Compounds identified in plant extracts applied to agriculture and seed treatment

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ABSTRACT: Plant extracts effects have been regarded and proven in researches under different applications in agriculture, including seed treatment. The plant extracts effectiveness is attributed to the presence of certain classes of compounds; therefore, studies that aim to identify and quantify these composites, which are present in plant extracts used in agriculture, are important, as well as the seed treatment. This research aimed to understand and describe through a systematic review, what were the main carried approaches, classes and identified compounds in studies with plant extracts to different applications in agriculture and the seed treatment. The period 2015 to 2020 was the one that exposed the higher research publication indexes, considering the theme under analysis, plant extracts in agriculture, seeking to identify or quantify the presence of metabolic composites, indicating a growing interest in this theme. Such studies pursued identifying and/or quantifying the compounds that are present in the plant extracts. The phenolic compounds constitute the priority class of metabolites to different functions, effects and applications in agriculture, mainly in seed treatment. The terpenes present a substantial potential as bioinsecticides to agriculture. Plant species that are rich in phenolic and terpenes compounds are a significant source of alternative control in the protection of the productive system. 

Key words: secondary metabolites, terpenes, seed treatment, alternative control.

INTRODUCTION

Plant compounds provide multiple potentialities, regarding their employment in agriculture, including the seed treatment (ARSHAD et al., 2019; AL-MOHIMADI; AL-ANI, 2019). Some studies have regarded the plant extract effect as resistance inducers (COSTA et al., 2019), growth promoters in plants or biostimulating effect (COZZOLINO et al., 2020), herbicidal effect (ZAKA et al., 2019; FINDURA et al., 2020), nematicidal effect (MÜLLER et al., 2016; COLTRO-RONCATO et al., 2016), insecticidal effect (PAVELA et al., 2018) and, mainly, phytopathogenic organisms control effect (MEENA et al., 2020; NCISE et al., 2020).

The effectiveness of plant extracts employed in agriculture to different purposes, particularly in the seed treatment, is found by the presence of some classes of majoritarian metabolites composites, such as phenolic compounds, terpenes, fatty acids and nitrogen compounds, which function in the most varied roles (MANGWENDE et al., 2019; CHANDEL & KUMAR, 2017, ZIDA et al., 2018).

Considering the previous description, some studies tried isolating, characterizing, and understanding the method and action of these
compounds (HAMAD et al., 2019; ANDRIANA et al., 2018; AFTAB et al., 2019; AHMED et al., 2019; DIKHOBA et al., 2019; COZZOLINO et al., 2020; PHAMBALA et al. 2020, ANIYA et al., 2020). However, there are only a few researches regarding plant extracts that try supporting its results from its chemical characterization and isolation of the active compounds, once the investigations are restricted to available information on literature or even qualitative/colorimetric tests to identify only the presence or absence of such composites.

In the last few years, a growing interest in the application of plant extracts as an alternative to the agrochemicals employment at cropping systems has become a reality (CARMELLO & CARDOSO, 2018; JANG & KUK, 2020; JANG & KUK, 2019; THUERIG et al., 2018; NARASIMHAMURTHY et al., 2019), hence, studies that aim the characterization of the existing compounds in plant extracts used in agriculture, including seed treatment.

Exploring the natural occurrence of metabolites can supply a safer and low-cost alternative to the farmers, promoting the local sustainable use of bio-resources (NCISE; DANIELS; NCHU, 2020). For this purpose, it is necessary to understand, from the already concluded pieces of research, the incidence or not, as well as the identification and quantification, of majority classes of metabolites active in species and genders of studied plants for different uses in agriculture, aiming different effects, resulting in useful information to the planning and execution of future research, oriented to the plant compounds employment.

Based on the above consideration, this research had as an objective the understanding and describing, through a systematic review, the main approaches, classes and compounds identified in studies with plant extracts under different applications in agriculture and in seed treatment.

DEVELOPMENT

In order to execute and constitute the range of this systematized review, some scientific papers, indexed to the Web of Science database, were selected. The decision of choosing this repertoire can be justified by its global database of indexation of papers linked to periodicals of great international visibility.

To provide a better search terms definition, a previous investigation was made, through different strategies based on Boolean operators, by means of basic research, with a temporal cut from January of 2010 to December of 2020. After the analysis of this
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indicators, with the distinction of the following items: publication year, realized approach regarding the determination or identification of the active composites in plant extracts, effects on agriculture, identified compounds, plant species/gender and reference. The data were submitted to analysis and Tables and graphs were elaborated.

Regarding the realized approach about the composition of the plant extract, considering the 219 analyzed studies, 47.94% of them made inferences related to the composition of the extracts only on literature database, 12.78% of them determined the presence of some class of compound, 15.52% of them were investigations that identified metabolites, and 23.74% of them did not mention the composition of the extract, and there was a greater expressiveness on the number of publications between the years of 2015 and 2020 (Figure 1) for all the cases.

From the data set of researches that explored the potentialities of plant extracts for different applications in agriculture and seed treatment (CASER et al., 2020; KARABUYUK & AYSAN, 2019), it was noticed that a great amount of them conducted their results from the inferences to available pieces of information on literature, or even there is no mention at all to any metabolite (MAMARABADI et al., 2018) that compose the plant extract. This demonstrated that scientific literature still lacks deeper investigations about the classes of compounds and their chemical constituent present in the plant extracts, as well as their effects in the proposed applications.

Besides the expressive number of publications that made inferences of their results only in literature data or that did not even mention the compounds, it is noticeable the interest and demand of Science, in the last years, for studies that search for identification and isolation of substances present in plant extracts, with a higher proportion to these approaches in the period of 2015 to 2020 (Figure 1) (ANDRIANA et al., 2018; AFTAB et al., 2019; ANIYA et al., 2020).

It must be highlighted the importance of the identification and the isolation of substances, such as secondary metabolites, originated from plant extracts, to assist in the understanding of the action mechanisms and the functions of these compounds. It is suggested, as a possible justification for a greater quantity of studies with an approach focused on inferences to literature, the complexity and difficulty on the isolation of the active principles, the limitation on equipment mastery, reagents, methodologies or even the operational cost on the part of the pieces of research (AFTAB et al., 2019).

One of the main methods employed to characterize and identify substances, in special the ones that compose the plant extracts is a methodology

![Figure 1 - Number of published and indexed articles in Web of Science about the employment of plant extracts in agriculture and application of seed between January of 2010 and December of 2020, inside each approach realized regarding the composition of such plant extracts.](image-url)

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The terpenes constitute a bigger group of plant metabolites, insoluble in water and synthesized from acetyl-CoA or from glycolytic, considering that all of their constituents are derived from the union of pentacarbonated unities with isopentane ramifications (TAIZ & ZEIGER, 2013). As the phenolic compounds, they also act in the growth promotion, defence against herbivores and pathogens, besides being considered an important source of substances that act against plant intoxication, such as terpene lactones, azadirachtin e gibberellins (DIKHOBÁ et al., 2019; AHMED et al., 2019).

Through the synthesis of one acetyl-CoA molecule with one of malonyl-CoA, after some reactive processes, it happens the formation of fatty acids with carbon chains of 16 to 18 atoms. Fatty acids are related to the synthesis of lipids, such as glycolipids, triacylglycerols or the ones that form cuticles in the plants, executing important functions, such as insecticides, mainly, as fungicides, as examples of palmitic acid, oleic acid, linoleic acid, stearic acid, arachidonic (VÁZQUEZ-COVARRUBIAS et al., 2015; AHMED et al., 2019; TEMBO et al., 2018).

Among the frequently identified composites in plants, the nitrogen compounds are found, being substances that have nitrogen in its chemical structure, such as alkaloids and glycosides, and are important in the prevention against the herbivores attack, through the volatile toxins liberation, such as nicotine, hydrocyanic acid and isothiocyanate (TAIZ & ZEIGER, 2013; KARABUYUK & AYSAN, 2019).

Besides the phenolic compounds, terpenes, fatty acids and nitrogen compounds, the plants produce many other substances, such as Phyto-vitamins, and sugars responsible for different functions (EZEONU et al., 2018; POTRICH et al., 2020).

Many pieces of research have proven that these secondary metabolites, derived from plant extracts, display action against predators and phytopathogenic organisms, based on their toxicity and capacity of repelling herbivores and microorganisms when tested in vitro and in vivo (COSTA et al., 2019; COZZOLINO et al., 2020; FINDURA et al., 2020; PAVELA et al., 2018; MEENA et al., 2020; NCISE et al., 2020). Furthermore, they act in the resistance induction, the building of polymers barriers, synthesis of enzymes related to defence mechanisms, growth promotion, herbicides, insecticides and the degradation of the cell wall of phytopathogenic organisms (ANZLOVAR et al., 2020; ROMERO-BASTIDAS et al., 2020).

Therefore, studies with secondary metabolites allow the identification of different practical applications of plant extracts in agriculture and seed treatment, due
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Considering the different applications of plant extracts in agriculture, from the total of 167 publications that have highlighted metabolites, 96 of them were linked to the application with effect in phytopathogenic organisms and the correlation of different classes of compounds; 62.5% phenolic compounds, 29.16% terpenes, 21.87% fatty acids and 19.79% nitrogen compounds (Figure 3A).

Some substances, such as antioxidative enzymes, specially peroxidase, polyphenol oxidase and phenylalanine ammonia-lyase, have a great capacity of controlling phytopathogenic organisms, such as bacteria, fungi and nematodes, because they are directly involved with the plant’s defensive system (SOUZA et al., 2015).

Conversely, 32 scientific papers that approached application to effects on insects, 56.25% attributed their effects to phenolic compounds, 50% to terpenes and 25% to nitrogen compounds (Figure 3B). Many pieces of research have proven several functional roles of terpenoids in agriculture, as well as seed treatment, considering that these are among the main bioactive composites that were highlighted with insecticide action (BALDIN et al., 2015). The terpenes group presented many volatile allelochemical substances, such as limonene, menthol, phytol, linalool, 1,8-cineole, and azadirachtin, which have been utilized as repellents, in many cases preventing and reducing the contact between plant-insect and, this way, avoiding some damages to the productive system (ARSHAD et al., 2019, NISSINEN et al., 2020).

GARCIA et al. (2019) evaluated the exposure of larvae, pupae and adults of Ceraeochrysa claveri to Azadirachta indica oil, high in azadirachtin, an important terpenoid. The authors identified that in the concentrations 0.5%, 1% and 2%, there was stress and death cell, besides promoting delay on the spermatogenesis of insects that were submitted to the treatment, proving how important it is the employment of natural extracts, rich in terpenes, as bioinsecticides for the agroecosystem handling.

Positive results were also reported by ARSHAD et al. (2019) in evaluating the effects of Azadirachta indica A. Juss and Melia azedarach L. extracts to control pest insects in cotton plants (Dysdercus koenigi Walk, Aphis gossypii Glover and Amrasca devastans Distan), showing an average of 65.4% and 58.8% of controlling for both extracts, respectively.

Concerning the application with the effect of resistance induction, from the total of 10 scientific papers that approached this theme, 60% of them reported phenolic compounds and 20% fatty acids (Figure 3C). From the 19 that studied the biostimulation effect and growth promotion, 78.95% of them highlighted phenolic substances, 21.05% nitrogen compounds, and 15.78% terpenoids (Figure 3D).

GARCIA et al. (2019) evaluated the exposure of larvae, pupae and adults of Ceraeochrysa claveri to Azadirachta indica oil, high in azadirachtin, an important terpenoid. The authors identified that in the concentrations 0.5%, 1% and 2%, there was stress and death cell, besides promoting delay on the spermatogenesis of insects that were submitted to the treatment, proving how important it is the employment of natural extracts, rich in terpenes, as bioinsecticides for the agroecosystem handling.
In relation to the application with herbicide effect, from the 12 publications that dealt with the matter, 75% of them presented a relationship with phenolic compounds, 25% with terpenes and 25% with other compounds (Figure 3E). Other plant extract applications, such as retrieval and handling of soils presented 6 publications, 50% of them highlighted phenolic compounds (Figure 3F).

When the classes of compounds are correlated to the different application approaches and plant extract effects in agriculture and seed treatment, there was a greater focus on phenolic compounds with predominance to all applications. Besides, the terpenes can be enhanced as an important class of metabolites in controlling insects.

Phenolic compounds, due to their substance heterogeneity, stand out as a class of metabolites that are gathered to the secondary metabolism of plants. For this reason, they present numberless functions, such as herbicides, biostimulation, insecticides, resistance inducers, and, mainly, fungicide (NISSINEN et al., 2020; ANIYA et al., 2020; LAKSHMEESHA et al., 2019).

Terpenes have been reported in the literature as important mechanisms to insect control, being the base to many industrial insecticides, due to their low persistence in the environment and low toxicity to mammals (TAHA-SALAIME et al., 2020; RODRÍGUEZ-MONTERO et al., 2020). A great part of plants produce substances arising from the mixture of volatile monoterpene and sesquiterpenes called essential oils, being toxic to the majority of insects (ARSHAD et al., 2019).

An important piece of data about the protective function of volatile terpenes is a certain mechanism, in some plant species, such as cotton, tobacco, among others, that only releases these compounds after the insect starts the plant intake (PEREIRA et al., 2020; TAHA-SALAIME et al., 2020).

Considering only the pieces of research that identified the active substances in the plant extracts, some plant species stand out, such as *Syzygium aromaticum*, *Curcuma longa* L., *Allium sativum* L and *Ocimum basilicum* (Table 1 and Table 2).

HAMAD et al. (2019) evaluated the fungicide action in extracts of *Syzygium aromaticum*, *Tectona grandis*, *Ocimum basilicum* and *Eucalyptus gomphocephala* in three phytopathogenic fungi, *Fusarium oxysporum*, *Rhizoctonia solani* and *Alternaria solani*, and the insecticide action against *Culex pipiens* larvae. The authors observed positive results of all extracts and, through GCMS analysis, identified that, for the extract of *T. grandis*, the most abundant compound was oxalate of cyclohexyl-Pentium (8.7%), for the extract of *E. gomphocephala*,
it was p-cymene (28.8%), the extract of *O. basilicum* contained estragole (65.9%), 3-alilguaiacol (65.8%) and acetate of eugenol (46.6%) for the extract and the essential oil of *S. aromaticum*, pointing out that all the extracts can be utilized as natural biofungicides and insecticides. LAKSHMEESHA et al. (2019) determined the action of nanoparticles of zinc oxide and *Syzygium aromaticum* extract, in controlling growth and production of mycotoxins of *Fusarium graminearum* and identified, through GCMS, elevated levels of eugenol, β-caryophyllene, and acetyl eugenol. The authors revealed that the application of the nanoparticles promoted a decrease in the ergosterol content and caused damages to the membrane integrity of the fungi.

In accordance with the first indicated results in this review, it was observed that, among the main classes of compounds identified in the pieces of research, the phenolic compounds and terpenes stand out as the prevailing categories among the identified substances, considering the application to control phytopathogenic organisms, and insects, herbicide effect and resistance induction as central themes of the studies.

The maintenance of the seeds’ sanitary quality, as well as the involved processes in their treatment, have been under the spotlight because it is one of the main spreading pathways of plant species (ANŽLOV AR et al., 2020). The fungi, insects, viruses and bacteria are among the organisms that influence directly the sprouting process, establishment in the field and storage of grains and seeds (SNEHA et al., 2020).

### Table 1 - Main isolated compounds in the analyzed studies with plant extracts and their effects on employment in agriculture.

<table>
<thead>
<tr>
<th>Main described compounds</th>
<th>Effect in agriculture</th>
<th>Species/Gender of the plant</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-Cymene, estragole, furfural, α-linolenic acid, 1βH-rommeina, eugenol acetate, ethylguaiacol, cyclohexylpentil oxalate, -4,4-dimethyl-2-pentene.</td>
<td>Phytopathogenic organisms</td>
<td><em>Ocimum basilicum</em>, <em>Eucalyptus gomphocephalawith</em>, <em>Syzygium aromaticum</em>, <em>Euphorbia paralias</em></td>
<td>HAMAD et al., 2019.</td>
</tr>
<tr>
<td>Guaiacol, benzene acetic acid, phenol, benzene acetic acid methyl ester, methyl salicylate, ácido vanilico, syringol, vanillic acid methyl ester and benzoic acid.</td>
<td>Herbicide effect</td>
<td>Tridax procumbens L.</td>
<td>ANDRIANA et al., 2018.</td>
</tr>
<tr>
<td>Octadecadienoic acid, O-Pentadecylclic acid, 1,2,3,4, butaneteterol, octadenoic acid and linoleic acid.</td>
<td>Phytopathogenic organisms</td>
<td><em>Nigella sativa</em> L.</td>
<td>AFTAB et al., 2019.</td>
</tr>
<tr>
<td>Triterpenóides, β-amyrin, a-amyrin, neophytadiene (4.38%) and palmitic acid.</td>
<td>Phytopathogenic organisms</td>
<td><em>Curtilis dentata</em>; <em>Markhamia obtusifolia</em></td>
<td>DIKHOBA et al., 2019.</td>
</tr>
<tr>
<td>Lauric acid, myristic acid, palmitic acid, ricinoleic acid, stearic acid, oleic acid, palmitic acid ethyl ester, 13-hexyloxyaclotridec-10-en-2-ona.</td>
<td>Other</td>
<td><em>Cocos nucifera</em>; <em>Carapa guianensis</em></td>
<td>BATAGLION et al., 2014.</td>
</tr>
<tr>
<td>Octadecadienoic acid, O-Pentadecylclic acid, 1,2,3,4, butaneteterol, octadenoic acid and linoleic acid.</td>
<td>Phytopathogenic organisms</td>
<td><em>Lepidium sativum</em>; <em>Punica granatum</em></td>
<td>TAYEL et al., 2016.</td>
</tr>
<tr>
<td>Phenolic, polyphenol, alkaloids, terpenoids, polypeptide, cardiac glycosides, reductive compounds and anthraquinones</td>
<td>Phytopathogenic organisms</td>
<td><em>Garcinia kola</em>,<em>Tetrapleura tetraptera</em></td>
<td>UMANA et al., 2016.</td>
</tr>
<tr>
<td>Furfural; 2-furannmethanol; benzyl alcohol; phenethyl alcohol.</td>
<td>Other</td>
<td><em>Nandina domestica</em> Thunb.</td>
<td>HU et al., 2018.</td>
</tr>
<tr>
<td>Sesquiterpene ketolactone, curcumin.</td>
<td>Phytopathogenic organisms</td>
<td><em>Curcuma zedoaria</em></td>
<td>HAN et al., 2018.</td>
</tr>
</tbody>
</table>

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Table 2 - Main isolated compounds in the analyzed studies with plant extracts and their effects on employment in agriculture.

<table>
<thead>
<tr>
<th>Main described compounds</th>
<th>Effect in agriculture</th>
<th>Species/Gender of the plant</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-O-cafeoyl Acid, 4-O-Feruloylquinic; nicotiflorin (Kaempferol-3-O-Rhamnoglucone; Q-3-O-glucoside; rutin (Quercetin-3-O-Rhamnoglucone; 5-O-Feruloylquinic acid; 3-O-Feruloylquinic acid; 5-O-p-Coumaroylquinic acid; 4-O-cafeoyl oil, 5-O-Feruloylquinic; 4-O-cafeoylquinic; 3-O-cafeoylquinic acid);</td>
<td>Phytopathogenic organisms</td>
<td>Licium europaeum</td>
<td>TEJ et al., 2018.</td>
</tr>
<tr>
<td>(-) - (S) -ar-turerone.</td>
<td>Phytopathogenic organisms</td>
<td>Curcuma longa L.</td>
<td>FU et al., 2018.</td>
</tr>
<tr>
<td>Allyl isothiocyanate.</td>
<td>Phytopathogenic organisms</td>
<td>Crambe abyssinica</td>
<td>COLTRO- RONCATO et al., 2016.</td>
</tr>
<tr>
<td>Quinone Acid; chlorogenic acid; Quercetin- glucuronide; Hispidulin; Tagitin; O-methyl titoni; Tiotundin 3-O</td>
<td>Insects</td>
<td>Tithonia diversifolia</td>
<td>PAVELA et al., 2018.</td>
</tr>
<tr>
<td>Cinnamic acid and flavone compounds, p-hydroxybenzoic acid and vanillic acid.</td>
<td>Resistance Induction</td>
<td>Solanum tuberosum</td>
<td>MOUSHIB et al., 2013.</td>
</tr>
<tr>
<td>Saliylic-Phenylpropanoid Acid.</td>
<td>Resistance Induction</td>
<td>Anacardium occidentale</td>
<td>ANDAYANIE et al., 2019.</td>
</tr>
<tr>
<td>Nicotina; β- Caryophylile; lupeol.</td>
<td>Insects</td>
<td>Nicotiana tabacum L.; Anadenanthera colubrina Vell; Agave americana L.</td>
<td>PEREIRA et al., 2020.</td>
</tr>
<tr>
<td>Luteolin 7-rutinoside, Apigenin-6-C-glucosyl-8-C-arabinoside.</td>
<td>Phytopathogenic organisms</td>
<td>Flourensis cernua</td>
<td>ALVAREZ- PEREZ et al., 2020.</td>
</tr>
<tr>
<td>n-feruloyl putrescine, Tryptophan, chlorogenic acid, Isoquercitrin, α-solanine, α-chaconine,</td>
<td>Phytopathogenic organisms</td>
<td>Solanum tuberosum.</td>
<td>PANE et al., 2020.</td>
</tr>
<tr>
<td>Saponins.</td>
<td>Other</td>
<td>Quillaja saponaria</td>
<td>ADOMAITI et al., 2020.</td>
</tr>
</tbody>
</table>

Although, the main form of control still is based on the treatment with agrochemical products, the employment of these substances has been questioned, due to adverse impacts, such as the emergence of resistant species, residue of great persistence in the environment and damage to other organisms. In this context, alternatives to the seed treatment have been suggested and researched, among them, there is the employment of plant extracts (GHIMIRE et al., 2020; ALSAHLI et al., 2018).

Of the studies that identified substances present in plant extracts to the application on seeds, it was noticed that *Allium sativum* L. had a great relevance among the pieces of research (Table 3). Mangawende et al. (2019) evaluated the effects of *Allium sativum* L., *Carica papaya* L., *Datura stramonium* L., *Lantana camara* L., *Tagetes minuta* L and *Zingiber officinale* Roscoe *in vitro* and *in vivo* extracts on the seed treatment of *Coriandrum sativum* L and *Alternaria alternata* (PPRI 18133) and identified that *A. sativum* L and *Z. officinale* R. presented similar effects, which are comparable to the synthetic fungicide Celest® XL. The fungicide effects of both extracts were attributed to some metabolites, such as dialil tio sulfinate and S-alil-L-cysteine sulfoxide.

ANŽLOVAR et al. (2020) evaluated extracts and the essential oil of *Solidago virgaurea*
Table 3 - Main isolated compounds in studies with plant extracts and their effects in the seed treatment.

<table>
<thead>
<tr>
<th>Main described compounds</th>
<th>Effect in agriculture</th>
<th>Species/Gender of the plant</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetradecanoic acid, Pentadecanoic acid, hexadecanoic acid, phytol, linalool, 1,8-cineole and 9, 12, 15-octadecanoic acid.</td>
<td>Phytopathogenic organisms</td>
<td>Chrysanthemum frutescens; Thespesia populnea var. Acutiloba</td>
<td>DERBALAH et al., 2012.</td>
</tr>
<tr>
<td>Butane, 1,1-diethoxy-2-methyl-; 4-Hydroxy-3-methylacetophenone; 3,7,11,15-Tetramethyl-2-hexadecen-1-ol; 2-decen-1-ol; 1-tridecene; Tridecanoic acid, Methyl ester; n-Hexadecanoic acid; Hexadecanoic acid, Ethyl ester; Phytol; 9,12-Octadecadienoic acid (Z,Z); 9,12,15-Octadecatrienoic acid, Methyl ester (Z, Z, Z); 4-tridecene, (Z); Phthalic acid, 2-methoxyethyl tetradecyl ester; 2-hexanone, 5-methyl, Z-2-dodecenol, Nonanoic acid; Oxalic acid, Dodecyl 2-methylphenyl ester; Methyl methane; Sulfite of (+)-phytol, linalool, 1,8 cineole; Lyanol; 1-ol; 2-tetra, cineol and 9, 12, 15-methyl-1-ol; 2Methyl methanoate; Propan; 1,1-diethyl-; 1-desoxy-d-altritol; 2- Mercaptothiazole; 8-Phellandrene; Cycloheptasiloxane tetracemethyle; Diethylcarbonyl-dicarbonyl-cyclo-diether; 1,4-tetra-cosamethyl-cyclo-dioxide; Tetratetracontane; Hexadecanoic acid methyl ester; Cyclononoxiloxane octadecamethyl; 6-Dodecatrien-3-ol, 3,7,11-trimethyl; Caryophyllene; 9-Octadecenoic acid (Z); 2,6-Octadecen-1-ol; 3,7 dimethyl acetate; Butanoic acid; α-Torbinsol acetate; MO-INOSITOL; 1,8 cineole; Lycan; 3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl); 3-cyclohexene-1-methanol, α-4-trimethyl-1-methyl</td>
<td>Phytopathogenic organisms</td>
<td>Allium sativum L</td>
<td>MUTHUKUMAR et al., 2010.</td>
</tr>
<tr>
<td>Curcumin, camphor, tumerone.</td>
<td>Resistance Induction</td>
<td>Curcuma longa L</td>
<td>ALSAHLI et al., 2018.</td>
</tr>
<tr>
<td>Orientine, Luteolin, Veratic acid, Chlorogenic acid, Protocatechuic acid, p-Coumaric and Ferulic acid.</td>
<td>Herbicide effect</td>
<td>Miscanthus sacchariflorus</td>
<td>GHIMIRE et al., 2020.</td>
</tr>
<tr>
<td>AgNPs</td>
<td>Other/herbicide effect</td>
<td>Ficus racemosa</td>
<td>SNEHA et al., 2020.</td>
</tr>
<tr>
<td>α-Pinene, Humulene epoxide II</td>
<td>Phytopathogenic organisms</td>
<td>Solidago spp.; Fallopia japonica</td>
<td>ANZLOVAR et al., 2020; JANES; DOLENC, 2020</td>
</tr>
</tbody>
</table>

L., Solidago canadensis L and Solidago gigantea Aiton and Fallopia japonica against fungi associated with wheat seeds, such as Alternaria alternata, Alternaria viridiosporia, Aspergillus flavus, Epicoccom nigrum and Fusarium poae. The authors determined that the extracts of S. canadensis promoted 61.8% of inhibition, 47.1% to S. gigantea and 56.9% to S. viridiosporia, against F. poae. The evaluation of the extracts of the Solidago spp. species, through GCMS, demonstrated that among their main chemical constituents, the terpenes are present, mostly the α-pinene, germacrene D and the bornyl-acetate.

SNEHA et al. (2020) synthesized silver nanoparticles (AgNPs), which contained extracts of different plant parts of Ficus racemosa, in order to determine the antifungal activity against Bacillus subtilis and Staphylococcus equorum, and in the spraying of Triticum aestivum L seeds. The authors confirmed the AgNPs antibacterial activity and the effect on the spraying of wheat seeds, which demonstrates the potentiality of the employment of plant extracts under different optics for application.

GHIMIRE et al. (2020) evaluated the allelopathic potential on the extracts of Miscanthus sacchariflorus on the concentrations of 100, 1000 and 10000 ppm in the spraying, plant growth, biomass and biochemical parameters of weeds (Chenopodium album, Bidens frondosa, Amanthus viridis, Artemisia princeps var. Orientalis, Commelina communis, Oleoothera biennis Erigerononensis, Digitaria ciliata and Echinochloa cramo). The employment of leaves’ extracts of M. sacchariflorus...
suppressed 100% of the sprouting of weed seeds, reduced the root length, aerial part, the mass of the fresh material, the mass of the dry material and the content of photosynthetic pigments and affected directly the leakage of electrolytic ions, aside from stimulating antioxidant enzymes activity. The GCMS analysis revealed the presence of 22 phenolic compounds, with the emphasis being placed on orientin, luteolin, veratric acid, chlorogenic acid, protocatechuic acid, p-Coumaric acid and ferulic acid, considering that the results were directly proportional to the used concentrations.

ALSAHLI et al. (2018) proved both fungicidal and resistance inductor actions on Curcuma longa L. extracts, in the seed treatment of Helianthus annus L to control the root rot of Fusarium solani (Mart.) Sacc. The GCMS analysis revealed the presence of three main compounds, ar-curcumin, camphor and α-turmerone. The authors determined, besides the reduction in the severity of diseases, the greater growth of sunflower plants. The increase in enzyme peroxidase and ammonia phenylalanine was verified, which indicated the resistance induction. The PCR (polymerase chain reaction) analysis showed the presence of three protein defence regulator genes (glutathione S-transferase 6, ascorbate peroxidase e defensin).

Taking into account the main substances identified by these pieces of research with plant extracts to seed treatment, the phenolic compounds and the terpenes stand out, with the application of controlling Phytopathogenic organisms, insects, herbicide and resistance induction (Table 3).

On account of different potentialities of plant extracts to the employment of agriculture, and considering that they were pointed out in pieces of research over the last ten years, researchers have been trying to identify and isolate compounds that are present in these extracts, including for the application in seed treatment (GHIMIRE et al., 2020; SNEHA et al., 2020; ANŽLOVAR et al., 2020).

It is of paramount importance to discuss the differences in the activities of plant extracts that can be attributed to the different photochemical groups synthesized by plant species. On the other hand, the methodologies employed during the preparation of extracts and their identification are defining and must be the focus of the development of future studies.

In light of all the aspects that were exposed in this review, it is possible to affirm that alternative treatments on seeds, such as the plant extracts employment, are effective and encouraging. It is noticeable that the majority of the studies with plant extracts to the different approaches on the application in agriculture, published in the last 10 years, in particular for seed treatment, support their results exclusively in literature, and just a few of them that determined or identified active substances in the extracts. It was observed that the phenolic compounds and terpenes have been the classes of metabolic composites that are important to the application in agriculture, especially in seed treatment, with emphasis on the control of Phytopathogenic organisms and insects.

CONCLUSION

The period between 2015 and 2020 presented the higher indexes on publication of pieces of research that explored plant extracts in agriculture, seeking to identify or quantify the presence of metabolic composites, indicating a growing interest in this theme. Among the main classes of active composites in plant extracts, the phenolic compounds with different functions, effects and applications in agriculture stand out, mainly in the seed treatment. The terpenes also showed huge potential in relation to the bioinsecticide action. Plant extracts of plant species that are rich in phenolic compounds and terpenes are a significant and promising source to function in the alternative biocontrol of several cropping systems.

In brief, it is observed that the employment of plant extracts for different applications in agriculture, striving for replacing and reducing the use of agrochemicals, consequently, employing ecologic strategies for handling productive systems, has received a lot of attention from researchers in the last few years.

ACKNOWLEDGEMENTS

The present research was performed with support of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) Finance Code 001.

DECLARATION OF CONFLICT OF INTEREST

The authors declare there is no conflict of interest. The funders did not have any role in the design of the study; in the collection, analysis or interpretation of the data; in the writing of the manuscript and in the decision of publishing the results.

AUTHORS’ CONTRIBUTIONS

All authors have contributed equally to the design and writing of the manuscript. All authors have critically revised the manuscript and approved the final version.
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Compounds identified in plant extracts applied to agriculture and seed treatment.