



COMPARATIVE BIOACTIVITY OF EXTRACTS FROM THREE *TAXUS* SPECIES GROWN IN RUSSIA

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SUMMARY

The investigation of antibacterial, antifungal, and cytotoxic activities of ethanol extracts from vegetative and generative parts of three *Taxus* species (*T. baccata* L., *T. cuspidata* Siebold et Zucc., and *T. canadensis* Marsh.) native to Russia was this study's aim. Cytotoxicity assessment was via the MTT assay (3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyltetrazolium bromide) against A-172 (glioblastoma), HeLa (cervical adenocarcinoma), HepG2 (hepatocellular carcinoma), and normal human embryonic mesenchymal stem (FetMSC) cells after 72 h of the treatment. Antifungal activity received comparative determination against *Fusarium oxysporum* L. and *Helminthosporium* L. using disc diffusion. Vegetative extracts showed potent cytotoxicity, especially *T. canadensis* shoots against HeLa and A-172 (IC₅₀ 5.7 ± 0.4 and 6.21 ± 0.3 µg/mL, respectively). However, the aril extracts displayed the lowest toxicity. Antifungal and bacteriostatic results also varied by species and pathogens. These results confirmed *Taxus* vegetative parts can be effective as promising sources of cytotoxic, antifungal, and antibacterial metabolites. Data on biological activity correlate with the accumulation of polyphenols in the tissues of studied plants. Histochemical studies have shown an abundant content of polyphenols in conductive, reserve, and epidermal tissues.

Keywords: *Taxus* species, cytotoxicity, antibacterial and antifungal activity, arillus, secondary metabolites

Key findings: *Taxus canadensis* shoot extracts exhibited the highest cytotoxicity against human cancer cell lines, whereas aril extracts were non-toxic. The yew extracts also revealed species- and organ-specific antibacterial and antifungal activity against the phytopathogenic fungi. Moreover, the research determined the content and localization of various classes of polyphenols of the studied plants.

Communicating Editor: Prof. Naqib Ullah Khan

Manuscript received: December 19, 2025; Accepted: August 31, 2026.

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Citation: Zaytseva SM, Liang J (2026). Comparative bioactivity of extracts from three *Taxus* species grown in Russia. *SABRAO J. Breed. Genet.* 58 (5) 2297-2308. <http://doi.org/10.54910/sabrao2026.58.5.29>.

INTRODUCTION

Yew (*Taxus* spp.) is an evergreen tree mostly found in temperate and tropical regions of the Northern Hemisphere (Thomas and Polwart, 2003; Hao *et al.*, 2008). These slow-growing, long-living trees produce the valuable rot-resistant wood. Their toxic taxoids attracted the research interest due to antitumor properties (Collins *et al.*, 2003), leading to paclitaxel (Taxol®), which contains baccatin III with a side chain at the 13th carbon (Paller and Antonarakis, 2011). Dozens of taxoid subclasses are generally existing (Qing-Wen and Oritani, 1999; Kochkin *et al.*, 2023).

Taxol induces apoptosis by binding to cancer cell cytoskeletons. However, yew handling requires caution, as poisoning is a cause of rapid cardiac arrest and respiratory depression, with resuscitation often ineffective (Willaert *et al.*, 2002; Reijnen *et al.*, 2017; Pilija *et al.*, 2018; Brooks-Lim *et al.*, 2021; Kolomiets and Maryin, 2024). However, among the gymnosperms, the *Taxus* only produces taxoids. The taxoid accumulation varies by species and plant parts. *T. cuspidata* shoots yield 25% more taxol than *T. media* var. *Hicksii* (Furmanova and Kropczynska, 2002).

The highest level of taxol occurs in *T. yunnanensis* bark and needles (Das and Rao, 1995; Li and Zhang, 2000), while the *T. baccata* needles contain more taxol than stems (Hook and Wang, 1999). Seeds accumulate minimal taxol, and the aril lacks it entirely, allowing birds to consume berries without harm (Kwak *et al.*, 1995; Trusov, 2016; Li *et al.*, 2017; Nichaev and Nichaev, 2018). Commercial chemical synthesis of paclitaxel remains unfeasible due to molecular complexity (Shao *et al.*, 2021). Cytochrome P450 oxygenases modify terpene backbones, expanding terpenoid diversity.

Beyond taxoids, yew produces various secondary metabolites with the highest bioactive compounds, such as phenolics, alkaloids, and polysaccharides (Lee *et al.*, 2016; Dang *et al.*, 2017; Zaytseva *et al.*, 2025). Polyphenols considerably participate in the processes of photosynthesis, respiration, and protection against various stress factors. Recent research highlighted their anticancer

potential through regulation of carcinogenesis pathways and cell cycle proteins (Zaytseva *et al.*, 2025). The ecological role of taxoids may involve defense against pathogens and herbivores (Soliman and Raizada, 2020). Natural yew populations occupy remote habitats with specific climatic requirements. Thus, taxol biosynthesis is a specific and unique feature of plants of the genus *Taxus*, and at the late stage of taxol assembly, its accumulation positively correlates with the accumulation of polyphenols. Similarly, the sites of the biosynthesis, transportation, and storage of taxol have different compartments and are in association with the sites of accumulation of polyphenols. (Russin *et al.*, 1995; Srinivasan *et al.*, 1996).

In Russia, only small endemic populations exist, viz., European yew (*T. baccata*) in Crimea and the North Caucasus and Japanese yew (*T. cuspidata*) in the Far East. However, their toxicity varies with habitat, climate conditions, and ontogenetic stage (Zhou *et al.*, 2019), and taxoid distribution among plant parts remains incompletely understood (Tabaszewska *et al.*, 2021; Gong *et al.*, 2024). Past studies on chemotaxonomy classified the plants based on biochemical differences (Schwikkard and Mulholland, 2014). Comparing cytotoxic effects may also reveal metabolomic variability among yew species.

With the scarcity of natural populations, evaluating the cytotoxic potential of introduced yew species cultivated in the Moscow region is crucial to expand the raw material base for anticancer substances. However, all the *Taxus* species have very low vegetative growth, limiting harvesting. Biotechnological methods, including in vitro cell selection, offer alternatives for preserving biodiversity and establishing high-producing cell lines (Zaytseva *et al.*, 2023). Such cultures have also supplied taxol for pharmaceutical industries.

Yew extracts considerably exhibited antibacterial, anti-inflammatory, and immunomodulatory activities. Given the rising antimicrobial resistance, natural agents increasingly become relevant. Different yew species vary in morphology, biochemistry, and

bioactivity. Some extracts were remarkable with robust bacterial inhibition, while others targeted fungi and viruses. Their extracts' activities also depend on the plant organ and vegetation stage (Zaytseva, 2018). Current research on bactericidal and fungicidal effects primarily focuses on European and Yunnan yew. The antifungal activity of less-studied species, particularly from different geographic zones, remains unknown. By comparing the antifungal spectra of the extracts obtained from various yew species, this study aimed to identify chemotaxonomic diversity in antibacterial activity and provide a scientific basis for developing new fungicides.

MATERIALS AND METHODS

Plant materials and extract preparation

The intact shoot tissues (needles and stems) were collections from introduced plants of the species *T. baccata* and *T. canadensis* in the Moscow Region and from male plants of the species *T. cuspidata* in the Far Eastern Region (Vladivostok). Mature seeds and red arils obtained from the species *T. canadensis* were also specimens collected. Ethanol extract preparation ensued by macerating 1 g of the plant material in 10 mL of 96% ethanol at 37 °C ± 1 °C for one hour, followed by filtration and evaporation to dryness.

Cell culture and cytotoxicity assay

Human cancer cell lines A-172 (glioblastoma), HeLa (cervical adenocarcinoma), HepG2 (hepatocellular carcinoma), and normal human embryonic mesenchymal stem cells (FetMSC) came from the Institute of Cytology RAS, Russia. The culturing of cells continued in appropriate media under standard conditions (37 °C, 5% CO₂). Cytotoxicity assessment used the MTT (3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyltetrazolium bromide) assay. The seeding of cells proceeded in 96-well plates and received treatment with extracts at concentrations ranging from 7.5 to 1000 µg/mL for 72 h. The IC₅₀ values underwent determination from dose-response curves.

Antifungal activity assay

For the work on primary screening of antifungal activity, desiccated ethanolic extracts (humidity 10%–12%) obtained from shoots and aril equal to 1 g were formulations used. All experiments took place on pure cultures of fungi of the *Fusarium oxysporum* L. and *Helminthosporium sativum* L. genera. These strains entailed identification and separation by the staff of the Laboratory of Mycology of the Institute of Phytopathology of the Russian Academy of Sciences. For the experiment, live fungus cultures, long stored in a refrigerator at a temperature of +4 °C, succeeded in their use, as they initially multiplied in a nutritious environment containing mineral salts on a phytohormone-free basis. Fungi growing in Petri dishes on a solid nutrient medium (Muller Hinton medium) were, according to the previously described method, in a light room at a temperature of 25 °C, with a photoperiod of 16 h and an intensity of 3000 lux. Dry plant extractive residue resulted from evaporated ethanolic extracts. For this 1-g panel of plant material, 10 mL of 96% ethyl alcohol sustained extraction over an hour at a temperature of 37 °C, incurred filtration through a paper filter (blue stripe) before drying and weighing to determine the exact mass. The lyophilized dry extractive residue hanger underwent dissolution in DMSO and addition to the composition of the nourishing medium after autoclaving. The extract concentrations were 100, 200, 300, and 400 mg/L.

Control served an environment without the extract, as well as a pure solvent (DMSO). For control in the study of fungicide activity, distilled water and dimethyl sulfoxide (DMSO)—a strong chemical solvent—were solutions used. DMSO gained rapid absorption by transdermal administration and exhibited low toxicity. This property can be applicable as a means of transdermally delivering poorly dissolved drugs in other solvents directly to their site of action. In addition, this antioxidant is popular as a growth inhibitor of pathogens with antifungal and antimicrobial action, a cryopreservative, an analgesic, and an anti-inflammatory. As a consequence, its effect on

the mycopathogen garnered separate studies in comparison with the control of water. Fungicidal activity detection of ethanolic plant extracts was by the mycelial growth of the fungus, measuring the diameter of the fungus in two planes. Plates underwent incubation at 25 °C for seven days, with the inhibition zones measured. During the cultivation period, measuring the diameter of the fungus ensued in two planes.

Antibacterial activity assay

The antibacterial activity determination employed the disk method. Investigated strains of bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Staphylococcus aureus*) entailed collection from the Department of Microbiology, Moscow Timiryazev Agricultural Academy. Bacterial isolates proceeded to transplanting onto dense-timing agar before culturing at 37 °C for 24 h. Colonies selected with a bacteriological loop underwent placement in sterile distilled water and were compared with the turbidity standard (0.5 McFarland standard). After agitation, taking 200 µl of the prepared bacterial suspension continued to be placed on a plate of nutrient agar in a Petri dish, evenly distributed with a sterile spatula. Two-layer sterile discs made of filter paper with a diameter of 6 mm incurred ethanolic extract injection before being laid out on the surface of the agar with applied bacterial culture. Freshly prepared ethanolic extracts of plant leaves (1 g of fresh plant material extracted 10 ml of heat in 96% ethyl alcohol over an hour in the dark) in the amount of 40 µl served to impregnate the discs, using 96% ethanol as a negative control. After cultivation at 37 °C for 24 h, the diameter of the inhibition zone reached measurement. The experiment had three repetitions.

Determination of the total content of phenolic compounds

The extraction of phenolic compounds continued with the crushing of the plant material (1000 mg) before being subjected to extraction with hot 96% ethanol (1 mL). The

extracts entailed determination spectrophotometrically for the sum of soluble phenolic compounds (with Folin-Denis reagent), flavans (with vanillin reagent), and flavonols (with aluminum chloride). Calibration curves for determining the total content of soluble phenolic compounds and flavans underwent construction using (–)-epicatechin, and for determining flavonols, their construction used a rutin (Zaytseva *et al.*, 2023).

For histochemical analysis, live fresh plant materials of the yew used as research objects were arils and shoots. The localization of phenolic compounds on temporary preparations reached determination by histochemical methods: for the amount of phenolic compounds, the material received staining with a 0.08% solution of the Fast Blue reagent. In studying the localization of flavans (catechins and proanthocyanidins), the study used a reaction with a vanillin reagent in hydrochloric acid vapors. In preserving the intracellular distribution of phenolic compounds, all reactions performed received nonpolar solvents (Soukupova *et al.*, 2000; Zaytseva *et al.*, 2023). The preparations incurred examination using a light microscope ("Karl Ziess").

Statistical analysis

The presentation of all recorded data based on various parameters was as mean ± standard deviation. The IC₅₀ value calculation used the median-effect analysis. The analysis performed had three each of biological and analytical replicates.

RESULTS AND DISCUSSION

Yew plants have a unique morphological feature: the formation of an aril. The yew seeds comprise a surrounding of a fleshy, cup-shaped aril, which changes color from green to bright red as seeds mature (Figure 1). Related to past studies, the aril occurred to be rich in secondary metabolites, which are conditionally edible for some bird species. This indirectly suggests containing the least amount and even



Figure 1. A) Canadian yew, B) Berry yew plants, C) Canadian yew shoot with seeds at the initial stages of development in June, and D and E) mature seeds in September.

Table 1. Accumulation of polyphenols in the shoots of various yew species and aril at different stages of development.

Samples	Concentration (mg/g fresh mass)		
	Total phenolic	Flavans	Flavonols
<i>T. canadensis</i>			
Shoot	67.2±4.6	37.5±3.4	42.8±2.6
green aril	54.7±3.9	19.3±0.7	13.4±0.5
red aril	48.4±3.9	39.7±3.4	2.1±0.3
<i>T. cuspidata</i>			
Shoot	79.5±4.2	22.3±1.7	47.7±2.7
<i>T. baccata</i>			
Shoot	85.3±4.7	24.0±1.8	55.6±3.9

being entirely devoid of taxol compared with other plant parts (Li *et al.*, 2017; Nichaev and Nichaev, 2018; Zaytseva *et al.*, 2025).

Formation and localization of polyphenols

According to our biochemical studies, the greatest accumulation of polyphenols is characteristic of *T. baccata* and *T. cuspidata* pointed yew. However, *T. canadensis* accumulates more flavans (Table 1). During the growing season, as the aril matures, the content of polyphenols changes. Against the background of a slight decrease in the total content of phenolic compounds in mature red arils, the proportion of flavans increases. When aril matures, the proportion of flavanols decreases—the most common polyphenols have the biosynthesis confined to chloroplasts. Substances of flavan nature dominated in the aril at various stages of vegetation, as the presented histochemical studies confirmed.

In the yew leaf, phenolic compounds sit in the thickness of the cuticle, in the cells of the epidermis and parenchyma. Polyphenols are ubiquitous in the terminal cells of the stomata (Figures 2A, B, and C). In parenchymal cells, polyphenols exist locally in vacuoles, cytoplasm, and cell walls. Phenolic compounds appear in the phloem and in the cell walls of xylem vessels. Many idioblasts contain these compounds among the cells of the core.

By the end of summer, the skin surrounding the yew seed becomes "fleshy" and massive and then turns red. Among the distribution of polyphenols in the parenchyma of the aril, zones where phenolic compounds prevail are in intercellular cells, vacuoles, and idioblasts. Such zones with polyphenols became filled with cells of the epidermis and the underlying layer of the parenchyma connected to the chalaza (Figures 2D and E).

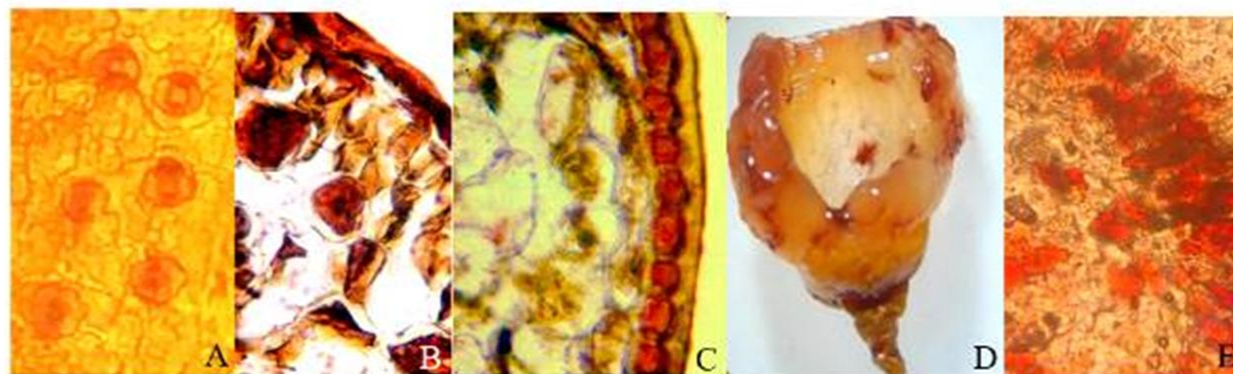


Figure 2. Reaction to determine the localization of the total content of phenolic compounds in the *Taxus*: A) flavans in the stomata of the yew leaf, B) total polyphenols in the cuticle, epidermis, and mesophyll of the yew leaf, C) total polyphenols in the upper part of the cuticle and cells of the epidermis of the yew stem, and D and E) total polyphenols in the aril.

Table 2. Comparison of the cytotoxic effect of extracts obtained from plants of the genus *Taxus* spp. IC₅₀ values for yew extracts after 72 hours of exposure on various human cells.

Sample	Concentration inhibiting cell viability by 50% IC ₅₀ , µg/ml			
	FetMSC	HepG2	HeLa	A-172
Shoot <i>T. canadensis</i>	>1000	636.0±31.6	5.7±0.4	6.21±0.3
Aril <i>T. canadensis</i>	>1000	>1000	>1000	602.10±27.1
Ripe seed <i>T. canadensis</i>	>1000	>1000	189.7±11.6	662.0±30.4
Shoot <i>T. cuspidata</i>	>1000	>1000	21.7±1.7	7.4±0.5
Shoot <i>T. baccata</i>	>1000	674.0±28.8	25.6±1.9	10.2±0.6

Cytotoxic activity of Yew extracts

The presented investigation based on the cytotoxicity of extracts obtained from various *Taxus* species determined the IC₅₀ values (the concentration inhibiting 50% of cell viability). The results clearly revealed the obtained extracts from the studied yew species exhibited low toxicity toward normal FetMSC cells (Table 2), which was undoubtedly and considerably a crucial factor for potential therapeutic applications. HepG2 liver carcinoma cells also showed considerable resistance in response to the action of the yew extracts. However, the extracts gathered from the shoots of the species *T. canadensis* and *T. baccata* (collected from the RGAU-MSHA Botanical Garden) displayed slight and identical cytotoxicity against this cell line.

In all tested scenarios, the most sensitive cell lines to the yew extracts were HeLa (human cervical adenocarcinoma, clone

M) and A-172 (human glioblastoma). The results further revealed the extractive substances obtained from the shoots of species *T. canadensis* possessed the greatest cytotoxic effect compared with other studied yew species. By comparing the acquired results with the cytotoxicity of the drug Paclitaxel (Taxol®), manufactured based on secondary metabolites from the species *Taxus*, the commercial drug was far more potent. It had an IC₅₀ of 3 ng/mL for susceptible cells and 35 ng/mL for resistant cells. The results expressed that the ethanol extracts obtained from 1 gram of intact vegetative tissues of yew were approximately 1000 times less toxic than the pure active pharmaceutical ingredient.

Cytotoxicity of extracts from generative organs

Determining the cytotoxicity of extracts obtained from mature seeds and stems of the

Canadian yew against human cancer cells was also successful, with this activity compared with extracts taken from vegetative organs. According to the IC₅₀ value (a concentration that suppresses cell viability by 50%), the extract of the vegetative parts of the Canadian yew demonstrated the greatest cytotoxicity against HeLa and A-172, while extracts from aril and mature seeds showed no pronounced cytotoxic effect on all cell groups. It was also noteworthy that aril and mature seed extracts have low toxicity not only for the studied tumor cell lines but also for normal embryonic cells. The cytotoxic effect of the shoot extracts was almost 100 times stronger than that of the generative organ extract (Table 2). Thus, for tumor cell lines (HepG2, HeLa, and A-172), aril extract did not exhibit a sufficient cytostatic effect, while extracts of mature seeds were cytotoxic.

Antifungal activity of Yew extracts

It is a well-known fact that secondary plant metabolites determine the biological activity of their extractives. The phenolic and terpenoid compounds exhibited the most pronounced effects. Regarding the cytotoxic effect of yew, its primary action has undoubted determinants of terpenoid substances—taxoids. However, the present results revealed the retention of the cytotoxic effect by yew aril tissues to produce the taxoids was unknown. This may refer to the abundant formation of phenolic substances, which exhibited a broad spectrum of biological activity, including cytotoxicity (Zaytseva, 2018; Kirakosyan *et al.*, 2024).

Thus, studying the fungicidal and antibacterial activity of various *Taxus* species not only provides a scientific foundation for the development of new natural biologically active agents or antimicrobials/biocides. It also contributes to a broader understanding of the biological properties and practical potential value of yew. The latest research showed secondary metabolites both inhibit the growth of human cancer cells and can stimulate various physiological processes, as reported in several past studies (Reijnen *et al.*, 2017; Piliya *et al.*, 2018).

A comparative assessment of the antifungal activity of yew extracts revealed species-, organ-, and concentration-dependent effects. The *T. canadensis* leaf extract reduced the growth of *Helminthosporium sativum*, with the strongest effect at 400 mg/L, whereas it stimulated the growth of *Fusarium oxysporum* at all tested concentrations (Figures 3A-B and 4A-B). The *T. canadensis* aril extract inhibited *F. oxysporum* at 300–400 mg/L but had little effect on *H. sativum* (Figures 3C and 4C-D). In comparison, *F. oxysporum* showed greater sensitivity to *T. baccata* leaf extract than *H. sativum* (Figures 5A and B). Overall, the antifungal response depended on the *Taxus* species, plant organ, fungal species, and extract concentration.

By working with extractive substances from generative organs of Canadian yew, represented by the aril, results revealed extracts with concentrations of 300 and 400 mg/L also inhibited the *Fusarium oxysporum* L. fungi compared with the control group. The results further disclosed only a low concentration of 100 mg/L extract exerted a slight stimulating effect on fungal growth. Different concentrations of yew aril extract had a nonsignificant effect on the growth of *Helminthosporium* L. compared with the control. In addition, DMSO as a solvent has an inhibitory effect on the growth of fungi; however, by using it in combination with yew extractives, and as the concentration of the extracts increases, varied inhibitory effects are evident on the growth traits of the two types of fungi.

Antibacterial activity of Yew extracts

Extractive substances of *T. canadensis* show high antibacterial activity, especially pronounced against *E. coli* and *S. aureus* (Table 3). The average diameter of the inhibition zone for *E. coli* was 14.03 ± 0.17 mm on average. Scientists have previously shown that the active components of plant secondary metabolism can destroy the microbial cytoskeleton and disrupt energy metabolism (Nesterovich *et al.*, 2023). One can observe this by the different physiological

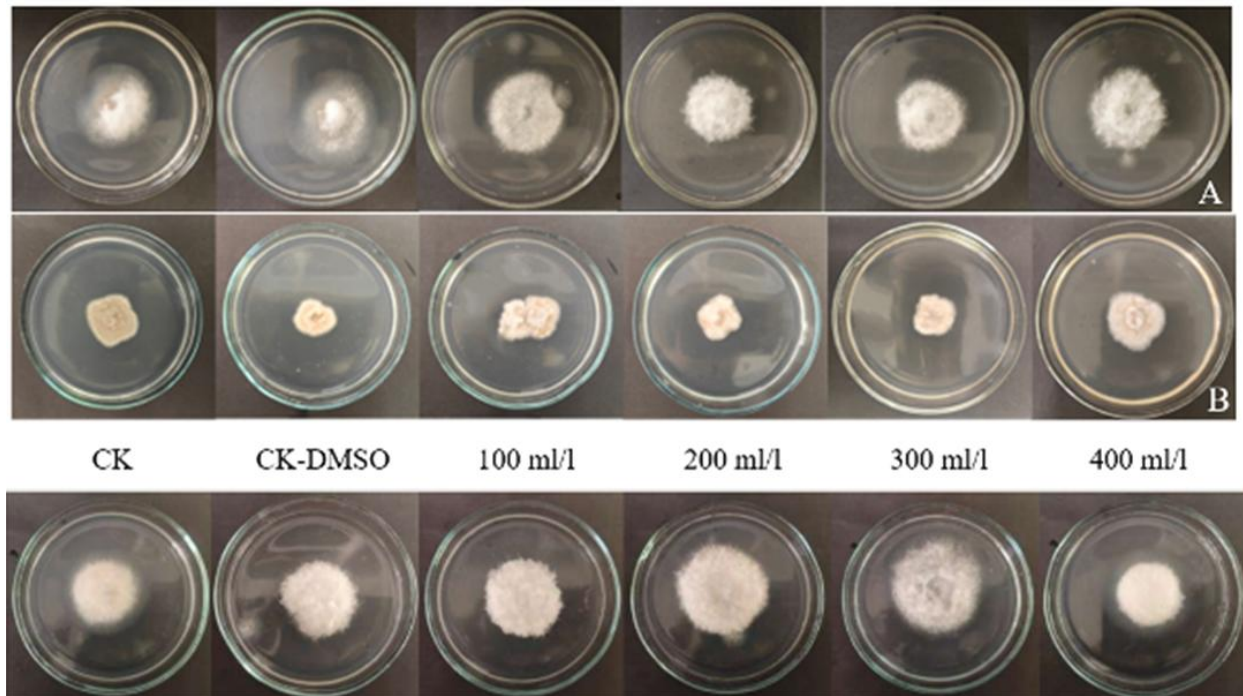


Figure 3. A) Effect of *T. canadensis* leaf extracts on the growth traits of *Helminthosporium sativum* L., and B) *Fusarium oxysporum* L. and aril extracts on the traits of *Fusarium oxysporum* L. (C).

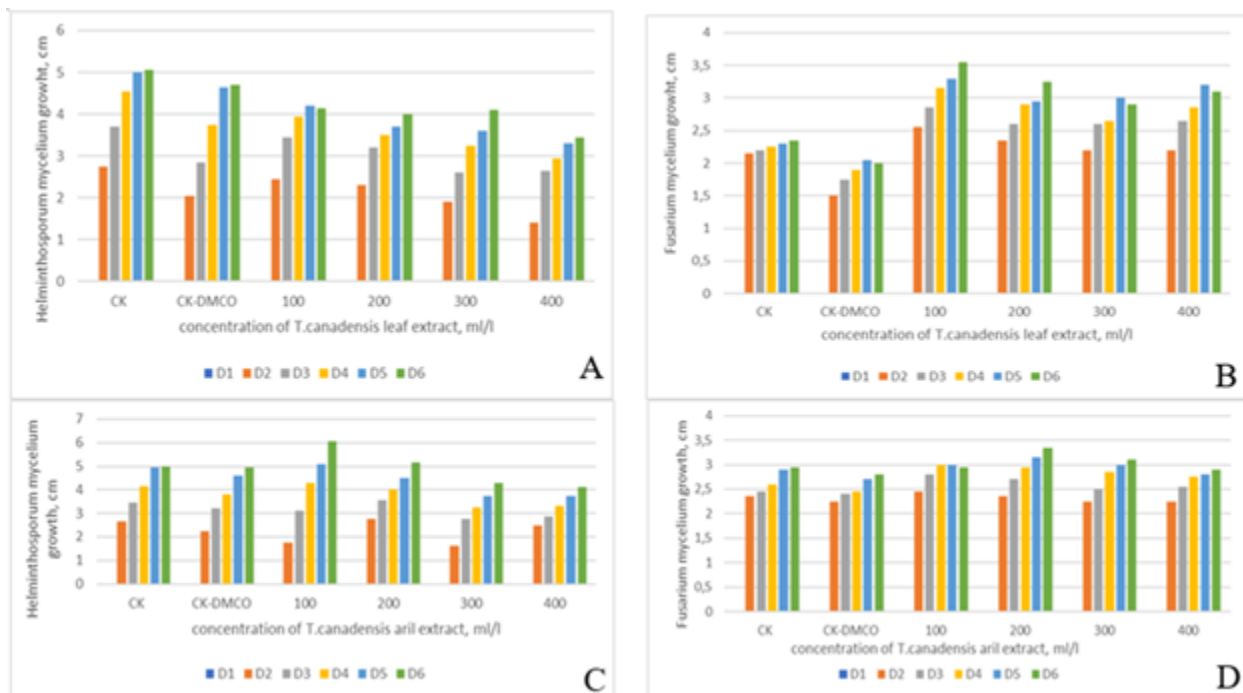


Figure 4. A) Effect of *T. canadensis* leaf extracts on the growth traits of *Helminthosporium sativum* L., and B) *Fusarium oxysporum* L., and aril extracts on the traits of *Helminthosporium sativum* L., (C) and *Fusarium oxysporum* L. (D).

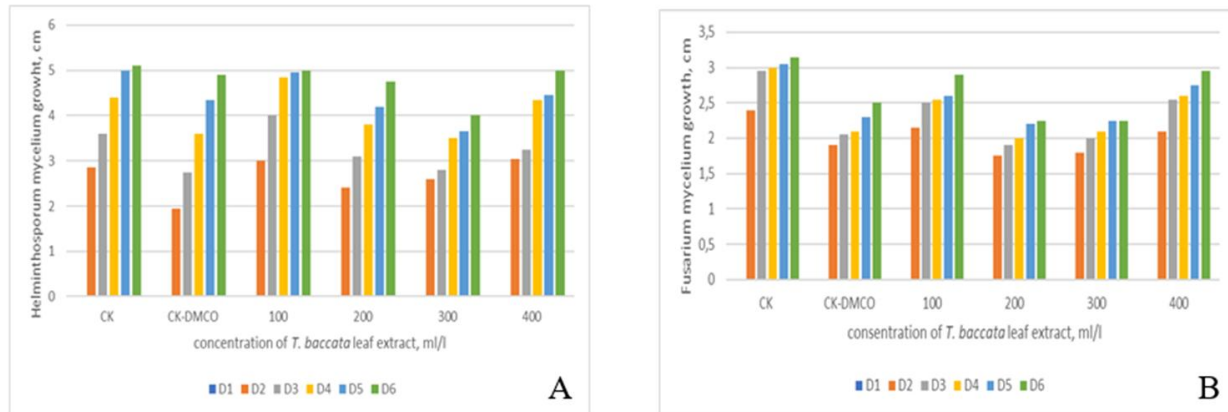


Figure 5. A) Effect of *T. baccata* leaf extracts on the growth traits of *Helminthosporium sativum* L., and B) *Fusarium oxysporum* L.

Table 3. Comparison of the antibacterial activity of ethanol extracts of shoots of various types of yew and aril.

Samples	Growth suppression zone (mm)			
	Gram-negative bacteria		Gram-positive bacteria	
	<i>E. coli</i>	<i>P. aeruginosa</i>	<i>S. aureus</i>	<i>B. subtilis</i>
Shoot <i>T. canadensis</i>	14.03 ± 0.17	7.5±0.4	10.75±0.6	6.3±0.3
red aril <i>T. canadensis</i>	9.2±0.5	6.0±0.3	8.6±0.5	5.5±0.2
Shoot <i>T. cuspidata</i>	9.75±0.5	9.25±0.5	8.25±0.7	6.1±0.3
Shoot <i>T. baccata</i>	11.0±0.7	7.25±0.8	8.5±0.8	7.25±0.8

responses from different representatives of bacteria to the identical composition of ethanolic extracts. Our next studies will involve an in-depth study of key antibacterial components and their molecular mechanisms of action.

The largest growth suppression zones were typical for gram-negative bacteria. As can be seen from the presented results (Table 3), the greatest bacteriostatic effect is characteristic of the vegetative organs of yew. The *T. canadensis* had the ultimate effect on bacteria, while extracts of *T. cuspidata* and *T. baccata* had almost solitary activity. However, one can note that aril extracts also exhibit an inhibitory effect on bacterial growth. These data once again indicate the role of polyphenols in suppressing the growth of pathogenic microflora. Overall, one can conclude that extracts from the vegetative parts of yew plants displayed the greater cytotoxic effect. Across all variants, the HeLa

(human cervical adenocarcinoma, clone M) and A-172 (human glioblastoma) cell lines proved the most sensitive to these yew extracts. However, the yew extracts provided the lowest toxicity to normal FetMSC cells and HepG2 liver carcinoma cells.

Among the studied yew species, Canadian yew deserves special attention due to its broad-spectrum cytotoxic effects on cancer cells. Furthermore, the seeds and aril parts of the species *T. canadensis* produced the secondary metabolic products that can exert a minor cytotoxic effect (Lee *et al.*, 2016; Dang *et al.*, 2017; Zaytseva *et al.*, 2025). The obtained low cytotoxicity of ethanol extracts of aril revealed mature pericarps of Canadian yew collected with caution may also be sources of valuable secondary metabolites for pharmacognosy (Kwak *et al.*, 1995). Studying not only the variations in taxoid accumulation but also their cytotoxic effect in combination with other active metabolites will

further allow us to better understand the differential accumulation of taxoids between these species. This is because of the limitation in each step of its biosynthesis by the availability of precursors, which differ in the sites of biosynthesis, transport, and localization within plants (Jiao *et al.*, 2022).

The results based on fungicidal activity suggested that yew extract has some antifungal potential, particularly in Canadian yew; however, its effect incurs influence from several factors, including the presence and absence of DMSO and the degree of defense mechanisms of various plant organs. The variation in the fungicidal activity of DMSO when used in combination with yew extractives may be due to high-concentration extracts being able to counteract the inhibitory effect of DMSO. Hence, this more accurately reflects the actual antibacterial effect of the yew extract itself. Overall, the study demonstrated that yew extracts from vegetative and generative organs possess some fungicidal potential; however, various factors influence their effectiveness. Therefore, the accumulated knowledge will enable accelerated propagation and selection of the most productive yew species and the efficient use of available resources, including the development of new antimicrobial agents.

CONCLUSIONS

Ethanol extracts from vegetative shoots of three *Taxus* species grown in Russia exhibited significant cytotoxicity to cancer cells (HeLa and A-172) with low toxicity to normal FetMSC cells, and the species *T. canadensis* shoot extracts had the robust activity. The species *T. canadensis* aril and ripe seed extracts showed weak cytotoxicity, which reflected the obvious organ-specific accumulation of cytotoxic metabolites in *Taxus* plants. *Taxus* extracts presented species- and concentration-dependent antifungal activity on fungi *Fusarium oxysporum* and *Helminthosporium* sp., with distinct effects among different species and organs. Ethanol extracts of various yew species had the largest growth suppression zone for gram-negative bacteria.

The *T. canadensis* vegetative organs proved the most promising raw material for isolating natural cytotoxic and antifungal secondary metabolites. This promising study provided an experimental evidence for the development of *Taxus*-derived natural anticancer and antifungal agents. Extracts from aril yew, devoid of toxic taxoids but rich in polyphenols, deserve special attention as promising components for pharmacognosy.

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