

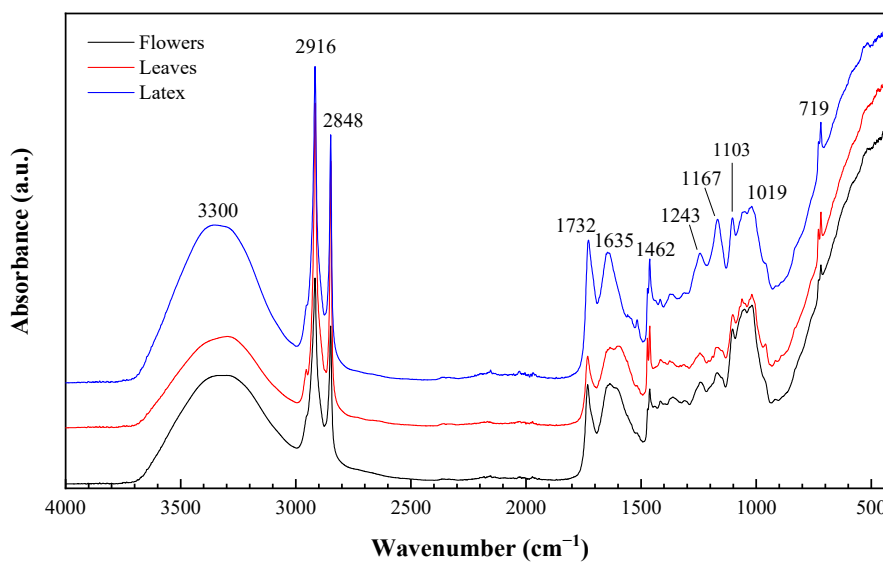
# Phytochemical Constituents and Antimicrobial Activity of *Euphorbia serrata* L. Extracts for *Borago officinalis* L. Crop Protection

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## SUPPORTING INFORMATION



**Figure S1.** *Euphorbia serrata* aerial part (**left**) and detail of the inflorescences (cyathia) (**right**).



**Figure S2.** Infrared spectra of *E. serrata* flowers, leaves, and latex.

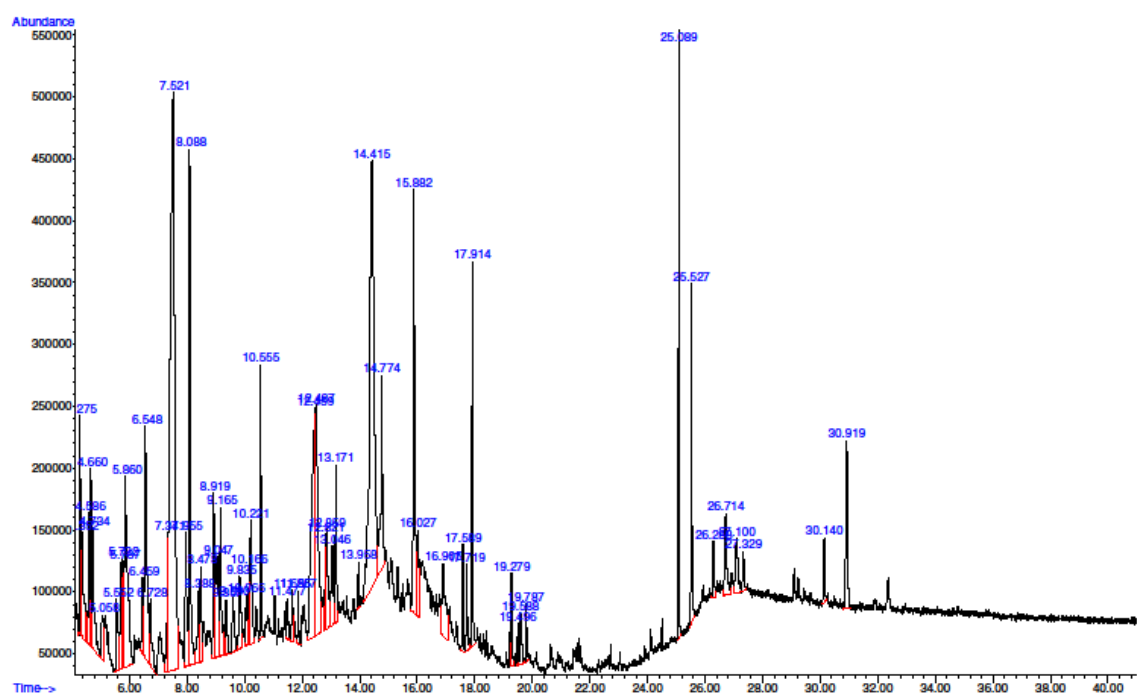
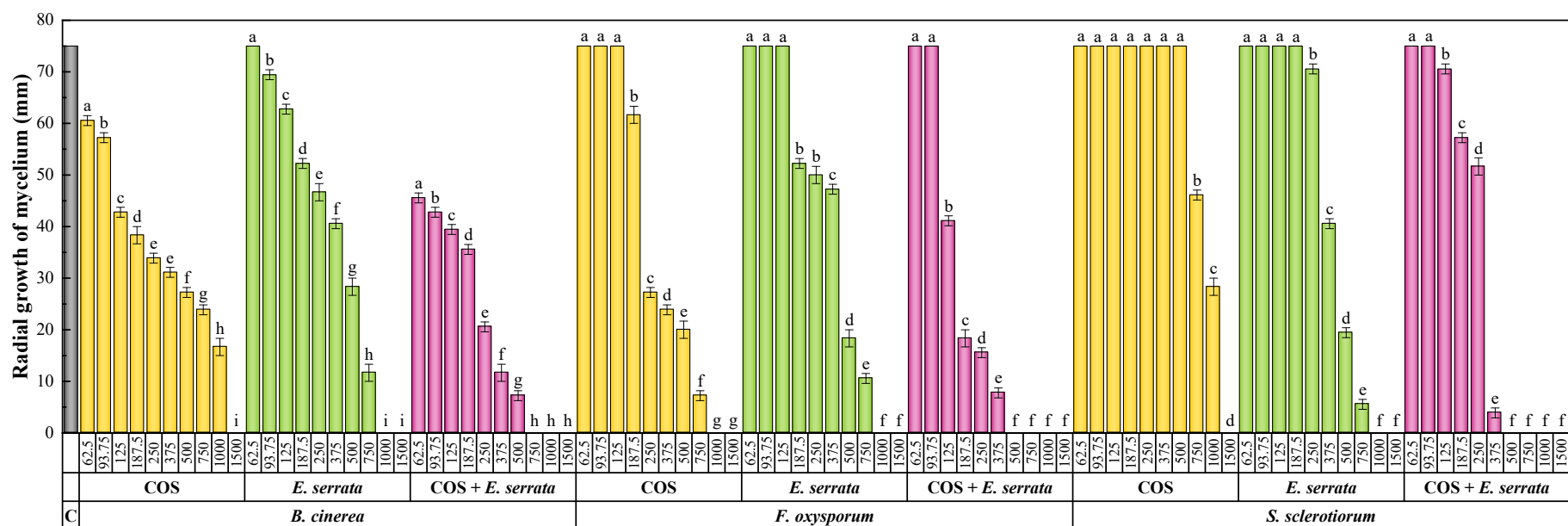


Figure S3. GC-MS chromatogram of *E. serrata* aerial parts hydromethanolic extract.



**Figure S4.** Inhibition of the radial growth of the mycelium of *B. cinerea*, *F. oxysporum*, and *S. sclerotiorum* in the *in vitro* tests performed with PDA medium amended with different concentrations (in the range of 62.5–1500 µg·mL<sup>-1</sup>) of chitosan oligomers (COS), *E. serrata* aerial part extract, and their conjugate complex (COS–*E. serrata*). The grey bar (C) represents the controls. The efficacies of concentrations labeled with the same letters are not statistically different at  $p < 0.05$ . Standard deviations are represented by error bars.

**Table S1.** Efficacy of plant extracts and essential oils reported in the literature against the phytopathogens under study.

Pathogen	Extraction Media	Plant	Efficacy	Ref.
<i>P. cichorii</i>	Methanol/water	<i>Ginkgo biloba</i> PE	MIC = 750 $\mu\text{g}\cdot\text{mL}^{-1}$	[1]
	Methanol	<i>Musa paradisiaca</i> PE	n.a., at 3% of extract	[2]
	Acetone	<i>Withania somnifera</i> PE	IZ > 90 mm, at 2–3% of extract	[3]
	Water, ethanol (95%), ethanol/water, acetone, or methanol	<i>Abies balsamea</i> PE	n.a.	[4]
		<i>Acer rubrum</i> PE	n.a.	
		<i>Acer saccharum</i> PE	IZ = n.a.→ 10 mm	
		<i>Alnus incana</i> subsp. <i>rugosa</i> PE	n.a.	
		<i>Larix laricina</i> PE	n.a.	
		<i>Picea glauca</i> PE	n.a.	
		<i>Picea mariana</i> PE	n.a.	
		<i>Pinus banksiana</i> PE	n.a.	
		<i>Pinus strobus</i> PE	n.a.	
		<i>Populus tremuloides</i> PE	n.a.	
		<i>Prunus avium</i> PE	n.a.	
		<i>Quercus rubra</i> PE	IZ = 5–10 mm	
	Methanol	<i>Leandra cornoides</i> PE	MIC > 1200 $\mu\text{g}\cdot\text{mL}^{-1}$	[5]
	Methanol/water	<i>Silene uniflora</i> PE	MIC = 1000 $\mu\text{g}\cdot\text{mL}^{-1}$	[6]
		COS– <i>S. uniflora</i> PE	MIC = 750 $\mu\text{g}\cdot\text{mL}^{-1}$	
<i>B. cinerea</i>	Aqueous ammonia	<i>Uncaria tomentosa</i> PE	MIC = 375 $\mu\text{g}\cdot\text{mL}^{-1}$	[7]
		COS– <i>U. tomentosa</i> PE	MIC = 93.75 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Natural eutectic solvent (1500 $\mu\text{g}\cdot\text{mL}^{-1}$ )	<i>Larrea cuneifolia</i> PE	IR = 92%	[8]
	Hexane, dichloromethane, methanol, water (500,000 $\mu\text{g}\cdot\text{mL}^{-1}$ )	<i>Vernonia amygdalina</i> PE	IR = 75.7%	[9]
	CO <sub>2</sub> extraction	<i>Glechoma hederacea</i> var. <i>longituba</i>	MIC $\geq$ 5000 $\mu\text{g}\cdot\text{mL}^{-1}$	[10]
	CO <sub>2</sub> extraction	<i>Pimenta dioica</i> PE	MIC = 2200 $\mu\text{g}\cdot\text{mL}^{-1}$	[11]
		<i>Cinnamomum cassia</i> PE	MIC = 600 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>Laurus nobilis</i> PE	MIC = 3000 $\mu\text{g}\cdot\text{mL}^{-1}$	
	CO <sub>2</sub> extraction	<i>Syzygium aromaticum</i> PE	MIC = 600 $\mu\text{g}\cdot\text{mL}^{-1}$	[12]
		<i>S. aromaticum</i> EO	MIC = 1200 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>L. nobilis</i> PE	MIC > 2000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>L. nobilis</i> EO	MIC > 2000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>Rosmarinus officinalis</i> PE	MIC > 2000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>R. officinalis</i> EO	MIC > 2000 $\mu\text{g}\cdot\text{mL}^{-1}$	

Pathogen	Extraction Media	Plant	Efficacy	Ref.
<i>F. oxysporum</i> spp.	Water	<i>Anabaena</i> sp. PE	MIC = 2500 $\mu\text{g}\cdot\text{mL}^{-1}$	[13]
		<i>Ecklonia</i> sp. PE	MIC = 5000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>Jania</i> sp. PE	MIC = 10,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Ethanol/water	<i>Achillea millefolium</i> PE	MIC > 20,000 $\mu\text{g}\cdot\text{mL}^{-1}$	[14]
		<i>Allium sativum</i> PE	MIC = 20,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>Artemisia dracunculus</i> PE	MIC > 20,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>Hyssopus officinalis</i> PE	MIC > 5000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>Mentha</i> sp. PE	MIC = 20,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>R. officinalis</i> PE	MIC > 20,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>Satureja hortensis</i> PE	MIC = 10,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>Tagetes patula</i> PE	MIC > 20,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>Valeriana officinalis</i> PE	MIC > 20,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Methanol	<i>Micromeria nervosa</i> PE	MIC = 0.5%	[15]
		<i>Origanum syriacum</i> PE	MIC = 0.06%	
		<i>Inula viscosa</i> PE	MIC > 2%	
		<i>Plumbago maritima</i> PE	MIC = 1% <sup>6</sup>	
	Water	<i>O. heracleoticum</i> PE	MIC > 500,000 $\mu\text{g}\cdot\text{mL}^{-1}$	[16]
		<i>Salvia officinalis</i> PE	MIC > 500,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		<i>R. officinalis</i> PE	MIC > 500,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Ethanol	<i>Pinus sylvestris</i> bark	MIC = 20,000 $\mu\text{g}\cdot\text{mL}^{-1}$	[17]
		<i>P. abies</i> bark	MIC = 20,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Methanol	<i>Liquidambar orientalis</i> PE	MIC > 400,000 $\mu\text{g}\cdot\text{mL}^{-1}$	[18]
		<i>Myrtus communis</i> PE	MIC = 400,000 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Methanol/water	<i>Armeria maritima</i> PE	MIC = 750 $\mu\text{g}\cdot\text{mL}^{-1}$	[19]
		COS– <i>A. maritima</i> PE	MIC = 500 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Ethanol	<i>Annona cherimola</i> PE	MIC = 16,000 $\mu\text{g}\cdot\text{mL}^{-1}$	[20]
	Water (5, 10, and 20%)	<i>Azadirachta indica</i> PE	n.a.	[21]
		<i>Parthenium hysterophorus</i> PE	IR = 2.6–15.9%	
		<i>Momordica charantia</i> PE	IR = 14.4–24.4%	
		<i>A. sativum</i> PE	IR = 52.6–63.3%	
		<i>Eucalyptus globulus</i> PE	IR = 34.3–61.8%	
		<i>Calotropis procera</i> PEs	n.a.	
		<i>Aloe vera</i> PE	IR = 16.6%	
		<i>Beta vulgaris</i> PE	IR = 6.3–10.3%	

Pathogen	Extraction Media	Plant	Efficacy	Ref.
		<i>D. stramonium</i> PE	IR = 61.1%	[22]
		Water (1%)	IR = 78%	
		Propanol(1%)	IR = 62%	
		Hexane	MIC = 1000 $\mu\text{g}\cdot\text{mL}^{-1}$	[23]
		Chloroform	MIC = 1000 $\mu\text{g}\cdot\text{mL}^{-1}$	
		Ethyl acetate	MIC = 500 $\mu\text{g}\cdot\text{mL}^{-1}$	
		Methanol	MIC = 500 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Crude extract (5, 10, and 20%)	<i>A. indica</i> PE	IR = 24.1–62.0%	[24]
		<i>Ocimum sanctum</i> PE	IR = 7.0–17.0%	
		<i>Datura metel</i> PE	IR = 10.1–34.2%	
		<i>Cassia alata</i> PE	IR = 46.8–74.7%	
		<i>Asparagus racemosus</i> PE	IR = 44.3–57.0%	
		<i>A. sativum</i> PE	IR = 17.6–34.2%	
		<i>Zingiber officinale</i> PE	IR = 23.7–39.5%	
	Ethanol	<i>Flourensia microphylla</i> PE	MIC = 1500 $\mu\text{L}\cdot\text{L}^{-1}$	[25]
		<i>Flourensia cernua</i> PE	MIC = 1500 $\mu\text{L}\cdot\text{L}^{-1}$	
		<i>Flourensia retinophylla</i> PE	MIC = 1500 $\mu\text{L}\cdot\text{L}^{-1}$	
	Water (5–50%)	<i>Moringa oleifera</i> PE	IR = 43.4–100%	[26]
		<i>M. oleifera</i> PE	IR = 48.8–100%	
		<i>M. oleifera</i> PE	IR = 36–100%	
	Essential oil	<i>Piper auritum</i> EO	MIC <sub>50</sub> = 6000–9000 $\mu\text{g}\cdot\text{mL}^{-1}$	[27]
	Water (25%)	<i>Acacia nilotica</i> PE	IR = 82%	[28]
		<i>Achras zapota</i> PE	IR = 34.8%	
		<i>Datura stramonium</i> PE s	IR = 67.5%	
		<i>Emblica officinalis</i> PE	IR = 79.5%	
		<i>Eucalyptus globulis</i> PE	IR = 59.3%	
		<i>Lawsonia inermis</i> PE	IR = 82.0%	
		<i>Mimusops elengi</i> PE	IR = 86.0%	
		<i>Peltophorum pterocarpum</i> PE	IR = 53.3%	
		<i>Polyanthia longifolia</i> PE	IR = 36.3%	
		<i>Prosopis juliflora</i> PE	IR = 80.3%	
		<i>P. granatum</i> PE	IR = 73.8%	
		<i>Syzygium cumini</i> PE	IR = 69.5%	

Pathogen	Extraction Media	Plant	Efficacy	Ref.
<i>S. sclerotiorum</i>	Water	<i>Filipendula</i> spp. PE	IR = 95.9%	[29]
		<i>A. sativum</i> PE	IR = 81.4%	
	Ethanolol	<i>Mentha spicata</i> PE	MIC = 5%	[30]
	Water	<i>A. sativum</i> PE	MIC = 7000 $\mu\text{g}\cdot\text{mL}^{-1}$	[31]
	Methanol/water	<i>A. maritima</i> PE	MIC = 375 $\mu\text{g}\cdot\text{mL}^{-1}$	[19]
		COS- <i>A. maritima</i> PE	MIC = 250 $\mu\text{g}\cdot\text{mL}^{-1}$	
	CO <sub>2</sub> extraction	<i>G. hederacea</i> var. <i>Longituba</i> PE	MIC $\geq$ 5000 $\mu\text{g}\cdot\text{mL}^{-1}$	[10]
	Hexane	<i>C. nocturnum</i> PE	MIC = 1000 $\mu\text{g}\cdot\text{mL}^{-1}$	[23]
	Chloroform		MIC = 500 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Ethyl acetate		MIC = 250 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Methanol		MIC = 500 $\mu\text{g}\cdot\text{mL}^{-1}$	
	Essential oils (1, 2.5, and 5%)	<i>Thymus vulgaris</i> EO	n.a.	[32]
		<i>Nigella sativa</i> EO	n.a.	
		<i>Origanum majorana</i> EO	MIC = 2.5%	
		<i>Syzygium aromaticum</i> EO	MIC = 2.5%	
	Essential oils (20%)	<i>Salvia rosmarinus</i> EO	n.a.	[33]
		<i>Ocimum basilicum</i> EO	IR = 4.1%	
		<i>A. sativum</i> EO	IR = 28.2%	
		<i>Cymbopogon citratus</i> EO	IR = 9.1%	
		<i>Nerium oleander</i> EO	IR = 14.1%	
		<i>A. indica</i> EO	IR = 35.5%	
		<i>Allium cepa</i> EO	IR = 16.9%	
	Essential oil	<i>Z. officinale</i> EO	MIC = 1000 $\mu\text{g}\cdot\text{mL}^{-1}$	[34]
	Water	<i>Trachystemon orientalis</i> PE	MIC = 7%	[35]
		<i>T. orientalis</i> PE	MIC = 1%	
	Crude extracts	<i>Rosmarinus officinalis</i> PE	MIC = 10%	[36]
		<i>Salvia fruticosa</i> PE	MIC = 20%	
	Ethanol	<i>M. spicata</i> PE	MIC = 5%	[30]
	Water	<i>A. sativum</i> PE	MIC = 5000 $\mu\text{g}\cdot\text{mL}^{-1}$	[31]

PE: plant extract; EO: essential oil; MIC: minimum inhibitory concentration; IZ: inhibition zone; IR: inhibition rate; MIC<sub>50</sub>: minimum inhibitory concentration that inhibited 50% of the radial growth; n.a.: no activity at the highest concentration tested.

**Table S2.** Minimum inhibitory concentrations (expressed in  $\mu\text{g}\cdot\text{mL}^{-1}$ ) of conventional antibiotics (for clinical use) against *P. cichorii* strain CITA Pci-5.

Bacteria	Penicillin	Ampicillin	Gentamicin	Ciprofloxacin	Tetracycline	Ref.
<i>P. cichorii</i>	$\geq 32$	$\geq 256$	3	6	24	[1]

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