Agrochemical rationale for catholyte application in foliar fertilizing for winter wheat plants

E A Aleksandrova, B L Aleksandrova, G A Shramko, Z T Khadisova, Kh Kh Akhmadova, Kh S Muzakaeva, M A Takaeva and M A Musaeva

1 Kuban State Agrarian University, Krasnodar, Russia
2 Grozny State Oil Technical University named after academician M D Millionshchikov, Grozny, Russia
3 Chechen State University, Medical Institute, Grozny, Russia

E-mail: alex2e@yandex.ru, sramko@list.ru, muzakaeva@mail.ru, karin-lada@mail.ru, milanama@mail.ru

Abstract. This paper introduces a new method of foliar fertilizing for winter wheat plants with electrochemically activated water – catholyte as a component of fertilizer solvent. The authors specified most effective 20 % concentration of catholyte recommended for foliar fertilizing for winter wheat plants in tillering phase in spring. It is shown that the yield of winter wheat of “Delta” variety due to multicomponent complex fertilizer (MCF) increased by 19.2 % (control 5.34 t/ha) and “Tanya” variety with FlorGumat Fertilizer of natural origin – by 8.7 % (control – 4.7 t/ha) while ensuring the food grain quality of the 4th class.

1. Introduction
Wheat has played an important food role on the planet and it has been one of the most common cereal crops for many centuries. At the same time, the main task of agro-industrial complex is to increase agricultural production profitability of winter wheat [1-4]. One of the most rational ways to solve this issue is to develop environmentally friendly, energy-saving technologies for its production. There are works on positive effect of electrochemically activated water (ECAW) on wheat seeds processing [5], as well as on possibility of its application in crop production and livestock [6-8]. However, until now, in the literature, almost no experimental data are available on the use of ECAW, specifically electrochemically activated water – catholyte (ECAW-C), in foliar fertilizing for wheat plants. Electrochemically activated (ECA) electrolysis water is obtained from weakly mineralized tap water in a diaphragm electrolyzer: anode has anolyte ECAW-A (pH < 7, oxidation reduction potential ORP > 0), cathode has catholyte ECAW-C (pH > 7, ORP < 0) [8].

Foliar fertilizing is deservedly considered a method of operational impact on the processes that determine the yield and its quality [9–13]. The main advantage of non-root fertilizing is the speed of their entry to the vegetative organs and better assimilation of nutrients by the plant.

Further application of ECAW in agriculture, namely in foliar fertilizing of winter wheat plants, requires agrochemical justification of its biological activity, environmental safety and economic efficiency. In this regard, purpose of this work is to research and develop elements of environmentally safe technology for production of winter wheat using electrochemically activated water – catholyte (ECAW-K) for foliar fertilizing of its plants. Targeted studies of the effect of ECAW-C solutions with foliar fertilizing of winter wheat plants have not been carried out until now. We have carried out this work for the first time.
2. Methods and materials

Specific features of foliar fertilizing for plants. In context of plant nutrition physiology, the use of foliar feeding is justified by the fact that a single application of fertilizers to the soil in autumn or spring is unable to provide the plant with all the necessary nutrients in ratios necessary for it in different periods of vegetation [9]. Foliar fertilizing is based on the ability of plants to absorb nutrients from green leaves and stems. In combination with the main fertilizer, it makes it possible to obtain a significantly greater yield than when all fertilizers are applied to the soil at the same time, even in a large dose. Recently, non-root fertilizing of plants applied jointly with spraying to control pests and diseases has become widespread. Humates are one of the groups of fertilizers used in a foliar feeding, the active substance of which are potassium salts of humic acids. Their action is considered as regulatory [13]; they affect the synthesis of sugars, chlorophyll, protein and especially oxidative processes.

Studied varieties of winter wheat and methods of its research. The effect of ECAW-C in the composition of aqueous solutions of fertilizers on the growth, development and productivity of winter wheat was studied by us on two selection varieties of Krasnodar Research Institute named after P.P. Lukyanenko: Delta and Tanya. Delta variety was studied by us for two years, sunflower was the previous crop. Surface tillage consisted of three-fold shallow plowing with heavy disc harrows BDT-3 to a depth of 10–12 cm, followed by rolling ring-spur rollers ZKKSH-6A. Before sowing, there was cultivation to a depth of 5–6 cm with the unit DT-75 + KPS-4.2 + BZSS-1.0. After sowing, the soil was re-rolled. Surface tillage by shallow plowing in all experiments included fertilizers: ammonium nitrate (34 % N), ammophos (12 % N and 52 % P2O5) and potassium salt (44 % K2O) at a dose of N50P50K60. At the beginning of growing season, winter wheat crops were fed with ammonium nitrate at a dose of N60 kg/ha, total background of fertilizers was N120P60K60.

Field experiments on Tanya variety were also carried out for two years, soy was the previous crop. Surface tillage was applied. At the end of September, crop residues were crushed with the help of disk guns BDT-3 in two tracks to a depth of 8–10 cm. Surface tillage – before sowing, cultivation was carried out to a depth of 5–6 cm by unit DT-75M + KPS-4.2 + BZSS-1.0. Ammonium nitrate (34 % N), ammophos (12 % N and 52 % P2O5) and potassium salt (44 % K2O) were applied as fertilizers at the rate of N50P50K60. Before spring vegetation resumption, nitrogen fertilizer was introduced at a dose of N50, total amount of fertilization was N100P50K60.

Fertilizers for foliar feeding. For foliar feeding for winter wheat plants of Tanya variety, a fertilizer of natural origin FlorGumat (pH 9.46) was used, which contained, g/l: humic acids – 18.0; nitrogen – 2.0; phosphorus (P2O5) – 2.0; potassium (K2O) – 3.5; magnesium (MgO) – 0.5; sulfur (SO4) – 5.0; boron – 0.9; molybdenum – 0.3; manganese – 3.0; zinc – 2.0; copper – 1.2; cobalt – 0.2; iron – 0.8. In spring, for foliar fertilizing for wheat crops in tillering phase FlorGumat solution with a concentration of 5 g/l was used.

To form plant cells of any plant nutrient medium should provide it with all the elements needed to build these cells in the proportions observed in chemical composition of plants [20–23]. Wheat, like any other crop, has its own optimal, due to hereditary properties of chemical composition of grain. Therefore, the nutrient medium for foliar feeding of vegetating wheat plants should include all the elements that are part of its grain. In this regard, we have proposed a new optimal composition of multicomponent complex fertilizer (MCF) for Delta wheat [14]. The MCF developed by us included micronutrients: P, N, K, CA, Mg and micronutrient elements: Fe, B, Mn, Cu, Mo, Fe, Zn, Ni, I, Co, Al, Sn, Sr in specially selected concentrations taking into account the chemical composition of winter wheat grain [20–23]. When preparing a working solution of complex fertilizer MCF initial salts containing micronutrients P, N, K, CA, Mg, involved Ca(H2PO4)2, (NH4)2SO4, NH4NO3, K2SO4, Mg(NO3)2. Preparing the solution of these salts was carried out by the described method [16–17]. The salinity of the solution with micronutrients was 1.25 g/l (0.125 wt. %).

To identify the effect of foliar fertilizing on the productivity of winter wheat, field experiments were conducted on the experimental field of educational farm "Kuban", in the 11-field grain-tilled crop rotation: soybean – winter wheat – corn for grain – winter wheat – sunflower – winter wheat –
winter wheat – peas – winter wheat – sugar beet – winter wheat. We used three fields for the experiment with a difference in the alternation of cultures in one year. Agricultural technology of winter wheat cultivation recommended for conditions of the Central zone of Krasnodar territory was applied. The flow rate of aqueous solution of fertilizer was 200 l/ha.

Schemes of field experiments and research methods:

The scheme of experiment with MCF on Delta variety wheat included 3 variants of non-root plant treatment:

1. Control – treatment with tap water (TW).
2. MCF+ TW.
3. MCF+20 % solution of ECAW-C.

This field experiment studied the effectiveness of MCF application in foliar fertilizing for plants, as well as ECAW-C as a component of solvent of MCF. The experiments involved agricultural technology of winter wheat cultivation recommended for conditions of the central zone of Krasnodar territory, considering the previous culture (sunflower – on Delta variety and soy – on Tanya variety).

The scheme of experiment with FlorGumat on winter wheat of Tanya variety contained 6 variants with solutions of ECAW-C of different concentrations:

1. Control – tap water (TW).
2. ECAW-C100 %.
3. FlorGumat + TW.
4. FlorGumat + 5 % solution of ECAW-C (solution of FlorGumat prepared on a mixture of 5 % ECAW-C and 95 % of original TW).
5. FlorGumat + 20 % solution of ECAW-C.
6. FlorGumat + 50 % solution of ECAW-C.

During the experiments, winter wheat crops were treated in tillering phase in spring. Repeatability of experiments with MCF and with FlorGumat is four-fold, placement of plots is systematic. The total area of the plot is 30 m², testing area – 20 m². Seeding rate – 5 million germinating seeds per 1 hectare, sowing was carried out by "Gaspardo" drill to a depth of 5 cm in the first decade of October.

The plants were treated with a knapsack sprayer. Consumption of aqueous solution of ECAW-C with fertilizing 200 l/ha, concentration of MCF – 1.94 g/l, FlorGumat – 5 g/l. Harvesting of winter crops was conducted by "Sampo" direct combine harvester with grain moisture 13–15 %.

To register the effect of foliar fertilizer, plant samples were taken 5 days after treatment with aqueous solutions of MCF and FlorGumat. From the plot of each of the studied variants, we selected 15 plants, cutting the stem below the third leaf from the top, putting them in water to prevent wilting and delivering to the laboratory.

Registration and phenological observations in the experiments took place in accordance with the methodology of state variety testing of agricultural crops [15–17] and educational literature [18]. The following phases of vegetation were considered: germination, tillering, stem-extension, earing, milk ripeness, wax and full ripeness of grain.

The following indicators were studied: density of standing plants, height, number of stems; area of leaf surface; accumulation of raw and completely dry mass; photosynthetic potential (PP) of crops; crop structure. Research results were processed statistically according to prescription by B.A. Dospekhov [17]. All tabular and graphical data represent averages of 3-12 multiple repetitions of characteristic experience with an indication of error. Reliability of difference between the variants was viewed by the Student's test at the level of significance t 0.05 and least significant difference – LSD_{0.05}.

Characteristics and composition of ECAW-C. For experimental and industrial tests to prepare ECAW we used apparatus "Izumrud-SI" produced by JSC SIC "ICARUS". Potentiometric measurements of pH, ORP and AOA were carried out using universal pH meter Sartorius Professional Meter PP-25.

Chemical elemental composition of ECAW-C, obtained both in apparatus "Melesta-M" and "Izumrud-SI", studied by mass spectrometry with inductively coupled plasma (ICP-MS), showed that the content of heavy metals in ECAW-C is significantly lower than corresponding MPC values for
drinking water, domestic and household use. Biotesting method showed ecological safety of ECAW-C impact on living organisms and populations at the cellular level. We established environmentally safe concentrations of aqueous solution ECAW-C (less than 30 %) for multicellular and unicellular organisms. At the same time ORP of ECAW-C reaches 600 mV and pH 10.2 in the apparatus "Melesta-M"; for, ECAW-C is characterized by the greatest disequilibrium with more intense relaxation processes. Negative ORP values indicate the presence of electron donors in the aqueous medium and possibility of recovery processes. As a result of oxidation-reduction reactions (ORR) accompanying the process of water electrolysis, the content of dissolved O\(_2\) in ECAW-C decreases, giving way to H\(_2\); CO\(_2\) almost completely disappears; hardness and dry residue decrease, there are mainly alkaline metal cations Na\(^+\) and K\(^+\). As a result of recovery process: NO\(_3^-\) →NO\(_2^-\) →NH\(_4^+\) nitrate ions convert into the ammonium form.

Based on the identified features of ECAW, we have determined the following scientific prerequisites for the feasibility of using ECAW-C as a biologically active aqueous solvent: environmental safety; being in a metastable, energetically and chemically active state; pH > 7; ORP < 0, increased content of NH\(_4^+\), H\(_2\), reduced content of dissolved CO\(_2\).

3. Results
3.1. Impact of foliar feeding with ECAW-C on growth, development and physiological parameters of winter wheat plants

The study results of effect of foliar fertilizing MCF and FlorGumat prepared with ECAW-C on the height of winter wheat plants are shown in table 1.

Table 1. Dynamics of winter wheat plants height depending on foliar fertilizing application in aqueous solutions on ECAW-C of different concentrations, cm.

| Variant | Phase of vegetation | Delta variety in tillering phase (spring) 35.9 cm | Tanya variety in tillering phase (spring) (24.5 cm) |
|---------|---------------------|-----------------------------------------------|-----------------------------------------------|
|         | stem-extension      | earing                                       | milk ripeness                                 |
| 1. Control (TW) | 64.8               | 83.6                                         | 87.1                                         |
| 2. MCF+ TW       | 67.0               | 86.0                                         | 88.8                                         |
| 3. MCF+20 % solution of ECAW-C | 68.3 | 87.2                                         | 89.4                                         |
| LSD\(_a\)         | 2.04               | 1.63                                         | 1.07                                         |
| 4. FlorGumat + TW | 52.1               | 70.6                                         | 73.4                                         |
| 5. FlorGumat + 5 % solution of ECAW-C | 52.2 | 70.8                                         | 73.6                                         |
| 6. FlorGumat + 20 % solution of ECAW-C | 52.3 | 71.8                                         | 75.0                                         |
| LSD\(_a\)         | 53.5               | 72.6                                         | 75.3                                         |
|                      | 53.8               | 72.9                                         | 76.4                                         |
|                      | 52.9               | 71.4                                         | 74.5                                         |
|                      | 1.23               | 1.02                                         | 1.14                                         |

As can be seen in vegetation period for two wheat varieties irrespective of applied fertilizers, plant height increased with the maximum value in milk ripeness stage. The most intense increase in height was observed in interfacial period of tillering – stem-extension: on Delta variety when processing MCF (variant 2), increase was 31.1 cm, in variant 3 (MCF+20 % solution ECAW-C) – 32.4 cm, which is 7.6 and 12.1 % higher than increase in height in control (28.9 cm). On Tanya variety, when using FlorGumat, there was an increase in height by 27.8 cm, and in combination with 20 % solution of ECAW-C, there was 29.3 cm increase. Applying of MCF for wheat plants of Delta variety in tillering phase in spring contributed to an increase in plant height in stem-extension phase by 3.4 % compared to control, and in combination with 20 % solution of ECAW-C by 5.4 %. The use of FlorGumat in combination with 20 % solution of ECAW-C (Tanya variety) made it possible to obtain a significant increase of 3.3 %.
The creation of effective and environmentally adaptive conditions for photosynthetic apparatus throughout vegetation period is a necessary condition for high yield formation. It is due to photosynthesis that organic substances are formed in green plants (dry matter of plants consists of 90–95 % organic substances) [23].

The productivity of plants is determined by the size and duration of leaf apparatus, nature of the use of its products for growth processes, accumulation of dry biomass and formation of economically valuable part of the crop. In this regard we have studied the elements of photosynthetic activity of plants: area of one plant’s leaf surface ($S_{PL}$), area of crops’ leaf surface ($S_{CL}$), PP and dry biomass of crops.

3.2. The study of elements of plants photosynthetic activity

Measurement of square of leaf surface area of one plant ($S_{PL}$) of winter wheat (table 2) showed that the use of FlorGumat and MCF in combination with 20 % aqueous solution of ECAW-C contributed to more intensive development of assimilation apparatus of plants.

Analysis of dynamics of $S_{PL}$ shows that the greatest increase in the area of leaf surface is observed in the period of tillering – stem-extension regardless of the applied foliar feeding. The increase in $S_{PL}$ of Delta wheat with use of aqueous solution of MCF in stem-extension phase was 11.8 %, earing – 5.1 %, milk ripeness – 18.9 %. MCF in combination with 20 % solution of ECAW-C provided a higher increase in $S_{PL}$: 18.1 % – in the phase of stem-extension; 9.8 % – in the phase of earing and 26.6 % – in the phase of milk ripeness. MCF impact on the value of $S_{PL}$ due to the use of 20 % solution of ECAW-C increased by the phase of stem-extension 1.6 times, earing – by 1.9 and milk ripeness – by 1.4 times.

### Table 2. Dynamics of square of one plant’s leaf surface of winter wheat with application of foliar fertilizing MCF and FlorGumat in aqueous solutions ECAW-C, cm²

| Variant | Phase of vegetation | stem-extension increase, % | earing increase, % | milk ripe stage increase, % |
|---------|---------------------|---------------------------|-------------------|----------------------------|
|         | Delta variety in tillering phase (spring) 46.8 cm² | 75.8 | 11.8 | 18.1 | 127.0 | 5.1 | 9.8 | 57.6 | 18.9 |
| 1. Control (TW) | 75.8 | 120.8 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 |
| 2. MCF+ TW. | 84.8 | 11.8 | 127.0 | 5.1 | 54.1 | 18.9 |
| 3. MCF + 20 % solution of ECAW-C. | 89.5 | 18.1 | 132.6 | 9.8 | 57.6 | 26.6 |
| LSD<sub>05</sub> | 3.65 | 0.77 | 2.88 | 2.88 |
| 1. Control (TW) | 69.7 | 8.9 | 31.0 | 7.4 |
| ECAW-C 100 % | 75.9 | 8.9 | 33.3 | 7.4 |
| 3. FlorGumat + TW. | 78.6 | 12.7 | 4.6 | 8.0 |
| 4. FlorGumat + 5 % solution of ECAW-C. | 77.2 | 10.7 | 3.7 | 8.7 |
| 5. FlorGumat + 20 % solution of ECAW-C. | 83.7 | 20.1 | 9.3 | 27.4 |
| 6. FlorGumat + 50 % solution of ECAW-C. | 79.8 | 14.5 | 5.8 | 22.6 |
| LSD<sub>05</sub> | 6.19 | 2.43 | 2.38 | 2.38 |

For Tanya wheat plants, application of FlorGumat contributed to an increase in $S_{PL}$ by 12.7 % in stem-extension phase, by 4.6 % – in earing, and by 8 % – in milk ripeness. In combination with 20 % solution of ECAW-C, FlorGumat provided the following growth according to vegetation phases: 20.1; 9.3; 27.4 %. FlorGumat impact in 20 % solution of ECAW-C increased respectively 1.6; 2.0; 3.4 times.

After earing phase, the value of $S_{PL}$ began to decrease due to the death of leaves of the lower, then middle layers and nutrients outflow to reproductive organs. It should be noted better preservation of
leaves in milk ripe stage compared with control when using FlorGumat and MCF in 20 % solution of ECAW-C (27.4 and 26.6 %, respectively).

Observations of dynamics of the area of crops leaves ($S_{CL}$) of winter wheat made it possible to note general patterns of leaf formation in plants regardless of wheat variety and fertilizer used (table 3). In tillering phase in spring, when the treatment of plants was carried out, for Delta variety $S_{CL}$ was 20.4 thousand m$^2$/ha, Tanya variety – 13.4 thousand m$^2$/ha. In the subsequent phases of growth and development of winter wheat, the pattern of change in $S_{CL}$ was similar to $S_{PL}$ (table 3), and $S_{CL}$ reached its maximum value in earing phase. In Tanya variety in control variant, the value of $S_{CL}$ in earing phase was 37.2 thousand m$^2$/ha, which is 2.8 times more than the leaf area in tillering phase. The leaf surface of Delta winter wheat crops in this phase reached 45 thousand m$^2$/ha, from tillering phase in spring its increase amounted to 2.2 times.

MCF+TW and MCF+ 20 % ECAW-C increased $S_{CL}$ in the period of tillering – stem-extension 1.7 and 1.8 times, respectively, and during interphase period stem-extension – earing – 1.5 times, providing sustaining growth of $S_{CL}$. The use of FlorGumat and FlorGumat+ 20 % ECAW-C contributed to a greater growth of $S_{CL}$ in interphase period tillering-stem-extension 2.4 and 2.7 times, respectively. However, in the period of stem-extension-earing, the rate of growth of $S_{CL}$ significantly decreased (2 times). Further, due to the death of lower leaves, there was a natural decrease in $S_{CL}$ in interphase period from earing to milk ripeness (2–3 times). As shown, the leaf area of crops depends not only on mineral and organo-mineral fertilizers introduced to soil, but foliar feeding as well.

Analysis of data on ECAW influence made it possible to note that in earing phase, the use of MCF+20 % ECAW-C provided an increase in $S_{CL}$ of Delta wheat by 25.5 %, while MCF+TW – by 16.6 %. The increase in $S_{LP}$ of Tanya wheat from the use of FlorGumat+ 20 % ECAW-C was 10.2 %, while FlorGumat + TW provided an increase of 4.0 %. These results demonstrate that the 20 % solution of ECAW-C increased the growth of leaves of winter wheat crops of Delta variety 1.5 times, and Tanya variety – 2.5 times by earing phase. Photosynthetic potential (PP) is a complex indicator of photosynthetic productivity of crops.

| Variant | Phase of vegetation | Delta Variety in tillering phase (spring) 20.4 thousand m$^2$/ha | Tanya Variety in tillering phase (spring) 13.4 thousand m$^2$/ha |
|---------|---------------------|---------------------------------------------------------------|---------------------------------------------------------------|
|         | stem-extension cm$^2$ | increase, % | earing cm$^2$ | increase, % | milk ripe stage cm$^2$ | increase, % |
| 1. Control (TW) | 30.8 | – | 45.0 | – | 17.2 | – |
| 2. MCF+TW | 35.7 | 15.9 | 52.5 | 16.6 | 21.9 | 27.3 |
| 3. MCF+20 % solution of ECAW-C | 37.5 | 21.7 | 56.5 | 25.5 | 23.9 | 38.9 |
| LSD$_{05}$ | 3.09 | 4.13 | 2.32 |
| 1. Control (TW) | 29.9 | – | 37.2 | – | 11.9 | – |
| 2. ECAW-C 100 % | 32.6 | 9.0 | 38.3 | 2.9 | 12.6 | 5.8 |
| 3. FlorGumat + TW | 33.1 | 10.7 | 38.7 | 4.0 | 12.7 | 6.7 |
| 4. FlorGumat + 5 % solution of ECAW-C | 33.8 | 13.0 | 39.1 | 5.1 | 13.1 | 10.0 |
| 5. FlorGumat + 20 % solution of ECAW-C | 36.0 | 20.4 | 41.0 | 10.2 | 15.0 | 26.0 |
| 6. FlorGumat + 50 % solution of ECAW-C | 34.3 | 14.7 | 39.6 | 6.5 | 14.5 | 21.8 |
| LSD$_{05}$ | 2.78 | 1.46 | 0.51 |

It makes it possible to evaluate the effectiveness of various methods of crops cultivation, including winter wheat. The effect of foliar fertilizing in 20 % solution of ECAW-C on PP of winter wheat crops of Delta variety is shown in table 4.
Table 4. Effect of foliar feedings in 20 % solution of ECAW-C on PP of winter wheat crops of Delta variety, million m²·day/ha

| Variant                              | Interphase period |        |        |        |
|--------------------------------------|-------------------|--------|--------|--------|
|                                      | tillering (in spring) | tillering (in spring) | output stem-extension | output stem-extension | earing | earing-milk ripeness | milk ripeness |
|                                      | – output stem-extension | – milk ripeness | – milk ripeness | – milk ripeness | – milk ripeness | – milk ripeness | – milk ripeness |
| 1. Control (TW)                      | 0.66              | 1.23   | 0.68   | 2.58   |
| 2. MCF+ TW.                          | 0.75              | 1.27   | 0.71   | 2.74   |
| 3. MCF+20 % solution of ECAW-C       | 0.81              | 1.30   | 0.74   | 2.84   |

Average values for 2 years

During tillering – earing period there was a natural growth of PP 1.6 – 1.8 times, and then from earing to milk ripeness there was a decline to the same extent. The decrease is associated with predominance of redistribution and outflow of accumulated assimilants from vegetative to generative organs.

The influence of MCF and ECAW-C was manifested to a greater extent in the interfacial period tillering – stem-extension: the increase in PP when treating winter wheat plants with a solution of MCF+TW was 13.6 %, and when MCF in combination with 20 % solution of ECAW-C – 21.2 %. As can be seen, ECAW-C increased the effect of MCF on PP 1.6 times. In other phases of vegetation growth of PP was at the level of 3–8 %. The total PP for the entire vegetation period from tillering in spring to milk ripeness was 2.74 million m²·day/ha (by 6.2 % higher than control), PP+20 % solution of ECAW-C provided the value of PP – 2.84 million m²·day/ha, which is 10 % higher than control. The level of amplification of the action of MCF on PP due to ECAW-C remained the same – 1.6 times.

According to phytometric indicators of winter wheat crops of different productivity [10], at PP = 2.7 million m²·day/ha, programmed yield is 5.5 t/ha. A comparative analysis of literature [10] and experimental data (table 4) shows that proposed methods of foliar feeding with MCF and ECAW-C are very effective, since the experimental values of PP (2.74 and 2.84 million m²·day/ha) obtained when processing MCF and MCF+20 % solution of ECAW-C, program the yield of 5.5 t/ha.

The accumulation of dry matter is a function of assimilation process and forms physiological basis of plant productivity. The accumulation of dry matter by plants in the process of growth and development characterizes the availability of the resources in them.

Data on dynamics of dry matter of Delta wheat during its vegetation are presented in table 5.

Table 5. Formation of winter wheat dry biomass of Delta variety during its vegetation with foliar feeding of MCF in 20 % solution ECAW-C, c/ha

| Variant                              | Phase of vegetation |        |
|--------------------------------------|---------------------|--------|
|                                      | stem-extension | earing | milk ripe stage |
|                                      |        |        |                  |
| 1. Control (TW)                      | 32.8   | 69.4   | 112.1            |
| 2. MCF+ TW.                          | 35.9   | 76.8   | 122.5            |
| 3. MCF+20 % solution of ECAW-C       | 37.9   | 80.5   | 127.7            |

Average figures for two years in tillering phase (in spring) 9.8 t/ha

On average, for 2 years of research, dry biomass in the interfacial period of tillering – stem-extension increased in control variant 3.3 times, in the treatment of plants by MCF – 3.6 times, and in the PKU+20 % solution ECAW-C – 3.8 times.

During vegetation period by the phase of milk ripeness the above-ground mass of winter wheat formed the maximum amount of dry matter 112.1 cwt/ha (control). The use of MCF provided an increase in this indicator by 9.3 %, and MCF+20 % solution of ECAW-C – by 14 %, i.e. ECAW-C, as in previous experiments, increased the effect of MCF by 1.5 times.

Registered by us increase in the area of the leaf surface of crops, PP and dry biomass when applying 20 % solution of ECAW-C as a solvent of fertilizers can serve as experimental evidence of photosynthetic, biological activity of ECAW-C.

The increase in biological yield of winter wheat of Delta variety due to 20 % solution of ECAW-C in combination with MCF reached 18.2 %, for Tanya variety under the influence of FlorGumat –
7.4%, at the same time more than half of the increase was provided only by ECAW-C. The increase in the yield of Delta wheat due to the use of MCF+TW amounted 8.4% with a yield in control variant 5.34 t/ha. Use of MCF in combination with 20% solution of ECAW-C contributed to the yield of 6.37 t/ha; the increase compared to the control variant was 1.03 t/ha (19.2%). As can be seen from these indicators, ECAW-C as a solvent of MCF provided a yield increase of more than 2 times. The highest yield of winter wheat grain of Tanya variety was obtained by applying foliar fertilizing with FlorGumat in 20% solution of ECAW-C. It amounted to an average of 5.11 t/ha over three years of studies, while providing an increase in yield of 8.7% at the control level of 4.7 t/ha. The use of FlorGumat+ TW gave an increase in yield of 4.1%. As can be seen from these indicators, 20% aqueous solution of ECAW-C as a solvent of FlorGumat provided an increase in yield more than 2 times, as in the experiments with MCF.

So, in cultivation technology for winter wheat in tillering stage in spring, it is recommended to use 20% aqueous solution of ECAW-C as a solvent of fertilizers for foliar fertilization of plants. Non-root feeding of agricultural crops should be considered in relation not only to the root, but also with air nutrition – photosynthesis. ECAW is characterized by simplicity, accessibility and ability to regulate electrochemical characteristics of ECAW-C and ECAW-A. It can easily be carried out with diaphragm installations (devices) of different performance. This makes it possible to widely use ECAW at farms. Currently, it can create a new direction of ECAW application for agricultural production intensification.

4. Conclusion
We introduce a new method of foliar fertilizing of winter wheat plants with the use of electrochemically activated water – catholyte (ECAW-C) as a component of fertilizer solvent.

2. The most effective 20% concentration of ECAW-C (pH 9.0 and ORP = -50 mV) recommended for foliar fertilization of winter wheat plants in the tillering phase in spring was specified on Tanya variety of winter wheat with the use of FlorGumat (5 g/l).

3. Application for foliar feeding of winter wheat of 20% solution of ECAW-C as a solvent of fertilizers increases their positive effect on indicators of leaves area of crops, PP, dry biomass, pigments ~1.5 times.

4. Based on increase in photosynthetic activity of winter wheat crops (leaf area, PP, dry biomass) and the content of chlorophyll a and chlorophyll b, a significant positive effect of foliar feeding of MCF in 20% solution of ECAW-C on photosynthesis processes was established.

5. Foliar fertilizing of plants in the tillering phase in spring with MCF and FlorGumat in 20% solution of ECAW-C contributed to an increase in the yield of winter wheat of Delta variety by 19.2% (control 5.34 t/ha) and Tanya variety – by 8.7% (control – 4.7 t/ha) while ensuring the quality indicators of food grain of the 4th class.

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