

Influence of Mineral Fertilizers on the Quality of Raw Materials of *Nigella sativa* L. in Uzbekistan

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Abstract

The article is devoted to the study of *N. sativa* cultivation using mineral fertilizers to increase the yield of medicinal plants and improve their chemical composition. Research shows that with the correct use of essential nutrients such as nitrogen, phosphorus and potassium, plant growth processes are accelerated, and the amount of biologically active substances such as thymoquinone and alkaloids increases significantly. As a result, the medicinal properties of *N. sativa* are enhanced. The correct choice of mineral fertilizer balance and the use of optimal agrotechnical methods increase the possibility of obtaining high-quality and environmentally friendly medicinal raw materials in agriculture.

Keywords

Nigella sativa, Mineral Fertilizers, Raw Materials, Agrochemical Composition of Soil, Phytochemical Composition of Raw Materials, Uzbekistan

1. Introduction

In recent years, effective measures have been taken at the global level to grow medicinal plants and use them rationally. Despite the achievements of modern medicine and technology, herbal medicine continues to be an important part of medical practice. Although the pharmaceutical industry has introduced modern methods of drug production, the majority of drugs are still produced on the basis of plant raw materials. As a result, the demand for medicinal plants is growing every year, which leads to a significant reduction in natural reserves of these plants. Despite the measures taken to protect the plant world, the restoration of depleted reserves is becoming an increasingly difficult task every year.

Today, drastic changes in ecology have a significant impact on the plant world. Over the next 30 years, the desert zone will expand due to a sharp increase in temperature. In order to increase drought resistance and improve water conservation, a number of scientists are actively developing technologies for growing medicinal plants using modern methods. According to scientists, the research is being conducted to study optimal cultivation technologies based on the ontogenetic indicators of plants. The main focus is on studying the morphometric and biometric characteristics of the plants being grown, as well as their phytochemical composition, biomass, and raw material reserves.

As in Uzbekistan, in a number of other countries, the pharmaceutical industry, which ensures the production of medicinal plant raw materials, is one of the strategic priority areas of state policy. This is due to at least three key aspects: protecting public health, developing the national pharmaceutical infrastructure and stimulating the growth of the agro-industrial complex of medicinal plants. In this regard, the development of local production, as well as an increase in the purchase of raw materials produced by agricultural enterprises of the country, is of key importance for meeting domestic needs, as well as for increasing the export of high-quality and environmentally friendly products.

There are 577 species of medicinal plants in the flora of Uzbekistan, belonging to 93 families and 381 genera [1], of which more than 140 species are cultivated. In scientific medicine, the use of 180 species of medicinal plants is currently permitted, 65% of which are found in the wild [2] [3]. Throughout the world, the consumption of herbal preparations made from medicinal plants is characterized by positive dynamics, and almost 40% of foreign pharmaceutical products are made on the basis of natural medicinal plants. According to experts from the World Health Organization, in the next ten years, the share of drugs made from plant materials will be 65% of the total volume of consumed pharmaceuticals. One of the main reasons for this is that the biologically active substances contained in products from medicinal plants are close in composition to substances in the human body, which makes the drugs obtained from them safe for the body, allows them to be taken for a long time without allergic reactions, and their cultivation and culture are also possible.

The flora of the Republic of Uzbekistan is rich in valuable plant species that are of great importance to the national economy. One of these plants is the genus *Nigella* L. of the Ranunculaceae family, which is an essential oil, pungent aromatic plant widely used in pharmaceutical practice and medicine. These plants have long been used in folk medicine and have high medicinal properties [4]. Currently, this plant is cultivated in various countries of the world, including Europe (Germany, Spain, Estonia, Ukraine, Moldova, Russia, Poland), Asia (Iran, Iraq, India, Pakistan, China, Afghanistan, Türkiye, Saudi Arabia, Uzbekistan, Azerbaijan, Dagestan), Africa (Egypt, Tunisia, Sudan, Ethiopia) and North America (USA) [5].

There are four species of black cumin widely used in the world: 1) *Nigella dam-*

ascena L.—mainly grown in European countries. In nature, it is found in the Caucasus and grown in small quantities. 2) *N. sativa* L.—the most common species today in different countries. This species was chosen as the object of our research. 3) *N. indica* Roxb.—this species is widely distributed in India, Afghanistan and Pakistan. 4) *N. glandulifera* Freyn & Sint.—in nature, it is found mainly in Turkmenistan and western regions [6].

The genus *Nigella* L. is a unique plant widely used in traditional medicine in the Middle East, Central and Southeast Asia. Its seeds have a well-studied spectrum of secondary metabolites, but knowledge of the structural and functional diversity of biologically active proteins and peptides is still limited [7]-[9]. *Nigella* oil has a preventive and therapeutic effect on diabetes mellitus, reducing the likelihood of morphological changes and maintaining the integrity of the pancreas, which helps to normalize blood sugar levels in elderly patients. The main mechanism of the antidiabetic effect of the plant is its ability to reduce the activity of gluconeogenesis in the liver [10]-[13]. Later, in 1995, a group of researchers tested the effectiveness of *N. sativa* oil extract and its main component, thymoquinone ($C_{10}H_{12}O_2$), as an anti-inflammatory agent [14].

Plants of the genus *Nigella*, particularly *N. sativa* (black cumin), are highly profitable crops in organic agriculture [15]. The chemical composition of their seeds varies depending on the place of growth and growing conditions and has been well studied in the Mediterranean and Arab countries. In the CIS countries, such studies are widely developed in Dagestan, Stavropol, Crimea and Belarus. Many foreign studies are devoted to the study of the essential and saturated fat composition of *N. sativa* seeds [16]-[19], however, studies of the adaptive potential of this species in various environmental conditions have been virtually non-existent [19].

The first clinical trials of *N. sativa* seeds were conducted in 1880, when Greenish found that the seeds contained 37% oil and 4.1% ash. Between 1960 and 1963, chemical analysis of the essential oil was first performed by Mahfouz and El-Dakhakny (1960) and Canonica (1963). These studies were complemented by subsequent studies, which found that the seeds contained various pharmacologically active components [19]. *N. sativa* seed oil contains palmitic acid and relatively rare C_{20} fatty acids, which are more common than in sunflower oil. Compared to palm oil, it is richer in unsaturated fatty acids and also contains significant amounts of palmitic acid [20]-[22].

The seeds of the *N. sativa* plant are used as a seasoning for meat products [23]-[25], and despite the difficulty of oil production, it has also attracted wide interest in the food industry [26] [27]. In medicine, black cumin oil has antibacterial properties, surpassing antibiotics such as ampicillin ($C_{16}H_{18}N_3NaO_4S$), tetracycline ($C_{22}H_{24}N_2O_8$), co-trimoxazole ($C_{24}H_{29}N_7O_6S$), gentamicin ($C_{21}H_{43}N_5O_7$) and nalidixic acid ($C_{12}H_{12}N_2O_3$) [28]. In recent years, there has been a growing interest among scientists both in our country and abroad in the chemical composition of species of the genus *Nigella*, especially in the possibilities of industrial cultivation

of seeds, making it an important crop for further research [6] [29]-[31].

N. sativa oil mainly consists of polyunsaturated fatty acids and is extracted by cold pressing [30]. The main unsaturated fatty acids contained in *N. sativa* include linoleic acid ($C_{18}H_{32}O_2$) 50% - 65%, oleic acid ($C_{18}H_{34}O_2$) 15% - 24%, as well as arachidonic acid ($C_{20}H_{32}O_2$), eicosanoid acid ($C_{20}H_{40}O_2$) [32]-[35]. Linoleic ($C_{18}H_{32}O_2$) and oleic ($C_{18}H_{34}O_2$) acids account for 85% or more of the total oil composition. The content of saturated fatty acids usually does not exceed 30% [36]. The high pharmacological activity of black cumin oil is primarily due to the high content of unsaturated fatty acids and essential oils. Thus, during the process of cold pressing of black cumin seed oil, in addition to fatty acids, some components of the essential oil are released, including thymoquinone ($C_{10}H_{12}O_2$), p-cymene ($n-CH_3C_6H_4CH(CH_3)_2$) and other components [27] [37]. It was found that many of the pharmacological effects of black cumin are directly related to the diversity of biologically active compounds in the seeds, including oils (up to 53%), proteins (16% - 28.3%), carbohydrates (24.9% - 33.9%), essential oils (up to 1.4% - 1.9%) and other compounds [38] [39].

In the course of scientific research aimed at determining the content of macro- and microelements in *N. sativa* seeds, it was found that black cumin seeds contain 56 chemical elements. In particular, their composition includes aluminum oxide (Al_2O_3) 2.174%, aluminum (Al) 1.150%, silicon oxide (SiO_2) 2.232%, silicon (Si) 1.043%, calcium oxide (CaO) 1.034%, calcium (Ca) 0.730%, potassium oxide (K_2O) 0.7402%, potassium (K) 0.6145%, phosphorus oxide (P_2O_5) 0.5558%, phosphorus (P) 0.2425%, sulfoxide (SO_3) 0.5860%, organosulfur compounds (S) 0.2347% and other compounds, which indicates their high content compared to other elements [40].

Black cumin seeds contain two types of alkaloids: the alkaloid isoquinoline (C_9H_7N) and the alkaloid pyrazole ($C_3H_4N_2$). In addition, α -geoderine, pentacyclic triterpenes and saponins have been found in the plant seeds [41]. Vanillin has been found in the roots and stems of the plant [41] [42], and up to 0.43% ascorbic acid ($C_6H_8O_6$) has been found in the leaves [43].

Kudinov in his work presented information on agrotechnical measures used in the propagation and cultivation of black cumin, such as soil preparation, treatment with mineral fertilizers and irrigation [44]. Under the conditions of introducing black cumin into culture, a study of the biological characteristics and quality of raw materials was conducted by Gabibullaeva in the conditions of Dagestan. In this study, the influence of the environment on seed yield (analysis by altitude zones), the influence of the duration of vegetation and the composition of fatty acids in the raw material of the plant were studied [19].

Our research analyzed the influence of mineral fertilizers in various conditions of Uzbekistan.

2. Material and Methods

Nigella sativa L. is an annual herbaceous plant reaching 70 centimeters in height.

The stem is straight, the leaves are narrow, pinnately divided, 2 - 3 centimeters long. The lower leaves of the stem are sessile, the upper ones are without petioles, arranged alternately. The flowers are large, have 5 - 8 petals, located singly at the ends of the branches. The fruit is a multi-locular capsule. The seeds are triangular, wrinkled, brown or black. Black cumin blooms in May-June, and the seeds ripen in July-August (**Figure 1**).



Figure 1. *N. sativa*—in the conditions of the Tashkent Botanical Garden.

In the period from 2021 to 2023, within the framework of the project to organize *N. sativa* plantations on rainfed lands in the foothills of Uzbekistan, scientific research was carried out to analyze the quality indicators of raw materials grown on rainfed lands (**Figure 2**).

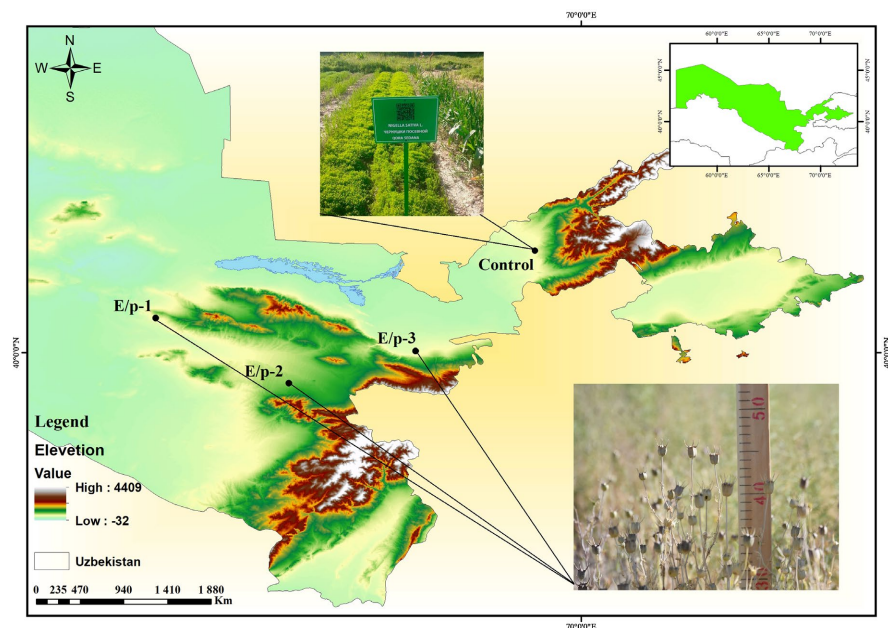


Figure 2. Map of research areas.

Modern instrumental methods, including gas chromatography and various methods of determination using high-performance liquid chromatography, were used

to study the phytochemical composition of black cumin [45]-[51].

For the cultivation of medicinal plants in the designated areas, the agrochemical composition of the soil is of great importance, since the soil must contain sufficient nutrients, organic matter and other elements to ensure optimal quality. Soil type, moisture and yield, including optimal soil conditions, are important factors in the cultivation of selected medicinal plant species or parts thereof.

In addition, humus, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), silicon (Si) and other microelements in the soil are the main chemical substances that determine its fertility (Figure 3). The presence of these chemical substances in certain quantities in the soil determines the yield of crops grown depending on their type. If the balance of these substances in the soil is disturbed, the yield of plants changes.



Figure 3. Creation of experimental plots of *N. sativa*.

Mineral fertilizers are an important resource for plant growth and development, especially nitrogen, phosphorus and potassium, which are essential microelements for plants. These elements not only ensure proper plant growth, but also have a positive effect on the process of photosynthesis, the synthesis of simple organic substances and crop yield. The use of mineral fertilizers can lead to improved quality characteristics of the product, including agrochemical composition, vitamin, min-

eral and antioxidant content.

Taking into account the above, the project conducted analyses of the impact of various mineral fertilizers on plantation cultivation. To determine the rate of application of mineral fertilizers and the timing of their application in various areas, experimental plots were organized based on various options (Figure 3).

Determination of soil properties and fertility includes assessment of various chemical characteristics and nutrient indices. High calcium, magnesium and potassium content in the soil creates favorable conditions for the absorption of ammonia nitrogen, and sufficient phosphorus promotes the absorption of nitrates. Therefore, determination of soil pH and conductivity is one of the factors determining plant development. Humus content in soil samples obtained from organized plantations is determined using a NETZSCH STA-409 PG thermal analyzer at a temperature of 390°C, *i.e.* until complete combustion of organic matter in the soil. In our previous studies, bioecological features of *Nigella sativa* were studied in different conditions of Uzbekistan [52].

3. Results

Agrochemical analysis plays an important role in assessing the quality of the soil, increasing its yield potential and determining the level of nutrient supply. This analysis helps to establish the suitability of agricultural land by determining the chemical composition of the soil, nutrient content, organic matter reserves and other agronomic indicators. A special chemical reagent is used to analyze soil samples in the laboratory, and based on the results of the study, complete information on the condition of the soil is formed. These data are used to develop fertilization regimes, select optimal crops for sowing and develop agronomic measures aimed at increasing the fertility of the land. The soil environment is characterized by pH value, and in the samples taken from our study site, pH ranged from 8.0 to 8.22, and conductivity (conductometric titration) ranged from 0.306 to 0.408 $\mu\text{S}/\text{cm}$ (Table 1).

Table 1. Agrochemical analysis of the soil of the studied areas.

Soil indicator	Experimental plot-1	Experimental plot-2	Experimental plot-3	Control
Humidity (%)	12.5 \pm 0.8	10.0 \pm 0.84	11.6 \pm 0.72	11.0 \pm 1.0
pH	8.15 \pm 0.04	8.0 \pm 0.05	8.22 \pm 0.04	8.10 \pm 0.1
Conductivity ($\mu\text{S}/\text{sm}$)	0.306 \pm 0.02	0.408 \pm 0.017	0.342 \pm 0.014	0.324 \pm 0.017
Soil hummus (%)	4.2 \pm 0.1	4 \pm 0.12	4 \pm 0.1	4.1 \pm 0.2
Total N content (%)	0.12 \pm 0.01	0.085 \pm 0.01	0.08 \pm 0.01	0.14 \pm 0.015
Total P content (%)	0.08 \pm 0.01	0.16 \pm 0.01	0.05 \pm 0.01	0.1 \pm 0.01
Total K content (%)	0.8 \pm 0.1	1.2 \pm 0.1	3 \pm 0.2	1.4 \pm 0.1

To analyze the impact of phosphorus, nitrogen and potassium fertilizers on the

biometric parameters of plants and the quality of plant raw materials in control variants, relevant studies were conducted. The amount of elements such as nitrogen, phosphorus and potassium in fertilizers directly affects the development of roots, stems and leaves of plants. Nitrogen helps to increase the green biomass of plants and activates metabolic processes, phosphorus ensures the development of the root system at the initial stages of growth, and potassium improves the ability of the plant to retain water, increasing its resistance to drought and enhancing the process of photosynthesis. In recent years, with the use of mineral fertilizers for growing *N. sativa*, an increase in the content of biologically active substances in plants, such as thymoquinone, flavonoids and alkaloids, has been observed. In the variants where nitrogen fertilizers were used, the fatty acid content in *N. sativa* oil increased by $\mu = 0.08\%$, in the variants with phosphorus fertilizers, this increase was $\mu = 0.11\%$, and in the variants with potassium fertilizers, no significant differences in the fatty acid content in the plant oil were observed. The difference in the fatty acid content in the oil of the plant raw materials from these variants compared to the control was $\mu = 0.002\%$ (Figure 4).

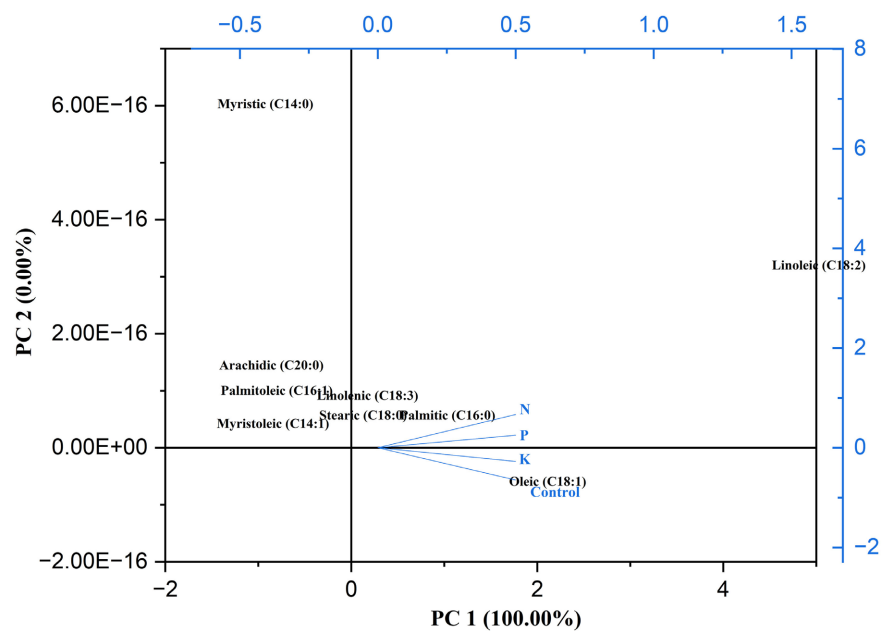


Figure 4. Effect of mineral fertilizers on the number of fatty acids in *N. sativa* oil.

Also, some types of fatty acids were determined in the composition of vegetable oil, and the content of linoleic acid ($C_{18:2}$) was the highest, amounting to $\mu = 45.73\%$, and the lowest content was myristolic acid ($C_{14:1}$) – $\mu = 0.1\%$. An increase in the nitrogen content leads to changes in the composition of fatty acids in relation to the total oil content. This improves the stability of the oil and increases its resistance to oxidation. Phosphorus is involved in energy exchange processes in plants, promoting the accumulation of unsaturated fatty acids in the plant, especially linoleic acid, in high concentrations. This improves the purity of the oil and its beneficial properties. With a sufficient potassium content, the amount of unsaturated

fatty acids increases, especially linoleic and linolenic acids. At the same time, this has a positive effect on the quality of the oil, improving its condition and biological activity.

The study of fatty acids, along with the identification of secondary metabolites, is of great importance for the analysis of the composition of vegetable oils. Fatty acids are aliphatic monobasic carboxylic acids, which are the main components of fats and oils. The main part of the oil is glycerides of linolenic, oleic and palmitic acids, while the oil from the seeds of *N. sativa* contains from 31% to 44% fats. Among them are semi-fatty oils, melantide glycoside and essential oils. According to the results of phytochemical analysis carried out using gas chromatography, the quantitative composition of oils extracted from black cummin seeds was accurately determined (Figure 5).

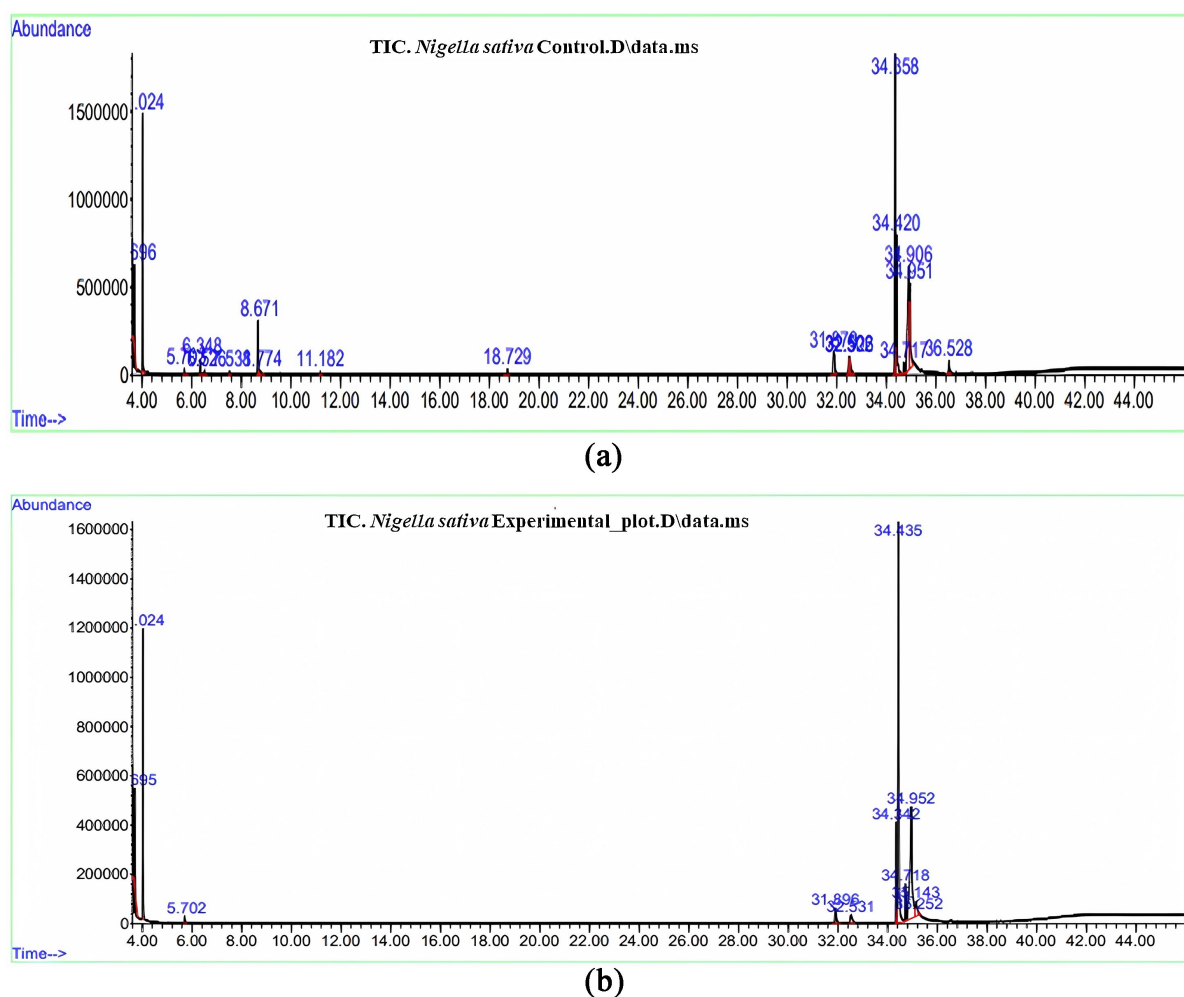


Figure 5. Chromatograms of oils extracted from black cummin grown under controlled conditions (a) and under the influence of mineral fertilizers (b).

The results show that the content of fatty acids, triglycerides and other compounds in black cummin oil is determined by the height or area of peaks, which reflects their relative amounts. The resulting chromatogram consists of peaks corresponding to

each fatty acid, which provide a spectrum of the oil composition and are used to determine the composition of fatty acids (e.g. oleic, linoleic, stearic) and their ratios. Chromatographic analysis plays an important role in developing vegetable oil standards and ensuring their compliance with consumer requirements.

4. Conclusion

The technology of growing *N. sativa* using mineral fertilizers plays an important role in increasing the yield of medicinal plants and improving their chemical composition. Research shows that with the correct use of essential nutrients such as nitrogen, phosphorus and potassium, plant growth processes are accelerated, and the amount of biologically active substances such as thymoquinone and alkaloids increases significantly. As a result, the medicinal properties of *N. sativa* are enhanced. The correct choice of the balance of mineral fertilizers and the use of optimal agro-technical methods increase the possibility of obtaining high-quality and environmentally friendly medicinal raw materials in agriculture. Based on the above, improving the technology of growing *N. sativa* using mineral fertilizers contributes not only to increasing the economic and therapeutic value of medicinal plants, but also to compliance with the principles of environmentally friendly oil production. This approach is of strategic importance for meeting the demand for high-quality and biologically active medicinal raw materials and can be widely used in healthcare, pharmaceutical and food industries.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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