Al-Kitab Journal for Pure Sciences (2023); 7(2):89-98.
https://doi.org/10.32441/kjps.07.02.p8

Al-Kitab Journal for Pure Sciences
ISSN: 2617-1260 (print), 2617-8141(online)

https://isnra.net/index.php/kjps

# Role of Phenolic Compounds in Allelopathic Activity

**Iman Radha Jasim[*1], Hala Muzher Yaqub[1], Faten Khaleel Ibrahim[2]**

[1]Department of Biology, College of Science, Mosul University, Mosul, Iraq.
[2]Department of Environmental Science, College of Environmental Science and Technology, University of Mosul, Iraq

*Corresponding Author: imsbio73@uomosul.edu.iq

**Citation**: Jasim IR, Yaqub HM, Ibrahim FK. Role of Phenolic Compounds in Allelopathic Activity. Al-Kitab Journal for Pure Sciences. 2023 Oct 14;7(2):89-98. Available from: https://doi.org/10.32441/kjps.07.02.p8.

**Keywords**: phenolic compound, secondary compounds, allelopathy.

**Article History**

| | |
|---|---|
| Received | 23 Aug. 2023 |
| Accepted | 04 Oct. 2023 |
| Available online | 14 Oct. 2023 |



## Abstract:

Phenolic compounds are vital plant allelochemical groups in the ecology, multiple parts of plants contain a variety of phenolic compounds these natural compounds help plants defend themselves against predatory plants. Plants' acetic acid and shikimic metabolic pathways produce phenolic chemicals. Additionally, these compounds exhibit a wide variety of structural forms. In many commercial processes, phenolic compounds are utilized to create chemicals including insecticides, explosives, medicines, and colors. Phenolic chemicals are widely used as herbicides for crop protection in an allelopathic approach., insecticides, and fungicides. They are also employed in the bleaching stage of paper production. The major goal of this evaluation is to draw attention to the ability of phenolic chemicals to allelopathic, which can offer us solutions to a variety of ecological issues, particularly those related to the conservation of the environmentally friendly development of forests, farms, with other alternatives to current synthetic pesticides include bioactive plant secondary metabolites by releasing phytotoxic substances from plant cells.

**Keywords:** phenolic compound, secondary compounds, allelopathy.

# دور المركبات الفينولية في الفعالية الاليلوباثية

**إيمان رضا جاسم*١، حلا مزهر يعقوب١، فاتن خليل ابراهيم٢**

١قسم الأحياء، كلية العلوم، جامعة الموصل، الموصل، العراق.

٢قسم العلوم البيئية، كلية العلوم والتكنولوجيا البيئية، جامعة الموصل، العراق

imsbio73@uomosul.edu.iq

## الخلاصة:

الأحماض الفينولية مركبات كيميائية نباتية حيوية في البيئة، تحتوي أجزاء متعددة من النباتات على مجموعة متنوعة من المركبات الفينولية، وتساعد هذه المركبات الطبيعية النباتات في الدفاع عن نفسها ضد الممرضات النباتية وينتج حامض الأسيتيك ومسارات التمثيل الغذائي في النباتات مواد كيميائية فينولية وبالإضافة إلى ذلك تظهر هذه المركبات مجموعة واسعة التراكيب الكيميائية. في العديد من التجارب يتم استخدام المركبات الفينولية لإنتاج مواد كيميائية بما في ذلك المبيدات الحشرية والأدوية والألوان. تستخدم المواد الكيميائية الفينولية على نطاق واسع كمبيدات أعشاب لحماية المحاصيل ومبيدات حشرية، ومبيدات الفطريات. كما أنها تستخدم في مرحلة التبييض لإنتاج الورق. الهدف الرئيسي من هذه المقالة هو التعرف على قدرة المواد الكيميائية الفينولية ، والتي يمكن أن توفر لنا حلولاً لمجموعة متنوعة من القضايا البيئية، لا سيما تلك المتعلقة بالحفاظ على البيئة وتنمية الغابات والمزارع، مع بدائل أخرى تشمل المبيدات الاصطناعية الحالية والنباتات النشطة بيولوجيًا عن طريق إطلاق مواد سامة من الخلايا النباتية.

**الكلمات المفتاحية:** الأحماض الفينولية ، المركبات الثانوية، الاليلوباثي.

## 1. INTRODUCTION:

Allelopathic interactions are caused in different crops or plants via phenolics. It is necessarily important to identify the phenolic compounds and confirm their presence and persistence in the environment throughout time in amounts sufficient to damage plant species, to show the function of phenolic in allelopathy. Any allelopathic substance needs to have its major mode of action determined. Only when a thorough biotic and abiotic variable that influences phenolic toxicity is known can the allelopathic effects of phenolic be acknowledged **[1]**. Due to the long-term cultivation of the same plant species on the same site, phenolic compounds are one of the main categories of phytotoxic chemicals that induce soil sickness. Decomposed plant residues are their source. A young apple orchard with replant disease was found abundant in phenolic compounds **[2]**. The main cause of replanting issues in managed tree ecosystems is autotoxicity.

Plant phenolic may be a significant factor in allelopathy, according to the **[3]** *Ageratum conyzoides* contain p-coumaric, gallic, ferulic, and p-hydroxybenzoic all reported to exhibit phytotoxic properties [4]. The natural evergreen broad-leaf trees did not exhibit any effects from the high soil phenolic levels when compared to leaves, bulbs' aqueous extract and volatile chemicals were far stronger inhibitors of germination and seedling development, seedlings of tested plants ' ability to germinate and thrive was hindered by the soil under the *Allium ursinum* that contained phenolic. both unbound as well as free forms of p-coumaric, ferulic, p-hydroxybenzoic, and vanillic acids found within allelopathic materials in solutions of leaves and buds. Furthermore, *Lantana camara* contains phenolic compounds with substantial allelopathic activity, including nopinene, eucalyptol, D-limonene, and triterpenoids called Lantadenes A and B [5]. These findings imply that *A. ursinum* affects the growth and germination of seeds in other herbaceous plants in the plant community by releasing volatile chemicals into the soil. Twenty-five substances were extracted and identified from the root exudates of rice, phenolic acids with the allelopathic potential of caffeic, p-coumaric, syringic, ferulic, and sinapic are some of the substances already present in oilseed radish [6, 7].

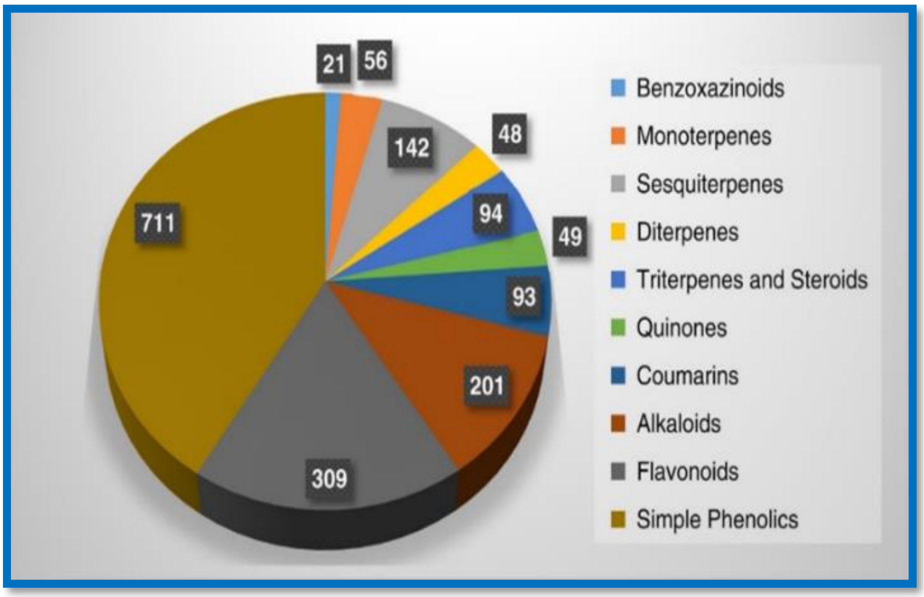


**Fig. 1: Total publications in allele chemicals since 2007 [ 8 ]**

- **Chemical composition**

Phenolics are composed of an aromatic hydrocarbon group and a straight hydroxyl group (-OH) relates to a benzene ring to form phenolic substances a class of chemicals that are essential and naturally occurring allelochemicals of plants within the environment [9]. The pentose-phosphate route is often where phenolic chemicals are produced. In the acetic acid and shikimic process of metabolism, condensation reactions between 4-phosphate erythrose and phosphoenolpyruvic acid, and 7-phosphate altoheptulose result in the production of phenolic chemicals [10].

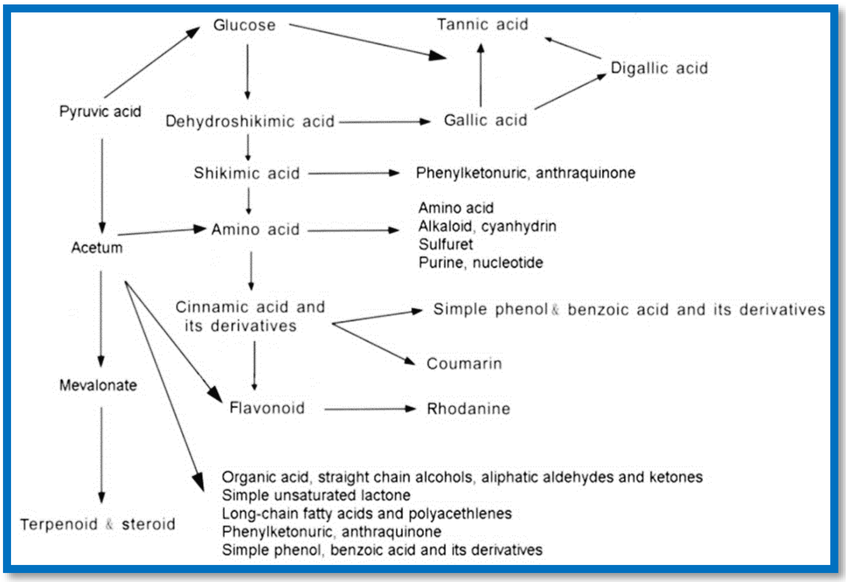


**Figure. 2: Major allelopathic compounds' biosynthetic routes.**

- **Phenolic effect on agriculture**

Allelochemicals such as vanillin and p-hydroxybenzoic, p-coumaric, ferulic, and caffeic in *Bidens pilosa*, covered by bioassays. Several substances in cover plant biomass, those of a phenolic character and produced through the malonic and shikimic acid pathways for plants, have allelopathic effects by decomposing residues that have been deposited on the soil surface, Secondary compounds are released due to plants towards the atmosphere. The method differs depending on the type of plant, kind of soil., and phenological stage **[11, 12]**. For instance, during the breakdown of its phytomass, rye releases a few substances with an allelopathic effect **[13]**, plants primarily create phenolic compounds for the goals of growth, development, and defense. These aromatic benzene ring molecules play an important role in the interactions between the biotic and abiotic stressors on the plant. They are an essential part of a plant's secondary metabolites and necessary for a variety of physiologic and mechanical functions.

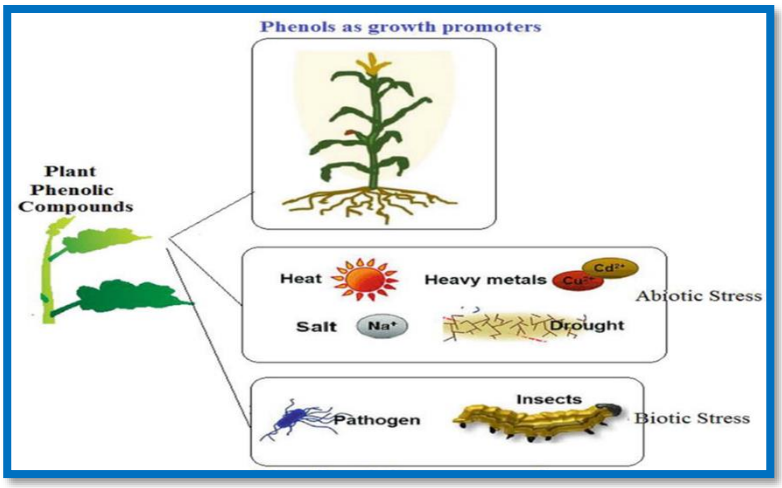


**Fig. 3: phenols as defense compounds**

Extracts of *Peganum harmala* leaf included Gallic acid, vanillic acid, 4-hydroxybenzoic acid, 3,4-dihydroxybenzoic acid, caffeic acid, syringic acid, and ferulic acid. In comparison to stem or root extracts, leaf extracts had a higher total phenolic acid concentration **[14]**.

Buckwheat's ability to control weed growth is attributed to a few phenolic acids and flavonoids **[15]**. Additionally, tomato and maize tissues had more phenolic compounds than buckwheat extracts **[16]**, showing analyze the primary phenolic substances with the potential to cause harm can be found in rye and oilseed radish shoots., The detrimental effects of such plants on weeds should be exploited for increasing crop production. Crop plants and natural vegetation containing phenols with detrimental effects should be screened for their capacity to suppress weeds. When describing the same species in the same experimental location **[16]**, Furthermore, it was discovered that higher levels of cinnamic acid in rye are related to lignification, the procedure that comes after plant leaching, volatilization, and dry matter degradation by soil microbes.

**[17]** In the phonological stage of plants, there may be interactions between bacteria, substances with an allelopathic potential, the nature of the soil, food for plants, pH, climate, and other factors. an impact on the phytotoxicity of those substances. It was also noted that the complete amount of phenols in a liquid extract of oilseed radish remains from a plant's stems and leaves was higher **[18]**, The main allelochemicals found in *T. procumbens* were phenolic compounds, which is similar to a recent study by **[19]** Vanillin was shown to be the main allelochemical in the current study's detection of phenolic acids in *Tridax procumbens*, with benzoic, ferulic, and ellagic. Vanillin, a phytotoxic substance, was also discovered in numerous other plants, including *Oryza sativa* **[20]**.

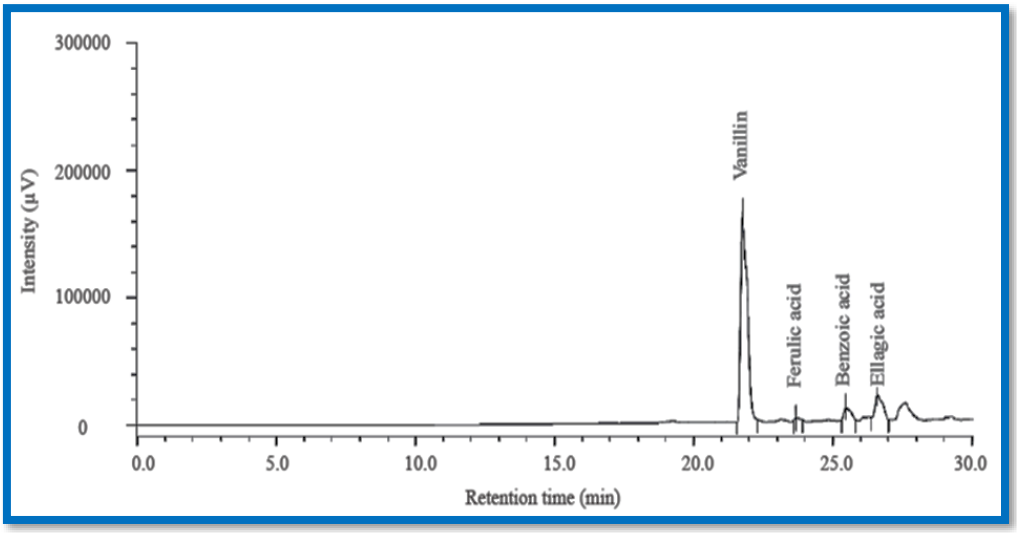


**Fig. 4: High performance liquid chromatography used to identify phenolic acids in T. procumbens [20]**

Cinnamic and benzoic acids, flavonoids, and terpenes are among the most allelochemicals and are phytotoxic. Allelochemicals harm the development of companion and succeeding crops in a few agroecosystems **[21]**.

## 2. Physiological and Ecological Mechanisms:

Phenolic allelochemicals have been found both in naturally occurring and controlled environments, where have been shown to create a variety of ecological including losses in crop productivity due to soil disease, failures in natural forest regeneration, and difficulties with the orchard replanting. The biosynthesis and buildup of phenolic compounds are the results of well-controlled processes. The routes for phenolic compounds have evolved throughout time in several plant families. especially when these chemicals take on specific favorable activities **[22]**.

### 2.1. Impacts on the Membrane Permeability and Regulations on Plant Nutrient Uptake

Plant tissue either slowly grows or dies due to the phenolic allelochemicals effect on cell membrane permeability, prevented from taking nutrients from their environment and have an impact on their regular growth **[23]**, demonstrated a correlation between increases in membrane permeability and decreases in phenyl-ß-glucosyltransferase (PGT) activity and phenol glycosylation via Benzoic acid and cinnamic acid in cucumber (*Cucumis sativus*).

### 2.2. Impacts on the Photosynthesis and Respiration of Plants

The main effects on photosynthesis have been a decrease in the amount of chlorophyll and photosynthesis. Cucumber seedlings were raised in benzoic and cinnamic acid derivative-containing solutions in the study **[24]**, demonstrating that intercellular $CO_2$ concentration stomatal conductance and leaf transpiration were all reduced. In seedlings, chlorogenic acid increased stomatal while ferulic acid decreased photosynthetic rate and stomatal, low, and intermediate chlorogenic acid concentrations reduced transpiration rate **[25]**.

### 2.3. Impacts on the length, division, and structure of the cell

The ability of phenolic allelochemicals to impact the development and growth of plants by preventing the division of cells, elongation of the roots, and cell ultra-structure **[26]**, discovered that coumarin decreased cellular activity and the quantity of Golgi bodies, increased cortex cell thickness, and slowed roots expansion of lettuce (*Lactuca sativa* L.) seedlings, Benzoic acid decreased the elongation of *Eutrema wasabi* roots after a 7-day treatment. Organelle structures were significantly harmed, and the root cells were organized erratically. Vanillic, caffeic, ferulic, coumaric, and chlorogenic acids are bioactive substances found in medicinal plants that have inhibitory activity **[27]**, The reaction of seedlings of *Rhododendron delavayi* demonstrated that biomass accumulation was restricted by three types of phenols—feru. acid, chlorogenic acid, and protocatechuic acid a rise in total Chl, Chl a, and Chl b, and carotenoid concentrations were stimulated. Stomatal opening, the ratio of stomatal openings, stomatal length, and stomatal width were all considerably suppressed by low doses of feru. acid.

### 2.4. Impact on the Function and Activities of Different Enzymes

Thanks to the cell membrane of a plant, phenolic allelochemicals enter and alter the function and activity of specific enzymes. At 0.1 mM, caffeine also increased reactive oxygen species (ROS) generation and significantly altered the activities of POD, which decreased rhizogenesis and inhibited root growth of mung bean. According to the findings of other investigations, ferulic acid treatment for 6 days decreased the maize (*Zea mays* L.) root's length and weight at the start of seedlings **[21]**. Additionally, there was a considerable decrease in the activity of hydrolase, maltase, phospholipase, and protease.

### 2.5. Impacts on Plant Endogenous Hormone Synthesis

DNA and RNA integrity may be compromised by any phenolic **[29]**, phenolic compounds almost emerge as a mixture and not as a single component. Therefore, it is likely that no one chemical ever contributed to allelopathy in the case of phenolic substances **[30]**.

## 3. Conclusions

These individual plant phenolic compounds affect several environmental species in opposing ways. It is also known that they have an impact on other plant metabolic processes. These phenolic substances take part in both the above- and below-ground defensive mechanisms of plants. They are created as root exudates and have an impact on the variety of the soil and the nearby plants. An overview of the functions of plant phenolic compounds as signaling, pigment, antibacterial, and defense agents in the plant kingdom is given in the current article.

## 4. References


[1] Einhellig FA. The physiology of allelochemical action: clues and views. In: Allelopathy, from Molecules to Ecosystems (Eds. Reigosa, M.J. and Pedrol, N.) pp.1-23, Science Publishers: Enfield, New Hampshire, 2002.

[2] Rehman F, Khan FA, Badruddin SM. Role of phenolics in plant defense against insect herbivory. Chemistry of phytopotentials: health, energy and environmental perspectives. 2012:309-13.

[3] Cheng F, Cheng Z. Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy. Frontiers in plant science. 2015 Nov 17;6:1020.

[4] Batish DR, Kaur S, Singh HP, Kohli RK. Role of root-mediated interactions in phytotoxic interference of Ageratum conyzoides with rice (Oryza sativa). Flora-Morphology, Distribution, Functional Ecology of Plants. 2009 Jan 1;204(5):388-95.

[5] Gindri DM, Coelho CM, Uarrota VG. Physiological and biochemical effects of Lantana camara L. allelochemicals on the seed germination of Avena sativa L. Pesquisa Agropecuária Tropical. 2020 Aug 24;50.

[6] Rehman MU, Hussain M, Ali M, Mustafa CB, Shafi J, Iqbal F. Allelopathy of Brassica. A review. Scientia Agriculturae. 2013;8:222-9.

[7] Papetti A, Milanese C, Zanchi C, Gazzani G. HPLC–DAD–ESI/MSn characterization of environmentally friendly polyphenolic extract from Raphanus sativus L. var.“Cherry Belle” skin and stability of its red components. Food research international. 2014 Nov 1;65:238-46.

[8] Macías FA, Mejías FJ, Molinillo JM. Recent advances in allelopathy for weed control: From knowledge to applications. Pest management science. 2019 Sep;75(9):2413-36.

[9] Li ZH, Wang Q, Ruan X, Pan CD, Jiang DA. Phenolics and plant allelopathy. Molecules. 2010 Dec 7;15(12):8933-52.

[10] Wang Q, Ruan X, Li ZH, Pan CD. Autotoxicity of plants and research of coniferous forest autotoxicity. Sci. Sil. Sin. 2006;43:134–142.

[11] Rueda-Ayala V, Jaeck O, Gerhards R. Investigation of biochemical and competitive effects of cover crops on crops and weeds. Crop Protection. 2015 May 1;71:79-87.

[12] Sampaio BL, Edrada-Ebel R, Da Costa FB. Effect of the environment on the secondary metabolic profile of Tithonia diversifolia: a model for environmental metabolomics of plants. Scientific reports. 2016 Jul 7;6(1):29265.

[13] Tanwir F, Dionisio G, Adhikari KB, Fomsgaard IS, Gregersen PL. Biosynthesis and chemical transformation of benzoxazinoids in rye during seed germination and the identification of a rye Bx6-like gene. Phytochemistry. 2017 Aug 1;140:95-107.

[14] YILAR M, Bayar Y, Onaran A. Chemical composition and allelopathic effect of Origanum onites L. essential oil. Plant Protection Bulletin. 2019 Sep 9;59(3):71-8.

[15] VRCHOTOVA N, SERA B, Dadáková E. HPLC and CE analysis of catechins, stilbens and quercetin in flowers and stems of Polygonum cuspidatum, P. sachalinense and P. x bohemicum. Journal of the Indian Chemical Society. 2010;87(10):1267-72.

[16] Souza M, Comin JJ, Kurtz C, Lovato PE, Lima AP, Kuhnen S. Phenolic compounds with allelopathic potential of Secale cereale L. and Raphanus sativus L. grown under an agroecological no-tillage system. Planta Daninha. 2019 Sep 30;37.

[17] Oliveira RA, Brunetto G, Loss A, Gatiboni LC, Kurtz C, Muller VM, Lovato PE, Oliveira BS, Souza M, Comin JJ. Decomposição e liberação de nutrientes de plantas de cobertura e seus efeitos em atributos químicos do solo e produtividade da cebola. Rev Bras Cienc Solo. 2016;40:e0150105.

[18] Bergamaschi KB. Capacidade antioxidante e composição química de resíduos vegetais visando seu aproveitamento. Piracicaba: USP. 2010.

[19] Monquero PA, Amaral LR, Inácio EM, Brunhara JP, Binha DP, Silva PV, Silva AC. Effect of green fertilizers on the suppression of different species of weeds. Planta Daninha. 2009;27:85-95.

[20] Andriana Y, Xuan TD. Contribution of phenolic acids and dimethyl sulfone to the allelopathic effect of invasive Tridax procumbens. Pesquisa Agropecuária Tropical. 2021 Jan 18;50:e64792.

[21] Mahugo Santana C, Sosa Ferrera Z, Esther Torres Padrón M, Juan Santana Rodríguez J. Methodologies for the extraction of phenolic compounds from environmental samples: new approaches. Molecules. 2009 Jan 9;14(1):298-320.

[22] Politycka B. Phenolics and the activities of phenylalanine ammonia-lyase, phenol-β-glucosyltransferase and β-glucosidase in cucumber roots as affected by phenolic allelochemicals. Acta physiologiae plantarum. 1998 Dec;20:405-10.

[23] Li HH, Inoue M, Nishimura H, Mizutani J, Tsuzuki E. Interactions of trans-cinnamic acid, its related phenolic allelochemicals, and abscisic acid in seedling growth and seed germination of lettuce. Journal of Chemical Ecology. 1993 Aug;19:1775-87.

[24] Yu JQ, Ye SF, Zhang MF, Hu WH. Effects of root exudates and aqueous root extracts of cucumber (Cucumis sativus) and allelochemicals, on photosynthesis and antioxidant enzymes in cucumber. Biochemical systematics and ecology. 2003 Feb 1;31(2):129-39.

[25] Fu YH, Quan WX, Li CC, Qian CY, Tang FH, Chen XJ. Allelopathic effects of phenolic acids on seedling growth and photosynthesis in Rhododendron delavayi Franch. Photosynthetica. 2019 Apr 1;57(2).

[26] Li HH, Inoue M, Nishimura H, Mizutani J, Tsuzuki E. Interactions of trans-cinnamic acid, its related phenolic allelochemicals, and abscisic acid in seedling growth and seed germination of lettuce. Journal of Chemical Ecology. 1993 Aug;19:1775-87.

[27] Singh AA, Rajeswari G, Nirmal LA, Jacob S. Synthesis and extraction routes of allelochemicals from plants and microbes: A review. Reviews in Analytical Chemistry. 2021 Sep 9;40(1):293-311. https://doi.org/10.1515/revac-2021-0139

[28] Devi SR, Prasad MN. Effect of ferulic acid on growth and hydrolytic enzyme activities of germinating maize seeds. Journal of Chemical Ecology. 1992 Nov;18:1981-90.

[29] Devi SR, Prasad MN. Effect of ferulic acid on growth and hydrolytic enzyme activities of germinating maize seeds. Journal of Chemical Ecology. 1992 Nov;18:1981-90.

[30] Ni HW. Present status and prospect of crop allelopathy in China. Rice allelopathy. 2000:41-8.