Mineral and water nutrition, soil cultivation technologies influence on onion yield, spatial variation and biochemical compound in the system of vegetable crop rotations of the Nizhneje Povolzhje region

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Abstract. To increase yields, it is necessary to improve the technologies for growing agricultural crops. Scientific research was carried out from 2016 to 2020. The optimal seeding rates per hectare, seasonal irrigation rates and doses of mineral nutrition were studied, this will reveal the levels of vegetable crop rotations adaptive intensification, its influence on soil indicators characterizing the soil formation evolutionary processes and the products quality. The objects of the study were onion hybrids of foreign selection Pandero F1, Benefit F1, Valero F1, Manas F1. The domestic zoned variety Volgodonets was taken as the standard one. As the result of the search for the optimal combination of moisture supply and mineral nutrition levels, it was established that for the Nizhneje Povolzhje region, in the conditions of the existing land use and the adopted soil preparation technologies, indicators that provide 80% of minimum water capacity are the optimal variant. For five years of observations (2016-2020) in the Astrakhan region, the Pandero F1 hybrid showed an average yield of 139.07 t/ha, Benefit F1 - 150.16 t/ha, Valero F1 - 123.73 t/ha, Manas F1 - 133.76 t/ha. In the Volgograd region, the same hybrids showed 103.10 t/ha; 129.57 t/ha; 111.06 t/ha; 104.09 t/ha, respectively. The research allows to recommend the production to include in the technological processes the soil basic preparation, namely autumn plowing, to plow not to 0.22 ... 0.25 m by a conventional plow, but to plow without soil overturning by the Paraplau unit to the depth of 0.42 ... 0.45 m. The authors offer to leave sowing by eight-row seeders and to change to sowing by a twelve-row seeder.

1. Introduction
The Nizhneje Povolzhje region in the past and, moreover, at present, is the region of intensive vegetable growing. Bulb onion is a strategic vegetable crop in the Russian Federation. With the population of 146,793.00 thousand people at the end of 2019, 1.60 million tons of onions were grown and delivered to the market in 2018, it amounted to 10.89 kg/year per person with the consumption rate of 28.40 kg, which is only 38.40% of the required one. In addition, this means that in order to meet the needs of the population and fill the "food basket” up to medical-based standards in Russia, it is necessary to grow and supply to the market 4169.00 thousand tons of onions. At present, we are content with onion production: in 2018 - 1.60 million tons, and in 2017 - 2.10 million tons, i.e. it is necessary to increase the production of this product in the country as a whole by more than 2 times.
The research purpose was to determine the optimal seeding rates for seeds per hectare, optimal seasonal irrigation rates and mineral nutrition doses, which made possible to identify the levels of vegetable crop rotations, its influence on soil indicators characterizing the soil formation evolutionary processes and the products quality.

2. Materials and methods
The test plots were set up on the light chestnut soils of the Pricaspian lowland in the Chernoyarsk region of the Astrakhan region and on the chestnut soils of the Ergeninskaya upland in the Gorodishchensky region of the Volgograd region. The multifactorial experiments included the study on the onion varieties and hybrids adaptation and application problems in order to identify the most high-yielding combinations of early, middle and late production (Factor A); to determine the optimal seeding rates for onion seeds per 1 hectare, ensuring the maximum crop productivity (Factor B); to determine the seasonal watering rates for light-chestnut and chestnut soils that provide maximum yield (Factor C); to determine the optimal levels of mineral nutrition, including both autumn feeding and the application of mineral fertilizers by fertigation method, which ensure not only the maximum yield, but also the obtained products quality (Factor D).

The research on the selected experimental fields was divided into two stages: Stage 1 - 2011-2015, the first rotation of cropping; Stage 2 - 2016-2020, the second rotation of cropping. At the first stage, the issues of varieties and hybrids wide range application and adaptation, both zoned in the Nizhneje Povolzhje and not included in the register, were investigated. As the scientific search result, we developed an upcoming experiments concept, which reflects research on the above-mentioned four factors. Based on the research second stage results, we determined the optimal seeding rate per hectare, the optimal seasonal irrigation rate and determined optimal doses of mineral nutrition, which made it possible to identify the levels of vegetable crop rotations adaptive intensification, its influence on soil indicators characterizing the soil formation evolutionary processes and manufactured products quality.

For the processing of samples and experimental field plots, the method of the field experiment by B.A. Dospekhov [1], as well as scientists’ scientific publications on the topic under discussion were used. The yield of onions was taken into account when harvesting by the continuous method.

3. Results and Discussion
The authors made the attempt to summarize the materials for 2016-2020 on the indicated topics by this work. We set the task of how to develop the strategic vegetable crop - onion production, in order to maximize the climatic and land potential of the Nizhneje Povolzhje region, which has an inherent advantage in our country: the Volga River discharges into the Caspian Sea 210.00 ... 230.00 of cubic kilometers of fresh water per year, the sum of positive temperatures above 10 ℃ is 3600 ... 3900 ℃ and the vast plains of dry steppes. In the last century, the Astrakhan and Volgograd regions had more than 210 thousand hectares of irrigated fields each one. Today these areas are exploited by less than 50%. There is an objective explanation for this: low power and energy supply, as well as highly costly production of the production unit under irrigation conditions; this is superimposed on the eternal Russian problem - the imperfection of the purchasing vegetable products system. Considering all this, we believe that, nevertheless, the growth of vegetable production in the country, especially onion, can, in the main, be provided by vegetable growers of the Astrakhan and Volgograd regions.

For a complete disclosure of the research materials presented below, the interrelated indicators characterizing the yield dependence on the levels of the onion mineral nutrition and moisture supply (Table 1) should be considered, after that the data on spatial variation (Table 2) and how the whole complex of the research influenced the onion quality characteristics and biochemical compound should be assessed.

The search for the optimal combination of moisture supply and mineral nutrition levels, carried out over the years of research, unequivocally confirmed us that for the Nizhneje Povolzhje region, under the conditions of the existing land use and the adopted soil preparation technologies, the optimal option are indicators that provide 80% of minimum water capacity, while in Astrakhan region, this is possible with a seasonal irrigation rate of 10,000 m³/ha, and in the Volgograd region - 8000 m³/ha. Such a difference in the needs of irrigation water is explained, mainly, by one factor, in the Astrakhan region the main tillage -
autumn plowing is carried out by the Paraplau unit to the depth of 0.42 ... 0.45 m, and in the Volgograd region it is performed by the PN-4-35 plow to the depth of 0.22 ... 0.25 m. The methods and volumes of applied mineral fertilizers differ significantly. Therefore, the autumn application of mineral fertilizers in the Astrakhan region is carried out under plowing by grain seeders, fertilizers are applied in granular form and complex in content (N30P78K78), and at vegetative fertilizing N496P128K128 is applied by fertigation method, that provides the volume of fertilizers for the crop formation in the amount of N526P206K206.

Table 1 - Yield dependence on levels of onions mineral nutrition and moisture supply.

| Variant of minimum water capacity; NPK | Agricultural Enterprise Zvolinsky O.V. | Variety, hybrid | 2016 | 2017 | 2018 | 2019 | 2020 |
|---------------------------------------|--------------------------------------|-----------------|------|------|------|------|------|
| 80% of minimum water capacity          | Volgodonets                          | 71.04           | 69.92| 75.55| 61.72| 68.53|
|                                       | Pandero F1                           | 135.15          | 139.25| 127.97| 141.13| 152.58|
|                                       | Benefit F1                           | 149.28          | 145.25| 132.22| 154.49| 169.54|
| N – 526 active ingredient kg/ha        | Valero F1               | 129.33          | 137.64| 104.74| 121.37| 125.59|
| P – 206 active ingredient kg/ha        | Manas F1                | 130.21          | 142.05| 109.17| 135.65| 151.70|
| 75% of minimum water capacity          | Volgodonets                          | 63.75           | 61.21| 68.97| 55.27| 53.89|
|                                       | Pandero F1                           | 121.17          | 125.85| 114.42| 129.41| 138.27|
|                                       | Benefit F1                           | 134.97          | 131.18| 129.81| 139.72| 149.75|
| N – 490 active ingredient kg/ha        | Valero F1               | 118.15          | 123.41| 98.61| 122.05| 136.79|
| P – 206 active ingredient kg/ha        | Manas F1                | 117.27          | 128.39| 98.31| 121.75| 121.11|
| 70% of minimum water capacity          | Volgodonets                          | 58.41           | 57.05| 61.21| 49.85| 48.05|
|                                       | Pandero F1                           | 101.27          | 104.17| 100.01| 115.44| 124.21|
|                                       | Benefit F1                           | 109.41          | 106.32| 104.17| 115.61| 127.44|
| N – 456 active ingredient kg/ha        | Valero F1               | 97.49           | 95.12| 94.75| 90.79| 94.01|
| P – 188 active ingredient kg/ha        | Manas F1                | 98.04           | 101.13| 74.81| 99.46| 113.31|
| K – 197 active ingredient kg/ha        | HCP05 on variants           | 5.45            | 5.55| 4.98| 5.51| 5.91|

| Variant of minimum water capacity; NPK | Agricultural Enterprise Zaitsev V.A. | Variety, hybrid | 2016 | 2017 | 2018 | 2019 | 2020 |
|---------------------------------------|--------------------------------------|-----------------|------|------|------|------|------|
| 80% of minimum water capacity          | Volgodonets                          | 72.77           | 74.83| 80.90| 69.46| 72.05|
|                                       | Pandero F1                           | 89.29           | 107.60| 102.34| 106.71| 109.55|
|                                       | Benefit F1                           | 119.45          | 122.92| 129.57| 135.05| 140.86|
| N – 326 active ingredient kg/ha        | Valero F1               | 110.51          | 104.06| 114.46| 109.30| 116.99|
| P – 188 active ingredient kg/ha        | Manas F1                | 104.56          | 104.56| 102.52| 108.38| 115.31|

3
P – 570 active ingredient kg/ha
K – 550 active ingredient kg/ha

| 75% of minimum water capacity | Volgodonets | 69.43 | 69.72 | 75.97 | 69.81 | 87.31 |
|------------------------------|-------------|-------|-------|-------|-------|-------|
| P – 305 active ingredient kg/ha | Pandero F₁ | 87.11 | 105.61 | 99.72 | 103.11 | 106.79 |
| K – 550 active ingredient kg/ha | Benefit F₁ | 104.21 | 118.32 | 121.48 | 130.17 | 138.19 |
| | Valero F₁ | 104.41 | 98.79 | 108.97 | 101.21 | 109.13 |

| 70% of minimum water capacity | Volgodonets | 66.31 | 68.79 | 74.53 | 64.03 | 66.71 |
|------------------------------|-------------|-------|-------|-------|-------|-------|
| P – 305 active ingredient kg/ha | Pandero F₁ | 84.41 | 103.27 | 87.81 | 101.89 | 108.12 |
| K – 550 active ingredient kg/ha | Benefit F₁ | 99.12 | 111.75 | 117.97 | 124.91 | 131.85 |
| | Valero F₁ | 97.49 | 93.31 | 101.27 | 97.82 | 101.49 |

| 70% of minimum water capacity | Volgodonets | 97.81 | 99.32 | 90.73 | 100.02 | 102.97 |
|------------------------------|-------------|-------|-------|-------|-------|-------|
| P – 570 active ingredient kg/ha | Pandero F₁ | 570 active | 570 active | 570 active | 285 active | 305 active |
| K – 550 active ingredient kg/ha | Benefit F₁ | 550 active | 285 active | 305 active | 550 active | 550 active |
| | Valero F₁ | 550 active | 285 active | 305 active | 550 active | 550 active |
| | Manas F₁ | 550 active | 285 active | 305 active | 550 active | 550 active |

| HCP<sub>0.5</sub> on variants | 4.66 | 4.31 | 4.98 | 5.03 | 5.34 |

**Table 2** - Spatial variation of the irrigated soils properties by drip irrigation in the north of the Astrakhan region and the south of the Volgograd region (layer 0.00 ... 0.25 m, average annual sample 2016 ... 2020).

| № | Indicator | Astrakhan region | Volgograd region |
|---|-----------|------------------|------------------|
| 1 | Medium and fine dust, % | 18.1…24.3 | 21.1…24.8 |
| 2 | Silt, % | 19.7…25.3 | 12.9…27.8 |
| 3 | Density, g/sm³ | 1.42…1.48 | 1.30…1.41 |
| 4 | Humus, % | 1.21…1.27 | 1.82…1.97 |
| 5 | pH | 7.82…8.40 | 7.62…8.12 |
| 6 | Exchangeable cations, milligram-equivalent /100g | 15.33…17.67 | 16.49…24.70 |
| | Ca<sup>2+</sup> | 11.20…12.00 | 10.45…17.05 |
| | Mg<sup>2+</sup> | 3.42…4.81 | 5.09…6.25 |
| | Na<sup>+</sup> | 0.32…0.39 | 0.41…0.61 |
| | K<sup>+</sup> | 0.39…0.47 | 0.54…0.79 |
| 7 | Easily soluble salts, milligram-equivalent /100g | 1.640…2.146 | 1.852…3.081 |
| | HCO₃⁻ | 0.550…0.670 | 0.610…0.720 |
| | Cl⁻ | 0.150…0.260 | 0.250…0.420 |
| | SO₄²⁻ | 0.046…0.369 | 0.070…0.610 |
| | Ca<sup>2+</sup> | 0.250…0.350 | 0.280…0.370 |
| | Mg<sup>2+</sup> | 0.250…0.375 | 0.125…0.250 |
| | Na<sup>+</sup> | 0.297…0.328 | 0.420…0.590 |
| | K<sup>+</sup> | 0.024…0.066 | 0.036…0.042 |
| 8 | Total salts, % at average, % | 0.073…0.078 | 0.061…0.079 | 0.0755 | 0.0700 |
| 9 | P<sub>2</sub>O₅, according to Machigin, mg/100g | 3.81…4.75 | 4.55…10.37 |
| 10 | K₂O, according to Machigin, mg/100g | 24.62…28.53 | 32.27…39.45 |
In the Volgograd region, fertilization [2] is carried out according to the different strategy. So, for the harvest of the current year, a complex fertilizer is applied [3] and much more attention is paid to the application of phosphorus and potassium than to the application of nitrogen, while phosphorus and potassium are not added to the vegetative dressing at all. In terms of weight, it is as follows: in autumn - N₁₂₀P₃₇₀K₅₇₀, while the fertilizer is applied superficially with a fertilizer spreader, followed by application of a disc header. Thus, in total, N₁₂₀P₃₇₀K₅₇₀ was applied per hectare to the experimental plots in the Volgograd region. That is, the farmers on the Ergeninskaya Upland, and accordingly, in our experiments, paid more attention to arable land saturation with phosphorus and potassium, and to a less extent - with nitrogen. At the same time, in the Pricaspian lowland conditions, another strategy is used, more and primary attention is paid to nitrogen; phosphorus and potassium are paid although less attention but quite sufficient for the formation of significantly higher onion hybrids yields. Note that for five years of observations (2016-2020) in the Astrakhan region, Pandero F1 hybrid gave an average yield of 139.07 t/ha, Benefit F1 - 150.16 t/ha, Valero F1 - 123.73 t/ha, Manas F1 - 133.76 t/ha. In the Volgograd region, the same hybrids gave 103.10 t/ha; 129.57 t/ha; 111.06 t/ha; 104.09 t/ha, respectively [4].

**Table 3 - Onion biochemical compound (average annual sample 2016 ... 2020).**

| №  | Biological compound                  | Unit of measure | Standard | Astrakhan region | Actual content | Volgograd region |
|----|-------------------------------------|-----------------|----------|------------------|----------------|------------------|
| 1  | Energy (kJ)                         | kJ in 100 g;   | -        | 180...190        | 175...180       |                  |
|    | Sugar                               | %               | -        | 4.5...11.7       | 4.2...4.5       |                  |
| 2  | Protein                             | g/100g          | -        | 0.70...0.75      | 0.55...0.60     |                  |
| 3  | Carbohydrates                       | g/100g          | -        | 9.5...10.0       | 9.6...11.0      |                  |
| 4  | Dry matter                          | g/100g          | -        | 9.5...10±1.4     | 8.5...9.0±1.1   |                  |
| 5  | Organic acids                       | g/100g          | -        | 0.10...0.11      | 0.11...0.12     |                  |
| 6  | Ascorbic acid                       | mg/100g         | -        | 11.410...11.575  | 9.642...9.831   |                  |
| 7  | Allicin essential oil               | mg/100g         | -        | 200...250        | 210...275       |                  |
| 8  | Cellulose                           | %               | -        | 9.5...9.7±1.4    | 8.1...8.3±1.3   |                  |
| 9  | Phosphorus                          | %               | -        | 0.010±0.012      | 0.009±0.011     |                  |
| 10 | Potassium                           | %               | -        | 0.12±0.14±0.03   | 0.12±0.15±0.03  |                  |
| 11 | Sulfur                              | %               | -        | 0.067±0.071      | 0.064±0.068     |                  |
| 12 | Calcium                             | %               | -        | 0.023±0.025      | 0.024±0.026     |                  |
| 13 | Iron                                | mg/kg           | -        | 6.86...6.91      | 7.25...7.31     |                  |
| 14 | Zink                                | mg/kg           | -        | 1.42±1.47±0.25   | 1.25±1.27±0.26  |                  |
| 15 | Mercury                             | mg/kg           | 0.02     | 0.002±0.003      | 0.001±0.002     |                  |
| 16 | Arsenic                             | mg/kg           | 0.2      | 0.015±0.016      | 0.011±0.013     |                  |
| 17 | Nitrates                            | mg/kg           | 80       | 39...76          | 21...38         |                  |
| 18 | Dichlorodiphenyltrichloroethane     | mg/kg           | 0.1      | 0.021±0.023      | 0.007±0.009     |                  |
| 19 | Hexachlorocyclohexane               | mg/kg           | 0.5      | 0.003±0.004      | 0.002±0.003     |                  |
| 20 | Cadmium                             | mg/kg           | 0.03     | 0.019±0.021      | 0.016±0.019     |                  |
| 21 | Specific activity of cesium-137     | bq/kg           | More than 0.85...0.88±3.17 | Less than 4.14...3.24±3.05 |
| 22 | Specific activity of strontium-90   | bq/kg           | More than 1.69...1.73±7.08 | Less than 0.48...0.50±1.30 |
| 23 | Salmonella bacteria                 | -               | Not allowed | Not found in 25 g | Not found in 25 g |
Over the past five years, the Volgodonets variety did not have a significant increase in yield over the years of research, nevertheless in the Volgograd region its yield was 74.00 t/ha, and in the Astrakhan region - 69.35 t/ha. Apparently, the Volgodonets variety manifested its highest productivity indicators, corresponding to its biological capabilities.

Intensive land use under the conditions of onion actually industrial production [5-8] significantly affected practically all indicators characterizing the soils properties in irrigated vegetable crop rotations. Medium and fine dust in the soil complex composition in the Astrakhan region contains 18.1 ... 24.3%, and in the Volgograd one this indicator is slightly higher - 21.1 ... 24.8%; silt - 19.7 ... 25.3% versus 12.9 ... 27.8%, that is, in fact, the content of silt on chestnut soils has a greater variation than on light chestnut soils. The Pricaspian lowland light chestnut soils have higher density values - 1.42 ... 1.48 g/cm³ than the Ergeninskaya Upland chestnut soils - 1.30 ... 1.41 g/cm³, but the light chestnut soils contain significantly less humus 1.21 ... 1.27% compared to chestnut 1.82 ... 1.97%. At the same time, the alkalinity (pH) in light chestnut soils is slightly higher than 7.82 ... 8.40 than in chestnut soils - 7.62 ... 8.12; exchangeable cations in light chestnut soils are below 15.33 ... 17.67 mg.eq/100g, than in chestnut soils - 16.49 ... 24.70 mg.eq/100g. This is natural for Ca, Mg, Na, K. The content of easily soluble salts in light chestnut soils is also noticeably lower - 1.640 ... 2.146 mg.eq/100g, on chestnut soils - 1.852 ... 3.081mg.eq/100g. Labile phosphorus and labile potassium on light chestnut soils are significantly lower than on chestnut soils. Over the entire period of the research, the complex of agrotechnical measures provided indicators for the onion biochemical compound. It should be noted that the difference in technologies, namely water and mineral nutrition, significantly affected the quantitative data of the biochemical compound. Thus, samples of onions in the Astrakhan region have significantly more sugar content 4.5 ... 11.7% (Table 3) than in the Volgograd region - 4.2 ... 4.5%, which means they have more energy - 180 ... 190 kJ per 100g and 175 ... 180kJ per 100g, respectively. Indicators for the content of carbohydrates, dry matter, organic acids and proteins practically do not differ. The content of ascorbic acid in the Astrakhan samples is noticeably higher than 11.410 ... 11.575 mg/100g than in the Volgograd samples - 9.642 ... 9.831 mg/100g. At the same time, the content of the allicin essential oil in the Volgograd samples is higher than 210 ... 275 mg/100g, than in the Astrakhan samples - 200 ... 250 mg/100g, it is believed that this is due to the lower vegetation norm of irrigation. The fiber in the Astrakhan onion samples is noticeably higher than 9.5 ... 9.7 ± 1.4%, compared to the Volgograd samples - 8.1 ... 8.3 ± 1.3%. A further increase in the efficiency of onion production is possible only with the implementation of a scientific and production hypothesis, which is the harmonious fusion of the most traditional technologies important components were developed on the light chestnut soils of the Pricaspian lowland and on the chestnut soils of the Ergeninskaya Upland. That is, it is necessary to include the best aspects in one technological process that ensure then increase in yields, both in the Pricaspian and Ergeni regions.

4. Conclusion

The carried out research allows to recommend the production to include in the technological processes the soil basic preparation, namely autumn plowing, to plow not to 0.22 ... 0.25 m by a conventional plow, but to plow without soil overturning by the Paraplau unit to the depth of 0.42 ... 0.45 m. The authors offer to leave sowing by eight-row seeders and to change to sowing by a twelve-row seeder. Taken in totality, this not only optimizes the feeding area of each onion plant, but also increases the volume of soil mass involved in the formation of the crop. The Pricaspian onion growers need to increase the doses of phosphorus and potassium fertilizers. The implementation of the proposed scientific and production hypothesis in practice, in our opinion, will give a significant increase in the yield of onion, which will undoubtedly have a positive influence on this production economic indicators.

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