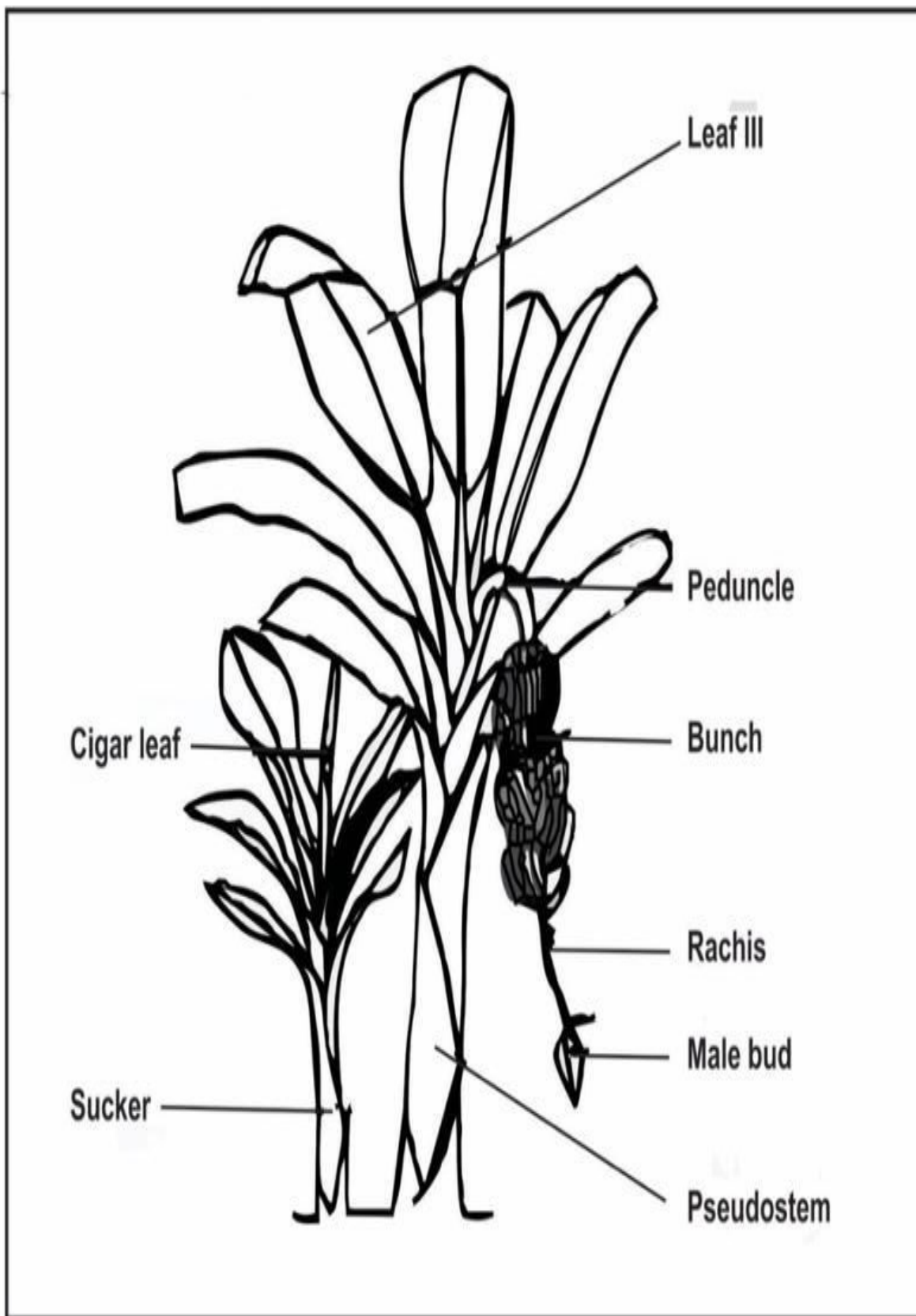


Figure.4 General morphology A) habitat (A1, suckers; A2, pseudostem; A3, petiole base; A4, inflorescence; A5, petiole; A6, leaf base; A7, 3rd leaf), B) inflorescence at early stages (B1, peduncle; B2, sterile bract; B3, female bud; B4, female flowers; B5, female bract), C) female flower (C1, ovary; C2, free tepal; C3, compound tepal; C4, stigma), D) compound tepal, E) free tepal, F) pistil with staminodes (F1, ovary; F2, staminodes; F3, style; F4, stigma), G) c.s of ovary, H) infructescence (H1, peduncle; H2, fruits; H3, rachis; H4, male bract; H5, male bud), I) male flower, J) rudimentary pistil with stamens (J1, rudimentary pistil; J2, stamens), K) fruit hand (K1, pedicel; K2, fruit; K3, fruit apex).

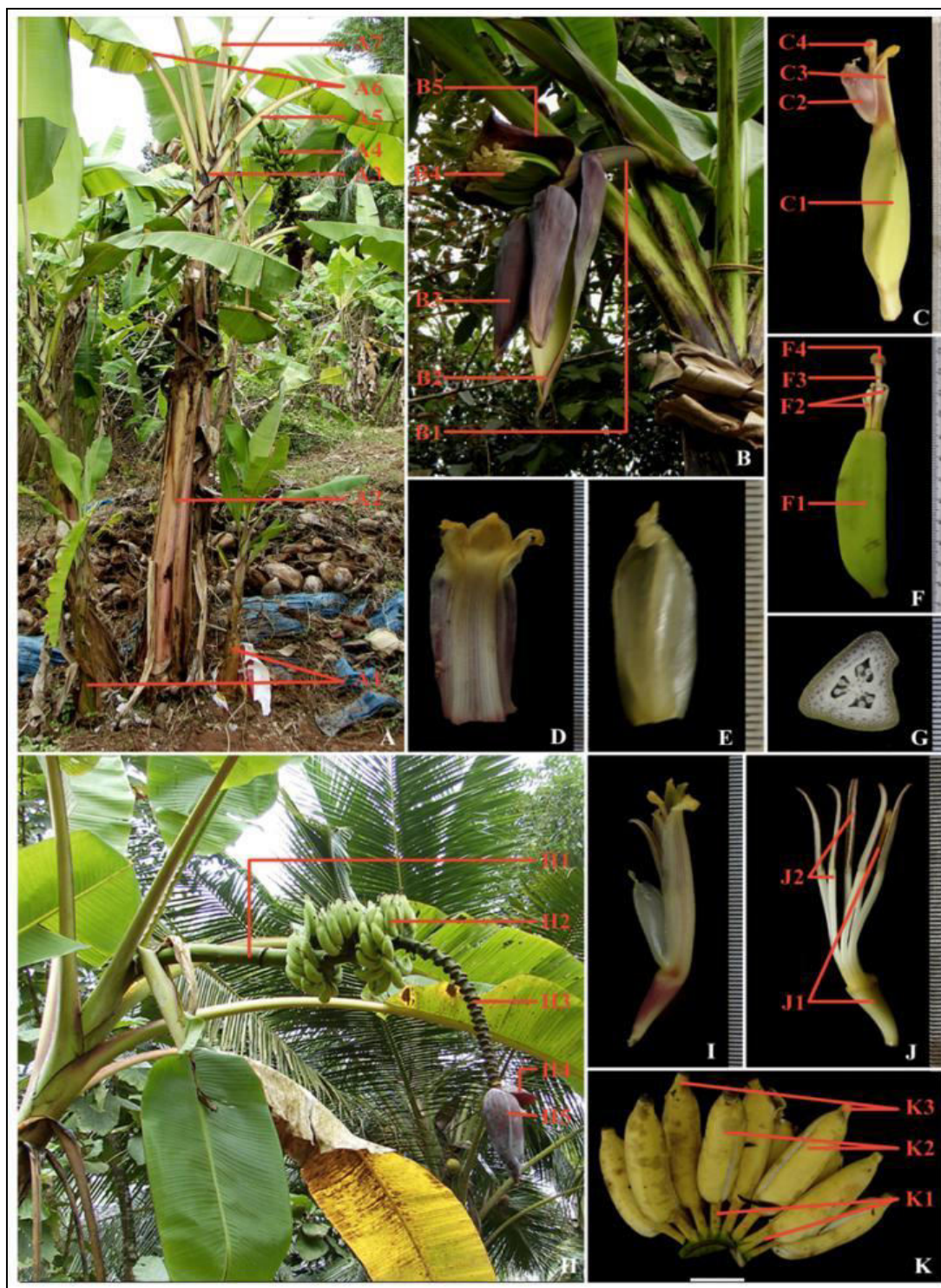


Figure.5 *Musa acuminata* Colla A) habitat, B) pseudostem coloration, C) inflorescence at early stage, D) leaf base, E) leaf apex, F) female flower, G) compound tepal, H) free tepal, I) pistil with staminodes, J) c.s of ovary, K) male bract abaxial surface, L) male flower, M) compound tepal, N) male flower, O) male flower, N)

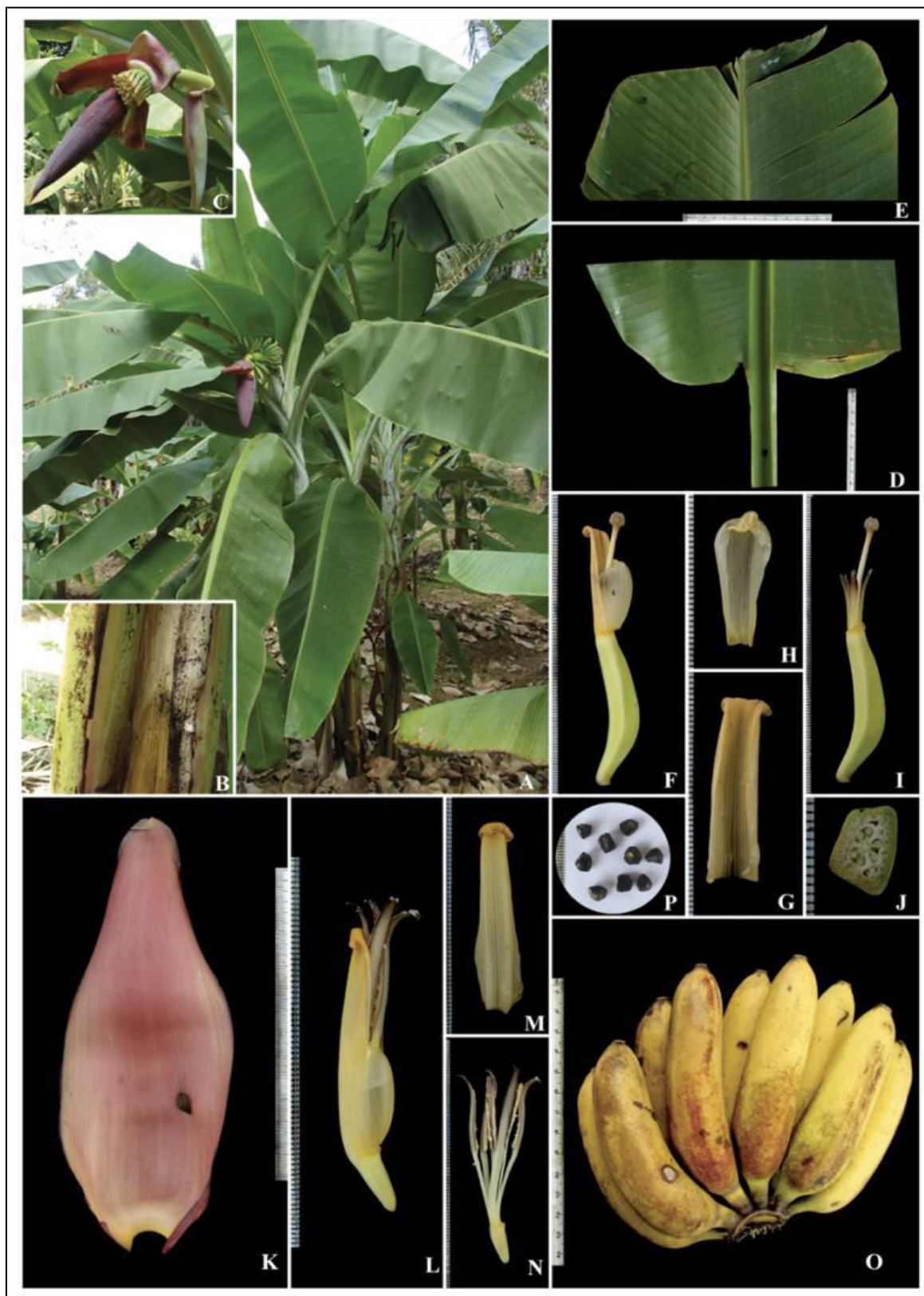


Figure.6 *Musa balbisiana* Colla A) habitat, B) infructescences with advanced stage of male bud, C) leaf base, D) leaf apex, E) female flower, F) compound tepal (female), G) free tepal (female), H) pistil with staminodes, I) c.s of ovary, J) male bract, K) female flower, L) compound tepal (male), M) free tepal (male), N) rudimentary pistil with stamen, O) ripened fruit hand, P) single fruit, Q) seeds.

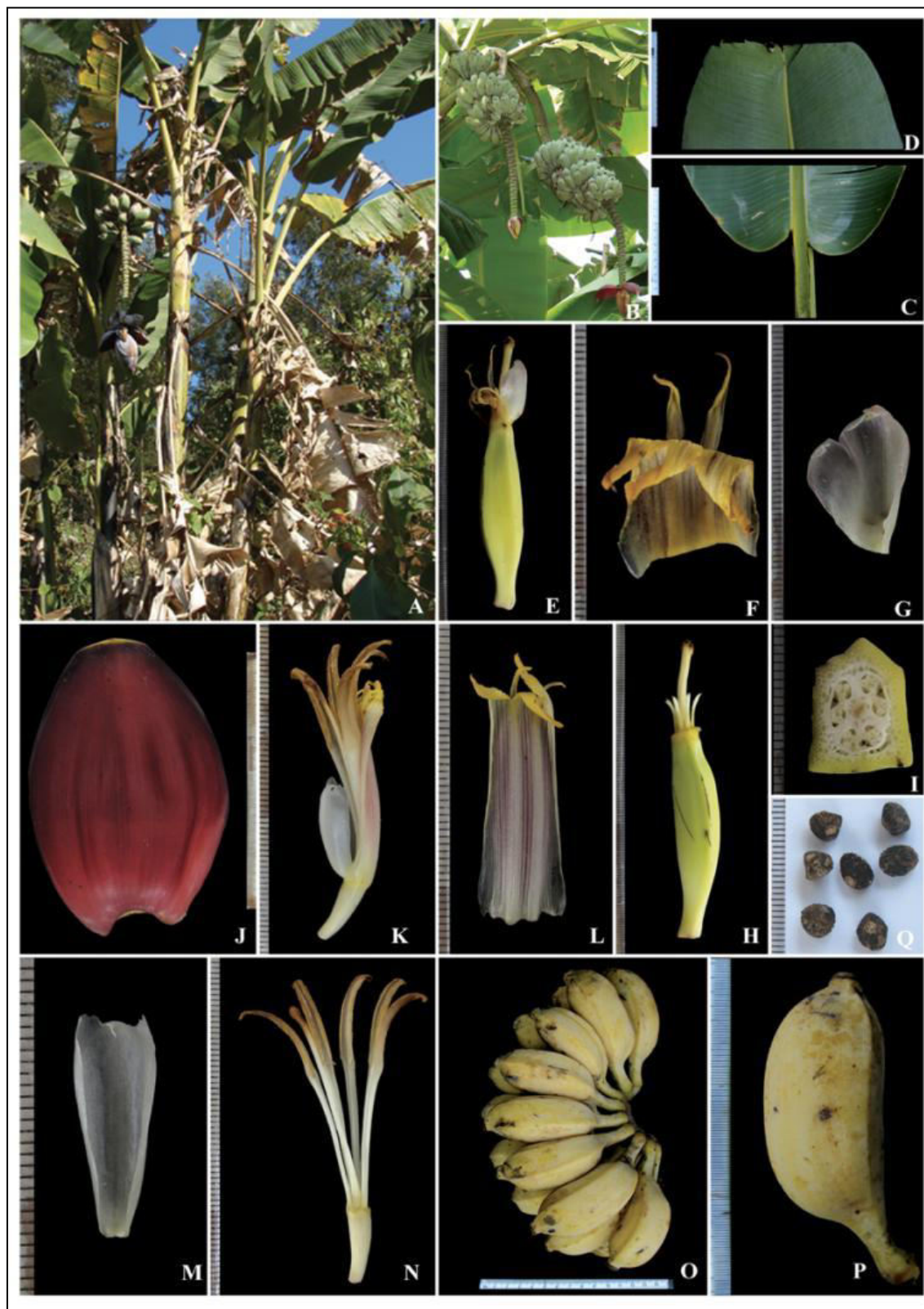


Figure.7 Description of *Musa accuminata* Colla (AA) Pisang lilin/Sundari a) skin and fruit chopped into small pieces, b) fruit bunch c) sections of fruit, description of *Musa x paradisiaca* L. (AAB) Etha d) mature fruit, e) mature fruit without skin, f) fruit skin, g) mature fruit cut into small slices, h) skin chopped into small pieces.

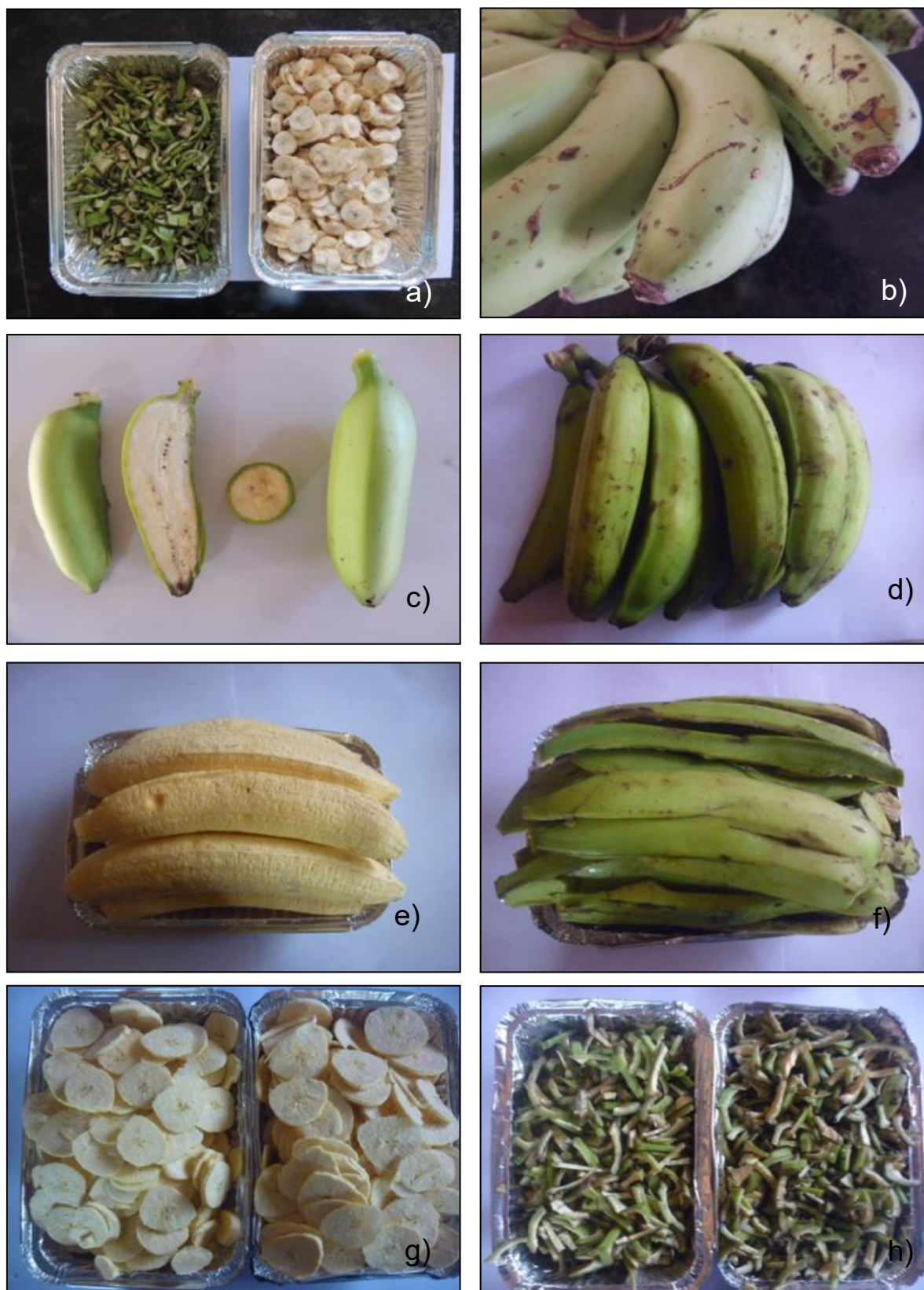


Figure.8 Description of *Musa accuminata* Colla (AA) Poovan a) fruit bunch, b) mature fruit without skin, c) fruit skin, d) mature fruit cut into small slices, e) skin cut into small pieces, f) fruit bunch, g) mature fruit without skin, h) fruit skin.



Figure.9 Description of *Musa accuminata* Colla (AA) Njalipoovan a) skin and fruit chopped into small pieces, b) fruit bunch c) sections of fruit, d) mature fruit, e) mature fruit without skin, f) mature fruit cut into small slices, g) fruit skin cut into small slices, h) fruit skin.

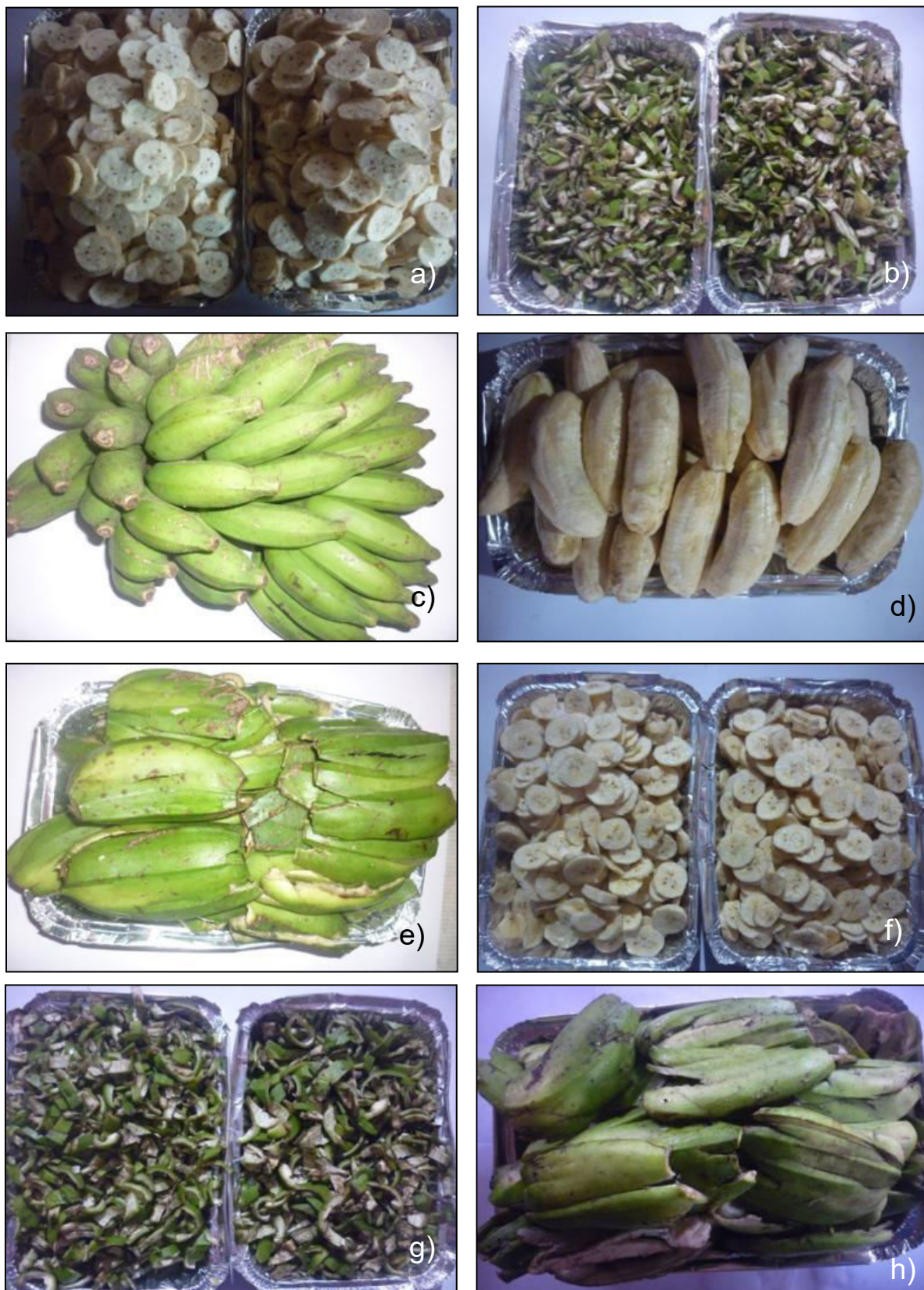


Figure.10 Description of *Musa accuminata* Colla (AA) Robusta a) fruit bunch, b) mature fruit without skin, c) fruit skin, d) mature fruit cut into small slices, e) d) mature fruit, e) fruit skin cut into small slices, f) description of *Musa x paradisiaca* L. (AAB) Chemkadali; fruit bunch, g) mature fruit cut into small slices, h) fruit skin.



Figure.11 Description of *Musa x paradisiaca* L. (AAB) Chemkadali a) fruit skin chopped into small pieces, b) fruit chopped into small pieces, c) description of *Musa accuminata* Colla (AA) Kanna; fruit bunch d) sections of fruit, d) mature fruit without skin, e) fruit skin, f) fruit chopped into small pieces, g) and h) fruit skin chopped into small pieces.



Figure.12 Description of fruit powder and peel of banana varieties a) Robusta fruit, b) Palayamkodon fruit, c) Njalipoovan fruit, d) Kannan fruit, e) Pachakadali fruit, f) Pachakadali peel, g) Kannan peel, h) Sundari peel.

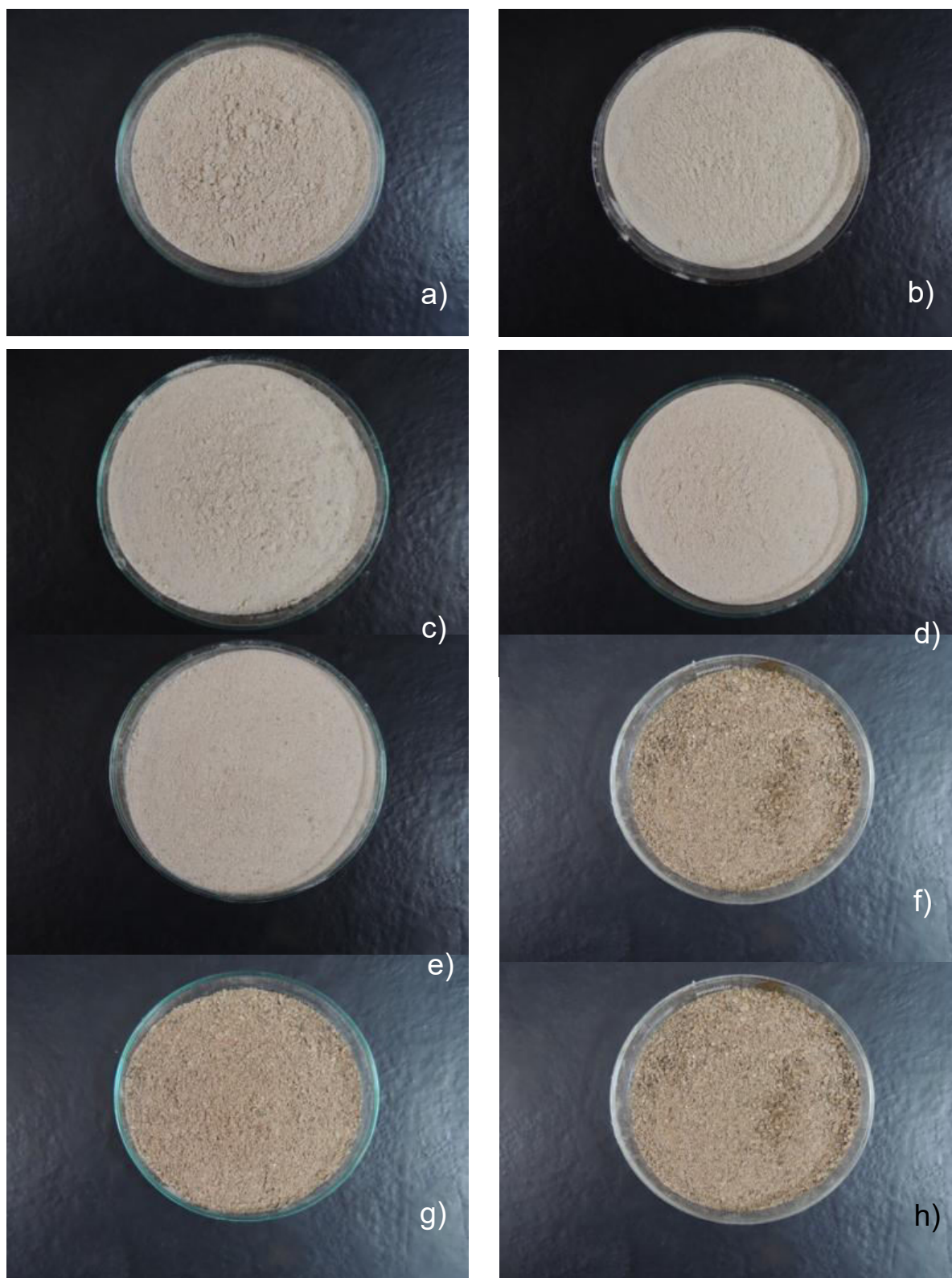


Figure.13 Green synthesised Copper nanoparticles of Robusta (B1), Etha (B2), Poovan (B3), Sundari (B4), Njalipoovan (B5), Palayamkodon (B6), Kannan (B8), Pachakadali (B9); a) dry fruit distilled water extracts, b) dry fruit propane extracts, c) dry fruit hexane extracts, d) dry fruit acetone extracts, e) dry fruit methanol extracts, f) dry skin distilled water extracts.

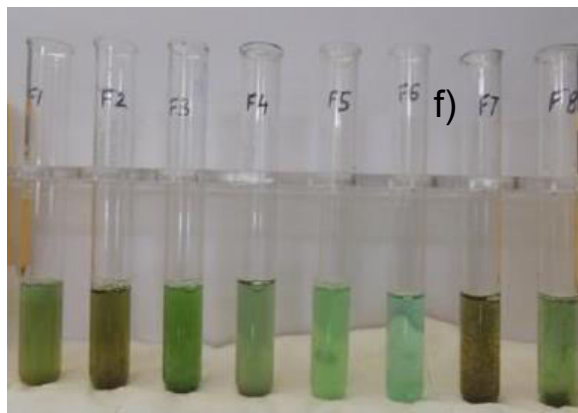
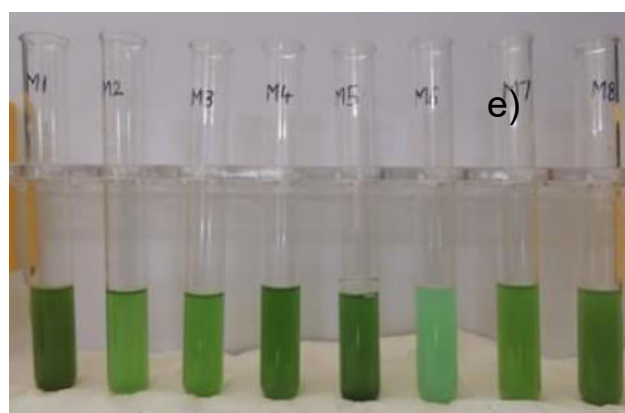
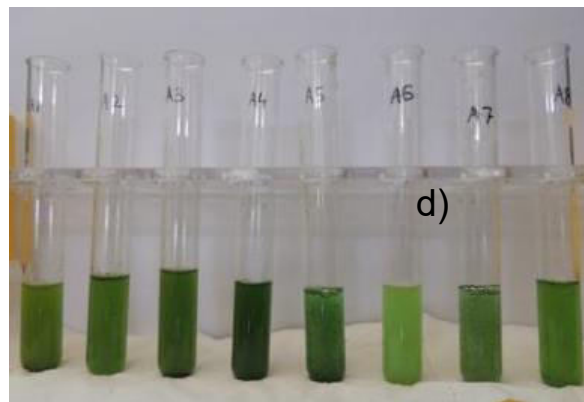
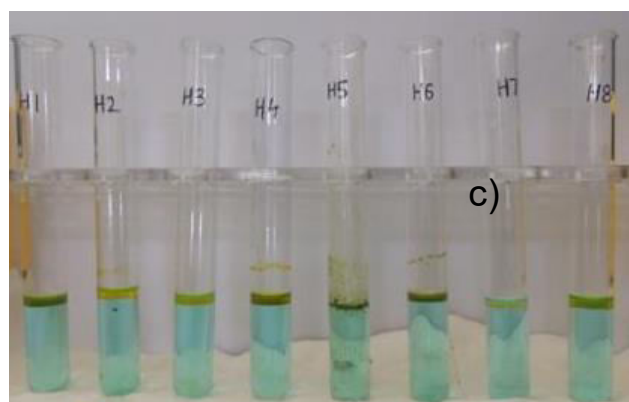
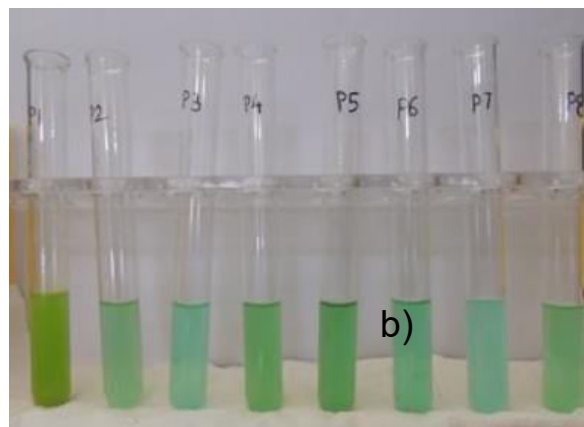
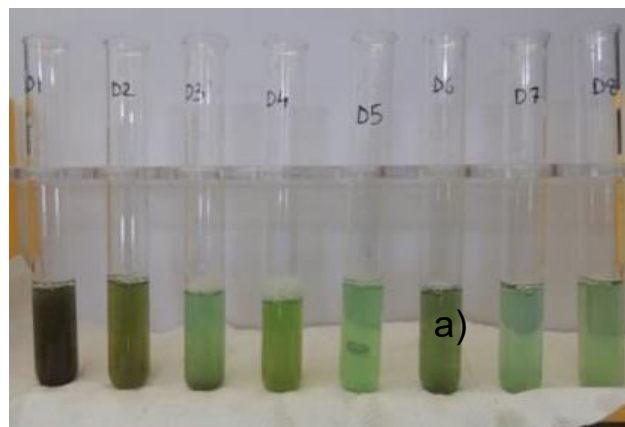


Figure.14 Green synthesised Zinc nanoparticles of Robusta (B1), Etha (B2), Poovan (B3), Sundari (B4), Njalipoovan (B5), Palayamkodan (B6), Kannan (B8), Pachakadali (B9); a) dry fruit distilled water extracts, b) dry fruit propane extracts, c) dry fruit hexane extracts, d) dry fruit acetone extracts, e) dry fruit methanol extracts, f) dry skin distilled water extracts.

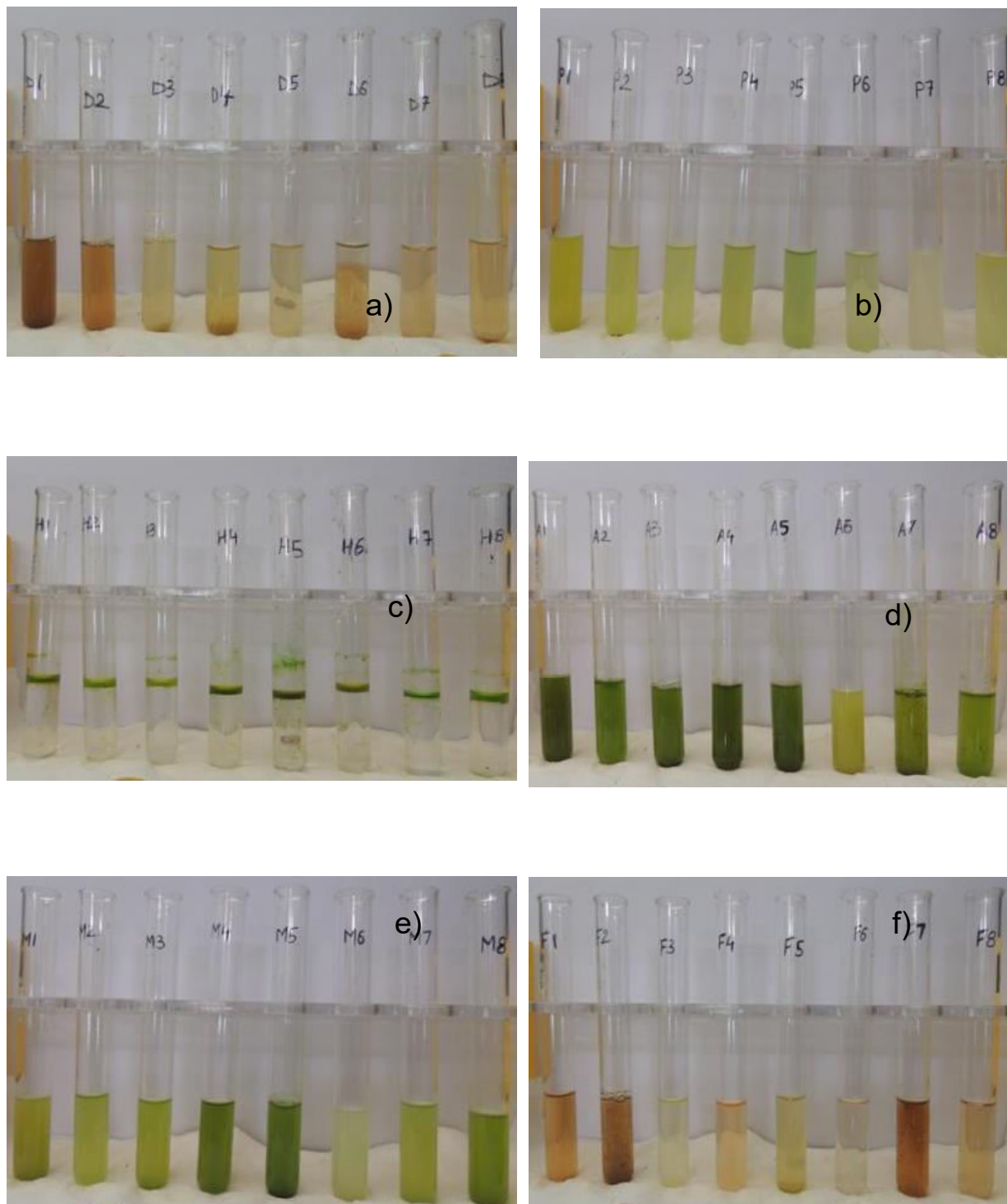


Figure.15 Antifungal activity study using well diffusion method of Eethavazha (*fruit*) 24 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 µl), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

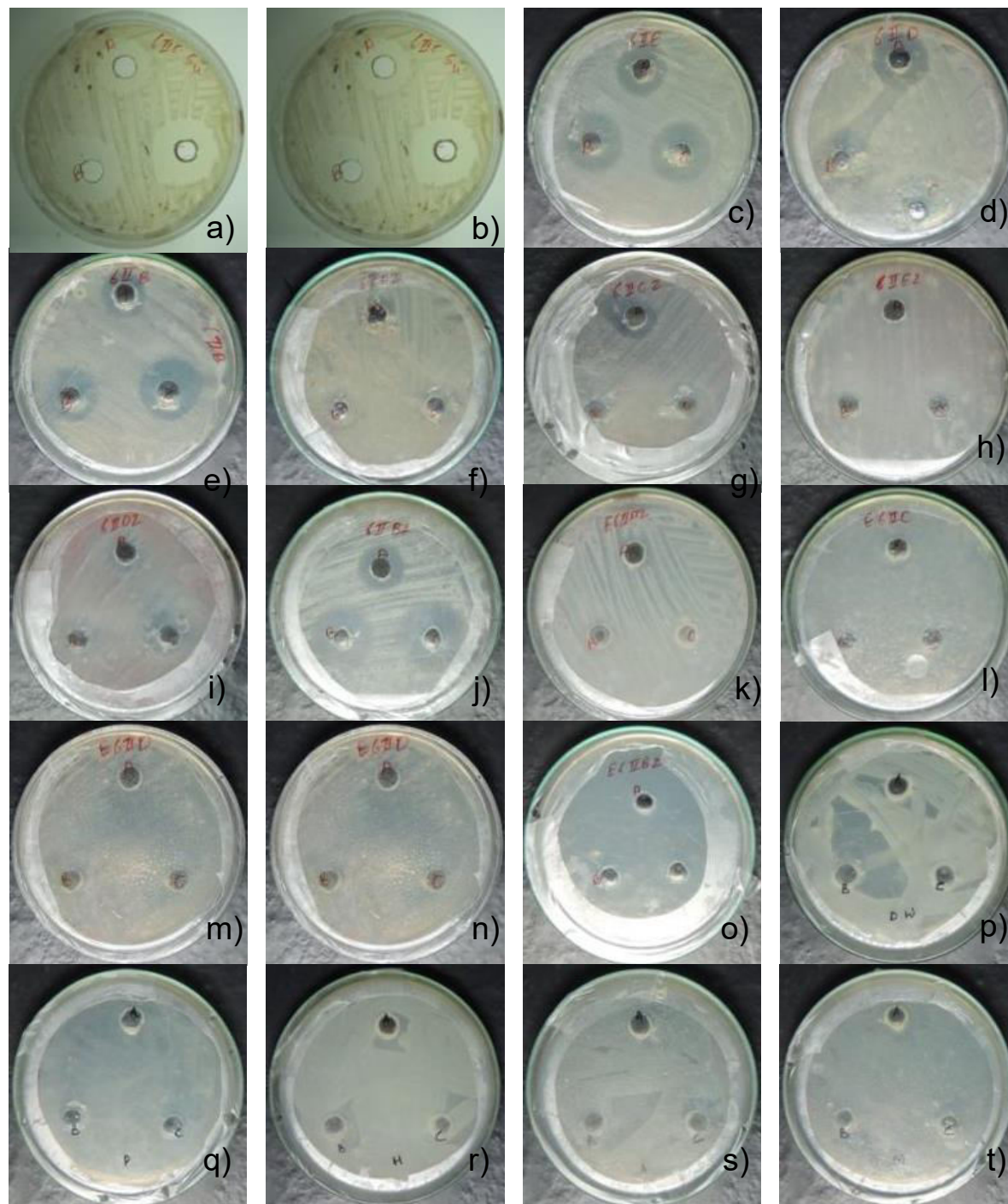


Figure.16 Antifungal activity study using well diffusion method of Eethavazha (*fruit*) 48 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

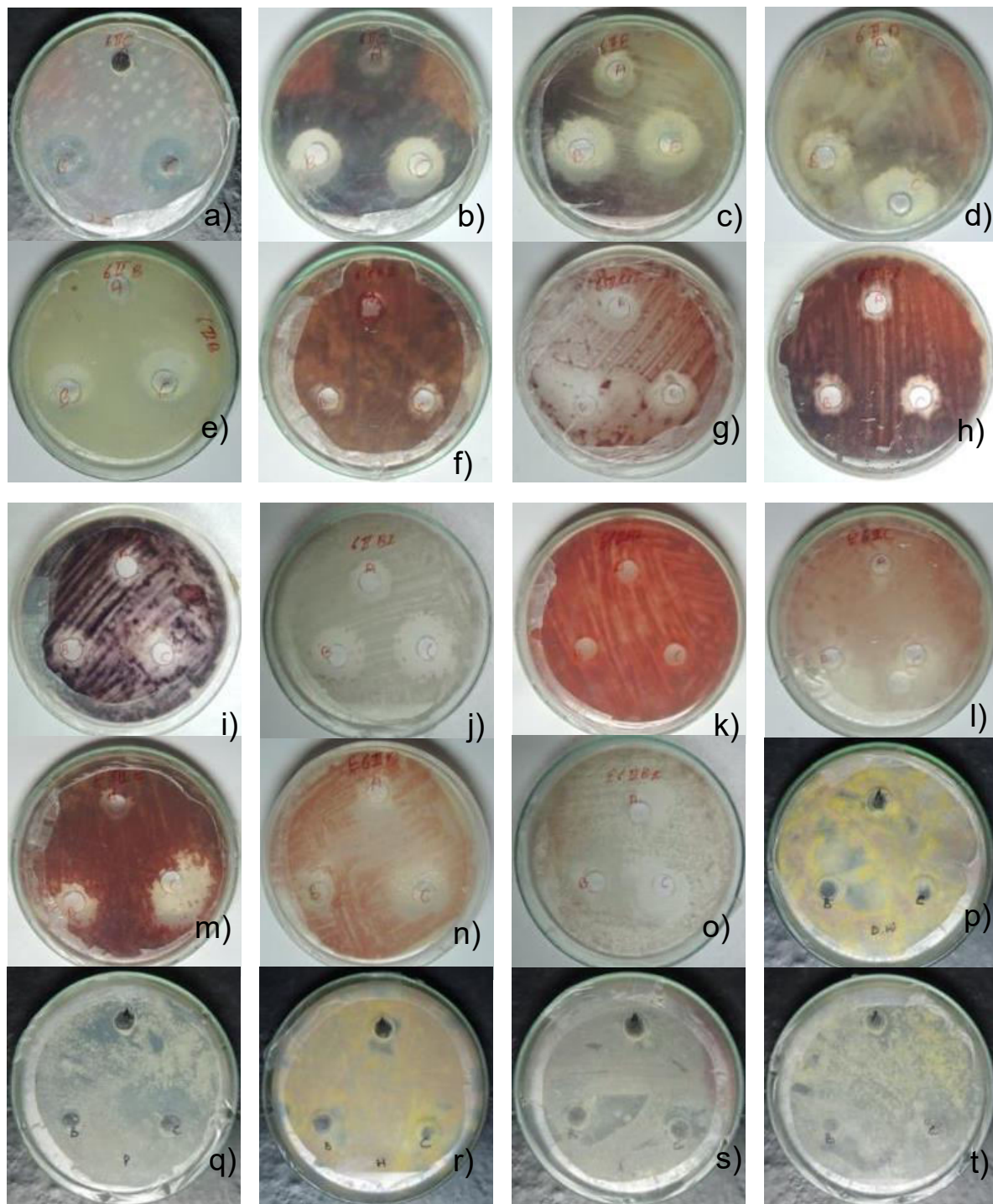


Figure.17 Antifungal activity study using well diffusion method of Eethavazha (*fruit*) 72 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

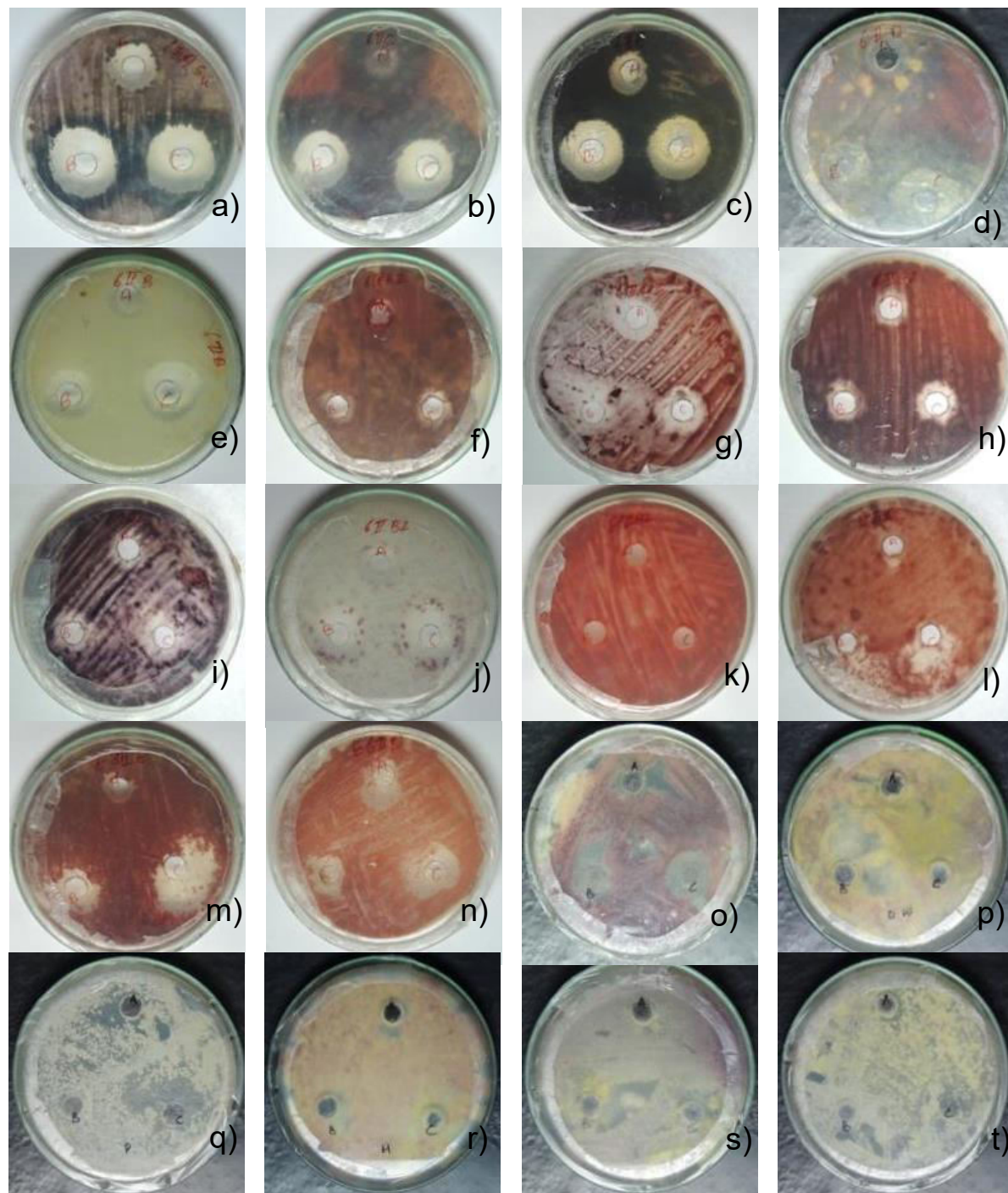


Figure.18 Antifungal activity study using well diffusion method of Kannan (*fruit*) 24 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

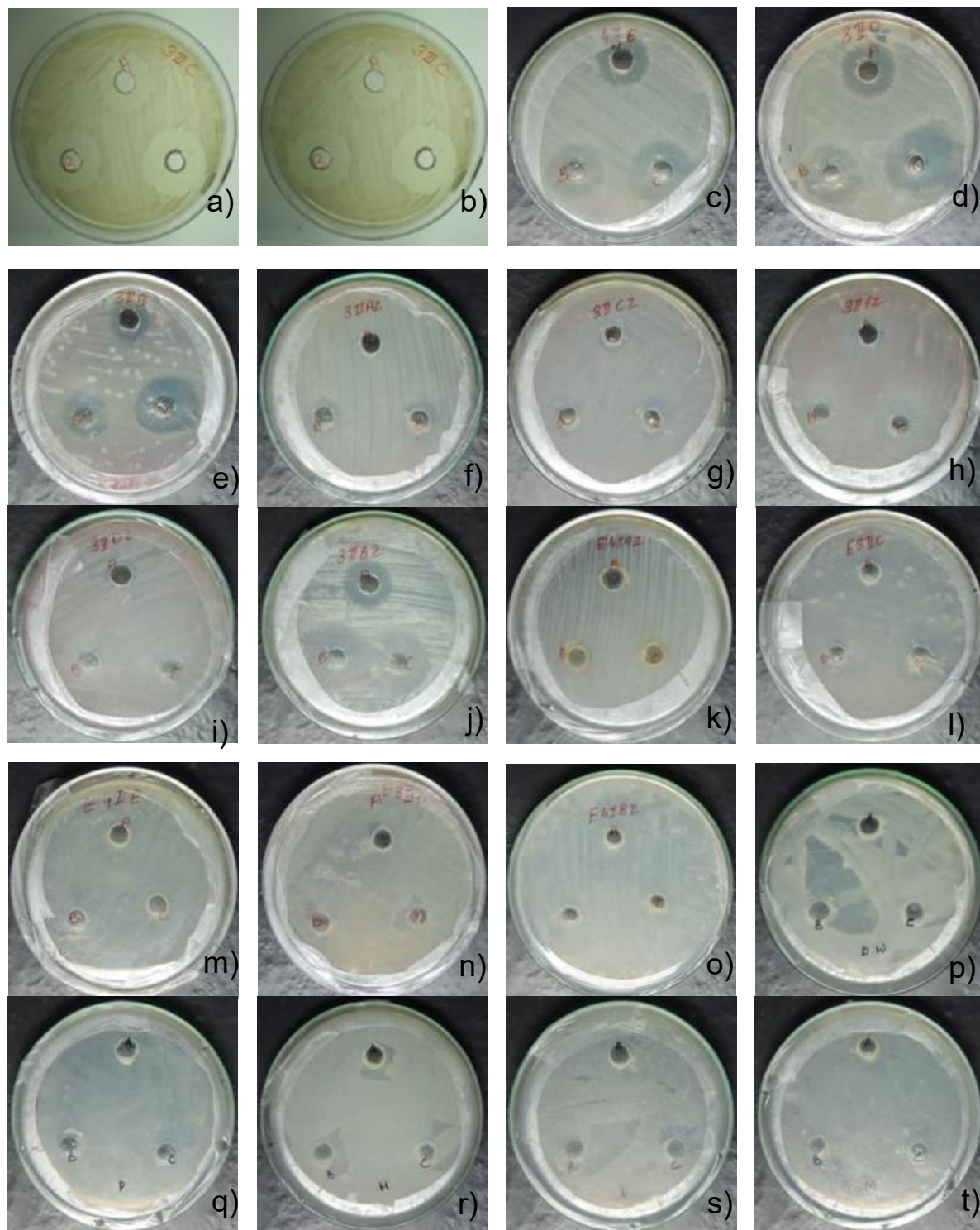


Figure.19 Antifungal activity study using well diffusion method of Kannan (*fruit*) 48 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

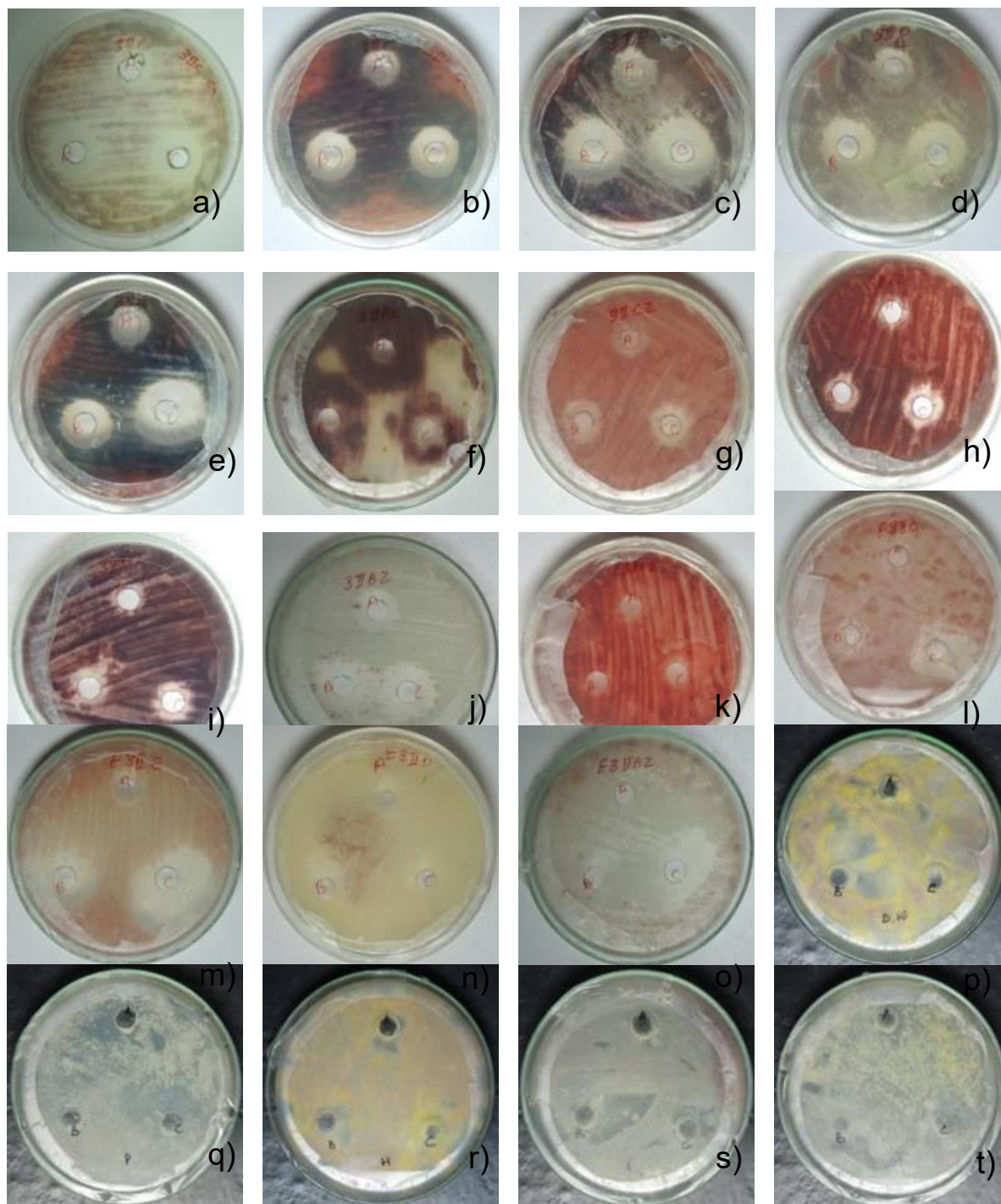


Figure.20 Antifungal activity study using well diffusion method of Kannan (*fruit*) 72 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

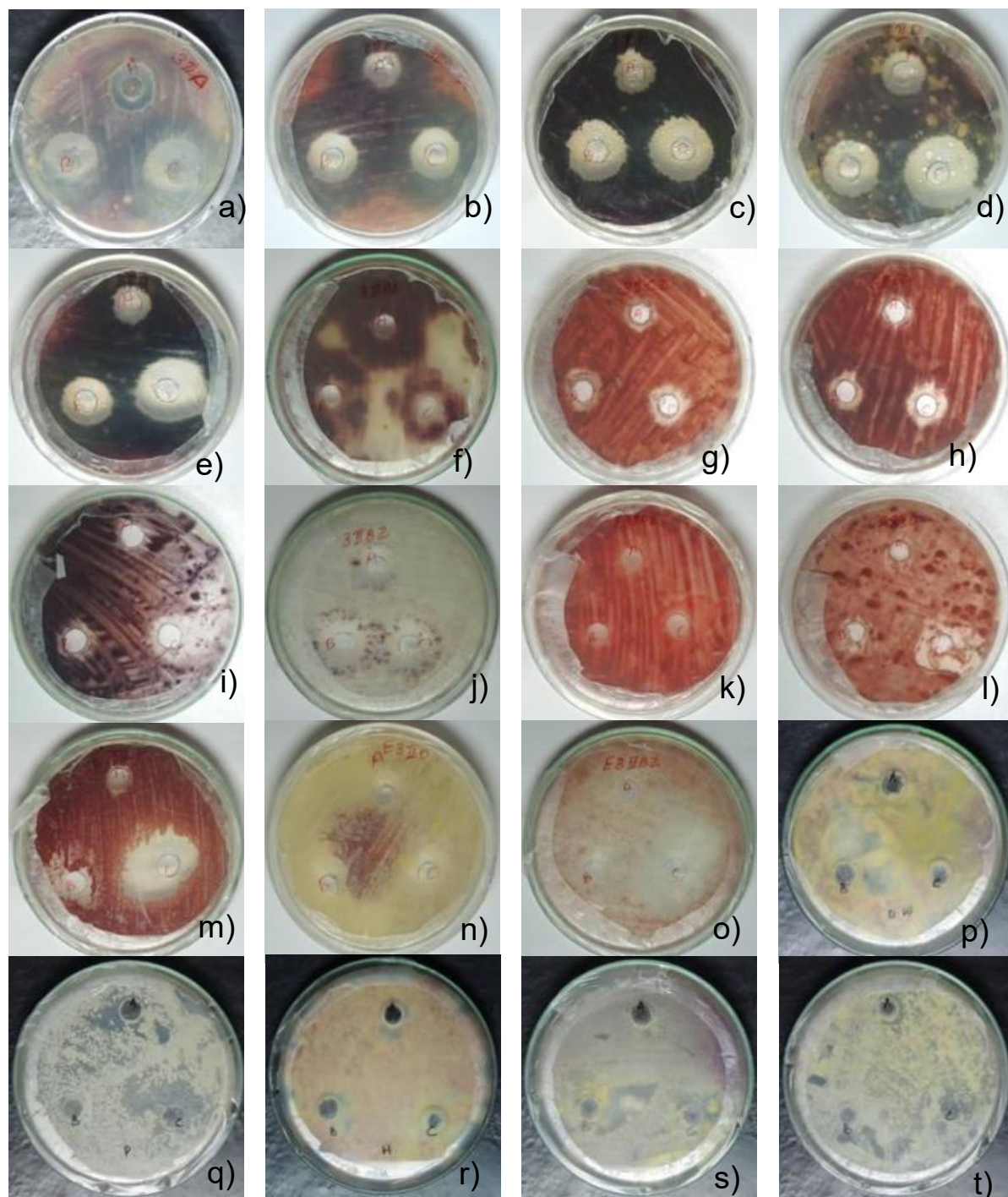


Figure.21 Antifungal activity study using well diffusion method of Njalipoovan (Fruit) 24 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

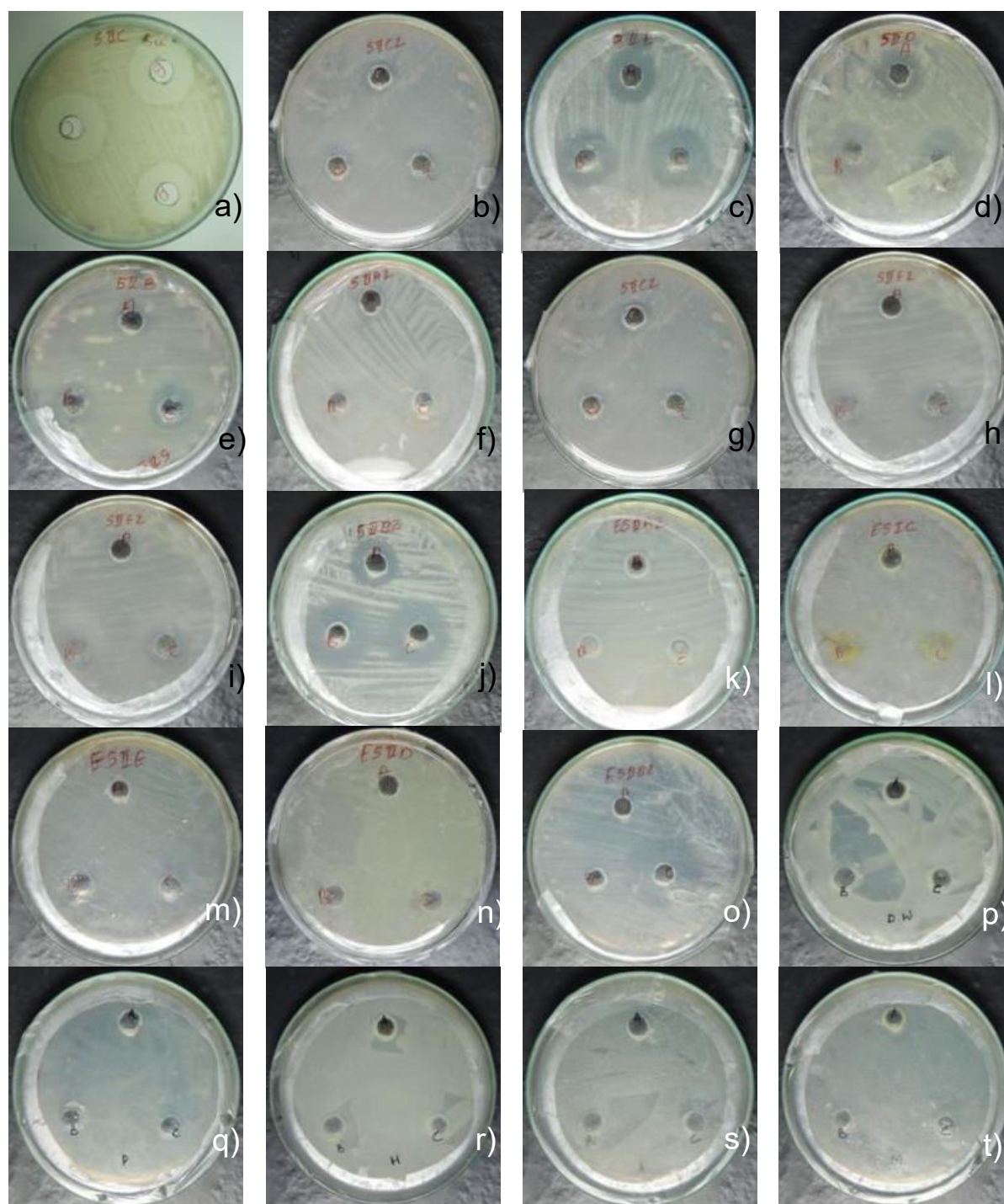


Figure.22 Antifungal activity study using well diffusion method of Njalipoovan (Fruit) 48 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

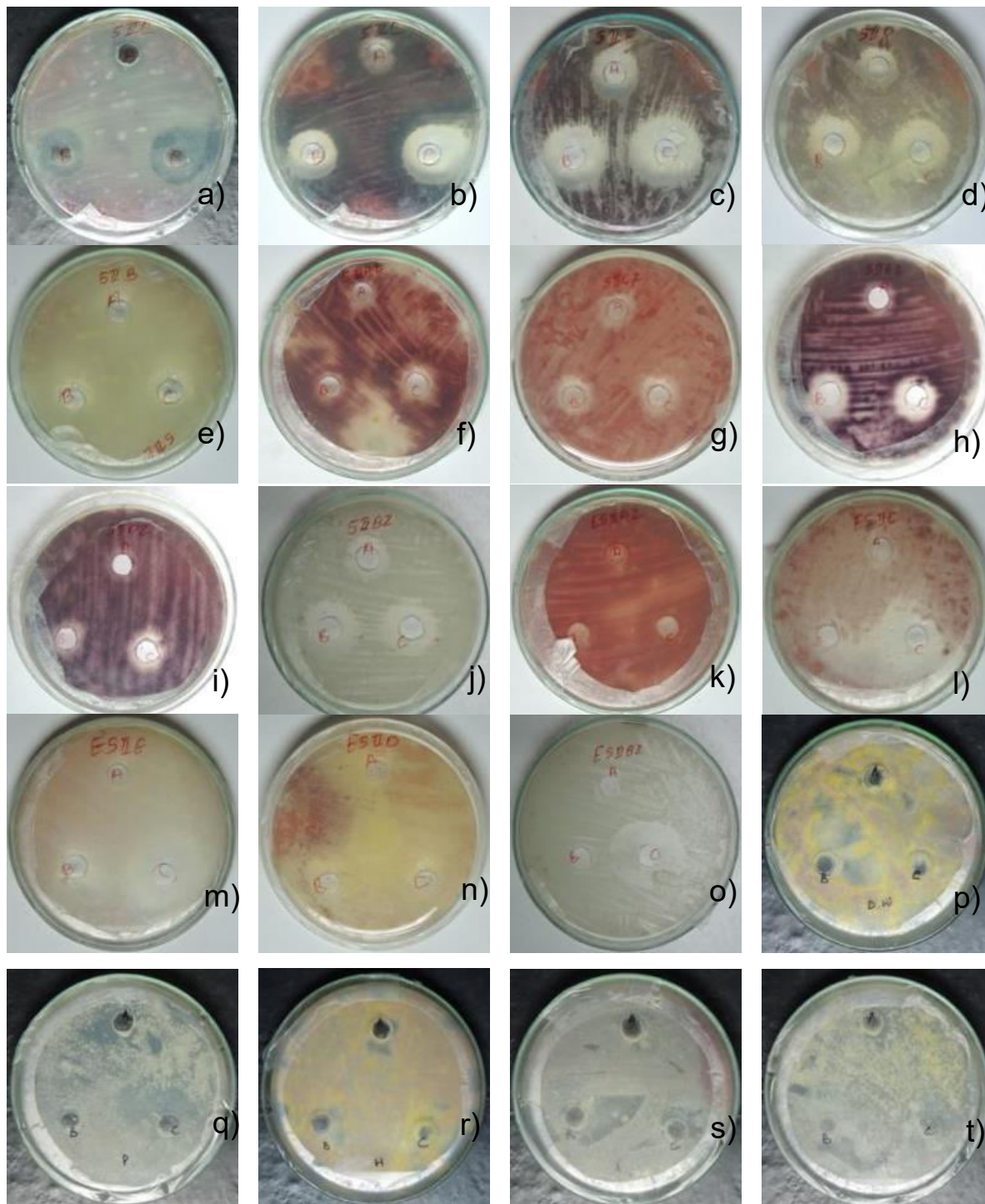


Figure.23 Antifungal activity study using well diffusion method of Njalipoovan (Fruit) 72 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

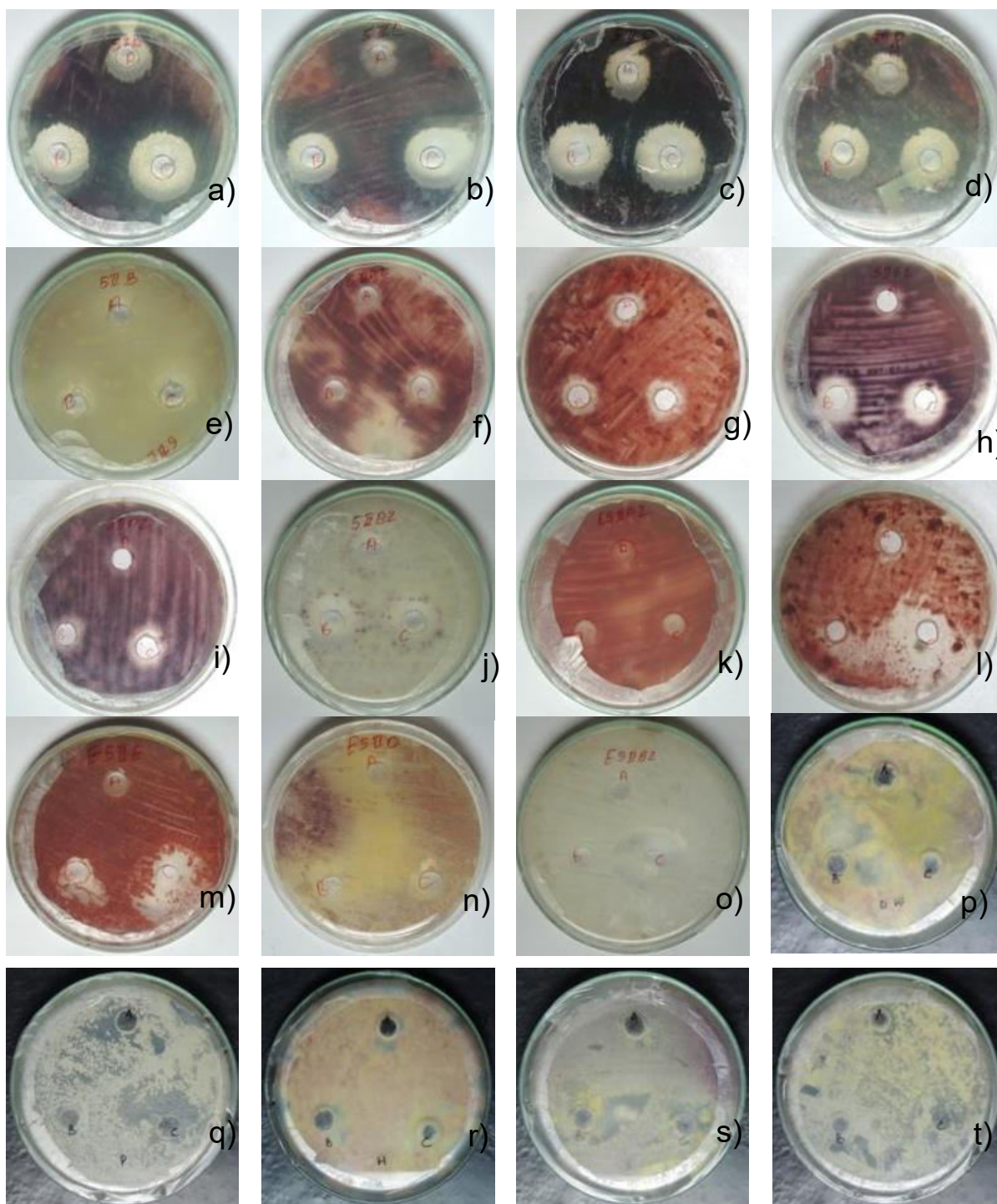


Figure.24 Antifungal activity study using well diffusion method of Pachakadali (Fruit) 24 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

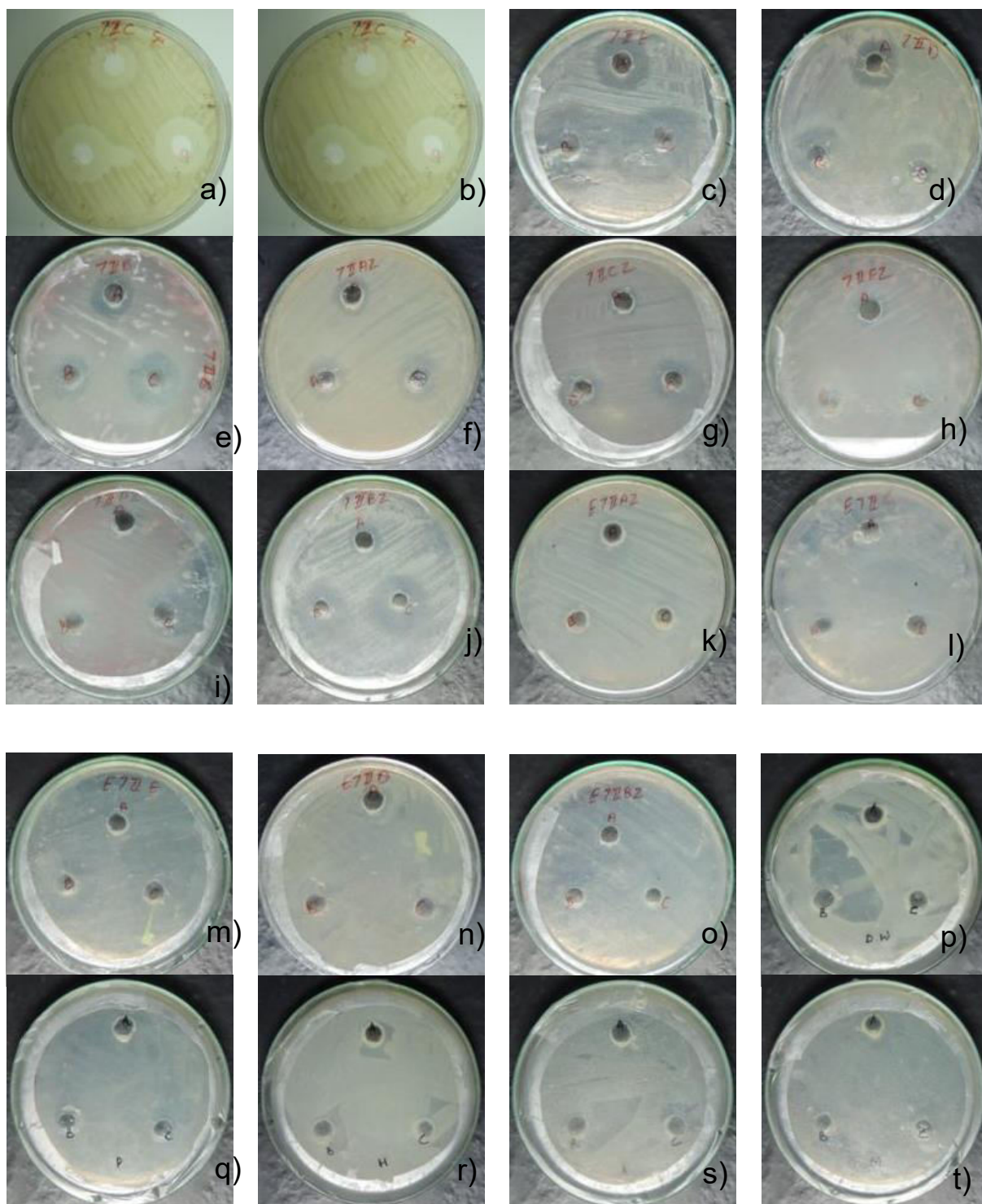


Figure.25 Antifungal activity study using well diffusion method of Pachakadali (Fruit) 48 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

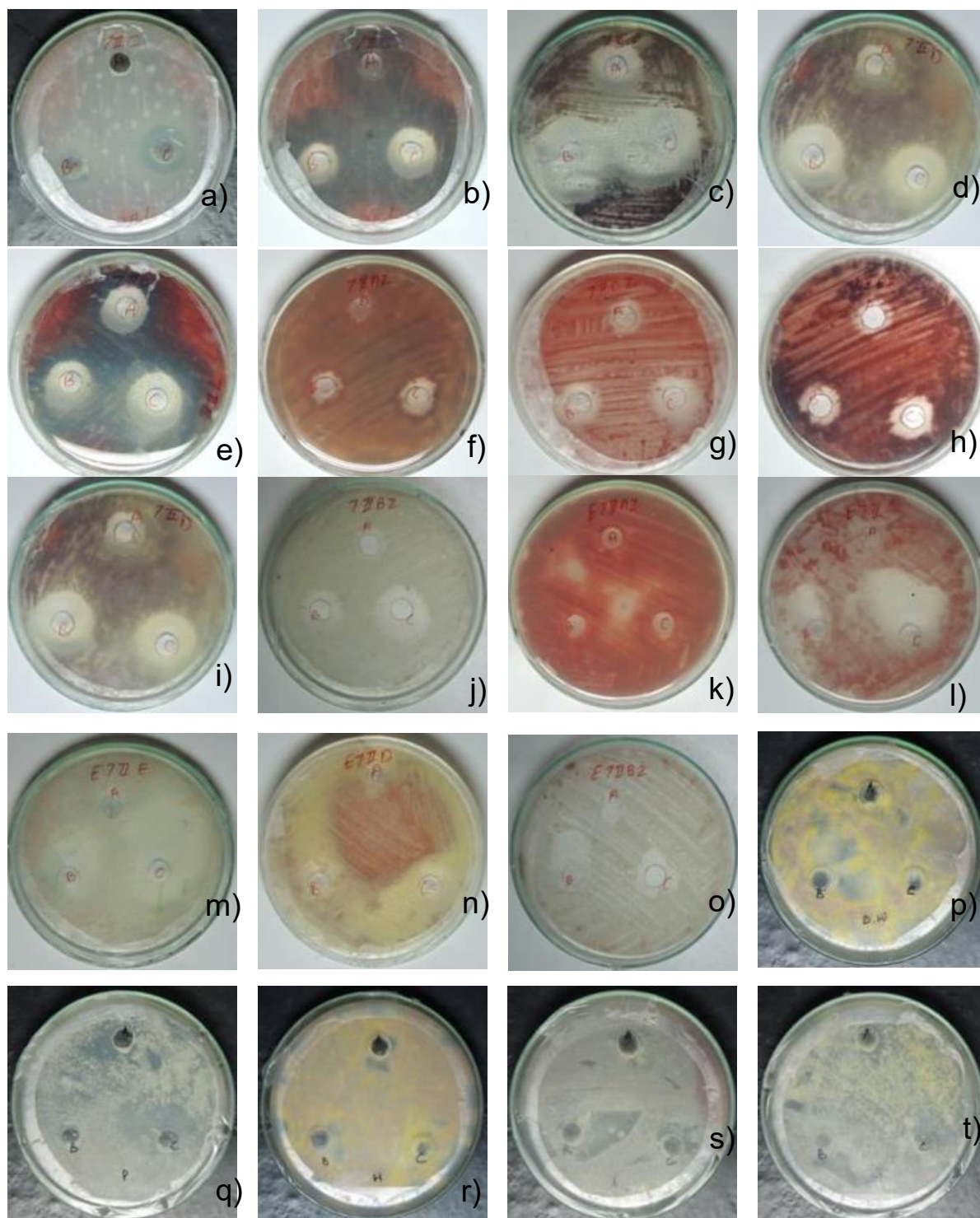


Figure.26 Antifungal activity study using well diffusion method of Pachakadali (Fruit) 72 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

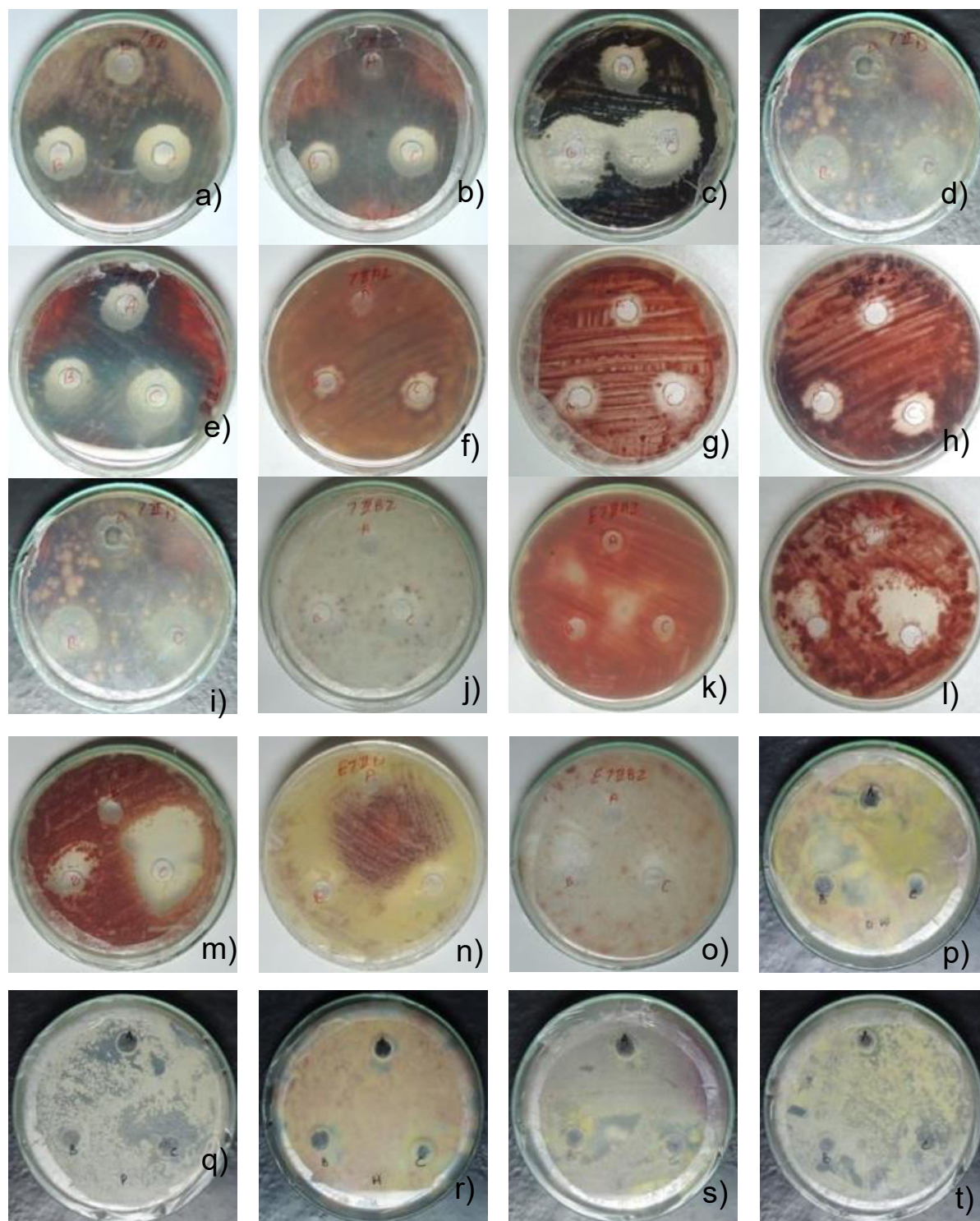


Figure.27 Antifungal activity study using well diffusion method of Palaymkodan (Fruit) 24 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

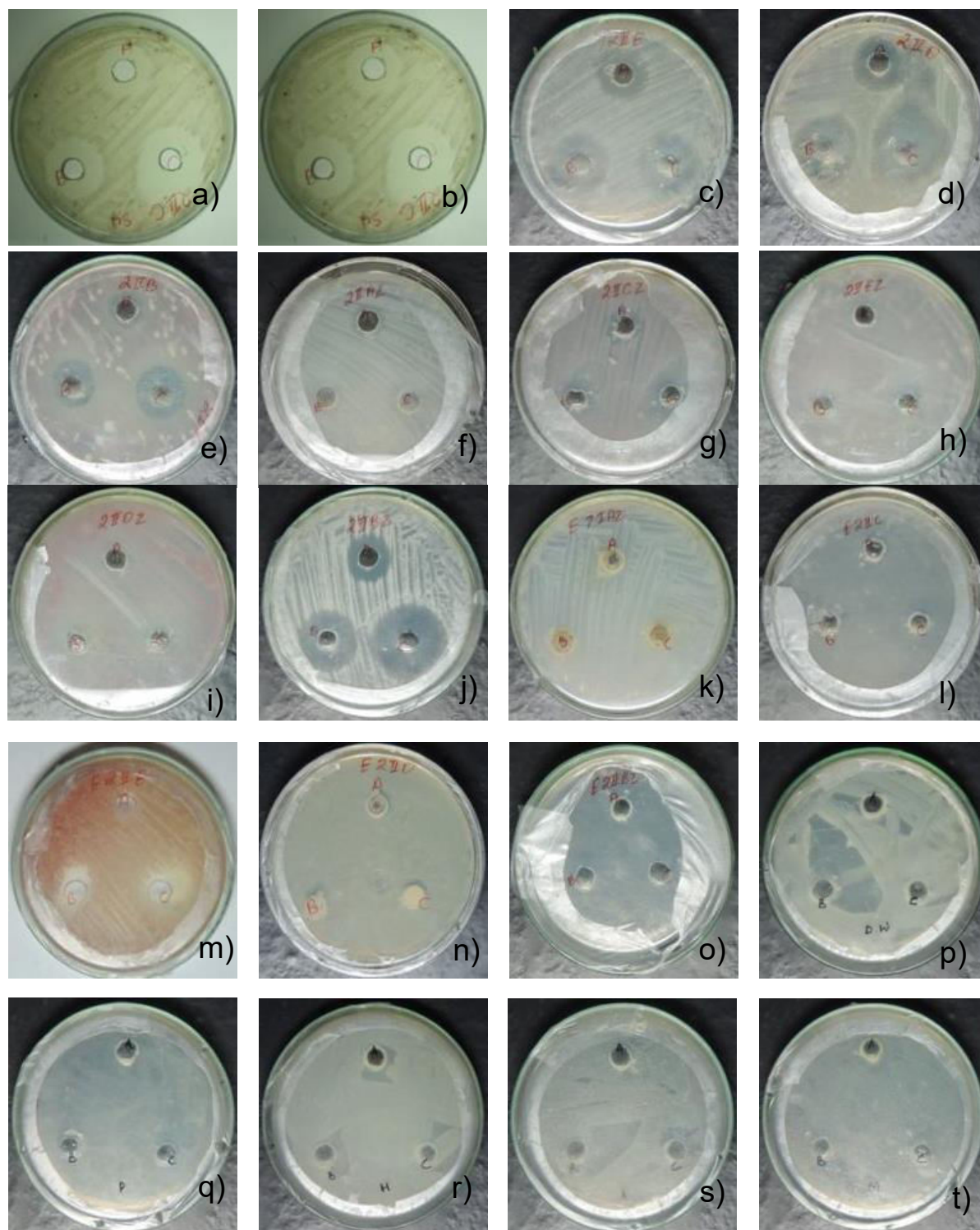


Figure.28 Antifungal activity study using well diffusion method of Palaymkodan (Fruit) 48 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

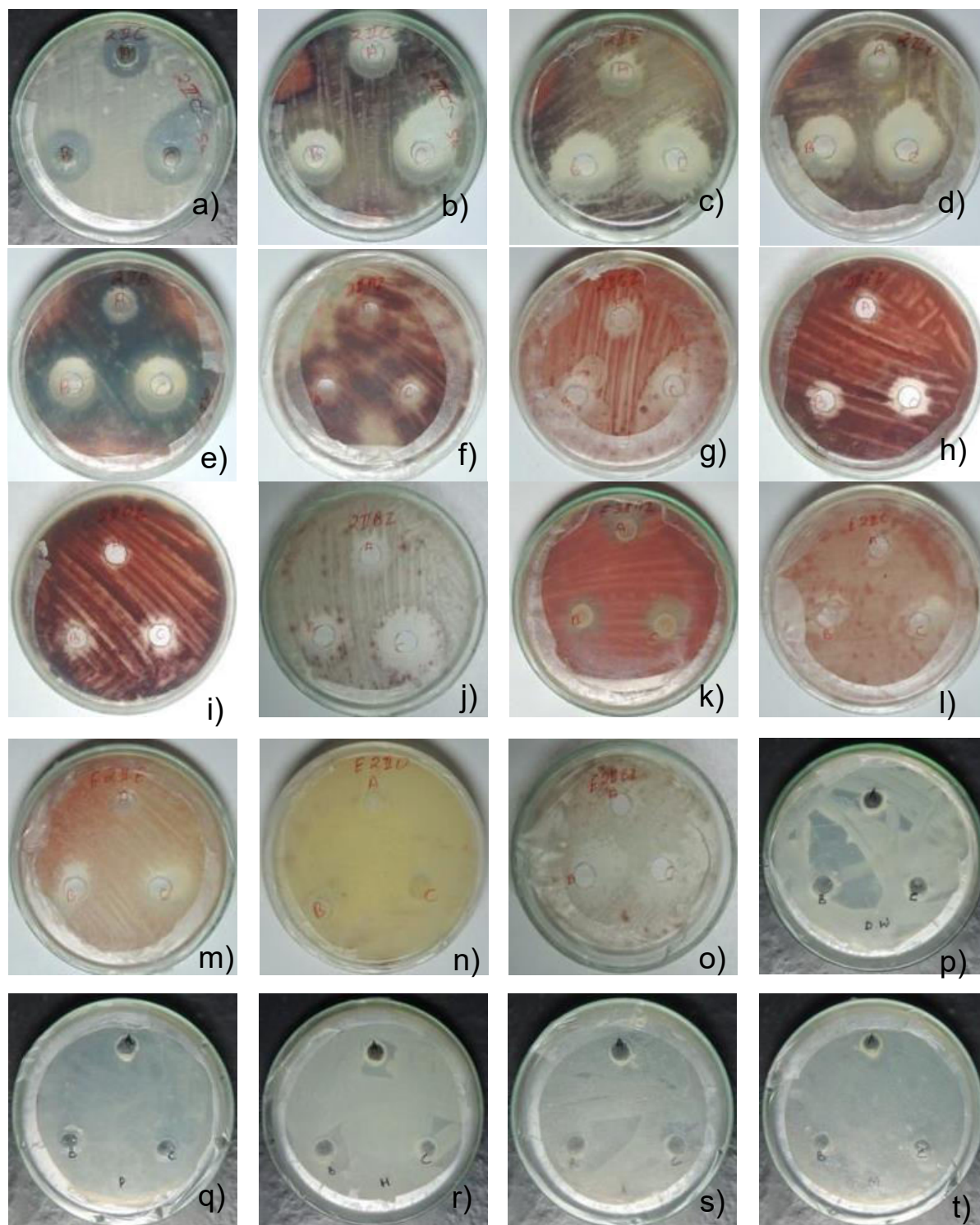


Figure.29 Antifungal activity study using well diffusion method of Palaymkodan (Fruit) 72 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

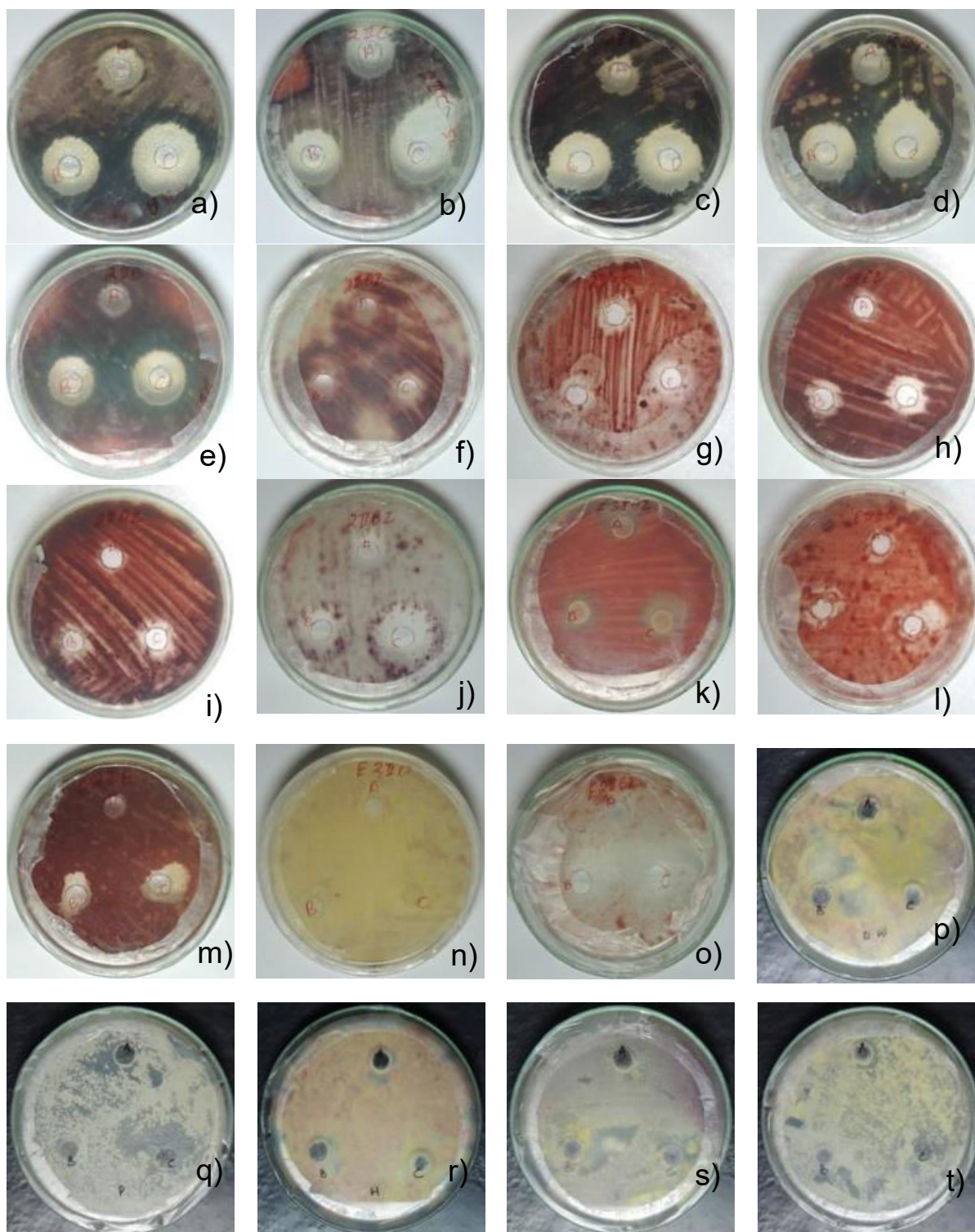


Figure.30 Antifungal activity study using well diffusion method of Poovan (Fruit) 24 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

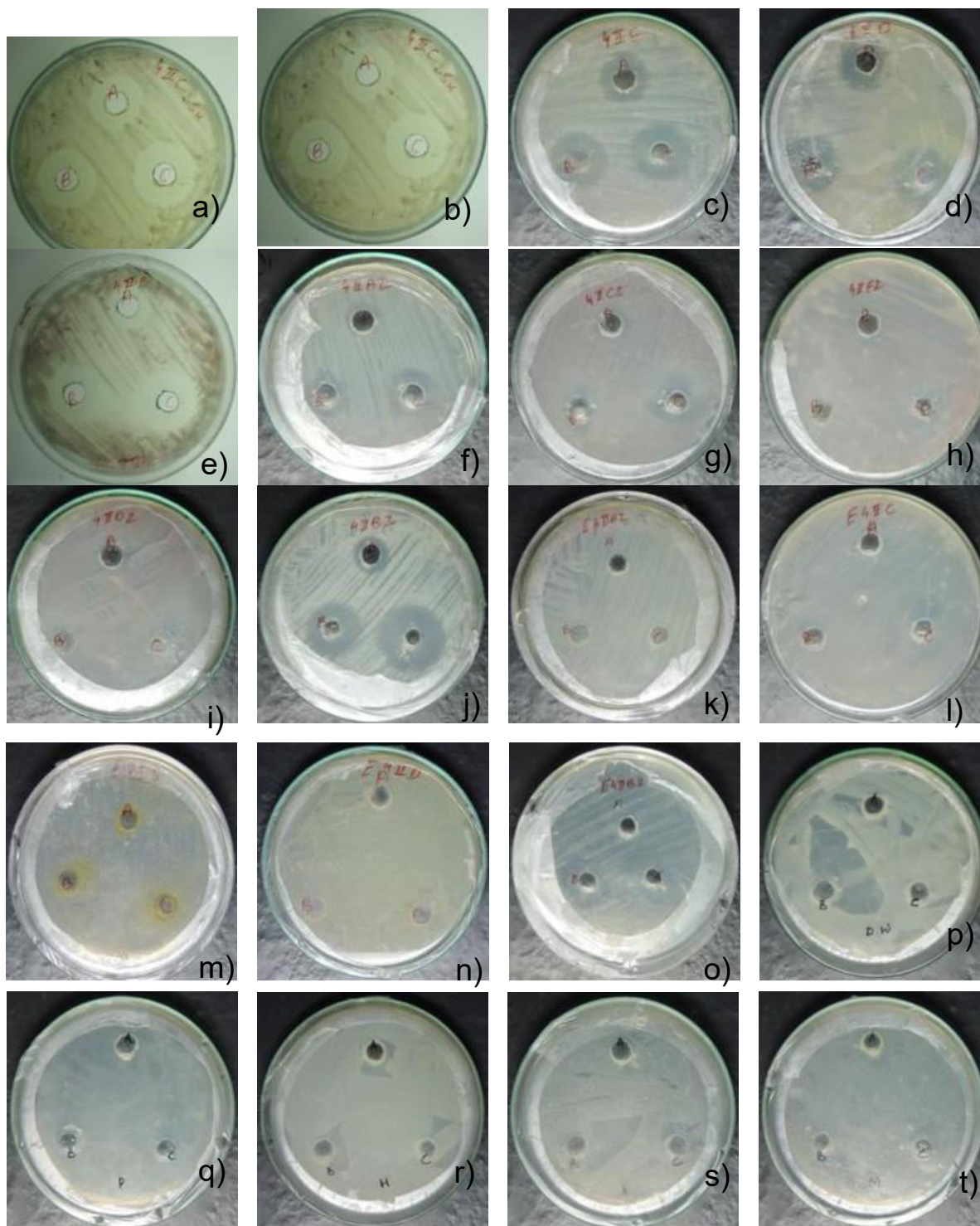


Figure.31 Antifungal activity study using well diffusion method of Poovan (Fruit) 48 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

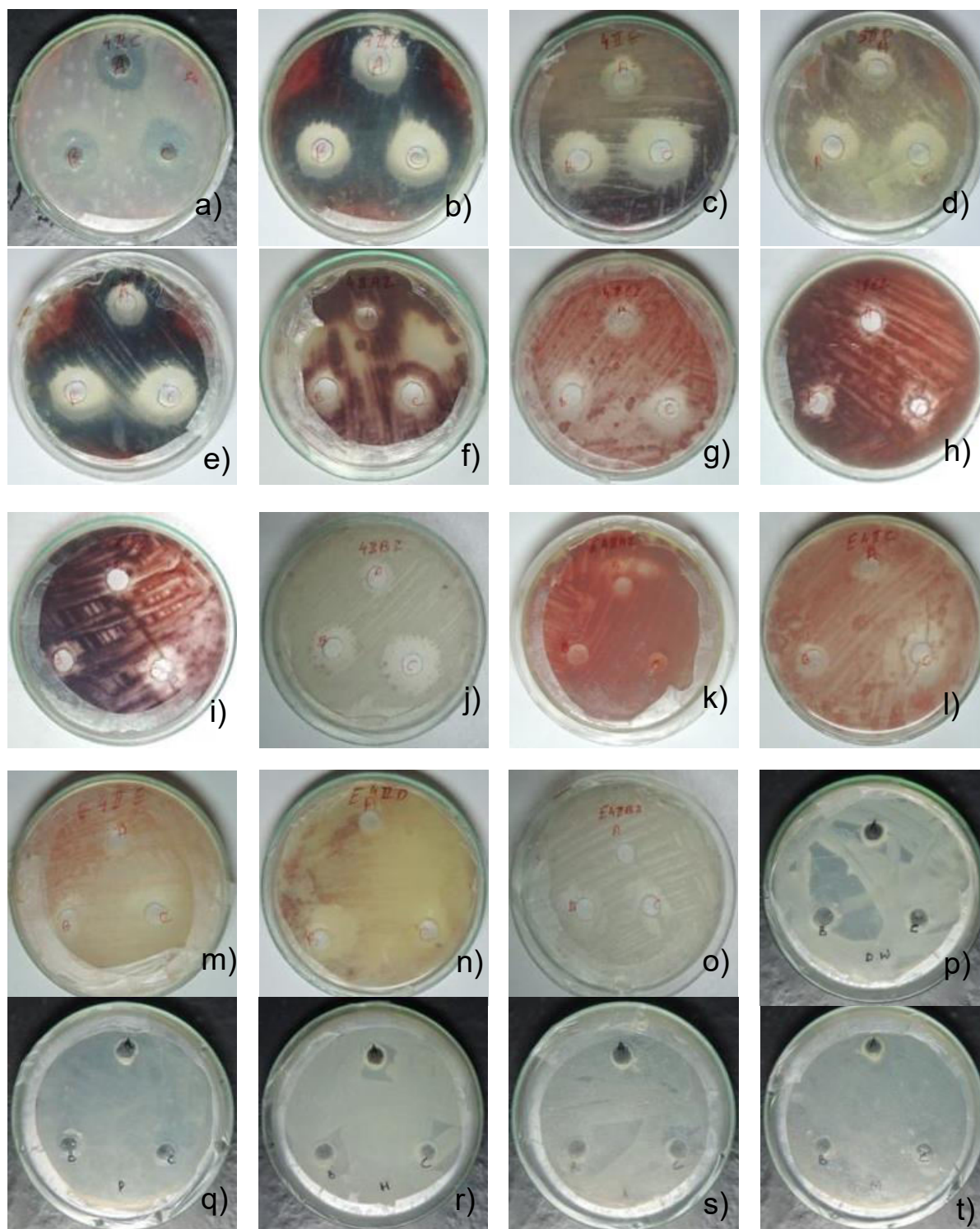


Figure.32 Antifungal activity study using well diffusion method of Poovan (Fruit) 72 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

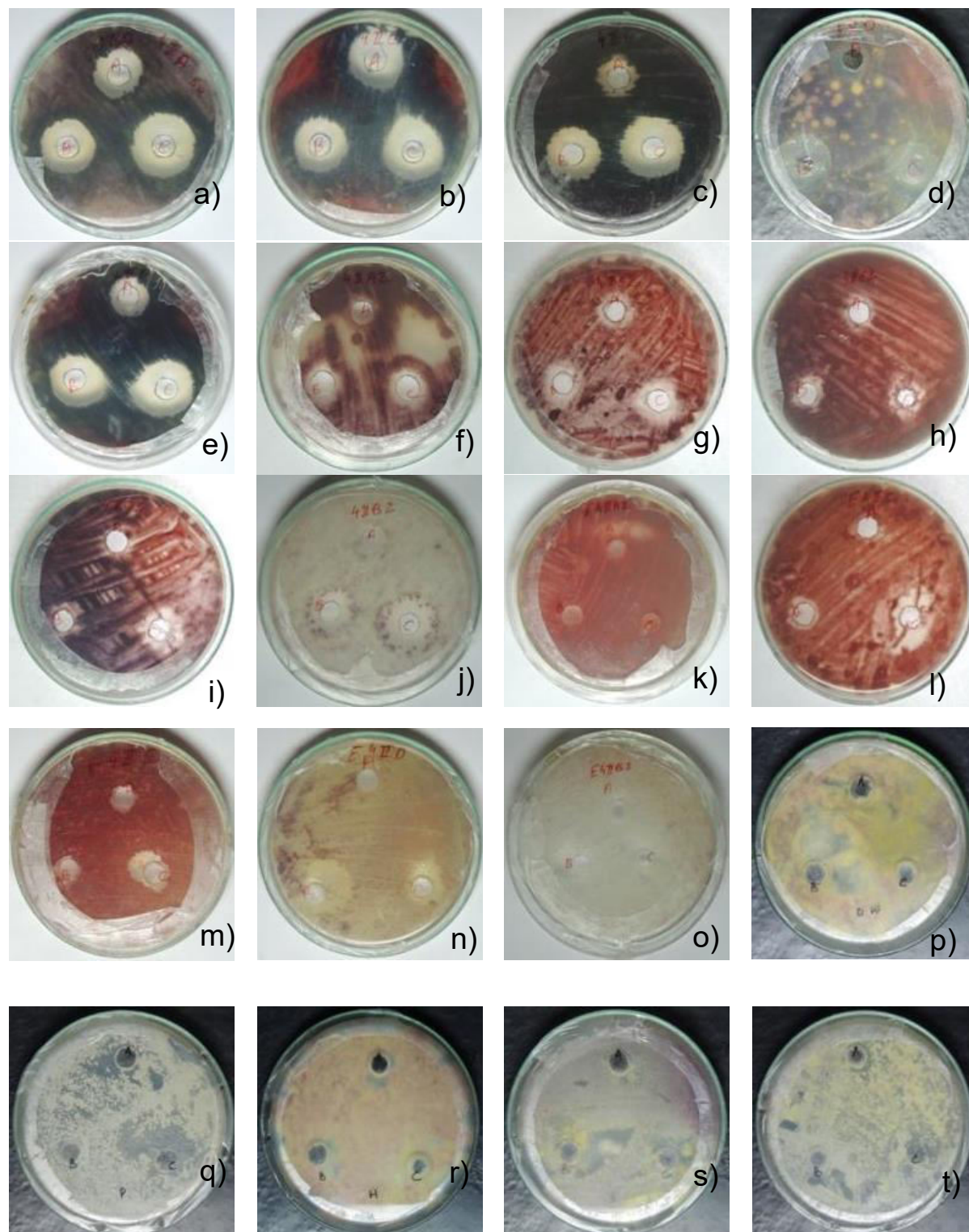


Figure.33 Antifungal activity study using well diffusion method of Sundari (fruit) 24 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

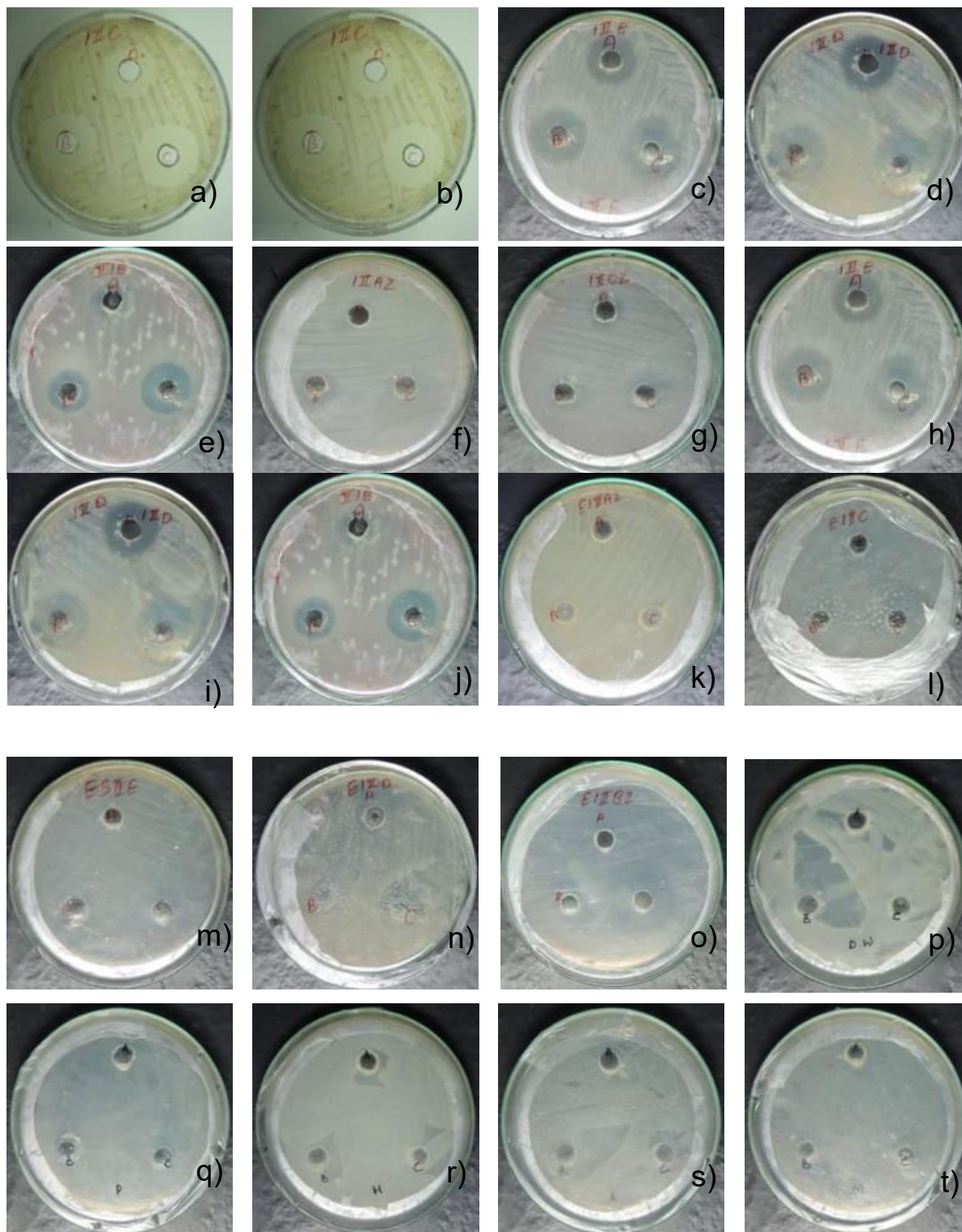


Figure.34 Antifungal activity study using well diffusion method of Sundari (Fruit) 48 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

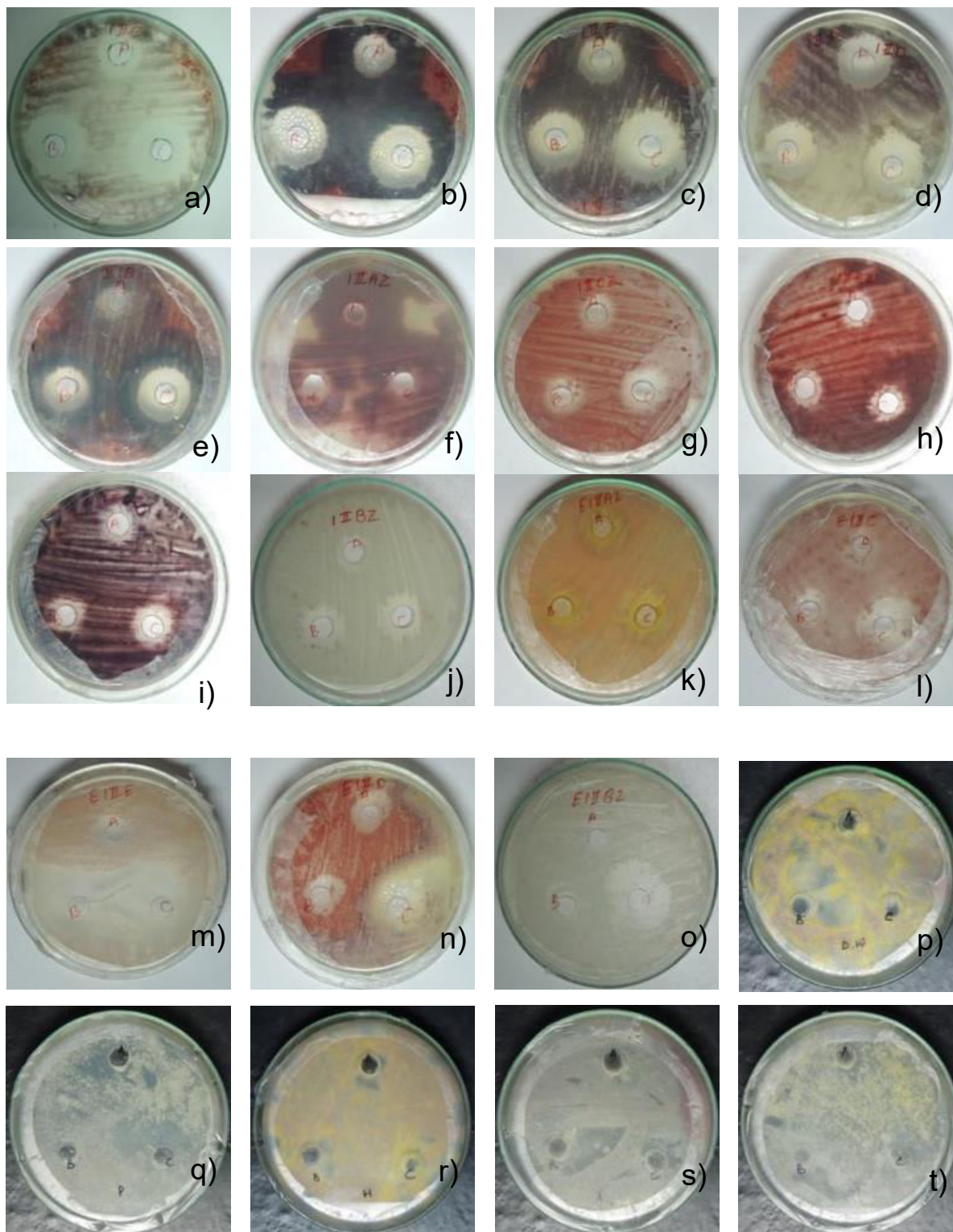


Figure.35 Antifungal activity study using well diffusion method of Sundari (Fruit) 72 hrs leaf extract nanoparticles (Cu) and (Zn) a) green synthesised Cu nanoparticle test plate (Distilled water; 50, 100 and 150 μ l), b) Propane, c) Ethanol, d) Acetone, e) Methanol, f) to j) above mentioned test plate in same order for Zn nanoparticles, k) to o) starch + solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol), p) to t) solvent control plates (Distilled water, Propane, Ethanol, Acetone, Methanol).

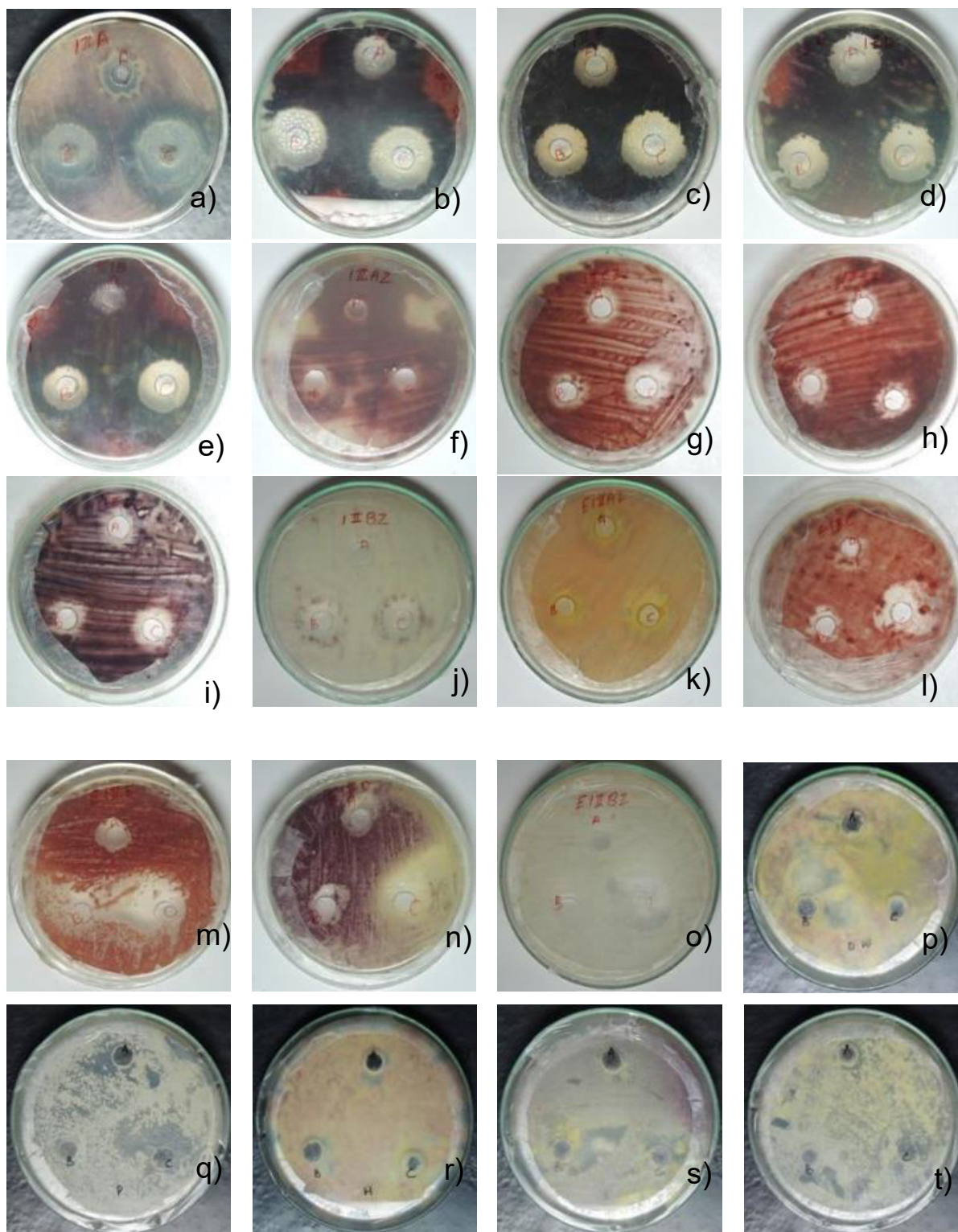


Figure.36 Copper nanoparticle formation of (Poovan) dry fruit extract under SEM imaging system with various resolutions.

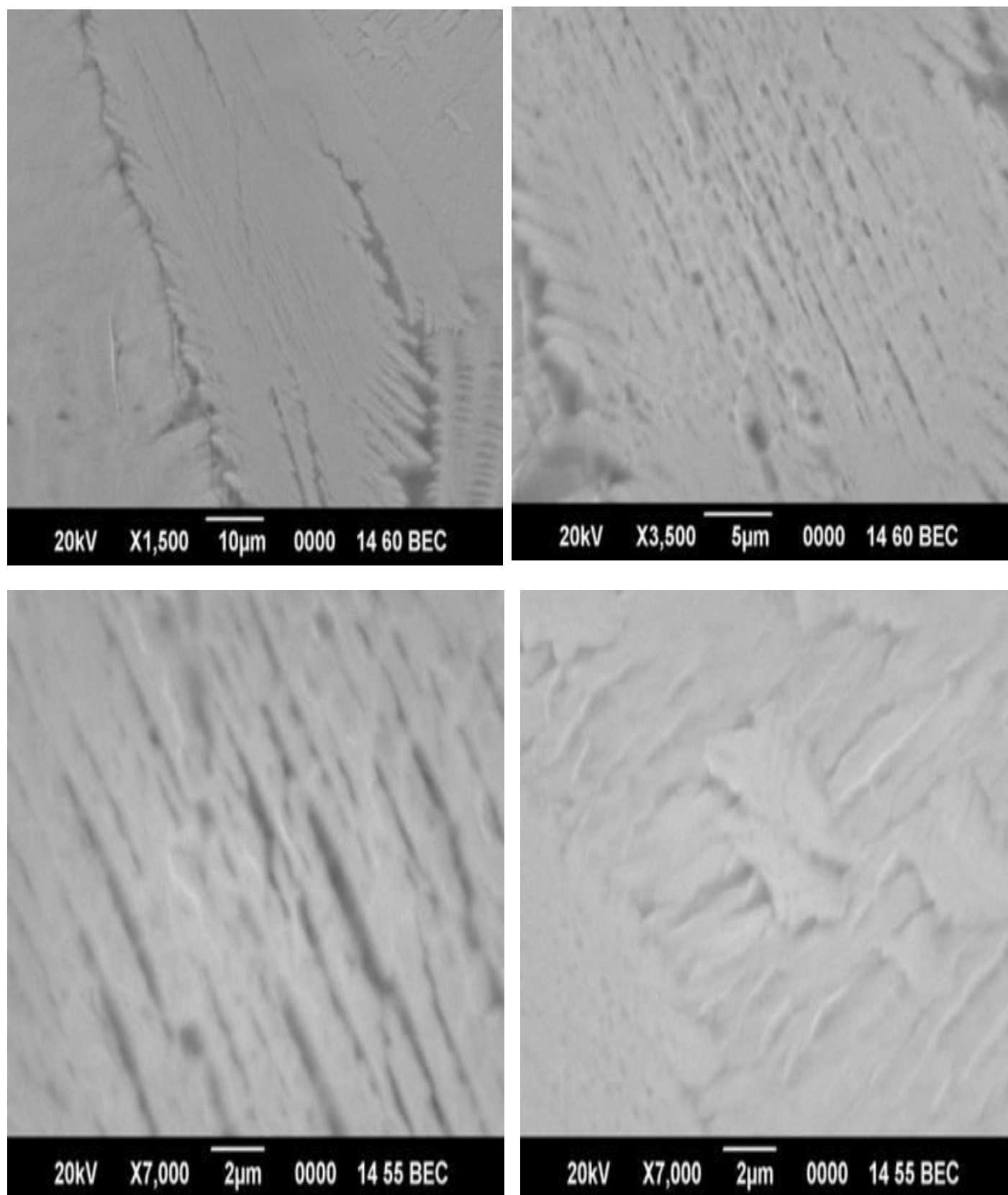


Figure.37 Zinc nanoparticle formation of (Sundari) dry fruit methanol extract under SEM imaging system with various resolutions.

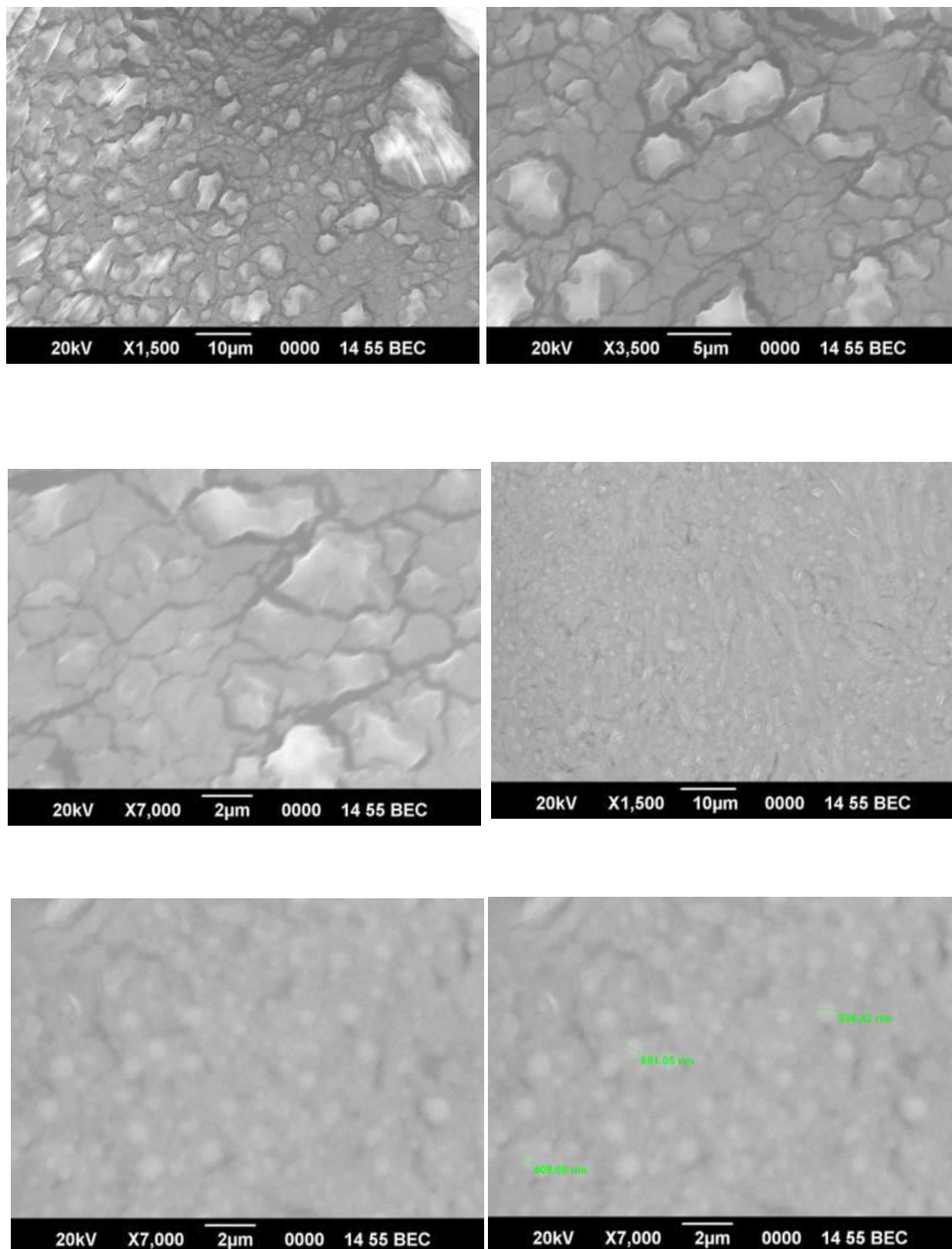
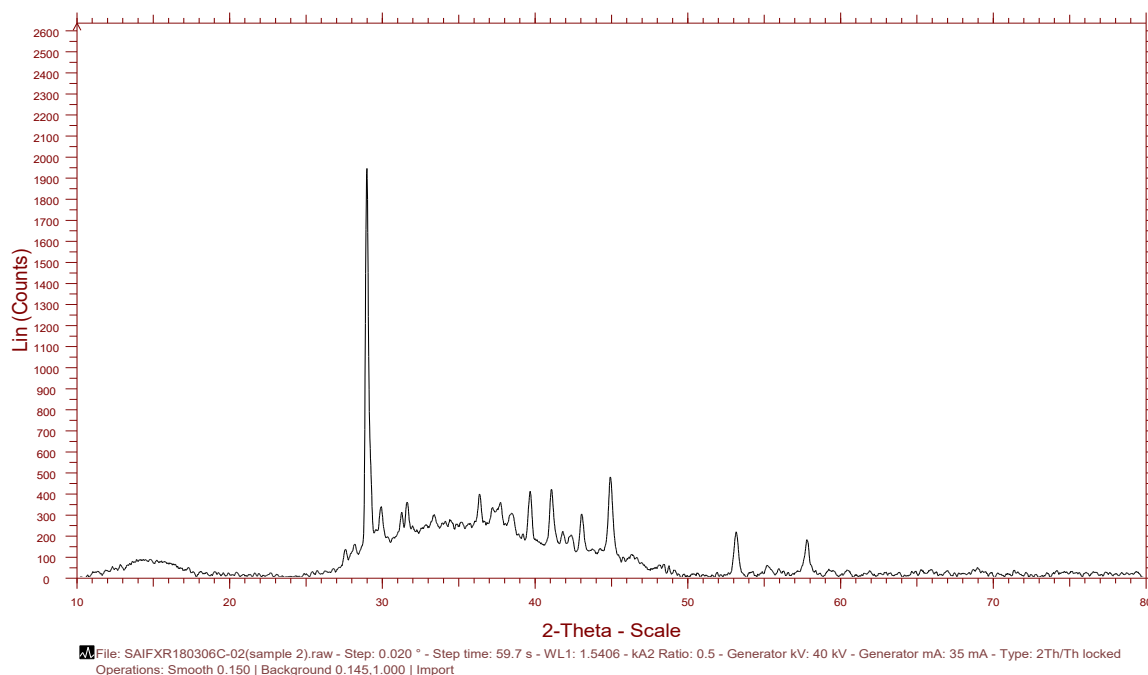


Figure.38 Copper nanoparticle formation of (Poovan) dry fruit distilled water extract under XRD imaging system.

Sample-2



Sample-2

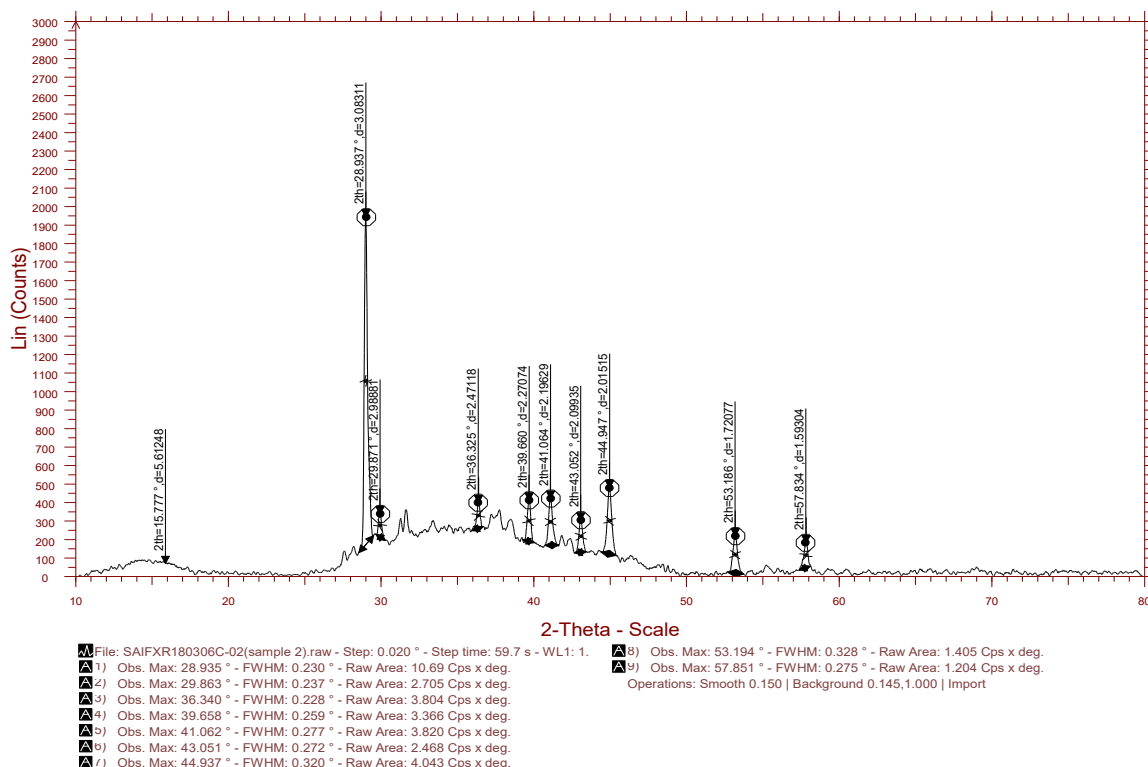


Figure.39 Zinc nanoparticle formation of (Sundari) dry fruit methanol extract under XRD imaging system.

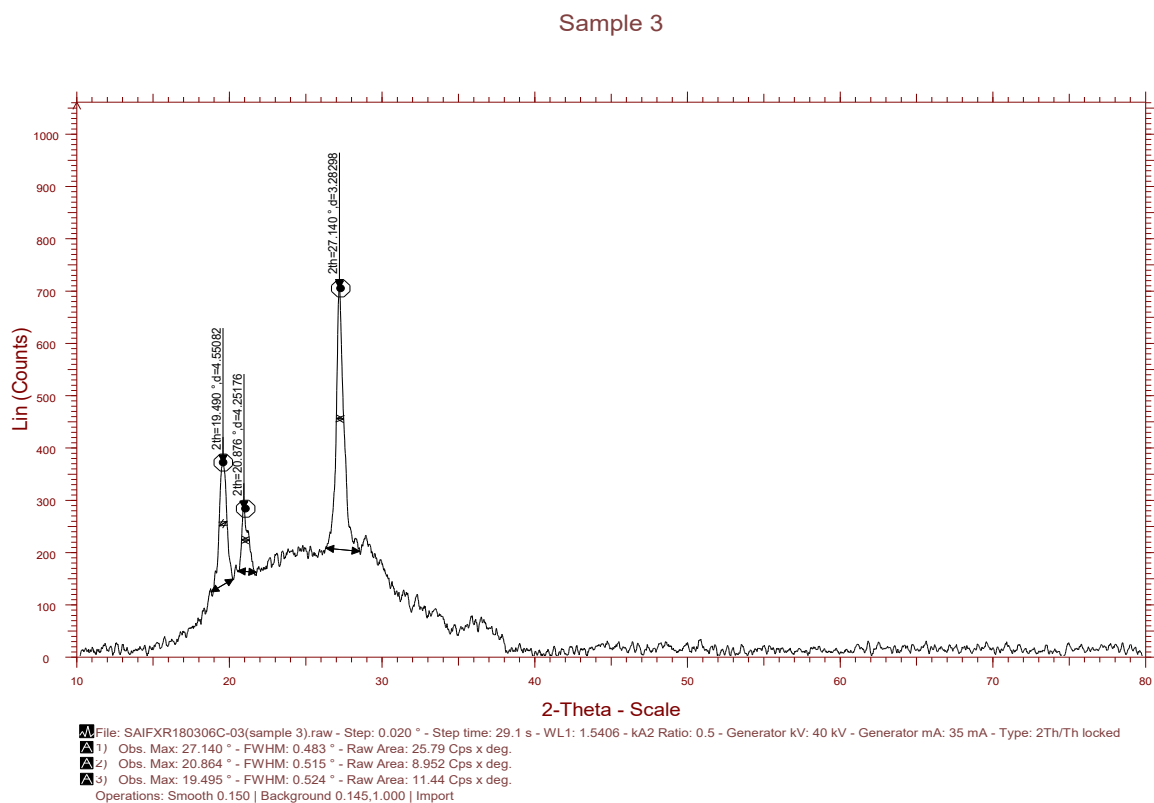
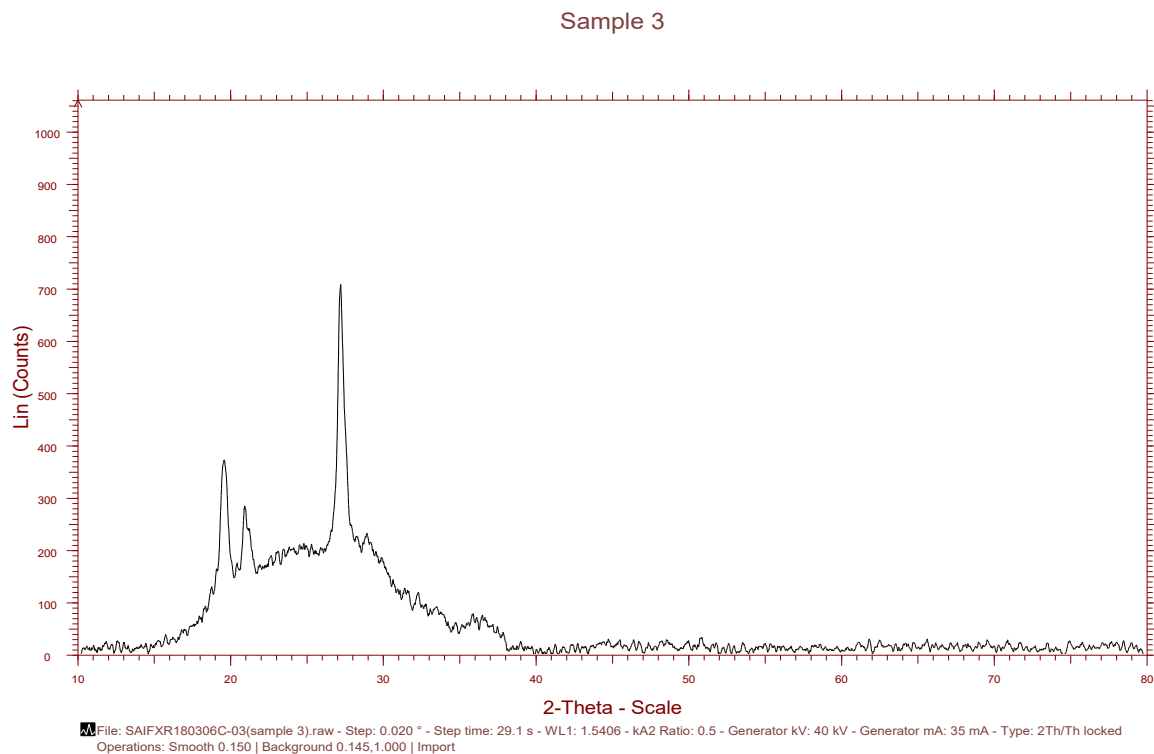


Table.1 Different vernacular names of *Musa paradisiaca* around the globe and India.

Language	Names
Scientific names	<i>Musa paradisiaca</i>
Name in various global languages	
French	Bananier
German	Banane
English	Banana
Name in various Indian languages	
Sanskrit	Kadali
Hindi	Kela
Urdu	Bonana
Marathi	Kela
Kannada	Baale
Gujarati	Kelphool
Malayalam	Vazha
Tamil	Vazhai

Table.2 Classification of edible bananas.

Genomic group	Score	References
AA diploid	15-23	Simmonds and Shepherd (1955); Stover and Simmonds (1987)
AAA triploid	15-23	
AAB triploid	24-46	
AB diploid	49	
ABB triploid	59-63	
ABBB tetraploid	67	Silayoi and Chomchalow (1987)
AA/AAA	15-25	
AAB	26-46	
ABB	59-63	
ABBB	67-69	
BB/BBB	70-75	

Table.3 Important banana varieties cultivated in different states of India.

State	Varieties grown
Andhra Pradesh	Dwarf Cavendish, Robusta, Rasthali, Amritpant, Thellachakrakeli, Karpooora Poovan, Chakrakeli, Monthan and Yenagu Bontha
Assam	Jahaji (Dwarf Cavendish), Chini Champa, Malbhog, Borjahaji (Robusta), Honda, Manjahaji, Chinia (Manohar), Kanchkol, Bhimkol, Jatikol, Digjowa, Kulpait, Bharat Moni
Bihar	Dwarf Cavendish, Alpon, Chinia, Chini Champa, Malbhig, Muthia, Kothia, Gauria
Gujarat	Dwarf Cavendish, Lacatan, Harichal (Lokhandi), Gandeve Selection, Basrai, Robusta, G-9, Harichal, Shrimati
Jharkhand	Basrai, Singapuri
Karnataka	Dwarf Cavendish, Robusta, Rasthali, Poovan, Monthan, Elakkibale
Kerala	Nendran (Plantain), Palayankodan (Poovan), Rasthali, Monthan, Red Banana, Robusta
Madhya Pradesh	Basrai
Maharashtra	Dwarf Cavendish, Basrai, Robusta, Lal Velchi, Safed Velchi, Rajeli Nendran, Grand Naine, Shreemanti, Red Banana
Orissa	Dwarf Cavendish, Robusta, Champa, Patkapura (Rasthali)
Tamil Nadu	Virupakshi, Robusta, Rad Banana, Poovan, Rasthali, Nendran, Monthan, Karpuravalli, Sakkai, Peyan, Matti
West Bengal	Champa, Mortman, Dwarf Cavendish, Giant Governor, Kanthali, Singapuri

Table.4 Zone of inhibition (24 hrs) against *Fusarium oxysporum* cubense by the distilled water extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in distilled water.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	-	-	-	0.9	1	1.2
	Zinc	0.1	0.4	0.6	-	-	-	0.1	0.7	1.5
Palenkodan	Copper	0.3	0.5	0.7	-	-	-	0.8	1	2
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.3	0.4
Kanan	Copper	0.3	0.5	0.7	-	-	-	0.3	0.8	1.1
	Zinc	0.1	0.4	0.6	-	-	-	0.1	0.2	0.6
Poovan	Copper	0.3	0.5	0.7	-	-	-	0.6	1	1.2
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.5	0.7
Njali poovan	Copper	0.3	0.5	0.7	0.1	0.2	0.3	0.8	1	1.1
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.5	0.7
Ethavaza	Copper	0.3	0.5	0.7	-	-	-	0.6	1.2	1.6
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.5	0.6
Pachakadali	Copper	0.3	0.5	0.7	-	-	-	0.4	1.1	1.3
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.4	0.7

Table.5 Zone of inhibition (24 hrs) against *Fusarium oxysporum* cubense by the methanol extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in methanol.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.1	0.2	1,4	0.2	0.7	0.9
	Zinc	0.1	0.4	0.6	0.1	0.2	1,4	0.3	0.6	0.8
Palenkodan	Copper	0.3	0.5	0.7	0.1	0.2	0.3	0.2	0.7	1
	Zinc	0.1	0.4	0.6	0.1	0.2	0.3	0.4	0.7	1.3
Kanan	Copper	0.3	0.5	0.7	0.4	0.7	1	0.4	0.6	1.3
	Zinc	0.1	0.4	0.6	0.4	0.7	1	0.5	0.8	1
Poovan	Copper	0.3	0.5	0.7	0.1	0.3	0.3	0.4	0.6	1.4
	Zinc	0.1	0.4	0.6	0.1	0.3	0.3	0.2	0.6	0.9
Njali poovan	Copper	0.3	0.5	0.7	0.4	0.1	0.9	0.1	0.3	0.6
	Zinc	0.1	0.4	0.6	0.4	0.1	0.9	0.4	0.6	0.8
Ethavaza	Copper	0.3	0.5	0.7	0.0	0.0	0.5	0.2	0.4	0.9
	Zinc	0.1	0.4	0.6	0.0	0.0	0.5	0.5	0.8	1
Pachakadali	Copper	0.3	0.5	0.7	0.1	0.3	0.9	0.2	0.3	0.6
	Zinc	0.1	0.4	0.6	0.1	0.3	0.9	0.2	0.7	1.1

Table.6 Zone of inhibition (24 hrs) against *Fusarium oxysporum* cubense by the isopropanol extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in isopropanol.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.0	0.2	0.5	0.3	0.8	1.1
	Zinc	0.1	0.4	0.6	0.0	0.2	0.5	0.3	0.5	0.8
Palenkodan	Copper	0.3	0.5	0.7	0.1	0.3	1	0.2	0.2	0.9
	Zinc	0.1	0.4	0.6	0.1	0.3	1	0.4	0.5	0.4
Kanan	Copper	0.3	0.5	0.7	0.1	0.2	1	0.2	0.6	1
	Zinc	0.1	0.4	0.6	0.1	0.2	1	0.3	0.4	0.5
Poovan	Copper	0.3	0.5	0.7	0.3	0.5	0.5	0.6	0.7	1.2
	Zinc	0.1	0.4	0.6	0.3	0.5	0.5	0.3	0.5	0.8
Njali poovan	Copper	0.3	0.5	0.7	0.1	0.3	0.5	0.2	0.6	1
	Zinc	0.1	0.4	0.6	0.1	0.3	0.5	0.4	0.5	0.4
Ethavaza	Copper	0.3	0.5	0.7	0.3	0.7	0.6	0.1	0.6	1
	Zinc	0.1	0.4	0.6	0.3	0.7	0.6	0.4	0.2	0.5
Pachakadali	Copper	0.3	0.5	0.7	0.1	1	2	0.1	0.2	0.8
	Zinc	0.1	0.4	0.6	0.1	1	2	0.2	0.4	0.6

Table.7 Zone of inhibition (24 hrs) against *Fusarium oxysporum* cubense by the acetone extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in acetone.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.0	0.1	0.2	0.9	1	1.3
	Zinc	0.1	0.4	0.6	0.0	0.1	0.2	0.2	0.6	0.9
Palenkodan	Copper	0.3	0.5	0.7	0.2	0.6	0.9	0.4	1.1	1.7
	Zinc	0.1	0.4	0.6	0.2	0.6	0.9	0.2	0.6	0.8
Kanan	Copper	0.3	0.5	0.7	-	-	1.1	0.8	1.1	1.2
	Zinc	0.1	0.4	0.6	-	-	1.1	0.4	1	0.6
Poovan	Copper	0.3	0.5	0.7	-	-	-	0.7	0.9	1
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.6	0.7
Njali poovan	Copper	0.3	0.5	0.7	-	-	-	0.5	1	1.2
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.6	0.8
Ethavaza	Copper	0.3	0.5	0.7	-	-	-	0.6	0.9	1
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.5	0.7
Pachakadali	Copper	0.3	0.5	0.7	0.2	0.3	0.4	0.5	0.9	1.1
	Zinc	0.1	0.4	0.6	0.2	0.3	0.4	0.3	0.6	1.2

Table.8 Zone of inhibition (24 hrs) against *Fusarium oxysporum* cubense by the ethanol extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in ethanol.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.2	0.7	1.2	1	0.4	0.9
	Zinc	0.1	0.4	0.6	0.2	0.7	1.2	0.2	0.4	0.6
Palenkodan	Copper	0.3	0.5	0.7	0.2	1.2	1.5	0.3	0.9	1
	Zinc	0.1	0.4	0.6	0.2	1.2	1.5	0.4	0.5	0.7
Kanan	Copper	0.3	0.5	0.7	0.1	0.6	1.2	0.1	0.3	1
	Zinc	0.1	0.4	0.6	0.1	0.6	1.2	0.4	0.6	0.8
Poovan	Copper	0.3	0.5	0.7	1.1	0.3	1.4	0.4	0.5	0.8
	Zinc	0.1	0.4	0.6	1.1	0.3	1.4	0.2	0.4	0.7
Njali poovan	Copper	0.3	0.5	0.7	0.1	2	2	0.3	0.9	0.9
	Zinc	0.1	0.4	0.6	0.1	2	2	0.3	0.5	0.7
Ethavaza	Copper	0.3	0.5	0.7	0.1	1.1	2	0.3	0.7	0.9
	Zinc	0.1	0.4	0.6	0.1	1.1	2	0.3	0.4	0.6
Pachakadali	Copper	0.3	0.5	0.7	0.3	1.2	1.3	0.3	0.6	1
	Zinc	0.1	0.4	0.6	0.3	1.2	1.3	0.3	0.5	0.7

Table.9 Zone of inhibition (48 hrs) against *Fusarium oxysporum* cubense by the distilled water extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in distilled water.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	-	-	-	0.9	1.1	1.2
	Zinc	0.1	0.4	0.6	-	-	-	0.1	0.7	1.5
Palenkodan	Copper	0.3	0.5	0.7	-	-	-	0.7	0.9	1.9
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.4	0.9
Kanan	Copper	0.3	0.5	0.7	-	-	-	0.3	0.8	1.1
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.7	0.9
Poovan	Copper	0.3	0.5	0.7	-	-	-	0.6	0.9	1
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.5	0.7
Njali poovan	Copper	0.3	0.5	0.7	0.1	0.2	0.3	0.9	1	1.1
	Zinc	0.1	0.4	0.6	-	-	-	0.7	0.5	0.7
Ethavaza	Copper	0.3	0.5	0.7	-	-	-	0.6	1.2	1.6
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.4	0.6
Pachakadali	Copper	0.3	0.5	0.7	-	-	-	0.4	1	1.1
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.4	0.7

Table.10 Zone of inhibition (48 hrs) against *Fusarium oxysporum* cubense by the methanol extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in methanol.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.1	0.2	1,4	0.2	0.7	0.9
	Zinc	0.1	0.4	0.6	0.1	0.2	1,4	0.4	0.6	0.8
Palenkodan	Copper	0.3	0.5	0.7	0.1	0.2	0.3	0.2	0.7	1
	Zinc	0.1	0.4	0.6	0.1	0.2	0.3	0.6	0.7	1.3
Kanan	Copper	0.3	0.5	0.7	0.4	0.7	1	0.4	0.6	1.3
	Zinc	0.1	0.4	0.6	0.4	0.7	1	0.6	0.9	1
Poovan	Copper	0.3	0.5	0.7	0.1	0.3	0.3	0.4	0.6	1.4
	Zinc	0.1	0.4	0.6	0.1	0.3	0.3	0.3	0.6	0.9
Njali poovan	Copper	0.3	0.5	0.7	0.4	0.1	0.9	0.1	0.3	0.6
	Zinc	0.1	0.4	0.6	0.4	0.1	0.9	0.4	0.6	0.8
Ethavaza	Copper	0.3	0.5	0.7	0.0	0.0	0.5	0.3	0.4	0.9
	Zinc	0.1	0.4	0.6	0.0	0.0	0.5	0.5	0.8	1
Pachakadali	Copper	0.3	0.5	0.7	0.1	0.3	0.9	0.2	0.3	0.6
	Zinc	0.1	0.4	0.6	0.1	0.3	0.9	0.6	0.7	1.1

Table.11 Zone of inhibition (48 hrs) against *Fusarium oxysporum* cubense by the isopropanol extract (50, 100 and 150 μ l) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in isopropanol.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.0	0.2	0.5	0.5	0.9	1.1
	Zinc	0.1	0.4	0.6	0.0	0.2	0.5	0.4	0.5	0.8
Palenkodan	Copper	0.3	0.5	0.7	0.1	0.3	1	0.2	0.4	0.9
	Zinc	0.1	0.4	0.6	0.1	0.3	1	0.4	0.5	0.4
Kanan	Copper	0.3	0.5	0.7	0.1	0.2	1	0.2	0.6	1
	Zinc	0.1	0.4	0.6	0.1	0.2	1	0.3	0.4	0.5
Poovan	Copper	0.3	0.5	0.7	0.3	0.5	0.5	0.7	0.9	1.2
	Zinc	0.1	0.4	0.6	0.3	0.5	0.5	0.3	0.5	0.8
Njali poovan	Copper	0.3	0.5	0.7	0.1	0.3	0.5	0.2	0.6	1.1
	Zinc	0.1	0.4	0.6	0.1	0.3	0.5	0.4	0.5	0.4
Ethavaza	Copper	0.3	0.5	0.7	0.3	0.7	0.6	0.1	0.6	1
	Zinc	0.1	0.4	0.6	0.3	0.7	0.6	0.1	0.2	0.5
Pachakadali	Copper	0.3	0.5	0.7	0.1	1	2	0.1	0.2	0.8
	Zinc	0.1	0.4	0.6	0.1	1	2	0.2	0.4	0.6

Table.12 Zone of inhibition (48 hrs) against *Fusarium oxysporum* cubense by the acetone extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in acetone.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.0	0.1	0.2	0.8	1.1	1.1
	Zinc	0.1	0.4	0.6	0.0	0.1	0.2	0.2	0.6	0.9
Palenkodan	Copper	0.3	0.5	0.7	0.2	0.6	0.9	0.4	1.1	1.7
	Zinc	0.1	0.4	0.6	0.2	0.6	0.9	0.2	0.6	0.8
Kanan	Copper	0.3	0.5	0.7	-	-	1.1	0.8	1.1	1.2
	Zinc	0.1	0.4	0.6	-	-	1.1	0.4	1	0.6
Poovan	Copper	0.3	0.5	0.7	-	-	-	0.7	0.9	1.1
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.6	0,7
Njali poovan	Copper	0.3	0.5	0.7	-	-	-	0.5	1	1.2
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.5	0.8
Ethavaza	Copper	0.3	0.5	0.7	-	-	-	0.6	0.9	1
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.5	0.7
Pachakadali	Copper	0.3	0.5	0.7	0.2	0.3	0.4	0.5	0.9	1.1
	Zinc	0.1	0.4	0.6	0.2	0.3	0.4	0.3	0.6	1.2

Table.13 Zone of inhibition (48 hrs) against *Fusarium oxysporum* cubense by the ethanol extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in ethanol.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.2	0.7	1.2	1.1	0.6	1
	Zinc	0.1	0.4	0.6	0.2	0.7	1.2	0.3	0.6	0.8
Palenkodan	Copper	0.3	0.5	0.7	0.2	1.2	1.5	0.3	0.9	1
	Zinc	0.1	0.4	0.6	0.2	1.2	1.5	0.4	0.5	0.7
Kanan	Copper	0.3	0.5	0.7	0.1	0.6	1.2	0.2	0.6	1
	Zinc	0.1	0.4	0.6	0.1	0.6	1.2	0.4	0.6	0.8
Poovan	Copper	0.3	0.5	0.7	1.1	0.3	1.4	0.4	0.5	0.8
	Zinc	0.1	0.4	0.6	1.1	0.3	1.4	0.2	0.4	0.7
Njali poovan	Copper	0.3	0.5	0.7	0.1	2	2	0.3	0.9	0.9
	Zinc	0.1	0.4	0.6	0.1	2	2	0.3	0.5	0.7
Ethavaza	Copper	0.3	0.5	0.7	0.1	1.1	2	0.3	0.7	0.9
	Zinc	0.1	0.4	0.6	0.1	1.1	2	0.3	0.4	0.6
Pachakadali	Copper	0.3	0.5	0.7	0.3	1.2	1.3	0.3	0.6	1
	Zinc	0.1	0.4	0.6	0.3	1.2	1.3	0.3	0.5	0.7

Table.14 Zone of inhibition (72 hrs) against *Fusarium oxysporum* cubense by the distilled water extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in distilled water.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	-	-	-	1	1.1	1.3
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.6	1.4
Palenkodan	Copper	0.3	0.5	0.7	-	-	-	0.9	1.1	1.8
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.6	0.6
Kanan	Copper	0.3	0.5	0.7	-	-	-	0.4	0.9	1.1
	Zinc	0.1	0.4	0.6	-	-	-	0.3	0.4	0.9
Poovan	Copper	0.3	0.5	0.7	-	-	-	0.6	1	1.2
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.5	0.7
Njali poovan	Copper	0.3	0.5	0.7	0.1	0.2	0.3	0.9	1	1.1
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.7	0.9
Ethavaza	Copper	0.3	0.5	0.7	-	-	-	0.9	1.2	1.6
	Zinc	0.1	0.4	0.6	-	-	-	0.2	0.5	0.6
Pachakadali	Copper	0.3	0.5	0.7	-	-	-	0.8	1.1	1.3
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.6	0.9

Table.15 Zone of inhibition (72 hrs) against *Fusarium oxysporum* cubense by the methanol extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in methanol.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.1	0.2	1,4	0.3	0.8	1
	Zinc	0.1	0.4	0.6	0.1	0.2	1,4	0.3	0.5	0.7
Palenkodan	Copper	0.3	0.5	0.7	0.1	0.2	0.3	0.2	0.6	0.8
	Zinc	0.1	0.4	0.6	0.1	0.2	0.3	0.4	0.7	1.3
Kanan	Copper	0.3	0.5	0.7	0.4	0.7	1	0.5	0.8	1.3
	Zinc	0.1	0.4	0.6	0.4	0.7	1	0.5	0.8	1
Poovan	Copper	0.3	0.5	0.7	0.1	0.3	0.3	0.5	0.8	1.4
	Zinc	0.1	0.4	0.6	0.1	0.3	0.3	0.2	0.7	1
Njali poovan	Copper	0.3	0.5	0.7	0.4	0.1	0.9	0.2	0.4	0.6
	Zinc	0.1	0.4	0.6	0.4	0.1	0.9	0.4	0.6	0.8
Ethavaza	Copper	0.3	0.5	0.7	0.0	0.0	0.5	0.2	0.4	1
	Zinc	0.1	0.4	0.6	0.0	0.0	0.5	0.4	0.9	1.1
Pachakadali	Copper	0.3	0.5	0.7	0.1	0.3	0.9	0.2	0.3	0.6
	Zinc	0.1	0.4	0.6	0.1	0.3	0.9	0.2	0.7	1.1

Table.16 Zone of inhibition (72 hrs) against *Fusarium oxysporum* cubense by the isopropanol extract (50, 100 and 150 μ l) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in isopropanol.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.0	0.2	0.5	0.4	0.9	1.1
	Zinc	0.1	0.4	0.6	0.0	0.2	0.5	0.4	0.6	0.9
Palenkodan	Copper	0.3	0.5	0.7	0.1	0.3	1	0.1	0.1	0.8
	Zinc	0.1	0.4	0.6	0.1	0.3	1	0.3	0.3	0.4
Kanan	Copper	0.3	0.5	0.7	0.1	0.2	1	0.2	0.6	1
	Zinc	0.1	0.4	0.6	0.1	0.2	1	0.3	0.4	0.5
Poovan	Copper	0.3	0.5	0.7	0.3	0.5	0.5	0.6	0.7	1.2
	Zinc	0.1	0.4	0.6	0.3	0.5	0.5	0.3	0.5	0.8
Njali poovan	Copper	0.3	0.5	0.7	0.1	0.3	0.5	0.2	0.6	1
	Zinc	0.1	0.4	0.6	0.1	0.3	0.5	0.4	0.5	0.4
Ethavaza	Copper	0.3	0.5	0.7	0.3	0.7	0.6	0.1	0.6	1
	Zinc	0.1	0.4	0.6	0.3	0.7	0.6	0.4	0.2	0.5
Pachakadali	Copper	0.3	0.5	0.7	0.1	1	2	0.1	0.2	0.8
	Zinc	0.1	0.4	0.6	0.1	1	2	0.2	0.7	0.9

Table.17 Zone of inhibition (72 hrs) against *Fusarium oxysporum* cubense by the acetone extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in acetone.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.0	0.1	0.2	0.9	1	1.3
	Zinc	0.1	0.4	0.6	0.0	0.1	0.2	0.2	0.6	0.9
Palenkodan	Copper	0.3	0.5	0.7	0.2	0.6	0.9	0.4	1.1	1.7
	Zinc	0.1	0.4	0.6	0.2	0.6	0.9	0.2	0.6	0.8
Kanan	Copper	0.3	0.5	0.7	-	-	1.1	0.8	1.1	1.2
	Zinc	0.1	0.4	0.6	-	-	1.1	0.4	1	0.6
Poovan	Copper	0.3	0.5	0.7	-	-	-	0.7	0.9	1
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.6	0,7
Njali poovan	Copper	0.3	0.5	0.7	-	-	-	0.5	1	1.2
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.6	0.8
Ethavaza	Copper	0.3	0.5	0.7	-	-	-	0.6	0.9	1
	Zinc	0.1	0.4	0.6	-	-	-	0.4	0.5	0.7
Pachakadali	Copper	0.3	0.5	0.7	0.2	0.3	0.4	0.5	0.9	1.1
	Zinc	0.1	0.4	0.6	0.2	0.3	0.4	0.3	0.6	1.2

Table.18 Zone of inhibition (72 hrs) against *Fusarium oxysporum* cubense by the ethanol extract (50, 100 and 150 µl) of various plant leaves (Sundari, Palenkodan, Kanan, Poovan, Nanjali poovan, Ethavazha, Pachakadali). Control; CuSO₄ and ZnSO₄ solution, Sample; dry fruit extract in ethanol.

Banana variety	Nanoparticles	Control			Sample			Test		
		Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)			Measure of zone of inhibition (cm)		
		50	100	150	50	100	150	50	100	150
Sundari	Copper	0.3	0.5	0.7	0.2	0.7	1.2	1	0.4	0.9
	Zinc	0.1	0.4	0.6	0.2	0.7	1.2	0.2	0.4	0.6
Palenkodan	Copper	0.3	0.5	0.7	0.2	1.2	1.5	0.3	0.9	1
	Zinc	0.1	0.4	0.6	0.2	1.2	1.5	0.4	0.5	0.7
Kanan	Copper	0.3	0.5	0.7	0.1	0.6	1.2	0.1	0.3	1
	Zinc	0.1	0.4	0.6	0.1	0.6	1.2	0.4	0.6	0.8
Poovan	Copper	0.3	0.5	0.7	1.1	0.3	1.4	0.4	0.5	0.8
	Zinc	0.1	0.4	0.6	1.1	0.3	1.4	0.2	0.4	0.7
Njali poovan	Copper	0.3	0.5	0.7	0.1	2	2	0.3	0.9	0.9
	Zinc	0.1	0.4	0.6	0.1	2	2	0.3	0.5	0.7
Ethavaza	Copper	0.3	0.5	0.7	0.1	1.1	2	0.3	0.7	0.9
	Zinc	0.1	0.4	0.6	0.1	1.1	2	0.3	0.4	0.6
Pachakadali	Copper	0.3	0.5	0.7	0.3	1.2	1.3	0.3	0.6	1
	Zinc	0.1	0.4	0.6	0.3	1.2	1.3	0.3	0.5	0.7

Table.19 Zone of inhibition against *Fusarium oxysporum* cubense by the various solvents (Distilled water, Propanol, Hexane, Acetone, Methanol) in 50, 100 and 150 µl volume during 24, 48 and 72 hrs of incubation period.

No	Control solvents	Measure of zone of inhibition (cm), 24 hrs			Measure of zone of inhibition (cm), 48 hrs			Measure of zone of inhibition (cm), 72 hrs		
		50	100	150	50	100	150	50	100	150
1	Distilled water	-	-	-	-	-	-	-	-	-
2	Propanol	1.7	-	2.1	1.3	-	2	-	-	1.5
3	Hexane	1.6	-	-	-	-	-	-	-	-
4	Acetone	-	-	1.7	-	-	1.5	-	-	1.4
5	Methanol	1.4	1.5	1.7	-	-	1.5	-	-	1.3

Table.20 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from distilled water extract (dry fruit) of Sundari banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.958	1.131	0.593	0.076	0.258	0.275
1 hr	0.800	1.119	0.560	0.087	0.218	0.265
1 ½ hr	0.850	0.906	0.524	0.112	0.174	0.246
2 hr	0.910	0.890	0.560	0.100	0.180	0.256
2 ½ hr	0.950	0.860	0.579	0.092	0.222	0.266

Table.21 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from methanol extract (dry fruit) of Sundari banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	1.192	0.758	0.279	0.024	0.127	0.344
1 hr	1.329	0.729	0.380	0.034	0.180	0.354
1 ½ hr	1.469	0.713	0.579	0.050	0.253	0.361
2 hr	1.443	0.709	0.545	0.061	0.223	0.369
2 ½ hr	1.412	0.701	0.534	0.074	0.233	0.372

Table.22 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from isopropanol extract (dry fruit) of Sundari banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.552	0.732	0.265	0.042	0.092	0.357
1 hr	0.530	0.720	0.245	0.049	0.094	0.360
1 ½ hr	0.514	0.707	0.241	0.051	0.096	0.367
2 hr	0.490	0.678	0.235	0.059	0.105	0.380
2 ½ hr	0.475	0.650	0.221	0.063	0.110	0.401

Table.23 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from acetone extract (dry fruit) of Sundari banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.756	1.103	0.480	1.109	0.112	1.210
1 hr	0.700	1.080	0.450	1.098	0.100	1.105
1 ½ hr	0.677	0.880	0.409	0.880	0.080	0.892
2 hr	0.620	0.679	0.389	0.779	0.050	0.860
2 ½ hr	0.609	0.820	0.360	0.578	0.047	0.830

Table.24 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from ethanol extract (dry fruit) of Sundari banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.539	0.886	0.234	0.109	0.120	0.267
1 hr	0.520	0.860	0.234	0.111	0.112	0.250
1 ½ hr	0.513	0.856	0.236	0.112	0.107	0.224
2 hr	0.490	0.810	0.230	0.130	0.105	0.212
2 ½ hr	0.478	0.790	0.229	0.152	0.103	0.185

Table.25 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from distilled water extract (dry fruit) of Palenkodan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	1.031	1.062	0.649	0.326	0.271	0.232
1 hr	1.031	1.059	0.650	0.310	0.280	0.200
1 ½ hr	1.032	1.050	0.655	0.200	0.293	0.140
2 hr	1.020	1.049	0.876	0.213	0.280	0.190
2 ½ hr	1.009	1.048	0.984	0.228	0.273	0.213

Table.26 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from methanol extract (dry fruit) of Palenkodan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.949	0.840	0.624	0.041	0.276	0.312
1 hr	0.952	0.811	0.634	0.012	0.282	0.326
1 ½ hr	0.956	0.796	0.644	0.002	0.289	0.331
2 hr	0.958	0.756	0.601	0.034	0.285	0.349
2 ½ hr	0.960	0.744	0.594	0.045	0.282	0.362

Table.27 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from isopropanol extract (dry fruit) of Palenkodan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.504	0.706	0.219	0.056	0.127	0.395
1 hr	0.489	0.650	0.211	0.063	0.126	0.401
1 ½ hr	0.470	0.564	0.209	0.072	0.124	0.406
2 hr	0.453	0.510	0.199	0.111	0.126	0.444
2 ½ hr	0.449	0.454	0.192	0.120	0.129	0.460

Table.28 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from acetone extract (dry fruit) of Palenkodan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.948	0.706	0.653	0.056	0.287	0.395
1 hr	0.900	0.650	0.555	0.063	0.256	0.401
1 ½ hr	0.839	0.564	0.559	0.072	0.224	0.406
2 hr	0.789	0.510	0.498	0.111	0.653	0.444
2 ½ hr	0.733	0.454	0.483	0.120	0.735	0.460

Table.29 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from ethanol extract (dry fruit) of Palenkodan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.665	0.960	0.362	0.172	0.005	0.220
1 hr	0.630	0.945	0.345	0.156	0.003	0.234
1 ½ hr	0.615	0.935	0.335	0.121	0.002	0.249
2 hr	0.500	0.937	0.320	0.100	0.005	0.280
2 ½ hr	0.556	0.940	0.308	0.087	0.007	0.310

Table.30 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from distilled water extract (dry fruit) of Kannan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.594	0.400	0.340	0.347	0.013	0.608
1 hr	0.530	0.410	0.342	0.336	0.013	0.598
1 ½ hr	0.611	0.423	0.344	0.332	0.013	0.589
2 hr	0.611	0.423	0.349	0.329	0.023	0.588
2 ½ hr	0.609	0.424	0.351	0.321	0.023	0.586

Table.31 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from methanol extract (dry fruit) of Kannan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.928	0.802	0.592	0.017	0.251	0.308
1 hr	0.930	0.790	0.430	0.018	0.255	0.316
1 ½ hr	0.911	0.765	0.182	0.020	0.259	0.326
2 hr	0.860	0.730	0.367	0.029	0.263	0.389
2 ½ hr	0.871	0.718	0.587	0.035	0.264	0.405

Table.32 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from isopropanol extract (dry fruit) of Kannan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.604	0.779	0.323	0.011	0.029	0.328
1 hr	0.590	0.759	0.210	0.009	0.036	0.333
1 ½ hr	0.544	0.742	0.285	0.008	0.045	0.343
2 hr	0.530	0.730	0.260	0.006	0.059	0.390
2 ½ hr	0.505	0.710	0.256	0.002	0.062	0.405

Table.33 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from acetone extract (dry fruit) of Kannan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	1.895	0.802	1.553	0.017	1.318	0.308
1 hr	1.760	0.790	1.490	0.018	1.213	0.316
1 ½ hr	1.561	0.765	1.304	0.020	1.087	0.326
2 hr	1.456	0.730	1.235	0.029	1.123	0.389
2 ½ hr	1.301	0.718	1.061	0.035	1.172	0.405

Table.34 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from ethanol extract (dry fruit) of Kannan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.634	0.919	0.345	0.156	0.007	0.203
1 hr	0.610	0.890	0.333	0.110	0.012	0.234
1 ½ hr	0.590	0.837	0.322	0.064	0.017	0.273
2 hr	0.550	0.768	0.310	0.055	0.009	0.290
2 ½ hr	0.527	0.650	0.295	0.042	0.002	0.310

Table.35 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from distilled water extract (dry fruit) of Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.637	0.423	0.362	0.336	0.031	0.607
1 hr	0.642	0.430	0.364	0.330	0.035	0.600
1 ½ hr	0.649	0.436	0.366	0.320	0.038	0.598
2 hr	0.650	0.436	0.367	0.322	0.038	0.600
2 ½ hr	0.651	0.435	0.368	0.324	0.038	0.601

Table.36 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from distilled water extract (dry fruit) of Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.727	0.741	0.448	0.043	0.132	0.360
1 hr	0.732	0.710	0.448	0.098	0.139	0.400
1 ½ hr	0.739	0.616	0.449	0.123	0.143	0.414
2 hr	0.742	0.690	0.452	0.111	0.144	0.400
2 ½ hr	0.746	0.757	0.455	0.059	0.145	0.360

Table.37 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from methanol extract (dry fruit) of Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	1.133	1.003	0.770	0.162	0.399	0.233
1 hr	1.090	0.910	0.750	0.112	0.390	0.259
1 ½ hr	1.042	0.888	0.723	0.081	0.389	0.270
2 hr	0.650	0.871	0.700	0.061	0.385	0.291
2 ½ hr	0.388	0.858	0.686	0.040	0.380	0.302

Table.38 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from isopropanol extract (dry fruit) of Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.587	0.803	0.283	0.025	0.059	0.309
1 hr	0.555	0.782	0.273	0.020	0.069	0.316
1 ½ hr	0.536	0.746	0.264	0.019	0.073	0.325
2 hr	0.510	0.731	0.250	0.012	0.076	0.340
2 ½ hr	0.494	0.720	0.246	0.010	0.081	0.360

Table.39 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from acetone extract (dry fruit) of Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.824	1.003	0.522	0.162	0.164	0.233
1 hr	0.800	0.910	0.590	0.112	0.130	0.259
1 ½ hr	0.722	0.888	0.442	0.081	0.115	0.270
2 hr	0.701	0.871	0.430	0.061	0.110	0.291
2 ½ hr	0.665	0.858	0.410	0.040	0.090	0.302

Table.40 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from ethanol extract (dry fruit) of Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.695	1.032	0.388	0.254	0.010	0.129
1 hr	0.653	0.981	0.371	0.200	0.008	0.147
1 ½ hr	0.632	0.935	0.356	0.171	0.005	0.174
2 hr	0.610	0.912	0.321	0.151	0.003	0.190
2 ½ hr	0.590	0.903	0.320	0.132	0.002	0.208

Table.41 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from distilled water extract (dry fruit) of Najali Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.904	0.963	0.553	0.125	0.218	0.270
1 hr	0.906	0.961	0.556	0.128	0.190	0.284
1 ½ hr	0.910	0.960	0.560	0.130	0.168	0.295
2 hr	0.900	0.950	0.554	0.122	0.176	0.295
2 ½ hr	0.897	0.945	0.538	0.103	0.184	0.296

Table.42 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from methanol extract (dry fruit) of Najali Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.815	0.790	0.440	0.084	0.113	0.483
1 hr	0.817	0.781	0.443	0.090	0.117	0.500
1 ½ hr	0.819	0.776	0.445	0.093	0.120	0.502
2 hr	0.670	0.770	0.447	0.112	0.125	0.504
2 ½ hr	0.337	0.764	0.450	0.132	0.129	0.506

Table.43 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from methanol extract (dry fruit) of Najali Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.913	0.937	0.540	0.096	0.166	0.291
1 hr	0.918	0.900	0.546	0.052	0.170	0.300
1 ½ hr	0.920	0.844	0.554	0.049	0.176	0.305
2 hr	0.923	0.829	0.556	0.041	0.178	0.319
2 ½ hr	0.926	0.811	0.559	0.032	0.179	0.323

Table.44 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from isopropanol extract (dry fruit) of Najali Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.459	0.748	0.157	0.007	0.183	0.382
1 hr	0.444	0.740	0.160	0.011	0.180	0.381
1 ½ hr	0.437	0.735	0.162	0.015	0.176	0.380
2 hr	0.435	0.700	0.161	0.039	0.180	0.400
2 ½ hr	0.432	0.685	0.160	0.060	0.184	0.455

Table.45 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from acetone extract (dry fruit) of Najali Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.892	0.937	0.605	0.096	0.239	0.291
1 hr	0.810	0.900	0.539	0.052	0.200	0.300
1 ½ hr	0.757	0.844	0.503	0.049	0.167	0.305
2 hr	0.710	0.829	0.460	0.041	0.120	0.319
2 ½ hr	0.678	0.811	0.432	0.032	0.114	0.323

Table.46 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from ethanol extract (dry fruit) of Najali Poovan banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.609	0.885	0.292	0.100	0.071	0.290
1 hr	0.590	0.851	0.281	0.081	0.069	0.309
1 ½ hr	0.550	0.820	0.296	0.038	0.068	0.322
2 hr	0.490	0.800	0.221	0.035	0.059	0.351
2 ½ hr	0.460	0.790	0.190	0.030	0.049	0.390

Table.47 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from distilled water extract (dry fruit) of Ethavazha banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.981	0.941	0.587	0.108	0.205	0.309
1 hr	0.985	0.949	0.588	0.128	0.210	0.299
1 ½ hr	0.993	0.953	0.590	0.133	0.213	0.289
2 hr	0.995	0.960	0.592	0.123	0.216	0.290
2 ½ hr	0.997	0.965	0.595	0.119	0.220	0.293

Table.48 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from methanol extract (dry fruit) of Ethavazha banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.915	0.801	0.595	0.019	0.237	0.321
1 hr	0.960	0.780	0.597	0.058	0.240	0.349
1 ½ hr	0.992	0.717	0.598	0.061	0.244	0.355
2 hr	0.996	0.680	0.600	0.072	0.245	0.369
2 ½ hr	0.998	0.676	0.601	0.089	0.246	0.394

Table.49 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from isopropanol extract (dry fruit) of Ethavazha banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.514	0.762	0.199	0.006	0.141	0.368
1 hr	0.490	0.741	0.177	0.012	0.143	0.370
1 ½ hr	0.466	0.732	0.188	0.018	0.147	0.374
2 hr	0.454	0.700	0.180	0.032	0.148	0.390
2 ½ hr	0.441	0.687	0.172	0.050	0.151	0.401

Table.50 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from acetone extract (dry fruit) of Ethavazha banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.870	0.801	0.552	0.006	0.781	0.368
1 hr	0.865	0.780	0.582	0.012	0.539	0.370
1 ½ hr	0.843	0.717	0.609	0.018	0.312	0.374
2 hr	0.760	0.680	0.589	0.032	0.210	0.390
2 ½ hr	0.685	0.676	0.400	0.050	0.072	0.401

Table.51 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from ethanol extract (dry fruit) of Ethavazha banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	1.303	1.558	0.975	1.147	0.640	0.871
1 hr	1.221	1.480	0.910	1.091	0.600	0.790
1 ½ hr	1.115	1.307	0.834	0.992	0.530	0.733
2 hr	1.049	1.110	0.790	0.950	0.480	0.700
2 ½ hr	0.999	0.998	0.760	0.930	0.390	0.691

Table.52 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from distilled water extract (dry fruit) of Pachakadali banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.631	0.588	0.372	0.159	0.084	0.436
1 hr	0.639	0.600	0.390	0.131	0.086	0.421
1 ½ hr	0.643	0.685	0.409	0.106	0.089	0.405
2 hr	0.650	0.999	0.410	0.139	0.090	0.420
2 ½ hr	0.653	1.609	0.412	0.155	0.092	0.434

Table.53 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from methanol extract (dry fruit) of Pachakadali banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.992	1.039	0.638	0.191	0.282	0.201
1 hr	0.993	0.982	0.642	0.165	0.290	0.211
1 ½ hr	0.995	0.935	0.647	0.135	0.296	0.218
2 hr	0.997	0.900	0.650	0.121	0.298	0.230
2 ½ hr	0.999	0.891	0.652	0.103	0.300	0.248

Table.54 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from isopropanol extract (dry fruit) of Pachakadali banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.536	0.801	0.246	0.032	0.100	0.331
1 hr	0.512	0.791	0.236	0.021	0.102	0.349
1 ½ hr	0.498	0.765	0.229	0.010	0.103	0.354
2 hr	0.478	0.700	0.221	0.009	0.105	0.416
2 ½ hr	0.467	0.690	0.211	0.005	0.108	0.374

Table.55 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from acetone extract (dry fruit) of Pachakadali banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.839	1.039	0.535	0.191	0.178	0.201
1 hr	0.790	0.982	0.490	0.165	0.139	0.211
1 ½ hr	0.717	0.935	0.442	0.135	0.108	0.218
2 hr	0.565	0.900	0.400	0.121	0.089	0.230
2 ½ hr	0.637	0.891	0.370	0.103	0.043	0.248

Table.56 Description of UV absorption spectrum of Copper and Zinc nanoparticles formed from ethanol extract (dry fruit) of Pachakadali banana variety during different time of incubation.

	Copper	Zinc	Copper	Zinc	Copper	Zinc
Time	435nm	385nm	560nm	435nm	680nm	560nm
½ hr	0.651	0.918	0.341	0.152	0.015	0.219
1 hr	0.610	0.890	0.333	0.112	0.019	0.239
1 ½ hr	0.598	0.875	0.322	0.097	0.022	0.258
2 hr	0.552	0.852	0.300	0.090	0.030	0.261
2 ½ hr	0.520	0.820	0.279	0.086	0.039	0.272

The zone of inhibition showed by *Fusarium oxysporum* cubense by zinc nano particles formed by liquid sap and latex extracts in solvents distilled water, propane, acetone, ethanol in 50 micro litre solution in 1/50 dilution was 0.1, 0.1, 0.5, 0.4 cm respectively; from 100 micro litre solution in 1/50 dilution was 0.2, 0.4, 0.6, 0.7cm respectively; from 150 micro litre solution in 1/50 dilution was 0.6, 0.7, 1, 1cm respectively.

Sundari (B4) Musa acuminate Colla (AA)

The antifungal activity with both zinc and copper nanoparticles with the various solvents showed a similar range of inhibition. The propane and ethanol extracts had a greater result than compared to others.

The zone of inhibition showed by *Fusarium oxysporum* cubense by copper nano particles formed by dry extracts in propane, ethanol in 50 micro litre solution was 0.2, 0.4 cm respectively; from 100 micro litre solution was 0.5, 0.7 cm respectively; from 150 micro litre solution was 0.9, 1cm respectively.

The zone of inhibition showed by *Fusarium oxysporum* cubense by zinc nano particles formed by dry extracts in propane, ethanol in 50 micro litre solution was 0.2, 0.5 cm respectively; from 100 micro litre solution was 0.4, 0.6 cm respectively; from 150 micro litre solution was 0.9, 1 cm respectively.

Njalipoovan (B5) Musa acuminate Colla (AB)

With methanol, propane and acetone extracts the anti-fungal activity was more with both copper and zinc nanoparticles. Ethanol and methanol was the best solvent for this banana variety. The fresh extract of sap and latex showed the highest inhibitory action against *Fusarium oxysporum*.

The zone of inhibition showed by *Fusarium oxysporum* cubense by copper nano particles formed by liquid sap and latex extracts in solvents distilled water, ethanol, methanol in 50 micro litre solution in 1/50 dilution was 0.2, 0.5, 0.7 cm respectively; from 100 micro litre solution in 1/50 dilution was 0.5, 0.9, 1 cm respectively; from 150 micro litre solution in 1/50 dilution was 0.9, 1.1, 1.2 cm respectively.

The zone of inhibition showed by *Fusarium oxysporum* cubense by zinc nano particles formed by liquid sap and latex extracts in solvents distilled water, ethanol, methanol in 50 micro litre solution in 1/50 dilution was 0.2, 0.4, 0.6 cm respectively; from 100 micro litre solution in 1/50 dilution was 0.4, 0.8, 1 cm respectively; from 150 micro litre solution in 1/50 dilution was 0.8, 1, 1.2 cm respectively.

Palayamkudan (B6) Musa x paradisiaca (AAB)

The antifungal activity with both zinc and copper nanoparticles with the various solvents showed a similar range of inhibition. The fresh extract of sap and latex with 1/10 and 1/50 dilution showed the highest inhibitory action against *Fusarium oxysporum*.

The zone of inhibition showed by *Fusarium oxysporum* cubense by copper nano particles formed by liquid sap and latex extracts in solvents distilled water, propane, acetone, ethanol in 50 micro litre solution in 1/50 dilution was 0.3, 0.6, 0.7, 0.8 cm respectively; from 100 micro litre solution in 1/50 dilution was 0.5, 0.8, 0.9, 1 cm respectively; from 150 micro litre solution in 1/50 dilution was 0.9, 1.1, 1.1, 1.2 cm respectively.

The zone of inhibition showed by *Fusarium oxysporum* cubense by zinc nano particles formed by liquid sap and latex extracts in solvents distilled water, propane,

acetone, ethanol in 50 micro litre solution in 1/50 dilution was 0.3, 0.3, 0.6, 0.8 cm respectively; from 100 micro litre solution in 1/50 dilution was 0.4, 0.6, 0.7, 0.8cm respectively; from 150 micro litre solution in 1/50 dilution was 0.8, 0.9, 1, 1.2 cm respectively.

Kannan (B8) Musa acuminata Colla (AAA)

The antifungal activity with both zinc and copper nanoparticles with the various solvents showed a similar range of inhibition. The propane and ethanol extracts had a greater result than compared to others.

The zone of inhibition showed by *Fusarium oxysporum* cubense by copper nano particles formed by dry extracts in propane, ethanol in 50 micro litre solution in 1/50 dilution was 0.2, 0.4 cm respectively; from 100 micro litre solution in 1/50 dilution was 0.5, 0.6 cm respectively; from 150 micro litre solution in 1/50 dilution was 0.8, 0.9 cm respectively.

The zone of inhibition showed by *Fusarium oxysporum* cubense by zinc nano particles formed by dry extracts in propane, ethanol in 50 micro litre solution in 1/50 dilution was 0.2, 0.5 cm respectively; from 100 micro litre solution in 1/50 dilution was 0.4, 0.5cm respectively; from 150 micro litre solution in 1/50 dilution was 0.8, 0.9 cm respectively.

Pachakadali (B9) Musa acuminata Colla (AAA)

A similar result was obtained with propane and acetone extracts with Cu and Zn nanoparticles with the least inhibitory action shown by the hexane extract. The zone of inhibition showed by *Fusarium oxysporum* cubense by copper nano particles formed by dry extracts in propane, ethanol in 50 micro litre solution in 1/50 dilution was 0.3, 0.6 cm respectively; from 100 micro litre solution in 1/50 dilution was 0.6, 0.7cm respectively; from 150 micro litre solution in 1/50 dilution was 0.9, 0.9 cm respectively.

The zone of inhibition showed by *Fusarium oxysporum* cubense by zinc nano particles formed by dry fruit extracts in propane, ethanol in 50 micro litre solution in 1/50 dilution was 0.3, 0.5 cm respectively; from 100 micro litre solution in 1/50 dilution was 0.5, 0.6cm respectively; from 150 micro litre solution in 1/50 dilution was 0.9, 1 cm respectively.

In conclusion, the results shows that dry skin and fruit extracts of Palemkodan, Njalipoovan, Etha, Pachakadali

with solvents, propane, ethanol, methanol and acetone and the fresh extract latex and sap of Palemkodan and Poovan with solvents isopropanol, ethanol, methanol with 1/10 and 1/50 dilution are used for the synthesis of copper and zinc nanoparticles. Copper and zinc nanoparticle shows greater antifungal activity than copper sulphate and zinc sulphate, respectively and dry extract. The maximum zone of inhibition was at 50 and 100 µl for all the test plates. This indicates that the zone of inhibition increases with as the concentration of nanoparticles increased. An overall result showed that ethanol, methanol and isopropanol could be used as a good solvents and skin of Njalipoovan and Etha could be used for controlling the *Fusarium oxysporum cubense* under invitro conditions.

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