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The influence of nitrogen fertilizer treated with low-temperature, low-pressure glow plasma on the growth and quality of selected species

Wpływ nawozów azotowych traktowanych niskotemperaturową, niskociśnieniową plazmą jarzeniową na wzrost i jakość wybranych gatunków

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Słowa kluczowe: amoniak, koperek odm. Moravan, niskotemperaturowa niskociśnieniowa plazma jarzeniowa, mieszanka traw Uniwersal, truskawka odm. Senga Sengana

Summary

Water treated with low-pressure glow plasma of low frequency takes unique properties which might be utilized as a novel, beneficial nitrogen fertilizer. That assumption is tested in this report. Thus, plantations of dill (*Anethum graveolens*) var. Moravan, grass Universal (5% westerwold ryegrass (*Lolium multiflorum*), 20% tall fescue (*Festuca arundinacea*), 40% perennial ryegrass (*Lolium perenne*), 35% red festuce (*Festuca rubra*) and strawberry ((*Fragaria) var.* Senga Sengana were watered with that nitrogen fertilizer (LPGPAm) prepared of 1% ammonia solution in tap water treated for 30 min with plasma generated at 38°C at 5x10^{-3} mbar, 800 V, 50 mA and 10 kHz frequency. Watering lasted from August 1th (sowing) till September 30th (harvesting) 2023 in a greenhouse. The effect of the use of watering plants with LPGPAm was checked involving the following parameters: plant height, mass of stems, total mass of crops, content of fat, proteins, carotenoids, ascorbic acid, sulphur content chlorophyll, content of dry mass, and ash and bioaccumulation of cations and anions.

Streszczenie

Woda traktowana niskociśnieniową plazmą jarzeniową o niskiej częstości przybiera unikalne właściwości, które sprawiają, iż mogłyby być stosowana jako nowy, wartościowy nawóz azotowy. Niniejsza praca służy sprawdzeniu tego założenia. Uprawy kopru ogrodowego (*Anethum graveolens*) odm. Moravan, mieszanki traw Uniwersal (skład: 5% życica westerwoldzka (*Lolium multiflorum*), 20% kostrzewa trzcinowa (*Festuca arundinacea*), 40% życica trwała (*Lolium perenne*), 35% kostrzewa czerwona (*Festuca rubra*)) i truskawki (*Fragaria*), odm. Senga Sengana, podlewano nawozem azotowym (LPGPAm), sporządzonym z 1% roztworu amoniaku w wodzie kranowej, traktowanego przez 30 min plazmą generowaną w 38°C przy 5×10^{-3} mbar, 800 V, 50 mA and częstości 10 kHz. Podlewanie trwało od 1 sierpnia (zasianie) do 30 września (zbiór) 2023 r. w inspektach. Badano wpływ podlewania roślin za pomocą LPGPAm, sprawdzając następujące parametry: wysokość roślin, masę łodyg, całkowitą masę plonów, zawartość tłuszczu, białek, karotenoidów, kwasu askorbinowego, siarki, chlorofilu, zawartość suchej masy i popiołu oraz bioakumulację kationów i anionów.

Introduction

Our former paper [1] demonstrates application of water treated under ammonia with low-temperature, low pressure glow plasma (LPGP) [2,3] in successful removal of temporary and permanent water hardness. In contact with such water (LPGPAm) even scale developed from hard water on various surfaces could be removed. These effects involved formation of smaller clathrates from LPGP treated water in which ammonia was arrested as the guest molecules. It was postulated that ammonia guest molecules guest molecules could form with water NH_4^+ cations. Additionally, the effect of the electromagnetic field generated by the source of LPGP could rise the guest molecules to their excited states. Therefore, the application of LPGPAm as nitrogen fertilizer was also suggested. It is known that the macrostructure of LPGP treated water and, hence, its functional properties strongly depend on the treatment time. In this study LPGPAm was prepared by 30 min exposure of the solution to LPGP. It is the most stable product containing the highest level of water molecules vibrating symmetrically [4]. There are several nitrogen fertilizers in use [5]. Unfortunately, their production and application is not always environmentally benign. It is accompanied with evolution of solid and/or volatile waste. In case of fossil fertilizers interaction with environment should be taken into account. In this paper suggestion of a suitability of LPGPAm as an ecologically benign nitrogen fertilizer is proven. Dill, grass and strawberries were taken as model plants. Selection of those plants for test objects in this paper results from the author's current large scale cultivation of those plants for practical purposes. They are also cultivate in backyard gardens. Garden dill (*Anethum graveolens*) belongs to the celery family (*Apiaceae*). Moravan variety is cultivated as a herb. That variety growths fast and can be sowed several times in the period from March till the middle of September. It propagates well and its single stems reach up to 1m. Its leafs are appreciated for its productivity and nutritional value. For its intensive, pleasant aroma, the plant itself as well an oil extracted from it is widely used as a spice [6].

Composition of commercially available universal grass called also the lown grass varies depending on properties of support and its destination. For instance, Universal grass Centnas used to be applied for sowing on all kinds of support. It can be utilized for arranging lawn grass, sowing on roadsides and other production of rolled lawn [7]. Various blends of grasses are very useful in so-called inteligent cities [8,9]. Usually, such blends contain three varieties of darnel (perennial ryegrass ~10%, multiflora ryegrass wester Estanzuela 284 ~ 15% and multiflora ryegrass Turtetra ~45%) as well as two varieties of fescue (tall fescue Starlet ~15% and red fescue Maxima ~15%). Such mixtrue well tollerates pruning [7]. Strawberry (*Fragaria x ananassa*) belongs to family Rosacea. For its fertility experiments were performed with the medium late variety Senga Sengana. Resistance of its root system to diseases, nematodes and to drought were also essential factor in favour that variety [10].

Materials and Methods

Materials

Plants – dill (*Anethum graveolens*) var. Moravan*:* Seeds were obtained from W. Legutko Breeding And Seed Company, Jutrosin, Poland, BK 1007-08302-MON, 2022 were used.

Strawberry (*Fragaria*) var. Senga Sengana: The seedlings were used exclusively for hobby gardening, produced by the Szkółka Sadzonek Truskawek Niewczas, 2022.

Grass mixture Universal: 5% westerwold ryegrass (*Lolium multiflorum*), 20% tall fescue (*Festuca arundinacea*), 40% perennial ryegrass (*Lolium perenne*), 35% red festuce (*Festuca rubra*): seeds only for hobby gardening manufactured by Centnas Poland, 2022 were used.

Water – Tap water from Częstochowa municipal supply system had pH 7,6, EMF= 351,8±0,3 mV and conductivity g=0,444±0,004 mS, It contained totally 672,28 mg minerals/L (193,27 mg Ca^{2+}/L, 46,21 mg Mg^{2+}/L, 23,18 mg Na^{+}/L, 5,27 mg K^{+}/L, 351,90 mg $HCO_3^{=}$/L, 51,20 mg $SO_4^{=}$/L, 6,52 mg Cl^{-}/L, 40µg Fe/L).

Gases – Ammonia solution from Merck (EC No.: 231-635-3) was used

Substrate – was composed of medium size turf fraction Florabalt® Pot Medium-Coarse (Floragard, Oldenburg, Federal Republic of Germany). The medium of pH 5.6, contained 1,2 g/L total salts including 210 mg N/L, 120 mg P_2O_5/L, 260 mg K_2O/L and 0,258% S. It was supplemented with multicomponent PG-Mix 18-10-20 fertilizer (1,20 kg/m^3) (Yara, Oslo, Norway).

Methods

Cultivation

The monofactorial experiment was carried out from August 1th (sowing) till September 30th (harvesting) 2023 in a greenhouse. Temperature in the greenhouse was set for 22 and 18°C during the day and night, respectively. The day time took 16 h since the sunup. The passing from the day into the night regime was controlled with computer. The automatic additional 16 h illumination with sodium lamps was used when natural light intensity decreased below 100 W/m^2. The experiment involved three sets of trays with 24 pots each. Ten seeds of the plant were sown into every pot. In one series of experiments 2 multiplates hosted 300 plants. In order to eliminate parietal effect 60 plants on the edge of trays were left apart and, therefore, only 240 plants were harvested. Since the experiments were run in triplicates maximum 720 plants were collected for a given series.

The watering was adjusted according to tensiometer readings (Irrometer model SR 150 mm) when soil water tension was < -40 kPa. The plants were watered by hand to avoid the accidental contact of water with leaves. Initially, plants consumed totally 3L water, that is 1L per each replication in the 5 day period until March 24th. In the subsequent 1 month period the watering was intensified and the same amount of water was administered to the plants in 3 day periods. In the final period of breading plants were watered daily consuming the same amount of water. In such manner the watering consumed totally 40 mL each kind water daily. The experiment terminated on September 30th when the plants were collected. The plants were then dried at 105°C for 4 hours to determine dry mass of the crops.

Saturation of water with ammonia

Ammonia solution was added to tap water to provide the 1% solution.

Treating water with low-temperature, low-pressure glow plasma (LPGP)

Water (200 mL) saturated with ammonia was placed in 250 mL glass bottles. The whole was placed in the chamber of the reactor and exposed to GP for 30 min. Plasma of 38°C was generated at 5×10^{-3} mbar, 800 V, 50 mA and 10 kHz frequency. The produced water was stored at ambient temperature in 100 mL closed teflon containers served as a standard.

Estimation of crop yield

Weights of samples were measured with Analytical laboratory scale RADWAG AS 220.R2 (Radom, Poland) with precision of ±0,0001g.

Estimation of dry mass

Samples were 24 h dried at 100-105°C. Weights of samples were measured with Analytical laboratory scale RADWAG AS 220.R2 (Radom, Poland) with precision of ±0,0001g.

Estimation of ash

In a vessel weighed with the 0,0002 g precision a substance was weighed with the same precision and the whole was inserted for 10 min into a front of an oven heated to 815°C. Subsequently, the vessel with the sample was shifted (2 cm/min) into the central region of the chamber. After returning the temperature of the oven to 815°C the analysed sample was maintained inside the chamber for further 25 min. After that time the sample was left in the open for cooling to room temperature than weighed with the 0,0002 g precision.

Fat content

A sample thoroughly disintegrated in a mortar was weighed (5 g±1 mg) then blended with anh. Na_2SO_4 (5 g) and transferred into extracting casing filling it in no more in 3/4th its height. The filled casing was closed with a fat-free cotton wool. The 3 h extraction with n-hexane (200 mL) was carried out in an Soxhlet apparatus equipped in a flask for collecting extract weighed with the ±1 mg precision. After that time, acetone (2 mL) was added to the flask with the extract cooled to room temperature. On blowing a stream of nitrogen the whole was slowly heated to remove acetone and n-hexane. The flask with extract was heated for 10 min in a drying box at 103°C then left in a desiccator for cooling to room temperature followed by weighing. The fat content (H) [g/100g or %] was estimated using Eq. (1)

$$H = [(m_2 - m_1)/m_0]\cdot 100 \qquad (1)$$

where
m_0 – mass of the sample,
m_1 – mass of empty extracting flask and
m_2 – mass of extracting flask with extract.

Protein content

The Kjeldahl method [11] was applied for the estimations.

Carbohydrate content

Mass of carbohydrates (M) was determined from Eq. (2)

$$M = 100\text{ g} - \text{mass of fat} - \text{mass of proteins} \quad (2)$$

Chlorophyll content

Leaves of cress (200 mg) were homogenized for 2 min in a cooled mortar then homogenized for further an additional 2 min with the acetone/ammonia (0.05 mol/dm^3) 8/2 blend (5 cm^3) cooled to 0-5°C. The extraction was continued for 2 more min. by addition of a subsequent 5 cm^3 of extracting acetone/ammonia blend. The resulting suspension of well disintegrated sample was transferred into 25 cm^3 measuring cylinder, the mortar was washed with extracting blend (10 cm^3) and the wash was combined with the extract. The extract was then centrifuged for 10 min at 5000 rpm, and decanted. The volume of the extract was increased to 25 cm^3 by adding the extracting blend. The experiments wererun in triplicates.

The absorbance (A) of resulting extract was taken at 470, 647 and 664 nm. The content of chlorophylls a and b in mg/g was estimated from the Eqs. (3) and (4), respectively.

$$chl.a = 25a/m \quad (3)$$

where:

$a = 11{,}78\ A_{664} - 2{,}29\ A_{647}$ and m denotes the weight (mg) of the fresh plant material.

$$chl.b = 25b/m \quad (4)$$

where:

$b = 20{,}05\ A_{647} - 4{,}77\ A_{664}$ and m denotes the weight (mg) of the fresh plant material.

Carotenoids content

The content of carotenoids (β-carotene and xanthophyll) was calculated from Eq. (5).

$$car = 25c//229\ m \quad (5)$$

where:

$c = 1000\ A_{470} - 3{,}27a - 104b$ and m denotes the weight (mg) of the fresh plant material.

Determination of ascorbic acid

Sample of the dried plant (1g) was disintegrated in a mortar 50 cm^3 distilled water and 5 cm^3 of 0.1M aqueous solution of potato starch added. This solution was titrated with a iodine solution following paper by Al Majidi and Al Qubury [12]. The estimations were triplicated.

Analyses for cations

Samples were mineralized in a microwave oven (MarsXpress CEM Company, Matthews, NC USA). Samples (0.5 g) were digested with nitric acid 65% analytical grade (10 cm^3). Determination of metals content was performed with atomic absorption spectrometry with electrothermal device (AA Varian 240 instrument). A palladium standard solution (1000 mg/dm^3) was used as a modifier.

Anion analyses with ion chromatography

A DX500 micropore (2 mm) ion chromatograph with a CD20 conductivity detector and GP40 gradient pump (Dionex, California) was used for ion separation and detection. Commercially available Ionpac CG12A guard and CS12A analytical columns (Dionex, California, USA) with carboxylic-phosphonic acid functional groups were used for cation analysis. Ionpac AG14 guard and AS14 analytical columns (Dionex, California) with quaternary ammonium functional groups were used for anion separation. Eluents were stored in vessels pressurized at 8 p.s.i. using high purity argon (BOC gases), and flow-rates were maintained at 0.45 ml/min for anions and 0.40 cm^3/min for cations using a GP40 gradient pump (Dionex, California, USA). Samples were loaded from an AS40 automated sampler (Dionex, California, USA).

Estimation of total sulphur

The sulfur content was determined using a CHNS/O FlashSmart Thermo Scientific analyser (Waltham, MA USA).

Results and Discussion

Watering dill with LPGPAm appeared beneficial in terms of the crop yield (*Photography* 1, Table 1).

Fotografia 1. Dill watered with tap, non-treated treated with LPGP without ammonia (left) and LPGPAm (right)

Photography 1. Koper ogrodowy podlewany nieplazmowaną wodą kranową (po lewej) i LPGPAm (po prawej)

The number of plants decreased but the total mass of plant remained constant. Observed effect results from an increase in mass of stems (Table 1).

Table 1. Quantitative characteristics of the dill crops watered with non-treated tap water and with LPGPAma

Tabela 1. Ilościowa charakterystyka plonu koperku po podlewaniu nieplazmowaną wodą kranową i LPGPAm

Estimations	Non-treated water	LPGPAm
Number of plants	12,44±0,23a	11,02±0,16b
Height of plants/1 pot [cm]	11,3±2,40a	15,40±2,10b
Total mass of plant [g]	11,52±0,43a	12,27±0,57a
Mass of stems [g]	2,53±0,13a	3,19±0,11b

[a]Average number of plants collected from triplicated experiments involving 3 × 24 trays. Each tray contained 10 seeds. Presented data were recalculated for the number of plants in one tray. Differences in numerical values for particular estimations in verses carrying the same letter are statistically unessential.

Except height of plants and number of leaves, watering with LPGPAm is definitely beneficial in case of strawberries (Photography 2 and Table 2). The period of monitored cultivation of these plants was too short for developing fruits. Therefore the effect of watering upon them was left apart.

Photography 2. Strawberries watered with tap water (left) and with LPGPAm (right)

Fotografia 2. Truskawki podlewane wodą kranową (po lewej) i LPGPAm (po prawej)

Table 2. Quantitative characteristics of the strawberry watered with LPGP-treated kinds of watera
Tabela 2. Ilościowa charakterystyka plonu truskawek po podlewaniu nieplazmowaną wodą kranową i LPGPAm

Estimations	Non-treated water	LPGPAm
Height of plants/1 pot [cm]	18,1±4,0a	22,4±2,1a
Total mass of plant [g]	59,52±0,51a	64,27±0,77b
Total number of leaves	12,2±1,1a	13,2±1,4a
Mass of stems [g]	13,53±0,13a	14,29±0,19b
Total mass of foliage [g]	16,93±0,39a	19,99±0,64b
Mass of one leaf [g]	3,559±0,012a	4,137±0,013b

[a]Average number of plants collected from triplicated experiments involving 3 × 24 trays. Each tray contained 10 seeds. Presented data were recalculated for the number of plants in one tray. Differences in numerical values for particular estimations in verses carrying the same letter are statistically unessential.

Watering grass with LPGPAm appears beneficial solely in terms of total mass of plants Photography 3 and Table 3). Watering with LPGPAm has practically no effect upon number of plants, height of plants and mass of stems.

Fotografia 3. Grass watered with LPGPAm (leftt) and with non-treated tap water (right)
Photography 3. Trawa podlewana LPGPAm (po lewej) i wodą kranową (po prawej)

Table 3. Quantitative characteristics of the grass watered with LPGP-treated kinds of watera

Tabela 3. Ilościowa charakterystyka plonu trawy po podlewaniu nieplazmowaną wodą kranową i LPGPAm

Estimations	Non-treatedwater	LPGPN
Number of plants	14,84±0,15a	15,02±0,16a
Height of plants/1 pot [cm]	18,1±4,0a	22,4±2,1a
Total mass of plant [g]	12,52±0,51a	24,27±0,77b
Mass of stems [g]	1,53±0,13a	1,89±0,19a

aAverage number of plants collected from triplicated experiments involving 3 × 24 trays. Each tray contained 10 seeds. Presented data were recalculated for the number of plants in one tray. Differences in numerical values for particular estimations in verses carrying the same letter are statistically unessential.

Watering dill with LPGPAm had no effect on the content of fat, proteins, carotenoids, ascorbic acid and sulphur containing compounds. Solely chlorophyll content increased. In case of strawberries watering with LPGPAm resulted in an decrease in fat content and sulphur containing compounds and an increase in the content of chlorophyll and carotenoids. No effect could be noted on the content of proteins and carbohydrates. Watering of grass with LPGPAm resulted in an increase in the content of proteins and chlorophyll whereas the level of fat, carbohydrates, carotenoids ascorbic acid and sulphur containing content remained unchanged (Table 4).

In case of all three tested plants watering with LPGPAm increased dry mass and ash content of the crops (Table 5). That effect was caused by bioaccumulation of cations and anions in the plants. In dill the watering with LPGPAm did not influence bioaccumulation of cations and an increase in the bioaccumulation of Cl and NO_3 anions. Such watering of strawberries favoured bioaccumulation of Ca^{2+} cations and Cl^- and NO_3^- anions. Increased bioaccumulation of the K^+, Ca^{2+} and Mg^{2+} cations and simultaneously bioaccumulation of Cl^-, NO_3^- and SO_4^{2-} anions (Tables 6 and 7) was noted in case of grass.

Table 4. Fat, protein, carbohydrate, chlorophylls, carotenoids, ascorbic acid and sulphur containing compounds content in plants watered with tap water and LPGPAma

Tabela 4. Zawartość tłuszczu, węglowodanów, chlorofilu karotenoidów, kwasu askorbinowego i związków siarki w plonach roślin podlewanych wodą kranową i LPGPAm.

Plant	Content [g/100g]					
	Fat		Proteins		Carbohydrates	
	Non-treated	LPGPAm	Non-treated	LPGPAm	Non-treated	LPGPAm
Dill	0,45±0,02a	0,42±0,02a	3,22±0,02a	3,27±0,02a	96,33±0,01a	96,31±0,01a
Strawberry	0,51±0,01a	0,46±0,01b	2,81±0,02a	2,86±0,02a	96,68±0,02a	96,68±0,02a
Grass	0,43±0,02a	0,41±0,01a	2,91±0,01a	2,96±0,01b	96,66±0,01a	96,68±0,01a

Plant	Chlorophyll [mg/g]					
	A		B		Total	
	Non-treated	LPGPAm	Non-treated	LPGPAm	Non-treated	LPGPAm
Dill	1,212±0,016a	1,294±0,014b	0,238±0,016a	0,318±0,013b	1,982±0,031a	2,282±0,021b
Strawberry	1,343±0,012a	1,436±0,016b	0,349±0,011a	0,429±0,017b	2,441±0,012a	2,731±0,015b
Grass	1,332±0,013a	1,469±0,009b	0,342±0,009a	0,402±0,004b	2,335±0,011a	2,634±0,017b

Plant	Carotenoids [mg/g]		Ascorbic acid [mg/g]		Sulphur compounds [%]	
	Non-treated	LPGPAm	Non-treated	LPGPAm	Non-treated	LPGPAm
Dill	0,323±0,016a	0,345±0,014a	0,282±0,013a	0,284±0,006a	0,04±0,02a	0,05±0,02a
Strawberry	0,331±0,013b	0,363±0,013b	0,529±0,010a	0,542±0,010a	0,09±0,01a	0,06±0,01b
Grass	0,328±0,008a	0,338±0,009a	0,233±0,012a	0,245±0,013a	0,03±0,01a	0,05±0,01a

[a]Differences in numerical values for particular estimations in verses carrying the same letter are statistically unessential.

Table 5. Content of dry mass and ash from crops watered with particular kinds of water[a]

Tabela 5. Zawartość suchej masy i popiołu z plonów podlewanych poszczególnymi rodzajami wody

Plant	Dry mass [g]		Ash [%]	
	Non-treated	LPGPAm	Non-treated	LPGPAm
Dill	12,9±0,1a	13,4±0,1b	1,73±0,02a	1,82±0,02b
Strawberry	9,3±0,2a	9,9±0,2b	3,52±0,02a	3,72±0,01b
Grass	5,6±0,1a	6,8±0,1b	1,13±0,01a	1,19±0,01b

[a]Differences in numerical values for particular estimations in verses carrying the same letter are statistically unessential

Table 6. Bioaccumulation of cations in plants watered with particular kinds of water[a]

Tabela 6. Bioakumulacja kationów w roślinach podlewanych poszczególnymi rodzajami wody

Plant	Content [mg/100g]											
	Na^{+}		K^{+}		Ca^{2+}		Mg^{2+}		Mn^{2+}		Fe^{3+}	
	Non -treated	LPG-PAm	Non -treated	LPG-PAm	Non-treated	LPG-PAm	Non -treated	LPG-PAm	Non -treated	LPG-PAm	Non -treated	LPG-PAm
Dill	21±1a	21±1a	369±3a	372±3a	156±2a	158±2a	47±1a	49±1a	0,3±0,1a	0,3±0,1a	1,5±0,2a	1,6±0,2a
Strawberry	25±1a	26±1a	377±2a	381±2a	161±1a	164±1b	46±1a	48±1a	0,4±0,1a	0,3±0,1a	1,6±0,1a	1,7±0,1a
Grass	26±1a	27±1a	376±2a	381±2b	163±1a	166±1b	46±1a	49±1b	0.3±0,1a	0,2±0,1a	1,8±0,1a	2,0±0,1a

[a]Differences in numerical values for particular estimations in verses carrying the same letter are statistically unessential

Table 7. Bioaccumulation of anions in plants watered with particular kinds of water[a]
Tabela 7. Bioakumulacja anionów w roślinach podlewanych poszczególnymi rodzajami wody

Plant	Content [mg/100g]									
	Cl^-		NO_2^-		NO_3^-		SO_4^{2-}		PO_4^{3-}	
	Non--treated	LPG--PAm	Non-treated	LPG-PAm	Non-treated	LPG--PAm	Non-treated	LPG-PAm	Non-treated	LPG-PAm
Dill	118,13±0,01a	128,15±0,01b	0,00±0,00a	0,00±0,00a	11,23±0,01a	11,28±0,01b	9,23±0,02a	9,27±0,02a	6,16±0,02a	6,16±0,02a
Strawberry	119,31±0,02a	126,43±0,02b	0,00±0,00a	0,00±0,00a	21,83±0,01a	21,99±0,01b	11,32±0,01a	11,31±0,01a	5,07±0,02a	5,07±0,02a
Grass	141,14±0,02a	146,23±0,02b	0,01±0,01a	0,00±0,00a	16,23±0,01a	17,03±0,01b	12,22±0,01a	12,43±0,01b	7,56±0,02a	7,56±0,02a

[a]Differences in numerical values for particular estimations in verses carrying the same letter are statistically unessential.

Presented results document that preparation of nitrogen fertilizer involving treatment of aqueous ammonia with low-temperature, low-pressure glow plasma is fully safe as on its generation and application no harmful products are formed. Measured parameters characterizing crops growth and properties showed that application of that fertilizer for watering tested plants was always beneficial.

Conclusions

Preparation of nitrogen fertilizer involving treatment of aqueous ammonia with low temperature, low pressure glow plasma is fully ecological safe as on its generation and application no harmful products are formed. Measured parameters characterizing crops growth and properties showed that application of that fertilizer for watering tested plants was always beneficial.

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