Spring rape seed yield and quality as affected by the cultivation year and cropping system

Bronislava Butkute[1], Sarunas Antanaitis[2], Vytas Masauskas[2]

[1] *Chemical Research Laboratory, Lithuanian Institute of Agriculture (LIA), Akademija, Kedainiai distr. 58344 Lithuania*
[2] *Department of Plant Nutrition and Agroecology of LIA Akademija, Kedainiai distr. 58344 Lithuania Email: brone@lzi.lt*

Abstract

Within a clover - winter wheat - spring oilseed rape (*Brassica napus* L.) cv. 'Maskot' - barley+clover rotation, the effects of cropping systems (control, organic, sustainable, intensive with the respective mineral fertilisation $N_0P_0K_0$, $N_0P_0K_{75}$, $N_{80}P_{40}K_{90}$, and $N_{120}P_{60}K_{140}$) on the rape seed, crude fat (CF), crude protein (CP) yield, CF and CP concentrations are discussed in the present paper. The field experiments were carried out during the seasons 2001-2005 on an Endocalcari-Epihypogleyic Cambisol. The harvest years differed significantly in meteorological conditions: from favourable for plants to uptake nutrients to extremely droughty, sunny and hot, and the effect of the cultivation year was significant at $P<0.01$ for the seed yield and its quality. Depending on the cultivation year the average seed yield varied within the range 1.5-2.4 t ha^{-1}, CF and CP concentrations 345-407 g kg^{-1}, 206-233 g kg^{-1} respectively, with a variation each year resulting from the cropping system. Depending on the cropping system the average seed yield harvested in the trial plots during the 5 experimental years ranged in the following order: control ≤organic<sustainable<intensive. The highest average CF concentration was from the control plots (409 g kg^{-1} adjusted to 9 % moisture), and the lowest from the plots of intensive cropping system (383 g kg^{-1}), and conversely, CP concentration was the lowest in the seed harvested in the control plots (207 g kg^{-1} adjusted to 9 % moisture).

Key words: spring oilseed rape, cropping systems, seed yield, crude fat, crude protein

Introduction

The rapeseed crop is of high importance for European agriculture, and its potential particularly increased in the EU-25 during the last few years. There is great potential for rapeseed cultivation in Eastern European countries, including Lithuania. Over the past decade rapeseed (*Brassica napus* L.) area has increased in Lithuania from 22.1 thousand ha in 1997 to over 109.4 thousand ha in 2005 (Department of Statistics …, 2005). Organic and sustainable agriculture is becoming increasingly important in the integration process with the shift of the EU agricultural policy from intensive agricultural production towards production systems that could secure healthy environment and lifestyle. Organic farming is spreading rapidly in Lithuania, therefore it is essential to estimate today's problems and prospects from the scientific standpoint. Rapeseed has become a commonly grown rotation crop with cereals and pastures. It has the advantages of reducing cereal root diseases, improving soil structure (due to a different root structure to cereals), preventing build up of herbicide resistant weeds and diversifying income (Scott, Brennan, Faour, 1999). *Brassica* crops provide large amounts of crop residue that is important for erosion control (Guy, 1999). However rapeseed has a greater ability to respond to environmental fluctuations than most crops (Johnson et al., 2004). The objective of the present study was to evaluate the variation of spring rape seed yield, crude fat, crude protein content as affected by the peculiarities of the cropping systems and cultivation year.

Materials and methods

Spring oilseed rape was grown on an *Endocalcari - Epihypogleyic Cambisol* in Dotnuva (55° 24' N), neutral light loam. The soil (0–20 cm depth) had 8.64-15.8 g kg^{-} of C_{org}, 150-215 mg kg^{-1} of P_2O_5, 103-198 mg kg^{-1} of K_2O, 1.48-1.86 g kg^{-1} of N and a pH of 7.1-7.7. The spring oilseed rape Swedish variety 'Maskot', was grown in four replications in a clover→winter wheat→spring oilseed rape→(barley+clover) rotation and the effects of cropping systems (control, organic, sustainable, intensive with the respective mineral fertilisation $N_0P_0K_0$, $N_0P_0K_{75}$, $N_{80}P_{40}K_{90}$, and $N_{120}P_{60}K_{140}$) on seed, crude fat (CF) and crude protein (CP) yield, CF and CP concentration were studied. Weed and pest control was performed according to the local recommendations in the plots of control, sustainable, intensive systems, and fungicides were applied only in the plots of intensive cropping after flowering. Samples were scanned by NIRS-6500. The statistics of equations for CF and CP predictions: coefficient of correlation in calibration RSQ and standard error in calibration SEC were 0.95 and 0.43 for CF, 0.96 and 0.40 for CP, respectively. All variables studied were determined for each plot and all values were adjusted to 9 % seed moisture content. Statistical tests, including variation of data, analysis of variance (ANOVA) were computed using the software Statistica, version 6.0.

Results

Climate conditions during seasons of rapeseed cultivation. In general, rapeseed growing conditions during the experimental period were variable: from favourable for plants to uptake nutrients in 2004 to stressful in 2003 (Fig. 1).

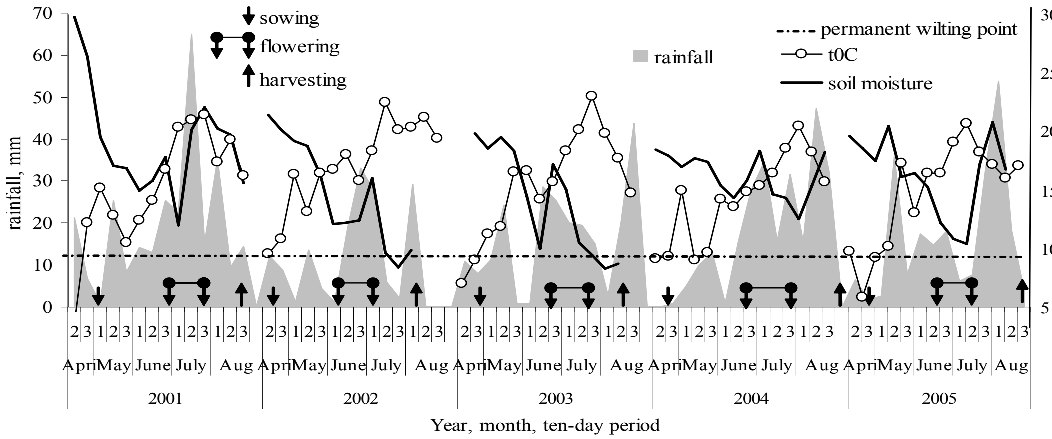

Figure 1. Climatic conditions from April to August during 2001-2005 at Dotnuva experimental site, Lithuania.

Until flowering the year 2001 was favourable for plant growth and development. During spring rape flowering the weather was warm but the amount of rainfall was 138% of the long-term mean. The year 2002 was exceptional with warm and dry weather from plant emergence to flowering, which significantly advanced flowering and seed maturation, however soil moisture was satisfactory. Moisture shortage, reaching even permanent wilting point, in the soil occurred after flowering, i.e. at the most intensive seed formation period. Due to the early drying out of vegetative mass, the supply of nutrients into seed was discontinued early. As a result, rape plants matured earlier than usual. In 2003 a spell of warm weather occurred at the end of April after oilseed rape sowing. Before the onset of plant flowering there was felt a shortage of moisture not only at the 0-20 cm, but also at deeper (to 50 cm) soil layers: the rather dry year of 2002 and period during the winter months severely reduced soil water recharge. July was far warmer than usual. An especially hot and dry period which started at the end of rape flowering was unfavourable for the formation, development and ripening of seed. The weather conditions in the spring of 2004 were similar to those of the year 2003, and although it was not rainy until the middle of June, the soil moisture did not drop below 15 %, therefore the plants developed in favourable conditions until flowering. During flowering the weather was cool with optimal moisture amount, as a result, flowering stage lasted longer than in the other experimental years. The weather became warmer only upon completion of rape flowering. Although the air temperature in August was by 1.5-2.0ºC higher than usual, the ample rainfall in August influenced the prolonged maturation of seeds. In the spring of 2005 after sowing the weather was cool with frosts, up to - 1^{o}C on the soil surface. The mean daily temperature reached ≥+10^{o}C approximately 10 days later than the long-term average. Although the rainfall amounted to 88 % of the norm, soil moisture reserves were sufficient. Warm weather with limited rainfall (80% of the norm) occurred in the second ten-day period of June, hot and dry weather occurred in the middle of July at the end of rape flowering and at the end of the month. Rainy weather settled during seed development and ripening period – the last days of July and in the first ten-day period of August, with excess rainfall at the beginning of August. Seeds matured unevenly on a plant. Spring rapeseed was harvested after the rainy period. Such extreme variations in the weather conditions observed during the experimental period affected seed yield and its quality.

Variability of rape seed quality, CP, CF and seed yield. Variability of seed yield, CF, CP concentration and yield of the Lithuania-grown spring rape *cv.* 'Maskot' of 2001-2005 harvest was studied and data of variation are presented in Fig. 2 as a statistical mean, minimum, maximum values and coefficient of variation (CV%). During the experimental period the seed, CF and CP yield varied with and within a year in a wide range: 1.01 – 3.26 t ha^{-1}, 400-1059 and 208-672 kg ha^{-1}, respectively, with the CV% > 20 %. CF and CP concentration accounted for 347-434 and 184-254 g kg^{-1} of the 9 % moisture of seed with a mean of 392 and 220 g kg^{-1} and coefficients of variation of 4.80 and 7.67 % in total for four years of study. The variation of these rape seed quality indicators was significantly lower than that of seed yield, CF and CP yields.

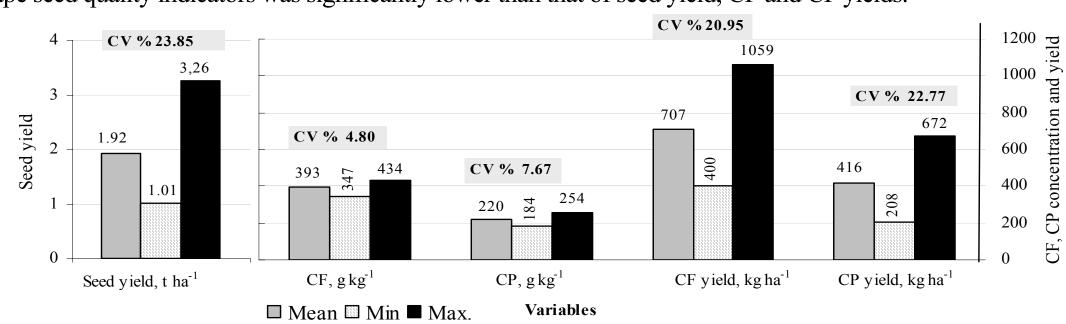

Figure 2. Variability of CF, CP concentration, seed, CF, and CP yield 2001-2005.

Summarised data, provided in Table 1, suggest that many of the tested characteristics varied more as a result of cultivation year rather than cropping systems applied. Consistent patterns of the CF and CP yield variability were similar to those of seed yield: due to the year's condition these indicators varied most in organic plots, and due to the application of different cropping systems the seed, CF and CF yields varied most in 2005 and 2002. Cultivation year's factor determined higher seed quality variation in the plots of intensive and sustainable cropping systems.

Table 1. Coefficients of variation (CV%) of rape seed yield and quality as affected by cultivation year and cropping system

Variable	CV % as influenced by cultivation year				CV % as influenced by cropping system				
	Control	Sustainable	Intensive	Organic	2001	2002	2003	2004	2005
Seed yield	17.17	21.02	21.62	23.37	9.66	19.99	7.49	20.39	24.57
CF conc.	3.33	4.65	5.47	3.05	2.9	3.18	4.46	-	1.83
CP conc.	7.03	7.32	7.74	5.67	3.51	5.89	5.22	-	3.22
CF yield	11.01	19.09	19.31	25.91	7.87	17.57	5.33	-	24.38
CP yield	12.12	12.92	17.74	28.85	12.91	24.56	11.5	-	22.75

Data of analysis of variance. Two-way analysis of variance with a four- replication design was performed on the data using the following factors: harvest year x cropping system (Table 2). Comparisons among factor means were done by using Fisher's criterion and least significant difference test (LSD at $^*P < 0.05$ and $^{**}P<0.01$ levels).

Table 2. Analyses of variance for the effect of factors on rape seed, CF, CP yield and quality

Variance	DF for variables		Fisher's criterion (F)				
	seed yield	other	Seed yield	CF	CP	CF yield	CP yield
Harvesting year (Y)	4	3	59.82**	54.23**	100.16**	42.51**	33.96**
Cropping system (S)	3	3	43.07**	28.39**	33.4**	15.99**	28.26**
Y x S	12	9	9.05**	3.13**	3.56**	9.66**	6.65**
Harvesting year (Y)				Means			
2001	1		2.02	384.8	232.0	775.6	469.4
2002	2		2.00	406.8	205.9	808.5	455.2
2003	3		1.54	374.9	233.4	577.2	396.2
2004	4		2.40	not tested	not tested	not tested	not tested
2005	5		1.65	404.1	206.9	647.6	327.4
LSD_{05}/LSD_{01}			0.125/0.166	5.93/7.92	4.33/5.78	47.38/63.27	31.64/42.25
Cropping system (S), fertilisation							
Control, $N_0P_0K_0$	1		1.69	408.7	206.8	635.2	338.9
Sustanaible, $N_{80}P_{40}K_{90}$	2		2.05	388.9	222.4	740.8	434.8
Intensive, $N_{120}P_{60}K_{140}$	3		2.22	383.1	226.9	775.2	478.0
Organic, $N_0P_0K_{75}$	4		1.72	389.9	221.1	657.8	396.6
LSD_{05}/LSD_{01}			0.111/0.148	5.93/7.92	4.33/5.78	47.38/63.27	31.64/42.25

Both factors tested and their interactions were significant at P<0.01 probability for all tested parameters of yield and quality. The study revealed that environmental conditions of spring rape growth period were the main factor for each of the tested component. The highest seed yield (1.9-2.90 t ha^{-1} or 2.4 t ha^{-1} on average) was harvested in the moderately cool and wet year 2004 with the longest growing and seed ripening period. In hot and dry year 2003 the crop produced the poorest seed yield. In a sunny year 2002 with sufficient soil moisture until the end of flowering the highest CF yield was produced. The cropping systems had a significant effect on rape seed yield and quality composition formation (Table 2, Fig.3). The highest average seed, CF, CP yields were produced in the plots of sustainable and intensive cropping, where nitrogen and plant protection had been applied. However, such regularity was not observed annually. CP concentrations were also the highest in the treatments applied with nitrogen (with some exceptions). Although control and organic plots were not treated with nitrogen, the seed ripened in the organic plots had a higher CP concentration annually compared with the control plots. In general, the CF concentration inversely correlated with CP concentration both under the effects of cultivation year and cropping systems.

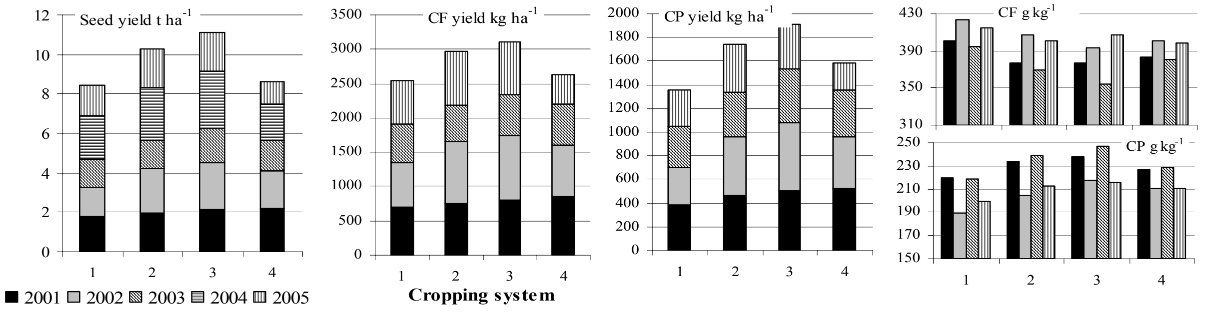

Figure 2. Seed, CF, CP yield and CF, CP concentration in relation to the cropping system in different rape cultivation years. Cropping system: 1-control, 2 -sustainable, 3-intensive, 4-organic.

Discussion

Our experimental evidence suggests that the yield of spring rape seed as well as the yield of CP and CF depended on the cropping systems, related to different supply of plants with nitrogen, which is the main nutrient, and on pest, weed and fungal disease control. Depending on treatment the averaged seed yield ranged in the following order: control⩽ organic<sustainable<intensive. Oilseed crops require large amount of N, but N nutrition is not always equally effective and interacts with environmental conditions, this has been noticed by Andersen et al., (1996), Kutcher et al., (2005), therefore the effect of the cultivation technologies applied in separate years was different. Heavy rain during flowering in 2001 might have caused flower damage, reduced pollination and prospective high yield in sustainable, and especially intensive cropping plots. The lowest seed, CF and CP yields were obtained in 2003 and 2005 when plants experienced moisture shortage at the end of flowering and during the stage of seed formation in siliques on the main stem. This observation agrees with the inferences made by other researchers (Champolivier, Merrien, 1996). K nutrition stimulates synthesis of storage proteins and other compounds (Armengaud et al., 2004) and this might have resulted in higher CP concentration in the seed from organic plots compared with the control plots.

References

Andersen M.N., Heidmann T., Plauborg F. 1996. The effects of drought and nitrogen on light interception, growth and yield of winter oilseed rape. Acta Agriculturae Scandinavica, Sect. B. 46 (1), 55–67.

Armengaud P., Breitling R., Amtmann A. 2004. The potassium-dependent transcriptome of *Arabidopsis* reveals a prominent role of jasmonic acid in nutrient signaling**.** Plant Physiol. 136 (1), 2556–2576.

Champolivier L., Merrien A. 1996. Effect of water stress applied at different growth stages to *Brassica napus* L. *var. oleifera* on yield, yield components and seed quality. European J. Agron. 5, 153-160.

Department of Statistics to the Government of the Republic of Lithuania, 2005. www.std.lt/en/. Available 17-09-06.

Guy S. O. 1999. Crop rotation and residue durability effects of *Brassica*s and other crops on winter wheat. Proc. 10th International Rapeseed Congress. Canberra, Australia. http://www.regional.org.au/au/gcirc/2/290.htm.

Johnson E., Beckie H., Warwick S. et al. 2004. Ecology and management of volunteer canola. www.canola-council.org/managing_vol_canola.pdf. Canola Council of Canada, Winipeg, MB. 5p.

Kutcher H.R., Malhi S.S., Gill K.S. 2005. Topography and management of nitrogen and fungicide affect diseases and productivity of canola. Agron. J. 97, 533-541.

Scott J. F., Brennan J. P., Faour K. Y. 1999. Economic analysis of the role of canola in southern and central NSW farming systems. Proc. 10th International Rapeseed Congress. Canberra, Australia. http://www.regional.org.au/au/gcirc/2/251.htm.