The efficiency of applying soil hydrogel to the light-chestnut soils of the Volga and Don inter stream area to stimulate seed sprouting for agricultural crops

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Abstract. The conducted research reveals that the introduction of hydrogel into the topsoil using conventional grain seeders facilitates the retention, accumulation, absorption, and differentiated distribution of soil moisture, and stimulates and accelerates the seed sprouting for agricultural crops. The use of a scientifically calculated hydrogel dosage (80 kg/ha) during the seeding period led to a 2.08-3.77 mm increase in the productive moisture content in the topsoil as compared to the plots without hydrogel. The plants in the field treated with polymer agents used 3.54-7.35 mm less soil moisture to sprout, which led to a 44.25-61.40% economy of water as compared to the untreated reference plots. The hydrogel plantings began sprouting earlier, between the 2nd and the 4th days, and their field survival was 7.2-28.6% higher, which influenced the further vegetation of the plants.

1. Introduction
The best field survival and faster sprouting of agricultural crops under dryland farming can be achieved through the complete absorption of the precipitation by the soil and the sufficient humidity of the topsoil. In the light-chestnut soils of the Volga and Don inter stream area, this result is difficult to achieve because of the severe shortage of atmospheric moisture (250-350 mm/year) and the uneven distribution of precipitation across the vegetation period. Under such climate conditions, seed sprouting is very slow and the field survival is quite low.

There were many attempts to improve the seed sprouting processes in arid climes by using various stimulation means that had both positive and negative results. Areas with various soils and climes employ various agricultural technologies like the adjusted seeding times and the use of fertilizers [1, 2, 3, 4, 5, 6], innovative tillage techniques [7, 8, 9], seed dressing [10, 11], etc. In the context of the Lower Volga Region, the research works dedicated to the short-term electrophysical treatment of seeds with direct and alternating currents are especially interesting [12, 13]. However, such works cannot solve the problems of water retention in agriculture.

The multiyear research of using polymer materials shows that with soil hydrogel, it is possible and achievable to ensure the better and earlier sprouting of field crops and the complete absorption and accumulation of precipitation moisture in light-chestnut salt soils in arid and sharp continental climates.

Hydrogel is a special substance - polyacrylamide, which promotes the absorption of moisture and agrochemicals dissolved in water many times greater than their own weight and further – cultivated
plants, supplying them, as they grow and develop during the growing season. It can absorb and retain up to 200-500% and more moisture per 1 g of dry preparation. When using hydrogel in soil, the supply of the vegetating plant mass with a vital volume of moisture and nutrients is increased and optimized to a greater extent, if the latter were used and dissolved in water. This reduces the possible risk of burning the underground part of the plants with fertilizers.

Hydrogel can not only provide the cultivated plant with moisture, but also have a reclamation effect on soil, which is expressed in the absorption of extra free water, thereby maintaining a favorable optimal water balance and reducing the effect of “overtop” and secondary salinization.

The data concerning soil hydrogel and the more detailed justification of the dosage, introduction methods, and application features for grains, legumes, industrial and other crops were presented earlier in other articles in indexed journals [14, 15, 16].

2. Materials and Methods
The subject of the research and experiments is a polyacrylamide-based polymer substance known as the soil hydrogel (ant its durable effects) that was used as a long-lie absorbing agent for soil and atmospheric moisture with the optimal dosage of 80 kg/ha. The hydrogel was introduced into the soil in the previous year. The description of the initial experiments with hydrogel was published in other articles [14, 15, 16].

The experiments took place in 2014-2018. The goal of the research was to achieve a complete and early sprouting of agricultural crops. The experiment team used the adaptable varieties of agricultural crops (given with the standard seed rate): chickpea – Privo 1 – 0.4 mln viable seeds/ha (drill planting, 0.15 m); spring barley – Volgogradskiy 08 – 3.5 mln viable seeds/ha (drill planting, 0.15 m); vining squash – Volzhskaya Seraya 92 – 0.005 mln viable seeds/ha (broad drill planting, 2.1х2.1 m); spring wheat (durum) – Nikolasha – 4.0 mln viable seeds/ha (drill planting, 0.15 m).

The experimental part of the research was carried out on the plots of the subzone of light chestnut soils (Experimental field of Volgograd State Agrarian University) - light chestnut low-power solonetnic medium loamy soil formed on carbonate loam.

The carbonate layer is located close to the soil surface (about 37 cm), which is associated with low water permeability and low carbonate leaching along the soil profile.

The humus content in the arable horizon of the soil of the experimental plot is very insignificant and ranges from 1.35 to 1.78%; down the profile, the supply of humus drops sharply and in horizon B1 is already 0.85%. According to the content of absorbed sodium, the soils are defined as moderately and strongly solonetzic, which corresponds to the sodium values in the soil adsorption complex from 6.20% to 12.89%.

**Morphological description of the soil section of the experimental site**
(Federal State Budgetary Educational Institution of Higher Education Volgograd State Agrarian University - Educational, research and production center "Gornaya Polyana," Sovetsky district, Volgograd):

**Horizon A(p)** - 0 - 25/25 cm - light brown, dry, silty-lumpy, medium loamy, the transition to horizon B1 is clear.

**Horizon B1** - 25 - 48/23 cm - dark brown, dry, lumpy-prismatic, heavy loamy, dense, gradually transforms into the B2 horizon.

**Horizon B2** - 48 - 70/22 cm - brown, fresh, lamellar-prismatic, heavy loamy, dense, boils violently, "white-eye" from 0.69 m to 1.20 m - "carbonate belt", gradually transforms into the BC horizon.

**Horizon BC** - 70 - 92/22 cm - light gray-brown, dry, silty-lamellar, medium loamy, dense, abundant "white-eyed", gradual transition to horizon C.

**Horizon C** starts from 92 cm - light gray, fresh, lamellar-granular, medium loamy, dense.

The soil profile boils violently from the action of 10% hydrochloric acid (HCl) solution from the depth of 42 cm.

The content of mineral nitrogen in the soil mass of the experimental plot is low, mobile phosphorus - 18-24 mg / kg (average), exchangeable potassium 320 - 360 mg / kg (increased). The bulk density in
a meter layer (0 ... 1.0 m) is on average 1.45 t / m$^3$, for a soil thickness of 0 ... 0.5 m, the bulk density is 1.39 t / m$^3$, for a layer 0 ... 1 m - 1.28 t / m$^3$, for layer 0 ... 0.2 m - 1.32 t / m$^3$. The total porosity in the upper horizons (0 ... 0.3 m) is 50.0%, for a meter layer - 47.5%. pH of the aqueous extract is 8.65 ... 8.76 (alkaline).

The maximum hygroscopicity in the arable layer (horizon A) is 5.77% of absolutely dry soil. There is no salinity with readily soluble salts; the dry residue is 0.17%.

Chemical and granulometric characteristics make it possible to assess these soils as good for agricultural production, but one must remember about the lack of humus and moisture.

The growth and development of all varieties and crops were monitored according to the rules of Gossortset of Russia – GOST 12038-84. The research team recorded the dates of planting (along with the seed rate, drilling depth, the use of tools and machinery, etc) and seedling stages for all of the crops. Individual phenological observations were carried out for each of the crops.

3. Results and Discussion

As noted before, the availability of water in the topsoil is a key component in crop vegetation that facilitates the even and good sprouting.

In experiments with hydrogel (at its scientifically grounded rate) with its simultaneous introduction with sowing of agricultural crops, it was found that at the first stages of plant development, the effect of this compound with a sufficient or excess amount of moisture in the sowing and arable soil layer does not have an antagonistic effect of “taking” moisture away from the seeds. The process of saturation with moisture and the increase in the size of the granules occurs simultaneously with the swelling of the seed. However, in those years when there is a sharp shortage of moisture in spring reserves, during the initial application, the hydrogel accumulates moisture faster than seeds, taking it away from the crop, and, therefore, there may be a fading effect - an excessively long interfacial period "sowing-seedlings". Subsequently, the antagonistic effect of the seedlings ends, and the hydrogel becomes, with an uneven moisture supply with precipitation in the spring and summer growing season (especially when it comes to spring growing season), very helpful for supplying plants with available water. With a constant saturation of the arable horizon with hydrogel in reasonable doses (after 1-2 years), this fading effect is leveled and disappears.

The research team monitored the long-term effects of using the polymer hydrogel in crop-rotation fields over a period of time and concluded that the use of hydrogel is feasible and rational in assuring water retention and stimulating the sprouting of agricultural crops (early and good sprouting). In particular, it proved effective when applied in a scientifically calculated dosage of 80 kg/ha and using the standard tillage technologies in the light-chestnut salt soils of the Lower Volga region (Table 1).

Table 1. The availability of moisture to agricultural crops in light-chestnut soil during planting and sprouting

| Crop          | Reference (no hydrogel) | Hydrogel (residual effects) |
|---------------|-------------------------|-----------------------------|
|               | Soil moisture (%) and moisture content (mm) in the 0.2 m layer |                     |
|               | Planting | Sprouting | Consum | Planting | Sprouting | Consum |
|               | %       | mm        | ed     | %         | mm        | ed     | mm |
| Chickpea      | 13.55   | 19.35     | 10.34  | 11.35     | 8.00      | 15.35  | 23.12 | 14.12  | 18.66  | 4.46   |
| Spring barley | 17.10   | 27.94     | 13.40  | 19.00     | 8.94      | 18.65  | 31.69 | 16.77  | 27.15  | 4.54   |
| Vining squash | 15.63   | 24.38     | 11.34  | 14.02     | 10.36     | 16.48  | 26.46 | 14.66  | 20.83  | 5.63   |
| Spring wheat  | 16.51   | 26.73     | 12.2   | 14.76     | 11.97     | 18.28  | 30.27 | 16.15  | 25.65  | 4.62   |

The data from Table 1 show that the immediate and long-term effects of hydrogel include the retention of the available moisture from planting until sprouting for three years since its application...
(residual effects). This leads to a reduction of water consumption (by plants, soil discharge, influent seepage) over the planting-sprouting period, which amounted on average to 3.54-7.35 mm for a 0-0.2 m layer of soil (light-chestnut soil of the Volga and Don inter stream region).

The same water-retaining properties of the hydrogel are verified by the accumulation of extra productive moisture under the plantings of all experiment crops. The average values for this parameter across the rotation area at planting amounted to 2.08-3.77 mm of accumulated water. These values fluctuated over the years and across cultures but remained steadily above the moisture of topsoil in plots treated with hydrogel.

The research team obtained interesting results in terms of assessing the planting-sprouting interstage period duration (Table 2). The plants in hydrogel plots transitioned from planting to sprouting faster than the reference plot plants. The average duration of the planting-sprouting period across the years is reduced by 2-4 days depending on the biological properties of the rotation crops and their varieties.

| Crop          | Reference (no hydrogel) | Hydrogel (residual effects) |
|---------------|-------------------------|-----------------------------|
|               | Planting | Sprouting | Duration, days | Planting | Sprouting | Duration, days |
| Chickpea      | 15.05.15 | 28.05.15  | 13             | 15.05.15 | 25.05.15  | 10             |
| Spring barley | 19.04.16 | 27.04.16  | 8              | 19.04.16 | 25.04.16  | 6              |
| Vining squash | 25.05.17 | 06.06.17  | 12             | 25.05.17 | 02.06.17  | 8              |
| Spring wheat  | 10.04.18 | 19.04.18  | 9              | 10.04.18 | 15.04.18  | 5              |

The beneficial effects of the hydrogel are evident in all of the experiment crops, irrespective of the differences in their physiological processes and biological properties, and the weather conditions of a given year. The chickpea is a drought-tolerant crop occupying significant areas in all of the soil and climate zones of the Lower Volga Region. The spring barley is a grain crop that is a lot less drought- and heat-tolerant than the chickpea. Squash is a very valuable cucurbit crop with high requirements for the fertility of the soil and the availability of sufficient moisture in the root area. Occasionally, it can withstand extreme vegetation conditions and withstand droughts. The spring (durum) wheat is a grain crop that can produce relatively large amounts of valuable high-quality grain even if the natural precipitation is insufficient.

Despite their differences, all of these crops had a positive reaction to the changes, i.e. the reduction of the planting-sprouting interstage period. Their field survival did not decrease as compared to the reference plants (Table 3).

| Crop            | Reference (no hydrogel) | Hydrogel (+residual effects) |
|-----------------|-------------------------|------------------------------|
|                 | Seed rate | Number of sprouting plants | FS in % of the seed rate | Seed rate | Number of sprouting plants | FS in % of the seed rate |
|                 | standard | (plants/m²) | (plants/10 ML for the squash) | | standard | (plants/m²) | (plants/10 ML for the squash) |
| Chickpea        | 40        | 32            | 80.0                      | 40        | 37            | 92.5                      |
| Spring barley   | 350       | 314           | 89.7                      | 350       | 339           | 96.9                      |
| Vining squash   | 14        | 7             | 50.0                      | 14        | 11            | 78.6                      |
| Spring wheat    | 400       | 342           | 85.5                      | 400       | 387           | 96.8                      |
The analysis of Table 3 data shows that the best field survival values were obtained from the plots treated with hydrogel and planted with certified seeds within the standard timeframe. The average sprouting plant count on the given date for the hydrogel crops was 7.2-28.6% higher than the reference depending on the crop cultivated in the given year.

4. Conclusion
Field survival is driven by many other factors apart from the topsoil moisture [17, 18, 19]. However, when all other conditions are equal and the presence of hydrogel in the soil (and thus the improved moisture availability in the topsoil) makes all the difference, the field crops sprout 2-4 days earlier and have a 7.2-28.6% better field survival, which proves the scientific and practical significance of the agricultural technique used. Besides, hydrogel also has positive long-term effects on water retention throughout the entire vegetation period of agricultural crops.

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