Optimization of the elements of onion production technology in an annual crop in the conditions of central Russia

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Abstract. The object of research is onion, cultivated as an annual crop in the Nonchernozem zone of the Russian Federation. The aim of the research is to develop an improved technology for the production of bulb in an annual crop, providing a yield of 70-80 t/ha on alluvial meadow soils of the Nonchernozem zone. Research method - field test. It has been established that the probability of performing each technological operation should be at least 95%. Sowing the seeds, which are previously cleansed from the rot, must be done at an earlier date. The required yield was achieved at $N_{200} P_{160} K_{280}$ + Humic chemical "Rostok" + 10 l/ha BisolbiSan, Azotovit, Phosphatovit biopreparations in equal proportions. The use of the microbiological preparation BisolbiSan in 1% concentration with chemical two-component fungicides (excluding copper-containing ones) increases the immunity of onion plants. In conditions of warm, humid summer, fungicidal treatments of onions are optimal at intervals of 7-10 days from the third decade of June to the end of July. The maximum weed suppression is provided by the post-sowing application of the Stomp Professional + Dual Gold tank mix (3 + 1 l/ha) in combination with the subsequent pre-emergence treatment with Reglon Forte (2 l/ha) and the post-emergence Goal 2E (0.5 l/ha).

1 Introduction

Increasing the production of onions by increasing yields [1-6] is seen as the main way for further development.

The production of bulbs, especially in the Central, North-West, and other regions of Russia similar in latitude, with the sum of active (more than 10 ^{0} C) average daily temperatures of 2000-2200 ^{o} C for the growing season, has its own special specifics.

Abundant cold night dews in late July - early August create favorable conditions for the spread of fungal diseases [7 - 8], especially false mildew.

The emergence of new varieties and hybrids resistant to fungal diseases. as well as new means of protecting plants [9 - 13], made it possible to obtain guaranteed yields.

The vegetation period of annual intensive varieties and hybrids is 100-110 days in the

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conditions of the Nonchernozem zone.

It has been established that the use of drip irrigation on onions [14 - 15] is economically feasible with an increase in yield by 12.0 t/ha. Usually this increase is greater.

To achieve a yield of 70 - 80 t/ha, it was necessary to optimize the constituent elements of the technology:

1. Weed control [16] in the previous field of crop rotation makes it possible to destroy resistant and partially resistant weeds (common ragwort, upturned amaranth, field bindweed, thistle of all kinds, etc.) to the soil herbicide Stomp applied after sowing. Introduction of herbicide of continuous action on the basis of active ingredient Glyphosate is recommended to be carried out in the fall after harvesting the previous crop and the growth of 2-3 leaves of perennial weeds. However, according to our observations, some weeds are partially resistant to this herbicide. Further study of this perennial and overwintering weed control operation was required.

2. Preparation of seeds for sowing [17] by incrustation with fungicides Tiram, Maxim et al., at the same time, we have established [18] a positive effect from the use of biological preparations for

pre-sowing preparation of seeds.

Studies of previous years established [19 - 23] the optimal depth of sowing seeds (~ 2.5 cm) and a sowing scheme (4 or 3 strips 6–9 cm wide with a density of 600–900 thousand plants per hectare).

A density of 600.0 thousand plants per hectare is preferable, since it provides higher product standard.

The operations that affect field germination are as follows: pre-sowing seed treatment, soil preparation methods, sowing process, and pre-emergence irrigation.

3. Application of mineral fertilizers - quantity, timing and methods. The largest yield of bulbs was obtained with applying azofoska $N_{120} P_{120} K_{120}$ for spring milling against the background of green manure (mustard).

Modern varieties and hybrids of onion with a yield of 70 t/ha carry out, on average, according to [24], kg/ha: nitrogen - 196.0; phosphorus - 105.0; potassium - 280.0. Such a significant removal can be compensated only with mineral fertilizers.

Application of significant doses of mineral fertilizers causes a decrease in the microbiological activity of the soil [25]. This does not contribute to a high yield.

The issue of timing and methods of fertilizing was not clear [26]. Spring application with subsequent milling provides embedding to a depth of no more than 8 - 10 centimeters. A high concentration of fertilizers at the same time inhibits the emergence and development of plants. Spring plowing leads to a significant loss of moisture. Here further research was needed.

4. Increasing the resistance of onions to pests and diseases. In recent years, quite effective methods of control have been found [27] through the use of rhizospheric associative bacteria and two-component pesticides of a new generation. It should be noted that these solutions had to be tested in onion culture.

5. Weed control [28] during the growing season is the most acute unresolved issue in technology. It provides for the pre-emergence application of Stomp Professional, followed by Goal 2E during the growing season in phase 2 - 3 leaves of onions. However, in the vegetable crop rotation there are a number of weeds that are resistant or partially resistant to the herbicide Stomp (common ragwort, upturned amaranth, field bindweed, sow thistle of all kinds, etc.). By the time Goal herbicide is applied, they are in the multi-leaf phase and tolerate its effects.

6. Root top dressing with mineral fertilizers [29 - 30] for vegetative plants together with rhizospheric associative bacteria of Extrasol preparations (strain *Bacillus subtilis Ch-13*), Azotovite (strain *Azotobakter chroococcum), and Phosphatovit (*strain *Bacillus mucilagi-*

nosus). At the same time, the yield increase relative to the control reached 20% and provided good onion resistance to false mildew.

Previously, we obtained [31] good results with a yield of up to 70.0 t/ha of onion and good resistance to false mildew with a total application rate of biological preparations of 20.0 l/ha in three repetitions together with fertilizers. It was necessary to conduct research on optimizing the norms and frequency of these top dressings.

7. The fight against false mildew in the Nonchernozem zone determines the size and quality of the onion crop. According to the recommendations of the developers [32], BisolbiSan (strain *Bacillus subtilis Ch-13*).

Good results are shown by the chemicals fungicides Ridomil Gold and analogues, as well as Revus Top (not registered on the onion).

Relevant are studies on optimizing the frequency of application of drugs in the intervals of 7-10 and 10-14 days.

The aim of the research was to improve the elements of the technology for the production of onion in an annual crop that provides a yield of 70–80 t/ha on alluvial meadow soils of the Nonchernozem zones of Russia.

2 Materials and methods

Due to the purpose of the research, the tasks were formulated and the following field experiments were set in a three-year cycle:

Experiment 1. The study of field germination in the treatment of seeds of onion with biological preparations BisolbiSan, Bisolbifit (strain *Bacillus subtilis Ch-13);* Azotovite (strain *Azotobacter chroococcus)*; Phosphatovit (strain *Bacillus mucilaginosus).* For the preparation of one kilogram of seeds a week before sowing, it was spent: Potassium lignohumate brand BM, containing salts of humic substances up to 18% - 2 ml. Distilled water - 20 ml. Bisolbisan - 6 ml. Bisolbifit - 6 gr. Azotovit - 6 ml. Phosphatovit - 6 ml.

After thorough mixing, the seeds were dried in an air stream at 35.0 ° C for 4 hours until a free flowing state.

Experiment 2. Optimization of the rates and terms of application of a mixture of associative rhizosphere bacteria of preparations BisolbiSan, Azotovit, Phosphatovit through drip irrigation in equal proportions with rates, l/ha: 10.0; 20.0; 30.0; 40.0 with 1% humic preparation "Rostok" (20.0 l/ha).

Bacterial preparations were introduced through drip irrigation in a mixture of 10.0 liters at a time with an interval of 10 days according to the options.

Experiment 3. Study of the effect of the use of fungicides Ridomil Gold and Metaxil together with the preparation BisolbiSan at 1% concentration on the spread of false mildew on onions.

Experiment 4. Determination of the most effective frequency of applying fungicides on onions from false mildew with an interval of 7 - 10 and 10 - 14 days.

Experiment 5. Evaluation of the effectiveness of the system for applying the system of herbicides on crops of onion.

The control variant in each experiment included similar technological operations with the experimental one, with the exception of the studied parameter (zero variant).

The soil of the site is alluvial meadow medium loamy. The humus content in the 0-20 cm layer is 3.0-3.2%. Salt extract pH 5.3-6.0. The content of the sum of absorbed bases is 45.0 mg. per 100 grams of soil in a layer of 0-20 cm. The content of P_2O_5 in a layer of 0-20 cm is 22.0 mg per 100 grams of soil (according to Chirikov), potassium -15.2 mg (according to Maslova), total nitrogen - 6.0 mg.

Under the experiments, azophoska $N_{160}P_{160}K_{160}$ was introduced according to [25] for processing with a vertically milling cultivator.

Sowing was carried out in the third decade of April with a Gaspardo Olimpia seeder according to the scheme 32+7+28+7+28+7+32. The estimated standing density is 650.0-700.0 thousand plants per hectare. The onion variety Forward (VNIIO, Poisk Agricultural Company) was used in the experiments.

All experiments were carried out in quadruple repetition. The size of the accounting plots in the experiments is 12 m ^{2}. The location of plots is systematic according to [33].

Climatic conditions during the growing season were characterized by an increased temperature background. Thus, the excess of the long-term average daily temperature was: 2019 - 2.8 ^{0}C; 2020 - 2.7 ^{0}C; 2021 - 3.3 ^{0}C.

At the same time, there was extremely erratic rainfall. So, 2019 - the lack of precipitation from April 25 to May 5 did not allow to get friendly seedlings, and massive ones (75%) appeared only on May 21. 2020 - abundant precipitation exceeding the long-term average in May (185.2%) and June (150.2) ensured good development of plants and downy mildew on onions. 2021 - The lack of moisture in June-July caused the absence of fungal diseases, and the excess of rainfall in September (159.3% of the long-term average) impaired harvesting

3 Results and discussions

Experiment 1. Pre-sowing treatment of seeds. Sowing (May 15, 2019) of seeds treated with biological preparations at average daily temperatures of 15–20 ^{0} C and sufficient humidity (80% HB) provided earlier shoots (May 29), which was 3 days ahead of the control (June 2).

Under the conditions of 2020, when sowing on April 24 and heavy rainfall after sowing, mass shoots of treated seeds took place on May 11–13, and untreated seeds on May 10–12. That is, the difference is not significant.

In 2021, the sowing was done on April 20. There was a subsequent prolonged cooling down to +5 ^{0} C with heavy rainfall. The appearance of mass seedlings was recorded on May 17 in both variants. The difference took place in plant density, thousand/ha: 620.0 and 587.0 - control. The difference of plants 33.0 thousand/ha with NSR $_{05}$ = 30.0 thousand/ha is significant. Field germination was 72.5% and 68.7%, respectively

Thus, seed treatment with biological preparations leads to an acceleration of germination by 3 days at average daily temperatures of 15–20 ^{0} C. At temperatures of 0–(+5) ^{0} C, seed treatment provides an increase in field germination by 5–6%.

The event space **S** is made up of all sown seeds of cultivated plants located in the field with certain actual environmental parameters. After the emergence of seedlings, which appear with probability **P(A)** from the sown seeds, we get a narrowing of the event space $\mathbf{S_1 = S \times P(A)}$ Mathematically, the number of standard plants at the time of harvest can be written as follows:

$$\mathbf{S \times P(A) \times P(A_1) \times P(A_2) \times P(A_3) \times P(A_k) = S_k} \tag{1}$$

The optimal result is possible only when each factor is equal to one. In reality, each of the operations is performed by the farmer with a certain probability of "success ". For greater clarity of further reasoning, let's expand Figure 1 in time:

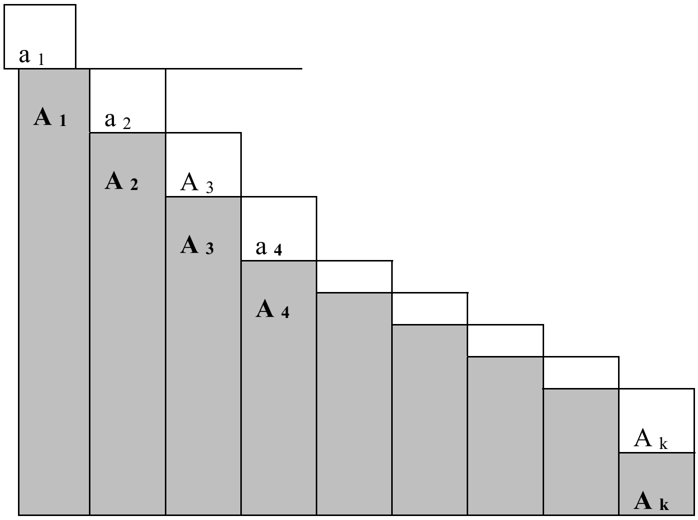

Fig. 1. Probabilistic model of crop technology, deployed in time: $\bar{A}_1$, $\bar{A}_2$, $\bar{A}_3$ ……..$\bar{A}_k$ - events of "failure" in the technological operation; $\mathbf{A_1, A_2, A_3, \ldots\ldots A_k}$ - events of "success"

We accept as a postulate that the probability of obtaining an optimal yield should be at least 50%, then formula (1) implies:

$$\mathbf{P(A) \times P(A_1) \times P(A_2) \times P(A_3) \times \ldots \times P(A_k) \geq 0{,}5}$$

We assume that when designing machines, you can lay:

$$\mathbf{P(A) = P(A_1) = P(A_2) = P(A_3) = \ldots = P(A_k)}$$

Then, from the calculation of **k** = 13 operations, we obtain $\mathbf{P(A_k) \geq 0{,}95}$

Thus, the probability of performing the optimal parameters of each technological operation should exceed 95%. Earlier in previous years, we managed to bring the field germination rate up to 80%.

Experiment 2. Study of the norms and terms of the introduction of biological products. In the course of testing in 2019-20, the application rate of drugs was 60.0; 70.0; 80.0; 90.0 l/ha did not show a significant difference in yield (49.0 - 52.0 t/ha) and the quality of the product.

It should be noted the highest content of dry matter (9.6%) and total sugars (7.37%) at a rate of biological products of 60.0 l/ha.

The results of the 2021 studies are shown in Table 1.

Table 1. Results of the field experience on optimizing the timing and rates of application of biological products in 2021. (onion Forward).

No. In order	Indicators	Control	Var 0 (only humates)	Var. 1 (Humates+10.0 l/ha bio)	Var. 2 (Humates+20 l/ha bio)	Var. 2 (Humates+ 30 l/ha bio)	Var. 2 (Humates+ 40 l/ha bio)
1	Productivity, t/ha	78.05	74.7	73.8	70.0	69.5	69.8
2	The coefficient of variation, %	11.5	6.2	4.4	4.7	5.9	7.2
3	Bulb weight, g	136.0	129.8	128.2	118.1	122.5	115.9
4	Number of	5.2	9.3	5.7	6.8	8.3	8.2

	non-standard bulbs, %						
5	Standing density, thousand pcs/ha	610.0	623.0	605.0	628.0	605.0	645.0
6	Bacteriosis, % by quantity / by mass	-	-	-	0.8/4.8	0.8/3.4	0.4/1.3
7	NSR $_{05}$ in terms of yield, t/ha	5.02					

The study of the application rates of biological products from zero to 40.0 l/ha led to the defeat of onions with bacteriosis at rates of 20.0 l/ha and more with a yield of 70.0 - 80.0 t/ha. The maximum yield was obtained on significantly indifferent variants: Control ($N_{200} P_{160} K_{280}$); Option 0 (Control + Humic preparation "Rostok"); Option 1 (Option 0 + 10 l/ha of biological products). At the same time, options 0 and 1 are the most balanced due to the highest content of vitamin C (6.0 - 6.5 mg%). The actual removal of mineral elements for the actual yield was $N_{110} P_{61} K_{135}$.

Thus, the yield of 70.0 - 80.0 t/ha is provided by mineral nutrition options with the humic preparation "Rostok" (20.0 l/ha) and biological products with a total norm of not more than 10.0 l/ha.

Experiment 3. Study of the effect of fungicides together with the drug BisolbiSan at 1% concentration on the spread of false mildew on onions.

2019 year. A combination of preparations Ridomil Gold - 2.5 kg/ha (2 treatments) + Thanos - 0.6 kg/ha (2 treatments) + Revus Top - 0.6 l/ha (1 treatment) was tested. The disease was recorded on July 20. The copper-containing drug Thanos is not effective enough in the fight against false mildew and does not completely prevent the disease of onion plants.

2020 Treatment intervals were maintained within 10-14 days. The preparations Ridomil Gold, Metaxil, Rapid Mix, Consento, Revus Top were tested according to the recommendations of the manufacturers.

The first diseased plants were recorded on July 24 in the variant without BisolbiSan.

Plant disease in the variant with BisolbiSan was recorded on July 28.

2021 Plant protection system against false mildew included Ridomil Gold - 2.5 l/ha (3 treatments) + Revus Top - 0.6 l/ha (3 treatments). However, in the conditions of the summer of 2021 with a hot dry July, false mildew was completely absent even in the control.

Thus, copper-containing preparations are not effective enough in the fight against false mildew. There is an increase in plant immunity with the use of BisolbiSan preparation (strain *Bacillus subtilis Ch-13*) in 1% concentration of the working solution together with chemical fungicides.

Experiment 4. Determination of the most effective frequency of fungicide application.

The first signs of false mildew on perennial bows in the Moscow region appear, as a rule, in the 20th of June. The deadline for protection is two weeks before harvesting - August 15th. Thus, the period of protection against false mildew is 50 days.

It should be noted that even in the recommendations of manufacturers, the interval of application of fungicides is very extended (usually 7-14 days) and does not give a clear guarantee of preventing the disease. In the case of a seven-day interval, we have 7 culture treatments, and a 14-day interval has 4 treatments. The experiments of 2019-2021 provided for intervals of 7-10 and 10-14 days.

Due to the warm June-July 2020 with heavy rainfall, epiphytoty took place on the crop with treatment intervals of 10-14 days. The variant with 7-10 day treatments ensured the absence of fungal diseases and the yield of 75.6 t/ha; with 10 - 14 day old - 47.0 t/ha, which was the result of fungal diseases.

Thus, it should be recognized that fungicide treatments with an interval of 7-10 days are optimal in hot, humid weather.

Experiment 5. Efficiency of the herbicide system application. After the autumn treatment of Glyphosate, a noticeable effect on weeds was observed through the suspension of their growth. Yellowing of the leaves was noted on the 3rd - 4th day, and complete drying of the aerial part of the weeds - after 3 - 4 weeks. Subsequently, 96 - 99% death of annual dicotyledonous weeds and 89 - 94% of field sow thistle were noted. Of the annual dicotyledonous weeds, the most resistant to the herbicide was the small-flowered galinsoga in the flowering phase.

The results of the experiments in 2021 are shown in Table 2.

Table 2. The effectiveness of the use of herbicide systems on crops of onion varieties Forward in 2021 against the background of the autumn application of Glyphosate 2,5 l/ha.

Option (sequence of application of herbicides)	Herbicide rate, l/ha	Decrease in weediness, % to control					
		May 27		July 7		August 21	
		quantities	masses	quantities	masses	quantities	masses
1. Gaitan - Reglon Forte - Goal 2E	4.5 - 2.0 - 0.5	86	89	74	86	55	66
2. Gaitan + Dual Gold - Reglon Forte - Goal 2E	3+1 - 2.0 - 0.5	93	95	89	93	63	77
3. Stomp Professional+Dual Gold - Reglon Forte - Goal 2E	2.0+1.0 – 2.0 – 0.5	97	99	93	95	79	87
4. Stomp Professional - Goal 2E (reference)	3.0 - 0.5	72	76	63	72	36	75
5.Control (3 manual weeding)*		(29)	(13)	(27)	(124)	(14)	(149)

* the control shows the number and weight of weeds in pcs/m ^{2} and g/m ^{2}

In spring, due to the high efficiency of autumn treatment and spring soil herbicides and pre-emergence - Reglon Forte, in the phase of the 1st true leaf, onions had 1-4 specimens per square meter of weeds and only one post-emergence spraying of Goal 2E had to be carried out at a rate of 0,5 l / ha in the phase of 2 true leaves in onions.

The highest weed suppression (93 - 97%) during 2 months of onion vegetation with a decrease in their biomass by 94% was achieved by using the tank mix Stomp Professional + Dual Gold (3+ 1 l/ha) in combination with successive treatments of Reglon Forte 2.0 l/ha and Goal 2E 0.5 l/ha. Pre-emergence application of the tank mixture Gaitan + Dual Gold (3+1 l/ha) in combination with Reglon Forte 2.0 l/ha and Goal 2E 2.0 l/ha reduced the infestation of crops by the time of the first - second weeding, respectively, by 93 - 89 % and by 95 - 93% in terms of the number and weight of weeds. At the same time, the common ragwort also completely died. It should be noted that by harvesting in this variant, onion crops were more clogged with small-flowered galinsoga.

Less effective was the system of applying pre- and post-emergence application of Reglon Forte 2.0 l/ha and Goal 2E 0.5 l/ha against the background of pre-emergence application of Gaitan 4.5 l/ha, which suppressed 74-86% of annual dicotyledonous weeds before the first and second weedings, with a decrease in their mass by 86 - 89%, which was inferior to the standard.

Thus, the system of pre-emergence application of the tank mixture Stomp Professional + Dual Gold (3+1 l/ha) on onions in combination with subsequent treatments: pre-emergence - Reglon Forte 2.0 l/ha and post-emergence - Goal 2E 0.5 l/ha , ensured the maximum suppression of weeds (by 93 - 97%), with a decrease in their mass by 95 - 99% and a significant increase in the yield of bulbs - 6.7 t/ha.

4 Conclusions

1. The probability of performing the optimal parameters of each technological operation should exceed 95%.
2. Seed treatment with biological preparations leads to an acceleration of germination by 3 days at average daily temperatures of 15–20 ^{0} C. At temperatures of 0 – +5 ^{0} C, seed treatment provides an increase in field germination by 5–6%.
3. The yield of 70.0 - 80.0 t/ha is provided by mineral nutrition options with the humic preparation "Rostok" (20.0 l/ha) and biological products associative rhizosphere bacteria with a total norm of not more than 10.0 l/ha.
4. Copper-containing preparations are not effective enough in the fight against false mildew. There is an increase in plant immunity with the use of BisolbiSan preparation (strain *Bacillus subtilis Ch-13*) in 1% concentration of the working solution together with chemical fungicides.
5. Fungicide treatments at intervals of 7 to 10 days are optimal in hot, humid weather.
6. The system of pre-emergence application of the tank mixture Stomp Professional + Dual Gold (3+1 l/ha) on onions in combination with subsequent treatments: pre-emergence - Reglon Forte 2.0 l/ha and post-emergence - Goal 2E 0.5 l/ha, provided the maximum suppression of weeds (by 93 - 97%), with a decrease in their mass by 95 - 99% and obtaining a significant increase in the yield of bulbs - 6.7 t / ha.

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