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Development of Controlled Release Systems in Plant Growth Regulators based on Cationic Polymers

Financiación

- Proyecto C.I. 71170 de la Universidad del Valle.
- Convocatoria 848 - Programa de Estancias Postdoctorales en Entidades del SNCTeI 2019 del Ministerio de Ciencia, Tecnología e Innovación (Minciencias).

PDF

Grupo de Investigación

Mindtech Research Group (Mindtech-RG)
Centro de Investigación y Desarrollo Mindtech
Mindtech s.a.s. (Montería/Barranquilla, Colombia)

Visitar Gruplac

Citación

Agudelo-Morales C.E., Lerma T.A., Martínez-Lara J.M., Mora-Guatapi M.A., Combatt E.M., Palencia M. Development of controlled release systems in plant growth regulators based on cationic polymers. Proyecto C.I. 71170, Mindtech s.a.s., Córdoba (Colombia). AFICAT (2021). Doi: 10.34294/aficat.21.08.003

Grupo de Investigación

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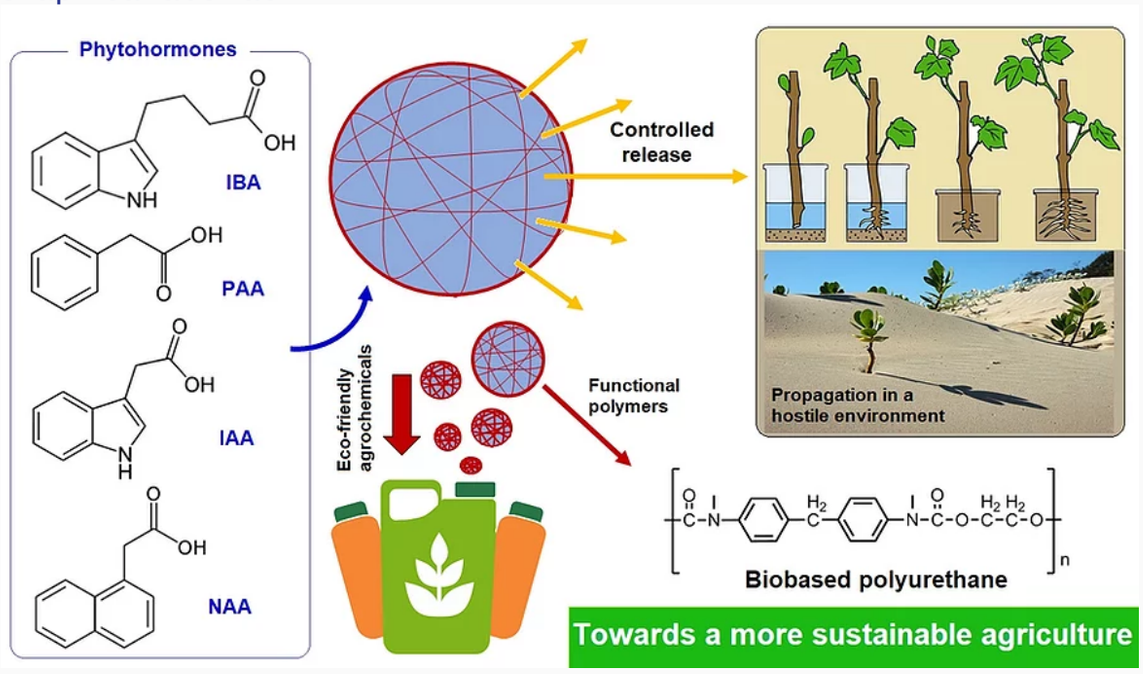
Development of Controlled Release Systems in Plant Growth Regulators based on Cationic Polymers

Graphical abstract

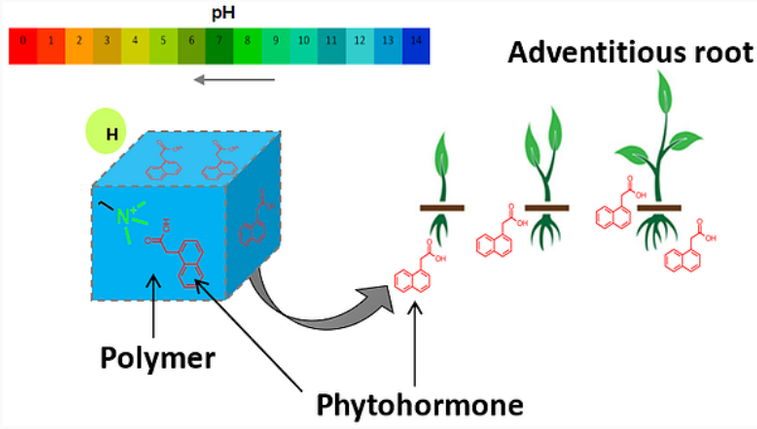


Description

ABSTRACT

Today, interest in using vegetative propagation in plantation management practices has increased considerably. However, many economically important species plants have a low genetic or physiological capacity for rapid adventitious root formation. Due to this, at present, the live stake is induced to form roots and shoots through chemical manipulations, by the use of phytohormones, but it´s release must be controlled since plants require an adequate hormonal concentration figure 1, or otherwise the stake dies before producing roots. For this purpose, it´s required to have a material synthesized in a polymeric matrix that able to interact favorably with the substance of interest and that it´s retention capacity can be regulated, to cover a wide type of crops and also have excellent mechanical properties such as high weathering resistance. Thus, the object of this research project is to develop controlled-release systems of plant growth regulators, through the synthesis and characterize cationic polyurethanes from diisocyanates and quaternary ammonium polyols with the ability to interact electrostatically with auxin-type phytohormones, such as naphthalene acetic acid (NAA) at pH values characteristic of agricultural soils.

Figure 1. Illustration of controlled-release of plant phytohormone from polymer structure.



RESEARCH PROBLEM

Live Staking (or propagation by cutting) is a fast, economical and effective method of asexual reproduction in compared to seed reproduction methods, which require more time for germination, higher energy consumption in fertilization and therefore higher costs. Within the advantages of asexual reproduction are that the new plant is arising from an adult plant or plant parts, only one parent is needed in reproduction, the offspring produced are genetically identical guaranteeing the desirable characteristics of the parents and it will also be sturdier than a seedling, facilitating the prevention or control of possible pest and disease attacks [1].

That is why today, the interest in using vegetative propagation by cuttings in plantation management practices has increased considerably. For example, the rooting stakes in Colombia has been used as a strategy for the production of native tree species for ecological restoration [2] and in crops propagation such as roses, cassava [3], cocoa, sugarcane, medicinal and aromatic plants [4]. However, there is a limitation that many important plants economically (propagation using cuttings is central to many forestry and horticulture industries), ecologically (important for stabilizing shifting environments such as coastal regions, estuaries or ecological restoration and river flood plains), and for human existence (food production) have a low genetic or physiological capacity for rapid adventitious root formation [5]. Hence, at present, the live stake is induced to form roots and shoots by chemical manipulations, through the use of plant hormones (also known as phytohormones), these are numerous organic compounds that regulate the growth of plants at very low concentrations are naturally synthesized in plants. The majority of physiological events occurring in plants are controlled by plant growth regulators [6]. Within this group, the plant growth regulator auxin are responsible for catalyzing the growth of adventitious roots and adaptation of the plant to new conditions, figure 2, [7], [8]; However, heterogeneity, complexity and dynamics in response to environmental challenges and of the soil generate that the results in a plant are disparate concerning another, since the phytohormone metabolism can vary according to the particular conditions of root environment the soil: such as pH, temperature and humidity [9], [10].

In addition to these variables, it must be taken into account that the dosage of plant hormones must be carefully controlled. For example: the application of very high concentrations of auxin inhibits the growth of shoots directly and similar effects are evident in propagation experiments. When cuttings are treated at the base with auxin, there is a concentration which is optimal for root formation, a small further increase giving a reduction in the number of roots, while a considerable increase leads to high mortality, often with rooting up to the level at which the cuttings were immersed in the solution [11] and very low auxin concentrations may accelerate root growth. In this sense, if the proper concentration is not reached, the stake dies before it produces roots, leading to a deficiency in crop production, dead seedling, delayed sowing and therefore an increase in planting costs. Therefore, the development of controlled release systems of rooting phytohormones represents an alternative to ensure a sustainable development of propagation asexual by root cutting, maximizing of the efficiency in this technique.

Figure 2. Some natural auxin (phytohormones) that regulate the growth of adventitious roots in plant.

As a result of the above, we seek to answer the following research question: Can cationic polyurethanes be used as smart or stimulus sensitive systems for the controlled release of plant-growth regulators?

JUSTIFICATION

An alternative for the development of controlled release device for phytohormones is the use of polymeric materials that can retain and release the chemical messengers (hormones) according to some external stimulus. This device can be synthesized using polyurethanes (PUs), which are polymers whose properties can be designed through a vast number of chemical reactions. These polymers are obtained by polycondensation reactions between a polyol and an isocyanate, widely used in various industrial sectors; include a wide range of modular-like structures with an extremely diverse range of properties. PUs are a unique class of thermoset and thermoplastic polymers that can display rigid or elastomeric behavior depending on their chemical and morphological structure, have excellent mechanical properties such as low density ratio, high mechanical strength, high elasticity, resilience, tear resistance and permanent deformation. However, due to the chemical properties of PUs, such as molecular orientation, crystallinity, crosslinked, and presence of urethanes groups, categorized as a “hard” segment strongly of the main chain, make the accessibility to polymer chains by enzymes or microorganisms to carry out its degradation is limited. This is one of the main reasons for not using this type of polymers in agricultural sciences, due to the gradual accumulation of polyurethanes in the soil through the generation of solid waste [12], [13]. Based upon on the above, the construction of controlled release devices for phytohormones in the soil that catalyze the rooting of cuttings is proposed. The active compound of these devices of PUs can be synthesized with quaternary ammonium groups that allow the electrostatic interaction with the phytohormone NAA and it is subsequent controlled release by varying the pH or ionic strength. The NAA, is used as a synthetic auxin, which is commonly applied to stimulate the rooting potential of plant cuttings.

In this project research, the synthesis of phytohormone controlled-release dispensers (device) in the soil will be carried out to catalyze the rooting of stakes, in such a way that the accumulation of the polymer in the soil is avoided and allow it is subsequent reuse, figure 3. The functionality of this polymer structure depends on the monomers and reaction conditions. For this reason, to provide the capacity to interact intermolecular electrostatic interaction with NAA, N-methyl-D-glucamine and glycidyl trimethyl ammonium chloride are used. This material is obtained through polycondensation reactions from a polyol and isocyanate, figure 4.

Figure 3. Functioning controlled-release dispensers (device).

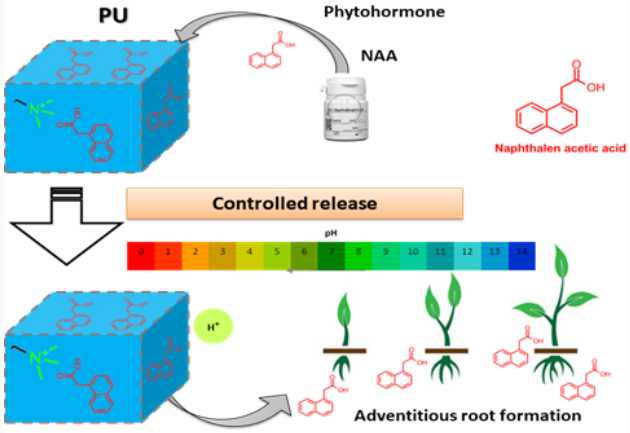
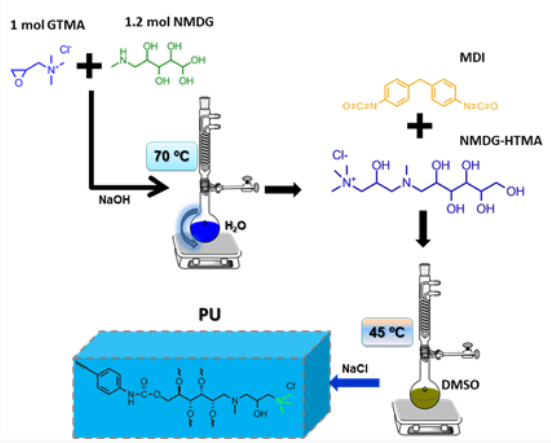


Figure 4. Synthesis of PU utilized in this research.



Objectives

MAIN OBJECTIVE

To develop controlled-release systems from plant growth regulators based on cationic polymers.

SPECIFIC OBJECTIVES

- To synthesize and characterize 3-(N-methyl-D-glucamine)-2-hydroxy-1-N-trimethyl propane ammonium chloride (NMDG-HTMA) from N-methyl-D-glucamine (NMDG) and glycidyltrimethylammonium chloride (GTMA).
- To synthesize and characterize cationic polyurethanes from 3-(N-methyl-D-glucamine)-2-hydroxy-1-N-trimethylpropane ammonium chloride from N-methyl-D-glucamine (NMDG).
- To evaluate the retention and release capacity of phytohormones, depending on the pH and ionic strength.

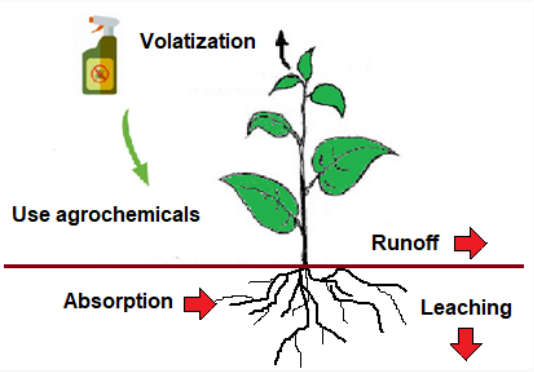
Fundamentals and Background

ENVIRONMENTAL POLLUTION FROM AGRICULTURAL INDUSTRY

GENERALIDADES

The agricultural industry is characterized by directing its production processes towards obtaining high-performance and quality products, which has led to common practices that are based on the excessive addition of agrochemicals, such as pesticides, antibiotics, synthetic fertilizers, hormones, and other chemical growth agents, as they are not absorbed or metabolized in plant, they can be soil transferred by many factors like: leaching, runoff, volatilization, plant injury, or others; which leads may lead to the destruction of biodiversity, the soil and water bodies contamination, figure 5 [14].

Figure 5. Movement of pesticides in the environment.



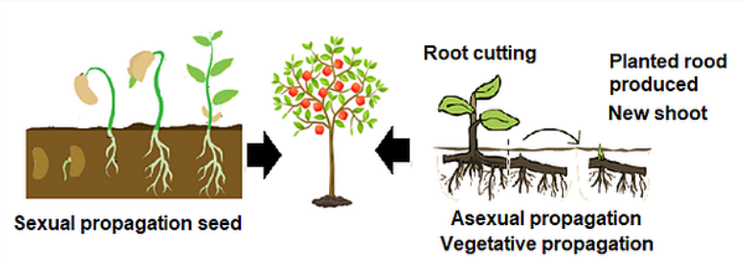
The decrease in agricultural land, ecological adversities such as soil erosion, climate change and the constant increase in population, demand new ideas that guarantee the food security of humanity. Therefore, chemical technologies can support the production of much more efficient crops that will ensure food security for decades to come. In this sense, this research project is considered positive and of great relevance, due to development of controlled-release dispensers (device) for phytohormones with potential application in the adventitious root formation in plants. Ensuring the sustainable development of propagation asexual by rooting cuttings in plantation management practices; reducing germination time, energy consumption in fertilization and low-costs.

VEGETATIVE PROPAGATION

GENERALITIES

Plants can be propagated by seeds (sexual propagation) and by cuttings (agamic or asexual propagation, also called multiplication), figure 6 [1]. The latter can be carried in a cell, a tissue or an organ such as roots, stems (stakes), branches or leaves because plant cells can regenerate the entire structure of the plant, which is it is known as cloning. This capacity is due to two characteristics of the cell: totipotency and dedifferentiation. Totipotency is the maximum power of a cell, which gives it the ability to direct the total development of an organism. This happens if the nucleus of a cell is identical to that of a zygote, which is, it contains the genetic information necessary to reconstitute all the parts of the plant and its functions through the reproduction of somatic cells based exclusively on mitosis. Otherwise, dedifferentiation is the process in which mature living cells can return to a meristematic condition and develop a new growth point. Currently, the use of agamic plant propagation has intensified due to that the plants do not have to go through the juvenile growth period, thus shortening the time needed to reach reproductive maturity and therefore produce the fruits of the plant faster. Through this technique, the genetic characteristics of the parent plant are reproduced in their entirety; therefore, homogeneous offspring and crops can be obtained. In contrast to this, agamic offspring can inherit viral diseases from parent plants[15]–[20].

Figure 6. Sexual and Asexual propagation.

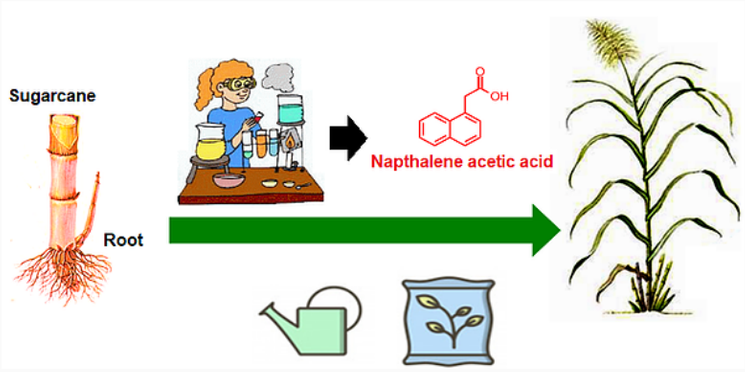


LIVE STAKES PROPAGATION

Live stakes are living woody plant cuttings capable of quickly rooting in moist soils. A stem cutting includes a piece of stem plus any attached leaves or buds. Stem cuttings can be taken from both herbaceous plants (e.g., garden flowers and houseplants) and woody trees and shrubs. Thus, the stem cutting only needs to form new roots to be a complete, independent plant. The success of the propagation by cuttings depends on the capacity of forming roots. The cutting can form a new plant genotypically equal to its parent plant, being induced to form adventitious roots (post-embryonic roots) by chemical, mechanical or environmental manipulations, figure 7. Adventitious roots are those that originate from any part of the plant (stems, leaves or other vegetative non-root organs), different from the roots of the plant embryo and in response to stress conditions, such as flooding, nutrient deprivation, and wounding [5]. This general definition distinguishes adventitious roots from primary and lateral roots. Within external factors, the physiological conditions such as hormonal balance are considered the most important that affect rooting cuttings [21]. The formation of these roots is carried out in the process of differentiation, in which the cells modify their morphogenetics to act as stem cells in the initiation of root primordium. Once the root primordia have been developed in the cuttings, then considerable metabolic activity occurs causing new root emergence from tissues. Among these activities, the cell wall lignification process is catalyzed by a particular peroxidase, which occurs during rooting. Here auxins play an important role in the mobilization of carbohydrates in the leaves and the upper stem, increasing the transport to the root zone and therefore the availability of sugar in the primordium [6], [7]. Auxin is strong growth regulators of aerial organs and the endogenous level of this hormone quantitatively regulate the shoot growth; and usually the growth rate of the root is inversely proportional to the endogenous concentration of indole-acetic acid (IAA) [22].

In general, live stake propagation is one of the most popular vegetative propagation techniques used for the multiplication of almost all tropical and subtropical fruit trees and in general, for both forest and ornamental trees and shrubs [23].

Figure 7. Adventitious roots by chemical, mechanical or environmental manipulations.



PHYTOHORMONES - PLANT GROWTH REGULATORS (PGRS)

GENERALITIES

Pioneering studies in the 19th century by Julius von Sachs and Charles Darwin showed that the growth processes of different plants are regulated by "substances" that move from one part of the plant to another. These substances are known as plant hormones or phytohormones, which are a structurally differentiated collection of small molecules derived from various essential metabolic pathways; they are similar to animal hormones in that they function as chemical messengers. Phytohormones are substances naturally produced by plants that control normal plant functions, such as root growth, fruit set and drop, growth and other development processes. Nevertheless, very similar chemicals are produced by fungi and bacteria that can also affect plant growth. A large number of related chemical compounds have been synthesized by humans that are used to regulate the growth of cultivated plants and such weeds killer; these manmade compounds are called plant growth regulators or PGRs. These important compounds, responsible for the gene expression patterns of various growth and development events, participate in the regulation of multiple physiological processes such as seed germination, rooting, tropic movements, tolerance to different types of stress biotic and abiotic, in the flowering stage, fruit ripening, and senescence, among others [24]. Plant hormones are not nutrients, but chemicals that in small amounts promote and influence the growth, development, and differentiation of cells and tissues.

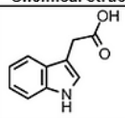
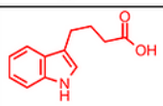
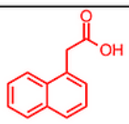
In general, these compounds are present in very low concentrations and are synthesized in a part of the plant, acting locally, at or near the site of synthesis, or in distant tissues. Over the years this collection of plant hormones has been growing, to the point of knowing its molecular mechanisms of biosynthesis, transport, and response. According to their physiological structure and function, these hormones are classified into several groups. Nine categories of phytohormones, that is, auxins, cytokinins (CK), gibberellins (GA), abscisic acid (ABA), ethylene (ETH), brassinosteroids (BR), salicylates (SA), jasmonates (JA) and strigolactones (SL), have been identified so far. The first five (auxin, CK, GA, ABA, and ETH) are sometimes referred to as the “classical” phytohormones.

AUXINS

The auxins were the first of the growth regulators to be identified, and this name has been applied to the whole group of growth-regulating substances. Natural auxins represent a heterogeneous group of small aromatic carboxylic acids that act as a main coordinative signal for virtually all plant growth and development processes [25]. Auxin is the major growth-promoting hormone for adventitious roots initiation, such as indole-3-acetic acid (IAA) and is the most common auxin found in plants, further homeostasis of this is associated with different developmental steps of the rooting process [26], [27] (see Table 1). These have multiple roles in plant growth and development, including embryo axis formation, vasculature development, lateral root formation and development, apical dominance, and tropisms. This is present in all parts of plant although in very different concentrations, being transported from its sites of biosynthesis and storage to other tissues. Thus transport in the plant can occurs in two distinct pathways: passive diffusion through the plasma membrane and active cell-to-cell transport, depending on the protonation state of auxinic biomolecules; which are primarily indole type derivatives, although also phenoxyacetic, benzoic or picolinic compounds can have auxin-type activity, this is directly related to the regulation of growth and development of the plant, through division, expansion and differentiation cell, being of particular relevance in the early embryogenesis of stem, coleoptile elongation, vascular differentiation, flowering induction, the formation of lateral and adventitious roots [28].

That is why auxins, both natural and synthetic, can be used to increase root growth, eliminate weeds and thin the fruits; the most widely used in the agricultural sector are natural auxin indole-3-acetic acid (IAA) (see table 1) and synthetic phytohormones: 2,4-dichlorophenoxyacetic acid (2,4-D), 3,6-dichloro-2-methoxybenzoic acid (Dicamba), 4-amino-3,5,6-trichloropicolinic acid (Picloram), used as herbicides due to their ability to generate disorders in morphogenesis and increased synthesis of ethylene; and 1-naphthalene acetic acid (NAA) (figure 11), which is a compound used in agriculture, both in pre-harvest and post-harvest, to induce rooting in the asexual propagation of forest, fruit and ornamental crops, such like roses[29], sugarcane and cassava; in turn, the derivatives of this synthetic auxin can be used as intermediaries in the synthesis of pharmaceuticals, photochemicals, and dyes [30]–[32]. Conversely, auxins can be toxic to plants in large concentrations; they are most toxic to dicots and less so to monocots.

Table 1. Some examples of use auxins [33].

Auxine	Chemical structure	Comments
Indole-3-acetic acid **(IAA)**		This auxine when applied externally initiates the formation of roots, causes cell elongation and general growth, forms lateral roots, and lessens the tendency to bend- “a tropism”.
Indole-3- butyric acid **(IBA)**		It induces rooting of cuttings and considerably shortens the time required to form these roots. It´s also used in seed treatment and spraying of foliage to promote acceleration of growth. However, little is known regarding the manner in which IBA is synthesized in plants. IBA inhibits primary root elongation and stimulates lateral root formation.
1-Naphthalen acetic acid **(NAA)**		This synthetic auxine is a synthetic auxin used as speeded up root formation, to induced growth of seed-less fruits and caused stems to grow stiff and woody; it´s an ingredient in many commercial plants rooting horticultural products and is also used for plant tissue culture. NAA is an organic compound, colorless solid or slightly yellow and; It features a carboxymethyl group (CH_2CO_2H) linked to the "1-position" of naphthalene. Synthetic auxins are not easily degraded by natural plant enzymes or microorganisms and are therefore more suitable for commercial use.

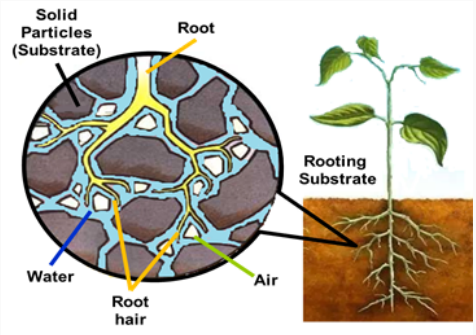
ROOTING SUBSTRATE

A substrate is any solid material that is different from the soil. Plants obtain a large proportion of their nutrients through the roots and from the surrounding substrate. The substrate must therefore be a suitable rooting medium and a provider of nutrients. Rooting substrates are usually made several proportions of organic component (peat moss, sphagnum moss) and an inorganic component (perlite, river sand, vermiculite, pumice stone or synthetic material blocks), in order to increases aeration for good development of the root’s growth cutting.

There are many factors that affect rooting, such as accurate control of moisture, temperature, light, hormone formulation and concentration, substrate media, and stock plant quality. A rooting substrate serves a variety of purposes, including primarily: holding the stake in place during the rooting period, to retain water to provide moisture and provide porosity necessary for sufficient aeration in the formation of adventitious roots. Furthermore, it´s use facilitates to extract the stake once it has been rooted without destroying the adventitious roots for subsequent planting in the land [34]. When applying phytohormones in with the use of a good substrate it allows to significantly improve the length of the roots in some plants; at times, the effectiveness of the substrates and hormonal products shows improvements in water holding capacity, increasing the development of roots for stem cuttings [35], [36].

The relationship between air, water, and the rooting medium plays a significant role in the success of macro-propagation by influencing the availability of oxygen that may be at the base of the live stake, where the roots are formed, figure 8. Therefore, a best substrate must have a highly porosity that facilitates the evacuation of water, the presence of air and good water holding capacity; additionally, stability at different conditions of pH and salinity. In evaluations carried out efficiency of rooting cuttings, they show better rooting performances, when combining the rooting substrate and the application of plant growth regulators. For example, in this evaluation [35]. It was found significant effects of root volume and clearly defined the substrate; auxin type and concentration to favor the generation of adventitious roots in cuttings Leucadendron.

Figure 8. Illustration of general composition of soils (regular substrate for agriculture).



POLYMER APPLIED IN AGRICULTURE

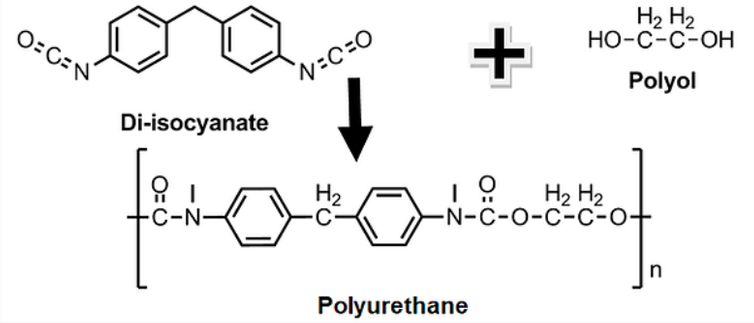
POLYURETHANES

Polyurethanes (PU) represent almost 8% of produced plastics which place them as the 6th most used polymer in the world, with an approximate production of 18 million tons per year, which is expected to reach to 22 million in 2020 [37], [38]. This statistic is directly associated with its synthesis advantages, mechanical and biological variations, since these materials can be obtained at room temperature with high yields, obtaining products with good mechanical resistance (to abrasion and corrosion), high melting points, and high resistance to degradation by biological factors. Furthermore, one advantage is that properties of PUs can be modulated and designed by correct selecting of their precursors, and in consequence, these are an excellent synthetic platform with potential applications in agriculture [39]. Therefore, PUs are widely used in industry as coatings, adhesives, synthetic fibers, paint additives, insulators, biomedical materials, in textiles and fibers, in the electronic industry, among others. Regarding the potential applications of PUs in the agricultural sector, they have been evaluated as samplers of contamination of metals [40], polycyclic aromatic compounds (pesticides), for the fertilizer coating and controlled release of functional bioactive [41], [42].

PUs are a widely used material in tissue engineering because of their good mechanical properties, biocompatibility, and biodegradability. The term encompasses a wide range of substances with diverse chemical, physical and biological properties, which have in common the presence of urethane functional group (–NH–CO–O–) in the repetitive unit of the polymer chain. The most common method of preparing polyurethane is condensation reaction of a diisocyanate and a polyol (in the presence of either a catalyst or ultraviolet light activation), illustrates the synthesis of a typical PU. Other suitable additives and catalysts may also be incorporated for the PU synthesis (Figura 9); the high yield of this chemical reaction is associated with the high reactivity of the isocyanate group (–N=C=O), which has an electropositive character on the carbon atom, making it an electrophile susceptible to nucleophilic attacks by hydroxyl, epoxide, amine, anhydride and carboxylic acid functional groups; in turn, nitrogen and oxygen atoms have a higher density of the electronic cloud, which makes them susceptible to electrophilic attacks [43]–[45]. Due to the cross-linking in PUs, they often possess an infinite molecular weight with a three-dimensional (3D) network build-up. This is the reason why small fraction of PUs may be referred to as a giant molecule and this explains why typical PUs often will not go soft or melt when they are heated. The incorporation of different additives alongside the isocyanates and polyols, as well as modifications to the processing conditions, makes it possible to obtain a wide range of characteristic features, which makes them suitable for various applications [46].

Polyols used for PU synthesis often consist of two or more –OH groups. There are different kinds of polyols available that can be prepared by various ways. On the other hand, isocyanates are incorporated into PU synthesis via a hydroxyl-group-containing compound due to their high reactivity, although the reaction is slow at room temperature. This slow speed may be due to the phase incompatibility of the polar and less dense polyol phase and the relatively non-polar and denser isocyanate phase [46].

Figure 9. Typical route for the synthesis of polyurethanes.



There are different evidences applications of polyurethanes to the development of modified release drug delivery and phytohormones release delivery research leveraging polyurethanes is a aim this research. In this sense, researchers mention different mechanisms of controlled drug release using polyurethane film or support matrix and recently, it has been carried out the encapsulation of small molecules (drugs) by means of saline precipitation of cationic polyurethanes; this is capable of quaternizing and self-assembling in nanomicels [47], [48]. In this research, they were able to encapsulate the drugs and later to carry out a sustained liberation according to the medium's pH.

PHYTOHORMONES IN COLOMBIAN AGRICULTURE

In the last 20 years in Colombia, agriculture has been reducing its contribution to the economy. According to World Bank reports, Colombia went from a contribution of 8.3 % of GDP in 2000 to 6.7 % in 2019 [49]. The low productivity of agriculture sector is one of the causes that have generated this decline in GDP and it is evident that it has declined when compared to the average of other Latin American countries. This low productivity may be due to multiple factors that include: Inadequate Agricultural Practices, high production costs, scarce operations research in agriculture, among others. One of the crop management practices is the plant propagation activity; highlighting: the soils management and rooted cuttings.

In Colombia, the agency state responsible of carry out technical, administrative and law control of the manufacture, formulation, packaging, registration, production, import, export, marketing and use of physiological plant regulators in the agricultural sector is the ICA (Colombian Agricultural Institute) [50]. This activity is done through the registration of commercial products containing "Physiological Regulators and Coadjutants for Agricultural Use", and currently has 74 different commercial products registered; which are offered by different national and foreign companies. The active ingredients (phytohormone and growth regulators of synthetic origin) containing these products are listed in table 2. It is important to say that, in Colombia, according the record of ICA there are 73 commercial products identifies as physiological regulators.

Table 2. Some examples of phytohormone and growth regulators registered in Colombia (table in Spanish according to ICA's information) [51].

COMMERCIAL NAME	ACTIVE PRINCIPLE
Hormonagro 1	Acido alfa naftalen acético regulador fisiológico
Pix sl	Cloruro de mepiquat: cloruro de 1.1. Dimetil piperidinio-formulacion a 20 °C
Ethrel 48 sl	Etefon: ácido 2 - cloro-etilfosforico, de formulación a 20 °C
Ergostim	Aatc
Cytozyime foliar	Nutrientes orgánicos
Royal mh 30	Hidracida maleica: sal potásica del 6- hidroxido-3 (2h) piridazinona, por 180 gramos
Progibb 10 sp	Acido giberelico: gilberelina a 3 de formulación a 20 ° c
Activol	Giberelina a
Progibb 90% sp	Ácido giberelico (giberelina a3) de formulación a 20° c
Dormex sl	Cianamida hidrogenada
Hormonagro a.n.a..	Acido -1- naftalenacetico
Cerone 720 sl	Etefo
Magiber wp	Ácido giberelico
Royaltac m	Alcoholes grasos
Prep 720 sl	Ethephon
Agrispon sl	Moleculas orgánicas: purinas, ácido nucleico, vitamina a, porfirina, morfogenos y glicosido
Ryzup sl	Acido giberelico
Biomex di	Brasinoesteroide
Finish	Etephon: acido 2 cloro etil fosfórico
Cytozyme semilla	Orgánicos: medio bacteriano de fermentación ácidos carboxílicos, aminoácidos, péptidos y proteína diferida
Ácido giberelico job 10% sp	Ácido giberelico
Sugar 720 sl	Etefon
Biofed	Epibrasinolid0
Nitrozyme	Citoquinina: quinetina (6-furfurilaminopurina)
Tachigaren 30 sl	Himexazol
Gibgro 10% sp	Giberelina ag 3
Gibgro 20%	Giberelina ag 3
Acigib 12.5 st	Acido giberelico
Marax	Acido giberelico
Acigib 10 sp	Acido giberelico
Boost 500 sc	Acibenzolar-s-metil
B-nine® wg	Daminozide
B-nine wg	Daminozide
Ma gib	Acido giberelico
Aib 0.4%	Acido indol 3-butirico
Aib 62 %	Acido indol 3-buritico
Aib 0.5%	Acido indol 3-butirico
Aib 35%	Acido indol butirico
Promalina	Acido giberelico (ag4 + ag7) 6 - bencyladenina
Acido giberelico 10 agricence	Acido giberelico
Gibgro 90 % sp	Giberelina ag3

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Results

DESCRIPCIÓN GENERAL DE LOS RESULTADOS

(Se agregará información posteriormente)

PRODUCTOS ASOCIADOS

(Se agregará información posteriormente)

Acknowledgment

Grupo de Investigación en Ciencias con Aplicaciones Tecnológicas (GI-CAT) (Cali, Colombia)

(Se agregará información posteriormente)

Mindtech Reseach Group (Mindtech-RG), Mindtech s.a.s. (Montería/Barranquilla, Colombia)

(Se agregará información posteriormente)

Departamento de Ingeniería Agrícola y Desarrollo Rural, Facultad de Ciencias Agronómicas, Universidad de Córdoba (Montería, Colombia)

(Se agregará información posteriormente)

Instituto de Ciencia y Tecnología Analítica Golden-Hammer (Montería, Colombia)

(Se agregará información posteriormente)

Minciencias: Convocatoria 848 - 2019

(Se agregará información posteriormente)