The change of coating process of NPK fertilizer with a biopolymer by using a continuous flow reactor

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Abstract. This paper illustrates the change of coating process reaction from a batch (or semi-batch) into continuous flow (V-star), where the core material consists of NPK macro-elements (16:16:16) and layer is a biodegradable polyvinyl alcohol. Moreover, an additive role of this project is to explore the parameters’ changes of nitrogen, in the soil after application of fertilizer coated with a biopolymer. Besides, the application results of coated biodegradable fertilizer on a virus free (in Vitro) rootstock VSL-2 plant biometrics. The biodegradability results of the coated nitrogen, phosphorous and potassium (NPK) fertilizer (Azafoska) demonstrate strongly dependence on the core material used.

1. Introduction

The studies of new forms of mineral (NPK) fertilizers is due to the need to maximise the agro-economic productivity of their application and ensure well balanced nutrition of plants, including the choice of the form of fertilizers taking into account their properties and composition. Fertilizers must fully satisfy the biological characteristics of crops in any specific soil (can subtract as well), agricultural conditions and climate. The right choice of fertilizer determines the direction of biochemical processes, ensures the growth and development of plants, their resistance to adverse environmental conditions. [1,2]

Therefore, the new forms of fertilizer can be obtained by coating them with biodegradable polymer (biopolymer) particles. They are widely used to create fundamentally new dosage forms called “drug delivery systems” or macromolecular therapeutic systems. The use of biopolymers allows for longer and continuously transfer a medicinal substance to the body according to a given program, and in many cases to a target organ. Promising carrier for producing particles are natural polysaccharides, in particular alginic acids. One of the main tasks of the development of agriculture is to increase the resistance of plants to diseases and increase the productivity. Many ways were approached in agriculture to increase the productivity of crop trees, but all methods are coming to fertilizer usage. Three main elements most needed by plants are nitrogen (N), phosphorous (P) and potassium (K), so they also known as macro-elements [1, 7]:

- N (nitrogen) is necessary for new shoots and creation of a chlorophyll plant
- P (Phosphoric acid) –promotes the ripening of flowers, fruits and develops the root system
K (potassium) does favourable affect on the process of photosynthesis and strengthens the immunity of plants, both against diseases and various pests.

However, solid nitrogen is fairly volatile and can move into an atmosphere or condense into nitrogen frost, therefore it was decided to control the release of nitrogen and other macro-elements in a plant needing.

There are many ways to control the NPK release, but the polymer coating was subscribed as one of the most efficient method to deliver the “feed” to the plants timely. [3] Moreover, the coating through polymer film to control the nutrient release can reduce the macro-elements (NPK) losses and minimize environmental contamination. Besides, biopolymer coated fertilizer does prolonged release of macro-elements (NPK) and provides evenly distributed mineral elements in the substrate of soil. In order to study the effects of coating material on the biopolymer coated fertilizer it is has to be improved the technology production of coated NPK.

There are many ways to coat the macro-elements in a batch tank, however, to enter the product (coated material) into industry, the chemical run method must be transferred into continuous flow process, thus, the change of the “reactor” will reduce the cost of obtaining the product. There are different types of reactors that can proceed the chemical processes in industry, but very few reactors that can continuously flow the chemical processes and well coat the fertilizer. Therefore, by citing the factor and economic evaluation, it was determined that the V-star chemical continuous flow reactor will be used to run the coating process of NPK fertilizer (Azafoska 16:16:16) with a biodegradable polyvinyl alcohol.

In other words, the coating process is well known to be in a batch (or semi-batch) tank reactor, but the idea of this project is to transfer the process into a continuous flow reactor where it will be possible to have a crystallisation process in a «non-stop» reactor. Therefore, to get into transferring conditions, the flow process must be very well controlled because the reactor that has high control proceeds is required for the changing system technology. [3, 6]

As it is illustrated in figure bellow (figure 1) V-star is a multistage reactor, which does transfer many chemical (liquid) reaction processes from batch into continuous flow. [2] The reactor is about six stages, which are parallel to each other on a horizontally (left-right) moving platform (with controlled movement speed) within heating (first 4 stages) ability.

The last two stage (stage 5 and 6) from figure above (figure 1) plays role as a condenser, where the cold water goes across the final stages and cools down the temperature of the product obtaining and the crystallisation process occurs after well mixing the reactants at first 4 stages. The received product
collects at stage 6. The volume of the reactor is 800 ml (100 ml for each stage) and 200 ml in stage-connection tubes, however, the volume of the reactor can be easily increased within more/bigger stages. [6]

2. Methodology
All an experimental work was done at the Chechen State University and the product was tested at Ltd. «Scientific Production Firm “Sady Chechni”. The virus-free rootstock material (VSL-2) also was produced at Ltd. «SPF “Sady Chechni”. Azafoska was from a company

In first tank 20 g of polyvinyl alcohol (PVA 17-99, 20 mesh) was dissolved in 100 g of deionised water. The solids have partially dissolved in deionised water at room temperature (25°C or 298 K), however, within further stirring and heating up the mixture, the solids have dissolved completely at 74°C (clearly dissolved). In a second tank, 100 g of Azafoska (Granulat «Gruppa INCO S. A within NPK 16:16:16) was dissolved in 500 ml dionised water, within stirring at room temperature (25℃ or 298 K) the granules were dissolved completely (clearly dissolved) with no heat required. Both solutions from tank 1 and tank 2 were pumped to the reactor (V-star) with 2 peristaltic pumps (1 pump for each tank) with a flow rate:

- 1-st tank → 20 ml/min
- 2-nd tank → 100 ml/min

It took 6 minutes (365 seconds) for the peristaltic pumps to empty both tanks 6.7 minutes to get the first product out at stages 6.
13 minutes to complete the whole reaction flow process.

The moving speed of the V-star reactor platform was chosen to be at 2 (15 cm / s). The product (Azafoska NPK 16:16:16 coated over with a polyvynil alcohol - biopolymer) was sticky, white and was collect at the last stage (stage 6) within 40°C within presence water, which was remover in a vacuum oven at 60°C and atmospheric pressure at 1 atm. After receiving dried product, the biodegradable fertilizer was fed into the soil (experimental 1 and control), where virus – free rootstock VSL -2 was planted and agro-ecological soil parameters were obtained by using GOSTs:

- GOST 26205-91 Determination of mobile compounds of phosphorus and potassium according to the method of Machigin in the modification of CINAO.
- GOST 26951-86. Determination of nitrates by the ionometric method.
- GOST 26489-85. Determination of exchange ammonium according to the CINAO method.
- GOST 26487-85 - pH, electrical conductivity.

3. Results and discussion
The results obtained after application of coated fertilizer with a biopolymer are given in the table bellow (table 1). The results indicated in table 1 illustrates, that, the coated fertilizer with a polyvynil alcohol does positively affect on the plants, where the stalks are increased almost 1.5 times (compared to the control), height – tripled, mass of tops 2.5 times and the leaf area is almost 2.5 times bigger than the control and 1.5 times than option number 2.

| №   | Option                | Quantity pieces / bushes | Height /cm | Mass of bushes / g | The leaf area |
|-----|-----------------------|--------------------------|------------|--------------------|---------------|
|     |                       | Stalks | Tubers   |                    |               |
| 1   | Control (No fertilizer)| 2.4    | 7.3      | 29.0               | 354           | 0.35         |

Table 1. Biometric indicators of rootstock VSL -2 plants depending on the fertilizer applied.
The agrochemical parameters of soil were given in the table below (table 2).

| Options | Repetition 1 | Repetition 2 |
|---------|--------------|--------------|
| Control (No fertilizer) | 6.2 | 6.1 |
| NPK (100 g) with Biopolymer (20 g, non-coated) | 6.8 | 6.7 |
| NPK coated with biopolymer – 120 g | 7.2 | 7.4 |

| Exchange ammonium content, mg / kg |
|-----------------------------------|
| Control (No fertilizer) | 11.3 | 11.1 |
| NPK (100 g) with Biopolymer (20 g, non-coated) | 13.9 | 13.7 |
| NPK coated with biopolymer – 120 g | 21.3 | 21.0 |

| The total content of mineral nitrogen, mg / kg |
|-----------------------------------------------|
| Control (No fertilizer) | 17.5 | 17.3 |
| NPK (100 g) with Biopolymer (20 g, non-coated) | 20.7 | 20.0 |
| NPK coated with biopolymer – 120 g | 28.5 | 27.4 |

From the table above (table 2), the results were repeated 2 times, where they show that, the total content of mineral nitrogen, at each time is bigger for coated fertilizer (Azafoska 16: 16: 16) with polyvynil alcohol (biopolymer) than the other options.

4. Conclusion
To sum up the research that was done in this paper, it is fairly to notice that, coated fertilizer (Azafoska) with a biopolymer (polyvynil alcohol) does effective result on the plant growth, therefore a good influence into the plant. V-star has successfully transferred the reaction process from batch-tank into continuous flow. The VSL-2 rootstock plant biometrics also were absorbed, where it was illustrated that the coated fertilizer with biopolymer does positively changes at many stages such as: mass of tops, leafs area and etc. It is clearly must be stated, due to the promising results from very first research, that the studies must be carried on with other sort-plants, at different ratios of biopolymer to fertilizer, with other coat and layer materials.

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