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Struggling against the Bunt and Smut Diseases of Wheat and Barley by Applying New Complex Fertilizers in the Organic Agriculture

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ABSTRACT

Cereal bunts and smuts cause a huge damage to the cereal croplands. Various fungicides are usually applied for taking struggling measures against the wheat bunt but they have very often toxic effect on humans and animals. To struggle against the smuts and bunts a complex organo-mineral fertilizer (AFM) endowed with fungicidal properties has been recommended, which is allowed to use in the organic agriculture as well.

The experimental results have disclosed that by soaking the cereal seeds with the solution of the mentioned fertilizer before the very start of sowing or even earlier, the possibility of the grain infection is prevented and economically justified yield is harvested. Thus, it is recommended to use the AFM as a means of seed disinfection.

Introduction

Cereal crop production is an important issue from the prospect of providing the safety of agri-food system in any country of the world. Along with expansion of cropland areas, cultivation of high-yieldig crop varieties, as well as introducing advanced fertilization and cultivation technologies (Gulyan, 2007, Hakobyan and Gulyan, 2007, Matevosyan and Gyulkhasyan, 2000), the implementation of efficient activities aimed at the struggle against the crop diseases is also of utmost significance for the increase of production dimensions (GOST 12044-93, FAO, UN Budapest, 2017, Laptiev, Kungurtseva, 2016, Mikhaylikova, et al., 2013). It is well known that the winter wheat and barley, as well as a number of cereal crops are more often damaged by the crop diseases of bunts, smuts and root rots (Avagyan, et al., 2017, Grigoryan and Asatryan, 1999, Mikhaylikova, et al., 2013, Pikushova, 2017, http://www.betarer.ru).

The plants diseased by the wheat bunt develop soot-like dustbags instead of ears which blast out during the harvest time and the spores are dispersed around. They can stay viable on the infected seeds in the soil for a long time. In the ears infected with cereal smut the fungal body gets transformed forming black soot-like spore mass, then they fall on the healthy flowers through the wind and germinate very quickly (http://www.betarer.ru).

There are multiple ways of struggling against the cereal bunt and smut; anyhow, the application of different fungicides (Dividend, Raxil, Polaris, Benefis, Scarlet, etc.) is currently the most widespread method. The disinfecting activities are carried out before sowing or even earlier (Avagyan, et al., 2017, Grigoryan and Asatryan, 1999, http://www.betarer.ru).

Some other scientists recommend to improve the phytosanitary conditions of the seed material in the cereal crops through the biological methods (e.g. Biocomposite-Correct), indicating that by applying the fungicides for a long time the useful microflora content of the soil medium undergoes some changes and some strains adapted to the fungicides appear in the soil or they become the reason for mutagenesis in the environment (Yevseev, et al., 2017, Yablokov, 1989). Nevertheless, this method hasn't found a widespread application.

The disadvantage of the method related to the application of fungicides against the bunt and smut diseases consists in the fact, that the active agents of the mentioned preparations have toxic impact on the humans, animals, as well as on the useful micro-organisms of the soil. Taking into account the abovementioned and considering the disinfected seed material as a harmful means for its accidental use in food products, bright colourants are mixed with disinfectants, whereupon the disinfected seeds become visible (Mikhaylikova, et al., 2013, Pikushova, 2017). Besides, such fungicides are prohibited for the use in the organic agriculture (Green Caucasus Standard. Code GC/DM/GCS-10.3).

Thus, there isn't any developed alternative method for the use of fungicides.

Materials and methods

The aim of the study is to enhance the effect of fungicidal complex fertilizer AFM (alternative fungicidal means) synthesized by our research group on the ability to prevent the infection with bunts and smuts of the winter wheat and spring barley. The effect of the mentioned fertilizer on the infectivity rate of the ears (spike) with the wheat bunt and loose smut, on the vegetation period of the plant, the structure of the yield elements, yield capacity, as well as on the grain qualitative indices has been investigated (Piskunov, 2004, Yagodin, 1987).

Field fertilization trials were conducted at the Solak community in Kotayk region, in 2016-2018 (the experimental plant - winter wheat) and at the Artik province of Shirak region in 2016-2017 (the experimental plant - spring barley). The seed grain for the field experiments was selected from the fields of the abovementioned communities, where the infectivity rate of the seeds with bunt and loose smut diseases made 1.94 %-2.35 % and 0.05 %-0.06 % respectively.

Field fertilization experiments were carried out with three repetitions and the size of an experimental material made 100 m^2 (5 m x 20 m). The winter wheat variety was Bezostaya 1, while the spring barley variety was Nutans local.

The experiments were conducted on the background of nitrogen-phosphorus-potassium ($N_{90}P_{90}K_{60}$). The double superphosphate and potassium chloride were applied during the soil preparation activities. The nitrogenous fertilizer with the dose of N_{30} was applied simultaneously with the sowing activities, the rest fertilizers were used in the plant bushing (shrubbing) period. AFM was applied prior to sowing by soaking the seeds (Tables 1-4).

During the experiments within the vegetation period phenological observations, measurements and calculations were conducted. The contamination of the ears with the wheat bunt and smut was determined through the accepted methodology (GOST 12044-93).

Results and discussions

The experiments in the Solak community were conducted on the leached black soils, where the humus content was 3.8 %, the mechanical composition was heavy clay and sandy (the physical clay - 48.4 %), and *pH* was 7.6. Out of the affordable nutrients the nitrogen content made 4.8 mg *N*, that of phosphorus - 1.8 mg P_2O_5 and potassium - 39.4 mg K_2O in100 g soil. According to the introduced data the soil type was poorly provided with nitrogen and phosphorus and well provided with potassium.

In the Artik province the experiments were conducted on simply black soils; the humus content was 4.2 %, *pH* - 7.1, the content of carbonates was 1.6 % and the physical clay made 51.6 %. As to the affordable nutrients, they were poorly provided with nitrogen (*N* - 5.7 mg), phosphorus content was very poor (P_2O_5 - 0.9 mg), while the mentioned soils were averagely provided with potassium (33.8 mg

K_2O in 100 g soil) (Melkonyan, et al., 2004, Soils of the Armenian SSR, 1976, Piskunov, 2004, Yagodin, 1987).

The results obtained from the winter wheat trials (Tables 1, 2) testify that the complex fertilizer AFM endowed with fungicidal properties has significantly promoted the seeds sprouting capacity in the field, the plant growing process, increase of the grain yield capacity, as well as the reduction of their infectivity rate with smuts and bunts of cereals.

So, according to the data of Table 1, in the control variant the sprouting capacity of the seeds infected with the mentioned diseases in natural medium has made all in all 60.0 %, while the seeds treated with the solution of AFM have demonstrated 65.8 %-75.0 % sprouting capacity. The field sprouting capacity of the seeds reached its maximum index when AFM was applied with the dose of 2.0 - 2.5 kg/ha. Similar results were recorded when Dividend was used with the dose of 2.0 kg/ha. In the variants where the seeds were treated with AFM and Dividend the height of the stems exceeded that of the control variant by 9.8 % - 13.7 %.

The data on the calculation of the number of spiciferous stems per unit area disclose that on the whole the mentioned indicator is rather low.

Table 1. The effect of AFM applied upon the fertilization background on the field sprouting capacity and plants vegetation process in the winter wheat*

Variants	The number of seeds sown per 1m², n	The number of sprouted seeds, n	Field sprouting capacity, %	Plants height, cm	The number of spiciferous shoots per 1m², n
$N_{90}P_{90}K_{60}$ background (control)	600	360	60,0	51	291
Background + AFM 1.0 kg/ha	600	395	65.8	56	345
Background +AFM 1.5 kg/ha	600	438	73.0	57	350
Background +AFM 2.0 kg/ha	600	450	75.0	58	356
Background +AFM 2.5 kg/ha	600	449	74.8	58	358
Background +Dividend 2.0 l/ha	600	448	74.7	56	355

Table 2. The effect of AFM applied upon the fertilization background on the mitigation of infection with bunt and smut diseases of the winter wheat and on its yield capacity*

Variants	The number of ears infected with wheat bunt per 1m², n	The number of ears infected with loose smut per 1m², n	The number of grains in an ear, n	The weight of the grains in an ear, g	The weight of 1000 grains, g	The yield of an ear c/ha
$N_{90}P_{90}K_{60}$ background (control)	2.30	0.08	15.3	0.60	39.2	17.6
Background + AFM 1.0 kg/ha	0.96	0.00	17.1	0.68	39.7	23.4
Background +AFM 1.5 kg/ha	0.71	0.00	18.0	0.72	40.1	25.2
Background +AFM 2.0 kg/ha	0.05	0.00	20.1	0.81	40.3	28.8
Background +AFM 2.5 kg/ha	0.02	0.00	20.0	0.81	40.5	29.0
Background +Dividend 2.0 l/ha	0.01	0.00	18.9	0.76	40.3	27.1

*Composed by the authors.

Besides, there are some differences between the variants; it is much lower in the control variant (291 n per 1m^2), the latter is followed by the variant where AFM with 1.0 kg/ha dosage has been applied. The application of AFM with the dose of 1.5-2.5 kg/ha and that of Dividend with the dose of 2.0 kg/ha have provided equal efficiency.

The effect of AFM is obvious on the prevention of bunt and smut diseases in winter wheat and on the increase of its yield capacity. Moreover, its effect is already observed starting from the dose of 1.0 kg/ha and the final outcome is recorded in case of its administration with the dose of 2.0-2.5 kg/ha. That is, from the prospect of its efficiency the AFM dosage of 2.0-2.5 kg/ha is quite equal to 2 l/ha Dividend and thus, it can completely substitute Dividend. Besides, AFM exerts more positive effect on the plant growth and yield capacity.

This is related to the content of growth stimulants and nutrients in the fertilizer, which in their turn promote the increase of the seed sprouting capacity in the field and the further growing process of the plant; particularly, increase of the grain number in an ear, partial growth in the weight of 1000 grains are recorded, which results in higher yield capacity (Tueva, 1966, Fedotov, et al., 2006, Genkel, 1969, Chernovina, 1970). So, according to the data of Table 2, in the variant of background (control) the number of the grains in an ear makes 15.3 n, their weight is only 0.60 g, while the weight of 1000 grains – 39.2 g and the grain yield -17.6 c/ha. Whereas, in case of applying AFM on the background of $N_{90}P_{90}K_{60}$ the mentioned indicators depending on the usage dose of AFM have made 17.1-20.1 n, 0.68-0.81 g, 39.7-40.5 g, 23.4-29.0 c/ha respectively.

In case of using Dividend on the background of fertilization the grain number in an ear, its weight and the weight of 1000 grains partially stay behind the same indicators observed in the best variants where the seeds have been treated with AFM. As a result, the grain yield is also rather low making 27.1 c/ha, which is less than the same index recorded in the variant of AFM (2.0-2.5 kg/ha) by 1.7-1.9 c/ha. In case of applying AFM with the dose of 1.0-1.5 kg/ha the grain yield is 1.9-3.7 c/ha lower than that of recorded in the variant where Dividend has been applied. It should be added that in those variants where AFM has been administered there is still partial effect of wheat bunt disease.

Similar efficiency has been provided in the sruggle against the bunt and smut diseases upon the use of AFM in the croplands of spring barley, which consist of common black soils located at the Artik province in the steppe zone of Armenia.

The results obtained from the experiments are summed up in Tables 3, 4. As we can see from the table data the sprouting capacity of the seeds contaminated with bunt and smut diseases in common way and further growing process of the plants, the infectivity rate with the mentioned diseases and the yield amout are greatly related to the experimented variant.

So, according to the data of Table 3, the application of complex fertilizer AFM has had a favorable effect on the field sprouting capacity and growth of spring barley. The sprouting capacity has increased by 5.8 %-13.7 %, the stems height - by 6.1 %-10.2 %, while the number of spiciferous stems per unit area has increased by 2.8 %-4.1 %.

Table 3. The effect of AFM applied upon the fertilization background on the field sprouting capacity and plant growth in spring barley*

Variants	The number of seeds sown per 1m^2, n	The number of sprouted seeds, n	Field sprouting capacity, %	Plants height, cm	The number of spiciferous shoots per 1m^2, n
$N_{90}P_{90}K_{60}$ background (control)	500	342	68.4	49	319
Background + AFM 1.0 kg/ha	500	362	72.4	52	328
Background +AFM 1.5 kg/ha	500	378	75.6	53	331
Background +AFM 2.0 kg/ha	500	389	77.8	53	332
Background +AFM 2.5 kg/ha	500	388	77.6	54	332
Background +Dividend 2.0 l/ha	500	367	73.4	53	330

*Composed by the authors.

The effect of AFM on the prevention of infectivity with bunt and smut diseases of the spring barley is also quite obvious (Table 4). In the control variant the number of ears infected with bunt and smut per unit area makes 1.84-1.94 and 0.02-0.05 n, while in case of using AFM with the dose of 2.0-2.5 kg/ha the infectivity rate with the mentioned diseases are completely prevented. According to the data of Table 4 the impact of Dividend on the plant growth of spring barley is lower than that of AFM, which is surely related to the availability of nutrients and growth stimulants in the complex fertilizer.

The effect of AFM on the grain number and weight in an ear of spring barley and on the increase of its yield capacity is as follows: in the best variants where AFM has been administered the number of grains against the control variant has increased by 1.1 %-19.3 %, the weight – by 1.4 %-22.5 % and the weight of thousand grains has also partially grown up (Table 4).

The impact of AFM is more observable on the yield capacity of spring barley. So, if in the control variant the grain yield has made 22.8 c/ha and in the variant, where Dividend has been applied it is 27.0 c/ha, then in the variant where AFM has been used with the dose of 2.0-2.5 kg/ha it has made 28.6-28.9 c/ha.

The effect of the complex fertilizer (AFM) on combating the bunt and smut diseases has been also experimented for the winter wheat in conditions of vegetation trials. The seed material infected with bunt and smut at the Solak community was used, which was again contaminated with the spores of bunt in laboratory conditions. The soil was taken from the experimental plots of the Solak community. The holding capacity (bulk) of vegetation vessels used for the experiments made 6.5 kg air-dry soil.

The fertilizers were introduced at the time when the vessels were filled with soil. Ammonium saltpeter, double superphosphate and potassium chloride were applied. Twenty five seeds were sown in each vessel and after their sprouting only 15 were left. During the plant vegetation period observations and calculations were carried out. Harvesting process was organized per vessels.

The results received from the experiments (Table 5) indicate that the application effect of the fertilizers, AFM and Dividend on the growth of spring barley is noticeable starting from the germination phase up to the end of vegetation priod. So, the field sprouting capacity of the seeds is much lower in the control variant making 73.6 % and it is higher in the variants of $N_2P_2K_2 + AFM$ (0.67 %), $N_2P_2K_2 + AFM$ (0.83 %) and $N_2P_2K_2 + Dividend$ (1 %) - 83.6 %-86.0 %.

The application of fertilizers and AFM has promoted the plant growth as well. The height of barley plants makes only 29.6 cm in the control variant, while in the best experimental variants ($N_2P_2K_2 + AFM$ 0.67 %, $N_2P_2K_2 + AFM$ 0.83 % and $N_2P_2K_2 + Dividend$ 1 %) it amounts to 38.1-40.6 cm.

The impact of AFM and Dividend on the infectivity rate of the ears with bunt and smut diseases is vivid. So, in the control and $N_2P_2K_2$ variants the number of ears infected with wheat bunt makes 3.06-3.14 n, while that of infected with loose smut is 0.06-0.07 n.

Table 4. The effect of AFM applied upon the fertilization background on the mitigation of infectivity of spring barley with bunt and smut diseases and on its yield capacity*

Variants	The number of ears infected with wheat bunt per 1m², n	The number of ears infected with loose smut per 1m², n	The number of grains in an ear, n	The weight of grains in an ear, g	The weight of 1000 grains, g	The grain yield c/ha
$N_{90}P_{90}K_{60}$ background (control)	1.94	0.05	17.6	0.71	40.4	22.8
Background + AFM 1.0 kg/ha	1.81	0.02	17.8	0.72	40.4	23.5
Background +AFM 1.5 kg/ha	0.00	0.00	18.1	0.74	40.9	24.6
Background +AFM 2.0 kg/ha	0.00	0.00	21.0	0.87	41.4	28.9
Background +AFM 2.5 kg/ha	0.00	0.00	20.8	0.86	41.4	28.6
Background +Dividend 2.0 l/ha	0.00	0.00	18.2	0.78	40.6	27.0

*Composed by the authors.

Table 5. The effect of AFM on the gowth, grain yield and infectivity rate with bunt and smut disease of the winter wheat (Vegetation experiments)*

Variants	Field sprouting capacity of seeds, %	Plants height, cm	The number of seeds infected with bunt and smut diseases in a vessel, n		In an ear		The weight of 1000 grains, g	The grain yield, g/vessel
			Wheat bunt	Loose smut	The number of grains, n	The weight of grains, g		
$N_{90}P_{90}K_{60}$ background (control)	73.6	29.6	3.06	0.07	12.8	0.44	34.6	6.80
Background + AFM 1.0 kg/ha	74.0	37.4	3.14	0.06	15.3	0.57	37.3	8.98
Background +AFM 1.5 kg/ha	75.8	38.1	2.94	0.05	15.6	0.59	37.7	9.38
Background +AFM 2.0 kg/ha	83.6	40.4	0.04	0.00	18.6	0.76	40.8	12.42
Background +AFM 2.5 kg/ha	85.1	40.6	0.00	0.00	18.7	0.77	40.9	12.71
Background +Dividend 2.0 l/ha	86.0	38.6	0.00	0.00	18.3	0.72	36.5	11.77

*Composed by the authors.

Some bunt-stricken ears have been also observed when 0.5 % of AFM solution has been applied on the background of $N_2P_2K_2$. Whereas, when the seeds were soaked with 0.67 %-0.83 % AFM solution prior to sowing, no infected ears were recorded at all.

The favorable effect of AFM and Dividend on the barley growth and yield capacity has been manifested through the increase of grain number in an ear, weight of 1000 grains and grain yield. Thus, the grain yield in the contol variant has made 6.8 g/vessel, in $N_2P_2K_2$ variant it is 8.98 g/vessel, while in the variants of $N_2P_2K_2 + AFM$ (0.67 %) and $N_2P_2K_2 + AFM$ (0.83 %) it makes 12.42-12.71 g/vessel. The high yield in the mentioned variants is related to the macro- and micro-elements promoting the plant growth, as well as to the content of growth stimulants, which in their turn result in high yield production.

Conclusion

Wheat bunt and loose smut diseases are rather widespread not only throughout Armenia, but also in the cereal croplands of other countries causing huge amount of damage to the plant growing process and yield capacity.

Different fungicides are usually applied in the struggle against the mentioned diseases. Anyhow, they have toxic effect on humans, animals and useful soil-dwelling micro-organisms. They are also prohibited for the use in the organic agriculture.

A complex fungicidal organo-mineral fertilizer has been recommended by our research group to struggle against the diseases, namely alternative fungicidal means. It is manufactured through the processing of biogen diatomite rocks from the Sisian province and contains silicium, aluminum, calcium, magnesium, phosphorus and iron which is enriched with additional amount of macro- and micro-elements and humus materials. This fertilizer is allowed for the use in the organic agriculture.

The experiments have shown that by soaking the seeds of winter wheat and spring barley, including those infected with bunt and smut diseases, with the solution of AFM prior to sowing process or even earlier, their infectivity rate with the mentioned diseases is somehow prevented.

Standard amount for AFM application has been identified, according to which the seeds should be soaked with up to 97.8 %-100 % AFM solution, whereby the infection of winter wheat and spring barley ears with bunt and smut diseases can be prevented. Such effect for Dividend is observed in case of applying 99.6 %-100 % solution, nevertheless, AFM surpasses Dividend in terms of its impact on grain number in an ear (by 5.5 %-6.0 %), weight (by 6.6 %) and yield capacity (by 6.3-7.0 %).

Based on the experimental results it is recommended to use AFM for the struggle against the bunt and smut diseases in the croplands of winter wheat and spring barley. The standard dose of the mentioned fertilizer makes 1.5-2.0 kg for 300-320 kg seed material.

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