



Plant extracts in agriculture and their applications in the treatment of seeds

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ABSTRACT: *The harmful effects caused by the use of toxic substances in agriculture have led to the development of alternative solutions, and researchers have focused on understanding the effectiveness and potential of plant extracts in agriculture. The aim of this systematic review was to understand the situation of research and scientific dissemination, as well as how current science has approached the use of plant extracts in agriculture, especially in seed applications. There is potential on the use of plant extracts in agriculture, demonstrated by a high number of publications over the last ten years, especially in the years 2018, 2019 and 2020, and Brazil stands out as the main country on this research area. Control of phytopathogenic microorganisms, insect control, biostimulant effect, resistance induction and herbicide effect have been the main themes explored for use in agriculture. The direct application of plant extracts is centered on plants and seeds, being this latter mainly focused on the control of phytopathogenic organisms and biostimulating effect.*

Key words: *biostimulant effects, insect control, phytopathogenic organisms, seed health.*

Extratos vegetais na agricultura e suas aplicações no tratamento de sementes

RESUMO: *Em resposta aos efeitos nocivos da utilização de substâncias tóxicas na agricultura, a ciência tem avançado no desenvolvimento de soluções alternativas, visando compreender a eficácia e o potencial de extratos vegetais na agricultura. Objetivou-se com esta revisão sistematizada compreender a situação da pesquisa e divulgação científica, bem como a maneira que a ciência atual tem abordado o uso de extratos vegetais na agricultura, especialmente na aplicação em sementes. O uso de extratos vegetais na agricultura tem potencial demonstrado pelo elevado número de publicações nos últimos dez anos, com destaque para os anos de 2018, 2019 e 2020, sendo o Brasil o país de maior produção de trabalhos voltados à essa área de estudo. Os temas controle de microrganismos fitopatogênicos, controle de insetos, efeito bioestimulante, indução de resistência e efeito herbicida tem sido os principais temas explorados para uso na agricultura. A aplicação de extratos vegetais é centrada principalmente em organismos fitopatogênicos associados a plantas e sementes, sendo que, para a aplicação em sementes, o foco está no controle de organismos fitopatogênicos e efeito de promoção de crescimento.*

Palavras-chave: *controle de insetos, promoção de crescimento, organismos fitopatogênicos, sanidade de sementes.*

INTRODUCTION

The process of agriculture expansion and the greater demand for food in recent years led to the rise in the use of synthetic products that are toxic for the management of production fields, which has been triggering a set of problems to the environment, farmers and consumers (SCHÜTTE et al., 2017).

Given the need for the application of ecological strategies in agriculture, there is an increasing interest in research in different areas, which aim to explore the potentialities of the plant extracts in agriculture (ARSHAD et al., 2019; AL-MOHMADI; AL-ANI, 2019). The plant extracts acts

as inducers of resistance in plants (COSTA et al., 2019), as biostimulants (COZZOLINO et al., 2020), have herbicide effect (ZAKA et al., 2019; FINDURA et al., 2020), nematicides (MÜLLER et al., 2016; COLTRO-RONCATO et al., 2016) and insecticides effects (PAVELA et al., 2018); and especially, fungicide effect for the control of phytopathogenic organisms (MEENA et al., 2020; NCISE et al., 2020).

There are innumerable potentialities for plant extracts in agriculture. The application in seed treatment has been explored as an alternative (KARABÜYÜK & AYSAN, 2019) for diverse purposes, especially in the control of phytopathogenic organisms linked to seeds. (MANGWENDE et al.,

2019; CHANDEL & KUMAR, 2017). Other purposes are biostimulant effect on germination and initial seedling establishment (RAFI et al., 2015), inducers of resistance in seedlings after emergence (ALSAHLI et al., 2018) and bioherbicides effect when related to the establishment of spontaneous plants (FINDURA et al., 2020; KAAB et al., 2020).

In agriculture, the seed has an important role, since it corresponds to the beginning of the stage of formation of an agricultural production field, and its quality can be affected by the presence of phytopathogenic organisms and pests (MAXIMIANO et al., 2018; PARIKH et al., 2018) which can damage the seeds during storage (WORDELL FILHO et al., 2016). Therefore, searching for a more sustainable agriculture, plant extracts have also been tested as an important tool for seed treatment (KAMRAN et al., 2013; CHANDEL & KUMAR, 2017; OJO et al., 2020).

Despite the intensification in the number of studies that aim to understand the efficacy and potential of plant extracts, this information is still very specific to the biological systems analyzed, without encompassing the production systems and all potentialities of application, generating gaps that need to be better understood. For this, in addition to the application of plant extracts, it becomes necessary to understand how and where the research in this field has been performed and disseminated, generating useful information for planning, executing and publishing future research directed to the use of plant extracts in agriculture, focusing on the application in seeds.

Given the above, the aim of this research was to understand, by a systematic review, the situation of research and scientific dissemination, as well as how current Science has been approaching the topic of the use of plant extracts in agriculture, especially the application in seeds.

Development

For the accomplishment and constitution of the scope of this systematic review, articles indexed in the database *Web of Science* were selected, since it is the main worldwide database for the indexing of articles linked to journals with high international visibility.

For a better definition of the terms for the search, previous searches were performed using different strategies based on boolean operators, using basic search, with a time frame from 2010 to August 2020. After the analysis of this search and evaluating the articles aligned with the topic of the review, the following set of key terms was defined: “plant* extract*” and agriculture; “plant* extract*” and “seed* treatment*”; “plant* extract*” and “alternative control*”; “plant*

extract*” and “seed germination” and “plant* extract*” and seed fungi. The inclusion criterion was defined as only those studies applied and directly related to the use of plant extracts in agriculture and; therefore, articles of review, and of the fields of zootechnics, medicine, fishing engineering, veterinary and researches that were not related to the subject in question were not selected.

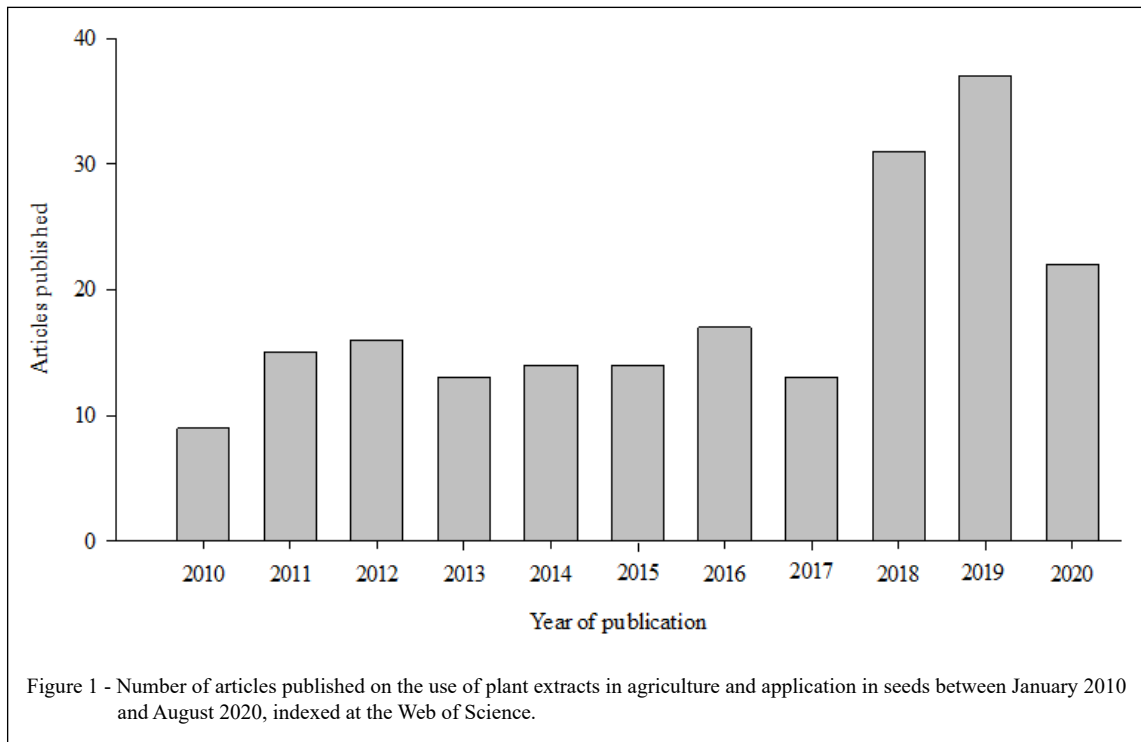
Therefore, 283 articles were selected, which were dealing with and making reference to the subject of study of this review. They were once more evaluated, excluding 82 duplicated, totalizing 201 studies in the final scope of the systematic review that were identified in relation to the year of publication, associated journal and countries in which the research was developed.

Subsequently, the guiding criteria and topics for data analysis were defined, namely: 1st Use in agriculture: (A) Insects: control of insect pests/ effect on the biology of insects/insect repellency; (B) Phytopathogenic organisms: control of diseases/effect on the biology of fungi/bacteria/nematodes (in vitro/ in vivo/both); (C) Herbicide effect: allelopathic effect/ control of plants; (D) Resistance induction: resistance to insects/pathogens/abiotic factors; (E) Biostimulant effect: growth promotion effect/production; (F) Others; 2nd Application: (A) Plant (in vitro/in vivo/both); (B) Postharvest (in vitro/in vivo/both); (C) Seeds (in vitro/in vivo/both) and (D) Others. 3rd Use intended for application in seeds: (A) Phytopathogenic organisms; (B) Pests; (C) Resistance; (D) Biostimulant and (E) Others.

The quali-quantitative analysis of the selected articles was performed using the bibliometric indicators, with the discrimination of the following items: title, year of publication, journal, country of research, topic in agriculture, application, and application in seeds. The data were subjected to analysis in Rstudio version 2020, and graphs and word clouds were created.

Regarding the year of publication, the highest frequency was verified in 2019, followed by 2018. A great number of publications was observed until August 2020, with the prediction that, until the end of the year, they would outnumber those of 2019. On the other hand, between years 2010 and 2017, a stability was observed in relation to the number of articles published on this topic (Figure 1).

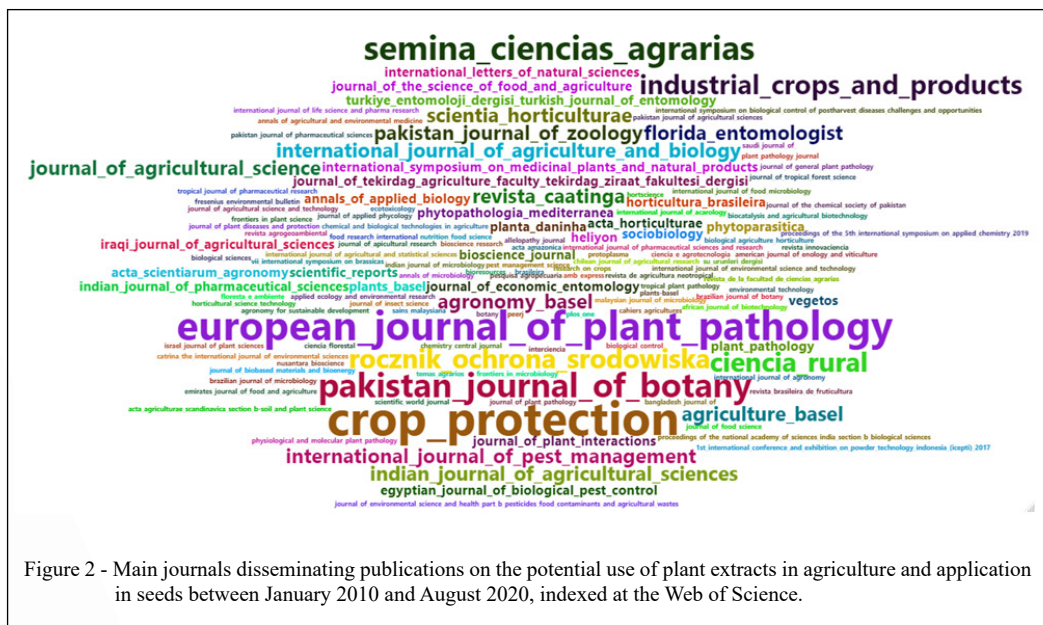
In recent years, one of the main demands of the population and a challenge faced by the agricultural sector is the need for safer and more sustainable approaches regarding the management of agricultural production systems in view of the harmful effects generated by the high toxicity and low biodegradability of diverse synthetic agrochemicals used (BOITEUX et al., 2019). An increase in the visibility of researches using plant extracts in agriculture is then perceived,



demonstrating potential alternatives for application in production systems (KHAN et al., 2020; CONFORTIN et al., 2019).

A total of 133 journals were identified publishing articles on the use of plant extracts in

agriculture, with *Crop Protection* presenting the highest frequency of publications, followed by the journals *European Journal of Plant Pathology*, *Pakistan Journal of Botany* and *Semina-Ciências Agrárias* (Figure 2).



These journals present international impact and visibility; nevertheless, 13.9% were Brazilian journals and 86.06% were journals published in other countries. The national journals present major importance not only in the dissemination of national studies, since they connect a great number of studies generated and developed in other countries on the topic of plant extracts in agriculture and in the treatment of seeds.

It was observed that, among the countries which presented the greatest frequency of publications referring to the potentialities of the use of plant extracts in agriculture and application in seeds over the past ten years are Brazil (20.4%), India (11.44%) and Pakistan (9.4%) (Figure 3A and 3B). In Latin America, Brazil leads the ranking of investments in agricultural research exactly for having a well-defined vocation and agricultural profile, with many Universities and Research Centers exclusively dedicated to scientific development in the field of Agrarian Sciences.

The Brazilian productive leadership is related, primarily, to technological aspects, but also to the edaphoclimatic characteristics and; especially, to the availability of production fields. Nonetheless, a great part of this production is still based on the use of pesticides (SOARES et al., 2019), boosting

investments in research on alternative technologies and ecological strategies aimed at agriculture (PEREIRA et al., 2018).

Another relevant factor is that in Brazil, great part of food production is derived from family agriculture or of small rural producers, who in turn have also practiced an agroecological-based agriculture (PEREIRA et al., 2018), using alternative sources for the control and management of pests and diseases, including the use of plant extracts (BARBOSA et al., 2015).

A similar situation is observed in India and in Pakistan (LAKSHMEESHA et al., 2019; KHAN et al., 2020), with researches aiming the use of plant extracts in agriculture for the control of phytopathogenic organisms (MEENA et al., 2020), insects (ZAKA et al., 2019), treatment of seeds (ATRI & TIWANA, 2019) and resistance induction (NARASIMHAMURTHY et al., 2019). Similar to what occurs in Brazil, family farming has great relevance in these two countries, making possible the use of alternative methods, such as plant extracts, for the management of the agroecosystem.

Considering the topic in agriculture, approximately 58.7% of the works explored the potential of plant extracts on phytopathogenic

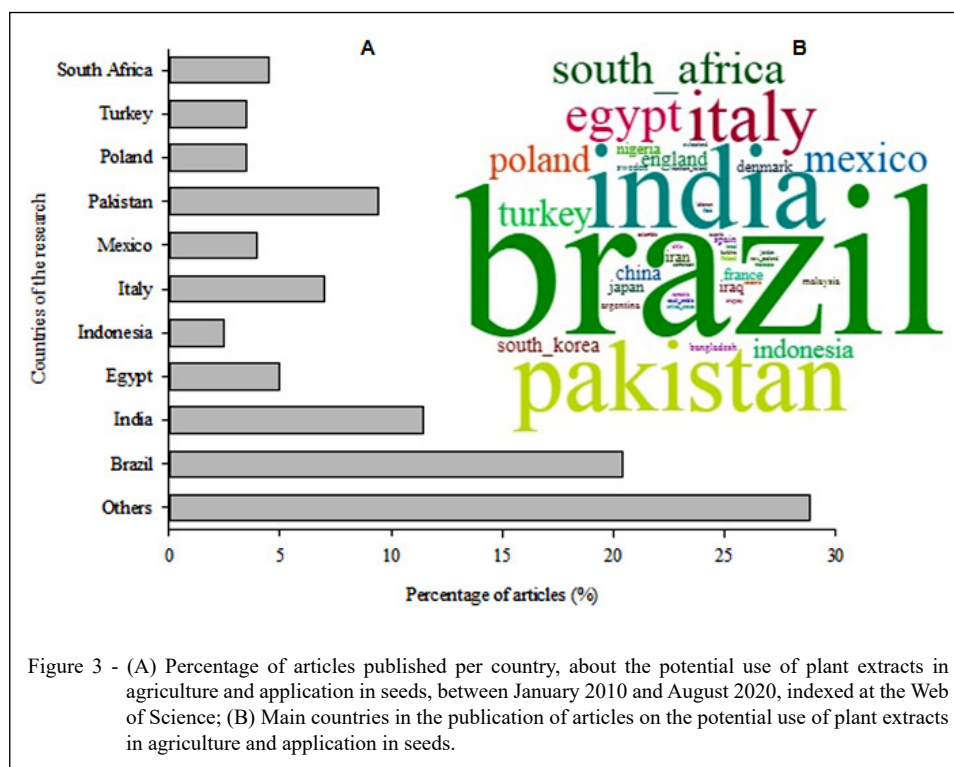


Figure 3 - (A) Percentage of articles published per country, about the potential use of plant extracts in agriculture and application in seeds, between January 2010 and August 2020, indexed at the Web of Science; (B) Main countries in the publication of articles on the potential use of plant extracts in agriculture and application in seeds.

organisms, either in the control of diseases in plants, as the effects on the biology of fungi (SILVA et al., 2020), of bacteria (KARABÜYÜK & AYSAN, 2019) or nematodes (SAHAYARAJ et al., 2018) (Figure 4A). Furthermore, it is observed that approximately 20% of the researches aimed the use for control, biology or repellency of insects (ZAKA et al., 2019; OJO et al., 2020), 12.43% of the researches explored the biostimulant effect in plants (COZZOLINO et al., 2020; MOLA et al., 2019), demonstrating a potential use in agriculture still little explored.

Other two applications also discussed in some articles; although, in smaller volume, were the use of plant compounds as a triggering source of natural resistance-inducing genes against phytopathogenic organisms, resistance to insects and abiotic factors (6.46%) (ALSAHLI et al., 2018) and herbicide or allelopathic effect on plant control (4.97%) (FINDURA et al., 2020), especially in the

management of spontaneous plants in horticulture (CASER et al., 2020).

Considering the application in agriculture, 34.84% of the studies evaluated the potential of the application directly in plants, being 23.9% under conditions *in vivo* and 10.9% under conditions *in vivo* and *in vitro* (Figure 4B). This evidenced the importance of understanding the direct application of plant compounds as potential alternative sources in agriculture for interactions plant/plant extracts and plant/plant extracts/phytopathogenic organisms. AL-MOHMADI and AL-ANI (2019) evaluated the effect of direct leaf application of licorice (*Glycyrrhiza glabra* L.) extract on the growth and productivity of grains of Sorghum cv. Rabih, and reported an increase in plant height and in the productivity of grains in the period of Spring and Fall, when the sorghum plants were sown at high density.

The potential of the direct application of plant compounds has also been explored in

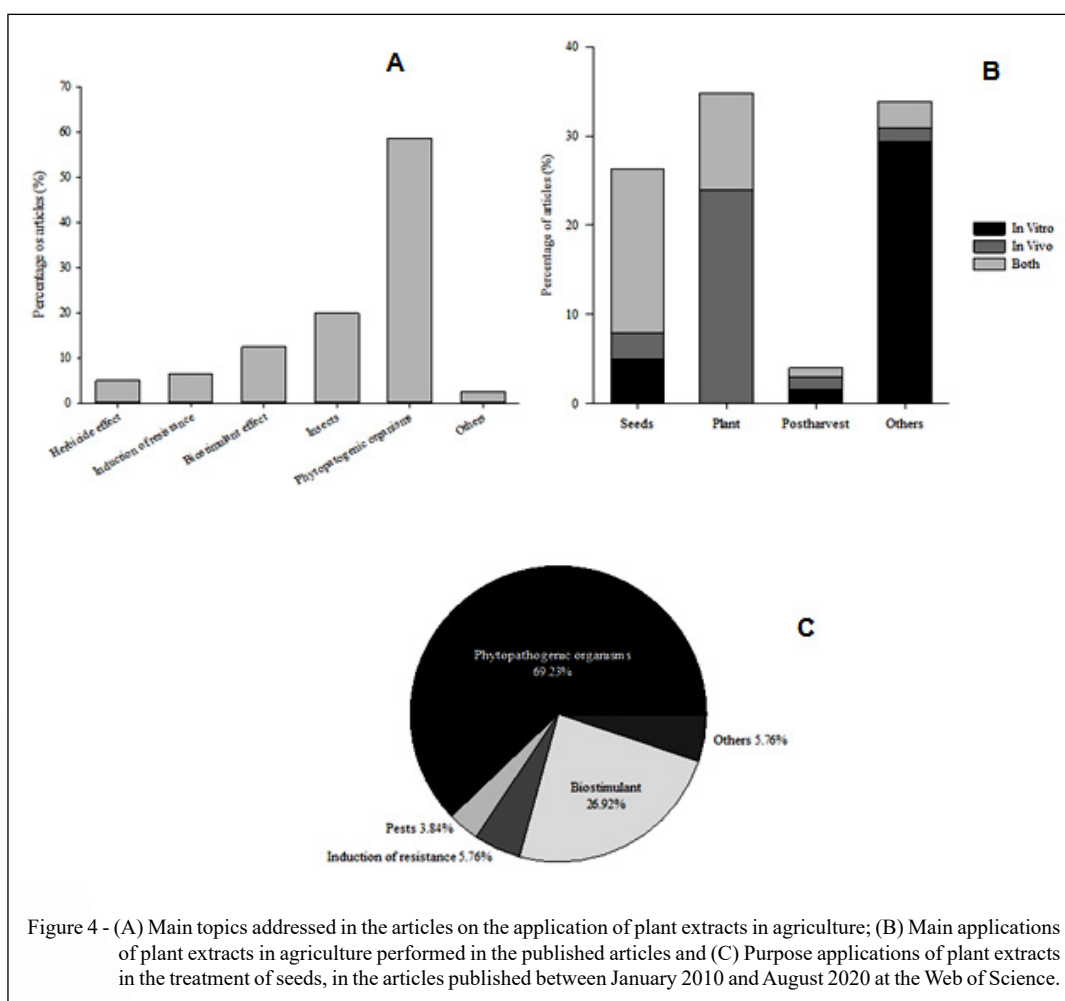


Figure 4 - (A) Main topics addressed in the articles on the application of plant extracts in agriculture; (B) Main applications of plant extracts in agriculture performed in the published articles and (C) Purpose applications of plant extracts in the treatment of seeds, in the articles published between January 2010 and August 2020 at the Web of Science.

vegetables, such as, for instance, in the study of JANG and KUK (2019), who evaluated the effect on the growth of lettuce, broccoli, endive and kale subjected to leaf spraying of 31 plant extracts from agricultural materials. These authors verified an increment from 31 to 45% in the fresh weight of lettuce sprayed with aqueous extract of *Allium tuberosum*, aqueous extract of *Glycine max* (cvs. Daewon and Haepum) leaves, fermented, aqueous and ethanolic extract of soybean (cv. Daewon) stems at the concentration of 5% when compared to the application of urea at 0.6, 0.8 and 1%.

KARABÜYÜK & AYSAN (2019) evaluated the effect of the treatment of seeds and the pulverization of tomato plants with twenty-nine plant extracts against the bacterial spot caused by *Pseudomonas syringae* pv.. Leaf pulverization at the concentration of 4.25 µl/ml of *Allium sativum*, *Eucalyptus camaldulensis*, *Origanum onites* and *Zingiber officinale* extracts reduced the incidence of the disease in 96-99% for all extracts, and when applied to the root, it was suppressed in 80-100% without promoting negative effects on the germination.

In a broader approach, SINGH et al. (2019) performed the treatment of seeds and plants of basmati rice with carbendazim, *Trichoderma harzianum*, *Pseudomonas fluorescens* and extract of *Sesbania punicea* (Cav.) Benth. against *Meloidogyne graminicola*, and verified that all treatments were efficient in the reduction of the population of nematodes; nevertheless, when applied *in vivo*, the extract of *Sesbania* increased the biomass of the rice plant in up to 68% in comparison with the other treatments. In addition to providing greater tolerance of the plant to *M. graminicola*, with a 37.7% reduction in the population of nematodes.

It is worth pointing out that, for other applications in agriculture, as well as for the topic in agriculture from the articles analyzed, there is a higher predominance of studies analyzing the direct effect in phytopathogenic organisms *in vitro* (OJO et al., 2020). Furthermore, 3.98% of the researches evaluated the potential of application in the postharvest sector, especially as organic coating and treatment of fruits (KOLTZ et al., 2020; BOITEUX et al., 2019; HERNÁNDEZ-GUERRERO et al., 2020).

The application of plant extracts in the treatment of seeds is also highlighted with 26.86% of the total of published articles (Figure 4B). Of them, as in the studies of application in plants, more than 68.5% have been performed under conditions *in vitro* + *in vivo*, 10.76% *in vivo* and 18.5% under condition *in vitro*.

Phytopathogenic organisms directly interfere in seed quality, affecting the initial

development of seedlings and the final establishment of production fields (ROCHA et al., 2020). Additionally, great part of the diseases that occur in adult plants derived from causal agents associated with seeds, making preventive management extremely important. This is reflected on the highest percentage of articles with this purpose (69.29%) among the total of researches that address the use of plant extracts in seeds (Figure 4C). Other applications of the plant extracts in seeds include the use as biostimulant (26.92%), in resistance induction (5.76%) and in pest control (3.84%).

Regarding the management of fungi associated with the seeds, CHANDEL and KUMAR (2017) studied the effect of eleven plant extracts on rot fungi of storage *Aspergillus* sp., and of field *Alternaria alternata*, *A. solani*, *Phoma* sp and *Fusarium* spp. and on the parameters of germination and vigor in pea (*Pisum sativa*) seeds and seedlings. The use of *Vitex negundo* and *Melia azadirachta* extracts at the concentration of 30% presented minimum rot of 1.94% compared to the untreated seeds (13.84%), with maximum germination superior to 96.41% for extracts of *Mentha piperata* and *Tagetes erecta*.

Considering that the first signs of defense in the plants are triggered still in the seed, by the activation of preventive local and systemic defense mechanisms in plants against pathogens, ALSAHLI et al. (2018) verified higher enzyme activity of guaiacol peroxidase (POX), phenylalanine ammonia lyase (PAL) and genes coding for defense in sunflower plants after the treatment of seeds with *Curcuma longa* L. extracts at the concentration of 10% against *Fusarium solani*. CHANDRASHEKHARA et al. (2010) verified significant increases in the parameters of quality and induction of resistance to mildew (*Sclerospora graminicola* [Sacc.] Schroe) in millet seeds (*Pennisetum galauicum* R. Br.) subjected to the treatment with extracts of *Azadirachta indica*, *Argemone mexicana*, *Commiphora caudata*, *Mentha piperita*, *Emblica officinales* and *Viscum album*.

The occurrence of pests in seeds during storage is another factor of great relevance for the agricultural sector. OJO et al. (2020) evaluated the efficiency of root and stem extracts of *Cleistopholis patens* (Benth) in the protection of cowpea seeds against infestation by *Callosobruchus maculatus* during storage and they reported mortality of 77.05% of the insects for a dose of 5% in a period of 24 hours after application for stem extract, at the same time that there were 50 and 95% of mortality of the insects subjected to root extract, as well as a reduction in oviposition and emergence of adults, at the same concentration.

Considering the various applications that have been explored in the studies with plant extracts, the use in the treatment of agricultural soils and potential natural sources of nitrification inhibitors can also be highlighted (MUÑOZ et al., 2014).

Among the main species and genera of plants used with potentialities of application in

agriculture and in the treatment of seeds, *Azadirachta indica* A. Juss. (11.94%), *Allium sativum* L. (7.46%) and *Eucalyptus* sp. (4.97%) were the most frequently studied (Table 1).

The genera *Acacia* sp., *Brassica* sp. and the species *Melia azedarach* L., *Rosmarinus officinalis* L. and *Zingiber officinale* R. were identified in 2.48%

Table 1 - Main species/genera used in studies on the potential of application of plant extracts in agriculture and in the treatment of seeds, in the articles published between January 4th 2010 and August 2020 at the Web of Science.

Specie/genera	Application in agriculture	Frequency (%)	References
<i>Azadirachta indica</i> A. Juss.	Phytopathogenic organisms; insects; biostimulant effect.	11.94	FEREIRA et al., 2014; ZAKA et al., 2019; FREIRE; SANTOS, 2018; HASSAN et al., 2013; KUMAR et al., 2012; SINGH; SINGH; PARMAR, 2013; KUMAR et al., 2011; NAHAR; SHAMSI, 2020; NNEDINMA et al., 2019; ARSHAD et al., 2019; AL-SAMARRAI et al., 2012; JALEEL et al., 2020; AHMED et al., 2019; MEENA et al., 2020; FIAZ et al., 2012; PODEROSO et al., 2016; ATRI; TIWANA, 2019; MAHMUD; HOSSAIN, 2017; REHMAN et al., 2019; TANVEER et al., 2016; GARCIA et al., 2019; HUSSAIN et al., 2015; EZEONU et al., 2018; DA SILVA et al., 2014.
<i>Allium sativum</i> L.	Phytopathogenic organisms; insects.	7.96	BOULOGNE et al., 2012; KARABUYUK; AYSAN, 2019; CHAND et al., 2016; KARABUYUK; AYSAN, 2018; SALJOQI et al., 2012; MAHMUD; HOSSAIN, 2017; MANGWENDE; KRITZINGER; AVELING, 2019; SINGH; et al., 2013; MUTHUKUMAR et al., 2010; UMARUSMAN; AYSAN; OZGUVEN, 2019; SHIFA; GOPALAKRISHNAN; VELAZHAHAN, 2018; RUIZ-COUTIÑO et al., 2019; LIMA et al., 2016; VIOLETH; HERRERA; Garcia, 2018; GOYAL; SHARMA, 2012; SAS-PIOTROWSKA; PIOTROWSKI, 2011.
<i>Eucalyptus</i> sp.	Phytopathogenic organisms; insects; herbicide effect; others.	4.97	HAMAD et al., 2019; KARABUYUK; AYSAN, 2019; KARABUYUK; AYSAN, 2018; SILVA; ANDRADE; BETTIOL., 2020; SHAPIRO-ILAN et al., 2013; KHAN et al., 2020; MUNOZ; QUILODRAN; NAVIA, 2014.
<i>Syzygium aromaticum</i> (L.) Merr. & L. M. Perry	Phytopathogenic organisms; others; insects.	3.98	HAMAD et al., 2019; SILVA et al., 2014; LAKSHMEESHA et al., 2019; CARMELLO; CARDOSO, 2018; UMARUSMAN; AYSAN; OZGUVEN, 2019; RUIZ-COUTIÑO et al., 2019; MASANGWA; AVELING; KRITZINGER, 2013; ZAKA et al., 2019.
<i>Curcuma longa</i> L.	Phytopathogenic organisms; biostimulant effect; insects; resistance induction.	3.98	MAMARABADI; TANHAEIAN; RAMEZANY, 2018; CHAND et al., 2016; TANVEER et al., 2016; SALJOQI et al., 2012; SIDDIQUE et al., 2019; ALSAHLI et al., 2018; HAN et al., 2018; FU et al., 2018.
<i>Cymbopogon citratus</i> (D.C.) Stapf.	Herbicide effect; phytopathogenic organisms; resistance induction; insects; mites.	3.48	SILVEIRA et al., 2010; CHAND et al., 2016; PEREIRA et al., 2012; REHMAN et al., 2019; NGUEFACK et al., 2013; VICENTINI et al., 2015; MANDIRIZA; KRITZINGER; AVELI, 2018.
<i>Lippia</i> sp.	Herbicide effect; insects; phytopathogenic organisms.	3.48	SILVEIRA et al., 2010; PHAMBALA et al., 2020; PODEROSO et al., 2016; RODRIGUEZ et al., 2011; MONTEIRO et al., 2014; TEMBO et al., 2018; FERREIRA et al., 2014.
<i>Acacia</i> sp.	Phytopathogenic organisms; biostimulant effect.	2.49	BAKA; RASHAD, 2016; TANVEER et al., 2016; HUSSAIN et al., 2017; HASSAN et al., 2013; RAFI; DAWAR; ZAKI, 2015.

of the analyzed researches (Table 1 and 2), whereas the genera *Citrus* sp., *Piper* sp., *Capsicum* sp., *Cinnamomum* sp. and the species *Punica granatum* L., *Ocimum basilicum* L., *Nicotiana tabacum* L. and *Carica papaya* L. were represented in 1.99% of the studies with applications in agriculture and in the treatments of seeds (Table 2).

The data indicated an increasing trend in the search for more sustainable strategies and with potential application in agriculture for different purposes, especially in the treatment of seeds. Among these strategies, plant extracts are indicated as viable alternatives to conventional treatments, promoting the rise in quality and reduction in the costs of the agricultural cultivations, minimizing the impacts

in the ecosystems. Furthermore, it is important to highlight that the proper use of plant extracts will depend on the methodology for making the extracts, the use of appropriate concentration and the number of applications for each expected objective.

CONCLUSION

The use of plant extracts in agriculture has a potential, demonstrated by the high number of publications, especially in the years 2018, 2019 and 2020, with Brazil being the country with the highest production of research directed to this field of study. Control of phytopathogenic organisms, effect in insects, biostimulant effect, induction of

Table 2 - Species/genera used in studies on the potential of application of plant extracts in agriculture and in the treatment of seeds, in the articles published between January 4th 2010 and August 2020 at the Web of Science.

Specie/genera	Application in agriculture	Frequency (%)	References
<i>Melia azedarach</i> L.	Phytopathogenic organisms; insects; mites; biostimulant effect.	2.48	SILVA et al., 2014; MEFTAH ET AL., 2011; ROY; MUKHOPADHYAY, 2012; ATRI; TIWANA, 2019; ARSHAD ET AL., 2019.
<i>Brassica</i> sp.	Phytopathogenic organisms; biostimulant effect.	2.48	KOLTZ et al., 2020; MASHELA; POFU; NZANZA, 2013; HASSAN et al., 2013; MONTEIRO et al., 2014; SZPARAGA; KOCIRA, 2018.
<i>Rosmarinus officinalis</i> L.	Phytopathogenic organisms; insects; others.	2.48	MENGULLOGLU; SOYLU, 2012; DELLAVALLE et al., 2011; RAMOS et al., 2019; KARAASLAN, 2018; MUELLER et al., 2016.
<i>Zingiber officinale</i> R.	Phytopathogenic organisms; resistance induction.	2.48	KARABUYUK; AYSAN, 2019; BHUTIA et al., 2016; COSTA et al., 2019; MANGWENDE; KRITZINGER; AVELING, 2019; ANDAYANIE et al., 2019.
<i>Carica papaya</i> L.	Phytopathogenic organisms; insects.	1.99	MASANGWA; KRITZINGER; AVELING, 2017; HERNANDEZ-GUERRERO et al., 2020; FIGUEROA-BRITO et al., 2011; MASANGWA; AVELING; KRITZINGER, 2013.
<i>Nicotiana tabacum</i> L.	Insects; others.	1.99	BOULOGNE et al., 2012; PHAMBALA et al., 2020; RUIZ-COUTIÑO et al., 2019; PEREIRA et al., 2020.
<i>Citrus</i> sp.	Insects; biostimulant effect; phytopathogenic organisms.	1.99	SHAPIRO-ILAN et al., 2013; MAHAKHAM et al., 2017; LIMA et al., 2016; ZAKA et al., 2019.
<i>Ocimum basilicum</i> L.	Phytopathogenic organisms.	1.99	HAMADET et al., 2019; HUSSAIN et al., 2015; IRAM et al., 2018; AHMED et al., 2010.
<i>Piper</i> sp.	Insects; herbicide effect.	1.99	BALDIN et al., 2015; JALEEL et al., 2020; MENDOZA; CELIS; PACHON, 2014; HARA; SZPARAGA; CZERWINSKA, 2018.
<i>Capsicum</i> sp.	Insects; phytopathogenic organisms; others.	1.99	SALJOQI et al., 2012; MEFTAH; BOUGHDAD; BOUCHELTA, 2011; AI-SAMARRAI; SINGH; SYARHABIL, 2012; RUIZ-COUTIÑO et al., 2019.
<i>Cinnamomum</i> sp.	Phytopathogenic organisms; biostimulant effect; others.	1.99	JANG; KIM; KUK, 2019; CARMELLO; CARDOSO, 2018; FLAVIO et al., 2014; RUIZ-COUTIÑO et al., 2019.
<i>Punica granatum</i> L.	Insects; phytopathogenic organisms; resistance induction.	1.99	POTRICH et al., 2020; QUATTRUCC et al., 2013; Tayel et al., 2016; PANGALLO et al., 2017.

resistance and herbicide effect have been the main topics explored for use in agriculture. The direct application of plant extracts is mainly centered in plants and seeds and, for the application in seeds, the focus is the control of phytopathogenic organisms and biostimulant effect.

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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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