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STUDY OF THE EFFECT OF FERTILIZATION AND SOWING RATES ON THE YIELD CAPACITY OF DENI DURUM WHEAT

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Abstract

At the Experimental and Implementation Base of the Agricultural University of Plovdiv, Bulgaria, a field experiment was conducted to determine the impact of two factors on the yield of Deni durum wheat. Four levels ($N_0P_0K_0$; $N_{60}P_{40}K_0$; $N_{120}P_{80}K_0$; $N_{180}P_{120}K_{60}$/ha) were tested for fertilization rate, being Factor A, and three levels (400, 500, 600 germinating seeds per m^2) were tested for sowing rate, being B. The experiment was performed after the precursor of rapeseed by the method of fractional plots in four repetitions during the period 2015 - 2018. As a result of the experiment, it was proved that: Deni wheat durum wheat shows its yield capacity to the greatest extent under the soil and climatic conditions of Plovdiv region when grown with fertilization rate: $N_{120}P_{80}K_0$ and sowing rate of 500 germinating seeds m^2. Grain yield increased from 3.29 t/ha to 4.75 t/ha or an average of 4.02 t/ha (13.6%) over the three-year experimental period 2015-2018. Structural elements of the yield, i.e. productive bushiness, number of spikelets, number of grains and mass of grains in the wheat-ear have the highest values at fertilization level with $N_{120}P_{80}K_0$ and sowing rate of 500 germinating seeds per m^2.

Key words: *durum wheat, fertilization rates, sowing rates, yield capacity.*

INTRODUCTION

Sowing rate is an important factor on which grain yield and grain quality depend. More and more manufacturers consider this factor as an instrument for maximizing profits. Subject to all technological practices, if optimal germination and spouting of the sown land is not achieved, maximum yield of good quality would be difficult to obtain, and even if the optimal sowing rate for dry years was determined, it would not be the same if the year is a wet one. A precautionary measure against lodging of the crops is to ensure optimal germination and sprouting of the plants, ensuring uniformity and moderate growth. The favourable distribution of plants on the nutritional surface leads to a better supply of light, water and nutrients. In very dense crops, the plants are depressed and yields are unsatisfactory, and in sparse crops, due to insufficient use of nutritional resources, less yields are obtained by the varieties compared to the potential yields. The issue of optimum density is up to date for every new variety at the appropriate place of cultivation.

Lloveras et al. (2004) determine sowing density as a factor of practical importance for durum wheat production since it can be controlled and recommend optimal sowing rates for the Mediterranean region from 371 to 508 germinating seeds/m^2.

Of all the components of the yield, sowing rate has the least effect on the mass of the grains in the ear according to Ozturk et al. (2006). The same author found an increase of 10% in the number of grains in the ear with decreasing the sowing rate from 625 to 325 germinating seeds/m^2.

In Diyarbakir, the effect of sowing rates of 50, 150, 250, 350, 450 and 550 germinating seeds/m^2 on the yield and its elements of the Aydin 93 and Firat 93 durum wheat varieties was studied. The highest productivity of 5102 kg/ha was obtained at a sowing rate of 250 germinating seeds/m^2, which is determined to be optimal (Kilic et al., 2010).

An experiment was conducted in Poland (Bobrecka-Jamro et al., 2013) with winter wheat of the Rywalka variety, in the years 2008/2009, 2009/2010 and 2010/2011 on a farm located in south-eastern Poland. It was fertilized with nitrogen rates of 40 to 120 kg/ha and foliar application compared to the control crops without nitrogen fertilization. Winter wheat production of the Rywalka variety has varied over the years of study. The highest yield was obtained after administration of nitrogen at a dose 120 kg/ha.

The concentrations of nitrogen, phosphorus and potassium in nine malting barley genotypes grown at four nitrogen levels 0, 40, 80, 120 kg N/ha were studied under a field fertilizing experiment. Genotypic reaction in regard to crude protein concentrations was stronger at unfertilized plants and it was considerably varying from 7.0% ("Kristi" and "70412296") to 10.0% ("2390300"). The higher nitrogen levels (N_{80} and N_{120}) led to similar values of grain crude protein in studied barley genotypes (Kostadinova et al., 2012).

A field experiment was carried out on the experimental field of Field Crop Institute, Chirpan, during the period 2004-2007 the following varieties were studied: Progres, Neptun 2, Beloslava, Saturn 1 and Vozhod under four norms of nitrogen fertilization - N_0, N_6, N_{12}, N_{18} kg/da. The results showed that nitrogen fertilization is a factor with a strong influence on the formation of leaf area of durum wheat. Compared with the impact of the variety, the effect of nitrogen fertilization on leaf area formation of durum wheat is more pronounced in the three phenological phases (spindling, ear formation and lactic ripeness). (Semkova and Saldzhiev, 2014). No research has been conducted on certain technology elements of the new Deni variety durum wheat. With this study we set ourselves the goal of establishing the optimum values of mineral fertilization and sowing rate for the cultivation of Deni variety durum wheat.

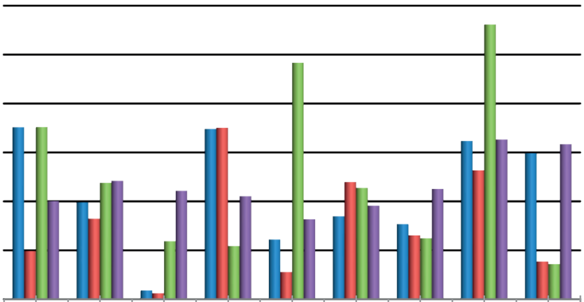
MATERIALS AND METHODS

The study was conducted in the period 2015-2018 in the Study, Experimental and Implementation base of the Agricultural University of Plovdiv using the method of fractional plots, repeated four times, with the size of the harvest plot of 15 m^2. The nutrient content of the soil in the layer up to 20 cm was respectively: N – 23.5 mg/1000 g, P2O5 - 39.3 mg/100 g, K_2O - 27.5 mg/100 g, humus 2.19%, CaCO3 - 7.3% (Popova et al., 2010).

We investigated the effect of two factors on the productivity of Deni durum wheat. Four levels ($N_0P_0K_0$; $N_{60}P_{40}K_0$; $N_{120}P_{80}K_0$; $N_{180}P_{120}K_{60}$ kg/ha) were tested for factor A - fertilization, and three levels (400, 500, 600 germinating seeds per m^2) were tested for factor B. The experiment was carried out after the precursor rapeseed by the method of fractional plots, repeated four times during the period 2015-2018.Durum wheat was grown after rapeseed as a precursor. For the variants with phosphorus fertilizers - 40, 80 and 120 kg/ha (the total amount of superphosphate) and the variants fertilized with potassium 60 kg/ha (the total amount of potassium sulphate), the fertilizers were introduced during the pre-sowing soil processing, while the nitrogen fertilizer (ammonium nitrate) - 1/3 of the quantity before sowing and the remaining 2/3 in early spring as nourishment. Sowing was carried out during the optimal for southern Bulgaria period from 20^{th} October to 5^{th} November. Weed, disease and pest control was carried out according to the established cultivation technology (Yanev et al., 2008).

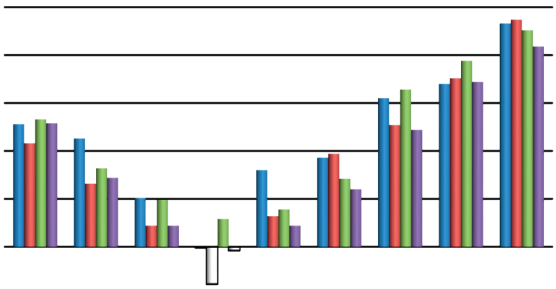
RESULTS AND DISCUSSIONS

During the growing season of durum wheat, the amount of rainfall was as follows: 2015/2016 - 396.5 mm, 2016/2017 - 278.3 mm/m^2, 2017/2018 - 457.2 mm/m^2, compared to the climatic norm of 419,6 mm/m^2 (Figure 1 and Figure 2). The total rainfall in the second year of the experiment is less than the climatic norm, but the harvest year of 2016/2017 was more favourable for the growth and development of durum wheat due to its better distribution during the critical stages of development of the plants and then the values of the structural elements of the yield were higher in the Deni variety. Adverse to the development of plants is the harvest year 2015-2016 due to the less rainfall during the period from February to June compared to the climatic norm, which had a negative impact on the productivity of durum wheat.



	X	XI	XII	I	II	III	IV	V	VI
2015-2016	70,3	39,6	3,6	69,6	24,4	33,9	30,7	64,7	59,7
2016-2017	19,7	32,9	2,4	70,1	11,1	47,9	26,1	52,7	15,4
2017-2018	70,4	47,6	23,7	21,7	96,7	45,5	24,9	112,3	14,4
Climatic norm	40,1	48,4	44,3	42,1	32,7	38,2	45,1	65,3	63,4

Figure 1. Precipitation by months, sum mm/m^2



	X	XI	XII	I	II	III	IV	V	VI
2015-2016	12,8	11,3	5,1	-0,1	8	9,3	15,5	17	23,3
2016-2017	10,8	6,6	2,2	-3,9	3,2	9,7	12,7	17,6	23,7
2017-2018	13,3	8,2	4,9	2,9	3,9	7,1	16,4	19,4	22,6
Climatic norm	12,9	7,2	2,2	-0,4	2,2	6	12,2	17,2	20,9

Figure 2. Monthly temperatures (average)

Plant development by phenophases

Individual phenophases were reported for 75% of the plants. The occurrence of phenophases in the Deni variety is presented in Table 1. What will be the duration of the period between the phenophases from sowing to germination depends on the amount of rainfall before sowing, but is also affected by the air temperature, with higher average daily temperatures causing faster and united sprouting of wheat.

Table 1. Plant development by phenophases (2015-2018)

Plant development by phenophases	2015-2016	2016-2017	2017-2018
Sowing	20.10	21.10	26.10
Sprouting	31.10	29.10	06.11
3rdleaf	18.11	16.11	24.11
Tillering	10.03	07.03	12.03
Shooting-up	14.04	05.04	09.04
Ear formation	08.05	03.05	08.05
Ripening	02.07	31.06	04.07

What will be the duration of the period between the phenophases from sowing to germination depends on the amount of rainfall before sowing, but is also affected by the air temperature, with higher average daily temperatures causing faster and united sprouting of wheat.

In the autumn of 2015, the amount of rainfall of 70.3 mm in October increased the soil moisture reserves and the sowing of durum wheat was carried out on 20.10.2015 (Table 1). This rainfall, as well as higher temperatures compared to the multiannual period of time (Figure 1 and Figure 2) were sufficient for germination of seeds and plants sprouted on 31.10.2015. The plants entered the tillering phenophase (autumn) on 18.11.2015. The average monthly temperatures in November and December were respectively by 4.10°C and 2.90°C higher than the monthly average norm, but as a result of the smaller amount of precipitation respectively by 8.8 mm and 40.7 mm, they had a retarding effect on the growth and development of durum wheat. Gradually, with the decrease in temperatures in the second and third 10-day periods of December, the growth processes in durum wheat also subsided. In January, the amount of precipitation was higher by 27.5 mm, while in February and March was less by 8.3 mm and 4.3 mm than the norm for the multiannual period. The month of February was also characterized by higher average monthly temperatures of 8.00°C (compared to 2.20°C in February for an average of thirty years), but the plants were in winter rest. During the first ten days of March, as the temperature rose, the plants resumed their vegetation. Rainfall in April was by 14.4 mm below the norm and this deferred the growth of durum wheat. Rainfall in May and June was less than the norm by 0.6 mm and 3.7 mm, respectively, while the average monthly temperature in June was by 2.4°C higher than the norm, which led to accelerated development of durum wheat. The grain filling and ripening phases occurred under favourable conditions of rainfall. Harvesting of durum wheat was carried out on 02.07.2016.

Under the climatic conditions of Central Southern Bulgaria, varieties that complete their growing season faster have the advantage of avoiding the later hot periods, and this could indicate good adaptability of Deni variety to be grown in Plovdiv region. The longer growing season of a wheat variety means higher yields unless grain filling occurs in extreme drought.

At high temperatures and water deficiency, factors known to accelerate phenophase development, it takes several days less to undergo the respective phenophase (Garsia del Moral et al., 1991). The same author (Garsia del Moral et al., 1991) found that a longer period of grain formation had a positive effect on obtaining more grains.

Adverse factors have the greatest effect on plants through the phenophase of ear formation when the processes of gametogenesis are completing and the pollen and ova are formed. The data in Table 2 shows the duration of the interphase periods expressed in number of days, the sum of active and average t°C for the occurrence of the individual phases in 2015-2016.

Table 2. Duration, temperature sum and precipitation during interphase periods (2015-2016)

Year	Interphase periods	Number of days	∑ *t active*, ºC	*t average*, ºC	Rainfall, mm/m^2
2015 - 2016	Sowing - sprouting	12	116.9	9.74	39.6
	Sprouting - 3rdleaf	19	225.1	11.85	0.0
	3rd leaf - tillering	113	688.7	5.65	145.0
	Tillering - shooting up	36	399.7	11.1	45.0
	Shooting up - ear formation	25	373.6	14.9	35.7
	Ear formation - ripening	57	1187.0	20.82	103.9

The sprouting of plants occurs in 12 days at the sum of active temperatures t°C - 116.9°C, and at an average temperature of 9.74°C with a rainfall for the period of 39.6 mm. The interphase period of "sprouting - 3rd leaf" runs for 19 days at a temperature sum of 225.1°C, an average temperature for the period 11.85°C, and quantity of rainfall of 0.0 mm. The longest is the duration of period "3rd leaf - tillering", 113 days, with the sum of active temperatures 688.7°C. The average temperatures t°C for the period are 5.65°C and the rainfall quantity is 145.0 mm. The interphase period "tillering-shooting up" is 36 days. The sum of active temperatures is 399.7°C. The average temperatures are 11.1°C and the quantity of rainfall is 45.0 mm. The duration of the interphase period "shooting up - ear formation" is 25 days. It occurs at a sum of active temperatures of 373.6°C, and quantity of rainfall of 35.7 mm. The average temperature t°C for the period is 14.9°C. The period between the phenophases of "ear formation-ripening" takes 57 days, at a sum of the active temperatures of 1187.0°C, and the average temperature for the period and the rainfall quantity are 20.82°C and 103.9 mm, respectively. The vegetation period of the Deni variety wheat is 262 days.

In the autumn of 2016, the rainfall quantity of 19.7 mm in October was by 33.3 mm less than the average for the multiannual period (Table 2) and hindered the additional soil processing before sowing. The sowing of wheat took place on 21.10.2016. The rainfall quantity in November was less by 17.1 mm compared to the thirty-year period, but sufficient (Figure 1) for germination of seeds, and plants sprouted on 29.10.2016. In December, the rainfall quantity was only 2.4 mm, which is by 43.6 mm less than the multiannual period, and gradually with the decrease of temperatures during the second and third 10-day period of November, the growth processes in wheat also subsided. In early winter, wheat is in the third leaf phase and early tillering.

Table 3. Duration, temperature sum and precipitation during interphase periods (2016-2017)

Year	Interphase periods	Number of days	∑ *t active*, ºC	*t average*, ºC	Rainfall, mm/m^2
2016 - 2017	Sowing - sprouting	9	371.8	41.3	0.4
	Sprouting - 3rd leaf	19	174.3	9.17	9.5
	3rd leaf - tillering	113	238.3	2.11	113.6
	Tillering - shooting up	30	307.7	10.3	41.3
	Shooting up - ear formation	29	388.2	13.4	28.4
	Ear formation - ripening	59	1224.9	20.76	65.8

In January, precipitation (snow only) exceeded by 29.1 mm the multiannual norm, while in February it was less by 20.9 mm, and in March exceeded by 9.9 mm the multiannual norm. January was characterized by very low temperatures and their maintenance for a long time, the average temperature for January being -3.9°C compared to the norm of -0.4°C. The measured minimum temperature for this month was 18.40°C, the plants were in winter rest, and the presence of thick snow cover protected the plants from frost. During the third 10-day period of February, as the temperatures rose, the plants resumed their vegetation. Rainfall in April was by 14.9 mm less than the norm, which had a retarding effect on the growth of durum wheat. The rainfall quantity in May of 52.7 mm was approximately equal to the norm, while in June - by 45.6 mm less than the norm, while the average monthly temperature in May and June was around the norm. The grain filling and ripening phases took place under less favourable conditions of rainfall. Wheat was harvested on 31.06.2017. The vegetation period of Deni variety durum wheat was 259 days for the harvest year of 2016-2017.

Table 4. Duration, temperature sum and precipitation during interphase periods (2017-2018)

Year	Interphase periods	Number of days	∑ *t active*, ºC	*t average* , ºC	Rainfall mm/m^2
2017 - 2018	Sowing - sprouting	12	105.3	8.775	9.8
	Sprouting - 3rd leaf	19	169.1	8.9	16.6
	3rd leaf – tillering	110	338.0	3.07	180.0
	Tillering-shooting up	29	277.4	9.565	56.8
	Shooting up – ear formation	30	529.2	17.64	18.6
	Ear formation-ripening	58	1223.6	21.10	221.4

In the autumn of 2017, the rainfall quantity of 70.4 mm in October was by 30.3 mm more than the average for the multiannual period (Figure 1). This made it possible to carry out quality processing and optimum sowing. The sowing of the wheat took place on 26.10.2017. The rainfall in November was 47.6 mm, which is around the climatic norm for this month. This rainfall was sufficient for the optimal germination and sprouting of the seeds (Table 4). The plants sprouted on 06.11.2017.

In December, precipitation was 23.7 mm, which is by 20.6 mm less than the norm of the multiannual period, but completely enough due to the accumulation of soil moisture in the previous months. Gradually, with the decrease in temperatures, the wheat growing processes also subsided in January. In January, the amount of precipitation was 21.7 mm, which is less than the climatic norm for the period. However, in February the precipitation was 96.7 mm, which is 64 mm more than the norm for this month and in March by 7.3 mm more than the multiannual period norm. The month of January was characterized by high temperatures with warm days with around 10°C, and an average temperature for the month of 2.9°C (Figure 2). The plants were in winter rest, there was almost no snow. During the third 10-day period of February, as the temperature rose, the plants resumed their vegetation. Precipitation in April was by 20.2 mm below the norm. This did not affect the wheat, which was very-well developed during this period and was entering the shooting up phase. The amount of precipitation in May was a record for the period, 112.3 litres, which was by 47 mm more than the norm for the period. Despite the heavy rainfall, no diseases were observed. Precipitation decreased gradually in June and was 14.4 mm, which is by 49 mm below the norm, while the average monthly temperature in May and June was slightly above the norm. The grain filling and ripening phases occurred under favourable conditions of rainfall. The wheat was harvested on 04.07.2018. In the third year of the experiment the duration of the vegetation period was 258 days.

The data presented in Table 5 show that, with respect to the tested factor of the mineral fertilizer, the best productivity results are obtained at the level of $N_{120}P_{80}K_0$ kg/ha. The grain yield of durum wheat at the lower fertilization level is less, however satisfactory. Durum wheat productivity decreases at the highest fertilization level which is $N_{180}P_{120}K_{60}$ kg/ha.

Table 5. Grain yield, t/ha

Fertilization rate	Cannopy density, seed/m²	Years			Average (2015-2018)	
		2016	2017	2018	t/ha	%
		t/ha	t/ha	t/ha		
$N_0P_0K_0$	400	2.95	4.13	3.50	3.53	100.0
	500	3.15	4.21	3.55	3.64	103.1
	600	3.23	4.27	3.62	3.71	105.1
$N_{60}P_{40}K_0$	400	3.19	4.23	3.59	3.67	104.0
	500	3.28	4.31	3.67	3.75	106.2
	600	3.37	4.45	3.78	3.87	109.6
$N_{120}P_{80}K_0$	400	3.31	4.39	3.70	3.80	107.6
	500	3.39	4.60	4.05	4.01	113.6
	600	3.34	4.48	3.85	3.89	110.2
$N_{180}P_{120}K_{60}$	400	3.29	4.43	3.76	3.81	107.9
	500	3.20	4.35	3.63	3.73	105.7
	600	3.14	4.30	3.54	3.66	103.7

	A	B	AXB	A	B	AXB	A	B	AXB
GD 5%	22.3	34.1	50.8	27.1	39.3	48.1	25.2	42.6	61.7

With respect to the other factor tested, which is sowing rate, an increase in grain yield was observed at sowing with 600 germinating seeds/m², and mineral fertilization level of $N_{60}P_{40}K_0$ kg/ha, however at a sowing rate of 500 germinating seeds/m² and a fertilization level of $N_{120}P_{80}K_0$ kg/ha the highest yield increase was achieved. At a sowing rate of 400 germinating seeds/m², the highest fertilization rate of $N_{180}P_{120}K_{60}$ kg/ha is most appropriate.

The greatest increase of the yield of Deni variety durum wheat under the interaction of the tested factors is achieved with mineral fertilization level of $N_{120}P_{80}K_0$ kg/ha, and a sowing rate of 500 germinating seeds/m². The obtained greater quantity of yield in this variant is within the range from 80 kg/ha in 2016 to 350 kg/ha in 2018, or an average of 210 kg/ha (13.6%) over the three-year study period. Second comes, in terms of average figures, the variant treated with $N_{120}P_{80}K_0$ kg/ha, and a sowing rate of 600 germinating seeds kg/ha, and on third place is the variant with fertilization $N_{180}P_{120}K_{60}$ kg/ha, and a sowing rate respectively of 400 germinating seeds/m^2, as grain yield increased on average, respectively by 360 kg/ha (10.2 %), 280 kg/ha (7.9 %).

The higher grain yield of the aforementioned variants can be explained by the optimal combination of mineral fertilization and sowing rate, which in turn led to an increase in the values of some of the structural elements of the crops (Table 6).

Table 6. Structural elements of the yield (average for 2015-2018)

Fertilization	Cannopy density, seed/m^2	Productivity tillering	Spikelets per spike, number	Grains per spike, number	Mass of the grains per spike, g
$N_0P_0K_0$	400	1.5	18.6	38.2	1.85
	500	1.4	18.4	36.7	1.59
	600	1.2	17.7	34.3	1.44
$N_{60}P_{40}K_0$	400	2.0	19.5	39.7	1.94
	500	1.8	19.2	37.3	1.88
	600	1.6	18.5	36.9	1.69
$N_{120}P_{80}K_0$	400	2.3	20.2	40.9	2.04
	500	2.7	21.1	42.1	2.15
	600	2.4	18.7	37.8	1.53
$N_{180}P_{120}K_{60}$	400	2.5	19.9	40.6	1.99
	500	2.1	19.6	40.1	1.71
	600	1.7	18.9	37.2	1.50

The highest are the values of the structural elements of the yield, as follows: productive tillering capacity - 2.7 tillers, number of spikelets in and ear - 21.1 pcs, number of grains in an ear - 42.1pcs, and weight of grains in an ear - 2.15 g of Deni variety durum wheat are reported for the variant with mineral fertilization $N_{120}P_{80}K_0$ kg/ha and a sowing rate of 500 germinating seeds/m^2.

Increasing the sowing rate over 500 germinating seeds/m^2 and fertilizing with $N_{180}P_{120}K_{60}$ kg/ha does not lead to an increase in grain yield due to the excessive density of the crops and the high level of fertilization, which results in the plants lodging.

CONCLUSIONS

The highest grain yield of Deni variety durum wheat was obtained at the mineral fertilization level of $N_{120}P_{80}K_0$ kg/ha and the sowing rate of 500 germinating seeds/m^2, from 3.39 t/ha to 4.60 t/ha, or averagely for the three years - 4.01 t/ha, which is by 13.6% more than the control variant.

Under this level of fertilization and sowing rate, the highest values of the structural elements of the yield were obtained - productive tillering capacity - 2.7 pcs; number of spikelets in an ear - 21.1 pcs; number of grains in an ear - 42.1 pcs, and weight of grains in an ear - 2.15 g.

The growing period of Deni variety wheat durum wheat varies from 258 days to 262 days.

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