



THE ANTIFUNGAL EFFECTS OF *DATURA STRAMONIUM* L., *D. METEL* L., *D. INNOXIA* Mill. IN FLORA OF TURKEY

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Received: 19.09.2017, Accepted: 02.11.2017

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doi: 10.22531/muglajsci.345175

Abstract

Medical plants are an important part of our lives. Various plant species have been used medically since ancient times. Most of the modern drugs are derived from plants. The demand for medical and aromatic plants in the world market is increasing. The main commercial centers of herbal drugs in the world are Japan, China, USA, Germany, Hong Kong, England, Italy, France and Spain. Turkey is also in an important position in the medicinal and aromatic plant market. Many plants collected from the nature are used to food, treatment, spices, beverage, and cosmetics etc. fields. In addition to these, researchers are conducting research showing that these crops can also be used in agricultural control. They have been supported by studies that these plants are highly effective against fungi causing harmful effects in plants. For this purpose, antifungal effects of *Datura* species (*Datura stramonium* L., *D. metel* L. ve *D. innoxia* Mill.) have been reviewed. Researches indicated that *Datura* sp. have antifungal activity some fungi. However, this effect varies according to concentration and types of solvents, part of plants such as root, seed, leaf, stem etc. The studies carried out show that each of the three *Datura* species has the potential to be a good fungicide by means of the compounds it contains

Keywords: Agricultural control, antifungal, *Datura stramonium* L., *D. innoxia* Mill., *D. metel* L.

TÜRKİYE FLORASINDAKİ *DATURA STRAMONIUM* L., *D. METEL* L., *D. INNOXIA* Mill. TÜRLERİNİN ANTİFUNGAL ETKİSİ

Öz

Tıbbi bitkiler hayatımızın önemli bir parçasıdır. Eski çağlardan beri çeşitli bitki türleri tıbbi olarak kullanılmaktadır. Modern ilaçların çoğu bitkilerden elde edilir. Dünya pazarında tıbbi ve aromatik bitkilere talep artmaktadır. Bitkisel ilaçların dünyadaki başlıca ticaret merkezleri Japonya, Çin, ABD, Almanya, Hong Kong, İngiltere, İtalya, Fransa ve İspanya'dır. Türkiye, tıbbi ve aromatik bitki pazarında da önemli bir konumdadır. Doğadan toplanan birçok bitki gıda, tedavi, baharat, içecek, kozmetik vb. alanlarda kullanılmaktadır. Bunlara ek olarak, araştırmacılar bu ürünlerin tarımsal mücadelede de kullanılabileceğini gösteren araştırmalar yürütmektedirler. Bu bitkilerin, bitkilerde zararlı etkilere neden olan mantarlara karşı oldukça etkili oldukları çalışmalarıyla desteklenmektedir. Bu amaçla, *Datura* türlerinin (*Datura stramonium* L., *D. metel* L. ve *D. innoxia* Mill.) antifungal etkileri derlenmiştir. Araştırmalar, *Datura* türlerinin bazı mantarlara karşı antifungal aktivite gösterdiğini bildirmektedir. Bununla birlikte, bu etki, konsantrasyon ve solvent tiplerine, kök, tohum, yaprak, gövde gibi bitkilerin bölümlerine göre değişmektedir. Yapılan çalışmalar, üç *Datura* türünün her birinin, içerdikleri bileşikler vasıtasıyla iyi bir fungusid olma potansiyeline sahip olduğunu göstermektedir.

Anahtar Kelimeler: Tarımsal mücadele, antifungal, *Datura stramonium* L., *D. innoxia* Mill., *D. metel* L.

1. Introduction

Medical plants are an important part of human life. In recent years, the alternative medicine system is in an important position. The value of herbal medicines is increasing because of the decrease in the level of the effect of synthetic drugs. The plants collected from nature are also used in food, treatment, spices, soft drinks, cosmetics and agricultural control. Fungal disease are observed very much nowadays and as a result yield losses occur. As the used fungicide-resistant strains grow, new drug searches are emerging. The use of medicinal plants for treating fungal infections is an advantage. The use of plants as antifungal agents may be an alternative to minimizing the residual problem.

Datura is a member of the family Solanaceae and is represented in our country by three species, *Datura stramonium* L., *D. innoxia* Mill., *D. metel* L.

Datura L. genus leaves are sinuate- dentate to entire. Flowers are solitary, axillary. This genus has tubular, 5-angled calyx and

infundibular corolla. Stamens inserted near base of corolla. Fruit is a septicidal capsule [1].

D. stramonium L. is a perennial herbaceous plant. Leaves are simple, alternate, dark green, broadly ovate, shallowly lobed and glabrous. Flowers are large, solitary and trumpet-shaped [2]. In some literature, this species is called thorn apple and jimson weed [3].

D. metel L. is a perennial green shrub, shrub or perennial herbaceous plant. Leaves are simple, alternate, long and green. Their margin is sinuate-dentate and the fruit is a very seedy capsule [4].

D. innoxia Mill. is a densely pubescent plant. Leaves are petiolate, ovate, largely sinuate to entire [1].

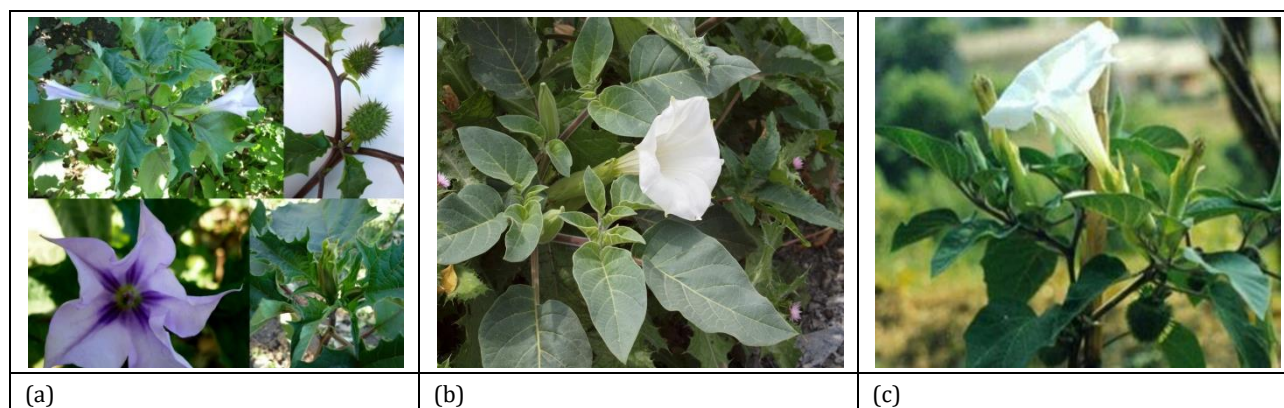


Figure 1: a) *D. stramonium* L., b) *D. innoxia* Mill., c) *D. metel* L. [5].

Secondary metabolites in plants have strong antibacterial and antifungal properties. It has been reported that the antimicrobial properties of *Datura* plant originate from compounds such as alkaloids, triterpenoids, steroids, flavonoids, triterpenes, phenolic compounds and tannins [6].

Datura sp. produce the alkaloids such as hyoscyamine and scopolamine used in pharmacology [7]. Philipov and Berkov [8] found 29 tropane alkaloids in the root, leaf and seed of *Datura stramonium* L. by GC-MS method in their study.

Datura stramonium L. has antibacterial, nematocidal, antifungal, contact toxicity, anticancer, antioxidant, antimicrobial, acaricidal, repellent and oviposition deterrent effects [3].

Datura stramonium L. leaves contain alkaloids in the range of 0.2-0.6%. Atropine, one of the active tropane group alkaloids, is commonly used in eye diseases and paralysis resulting from the nervous system [9]. Atropine is also used in Parkinson's disease, diarrhea, bronchial asthma and peptic ulcer [10]. Atropine intake in excess of 10 mg may potentially have a lethal effect. Each of the DS seeds contains about 0.06 mg of atropine, so consumption of a capsule containing about 50-100 seeds can lead to severe anticholinergic toxicity [11].

Datura stramonium L. is a wild plant that grows in almost every region of our country on the roadsides and in empty areas. Plants are collected and dried and then leaves are prepared as cigarette for asthma and bronchitis. Seeds are used in acne, eczema, hemorrhoid treatment and antispasmodic. Ointment is also applied against regional pain [11]. The flowers of *Datura stramonium* L. especially the leaves, are used against asthma, cough and cramps [9].

Aerial parts of *Datura metel* L. include datura metelin C,D,E,G, leaves contain secowithametelin, daturiline, and vitamin C, also roots have hyocine, hyoscyamine secondary metabolites [12].

Datura innoxia Mill. (Solanaceae) contains many alkaloids. Within 50 of excess alkaloids were detected [13].

2. Results

This review was carried out to investigate the antifungal effects of *Datura* species grown in Turkey. Many articles have been examined in our research and the results have been presented. The analyzed articles and the results are given in paragraphs. According to our research, *Datura stramonium* L., *D. metel* L. and *D. innoxia* Mill. have antifungal effects at different rates on different fungi.

Iranbakhsh et al. [14] reported that seed extract of *Datura stramonium* L. had inhibitory effect on *Certocystis ulmi* by 11 mm, on *Fusarium semitectum* by 6 mm but it wasn't effective on *Rhizoctonia solani*; flower extract had inhibitory effect on

Certocystis ulmi by 20 mm, on *Rhizoctonia solani* by 15 mm but it wasn't effective on *Fusarium semitectum*; in the generative stage, root extract had inhibitory effect on *Certocystis ulmi* by 10 mm, on *Fusarium semitectum* by 6 mm but it wasn't effective on *Rhizoctonia solani*; in the vegetative stage, root extract had inhibitory effect on *Certocystis ulmi* by 16 mm, but it wasn't effective on *Rhizoctonia solani* and *Fusarium semitectum*; in the generative stage, stem extract had inhibitory effect on *Fusarium semitectum* by 8 mm, but it wasn't effective on *Certocystis ulmi* and *Rhizoctonia solani*; in the vegetative stage, stem extract had inhibitory effect on *Certocystis ulmi* by 10 mm, on *Rhizoctonia solani* by 20 mm and on *Fusarium semitectum* by 6 mm; in the generative stage, leaf extract had inhibitory effect on *Fusarium semitectum* by 10 mm, on *Certocystis ulmi* by 11 mm, but it wasn't effective on *Rhizoctonia solani*; in the vegetative stage, leaf extract had inhibitory effect on *Fusarium semitectum* by 5 mm, on *Certocystis ulmi* by 8 mm, but it wasn't effective on *Rhizoctonia solani*; also methanol extracts were effective on *Certocystis ulmi* by 12 mm, on *Fusarium semitectum* by 10 mm and no effective on *Rhizoctonia solani* and all extracts have no inhibitory effect on *Fusarium colmorum*.

Türküsay and Onoğur [15] researched *Ficus carica* L., *Hedera helix* L., *Datura stramonium* L., *Nicotiana tabacum* L., *Xanthium strumarium* L., *Avena sativa* L. extracts antifungal effect against *Alternaria alternata*, *A. solani*, *Botrytis cinerea* and *Dreschslera sorokiniana*. *H. helix* L. leaf extracts inhibited spore germination at the highest level and *D. stramonium* L. followed it. However, *H. helix* L. has come to the forefront in preventing pathogens colonies growth, followed by *Ficus carica* L. and *Avena sativa* L. extracts.

Rodino et al. [16] reported that extract of jimsonweed (*Datura stramonium* L.), common cocklebur (*Xanthium strumarium* L.), rosemary (*Rosmarinus officinalis* L.) and wormwood (*Artemisia absinthium* L.) showed antifungal properties by inhibiting mycelial growth against *Alternaria alternata*; generally ethanol extracts exhibited a higher antifungal property than aqueous extracts. Among the aqueous extracts, Jimsonweed showed the best antifungal activity and flowers of jimsonweed has a better effect than leaves.

Sasode et al. [17] reported that 10% crude extract of the devil's apple inhibited the growth of the *Alternaria brassicae* fungus by 39.22% and its 10% boiled extract had 19.92% inhibitory effect.

Rodino et al. [16] observed that 2.5%, 5% and 10% leaf ethanol extracts of devil's apple inhibited mycelium growth against *Alternaria alternata* and their inhibition percentages were 30%, 83.33%, 60%, respectively. On the other hand,

researchers reported that 2.5 %, 5% and 10% fruit ethanol extract of devil's apple inhibition rates were 20 %, 50 %, 16.7 %, respectively. Whereas, Kumar et al. [18] determined that 40 % doses of devil's apple ethanol extract inhibited mycelium growth 93.36 %. In addition, , Bagri et al. [19] reported that *Datura* sp. leaf preparations inhibited micelle growth and spore germination of *Alternaria alternata* and caused a high level of decrease in fruit decay density and also, *Datura* sp. leaf preparation was as effective as Kitazine fungus.

Khallil [20] reported that spore germination of *Alternaria solani* in the devil apple's aqueous extract was %69.1±6.5.

Kumar Meena et al. [21] reported that the extract of 25% of the leaves of *Datura stramonium* L. reduced the growth of *Alternaria alternata* fungus by 56.78% and the increased doses prevented the fungus growth, so much.

Kantwa et al. [22] reported that the *Datura* leaf extract inhibited mycelial growth of *Alternaria alternata* fungus by 40.33%.

Anamika and Simon [23] determined that 10% aqueous extract of *Datura stramonium* L. inhibited the growth of *Alternaria alternata* fungus by 40.9% and spore germination by 32.5%.

Hannan et al. [24] reported that *Datura stramonium* L. extract is highly effective against *Alternaria alternata*.

Satish et al. [25] found that the antifungal effect of 25% aqueous extract of *Datura stramonium* L. against to some *Fusarium* species was 87.25 ± 0.85% for *F. equiseti*; 75.00 ± 1.08 for *F. moniliforme*; 68.25 ± 1.11% for *F. semitectum*; 62.00 ± 0.91% for *F. graminearum*; 67.50 ± 1.19% for *F. oxysporum*; 77.00 ± 1.29 for *F. proliferatum*; 70.00 ± 0.91% for *F. solani* and 66.75 ± 1.11% for *F. lateritium*.

Surender Kumar [26] reported that *Datura stramonium* L. extract inhibited mycelial growth of *Fusarium moniliforme* by 56%.

Sharma et al. [27] investigated the antifungal effect of extracts obtained from *Datura stramonium* L. against *Aspergillus flavus*, *Aspergillus niger*, *Fusarium culmorum* and *Rhizopus stolonifer*. The most effective extract was a methanol extract, and the most effective part of the plant was leaf for *Rhizopus stolonifer*, while callus extract was for other fungi; The best antifungal effect was against *Rhizopus stolonifer* fungus, followed by *Fusarium culmorum*, *Aspergillus flavus* and *Aspergillus niger* respectively.

Uma Reddy [28] reported that leaf extract of *D. stramonium* L. was effective against *Aspergillus niger* and *Fusarium* sp.

Singh et al. [29] determined that extract of eucalyptus (*Eucalyptus* sp.), devil's apple (*Datura stramonium* L.) and stabragh (kapok tree) (*Calotropis procera* (Aiton) W.T. Aiton) limited *Fusarium oxysporum* f.sp. *chrysenthemii* fungus growth.

Shivpuri et al. [30] reported that extracts of *Datura stramonium* L., *Azadirachta indica* Juss., *Polyalthia longifolia* (Sonn.) Thwaites, *Ocimum sanctum* Linn. showed antifungal properties against *F. oxysporum* fungus.

Arzoo ve Biswas [31] claimed that *Datura stramonium* L. aqueous extract inhibited mycelial growth of *Fusarium oxysporum* f.sp. *lycopersici* by 13% .

In the study conducted by Salman and Faraj [32], the effect of *Datura stramonium* L. extract against *Candida albicans* was investigated. The minimum inhibitory concentration (MIC) was 3.12 mg / ml. *Datura stramonium* L. leaf extract was tested for sensitivity to different concentrations and as a result zone of inhibition was determined as 12.00 mm at 200 mg / ml, 17.00 mm at 150 mg / ml and 26.00 mm at 100 mg / ml, respectively.

Chohan et al. [33] reported that 8% aqueous extract of *Datura stramonium* L. leaves inhibited *Fusarium oxysporum* mycelial growth by 28.5%.

Bhardwaj et al. [34] investigated the inhibitory effect of *Datura stramonium* L. methanol leaf extract on *Colletotrichum lindemuthianum* in vitro media. 40% inhibition at 250 ppm, 55.56% inhibition at 500 ppm and 60% inhibition at 1000 ppm. In another study, it was reported that *Datura metel* L. leaf extract showed a strong antifungal effect against *Macrophomina phaseolina* and methanol extract gave better results than chloroform extract. The MIC value of methanol extract of *Datura metel* L. was determined to be 20 µg / disc [35].

Mogita et al. [36] *Allium sativum* L., *A. cepa* L., *Cleome gynandra* L., *Azadirachta indica* Juss. , *Datura stramonium* L., *Aloe vera* (L.) Burnm., *Lantana camara* L. and *Eucalyptus globulus* Labill. In vitro antifungal activity against *C. lindemuthianum* was observed and the best antifungal activity was observed in *Aloe vera* leaf extract (90.6%) and *Datura stramonium* L. extract (65.99%) was second.

Sahu et al. [37] reported that *Datura stramonium* L. extract showed a 34.65% mycelial inhibition effect against *Alternaria solani*.

Shinde and Dhale [38] investigated the antifungal activity of *Ocimum tenuiflorum* L. and *Datura stramonium* L. extracts on *Fusarium oxysporum* and *Rhizopus stolonifer* fungi. According to this study, *Datura stramonium* L. stem bark alcoholic extract showed maximum antifungal activity. In the plants parts, the most antifungal effect on both fungus was at stem bark extract and then were at leaves and root bark respectively.

In a study conducted by Alemu et al. [39] , antifungal effects of 20 plants against *Colletotrichum gloeosporioides* were investigated. *Datura stramonium* L. methanol extract showed a very good antifungal effect against the tested fungus, *Datura stramonium* L. and *Eucalyptus globulus* Labill. of leaf extracts inhibited the pathogenic spore germination more than the other extracts (14.7% and 15.7%, respectively).

As a result of research, it was stated that the seed extract of *Datura stramonium* L. contains atropine alkaloids, scopolamine and diterpenes and is effective against *F. oxysporum* [40].

Satish et al. [41] researched that effect of jimsonweed (*Datura stramonium* L.), acacia (*Acacia nilotica* (L.) Willd. ex. Delile), sapodilla tree (*Achras zapota* L.), Indian gooseberry (*Emblica officinalis* Gaertn.), eucalyptus (*Eucalyptus globulus* Labill.), henna (*Lawsonia inermis* L.), Spanish cherry (*Mimusops elengi* L.), yellow flame tree (*Peltophorum pterocarpum* (DC.) Backer ex. K.Heyne), Buddha tree (*Polyalthia longifolia* (Sonn.) Thwaites), *Prosopis juliflora* (Sw.) DC, pomegranate (*Punica granatum* L.) and *Syzygium cumini* (L.) Skeels against *Aspergillus* species *A. candidus*, *A. columnaris*, *A. flavipes*, *A. flavus*, *A. fumigatus*, *A. niger*, *A. ochraceus* ve *A. tamarii*. In general, the extracts of all plants are effective against the fungus species; but the effect of the eucalyptus on the *A. ochraceus* and *A. tamarii* fungi was minimal; *Achras zapota* L. and *Polyalthia longifolia* (Sonn.) Thwaites extracts were less effective than the extracts of other plants. The effect ratios of *Datura stramonium* L. 25% aqueous extract against *Aspergillus* sp. were *Aspergillus candidus* (87.25 ± 0.85), *A. niger* (77.00 ± 1.29), *A. flavus* (75.00 ± 1.08), *A. tamarii* 70.00 ± 0.91), *A. ochraceus* (68.25 ± 1.11), *A. fumigatus* (67.50 ± 1.19), *A. flavipes* (66.75 ± 1.11) and *A. columnaris* (62.00 ± 0.91). In addition, the effects of different extracts of *Datura stramonium* L. against *Aspergillus flavus* were methanol extract (83.09 ± 1.26), ethanol (67.17 ± 0.86), chloroform (66.08 ± 1.08), benzene (40.45 ± 1.31) and petroleum ether (35.79 ± 1.07).

Hongxia et al. [42] indicated that the extract obtained from seeds of *Datura stramonium* L. was a strong inhibitory effect,

completely inhibiting the growth of *Gibberella zeae* and inhibited the growth of *Phytophthora capsici* by 96.91%.

Mohammed et al. [43] reported that alkaloids of *Datura stramonium* L. was high antifungal effect on *Aspergillus flavus* (zone of inhibition 9.00 ± 0.73 mm).

Abayhne et al. [44] reported that *Datura stramonium* L. aqueous extract had good antifungal effects against *Phytophthora infestans*.

In their research, Begum et al. [45] found that *Datura metel* L. leaf extract was antifungal effect against *Alternaria alternata* 42% , *Curvularia lunata* 37 % , *Fusarium equiseti* 38 % , *Macrophomina phaseolina* 53 % , *Botryodiplodia theobromae* 71 % and *Colletotrichum corchori* 54 %.

Ranaware et al. [46] found that *Datura metel* L. leaf aqueous extract had a 44.25% antifungal effect on *Alternaria carthami*.

In a study conducted, methanol, chloroform and aqueous extracts obtained from leaf, root and stem of *Datura metel* L. were effective against *Candida albicans*, *Aspergillus niger*. The methanolic extract of the plant shows the maximum inhibition at the concentration of 15 mg / 0.1 against both the fungi [12].

Datura metel L. has Withanolide compound which is antifungal steroidal lactones [47]. Withanolide compounds show significant cytotoxic, antibacterial, antitumor, anti-inflammatory, sedative, cytostatic, hepatoprotective and immunosuppressive activity [48]. Singh et al. [49] conducted a study of the withanolide compounds Withametelin inhibited spore germination against 23 fungi (except *Curvularia maculans* and *Colletotrichum sp.*) at concentrations of 125 to 1000 ppm. *Alternaria alternata*, *A. brassicae*, *Cercospora abelmoschi*, *Curvularia sp.*, *Heterosporium sp.* and *Ustilago cynodontis* fungi were observed to inhibit germination at a concentration of 125 ppm (lowest concentration).

It has been determined that the methanol extract of *Datura metel* L. has an inhibitory effect on *Aspergillus fumigatus*, *A. flavus* and *A. niger* and the disk diffusion method has a significant activity against *Aspergillus* with a concentration of 0.062 mg methanol extract of *D. metel* L. [50].

A leaf extract of *Datura metel* L. protected *Pennisetum glaucum* against downy mildew disease caused by *Sclerospora graminicola*. On the other hand, *Datura metel* L. seed application by leaf extract was indicated to show 79% and 67% protection against downy mildew disease in greenhouse and field conditions respectively. It was also found that this extract is active in early and later stages of resistant plant growth. It has been observed that the highest value of the effect against *Sclerospora graminicola* was obtained by applying 2% *Datura metel* L. for 3 hours [51].

Carvalho et al. [52] found that the aqueous extract of *Datura metel* L. plant did not prevent or even encourage the growth of *Alternaria alternata*.

Vikhe et al. [53] reported that 100 % dozes *Datura metel* L. aqueous extract suppressed growth of *Fusarium oxysporum*, *Alternaria alternata*, *Aspergillus niger*, *Aspergillus flavus*, *Phoma* sps., *Bipolaris* sps., *Helminthosporium*, *Rhizopus* sps., *Curvularia* sps., *Mucor* sps. and *Cladosporium herbarum* fungus.

Tiwari and Srivastava [54] stated that *Datura alba* (Syn. *Datura metel* L.) showed antifungal activity against *Fusarium oxysporum*, *Alternaria porri*, *Aspergillus niger* ve *Sclerotium cepivorum*.

Ali et al. [55] reported that leaf extract (10%) of *Datura fastuosa* (Syn. *Datura metel* L.) showed 19.34% inhibition against *Fusarium oxysporum f.sp. pisi*.

Mahmood et al. [56] investigated the antifungal effect of various doses (200 ppm, 400 ppm and 600 ppm) of aqueous extracts of *Datura alba* (Syn. *Datura metel* L.) against *Fusarium solani*. Researchers have determined that 200 ppm and 400 ppm doses are better than the 600 ppm dose with a 83% inhibition rate.

Dabur et al. [57] reported that 2- (3, 4 - dimethyl - 2, 5 - dihydro - 1H -pyrrol- 2-yl) -1 - methylethyl pentanoate compounds which is isolated from *Datura metel* L were effective *Candida albicans*, *Candida tropicalis*, *Aspergillus fumigatus*, *Aspergillus flavus* ve *Aspergillus niger*.

The research conducted by Rajesh and Sharma [58] concluded that only chloroform extracts of *D. metel* L. effective against *Aspergillus fumigatus*, *A. flavus* ve *A. niger* and acetone, hexane, methanolic extracts of this plant no antifungal activity against fungus. However, The minimum inhibitory concentration (MIC) of chloroform fraction of *D. metel* L. was 625.0 $\mu\text{g ml}^{-1}$ against *A. fumigatus*, *A. flavus* and *A. niger*, by microbroth dilution and percent spore germination inhibition assays. But the MIC by disc diffusion assay was observed to be 12.5 $\mu\text{g disc}^{-1}$.

Kagale et al. [59] researched that effect of *Datura metel* L. extracts on mycelial growth and sclerotia production against *Rhizoctonia solani*. Colony diameter was determined as 14 mm in hot water, 12,6 in cold water, 7 mm in methanol, 21 mm in chloroform and 15 mm in petroleum ether.

In a study conducted by Khan and Nasreen [60] , inhibition of mycelial growth in 10% methanol *Datura metel* L. leaf extract was found to be 68.65% in *Colletotrichum capsici*, 69.69% in *Colletotrichum lindemuthianum*, 50.00% in *Fusarium moniliforme*, , 63.33% in *Bipolaris oryzae*, 64.70% in *Curvularia lunata*, 75.55% in *Rhizoctonia solani*, 37.25% in *Macrophomina phaseolina*, 57.50% in *Pyricularia oryzae* and 57.77% in *Fusarium oxysporum*. In addition, inhibition of mycelial growth of 10 % methanol in *Datura stramonium* L. leaf extract was 76.11% in *Colletotrichum capsici*, 42.42% in *Colletotrichum lindemuthianum*, 53.33% in *Fusarium moniliforme*, 72.85% in *Alternaria alternata* and 52.22% in *Bipolaris oryzae*, 75.29% in *Curvularia lunata*, 62.22% in *Rhizoctonia solani*, 64.70% in *Macrophomina phaseolina*, 65.00% in *Pyricularia oryzae* and 63.33% in *Fusarium oxysporum*.

Shafique and Shafique [61] investigated the effect of *Datura metel* L. extract on *Ascochyta rabiei* in their research and found that 1.2.3.4% w / v n-hexane concentrations of shoot and root extracts of *D. metel* L. suppressed fungus growth. Percentage decrease in colony diameter of *Ascochyta rabiei* varied at shoot and root extracts. In the shoot extract, 34% in 1% n-hexane, 22% in 2%, 30 % in 3% and 28% in 4% colony diameter decreased. Whereas, in the root extract, 34% in 1% n-hexane, 36% in 2%, 22% in 3% and 41% in 4% colony diameter decreased. In another study on the same fungus, the effect of *Datura metel* L. shoot and root on the fungus growth of aqueous and methanol extracts was investigated. Shoot and root extracts prepared with water showed significant antifungal effect compared to control but it was reported that shoot extract had better results than root extract. It was also concluded that the methanol extract was more effective than the aqueous extract in inhibiting the formation of fungi [62].

In another study, *Datura metel* L. leaf and flower extracts obtained with different solvents (petroleum ether, chloroform, methanol and aqueous) against different fungi (*Trichoderma harzianum*, *Trichoderma viride*, *Fusarium oxysporum f. melonis*, *Fusarium oxysporum f. lycopersici* and *Fusarium oxysporum f. tuberosi*.) were investigated. *D. metel* L. leaf and flower extracts showed antifungal activity against fungus at each concentration (1%, 2%, 3%, 4%), *Fusarium oxysporum f. sp. melonis* more sensitive to the *D. metel* L. leaf extract than the other two

Fusarium species. It was also concluded that the antifungal effect of *D. metel* L. flower aqueous extract against *T. viridis* was higher (69%) and both *Trichoderma* fungi was more sensitive to *D. metel* L. organic extracts than *Fusarium* species [63].

Jabeen et al. [64] researched that fruit extract with different solvent fractions of *Datura metel* L. had antifungal activity against *Saclerotium rolfii* Sacc. and researchers found that the chloroform fraction had the best antifungal effect. It was also reported that the ethyl acetate fraction had less antifungal activity than the chloroform fraction and n-hexane, n-butanol, aqueous fractions did not show antifungal activity.

In the study conducted by Ravikumar and Garampalli [65], it was determined that the antifungal activity ratio of *Datura metel* L. 4% aqueous extract was 21.30% and the antifungal activity rate of 2% aqueous extract was 6.66% against *Alternaria solani*.

Anwar et al. [66] determined that the aqueous extract of the devil's apple (*Datura metel* L.) decreased the growth of *Alternaria alternata* fungus by 9.41%.

Javaid et al. [67] investigated that root, leaf and stem aqueous and hexane extracts of *Datura alba* Rumph. ex Nees had antifungal activity against *Macrophomina phaseolina*. At all concentrations (1, 2, 3 and 4%), aqueous extracts showed the same effect as hexane extracts nearly; among aqueous extracts, with (% 85-92) inhibitory effect the root extract showed the best antifungal property (inhibitory rate at leaf extract was % 60-65, also at stem extract was % 72-83); also among hexane extracts, the leaf extract showed more inhibitory effect with % 72-84 than stem and root extracts (% 59-79 and % 57-62, respectively).

Javaid and Saddique [68] reported that methanolic leaf and fruit extracts of *Datura metel* L. were highly effective against *Macrophomina phaseolina*. It was also concluded that leaf extracts with all concentrations of chloroform, n-butanol and ethyl acetate fraction (3.125-200 mg mL⁻¹) and n-hexane fraction fruit extract prevented fungus growth.

Saha et al. [69] investigated the effect of aqueous and ethanol extracts of some plants on tea (*Camellia sinensis* L.) fungi. Aqueous and ethanol extracts of *Datura metel* L. highly effective on *Colletotrichum camelliae*, *Curvularia eragrostidis* and *Botryodiplodia theobromae*, while this plants aqueous and ethanol extracts was 100 % effective on *Colletotrichum camelliae*.

At the research conducted by Ishnava et al. [70] is reported that extract (50 g/ 250 ml) of obtained from *Datura metel* L. leaves by use of solvents such as hexane, ethyl acetate, methanol and distilled water no antifungal effective against *Aspergillus flavus*, *Aspergillus nidulans*, *Trichoderma harzianum*, *Trichoderma virans* and *Fuserium oxysporium*, methanol extract of *D. metel* L. showed minimum activity (3 mm) against *Aspergillus parasi*, minimum inhibitory concentration (MIC) was 60 ppm and this plant played a more active role than *Adhatoda vasica* Nees., *Aegle marmelos* (L.) Correa, *Annona squamosa* L., *Azadirachta indica* Juss., *Citrus limon* (L.) Osbeck, *Cleome gynandra* L., *Holoptelea integrifolia* (Roxb.) Planch, *Jatropha curcas* L., *Moringa oleifera* Lam., *Murraya koenigii* (L.) Spreng, *Nicotiana tabacum* L., *Ocimum sanctum* Linn., *Ricinus communis* L., *Trigonella foenum-graecum* Linn., *Vitex negundo* Linn., *Zingiber officinale* Roscoe against *Alternaria sp.* and *D. metel* L. showed antifungal activity against *Aspergillus niger*, *Aspergillus awamori*.

Sharma et al. [71], it was found that aqueous extract of *Datura metel* L. against *Sclerotinia sclerotiorum* (17 mm inhibition length) was effective but *Datura* had no effect against *Rhizoctonia solani* and *Fusarium oxysporum*. The maximum

antifungal activity of methanol extract was found to be active in leaves of *Datura metel* L. against *Sclerotinia sclerotiorum* with an inhibition length of 30 mm and inhibition length of 9 mm against *Rhizoctonia solani* as observed but no effect against *Fusarium oxysporum*.

In the study carried out by Malik [72], fungicidal properties of different alcohol concentrations (10%, 25%, 50%) against *Aspergillus flavus* of *Alstonia scholaris* (L.) R.Br., *Argemone mexicana* L. and *Datura alba* species were investigated and it has been observed that as the alcohol concentration increases, the inhibition rate of fungus radial growth increases.

Datura innoxia Mill. leaf, root, stem and seed extracts were obtained with methanol. These extracts were tested in *Aspergillus niger*, *A. flavus*, *Alternaria solani*, *Helianthus sporium* and *Fusarium solani* and it was determined that *Datura innoxia* Mill. Leaf, root, stem and seed methanol extracts were effective against to *Fusarium solani* but *Aspergillus niger* showed resistant to this plant extracts. It is reported that maximum inhibition percentage of leaves, stem, root and seed extracts were 79 %, 57.31 %, 85.36 %, 75.60 against *F. solani* respectively [73].

Barman et al. [74], *Datura innoxia* Mill. were found to be effective against *Alternaria alternata* fungus.

Patil and Suryawanshi [75] reported that *Datura innoxia* Mill. leaf aqueous extract 's (100 mg / 100 ml) inhibition fungus growth percentage was 46.67 against *Alternaria alternata*.

Pawar [76] investigated effect of 18 plant extracts against 5 pathogenic fungi (*Alternaria alternata*, *Aspergillus niger*, *Curvularia lunata*, *Fusarium moniliforme* and *Trichoderma viride*) and it is reported that *Callistemon rigidus* R.Br., *Capsicum annum* L., *Datura innoxia* Mill., *Dolichandrone falcata* Wall. ex. DC., *Lantana camara* L. and *Vitex negundo* Linn. leaf extracts showed good antifungal activity against these fungi.

Abu Taleb et al. [77] reported that ethanol extracts (20%) of *Datura innoxia* Mill. inhibited *Fusarium solani* growth and sporulation.

In a study by Guleria and Kumar [78] *Murraya koenigii* (L.) Spreng., *Datura innoxia* Mill., *Eucalyptus globulus* Labill., *Azadirachta indica* Juss., *Agave americana* L., *Solanum xanthocarpum* Schrad & Wendl. and *Adhatoda vasica* Nees. didn't show inhibition effect against *Alternaria alternata* and *Curvularia lunata* at TLC plate.

Zaker [79] investigated the antifungal effects of methanolic and aqueous extracts of 6 different plants (*Lavender*, *Datura*, *Artemisia*, *Thyme* and *Savory*) at different concentrations (5, 10, 15%) against *Fusarium solani*. It was reported that *Datura* and *Lavender* methanol extracts were less effective at all three concentrations and *Datura*, *Thyme*, *Savory*, *Lavender* methanolic extracts (5%) showed the lowest antimycelial effect.

Jalander et al. (2012) researched different concentrations (%5, %10, %15, %20) of *Datura stramonium* L., *D. innoxia* Mill., *D. metel* L. ve *D. ferox* L. aqueous leaf extracts effects on mycelial growth against *Alternaria solani* (Ell. & Mart.) Grout ve *Fusarium oxysporum sp. udum* Butler. and they have investigated that other concentrations except 5 % showed antifungal activity. In addition, the best results have been obtained in 20 % *Datura stramonium* L. leaf aqueous extract. However, 5 % leaf aqueous extract increased pathogenic fungi growth compared to control.

3. Conclusion

In this review, antifungal effects of *D. stramonium* L., *D. innoxia* Mill. and *D. metel* L. investigated. It was concluded that three *Datura* species exhibited antifungal activity at different rates against different fungi. In addition, the antifungal effect of this

species varies depending on the plant part and type of solvent. The investigations show that there is a good potential to be used as a good fungicide in agricultural control thanks to the secondary metabolites it contains. The use of plants as antifungal agents may be an alternative to minimizing the residual problem.

4. References

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