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RISK OF CULTIVATION AND EFFECT OF MINERAL FERTILIZATION ON WINTER OILSEED RAPE UNDER THE CONDITIONS OF NORTH-EAST BULGARIA

ABSTRACT

This investigation provides data from two field trials. During the period 1999-2002 a comparative investigation was carried out to test winter oilseed rape varieties Polo, Marita, Bor, Kana, Gara, Mar and Leo in order to select the most productive one to continue the studies on agronomic factors. During the period 2000-2004 a fertilization trial was initiated with variety Gara to investigate the rates and ratios of macro-fertilization (NPK) in winter oilseed rape under the conditions of Dobroudja region. Sixty combinations were studied as follows: 3 rates of fertilization with potassium (0, 40, and 80 kg $\times ha^{-1}$ K_2O), 4 rates of phosphorus fertilization (0, 40, and 120 kg$\times ha^{-1}$ P_2O_5), and 5 rates of nitrogen fertilization (0, 40, 120 and 160 kg $\times$ ha^{-1} N). During the 5-year period, in two of the years oilseed rape was not harvested. Two risk periods were established which limited the area for growing of oilseed rape in Bulgaria: August-September and the winter period. The sowing period was characterized with a risk of drought in 26.9% of the years, or by intensive rainfalls and formation of soil crust, both factors limiting the formation of a regular spatial pattern of the crop. The successful wintering of oilseed rape can not be ensured because in 34.6% of the years for a period of 52 years, days with air temperature -15^{o}C, or insufficient snow cover, were registered. The comparative testing of the oilseed rape varieties revealed that variety Gara showed the highest productivity and stability by years under the conditions of North-East Bulgaria. The other varieties did not differ by this criterion. The investigation on NPK-fertilization established that averaged for the rates of potassium and phosphorus fertilization, phosphorus was the factor with the highest effect on oilseed yield from rape up to rate N_{160}. The tendency towards significant differences according to the previous investigated rate continued up to rate N_{80} in dry years, and up to N_{120} in years with good moisture reserve. During the year with good moisture reserve, a well expressed effect from the independent use of phosphorus and potassium fertilization was established, as well as the interaction between nitrogen and phosphorus, and phosphorus and potassium, which implies the necessity of the obligatory presence of phosphorus in the fertilization rate with moderate doses (P_{80}). As a result from this, fertilization with $N_{120}P_{80}$ can be recommended as agronomically optimal under the conditions of Dobroudja region.

Key words: cultivation risk, fertilization, nitrogen, NorthEast Bulgaria, phosphorus, potassium, seed yield, variety, winter oilseed rape

INTRODUCTION

Growing of winter oilseed rape in Bulgaria started at the end of the 19th century and the maximum distribution of the crop was at the beginning of the 20th century with an area of about 6×10^4 ha. During the 30's of the last century oilseed rape was grown on about 10^4 ha, the area varying between 3 and 22×10^3 ha in the individual

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years as a consequence from the lost interest in its cultivation after years with 100% frost damage on the crops and due to unstable yields (Koedjikov *et al.*, 1977).

The region of Dobroudja was traditional for winter oilseed rape production in the past. By the end of the 40's and beginning of the 50's oilseed rape was gradually replaced by sunflower, which is a more reliable crop for the conditions of this region (Djelepov, 1996). In 1951, with the establishment of Dobroudja Agricultural Institute near General Toshevo, a state order was given to begin a research program on oilseed rape, which ended several years later because the crop was entirely replaced by sunflower.

During the 70's and 80's of the last century rape for seeds has been grown occasionally, the reported areas for the entire country being 15-30 ha, a large part of them for seed production, and the seeds were used to grow green fodder. The interest to the crop was renewed during the 90's when representatives of German seed producers and processing factories offered to Bulgarian farmers in this region free seeds and contracts for export.

However, the interest to oilseed rape is still insufficient and it is an alternative oleaginous crop. Therefore there are still not enough investigations on its growing under the conditions of Bulgaria.

The first agrotechnical trials in Dobroudja region showed that the optimal sowing date is 20-30 August, and the suitable design is a lane with 4 rows, 25 cm between the rows (Djelepov, 1996).

Stefanova (1990) investigated two "00" varieties and one "0" variety of winter oilseed rape under the conditions of Central North Bulgaria and for a period of 4 years established a mean yield from 3850 to 4320 $kg.ha^{-1}$. The sowing term was also studied there. The best wintering was found for the term of sowing after 30th August. The lowest crop density, being the result of frost damage, was found when the term of sowing exceeded 10th October. The recommended term of sowing should be between 20th August and mid-September. The optimal sowing norm for the above period was 6 $kg \times ha^{-1}$. Comparing winter and spring oilseed rape, the author gave preference to winter oilseed rape because plants utilized more efficiently autumn and winter precipitation and was not affected by summer high temperatures typical for the region.

The investigations of Stefanov and Gyurov (1985, 1986) carried out with "00" winter oilseed rape varieties confirm the high productivity of the crop under the conditions of Bulgaria and discuss some advantages of the oil with regard to its high oleic composition.

Delchev and Kostov (1997) identify the requirement of oilseed rape to mineral fertilization as close to that of winter wheat and recommend fertilization with $N_{180}PK$ for soils with low nitrogen reserves. The high requirements of oilseed rape to nitrogen need establishing the optimal rates in order to meet modern requirements of agriculture as formulated also by Jeuffer *et al.* (2002), namely: selecting genotypes with reduced needs of nitrogen fertilization; increasing or maintaining yield level when obtaining quality production and decreasing fertilization expenses; environmentally friendly usage of nitrogen fertilizers.

The present study is just one stage of the agronomical investigations on oilseed rape. Its goals and tasks are as follows:

(1) to analyze the risk of sowing, wintering and growing of winter oilseed rape in Dobroudja;
(2) to carry out comparative testing of several field-selection winter oilseed rape varieties; (3) to clarify the response of winter oilseed rape to rates and ratios of NPK-fertilization under conditions of slightly leached chernozems.

MATERIAL AND METHODS

During 1999-2004, two field trials were performed at Dobroudja Agricultural Institute – General Toshevo.

The first trial was sown in August 1999 with the aim to carry out comparative testing of 7 winter oilseed rape varieties bred by Małyszyn and Borowo, former Experimental Stations ofIHAR – Polo, Marita, Bor, Kana, Gara, Mar and Leo – to establish their suitability under the conditions of North-East Bulgaria.

The second trial was initiated early in the autumn of 2000 with variety Gara and continued for 4 years. Norms and ratios of NPK fertilization were investigated, testing the following 60 combinations of rates according to factors:

Factor A – Potassium fertilization - 0, 40 and 80 kg × ha^{-1} (K_2O);
Factor B – Phosphorus fertilization - 0, 40, 80 and 120 kg × ha^{-1} (P_2O_5);
Factor C – Nitrogen fertilization - 0, 40, 80, 120 and 160 kg × ha^{-1} (N).

Both trials were carried out after previous crop winter wheat fertilized with $N_{120}P_{100}$. After harvesting the previous crop and clearing the field from post-harvest residues and prior to pre-sowing ploughing, fertilization with triple super phosphate and potassium chloride was applied as follows: first trial - $P_{80}K_0$; second trial - according to the accepted methodology. Pre-sowing ploughing was done at depth 18 cm followed by triple disking. Sowing was done by a plot-sowing machine: at 12 cm distance between the rows in the first trial, and at distance 18 cm between the rows in the second trial; the sowing norm for both trials was 5 $kg.ha^{-1}$. Oilseed rape was fertilized with nitrogen before the beginning of spring vegetation, as follows: with N_{120} in the first trial and according to the accepted methodology in the second trial. Harvesting during 2000 and 2001 was done in two stages - mowing and thrashing, and during 2004 in one stage, the harvest plot being 12 m^2, in four replications. The change of the way of harvesting was based on our direct observations on the variety. They showed that the pods of variety Gara were resistant to dehiscence, which is an important character according to Bruce et. al (2001) with a view of mechanized harvesting of oilseed rape. This allowed to change to direct harvesting with a small plot harvester in the last year of the study.

The trials were representative for the conditions of the slightly leached chernozem soils in North-East Bulgaria. This soil type is characterized according to Yolevsky *et al.* (1959) by a comparatively powerful humus horizon (60-80 cm), medium humus type with 3.1-3.8% humus content in the ploughing layer, and neutral pH of the soil solution. By its content of macro-elements, this type of soil is characterized with moderate reserves of total nitrogen, with low reserves of total and mobile phosphorus and good reserves of total and mobile potassium. Concerning their physical composition, the slightly leached chernozems are sandy-clay soils with volume 1.3-1.4 g per cm^3, lower limit of available moisture 12.2-14.0%

and from an agro-physical point of view are considered some of the most fertile soils for growing of field crops in Bulgaria.

Geographically, the Dobroudja region is a plateau and the trial field is situated in its east plain at altitude 235 m (Georgiev, 1960). Climatically, it belongs to the north-east climatic region of the moderate-continental climatic part of Bulgaria (Sabev and Stanev, 1963). The mean annual air temperature is 10.9°C, and in July it is about 21°C. The deficiency in the moisture balance is 268 mm, and the highest absolute air temperatures during summer and winter are respectively higher or lower than in the rest plain areas in Bulgaria.

The meteorological data were provided by the Meteorological station on the territory of Dobroudja Agricultural Institute, and the climatic norms used are based on our previous publications (Tonev and Kostadinov, 2000).

RESULTS AND DISCUSSION

Abiotic conditions for growing of winter rape in Dobroudja region

Sowing of rape by years was done as follows: 17th August 1999; 5th September 2000; 14th September 2001; 10th September 2002; 26th August 2003. The sowing date of oilseed rape was within the optimal term, according to the recommendations mentioned previously, although it depended on the possibilities for soil tillage before sowing.

Germination of oilseed rape in the consecutive years depended directly on soil moisture influenced by the precipitation. Amount of precipitation in the consecutive years was shown in Table 1.

Table 1

Precipitation in August and September (within the years 1999-2003) by decades [mm]

Year	August			September		
	1-10	11-20	21-31	1-10	11-20	21-30
1999	5.8	0.5	31.6	181.4	7.3	0.1
2000	21.5	0.1	22.1	16.8	42.2	13.2
2001	0.0	0.1	14.3	14.5	14.7	0.1
2002	71.9	4.7	0.5	2.1	25.5	64.7
2003	19.7	12.8	4.4	5.7	110.3	0.0

The following peculiarities of germination and initial crop formation were established by years:

In the first and the last year the period of rape sprouting coincided with intensive and abundant rainfalls (total sum for the decades 181.4 and 110.3 mm) forming soil crust. Germination of most of the seeds was impeded and the crop remained of irregular spatial pattern.

Germination in the second year of the study (2002) was normal due to the favourable precipitation. It was followed by extreme drought during most of the vegetation period; in October and December the lowest precipitation sums for this region were registered - 5.7 and 1.5 mm (Fig 1). The percent of precipitation

sums according to the norm during the rest of the months were as follows: for the autumn-winter period (October - March) - 58.2%, and 50.8% for the period April-June;

Sowing of oilseed rape was late in 2001 because the summer was one of the driest in the region of Dobroudja, content of productive moisture in the 0-30 soil horizon was ~ 0 mm as early as the beginning of July, air temperatures were high and soil tillage lead to formation of dust. The rainfalls in September did not contribute to moisturizing of soil and to germination, both of oilseed rape and the winter crops; the precipitation sum for October was only 0.5 mm, and the rainfalls in November coincided with decrease of air temperatures. Germination of autumn crops began after the worming of the weather at the end of January, and oilseed rape never germinated.

The autumn conditions in 2002 were favourable for sowing and germination of oilseed rape, but the crops were frost-damaged during the first decade of December; the reasons for this will be considered bellow.

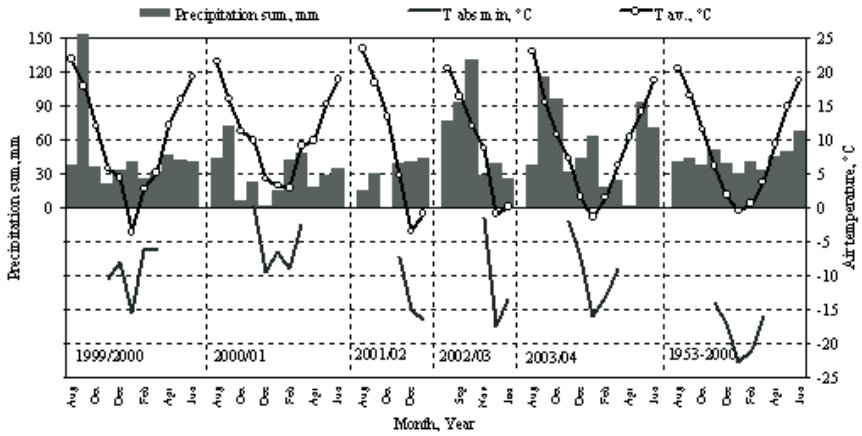

Fig. 1. Precipitation sum by months, absolute minimum, absolute maximum, and month air temperature for the period August-June (Note: the data for 2001/02 and 2003/04 are given to January)

These results show that the first limiting factor which makes growing of oilseed rape under the conditions of Dobroudja region risky, i.e. is a limiting factor for its distribution, is the insufficient moisture during the sowing period (August-September). The reasons for this are the low precipitation sum, as well as drying of soil after tillage when preparing it for sowing. When analyzing the precipitation sum during the three important decades (from 11 August to 10 September) for the period 1953-2004 (a total of 52 years), it became clear that in 14 years (26.9%) the sum was below 20 mm, which is insufficient to produce a crop with regular spatial pattern.

In parallel with this, when discussing the physical properties of slightly leached chernozem, the intensive and abundant rainfall should also be considered a risk factor because they lead to compactness of soil and forming of a soil crust. This kind of rainfalls are the reason for the irregular germination during two years of our investigation.

Winter frost damage is a risk factor for oilseed rape production under the conditions of North-East Bulgaria. This phenomenon was registered during our investigation in December 2002, when for several hours air temperature decreased from a positive value to -15.5 °C, the snow cover being insignificant. Due to the lack of hardening this caused almost 100% frost damage to barley and over 80% frost damage to wheat (Tonev *et al.*, 2003). During this cold weather oilseed rape was 100% frost-damaged.The unstable climate typical for this region may cause more serious frost damage on winter crops than in countries with more severe winters. The reason for this are not so much the extremely low air temperatures as the lack of snow cover. The region of North-East Bulgaria is characterized with constant winds, which, on the one hand give the impression of severe winters, and on the other hand cause wind erosion; additionally the winds affect the distribution of snow on the ground (Tonev and Iliev, 2005). Therefore a thickness of the snow cover less than 3 cm can not be considered protective since the wind dynamics leads to formation of snow mounds at the expense of baring large field areas.

Assuming that air temperature of -15°C is critical for wintering of oilseed rape, analysis was made on the risk of wintering of this crop under the conditions of Dobroudja region based on the data from the meteorological station on the territory of the Institute (Table 2).

Table 2

Frequency of the risk years for wintering oilseed rape under the conditions of North-East Bulgaria

Month	No of years with T_{min} below -15°C		Relative share of the risk [%]	
	Total	Lack of snow cover	Relatively to years with T_{min} below -15°C	Relatively to total number of years
December	6	2	33.3	3.8
January	18	12	66.7	23.1
February	12	6	50.0	11.5
March	2	-	-	-
November - March	28	18	64.3	34.6

The results showed that in 53.8% of the years air temperatures during the winter period dropped down to -15° C, and in 34.6% of them (1 of every 3 years) plants practically had no protective snow cover. Such conditions should be expected during January (one of every 4 years). Such frequency of risk is definitely high and is one of the main reasons for the decrease in the interest to this crop, which will probably be a stable tendency in the future. A conditional advantage can be considered the fact that frost damages in this crop can be detected in time (early spring) to repair them partially by ploughing the fields and sowing another crop.

Comparative testing of the productivity of oilseed rape varieties developed by Małyszyn and Borowo, former Experimental Stations of IHAR under the conditions of North-East Bulgaria.

The data on seed yield from the tested varieties are given in Table 3.

As previously pointed out, regardless of the fact that the trial was sown for 3 years, the results include a two-year period due to the lack of germination during the last year of the investigation.

Table 3

Seed yield from variety trial (years of harvest 2000 and 2001) [kg × ha^{-1}]

Variety	1999/2000		2000/01		Average	
	[kg × ha^{-1}]	%	[kg × ha^{-1}]	%	[kg × ha^{-1}]	%
Polo - *Control*	3384	100.0	1541	100.0	2463	100.0
Marita	3477	102.7	1541	100.0	2509	101.9
Bor	3267	96.5	1779*	115.4	2523	102.4
Kana	3230	95.4	1687	109.5	2459	99.8
Gara	3569	105.5	2145***	139.2	2857	116.0
Mar	3131	92.5	1810*	117.5	2471	100.3
Leo	3230	95.4	1706	110.7	2468	100.2
LSD at 5 %	1152		210		580	
1 %	1578		287		777	
0.1 %	2151		391		1020	

*, *** - Significant differences according to variety Polo at P = 5 and 0.1 %

Seed yield during the first year varied according to the genotype from 3131 kg × ha^{-1} (Mar) to 3569 kg × ha^{-1} (Gara). A peculiarity of these years was the formation of a relatively high yields from oilseed rape in spite of the low density of the crops. This high compensating ability of oilseed rape has been confirmed by other investigations, as well (Leach *et al.*, 1999); according to them oilseed rape shows a satisfactory productivity within the range of 50-150 plants per dka. It should be noted, however, that in a crop with low density, yields by replications varied highly and the difference between the highest and lowest yield as compared to mean yield was great, as follows: 73.0% of variety Polo, 51.9% of Marita, 49.9% of Bor, 45.1% of Kana, 76.1% of Gara, 22.9% of Mar, and 39.0% of Leo. This shows that the advantage of variety Gara is mainly at the expense of the yield from one of the replications and explains the high values of the significant differences calculated through dispersion analysis. Therefore the independent effect of the genotype expressed through the *F*-criteria was low ($F = 0.16^{NS}$).

The second year of the investigation was characterized with a low monthly precipitation sum during almost the entire period of oilseed rape vegetation and therefore seed yield was two times lower than the yield obtained in harvest year 2000. The yield varied from 1541 kg × ha^{-1} in varieties Polo and Marita to 2145 kg × ha^{-1} in variety Gara, and the relative differences between the replications were low. The independent effect of the genotype on yield value was well expressed ($F = 0.47^{***}$), and the significant differences of yield in comparison to the check variety were calculated for the varieties Bor, Gara and Mar.

Averaged for a period of 2 years, variety Gara realized the highest productivity and stability of results under the conditions of North-East Bulgaria. The other investigated varieties of winter oilseed rape gave an yield very close by mean value (between 2459 and 2523 kg.ha^{-1}) and conceded to variety Gara also by plasticity to the year conditions.

Responsiveness of winter oilseed rape to norms and ratios o NPK-fertilization under conditions of the slightly leached chernozem soil in Dobroudja region

During the first year of the investigation, when yield value was limited by a long drought, seed yield varied under the effect of mineral fertilization from 1884 to 2668 kg × ha^{-1}. Therefore the optimization of fertilization in this crop lead to a relative change of yield with 41.6%. Maximum yields were obtained from several variants, which allows to think that in dry years highest yields from oilseed rape may be obtained at fertilization with $N_{160}P_{40\text{-}120}K_{40\text{-}80}$. Obviously, the responsiveness of this crop to mineral fertilization is best expressed with regard to nitrogen.

During the last year of the study, which was the second year for this trial after the complete destruction by frost of the crops in the two previous years, and which was the most favourable with regard to moisture reserves, yields were two times higher. They varied under the effect of mineral fertilization from 3440 kg.ha^{-1} ($N_0P_0K_0$) to 5718 kg × ha^{-1} ($N_{160}P_{80}K_0$); the yields from the variants fertilized with $N_{160}P_{120}K_{40\text{-}80}$ were closest to the maximum yield. During the same year rape was more responsive to optimized mineral fertilization and the yield changed with up to 66.2%.

The considerable variation of mean yield as affected by the year conditions is typical for this region in contrast to regions with more stable climatic conditions (Stojtova *et al.*, 2001).

The averaged data for the period given in Table 4 show the following tendencies with regard to yield change under the effect of fertilization:

Table 4

Seed yield from oilseed rape according to the used NPK fertilization – average for 2 years, [kg × ha^{-1}]

Potassium rate	Phosphorus rate	Nitrogen rate				
		0	40	80	120	180
0	0	2667	2875	3452	3682	3910
	40	3006	3265	3591	3946	4101
	80	3026	3303	3798	3976	4137
	120	3026	3404	3682	3854	4060
40	0	2914	3137	3480	3690	4003
	40	2995	3305	3470	3785	3893
	80	3044	3403	3740	3893	4174
	120	3093	3572	3688	3979	4149
80	0	3040	3617	3939	4082	3960
	40	3067	3382	3815	3949	3879
	80	3101	3188	3759	4161	4004
	120	3114	3478	3708	3937	4124

Lowest yield was obtained without using any mineral fertilization (2667 kg × ha^{-1}), and the maximum yield was from the variant fertilized with $N_{160}P_{80}K_{40}$.

The tendencies characterizing the effect from the type of mineral fertilization showed that oilseed rape is highly responsive to nitrogen fertilization and requires moderate phosphorus and potassium dressing.

The independent nitrogen fertilization (without applying phosphorus and potassium) had a high effect on yield, increasing it proportionally to the increase of the nitrogen rate in the tested range from 2667 to 3910 kg × ha^{-1}, i.e. with 46.6%.

The independent phosphorus fertilization (at N_0K_0) also had a positive effect, though lower, up to rate P_{80}, to the amount of 13.5%.

The independent potassium fertilization also changed positively yield value up to rate K_{80} - from 2667 to 3040 kg × ha^{-1}, i.e. with 14.0%. This result was unexpected under the conditions of the chernozem soil which contain a good reserve of potassium and requires further investigations.

To clarify the significant correlations, a multi-factor dispersion analysis was carried out on the data for seed yield by years (Table 5).

Table 5

Results from the multi-factor dispersion analysis of yield

Fertili zation	LSD at::				Rates of fertilization [kg × ha^{-1}]				
	5 %	1 %	0.1 %	Criteria	0	40	80	120	160
				2000/01					
N	130	172	220	36.46***	1961	$+187^{B}$	$+530^{C}$	$+615^{C}$	$+639^{C}$
P	116	154	197	0.35^{NS}	2321	$+58^{NS}$	$+40^{NS}$	$+40^{NS}$	
K	101	133	170	0.9^{NS}	2314	$+65^{NS}$	$+61^{NS}$		
N × P				0.12^{NS}					
N × K				0.49^{NS}					
P × K				0.2^{NS}					
N × P × K				0.07^{NS}					
				2003/04					
N	217	287	367	47.66***	4022	$+484^{C}$	$+880^{C}$	$+1200^{C}$	$+1443^{C}$
P	194	257	328	3.46*	4672	$+130^{NS}$	$+281^{B}$	$+245^{A}$	
K	168	222	284	3.72*	4762	-9^{NS}	$+193^{A}$		
N × P				1.86*					
N × K				1.05NS					
P × K				3.86**					
N × P × K				0.47^{NS}					

Notes:
*,**,*** – Significant value of *F*-criteria at 5, 1 and 0,1 %, respectively
A,B,C – Significant differences, according to the control rate (0 $kg.ha^{-1}$) at 5, 1 and 0.1 %, respectively
NS – Not significant values of *F*-criteria and differences

Averaged for the investigated rates of phosphorus and potassium fertilization, nitrogen was the factor with an especially high effect on the oilseed rape yield value. Although seed yield increased up to rate N_{160}, it should be mentioned that the tendency towards significant differences according to the previous investigated rate continued up to fertilization with N_{80} during the dry year 2000/01, and up to N_{120} during the year with good moisture content. Therefore rate N_{120} should be considered optimal for the conditions of the slightly leached chernozems in Dobroudja.

During the year with good moisture reserve, a well expressed effect was established from the independent use of phosphorus and potassium, as well as interactions between nitrogen and phosphorus, and phosphorus and potassium. The interaction of phosphorus with the other macro elements made it important for balanced mineral fertilization of oilseed rape, as confirmed by other researchers, as well (Cheema *et al.*, 2001; Brennan and Bolland, 2001). This implies its obligatory involvement in the fertilization rate with moderate doses (P_{80}).

As a result from this analysis fertilization with $N_{120}P_{80}$ can be recommended as agronomically optimal for the conditions of Dobroudja region at the initial stage of the investigations on winter oilseed rape.

CONCLUSIONS

Two risky periods were determined which reduce the area of oilseed rape in Bulgaria: August - September and the winter period. The sowing period is characterized with risk of drought in 26.9% of the years or of intensive rainfalls forming soil crust during germination; both factors limit the formation of a regular spatial pattern of the crop.

The successful wintering of rape can not be ensured because in 34.6% of 52 years days with air temperature below -15°C were registered, with or without sufficient snow cover.

The comparative testing of the rape varieties established that variety Gara realized the highest productivity and stability by years under the conditions of North-East Bulgaria. The other varieties did not differ very much by this criterion.

The investigation on the NPK-fertilization found out that averaged for the tested rates of phosphorus and potassium fertilization nitrogen was the factor with highest effect on yield value up to rate N_{160}. The tendency toward statistically significant differences according to the previous investigated rate continued to fertilization with N_{80} during the dry year and to N_{120} in the year with good moisture content.

During the year with good moisture content a well expressed effect was established from the use of phosphorus and potassium independently, as well as interactions between nitrogen and phosphorus and phosphorus and potassium, which makes the involvement of phosphorus in the fertilization norm with moderated doses (P_{80}) necessary.

As a result from the investigations carried out fertilization with $N_{120}P_{80}$ can be recommended as agronomically optimal under the conditions of Dobroudja at the initial stage of the investigations on winter oilseed rape.

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