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Efficiency of Nano Herbicide for Growing Topinsunflower

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Topinsunflower is comparatively new crop in Georgia, created by breeders for the purpose of increasing harvest, distinguished by its high caulis – up to 4 meters and high yield of green mass and tubers. It is a hybrid of Jerusalem artichoke and sunflower. The amount of inulin indicated in concentrated topinsunflower extracts with a solids content exceeded more than 30%, which is a guarantee of profitability for the processing industry. In the course of laboratory studies, we found that topinsunflower tubers should be peeled first and with a long processing period, they should be peeled immediately before processing. By laboratory studies on similar works, it found that topinsunflower practically does not accumulate pesticides, nitrates, radionuclides, heavy metal salts from soils fertilized with high doses of mineral nano fertilizers used in the experiments. Interest in topinsunflower production in Georgia is growing day by day. The desire of farmers to expand their knowledge in the field of agro-technologies of growing with the use of nano chemicals and nanotechnologies has also increased. By precise agricultural growth technology topinsunflower tubers contain 47% protein, mineral salts, soluble polysaccharides, fructose, trace elements, vitamins BB1 and C, more than 17% of inulin, etc. The use of the proposed 6-variant trial scheme and nano herbicides in topinsunflower plantations significantly increased the yield of green mass and tubers, the content of inulin in it without residuals, which is very important for the pharmaceutical industry for the production of drugs, including insulin for diabetics. *© 2024 Bull. Georg. Natl. Acad. Sci.*

new hybrid, nano herbicide, precise agriculture, inulin value

Topinsunflower (*Asteraceae*) was created at the end of the last century by breeders with the help of interspecific hybridization of topinambur (Earth pear) and sunflower. Topinsunflower is a large, herbaceous, multi-flowered plant up to 4 m tall. It has lateral leaves, frequent foliage throughout the growing season and a strong root system at the end of which forms tubers. It is also called a hybrid of the Jerusalem artichoke and underground artichoke, it is compared to the potato, but it is the closest relative of the sunflower. Topinsunflower as a hybrid plant belongs to the tuberous genus (*Helianthus tuberosus L.).* It's a perennial herbaceous tuberous hybrid of the Compositae family. The root system is powerful, deep. On underground shoots (stolon) it forms edible tubers (white inside with a purple

coating of the peel), tasting similar to a cabbage stump or turnip with a sweetish aftertaste. The stem is straight, strong, erect, sometimes 4 meters high, at the top with branching baskets (3-5 u.), pubescent with short hairs. The flowers are collected in baskets with a diameter of 5-14 cm. Leaves are serrate-toothed, petiolate, pubescent, lower-ovate or heart-shaped-ovate, opposite, upper – elongated-ovate or lanceolate, alternate. The median tubular flowers are yellow, bisexual, the marginal sterile pseudo-reed flowers are golden yellow, there are from ten to fifteen of them. Blooms in August. The fruit is an achene, ripens at the end of September [1-3].

Tubers of topinsunflower are one of the few natural sources of inulin. This substance has a unique effect on the body of a healthy and sick person – especially for patients with type 1 and type 2 diabetes. Besides of biomass increasing, second significant target of our research was finding ways of growing this crop for the evolution of inulin content in tubers. Existing technologies of growing for obtaining high-quality products for agricultural animals as a feed is satisfactory, but not for containing of inulin for insulin production. Different agro-technical background influence on inulin contain, analysis of the biochemical composition of topinsunflower and energy value was main target for modern agriculture in over of world [4-6].

Topinsunflower can be eaten in any forms, and not only its roots, but also young leaves. Of course, the tubers of topinsunflower (in vegetable salads) bring the greatest health benefits. They can be boiled, stewed, fried, salted and marinated. At the same time, it is better not to peel the tubers, because it is in the peel that contains a large dose of all the benefits, but simply should be thoroughly washed with a brush under running water [7, 8].

Materials and Methods

With the increase of the resources for grain crops production between 1999 and 2023, topinsunflower was included into forage crop rotations and various experiments and laboratory studies of the resulting mass of this crop were carried out in various directions. In different crop rotations, our group of scientists actually completely studied this hybrid, crop in an agro-technological context and continued the work begun in 2009 with the inclusion of chemical nano preparations, like nano herbicide, nano additives for mineral fertilizers, etc. [9].

Consulting with specialists in phyto-preparations and phyto-therapies, work in the direction of agro-technological methods to increase the content of clean inulin (free from mineral fertilizers and pesticide contaminants) in the tubers of this hybrid intensified. This aroused interest in drug manufacturers and gave a more rational meaning to the production of tubers compared to green mass. The particular interest was the inclusion in agricultural technology of cultivation of the nano-herbicide (nanocopper-076) and quickly soluble nano-mineral (NF-3107) with special fertilizers of NPK when irrigated with using fertigation advance technology (with using of drip irrigation), including with the introduction of trace elements Fe, B, Mn, Zn, Co, Mo, Cu treated with above mentioned nano-elements [10].

From the initial results, it became clear that the issue of efficient production of chemically clean inulin raw materials in Georgia can be solved with the help of the cultivation technology, worked out and developed by our team of scientists. Alongside the classical forage crop rotation scheme, we also used grain cereals (barley, oats) silage crops (corn, Sudan grass), grain legumes (soybeans, chickpeas, lentils), etc. [11].

Taking into account the peculiarities of sowing an annual crop of topinsunflower for food and forage, as well as pharmacy industry purposes, large areas were sown with crops necessary to restore the soil structure, since topinsunflower, despite high doses of fertilizer and nano herbicides, exhausts the soil and worsens its structure. To intensify sowing and increase the volume and number of tubers in the crop rotation contributed to high profitability.

Here we mean an increase not only in the biological mass, but also in the content of inulin in topinsunflower tubers.

Results

Topinsunflower as a crop was intended mainly for the production of forage and row material for medicine drugs production for diabetic human population. The studies found that the topinsunflower differed from its parents not only in morphological, but also in biological properties – specifically in the content of inulin. It belongs to a preparation of plant origin and has much in common with topinambure although it gives almost 2 times more above-ground and underground biological mass. Here, the properties of heterosis appeared, which increased the yield of biological mass by 32% compared to topinambure.

The plant completed a powerful growth during the period of budding and flowering. The average yield of green mass in different municipalities of Georgia averaged 50 t/ha, and tubers up to 30 t/ha [12]. The green mass could be mowed 2 times per season, but at the same time, according to our data, in this case the yield of tubers decreased by an average of 17%. Root crops of topinsunflower, with a 2-fold mowing of the above-ground mass, contained less fiber, organic acids, pectin, proteins, fats, carbohydrates, essential amino acids, but they contained more iron than in a single mowing. There were a lot of silicon, potassium, calcium, magnesium, fluorine, chromium, as well as B vitamins: B1, B2, B6, CC, PP and A. [13]. However, the most valuable for manufacturers of pharmaceutical insulin was the inulin contained in topinsunflower – a natural source of insulin, which also makes it an almost indispensable food product for both type 1 and type 2 diabetics.

Several types of food and forage were prepared from the green mass of topinsunflower. In the flowering phase, it was distinguished by a relatively high yield and nutritional value [14]. Stationary field trials have become more intense in recent years with the study of its nutritional value (Table 1).

Our research work was associated with the influence of types and norms of mineral fertilizers on the biological yield of plants (green mass + tubers), the influence of ecosystem parameters of various districts, and the growing area in this case was strictly 70x70 cm in all variants of experiments with an accounting area of 100 m^2.

The following observations were made on the following data:

1. Green mass;
2. Tuber harvest;
3. Chemical composition and nutritional value;
4. Processing of tubers and the content of inulin in them;
5. Economic efficiency.

Against the background of optimal doses of mineral fertilizers with nano additives, a highly productive diagnostic model of the yield of topin-

Table 1. Energy and nutritional value of green mass and tubers of topinsunflower

Topinsunflower	Nutrients, g/kg							Digestibility, %				Content energies, mrl	In dry mass	
Plant parts and average yield	Proteins	Fat	Cellulose	nitrogen free Extraction Substance	powdery mildew	PP	Ca	Fresh protein	Row fat	Row fiber	BAEV		Energy	Digestible Protein in natural mass, g/kg
Green Mass (123 t/h)	267	21	46	621	37	5.3	2.7	86	92	89	96	753	742	362
Tubers (162 t/h)	62	4	29	868	52	2.3	0.4	47	-	-	86	614	182	92

sunflower was studied by differentiating the parameters of the ecosystem and morphological tests and the influence of phenological phases to determine the variant with a feeding area of 70x70 cm (the total area of the plot was 140 m^2) in terms of the quantity and quality of the harvest (including green mass, so are clubs).

It should be noted that the fifth option surpassed the other variables in all parameters, which is mainly due to the optimization of mineral nutrition parameters and processed fertilizers with nano preparations. In all variants, the growing area did not change despite the increase in doses of $N_{120}P_{90}K_{60}$+nanocopper (as the herbicide) and nano microelements in fertilizers, at the rate of each irrigation (3-4) not less than 600 m^3 water on a ha in the complex of nitrogen fertilizers 120 kg/ha; Phosphorous-potassium respectively 90-60 kg/ha.

In accordance with our analyses, topinsunflower tubers contained up to 47% protein, mineral salts, soluble polysaccharide, fructose, microelements, without nitrogen extractives, as well as vitamins BB1, vitamin C, carotene, up to 17% inulin. The sugar content in the tubers increased by reducing the timing of the collection of green mass. Such a high content of clean inulin made it possible to produce various high quality pharmaceutical and nutritional products from tubers [15,16].

From topinsunflower tubers, cellulose and inulin-containing flour are obtained for patients with type 1 and type 2 diabetes, which is used to prepare especially valuable dietary products and medicines, the demand for which is steadily growing on the international market [17].

As already mentioned, topinsunflower is an important raw material for animal feed and the food industry for the population. Processing of unprocessed arable raw materials – drying in dryers and making juice from tubers, and then syrup – is possible throughout the year. Dried topinsunflower could be processed into flour at any time for up to 12 months. As for the syrup, it was prepared from freshly squeezed juice 2-3 days after harvest from tubers of our pilot plots and time of use increased because row material was much more cleaner (approximately on 36%), than tubers obtained from conventional cultivation [18].

Laboratory experiments and production conditions have shown that topinsunflower tubers should be processed with less time and electricity power. Our innovative technologies are used in the production of insulin drugs and their packaging in nano plastic films. After processing of tubers green mass (obtained pomace), our collegues used it as an additive to animal feed. Studies have found that topinsunflower bulbs and green mass contain more carbohydrates, vitamins, proteins and other nutrients than the very popular nodule potato crop. The vegetation and nutritional value of the above-ground mass of topinsunflower is better, so that the silage mass contained up to 8 percent of sugar is obtained in greater quantities. Topinsunflower is also widely used in terms of biological indicators, as it‘s a very useful feed for all types of farm animals (Table 1).

The results of complex lab studies and the energy value and nutritional value of topinsunflower tubers showed that the nutritional value of topinsunflower tubers is due to the high content of functional macro and micronutrients, such as inulin, pectin substances of food long fibers and mineral elements. This determines the prospects of using topinsunflower as a raw material for the production of physiologically valuable products, especially so popular drug like insulin, processed from the inulin.

Inulin of topinsunflower is also used as an indispensable component of substitute for diabetic’s drugs and food. As an emulsifier, dispersant and gelling agent, inulin is also widely used in various sectors of the food industry – in the baking and confectionery industries as an additive in the production of meat and dairy products. Many different products and drinks with inulin are known on the commercial market: dairy, including ice cream and cheese, bakery cakes and pasta, meat, cereals,

Table 2. The content of inulin in tubers according to the scheme of experiments, 2019-2023

№ of var.	70x70 cm and nutritional standards, kg. a.m.	Harvest tubers, t/ha	Moisture in tubers, %	Content dry substances, %	Content inulin, %	Inulin in terms on dry matter, %, 33.4
1	Topinambur $N_{60}P_{60}K_{45}$ (control)	19.6	77.6	22.4	14.4	28.4
2	Topinsunflower $N_{60}P_{60}K_{45}$ + nanocooper	24.8	79.8	21.3	15.8	32.9
3	Topinsunflower $N_{90}P_{60}K_{45}$+ nanocooper	25.8	81.3	21.2	16.0	32.6
4	Topinsunflower $N_{100}P_{90}K_{60}$+ nanocooper	27.9	80.6	21.5	16.5	32.8
5	Topinsunflower $N_{120}P_{90}K_{60}$+ nanocooper	31.6	81.4	21.4	16.8	33.2

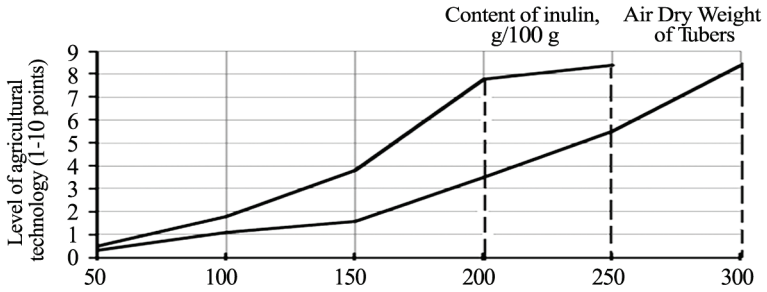

Fig. Changes in inulin content depending on nano fertilizers and nano herbicide.

including muesli, bars, confectionery, spreads and mayonnaise, juice drinks, baby food. Recently, the production of cosmetic products based on inulin has been established. Separately, the use of medical inulin should be highlighted [19].

The introduction of dry powder from topinsunflower is carried out at temperatures not exceeding 80°C and its introduction is carried out at the rate of 1-10% relative to the mass of the components of the confectionery product insulin, and in the case of obtaining a filling of the confectionery product, its content can be up to 30% relative to the mass filling enriched with a natural biologically active additive (Table 2).

All the above mention methods of topinsunflower processing are characterized by the presence of such a common drawback as the influence of high temperatures, which is usually accompanied by the loss of biologically active substances, which unlike the first on the contrary, contribute to the preservation of Biologically Active Radiation (BAR), which in scientific area of Georgia during experiments was 22.4%. Also, one of the tasks for the processing of topinsunflower inulin to insulin is the issue of complex processing, which was dealt with by related scientists of our university [20].

The Figure below shows the dependence of mineral fertilizers treated with nano-preparations and using of nano-herbicide on the growth of the air-dry clean from edditives topinsunflower tuber's mass and the content of inulin in tubers. Containing of clean inulin was especially high in the sixth variant of the experiment, and the yield of inulin was also the highest and amounted to 16.8%.

Purification of the obtained topinsunflower inulin extract was carried out with alcohol to free the extract from suspended colloidal particles that interfere with the isolation of pure inulin. In this case, alcohol was used, because inulin is insoluble.

Conclusions

All of the above indicates that topinsunflower is a very useful healing and economically highly profitable (up to 360%) plant that can be a full-fledged component of the daily and therapeutic and prophylactic diets for humans and animals. Our studies of topinsunflower (including its green mass, tubers, flour/powder of topinsunflower and inulin content) indicate great prospects for the cultivation of this hybrid crop to increase the production and quality assessment of medical insulin.

The obtained results can be used as a theoretical justification for the development of the technology of functional food ingredients from plant origin. In particular, it is possible to substantiate the direction of regulation of the medicinal properties of inulin during storage in applied research aimed at creating special-purpose food products with the integrated use of medicinal and food purposes.

The inulin content variants revealed very interesting trend among the compared to topinsunflower, where the content of dry matter is less than in the best-yielding variants, the content of inulin is 1.4% higher, depending on the method and level of agricultural technology.

The amount of inulin indicated in concentrated topinsunflower extracts with a solids content exceeded more than 30%, which is a guarantee of profitability for the processing industry. In the course of laboratory studies, we found that topinsunflower tubers should be peeled first and with a long processing period, they should be peeled immediately before processing.

By laboratory studies on similar works, it found that topinsunflower practically does not accumulate pesticides, nitrates, radionuclides, heavy metal salts from soils fertilized with high doses of mineral nano fertilizers used in the experiments. Interest in topinsunflower production in Georgia is growing day by day. The desire of farmers to expand their knowledge in the field of agro-technologies of growing with the use of nano chemicals and nanotechnologies has also increased.

All of the above determines the prospect of widespread use of topinsunflower mass both in food and in medicine, of which special attention should be paid to inulin. At the same time, this is the best preventive measure for the majority of the population, because today the number of people with diabetes is increasing day by day all over the world, including in Georgia, and most importantly, this disease is not seasonal and specific. The processing of topinsunflower tubers into insulin for treatment is also a proven method and it is widely used.

ინდუსტრიული ბიოტექნოლოგია

ნანო ჰერბიციდის ეფექტურობა ტოპინმზესუმზირას კულტივირებაში

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ტოპინმზესუმზირა საქართველოსთვის შედარებით ახალი კულტურაა, ის ტოპინამბურის და მზესუმზირას ჰიბრიდია, გამოირჩევა დიდი სიმაღლით – 4 მეტრამდე, მწვანე მასისა და ტუბერების მაღალი მოსავლიანობით. უვითარდება ძლიერი ღერო და დიდი ფოთლები, ხოლო ღეროს თავზე 3-5 გვირგვინი. მოყვანის 6-ვარიანტიანი ცდის სქემის, ნანოტექნოლოგიური ჰერბიციდისა და ნაწილობრივ ნანო სასუქების დანამატების გამოყენებამ მნიშვნელოვნად გაზარდა მწვანე მასისა და ტუბერების ბიოლოგიური მოსავლიანობა, მასში ბიოლოგიურად აქტიური ნივთიერება – „სუფთა” ინულინის შემცველობა, რაც მეტად მნიშვნელოვანია ფარმაცევტული მრეწველობისათვის, ვინაიდან გაიაფდა სამედიცინო პრეპარატ ინსულინის წარმოება და ამაღლდა მისი ხარისხი, მასთან შემცირდა ნედლეულისა და პრეპარატის თვითღირებულება, ამაღლდა ამ კულტურის ტუბერების მოყვანისა და გადამუშავების რენტაბელობის დონე ზუსტი მიწათმოქმედების პირობებში.

REFERENCES

1. Korakhashvili A. (2001) Annual management plan for farming by computer program BARMEX, EFITA Third Conference on Precis Agriculture, pp. 87-95. Montpellier, France.
2. Chankvetadze N., Korakhashvili A. (2001) Productivity of topinsunflower in the foothills of Georgia. Problems of Agricultural Sciences. *Collection of Scientific Papers,* XIII: 97-99 (in Georgian).
3. Korakhashvili A. (2003) Forage production, 275 p. GTU, Tbilisi (in Georgian).
4. Korakhashvili A. (2020) Forage energy efficiency, 205 p. Kutaisi (in Georgian).
5. Chankvetadze N., Korakhashvili A. (2003) Results of topinsunflower cultivation in irrigated conditions of Eastern Georgia, problems of agrarian sciences. *Collection of Scientific Papers,* XIII: 11-12. Tbilisi (in Georgian).
6. Ferteren I. I. (1979) Ierusalim artishok, pp. 120-138. "Selkhozgit", Frunze. (in Russian).
7. Barden A. John (1987) Plant Science, 551 p. New York, USA.
8. Korakhashvili A., Chankvetadze N., Vepkhvadze I. (2008) Opportunities for growing of topinsunflower in Georgia, *Collection of Scientific Papers,* pp. 81-86. Gori, Georgia.
9. Kakabadze N., Aleksidze G., Jinjixadze T. (2016) Genetic resources of vegetable-horticultural plants of Georgia, pp. 23-40. National Academy of Agriculture Science. Korea.
10. Kochnev N. K., Reshetnik L. A. (1997) Lechebno-dieticheskie svoistva topinambura, pp. 6-11. Irkutsk (in Russian).
11. Kakabadze N. (2018) The peculiarities of vegetable technology in Georgia**.** *Bulleten of the Georgian Academy of Agricultural Sciences,* 12: 124 p. Tbilisi.
12. Korakhashvili A., Sanikidze T. (2017) Adaptation of food safety communication systems RASFF and INFOSAN in Georgia, pp. 20-29. AASSA-INSA-NISCAR, New Delhi, India.
13. Pasko N.M. Topinsunflower - biotechnological potential for food, medicinal, technical, feed and ecological purposes, pp. 24-76. URL: http: (agroyug.ru/page/list/item).
14. Korakhashvili A., Sanikidze T., Korakhashvili L. (2018) Effective innovation technology of seed pilling for legumes. AASSA Workshop, pp. 26-29. Jakarta, Indonesia.
15. Dan A. (2009) Physicochemical studies on the biopolymer-inulin: a critical evaluation of its self-aggregation, aggregate-morphology, interaction with water and thermal stability, Biopolymers, pp. 687-692.
16. Korakhashvili A. et al. (2011) Research of cinnamonic calcareous soil fertilizing systems for pastures of Akhaltsikhe District (in cooporation), *Communications in Soil Sciences and Plant Analysis,* 42, 7: 767-786. Taylor and Francis, USA.
17. Kacharava T., Korakhashvili A. (2007) Medicinal and aromatic plants biodiversity in Georgia Global Summit (GOSMAP-3), pp. 104-111. Chiang Mai, Tailand.
18. Roberfroid M.B. (2005) Introducing inulin type fructans, *British Journal of Nutrition*, pp.12-18.
19. Korakhashvili A. (2021) Growing technology for soybeans with nano herbicides, *International Magazine. Annals of Agrarian Science,* **19,** 3: 199-203.
20. Kacharava T., Korakhashvili A. (2004) Measures to protection and utilization of Georgian wild and naturalized medicinal and aromatic plants, pp. 27-33. ECP/GR (IPGRI), Skopje, Macedonia, FYR.

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