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DEVELOPMENT, PRODUCTIVITY AND QUALITY OF NAKED OAT GRAIN AFTER TREATMENT WITH BIOFERTILIZER IN THE CONDITIONS OF ORGANIC AGRICULTURE

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Abstract

The importance of oats as a healthy food for people is growing, and this draws attention to the production of environmentally friendly products, using environmentally friendly approaches and tools in agriculture. The study was conducted at the Demonstration Center for Organic Agriculture at the AU, Bulgaria during the 2013-2015 period. The aim of the study is the influence of biofertilizer Amalgerol on germination, development, productivity and some quality indicators of the grain in naked oats. Applied by seed treatment and vegetation on plants, increases the percentage of sprouted and harvested plants by 10% at a dose of 5 l/ha and by 13.4% at a dose of 10 l/ha. Amalgerol increases the weight of the grain from one plant in the adverse weather conditions of 2014 by 0.25 g to 0.30 g at different fertilization doses, as well as the weight of 1000 grains by 3.70 to 4.19% compared to the control. The effect on grain yield was positive by 17.26% at a dose of 5 l/ha and by 35.69% at a dose of 10 l/ha above the control. Amalgerol (10 l/ha) increases the hectolitre weight of the grain. There is more crude protein and crude fat in the grain in the unfertilized variant, and starch in the variants treated with Amalgerol (5 l/ha) - 51.18% and (10 l/ha) - 49.43%.

Key words*: naked oats, organic agriculture, organic fertilizer, grain yield.*

INTRODUCTION

Oats (*Avena sativa* L.) are becoming an increasingly attractive crop for Bulgarian agriculture. Its production is still insufficient to meet the needs of the market. Grain production is a major sector covering nearly 60% of the country's arable land and provides about 30% of the commodity production of the crop sector. The general vulnerability of production is determined by the strength of the negative impacts of climate change, globalization and regional integration, as well as by its adaptive capabilities (Alexiev A., 2008). In Bulgaria, oats are grown mainly for grain, as fodder for young animals and breeding animals. In countries with a tradition of oat production, special interest is in the multifaceted use of grain - for feed and human food (Cudderford, 1995). The good absorption of nutrients and vitamins in oatmeal make it particularly suitable for children's and dietary nutrition (Welch, 1995). In Bulgaria, oats are grown at about 50.000 ha and in recent years with the development of private agriculture there has been an increase in areas. Compliance with the conditions in the agroecosystem and agro-technological requirements of the culture is a basic prerequisite for the realization of high productive opportunities. The main points in the cultivation of oats are the observance of the term for sowing, the plant protection measures and the terms of harvesting. They are also leading for its successful cultivation in organic farming. The aim is to create varieties of oats suitable for the specific climatic and agro-ecological conditions of our country. As a result, new varieties of oats with high productive potential and ecological plasticity are created. Drought is the most important factor limiting grain production. The studies of a number of researchers are focused on studying the adaptation of new crop varieties to water stress in the conditions of increasingly prevailing extremely high air temperatures in the environment: 40-44°C (Slavov N. et al., 2000). In France, studies have focused on the length of growth periods, cold resistance, disease and their productivity in different agro-ecological regions of the country. As a result of a study by on sowing dates, it was found that plant deaths during the winter range from 48% to 50%. At the lowest crop density of 200 g.s./ m^2, the losses were greatest. The optimal sowing period according to the author is 20.IX. to 1.X., and the optimal density is 400 g.s/m². According the Chisinau region, the most suitable time for sowing is the middle of month IX. Research shows that the optimal sowing rates are different, depending on the different agro-ecological areas (Georgieva T. et al., 1994). According to organic and mineral fertilization significantly increases the yield of oats. In the study of other authors (Turkin A., 1987; Savova T., 2001) it is stated that the utilization rate of nitrogen varies sharply by year depending on rainfall and soil moisture, and in dry years it decreases, and in wet increases significantly to 60-90%. The research of show that nitrogen uptake with primary fertilization plays an important role in growth and development in the early stages of organogenesis. A similar effect from nitrogen nutrition and of precrop (Delibaltova V. et al., 2010) was reported in other cereals in another studyes (Neshev N. et al., 2018). In the Czech Republic, a study was conducted on the influence of climatic factors on oat yield (Tichy F. et al., 1992), as a result of which the closest correlation between grain yield was reported with the number of grains in the panicle. The yield is negatively affected by the high air temperatures in the period from germination to harvest. High temperatures for 5 days after the panicle emergence reduce the number of grains in the panicle (Tichy F. et al., 1992). In other experiments, the dependences of yield and agri-environmental factors are analyzed. The size of the yield is more influenced by the sowing period than the sowing rate. The sowing rate and sowing date affect the weight of the grain in the panicle. Absolute and hectolitre weight change significantly depending on the meteorological conditions in the individual years and to a lesser extent on the date of sowing and the sowing rate. Many of the studies with oats are focused on the biological manifestations and economic qualities of the grain intended for fodder (Georgieva T. et al., 1990; Georgieva, T. et al., 1994). The potential of wintering naked oats in Bulgaria has also been assessed, but it has low winter hardiness (Antonova N., 2005). The first spring naked oat variety Mina was registered in Bulgaria (Antonova N. et al., 1995), and in 2010 the first naked wintering oat variety was registered in the selection.

A connection has been established between early maturity and drought resistance - varieties with low and medium drought resistance avoid water stress by shortening the growing period (Savova T., 2002). Studies on fertilization have shown that oats respond to fertilization especially with nitrogen, which is characterized by strong growth and high yields (Savova T. et al., 2005). In organic farming, oats are suitable for growing due to stable grain yields even on nutrient-poor soils and the valuable nutritional qualities of the produce.

The interest in organic farming, improving the quality and yield of naked oats, obtaining ecologically clean products, provokes the purpose of this study.

MATERIALS AND METHODS

The experiment was conducted at the Demonstration Biological Farm at the Agroecological Center at the Agricultural University - Plovdiv, Bulgaria in the period 2013 and 2015. A two-factor field experiment using the block method in three replications with the size of the reporting plot 10.5 m^2 after the predecessor pepper was set. Amalgerol biofertilizer and Mina spring naked oats were used in the conditions of organic farming. Sowing was done with 600 g.s./m^2 in early March. The factors were studied: A - the influence of the year; B) biofertilizer: B1 - control - without fertilization; B2 - Amalgerol - pre-sowing treatment of the grain in a semi-wet way in a dose of 0.5 l/100 kg grain + two vegetation treatments in doses of 5 l/ha in phenophases: I - in: tillering - stem elongation; II: panicle emergence; B3 - Amalgerol - pre-sowing treatment of the grain in a semi-wet way in a dose of 10 l/100 kg grain + two vegetation treatments in doses of 10 l/ha in phenophases: I - in: tillering - stem elongation; II: panicle emergence. The indicators were studied: number of sprouted plants/m^2, duration of phenological phases, overal and productive tillering, elements of the panicle, mass of 1000 grains (g), hectolitre weight, kg/100 l grain, grain yield kg/ha. Biochemical parameters of the grain: content of crude protein (Keldal's method according to BSS 13490 in wheat), starch (by polygraph method as a percentage of

absolute dry matter), crude fat (according to BSS 3412).
Amalgerol - has a certificate and can be used in organic production according to Regulation (EC) 834/2007 and Regulation (EC) 889/2008. Statistical data processing was performed using SPSS V.9.0 for Microsoft Windows (SAS Institute Inc. 1999).

RESULTS AND DISCUSSIONS

The meteorological situation during the study period is relatively favorable for the development of spring oats. In general, the temperature values are above the norm during all months of the vegetation period, but the precipitation is unevenly distributed over months. The shift of sowing outside the optimal agro-technical terms (April) due to heavy rainfall in March 2014, does not reflect well on the development and overall oat yield.

1. Phenological development

During the study period, the development of oats took place in conditions of completely different meteorological years. During the first vegetation year 2013 the sowing was carried out in an optimal agro-technological term (March) and the plants germinate in 14 days in all variants (Table 1).

Table 1. Duration of the interphase periods and vegetation by years in days

Variants	Interphase periods								
	Sowing - Germinations	Germinations - 3-rd leaf	3-rd leaf – tillering	Tillering– Stem elongation	Stem elongation - Panicle emergence	Panicle emergence – milk ripeness	Milk ripeness – Wax ripeness	Wax ripeness – Ful ripeness	Vegetation duration
2013									
Control	14	13	6	21	22	12	14	16	118
Amalgerol 5	14	13	6	21	22	12	14	16	118
Amalgerol 10	14	13	6	21	22	12	14	16	118
2014									
Control	9	5	5	22	20	19	11	13	106
Amalgerol 5	9	5	5	22	20	19	11	13	106
Amalgerol 10	9	5	5	22	20	19	11	13	106
2015									
Control	13	10	5	20	22	11	12	15	108
Amalgerol 5	13	10	5	20	22	11	12	15	108
Amalgerol 10	13	10	5	20	22	11	12	15	108

19 days after sowing the plants enter the tillering phase, and another 21 days pass until the stem elongation phenophase. Panicle emergence occurs after 22 days, when the second vegetation treatment with Amalgerol is applied. Milk and wax ripeness pass in conditions of abundant rainfall and temperature values above the norm for the long term, which favors the normal nutrition of the grain in the panicle. Full ripeness occurs 118 days after sowing. In 2014, sowing was hampered by heavy rainfall in March and April. Germination occurs 9 days after sowing. Phenophase tillering occurs on day 19 and lasts 22 days. The period from panicle emergence to waxy ripeness passes at high temperatures, which adversely affects the pollination and subsequent pouring and feeding of the grain. The duration of these periods is 26 days. Full ripeness occurs 106 days after sowing. The plants provide the necessary number of days for development, but due to the delayed sowing and the shift of the vegetation to the unfavorable warmer months of the year, the interphase periods are greatly shortened, which adversely affects the yield.
In 2015 the meteorological conditions are close to those of 2013. The plants germinate in 13 days and the duration of the vegetation is 108 days.
From our observations on the variants treated with Amalgerol at a dose of 5 l/ha and Amalgerol at a dose of 10 l/ha, no effect on the duration of the interphase periods compared to the untreated control was found.

2. Number of germinated and harvested plants

Ensuring a normal number of germinated plants is the first step in forming a normally, with optimal number of plants per dka, crop (Table 2). During the study period, the plants germinated normally with over 500 pieces per m^2. All variants germinate with between 561 and 570 plants/m^2 which determines the good sowing density. Although there is no statistically proven difference between the fertilization and control variants, the highest percentage of sprouted plants compared to the sowing rate was reported in the variant treated with Amalgerol - 5 l/ha - 95%, which is 1.48% above the untreated control.

Table 2. Number of germinated and number of harvested plants by variants on average for the study period

Variants	Number of germinated plants/m^2	% relative to sowing rate	% relative to contol	Number of harvested plants/m^2	% relative to germinated	% relative to contol
Control	561.66a	93.61	0	378.33b	67.36	0
Amalgerol 5	570.00a	95.00	1.48	422.67ab	74.15	10.08
Amalgerol 10	563.66a	93.94	0.4	430.67a	76.40	13.42

*Means followed by the same letter are not statistically different ($P<0.05$) by Duncan's multiple range test

A positive effect of seed treatment before sowing with Amalgerol is possible.

During the vegetation, a reduction in the number of plants was observed, harvesting 378 plants/m^2 (67.36%) in the untreated control variant to 431 plants/m^2 (76.4%) of the germinated in the variant treated with Amalgerol – 10 l/ha.

This difference compared to the control is statistically proven and the treatment with Amalgerol - 10 l/ha has been proven to increase the number of harvested plants per ha. There is a percentage increase in the treated variant with Amalgerol 5 l/ha - 74.15% compared to the control (67.36%), but this difference is not proven statistically.

3. Tillering

One of the indicators that strongly influence the yield is the overall and productive tillering of the variety (Savova et al., 2005).

From the data in Table 3 there is a slight increase in the number of overall and productive tillering in both treatment options with Amalgerol, better expressed during the unfavorable for the development of oats 2014.

This fact is explained by the stimulating effect of the applied organic fertilizer Amalgerol.

Table 3. Overall and productive tillering (number of tillers/plant)

Variants	Overall tillering			Average	Productive tillering			Average
	Year				Year			
	2013	2014	2015		2013	2014	2015	
Control	1	1	1	1	1	1	1	1
Amalgerol 5	1.01	1.2	1	1.06	1.1	1	1	1.03
Amalgerol 10	1	1	1.1	1.02	1	1	1.1	1.02

4. Structural elements of the panicle

The structural elements of the yield associated with the panicle directly affect the grain yield (Table 4). In 2013, the formation of a longer panicle length was observed during treatment with Amalgerol, respectively by 3.65 cm for Amalgerol - 5 l/ha to 11 cm for Amalgerol - 10 l/ha, compared to the control. A higher value of the other indicators of the panicle is reported.

As a final result, the weight of the grain in the panicle was increased in the treated variants by 0.19 g for the Amalgerol 10 l/ha variant to 0.44 g for the Amalgerol 5 l/ha variant, compared to the untreated control. In the second year of the study, a longer panicle length was again reported by 2.20 cm for the Amalgerol 5 l/ha variant, up to 10.31 cm for the Amalgerol 10 l/ha variant compared to the control.

Table 4. Elements of the panicle by variants in the study period

Variants	Panicle length (cm)	Number of grains in a panicle	Grain weight in a panicle (g)	Grain weight of one plant (g)
2013				
Control	11.33	16.57	0.33	0.33
Amalgerol 5	14.98	36.20	0.74	0.77
Amalgerol 10	22.33	22.67	0.52	0.52
2014				
Control	10.01	10.02	0.20	0.20
Amalgerol 5	12.21	21.20	0.45	0.45
Amalgerol 10	20.32	22.11	0.50	0.50
2015				
Control	11.12	20.51	0.35	0.35
Amalgerol 5	13.65	35.21	0.61	0.61
Amalgerol 10	19.24	38.67	0.67	0.67
Average for the period				
Control	10.82c	15.7b	0.29b	0.29b
Amalgerol 5	13.61b	30.87a	0.60a	0.61a
Amalgerol 10	20.63a	27.72a	0.56a	0.56a

*Means followed by the same letter are not statistically different ($P<0.05$) by Duncan's multiple range test

The values of the other indicators are also higher. Same trend was observed in the third year of the study. On average for the study period, treatment with Amalgerol at a dose of 10 l/ha has been shown to increase the length of the panicle compared to other variants - 20.63 cm. The positive effect of treatment with Amalgerol to increase the values of number of grains, grain weight in a panicle and grain weight per plant has been proven.

5. Grain yield, kg/ha

The years of research differ categorically from each other, with more favorable meteorological conditions for the formation of high yields in 2013. The data in table shows that the conditions of the year are a strong factor determining the yield. With a proven highest grain yield is 2013 - 1265.5 kg/ha and 2015 - 1182.5 kg/ha between which there is no proven difference, and with a proven lowest yield is 2014 - 809.8 kg/ha (Table 5).

The independent effect of Amalgerol biofertilizer is also proved statistically, as higher yields were reported when treated with a dose of 10 l/ha - 1252.5 kg/ha.

The yield values in the year vary, as they are proven to be higher when fertilizing with a higher dose in 2013 - 1485.7 kg/ha and 2014 - 911.8 kg/ha compared to other variant.

Table 5. Influence of the year and organic fertilizer on grain yield by years and average for the study period, kg/ha

Influence of year factor on yield	
2013	1265.5a
2014	809.8b
2015	1182.5a
Influence of biofertilizer factor on yield	
Control	942.6b
Amalgerol 5	1105.3ab
Amalgerol 10	1252.5a

Variant	2013		2014		2015		Average for the period, kg/ha	Average % relative to control
	Grain yield, kg/ha	% relative to control	Grain yield, kg/ha	% relative to control	Grain yield, kg/ha	% relative to control		
Control	1066.6 c	100	709.2 b	100	1052.1a	100	942.6b	100
Amalgerol 5	1244.2 b	117	808.5 b	114	1263.2a	120	1105.3ab	117.26
Amalgerol 10	1485.7 a	139	911.8 a	128	1439.8a	142	1279.1a	135.69

*Means followed by the same letter are not statistically different ($P<0.05$) by Duncan's multiple range test

In 2015, no proven difference between the variants in the study was found, although the two variants of fertilization with Amalgerol achieved higher yields compared to the untreated control. Another study found positive economic efficiency of the application of Amalgerol in wheat in organic farming (Atanasov D. et al., 2020).

On average over the study period, a higher grain yield was reported in the Amalgerol-treated variants compared to the control, by 17% for Amalgerol 5 l/ha and 35% for Amalgerol at a dose of 10 l/ha, respectively. We have a proven difference with increase compared to the control in the variant treated with Amalgerol 10 l/ha - 1279.1 kg/ha. It can be summarized that the treatment with biofertilizer Amalgerol has been proven to increase grain yield in naked oats Mina.

6. Mass of 1000 grains, g

The results in Table 6 show that the conditions of the year have a strong influence on the seed mass index. With proven most favorable conditions for the realization of higher values of the indicator are 2013 (22.01 g) and 2015 (21.95 g) years compared to 2014.

Table 6. Mass per 1000 grains by variants and years

Influence of year factor	
2013	22.01a
2014	20.80b
2015	21.95a

Variant	2013		2014		2015		Average for the period, g
	(g)	Rank , %	(g)	Rank , %	(g)	Rank , %	
Control	22.37 a	100.00	20.27 a	100.00	21.53a	100.00	21.38a
Amalgerol 5	22.00 a	98.34	21.02 a	103.70	22.15a	102.88	21.72a
Amalgerol 10	21.66 a	96.83	21.12 a	104.19	22.17a	102.97	21.64a

*Means followed by the same letter are not statistically different ($P<0.05$) by Duncan's multiple range test

Within the year the values vary and no proven differences between the options are found. On average for the study period, the values of the indicator are close - from 21.38 g in the unfertilized control to 21.72 g in the variant treated with Amalgerol at a dose of 5 l/ha, and no proven difference was found.

7. Hectolitre weight, kg

The hectoliter weight serves as a guide for the potential yield and quality or the so-called grain flour yield. In 2013, with the largest hectolitre weight of 97.55 kg was the variant treated with Amalgerol at a dose of 10 l/ha, and between the variant Amalgerol 5 l/ha and the control, the difference was 0.11% in favor of Amalgerol. During the second and third years of the study, a higher hectolitre weight was again observed when treated with Amalgerol at a dose of 10 l/ha (Table 7).

From the obtained results on average for the period, it can be said that fertilization with Amalgerol at a dose of 10 l/ha has been proven to increase the hectolitre weight of grain in the variety Mina - 96.78 kg (by 2.29% above the unfertilized control). At the lower treatment dose, the values of the indicator are close to the control.

Table 7. Hectolitre weight of grain, kg

Variant	2013	2014	2015	Average for the period	Rank, %
Control	94.48	94.94	94.42	94.61b	100
Amalgerol 5	94.58	94.30	94.70	94.53b	99.91
Amalgerol 10	97.55	96.44	96.35	96.78a	102.29

*Means followed by the same letter are not statistically different ($P<0.05$) by Duncan's multiple range test

8. Content of crude protein, starch and fat in the grain. Although with small differences, the highest crude protein content was reported in the control - 15.22%, followed by the variant treated with Amalgerol at a dose of 10 l/ha (14.38%) (Table 8). The grain in the variant treated with Amalgerol at a dose of 5 l/ha has a lower protein content, it has the highest starch content (51.18%), followed by the control. In terms of fat content in the grain, the control variant has the highest value - 7.92%, followed by the variant with a lower fertilization dose, and the lowest is the fat content in the fertilization variant Amalgerol 10 l/ha. Although there are no major differences between the fat content options, low values of this indicator are important for longer grain storage. From the data for the chemical analysis of the grain obtained from organic cultivation of the variety it can be seen that the grain has quality indicators close to those obtained from conventional cultivation of the same variety (Geogieva T. et al., 2011). This confirms the possibility of obtaining environmentally friendly, quality products using Amalgerol in organic farming.

Table 8. Content of crude protein, starch and crude fat by variants

Variant	Absolutely dry matteri, %	Results to absolute dry matter, %		
		Crude protein	Starch	Crude fat
Control	89.90	15.22	48.87	7.92
Amalgerol 5	90.32	13.69	51.18	7.81
Amalgerol 10	90.03	14.38	49.43	7.53

CONCLUSIONS

There are no differences in the duration of the interphase period in the variety Mina after application of biofertilizer Amalgerol in the studied doses. The treatment of the seeds before sowing with Amalgerol leads to an increase in the percentage of sprouted plants, and applied and vegetatively increases the percentage of harvested plants by 10% at a dose of 5 l and by 13.4% at a dose of 10 l/ha. At the higher fertilization dose, the difference was statistically proven compared to the control. Amalgerol has been shown to increase grain weight per plant by 0.32 g at 5 l/ha and 0.27 g at 10 l/ha. The positive effect for increasing the grain yield after application of Amalgerol by an average of 17% at a dose of 5 l/ha and by 35% at a dose of 10 l/ha in the conditions of organic farming has been proven. By increasing the dose of Amalgerol, the mass of 1000 grains increases, but this is not proven. Treatment with a dose of 10 l/ha has been shown to increase the hectoliter weight of the grain - 96.8 kg compared to 94.6 kg for the control. Between the variants with Amalgerol in doses of 5 and 10 l/ha, the differences in the content of crude protein, starch and fat in the grain of the Mina variety are insignificant. The highest amount of crude protein and crude fat is in the control variant, and starch in the variants treated with Amalgerol 5 and 10 l/ha, respect-tively 51.18% and 49.43%.

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