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Research article

The Use of the Organic Product of Rice Hulls Pyrolysis as a Plant Growth Stimulant

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Abstract:

We introduced the results of laboratory and field tests on the use of the organic product (OP)ofrice hulls pyrolysis as a plant growth stimulant and recommendations on its practical application in crop farming.It was proved that pretreatment of seeds by a new growth stimulant (the OP aqueous solution) has a positive effect on the increase in germination energy, seedling growth rate, and the resistance of seedlings to lodging and to stress factors during the vegetation period in dry, wet and cold years.It was established that the optimum OP aqueous solution concentration for wheat, oats and rice is 0.3%, and for corn, soybean, safflowerand sunflower it is 0.6%.

Keywords: Rice hulls, organic product, plantgrowth stimulant.

1 Introduction

The rice hullis arice processing waste of low demand in practice. The global annual volume of rice hullsgeneration is 150,000,000 to 200,000,000 tons. Kazakhstan, mostly the Kyzylorda region, produces up to 90,000tonsa year. More than half of this waste is not in use and is accumulated in heaps, creating environmental problems.

The National Center for Mineral Raw Materials Complex Processing of the Republic of Kazakhstan has developed a technology of rice hullscomplex processing (Sukharnikov Yu.I., et al, 2012) to obtain two products: silicacarbon and organic product.Its essence is as follows: rice hull after mechanical cleaning from foreign matters is exposed to pyrolysis at a temperature of 600-650°C for 20 to 30 minutes.The produced solid silicacarbon is a multifunctional material (Sukharnikov Yu.I., et al, 2013)which can be used as a filler of rubbers and carbon materials, a sorbent, and a feed additive in poultry.

The liquid organic product (OP) contains 45-55% aliphatic and 22-28% aromatic hydrocarbons, and the rest is water. The hydrocarbons are composed of about 40% sulfuric-esterfraction in which 43% are acids (mainly cinnamic, protocatechuic, and resorcinol), 19% are phenols (prevailed cresols, phenols andguaiacol), 1%is alcohols and 35% are neutral substances.The organic product has a high antimicrobial activity against staphylococcus, streptococcus, tuberculosis, dysentery and intestinal sticks, salmonella, and candida fungi.The OP does not contain benzopyrene and consequently there are no carcinogenic substances.According to the report of the Scientific and Practical Center for Sanitary and Epidemiological Examination and Monitoring under the Ministry of Health of the Republic of Kazakhstan,the OPby intragastric intake refers to the 4^{th}class of danger (low-hazard)and can be recommended for extensiveapplication.

A pilot-scale plant was established to process 300 kg of rice hulls per day and produce 100 kg of silicacarbonand 75 kg of organic product.

Taking into account the OP composition and properties as well as the composition of the known plant growth stimulants based on different drugs (Agafonov Yu.V. et al, 1997; Vereshchagin A. L. et al, 2006 ; Karavayev V.A. et al, 2011), including the most common in practice sodium humate (Sagalbekov U. M. et al, 1999; Okinko N.P., 1987), the OP must show some stimulatory effects on the growth and development of plants.

In the processes of growth,in addition with the generalconditions of nourishment, physiologically active substances –usually organic compounds –are of a great importance as they have strong physiological effects even in trace amounts. Among these are auxins, vitamins, purines, certain amino acids, growth inhibitors, and other compounds.

They should be considered as essential factors of life that play a specific role in the plant growth process by their ability to increase metabolism, towards the synthesis of structural formation that is typical for growing cells.

Growth stimulantsare substances which are usedin trace concentrations and promote a growth, notwithstanding their origin and mode of action (Grebinsky S.O., 1961; Kozmina L.M., 1990).

In small doses, their application promotes the growth and development of plants and accelerates their ripeningbyseven to ten days, which is especially important in the Northern Kazakhstan climate with a short growing season. They help to increase the efficiency ofmineral fertilizers, improve mineral nutrition, especially under extreme conditions (high or low temperature, lack or excess of water, etc.), and increase the resistance of plants to diseases. Growth stimulants accelerate the decomposition of pesticides accumulated in the soil andreduce the content of nitrates and heavy metal ions in the product. Theyeventuallyforcetheplantgrowth, increase the yield gain, accelerate ripening and improve the quality of seeds.

Plant growth regulators can strengthen or weaken the properties of plants within the normal reaction determined by the genotype and heredity.They are part of a comprehensive chemicalization in crop farming. Plant growth stimulants compensate the imperfections of sorts and hybrids, though they do not have a universal significance and cannot replace other factors of yield formation.

The role of plant growth regulators has increased dramatically due to the widespread use of intensive technologies of cultivation of farmingcrops.Concentration of resources for the purpose of obtaining the maximum benefit required a complex application of chemicals and determination of the optimal ratio. In this regard, the chemical regulation of plant growth and development must be closely linked to the other intensive technologies and evaluated in field experiments.

Thus, pretreatment of seeds with a growth stimulant has a positive effect on the germination energy, field seeds quality, seedling growth intensity, root formation, tillering,the number of capsules and the absolute mass of seeds. It increases the resistance of germination to lodging, to stress factors of the vegetation period in dry, wet and cold years, and to high doses of mineral fertilizers.

With aim of determining stimulant properties which influence on the plantgrowth we conducted tests on application of aqueous solutions with different organic productconcentrations.

2 Essential part

2.1 Laboratory researches

The aim of the study was to establish the effectiveness of the OP as a plant growth factor and determine the optimal concentration of its solutions for a variety of crops.

We studied the effect of different concentrations of the OP aqueous solution on the germination energy, laboratory germination, further growth and development of plants and specified the standards for applicationof the new growth regulators.The research and tests were conducted on seeds of the following crops: spring wheat – sort*Arai*, oats – sort *Kazakhstan-10*, maize – hybrid *ZPSK-704*,soy–sort*Zhalpaksai*, sunflower – sort *Kazakhstan-3124*, and safflower – sort *Akmai*.

Seeds of the test cropswere steeped during 60 minutes in aqueous solutions with different OPconcentrations: 0.3%, 0.6%and 0.9%.Thenseeds of thetest crops were removed from the treatment solution and dried for 20-24 hours to air-dry condition. Afterwards the treated seeds were thoroughly mixed and let germinate.

The germination of seeds was carried out under the optimum conditions in four-time replications. The germination temperature for wheat, soybean, sunflower, safflower and oats was + 18°Cto+ 20°C, and for corn the temperature was + 30°C during the first six hours, and + 20°C the rest of the time. Vessels with water were set at the bottom of the thermostat in order to maintain a humid atmosphere in an oven (the 90-95% relative humidity).

During the testwestudied the germination and viability, conductedphenological observations of the growth and development of crops, recorded the plant population, height, accumulated green and absolutely dry weight,and estimated the crop structure and yield.

The field experiments were conducted in heavy loamy meadow-chestnut irrigated soils of thesubmontane areas, in the Agrouniversitetscientificexperimental farm in Enbekshi-Kazakh district of Almaty region (Figures 1 and 2).

Figure 1. Field work

Figure 2. Phenological observations and plant growth measurement

The results of laboratory studies on the effect of different concentrations of the OP aqueous solution on the germination energy and laboratory germination of seeds of oats, safflower, soybean, sunflower and maize (Table 1) showed that the studied growth promoterincreasesboth viability and laboratory germination of seeds ofthe test crops.

Table 1. Effect of the growthstimulant (the organic product of rice hullspyrolysis) on sowing qualities of seeds of field crops

Variant		Germination energy		Laboratory germination	
		Seeds germinated	%	Seeds came up	%
1. Sunflower					
Reference		51	25.5	44.6	89.1
Solution concentration, %	0.3	54	27.0	45.3	90.6
	0.6	58	29.0	47.2	94.3
	0.9	52	26.0	44.1	88.1
2. Corn					
Reference		25	50	45.2	90.4
Solution concentration,%	0.3	26.5	53	46.4	92.8
	0.6	28.5	57	48.3	96.6
	0.9	25.5	51	47.3	87.4
3. Soybean					
Reference		23.5	47	41.8	83.6
Solution concentration, %	0.3	26.5	53	42.7	85.4
	0.6	29	58	44.8	89.6
	0.9	25	50	40.1	80.2
4. Safflower					
Reference		49	49	84.3	84.3

Solution concentration, %	0.3	54	54	86.1	86.1
	0.6	57	57	94.4	94.4
	0.9	49	49	89.6	89.6
5. Oats					
Reference		56	56	88.1	88.1
Solution concentration, %	0.3	66	66	96.4	96.4
	0.6	60	60	91.1	91.1
	0.9	50	50	80.4	80.4

The best results of germination (66%) and coming-up (96.4%) of oats and wheat seedswere obtained bytreating themwith the 0.3% aqueous solution (Figure 3), and for sunflower, soybean, safflower, and corn seeds by treating with the0.6 % aqueous solution (Figure 4). Herewith the highest germination energy (57-58%) and laboratory germination (93.3- 96%) wereachieved.

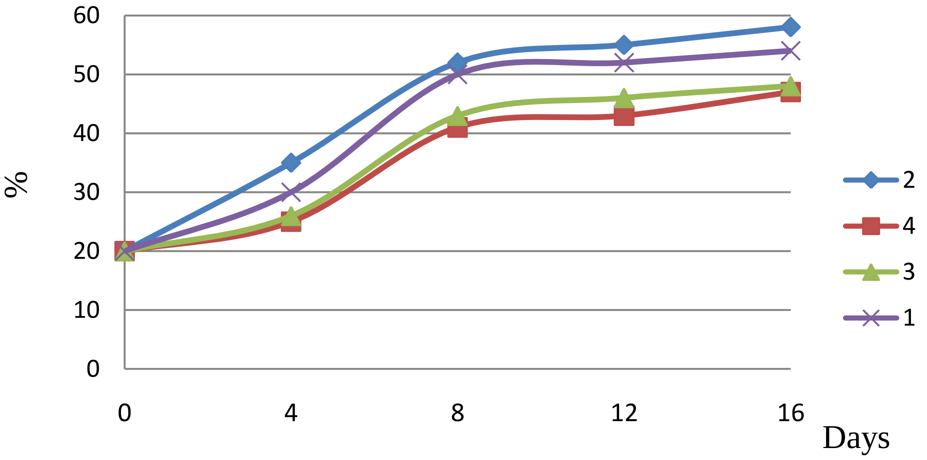

Figure 3. The dynamics of germination energy (%) of corn seedstreatedwith theOP aqueous solution (%): 1–0.3%; 2–0.6%; 3–0.9%; and 4– reference (zero OP in water).

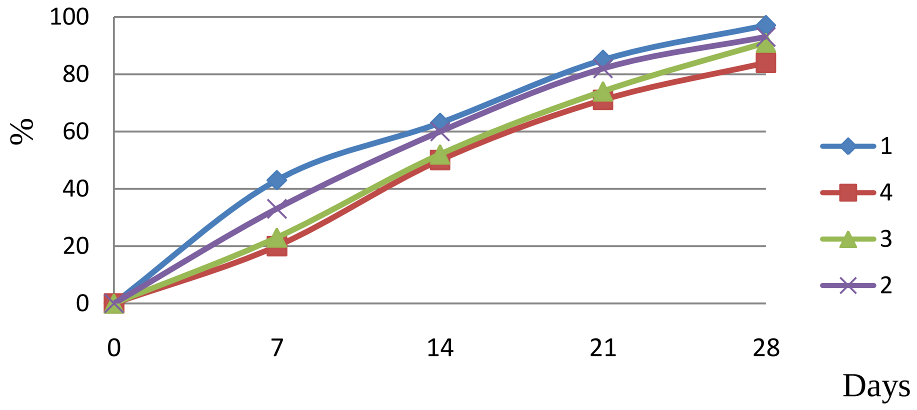

Figure 4. The dynamics of laboratory germination (%) of meadow wheat and oat seedstreated withthe OP aqueous solution (%): 1–0.3%; 2–0.6%; 3–0.9%and 4 –reference (zero OP in water).

For oat seeds the optimal concentration of the studied growth stimulantis 0.3%, where the greatest germination energy(66%) and laboratory germination(96.4%) were observed, that is higher than the referenceby 16.1%. A further increase in concentration up to 0.6-0.9% reduces this index to 5.3-16.0%.

Observations for the field germination of seeds (Table 2) depending on theamountof the plant growth promotershowed that the greatest field germination was recorded forthe variants where the seeds of corn, soy, safflower and sunflower were treated with the0.6% OP aqueous solution. The rate was 82- 92% depending on the studied crops.Maize and sunflower seedsshowed the highest value of field germination(90-92%), safflower 88-90%, and soybean 82-86%. A higher concentration (0.9%) reduced germination by 2-13%, even compared with the reference.Whileprocessing the seeds with the0.3% solution, the germination ratewas slightly lower than when treating with the0.6% concentration,by 8-12%lower in comparison with the optimum.

For the spring wheat seeds the better OP aqueous solution concentration was 0.3%. A further increase in the concentration to 0.6 and 0.9% reduced the germination rate by 4-10%, and 2.3-2.7 % as compared to the reference.

Table 2. Field germination of crop seeds depending on theamount of the OPplant growth stimulant

№	Crop	Solution concentration, %			
		Reference	0.3%	0.6%	0.9%
1	Sunflower	81.0	84.0	88.0	76.0
2	Corn	83.0	86.0	92.0	80.0
3	Soybean	71.0	74.0	86.0	72.0
4	Safflower	82.0	86.0	90.0	78.0
5	Wheat	73.3	76.0	70.0	66.0

The value of field germination influenced the plant density, growth, development, yield structure and productivity of all crops (Tables 3-8).

Table 3. Effect of the growth stimulant(the organic product ofrice hullspyrolysis)on the spring wheat crop yieldandthe crop structure

Experiment variant		Number of plants per sq m before the harvesting	Structure of the crop						
			Productive tillering capacity	Plant height, cm	Length of ear, cm	Number of grains per ear	Weight of grain sq m/g	Weightof 100 grains, g	Biological yield, tons/hectare
Reference		243.6	1.1	81.0	7.5	23	24.8	39.3	2.43
OP solution concentration, %	0.3	261.6	1.3	93.0	8.7	27	28.2	40.8	2.82
	0.6	236.0	1.2	76.0	8.1	24	23.3	40.2	2.33
	0.9	220.4	1.0	73.0	7.3	21	20.7	38.9	2.07

Table 4. Effect of the growth stimulant (the organic product of rice hulls pyrolysis) on the soybean crop yield and the cropstructure

Experiment variant		Number of plants per sq m	Structure of the crop					
			Plant height, cm	Number of pods per experimental plant	Number of grains per pod	Weight of grains perplant, g	Weight of 1,000 plants, g	Biological yield, tons/hectare
Reference		36.6	55.5	13.0	3.0	6.1	155	2.23
OP solution concentration, %	0.3	38.1	89.0	20.0	3.0	7.8	161	3.11
	0.6	44.4	85.0	29.0	3.0	8.5	158	3.77
	0.9	33.0	72.0	6	3.0	2.8	153	0.92

Table 5. Effect of the growth stimulant on the safflower crop yield and the crop structure

Experiment variant		Number of plants per sq m	Structure of the crop					
			Plant height, cm	Number of anthodiums per plant, pcs	Number of grains per anthodium	Weight of grains per plant, g	Weight of 1000 seeds, g	Biological yield, tons/hectare
Reference		27.2	56.1	5.0	26.1	5.0	38.2	1.36
OP solution concentration, %	0.3	27.6	65.4	6.1	27.2	6.4	38.7	1.77
	0.6	28.8	67.3	6.3	28.0	6.9	39.3	1.99
	0.9	26.0	63.2	4.8	25.3	4.6	38.0	1.20

Table 6. Effect of the growth stimulant on the corn crop yield and the crop structure

Experiment variant		Number of plants per sq m	Structure of the crop				
			Plant height, cm	Weight of grain in ear, g	Number of grains per ear, pcs	Weight of 1,000 grains, g	Biological yield, tons/hectare
Reference		5.6	177	147.9	510	290	8.28
OP solution concentration, %	0.3	5.8	530	161.6	530	305	9.37
	0.6	6.4	535	166.4	535	311	10.65
	0.9	5,1	512	150.5	512	294	7.67

Table 7. Effect of the growth stimulant on the sunflower crop yield and the crop structure

Variant		Number of plantsper meter	Structure of the crop					
			Plant height, cm	Diameter of sunflower, cm	Number of seeds per ear	Weight of seeds per ear, g	Weight of 1,000 seeds, g	Biological yield, tons/hectare
Reference		4.9	136	16	470	27.1	57.7	1.33
OP solution concentration, %	0.3	5.0	139	17	485	28.2	58.1	1.41
	0.6	5.6	142	18	497	30.1	60.6	1.69
	0.9	4.2	128	14	451	25.7	56.9	1.08

Table 8. Effect of the growth stimulant on the potato crop yield and the crop structure

Variant		Number of bushes per meter	Number of tubers per bush	Weight of tubers per bush, g	Crop yield, tons/hectare
Reference		4	5.2	230.5	13.14
OP solution concentration, %	0.3	4	7.1	275.1	15.68
	0.6	4	8.3	302.3	17.23
	0.9	4	6.9	258.1	14.71

2.2 Performance test

The Birlik LLP farming company tested the effectiveness of the new growth promoteron the germination energy andgerminating ability of seeds of the *Emerald* sort of rice.

Tests were conducted according to the standard practice. The day before sowing, seeds of the test crop (315 kg) were seeped in the 0.3 and 0.6%OP aqueous solutionsduring 60 minutes. Then the treated seeds were removed from the treatment solution, dried to air-dry condition at a temperature of 20-30°C and sown in optimal agrotechnical termsusing the regionalfarm production technology. The rice seeds which were not treated with the OP solution served as a reference. During the vegetation,the phase of rice development was observed.

The results of the field studies have shown that the greatest germination was recorded for the seeds which were treated with the 0.3% OP aqueous solution, and the germination of seeds treated with the0.6% solution was by7% lower than the first ones. However, the rice germination in the bothcases was higher as compared tothe untreated seeds by 18.5% and 11.3% respectively.

The yield records were carried out before harvesting (biological) and after harvesting (bunker), according to the established methodology. The yield of rice on the test areas was 4.92t/ha and 4.51 t/harespectively, while the referencewas 4.33 t/ha, which is less by 15-18%.

3 Conclusion

Thus, pretreatment of seeds by the new growth stimulant (an aqueous solution of the organic product ofrice hulls pyrolysis) has a positive effect on the increasing of germination energy, seedling growth intensity, resistance of germination to lodging, and to stress factors of the vegetation period in dry, wet and cold years.

The laboratory and field experiments withspring wheat seeds showed that the best solution was the0.3% solution of the organic product ofrice hulls pyrolysis.Its further increase to 0.6% and 0.9% reduces the germination rate by 4-10%.

The greatest field germination of corn, soybean, safflower and sunflower was where the seeds were treated with the 0.6% OP solution. The highest field germination was registered for corn and sunflower seeds(90-92%), safflower(88-90%), and soybean seeds(82-86%).

The production tests in the Birlik LLP farming company proved that the germination and crop yield of Emerald rice which seeds were treated with the 0.3% OP aqueous solution, were higher by 15-18% than the referenceseeds which did notunderwentpretreatment. The technology is recommended for practical application in farming.

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