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PHYTOCHEMICAL PROFILE AND MAIN BIOACTIVE CONSTITUENTS OF THE PLANT *NIGELLA SATIVA* L.

Răzvan Ionuț Iacob¹, Romeo T. Cristina¹, Maria-Larisa Ardelean (căs.Rusu)¹, Florin Muselin¹, Eugenia Dumitrescu^{1,*}

¹ University of Life Sciences „King Michael I” from Timișoara, Faculty of Veterinary Medicine,
300645, Calea Aradului No 119, Timișoara, Romania;

Abstract: *Nigella sativa* L. (black cumin) is an annual species of the family Ranunculaceae, traditionally used in the Middle East, North Africa and South Asia both as a spice and as a medicinal remedy for respiratory, digestive and metabolic disorders. The seeds have a high content of fixed oil (approximately 26–40 percent), proteins, carbohydrates, fibre and minerals, and the oil is dominated by polyunsaturated fatty acids, particularly linoleic and oleic acids, which confer high nutritional and functional value. The volatile fraction of the seeds is rich in thymoquinone, thymohydroquinone, dithymoquinone, p-cymene and thujene isomers, compounds regarded as chemical markers of essential oil quality. In addition, the seeds contain alkaloids, triterpene saponins, phytosterols, flavonoids and phenolic acids, which underlie an antioxidant, anti-inflammatory, hepatoprotective, cardiometabolic, neuroprotective, antimicrobial and antitumour potential demonstrated in numerous preclinical and clinical studies. Recent advances in extraction methods and in the formulation of extracts and thymoquinone (including nanoformulations) have improved the bioavailability and stability of the active compounds, consolidating *N. sativa* as a model species in phytotherapy and modern pharmacological research.

Keywords: *Nigella sativa*, black cumin, thymoquinone, volatile oil, polyunsaturated fatty acids, phytochemical profile, pharmacological activity.

• Introduction

Nigella sativa L., commonly known as black cumin or black seed, is an annual herbaceous medicinal plant belonging to the Ranunculaceae family, used for centuries both as a spice and a traditional remedy. Its seeds have traditionally been employed to treat respiratory disorders, gastrointestinal ailments, diabetes, pain, and to support the immune system. Scientific interest in *N. sativa* has increased significantly in recent decades due to numerous experimental and clinical studies demonstrating antioxidant, anti-inflammatory, hepatoprotective, cardiometabolic, neuroprotective, antimicrobial, and antitumour activities, all closely linked to the complex phytochemical composition of its seeds and oil. The volatile fraction rich in thymoquinone and the fixed oil abundant in polyunsaturated fatty acids are considered the main components responsible for these effects. Thanks to this combination of nutritional value and broad pharmacological potential, *N. sativa* is now regarded as a strategic species for the development of dietary supplements, pharmaceutical products, and natural remedies.

• Taxonomy, origin and geographical distribution

Nigella sativa belongs to the genus *Nigella*, subfamily Ranunculoideae, family Ranunculaceae, order Ranunculales. The genus comprises about 14–22 annual species distributed mainly across the Mediterranean and Irano-Turanian regions. *N. sativa* is a diploid species ($2n = 12$) with a stable karyotype consisting of six chromosome pairs. Studies indicate a relatively conserved genetic background, although polyploidy induction has been explored as a breeding strategy. Morphologically, it is an annual herbaceous plant with erect, branched stems typically ranging from 20 to 60 cm in height. The leaves are finely divided and thread-like, while the white or pale blue flowers have large, coloured sepals more prominent than the petals. The fruit is a swollen capsule composed of several united follicles containing numerous small black seeds, which represent the primary raw material for culinary and medicinal uses. The species originated in Western Asia and Eastern Europe, with a native range extending from Romania and Bulgaria to Western and Southwestern Iran, including the Levant, Cyprus, Turkey, Iran, and Iraq. Currently, *N. sativa* is widely cultivated in Egypt, Syria, Turkey, Iran, Pakistan, India, and Bangladesh, as well as in parts of North Africa and Central and Southern Europe. The species shows high adaptability to semi-arid climates and a wide variety of soils, requiring low agronomic inputs, which makes it suitable for marginal lands and low-resource farming systems. Its current distribution reflects both natural expansion and intentional introduction, driven by the culinary, preservative, and medicinal-pharmaceutical value of its seeds.



Fig 1. *Nigella Sativa*

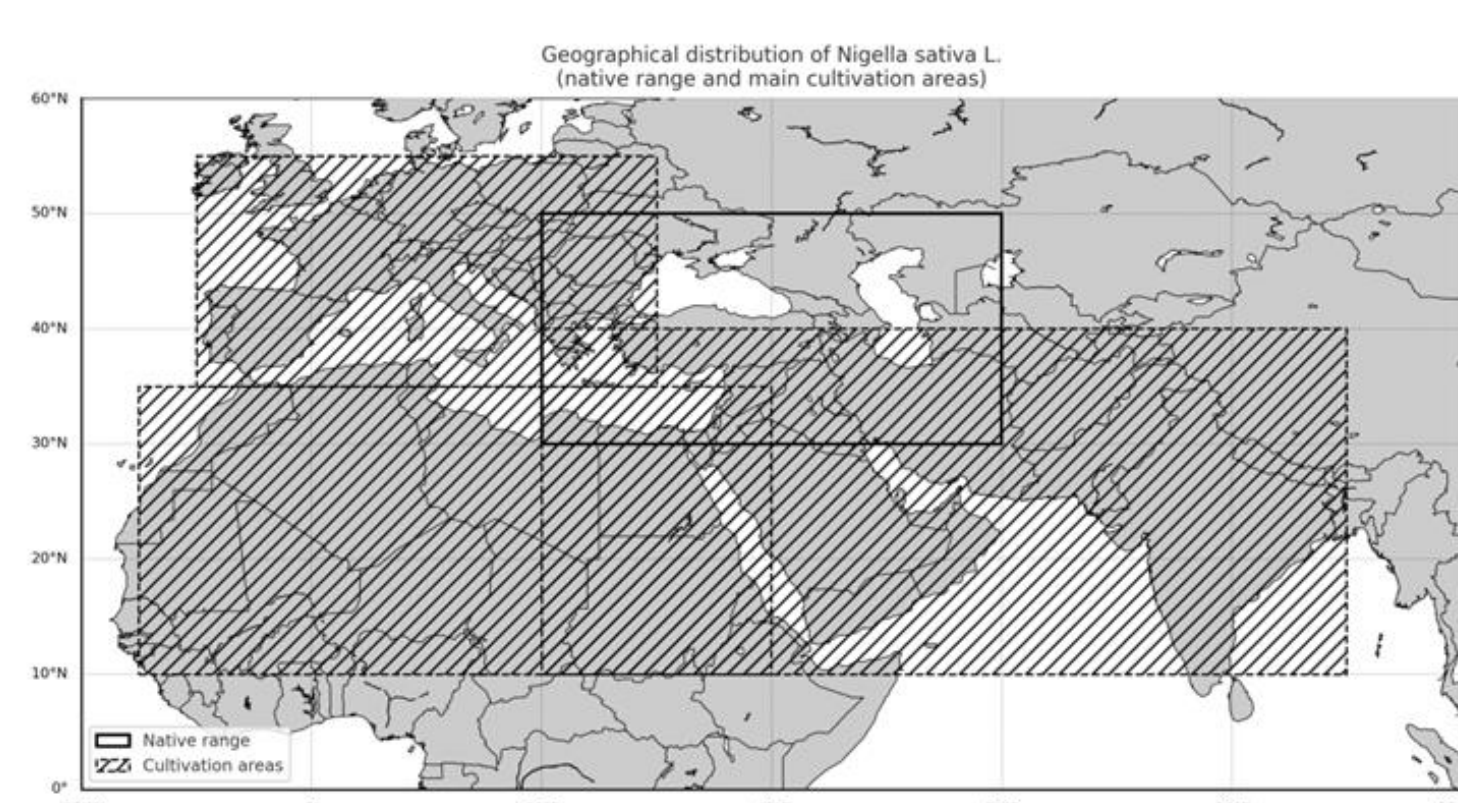


Fig 2. Geographical Distribution of *Nigella sativa* L.

• Pharmacological relevance of the phytochemical profile

The seeds of *Nigella sativa* have a valuable nutritional composition, containing approximately 26–40% oil, 14–21% protein, 17–19% carbohydrates, and 8–16% fibre, with the remainder consisting of ash and moisture. Their mineral profile is rich in potassium, calcium, magnesium, phosphorus, sodium, and iron, along with trace elements such as zinc and copper, enhancing their nutritional significance. The fixed oil is dominated by linoleic acid (50–65%), followed by oleic acid (around 20–25%), while palmitic acid is the main saturated fatty acid. The high ratio of polyunsaturated to saturated fatty acids, combined with tocopherols and phytosterols, supports a notable cardioprotective and hypolipidaemic potential. The volatile oil, responsible for the plant's characteristic aroma, also contributes substantially to its pharmacological activity, with thymoquinone recognised as the main determinant of its antioxidant, anti-inflammatory, anticancer, neuroprotective, and hepatoprotective effects, alongside thymohydroquinone, dithymoquinone, p-cymene, α - and β -thujene, and other terpenes used as quality markers. Additionally, the seeds contain alkaloids, triterpenoid saponins, phytosterols, flavonoids, and phenolic acids—a combination providing both lipophilic and hydrophilic antioxidants capable of neutralising reactive oxygen and nitrogen species. This complex phytochemical composition explains the plant's wide range of health benefits, from modulating oxidative stress and inflammation to offering hepatic protection, improving cardiometabolic parameters, supporting cognitive function, and displaying antimicrobial and antiparasitic activity, including against antibiotic-resistant strains.

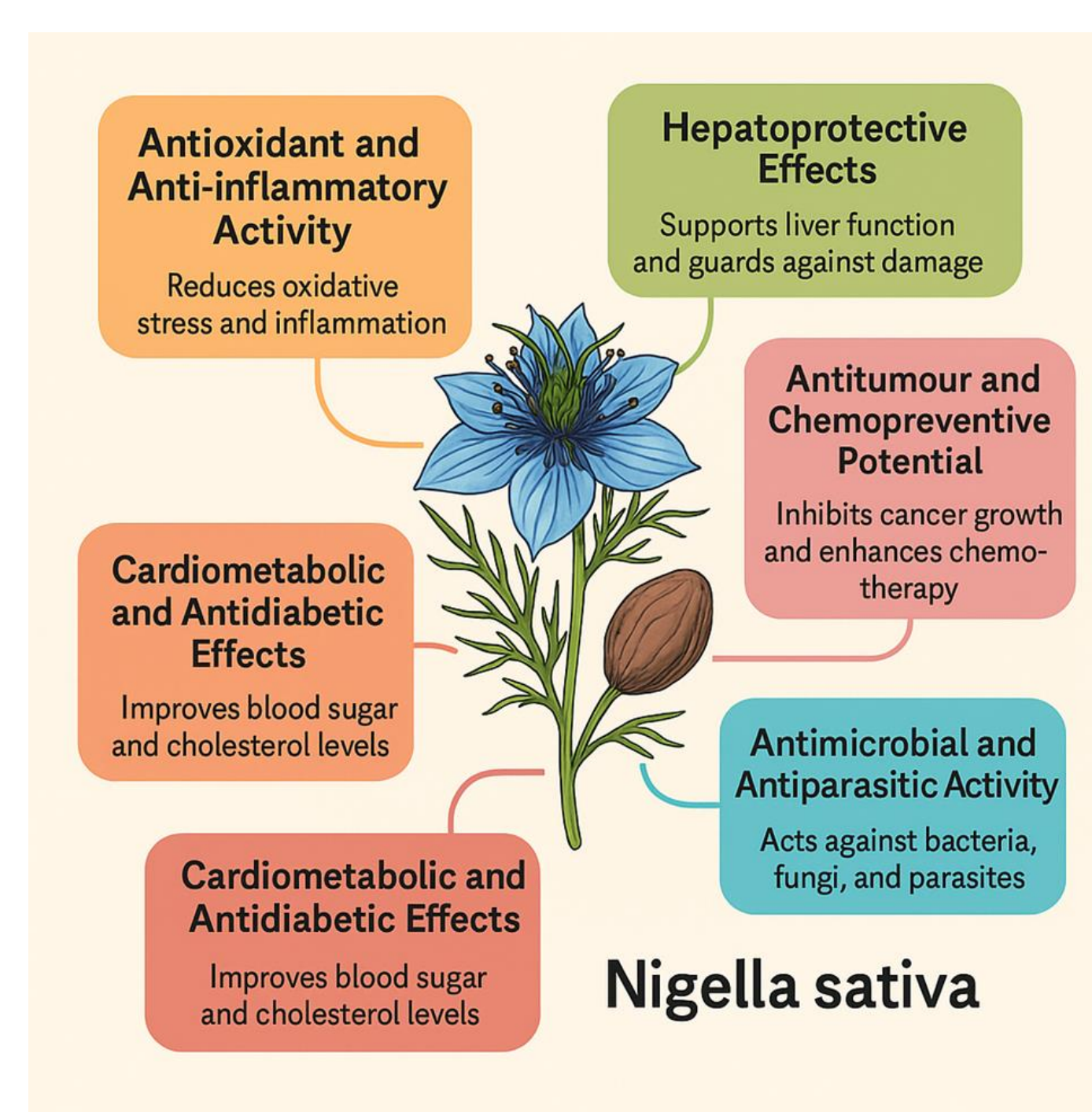


Fig 3. Therapeutic properties of *Nigella sativa* seeds

• Conclusions

Nigella sativa L. is a medicinal and aromatic species at the nexus of nutrition and pharmacology. Its seeds pair high nutritional value with a complex phytochemical profile rich in PUFAs, thymoquinone, phenolics, alkaloids, saponins and phytosterols, underpinning antioxidant, anti-inflammatory, hepatoprotective, cardiometabolic, neuroprotective, antimicrobial and antitumour effects. The plant suits sustainable agriculture due to semi-arid adaptability and low inputs, while modern extraction and nanoformulations improve thymoquinone bioavailability. Priorities include standardising extracts, clarifying compound synergies and running controlled trials for type 2 diabetes, metabolic syndrome, cardiovascular and neurodegenerative diseases.