Lilija Borovko
Research Institute of Agriculture Agency of LUA, Latvia

The influence of nitrogen and potasium fertilization and of the use of growth regulators on yield and seed quality of spring oilseed rape in Latvia conditions

Wpływ nawożenia azotem i potasem oraz zastosowania regulatorów wzrostu na plon i jakość nasion rzepaku jarego w warunkach Łotwy

Key words: spring oilseed rape, spring rapeseed, mineral fertilizer, growth regulators, yield components, seed yield

During several recent years the Research Institute of Agriculture has carried out field trials on soddy-podzolic sandy clay soil. The effects of increased nitrogen and potassium doses, namely, (NK) 60–140 kg·ha^{-1}, were tested in 2003–2005. The formation of spring rape yield and its quality were estimated. Phosphorus dose was equal in all variants — 70 kg·ha^{-1} P_2O_5. Following mixtures of plant growth regulator with fungicide were tested in the trials: Modus 0.5 l·ha^{-1} + Folicur 0.5 l·ha^{-1}, Modus 0.5 l·ha^{-1} + Juventus 0.5 l·ha^{-1}, Cycocel 0.5 l·ha^{-1} + Folicur 0.5 l·ha^{-1}, Cycocel 0.5 l·ha^{-1} + Juventus 0.5 l ha^{-1}. The mixtures were applied by spraying them throughout the plant florescence-bud formation period. The results of the three-year field trials have proved that the application of nitrogen and potassium doses significantly influences the formation of yield element structure, the seed yield and its quality. The number of branches increased by 2–3, the number of pods on the plant by 38–95, the number of seeds per pod 2–5 and a 1000 seed weight by 0.2–0.7 g on average.

The increasing dose of (NK) from 60 to 100 kg·ha^{-1} resulted in yield increase: 0.75–1.09 t·ha^{-1}. The use of NK doses promoted the accumulation of crude protein from 22.12 to 24.13% but decreased the oil content in seeds from 47.06 to 43.72%. Growth regulator with fungicide mixtures increased the following traits: the number of side branches on plant by 2–3, the number of pods on a plant by 21–33, the number of seeds per pod by 2–3, a 1000 seeds weight by 3.5–4.2 g on average. The Cycocel + Folicur mixture was the best variant of growth regulator with fungicide and produced oil yield of 1389 kg·ha^{-1}. Other mixtures ensured the oil yield 1230–1310 kg·ha^{-1}.

Słowa kluczowe: rzepak jary, nawożenie mineralne, regulatory wzrostu, plon, składniki plonu

W Łotewskim Rolniczym Instytucie Badawczym przeprowadzono w latach 2003–2005 doświadczenia polowe nad uprawą rzepaku jarego na darniowo-bielicowych glebach piaskowo-gliniastych. Badano wpływ wzrastających dawek nawożenia azotowego i potasowego w zakresie NK 60–140 kg·ha^{-1} na kształtowanie się plonu rzepaku jarego oraz jego jakość. Poziom nawożenia fosforowego był równy we wszystkich kombinacjach i wynosił 70 kg·ha^{-1} w przeliczeniu na P_2O_5. W doświadczeniu badane były również następujące dawki mieszanin regulatorów wzrostu z fungicydami: Modus 0,5 l·ha^{-1} + Folicur 0,5 l·ha^{-1}, Modus 0,5 l·ha^{-1} + Juventus 0,5 l·ha^{-1}, Cycocel 0,5 l·ha^{-1} + Folicur 0,5 l·ha^{-1}, Cycocel 0,5 l·ha^{-1} + Juventus 0,5 l·ha^{-1}. Oprysków dokonywano w ciągu okresu formowania

pąków kwiatowych. Wyniki trzyletniego doświadczenia polowego wykazały, że stosowanie nawozów azotowych i potasowych (w zakresie od NK_{60} do NK_{140} kg·ha^{-1}) wyraźnie wpływa na strukturę plonu, jego wysokość i jakość. Istotne zwiększenie plonu o 0,75–1,09 t·ha^{-1} otrzymano przy zwiększeniu dawki NK z 60 do 100 kg·ha^{-1}. Pod wpływem zwiększania tego nawożenia średnia liczba rozgałęzień wzrosła o 2 do 3, liczba łuszczyn na roślinie o 38 do 95, liczba nasion w łuszczynie o 2 do 5, a masa 1000 nasion o 0,2 do 0,7 g. Zwiększenie stosowanego nawożenia azotu i potasu z poziomu 60 do 100 kg·ha^{-1} powodowało zwiększenie zawartości w nasionach białka ogólnego z 22,12 do 24,13%, ale obniżało zawartość oleju z 47,06 do 43,72%. Zastosowanie mieszanin regulatorów wzrostu z fugicydami zwiększało liczbę bocznych rozgałęzień średnio o 2 do 3, liczbę łuszczyn na roślinie o 21 do 33, liczbę nasion w łuszczynie o 2 do 3, masę 1000 nasion o 3,5 do 4,2 g. Zastosowanie mieszanin fungicydów z regulatorami wzrostu w niższych dawkach (połowę zalecanych) poprawiło wyrównanie kwitnienia i dojrzewania łuszczyn, podniosło plon nasion i ich jakość. Zastosowanie mieszanin preparatów wpłynęło dodatnio powodując wzrost liczby rozgałęzień, liczby łuszczyn na roślinie, liczby nasion w łuszczynie i masy 1000 nasion. Zastosowanie badanych mieszanek fungicydów z regulatorami wzrostu zapewniło wzrost plonu nasion o 0,62–0,91 t·ha^{-1} oraz plonu oleju o 300–429 kg·ha^{-1}.

W doświadczeniu najlepszą kombinacją okazała się kombinacja Cycocel + Folicur dając plon oleju w wysokości 1389 kg·ha^{-1}. Inne mieszanki zapewniały plony oleju na poziomie 1230–1310 kg·ha^{-1}.

Introduction

In spring rape cultivation, beside seed productiveness, of great importance there is a biochemical composition of seed rape that characterizes food and nutrient values of this culture. The research conducted by many scientists has proved that the content of seed rape, to a great extent, depends on weather conditions, variety, and agro-technical cultivation methods (Yakovchik 2006, Zholik 2006). The nutrient quickly caused the interruption of growth and yields formation and decreased seed quality of spring oilseed rape. Phosphorus is necessary to form a strong assemblage of rootlets, to increase seed yield, and to accelerate maturation. Oilseed rape plants are supplied with phosphorus mainly at the expense of reserves in soil (70–80%) as oilseed rape assimilates well background phosphorus from soil (Schroder 1992).

There is no consensus of opinion in the literature regarding the influence of potassium on spring oilseed rape yield formation and seed quality. According to Savenkov (2000), the application of potassium fertilizers has not led to substantial increase in seed yield, having just a slight influence on protein content and oil content of oilseed rapeseed. The tests carried out in Germany have proved that a full-value nutrition increased both seed yield (by 0.02–0.03 t ha^{-1}) and oil content within seeds (Schroder 1992).

It is considered that the basic element that affects the yield and the seed quality is nitrogen. Provided that a correctly set dose is applied, nitrogen increases the seed yield while overdosing can promote lodging of plants, outbreak of fungi diseases and reduction of oil content within seeds (Shpaar, Makovski, Zaharenko,

Postnikov, Sherbakov 1999). In order to achieve sufficient formation of seed yield components, it is recommended to split the applied doses of nitrogen fertilizer (Schulz, Schroder 1992). The first dose of fertilizer 60–80 kg·ha^{-1} was applied before sowing, or immediately after it, but the second one — 40–60 kg·ha^{-1} — at the stage of formation of stems (Cramer 1990; Feger, Orlovius 1995; Finck 1991).

The influence of growth regulators on the seed yield was researched, in essence, on winter rape aiming to the shortening of plant stems, stimulation of the formation of lateral shoots and auxiliary buds, reduction of lodging, guaranteeing high content of oil, and uniform ripening of pods on the main and lateral shoots (Makowski, Gienapp 1998; Vošak a kolektiv 2000).

Materials and methods

Field trials were conducted on soddy-podzolic sandy clay with pH — 6.2, organic matter content 33 g·kg^{-1} (method of Turin), P_2O_5 content (high) 195 mg·kg^{-1}, K_2O content (medium) 147 mg·kg^{-1} (DL method). The soil parameters were suitable for oilseed rape cultivation. Traditional farming techniques were applied. The following mineral fertilizers were applied: P_2O_5 70 kg·ha^{-1} in the form of superphosphate, K_2O in the form of potassium chloride, and nitrogen in the form of ammonium nitrate before the sowing of spring oilseed rape variety Olga. The investigated NK rates were: 0, 60, 80 (60 + 20), 100 (60 + 40), 120 (60 + 60) and 140 (60 + 80) kg·ha^{-1}. NK_{60} was introduced before sowing as a basic fertilizer, the rest at the stage of stem formation 20–80 kg·ha^{-1} according to variants.

Mixtures of plant growth regulator with fungicides were also investigated in the trials. The aim of investigation was to find what is the influence of applied growth regulator/fungicide mixtures on the yield formation and seed quality and on efficiency concerning disease control. Fungicide Folicur (tebucanazole 125 g·1^{-1}, triadimephone 100 g·1^{-1}), Juventus (metconazole — 60 g 1^{-1}), and plant growth regulators, and Moddus 250 e.k (trinexapac-ethyl 250 g·1^{-1}) and Cycocel 750 (chlormequate chloride 750 g·1^{-1}) were examined. Preparations were applied in half doses (0,5 1·ha^{-1}). The following preparation mixtures were made: Modus + Folicur, Modus + Juventus; Cycocel + Folicur; Cycocel + Juventus. Sprayings were done throughout plant florescence-bud formation period (GS 50). Data analysis was performed by ANOVA (Arhipova, Balina 2003). Interactions between factors were calculated using the dispersion analysis.

Results and discussions

The research has proved that mineral fertilizers significantly effected the growth and development of plants, and yield formation and quality of spring oilseed rape confirming the data of other research studies (Pileup, Belyavsky 1999; Buryakov 1990). The structure analysis of rape plants proved that (NK) 60 –140 kg·ha^{-1} fertilizer made a positive impact upon the elements that form the rape yield. The number of the first level branches increased by 2–3, the number of pods — 38–95, the number of seeds within pod — 2–5 and the mass of 1000 seeds by 0.2–0.7 g on average. The changes within yield structure were closely related to NK fertilizer rates. This relationship has been reflected by regression equations (Table 1).

Table 1

The influence of different rates of NK fertilizers on spring rape yield components *Wpływ dawek nawożenia NK na składniki plonu rzepaku jarego*

Variants *Kombinacje*	Number of first grade branches *Liczba rozgał. I rzędu*	Number of pods per plant *Liczba łuszczyn na roślinie*	Number of seeds per pod *Liczba nasion w łuszczynie*	Mass of seeds per 1 plant [g] *Masa nasion na roślinie*	Mass of 1000 seeds [g] *Masa 1000 nasion*
NK_0	3	45	21	1,9	3,5
NK_{60}	4	83	23	4,5	3,7
NK_{80}	5	94	24	5,0	3,8
NK_{100}	6	111	24	5,4	3,9
NK_{120}	6	116	25	5,7	4,0
NK_{140}	7	135	26	7,9	4,2
LSD — $NIR_{0.05}$	0.63	20.40	0.92	0.84	0.21
Regression equation *Równanie regresji*	y = 0,0289x + 2,7568	y = 0,6286x + 44,946	y = 0,0343x + 20,973	y = 0,0378x + 1,9135	y = 0,0048x + 3,4514
Determination coefficient *Współczynnik determinacji*	R^2 = 0,9521	R^2 = 0,9928	R^2 = 0,9796	R^2 = 0,9346	R^2 = 0,9568
Correlation coefficient *Współczynnik korelacji*	r = 0,98	r = 0,99	r = 0,99	r = 0,97	r = 0,98

The seed yield of spring oilseed rape variety Olga ranged from 2.06 to 3.15 t·ha^{-1} (Table 2). Applying nitrogen and potassium fertilizers (the dose of 60 to 100 kg·ha^{-1}) substantially increased the oilseed rape yield. When increasing the

nitrogen and potassium doses, no increase in the spring rape oilseed yield was observed. The highest seed yield was obtained when introducing NK_{100} — 3.15 t·ha^{-1} seeds. The yield increase was observed when the applied portion of nitrogen increased from 60 to 100 kg·ha^{-1} and potassium from 60 to 100 kg·ha^{-1}. The increase of seed yield was 0.75 to 1.09 t·ha^{-1} ($LSD_{0.05}$ = 0.21 t·ha^{-1}).

Table 2

The influence of different rates of NK fertilizers upon the spring rape yield and seed quality
Wpływ dawek nawożenia NK na plon i jakość plonu rzepaku jarego

Variants *Kombinacja*	Seed yield *Plon nasion* [t·ha^{-1}]	Oil yield *Plon tłuszczu* [kg·ha^{-1}]	Protein content *Zawartość białka* [%]	Oil content *Zawartość tłuszczu* [%]
NK_0	2.06	881	22.12	47.06
NK_{60}	2.81	1173	22.61	46.09
NK_{80}	3.02	1268	22.82	45.54
NK_{100}	3.15	1295	22.95	45.01
NK_{120}	3.09	1254	23.70	44.02
NK_{140}	3.00	1199	24.13	43.72
LSD — $NIR_{0.05}$	0.21		0.62	1.22

Mineral fertilizers caused a significant protein increase within spring oilseed rape yield corresponding to research results of Savenkov (Savenkov 2007). As a result of the introduction of nitrogen and potassium fertilizers, crude protein content increased by 0.49–2.01%. The change in crude protein content in spring oilseed rape under the influence of different rates of NK fertilizers can be represented as a straight-line regression equation: $y = 0.0139x + 21.894$; $R^2 = 0.8841$. The value of the coefficient of correlation (r = 0.94) points to a close linear relationship existing between the searched factors. When increasing NK fertilizer dose, the oil content decreased by 0.97–3.34%, and we observed a strong negative correlation (r = –0.98). The oil content change is reflected by a regression equation: $y = –0.0249x + 47.316$; $R^2 = 0.9593$.

In spite of the reduction of oil content in seeds, the total yield of oil was 881–1295 kg·ha^{-1} (depending on rates of mineral fertilizers). The highest oilseed yield, namely, 1295 kg·ha^{-1}, was obtained when introducing 100 kg·ha^{-1} of nitrogen and 100 kg·ha^{-1} of potassium fertilizers bringing higher seed yields.

The research proved the following: when applying the azoli preparations in mixture with preparations of chlormequate and trinexapac-ethyl compounds and employing minified doses (Moddus + Folicur, Modus + Juventus, Cycocel + Folicur, Cycocel + Juventus), we observed the impact on the rape plant development, and harvest-structure formation elements. There is a positive and strong correlation between the seed yield and the yield structure elements (Table 3).

Table 3

The influence of growth regulator and fungicide mixtures on yield components of spring oilseed rape — *Wpływ regulatorów wzrostu i fungicidów na składniki plonu rzepaku jarego*

Variants *Kombinacja*	Number of first grade branches *Liczba rozgał. I rzędu*	Number of pods per plant *Liczba łuszczyn na roślinie*	Number of seeds per pod *Liczba nasion w łuszczynie*	Mass of seeds on 1 plant *Masa nasion z rośliny* [g]	Mass of 1000 seeds *Masa 1000 nasion* [g]
Control — *Kontrola*	4	63	21	2,4	3,5
Moddus GS 30 + Folicur GS 70	6	86	22	3,9	3,9
Moddus + Folicur GS 50	7	84	24	4,3	4,0
Moddus + Juventus GS 50	6	86	23	3,9	3,9
Cycocel + Folicur GS 50	6	96	24	4,8	4,0
Cycocel + Juventus GS 50	7	91	24	4,1	4,2
LSD — $NIR_{0.05}$	1.13	16.14	1.39	1.23	0.22
Correlation coefficient*	0.86	0.98	0.89	0.99	0.98

* Correlation coefficient between seed yield and yield component
Współczynnik korelacji pomiędzy plonem nasion i składnikami plonu

The number of side branches increased, on average, by 2–3, the number of pods on a plant by 21–33, the number of seeds per pod by 2–3, the mass of 1000 seeds by 3.5–4.2 g as the result of applying the preparation mixtures. Throughout the research period we observed that plant-growing regulators, when mixed with fungicides, provided evenness of florescence and pod ripening.

The results of field experience confirm that the application of growth regulators in the mixture with the fungicides had a positive impact on the seed yield and seed quality of spring rape (Table 4).

The increase of yield was 0.62–0.91 $t \cdot ha^{-1}$ ($LSD_{0.05}$ 0,35 $t \cdot ha^{-1}$). When applying the preparations (a full portion or in a mixture) we did not observe any significant differences. The highest increase in seed yield 0.91 $t \cdot ha^{-1}$ was ensured when applying the container mixture of Cycocel + Folicur, during the developing of rape (GS 50). Applying the fungicides in mixture with growth regulators, during the initial stage of rape budding, a steadier blossoming and ripening of pods on the main and lateral shoots was ensured, and the accumulation of oil content in the seeds increased by 0.78–2.14%. The most effective was applying of the mixture Cycocel + Juventus, and Cycocel + Folicur: the oil yield was 1310–1389 $kg \cdot ha^{-1}$. The research results confirm the following: applying the preparation mixture once, and in small rates (in order to increase rapeseed productiveness and quality) we reduced the chemical load put upon one unity of the area, and reduced the environment pollution. It seems that our research provided important results.

Table 4

The influence of different mixtures of growth regulators and fungicides on yield and seed quality of spring oilseed rape — *Wpływ różnych mieszanek regulatorów wzrostu i środków grzybobójczych na plon i jakość nasion rzepaku*

Variants *Kombinacje*	Seed yield *Plon nasion* [t·ha^{-1}]	Oil yield *Plon tłuszczu* [kg·ha^{-1}]	Protein content *Zawartość białka* [%]	Oil content *Zawartość tłuszczu* [%]
Control — *Kontrola*	2.30	960	22.75	45.75
Moddus GS 30 + Folicur GS 70	2.92	1230	22.96	45.86
Moddus + Folicur GS 50	3.04	1275	21.16	45.90
Moddus + Juventus GS 50	2.96	1260	22.36	46.54
Cycocel + Folicur GS 50	3.21	1389	22.54	47.22
Cycocel + Juventus GS 50	3.04	1310	22.43	47.20
LSD — $NIR_{0.05}$	0.35	164.8	0.94	1.23

Conclusions

1. The results gained by three-year field trials prove that appliance of nitrogen and potassium fertilizers (at the range of NK_{60} to NK_{140} kg·ha^{-1}) considerably increased spring rape oilseed yield. A significant harvest increase, namely, 0.75–1.09 t·ha^{-1} was obtained when applying (NK) 60–100 kg·ha^{-1}.
2. Nitrogen and potassium fertilizers make a positive impact on the element structure that form rape yield. Taking into account the NK rates, the lateral branches of spring rape plants increased by 2–3, the number of pods on a plant — 38–95, the number of seeds per pod — 2–5, and the mass of 1000 seeds by 0.2–0.7 g.
3. The introduction of mineral fertilizers exerted remarkable influence on the qualitative composition of spring oilseed rape. Higher doses of nitrogen and potassium rates increased the protein content and decreased oil content within seeds.
4. Applying the fungicide and growth-regulators in mixtures, in lower rates, provided the evenness of florescence and pod ripening, and granted essential rise in rape harvest, improving its quality.
5. Application of preparation mixtures significantly influenced the increase of the number of branches on stems, the number of pods per plant, the number of seeds per pod, and the mass of 1000 seeds.
6. Application of the researched preparation mixtures ensured the increase of seed yield; namely, to 0.62–0.91 t·ha^{-1}, and the oil yield to 300–429 kg·ha^{-1}.

References

Arhipova I., Balina S. 2003. Statistika ekonomika. Datorzinibu Centrs, 349.

Buryakov Y. 1990. The Intensive Technology of Rape Production. Moscow, Rosapromizdat, 188.

Cramer N. 1990. Raps. Züchtung, Anbau und Vermarktung von Kornerraps. Ulmer-Verlag, Stuttgart, 147.

Feger G., Orlovius K. 1995. Wichtige Nathrstoffe für den Raps. Ratgeber für die Landwirtschaft, 10: 19.

Finck A. 1991. Dungung – ertragsteigermd qualitätsverbessemd, umweltgerecht. Eugen Ulmer Verlag Stuttgart, 310.

Makowski N., Gienapp Ch. 1998. Entscheidungshilfen fur die Rapsbestellung. Neue Landwirtschaft., 7: 54-55.

Pilyuk Y., Belyavsky V. 1999. The Basic Ways of Production Growth of Vegetable Oil. The Problems of Agriculture Production under Changing Economic and Ecologic Conditions. Part 2. Agronomy. Smolensk, 12-14.

Savenkov V. 2000. Role of Mineral Fertilizers in Growing of Harvest and Quality of Spring Oilseed Rape. In: Artemov I.V. Scientific Provision of Rape Sowing Branch and the Ways of Enforcement of Biological Potential of Rape. Lipetsk, 110-113.

Savenkov V. 2007. Rational Use of Technogenic and Biologic Means in Rape Cultivation in the Central Russia. Author's Summary, Voronezh.

Shpaar D., Makovski H., Zaharenko B., Postnikov A., Sherbakov B. 1999. Rape. Minsk, 204.

Schroder G. 1992. Raps hat hohe Anspruche. Neue Landwirtschaft., 7: 43-45.

Schulz R., Schroder G. 1992. Hoher Aufwand lohnt sich nicht – Intensität beim Rapsanbau abhängig von der neuen Marktordnung. Bauern-Zeitung, 16: 19.

Vošak a kolektiv. 2000. Repka. Praha, 321.

Yakovchik S. 2006. Peculiarities of Formation and Accumulation of Oil and Protein within Spring Oilseed Rape. Rape: Oil, Protein, Biological Fuel. Minsk: 109-113.

Zholik G. 2006. The Peculiarities of Formation of Rapeseed and Winter Rape in Accordance with Technologies and Environment Factors: Monograph. Gorky.