Acta Agrophysica, 2006, 8(1), 205-218

ESTIMATION OF AGRONOMIC PARAMETERS OF WINTER OILSEED RAPE FROM FIELD REFLECTANCE DATA

Jan Piekarczyk[1], *Marek Wójtowicz*[2], *Andrzej Wójtowicz*[3]

[1]Institute of Physical Geography and Environmental Planning, Adam Mickiewicz University
ul. Dzięgielowa 27, 61-680 Poznań
e-mail: piekjan@amu.edu.pl
[2]Plant Breeding and Acclimatization Institute, ul. Strzeszyńska 36, 60-479 Poznań
[3]Institute of Plant Protection, ul. Miczurina 20, 60-318 Poznań

A b s t r a c t. Spectral behaviour of winter oilseed rape experimental plots was analysed in relation to plant density variations. Field spectral measurements made with the CIMEL CE313 luminance meter at two wavelengths, 650 nm and 850 nm, were evaluated for their use in two widely used reflectance indices: NDVI and RVI. Statistically significant differences of reflectance factors and vegetation indices between plots with various seeding rates were observed. The spectral data were related, through correlation analysis, to phytometric winter oilseed rape variables. Two crop agronomic parameters: number of plants per square meter after emergence (NPL) and after winter (NPW), and four parameters of individual plants: number of leaves per rosette (NLR), fresh matter of a plant (FMP), number of branches per plant (NBP), height of apical growing point (HAGP), and diameter of root collar (DRC) were analysed. These parameters can be used for estimation of winter oilseed rape crop disposition to winter. Both crop parameters, NPL and NPW, related more closely to spectral data than did the individual plant parameters. No statistically significant correlation was observed only between HAGP and the spectral data. The obtained results confirm the information potential of field spectrometry for estimating winter oilseed rape crop status.

K e y w o r d s: winter oilseed rape, remote sensing, field spectrometry, vegetation indices

INTRODUCTION

Winter oilseed rape (*Brassica napus* L.) in Western Poland usually establishes in October and November. After winter, the growth resumes at the end of March or beginning of April. The autumn period of winter oilseed rape development is very important since plants should be well prepared to withstand frosty weather in wintertime. Before or during winter the generative development starts, and if oilseed rape is sown in August, flower initiation usually takes place from early November [7]. Flower, pod and seed number depends on the onset of flower initiation [13]. High and stable yield of winter oilseed rape crop requires – as a prior condition - a good stand formation before the onset of winter [19]. Thus, reliable estimation of actual status of the winter oilseed rape crop in autumn is of great importance. Remote sensing techniques have the potential to provide quantitative and timely information on agricultural crops over large areas.

A lot of research has been dedicated to the description of spectral properties of different agricultural crops, like wheat and barley [10], corn [4], beans and peas [17], rice [21] or winter oilseed rape [15]. However, to date, no studies have quantified the relationships between winter oilseed rape crop parameters and spectral information. Spectral reflectance from vegetation is low in the visible region of the electromagnetic spectrum because of strong absorption by chlorophyll in plant leaves. In the near-infrared region plant reflectance increases significantly due to micro-cellular structures in leaf material. Spectral reflectance from vegetation in the visible and near-infrared wavelengths is very well correlated with various plant biophysical parameters: leaf area index, biomass and ground cover [2,20]. In order to maximize the contribution of vegetation reflectance information and to minimize the effects of exogenous factors, several vegetation indices have been developed. The focusing of the multi-spectral signal by combination of responses in different spectral regions, in the format of a ratio, or as a linear transformation, may therefore yield more accurate estimate of biophysical plant parameters. A reliable remote sensing method for assessing the state of arable crops can be developed on the basis of detailed spectral characteristics obtained from ground-based reflectance measurements and then can be used in air and satellite crop monitoring.

In this study the goal is to follow changes in the winter oilseed rape crop reflectance through the autumn and the beginning of the spring growing season and to investigate the relationship between agronomic parameters of this crop and spectral data.

MATERIALS AND METHODS

The experiment was carried out at the Plant Breeding and Acclimatization Institute Experimental Station in Zielęcin (52°10’ N, 16°22’ E). The winter oilseed rape variety Kana was sown in randomized plots on 25th August at four seeding rates (SR): 40, 80, 120 and 160 seeds m^{-2}. The plants emerged by 24th September. Before the sowing, all the plots were fertilized with 20 kg/ha of N in the form of ammonium sulphate, 39 kg ha^{-1} of P_2O_5 and 160 kg ha^{-1} of K_2O. Two crop agronomic parameters: number of plants per square meter after emergence (NPL) and after winter (NPW), and five parameters of individual plants: number of leaves per rosette (NLR), fresh matter of a plant (FMP), number of branches per plant (NBP), height of apical growing point (HAGP) and diameter of root collar (DRC) were assessed. These parameters can be used for the estimation of winter oilseed rape crop preparation for winter [14]. Measurements of NPL, NLR, FMP, NBP, HAGP and DRC were taken in the last decade of November, while NPW was measured in the first decade of April. In summer, after plants emergence and in early spring after the start of plants regrowth, on each plot, at one section 333 cm long, the number of plants per area unit was counted. For individual plant parameters at each plot 15 plants were randomly chosen. The onset of plant development in the spring occurred on 30th March.

Field spectral reflectance measurements were made at five dates: three in autumn and two in early spring. For spectral measurements the CIMEL CE313 luminance meter was used, with a sensor field-of-view of 10°. Two wavelengths, 650 nm and 850 nm, were evaluated for their use in the reflectance indices. The luminance meter head was mounted on a hand-held boom, elevated approximately 2.5 meters above the canopy. Illumination conditions, plant cover and growing stages of winter oilseed rape on the measurement dates are presented in Table 1. All spectral measurements were taken on cloudless days within one hour of solar noon. Reference panel (Spectralon) measurements were collected immediately before the luminance measurements from the oilseed rape plots. Canopy reflectance factors (R_{650} and R_{850}) were calculated as the ratio of the reflected radiance from vegetation to that reflected from a reference panel [18]. The four spectra were obtained for each plot, at nadir direction, and then averaged. First day of the field campaign, before emergence of plants, the reflectance of the bare, dry soil was measured for spectral characterization of the canopy background.

Digital photographs, corresponding to the luminance meter field of view, were taken at each measurement date to estimate the percentage green vegetation cover.

Data are presented in terms of reflectance factors of two wavelengths: R_{850} and R_{650} and two commonly applied vegetation indices calculated from these factors:

$NDVI = (R_{850}-R_{650})/(R_{850}+R_{650})$,

$RVI = R_{850}/R_{650}$,

where: R_{650} and R_{850} are reflectance factors in the 650 and 850 nm bands, respectively.

The obtained results were estimated by analysis of variance and the significance of differences was determined at confidence level p , 0.05 by Tukey test.

RESULTS

Table 1 contains mean values of two reflectance factors (R_{850}, R_{650}) and two vegetation indices (RVI, NDVI) from winter oilseed rape plots with different SR in the autumn and early spring. In autumn, after germination, oilseed rape plants grow very fast and a rapid change is observed from soil to plants as the dominant influence on the spectral behaviour at the individual wavelengths and vegetation indices. As a result of plant development and increase of ground cover the reflectance in the near-infrared wavelength increased and in the red wavelength decreased. At the beginning of oilseed rape plants development, NDVI changed more than RVI, R_{650} and R_{850}. Till the 24th September, mean NDVI values increased more than three times, while mean RVI less than two times (Tab. 1). Four weeks after emergence, as expected, the greatest percentage cover, 23.3%, was observed on plots with the highest seeding rate. Thus the red reflectance from these plots was the lowest and the near-infrared reflectance, as well as values of both vegetation indices, were the highest.

Later in the autumn, in the period of 24th September to 23rd October, densely sown plants developed slower due to stronger plant competition. Ground cover on plots with seeding rate (SR) of 160 increased only three and a half times, while on plots with SR 40 more than six times. In this period of time RVI increased more than NDVI. The former index changed almost five and a half times, while the latter only two and a half times.

Low temperature and low light intensity during the winter caused a significant loss of oilseed rape plants foliage. Mean ground cover from all plots decreased from 69.4% on 23rd October to 40.6% on 3rd April. At the beginning of the spring, three days after the start of spring regrowth, the greatest ground cover, NDVI and RVI were observed on plots with SR 80. This indicates that plants from these plots were most favourably disposed for individual plant growth. In the period of winter, as well as after the start of regrowth in April, RVI changed more than NDVI and both reflectance factors.

Statistically significant differences of reflectance factors and vegetation indices between plots with various SR were observed on 24th September, 23rd October and 3rd April (Tab. 1). The greatest variation among the plots occurred early in the plant development, on 24th September, when plants were in the stage of three leaves. At that time NDVI provided fivefold statistically significant differences between combinations of SR, while RVI only fourfold. Statistically significant differences in NDVI were found only between plots with SR 80 and 120. Variation in vegetation indices and reflectance factors, caused by different plant densities, decreased on 23rd October, when oilseed rape plants were in the stage of six leaves. On that date both vegetation indices provided statistically significant difference only between three combinations of SR; 80 and 40, 160 and 40, and 160 and 120, but differences in RVI were slightly greater than in NDVI.

Shortly after the start of regrowth in the spring, on 3rd April, RVI values from plots with SR 80 differed significantly from all plots with other SR, while NDVI showed statistically significant difference only between two combinations of SR:

80 and 160, 80 and 40. On the last measurement date (30th April), when plants were in the stage of yellow bud and the mean ground cover on all plots was 87.5% there were no significant differences between plots with different plant densities.

Table 1. Mean values of two spectral reflectance factors (R_{650} and R_{850}), two vegetation indices (NDVI and RVI) and ground cover (GC), from plots with four seeding rates (SR) of winter oilseed rape on five measurements dates with different solar zenith angles (θ_s). SD – least significant difference at P = 0.01

Date	θ_s (°)	Growing stage	SR (seeds m^{-2})	GC (%)	Reflectance factors		Vegetation indices	
					R_{650}	R_{850}	NDVI	RVI
20th August	51	bare soil	40	0	15.2a	19.5a	0.122a	1.28a
			80	0	15.5a	19.6a	0.116a	1.24a
			120	0	15.8a	19.5a	0.106a	1.22a
			160	0	15.9a	19.7a	0.107a	1.24a
			Mean:		15,6	19.6	0.113	1.25
				SD	0.8	0.9	0.035	0.089
24th September	53	3 leaves	40	10.5	13.9a	24.8b	0.280c	1.79c
			80	16.2	11.6b	24.3b	0.352b	2.10bc
			120	18.1	12.2b	25.7ab	0.358b	2.13b
			160	23.3	10.7b	26.9a	0.434a	2.57a
			Mean:	17.0	12.2	25.5	0.353	2.15
				SD	1.6	1.7	0.058	0.31
23rd October	63	6 leaves	40	63.4	4.7a	44.0b	0.806b	9.68b
			80	73.2	4.1ab	47.6ab	0.842a	11.78a
			120	65.8	4.3ab	48.6ab	0.836a	11.40a
			160	75.2	4.0b	51.1a	0.854a	12.95a
			Mean	69.4	4.3	47.8	0.834	11.45
				SD	0.6	5.7	0.025	1.68
3rd April	45	stem formation	40	36.1	7.4a	29.5b	0.594b	4.02b
			80	48.7	6.6b	33.6a	0.668a	5.18a
			120	40.2	7.0ab	30.7ab	0.624b	4.39b
			160	37.4	6.9ab	29.2b	0.617b	4.27b
			Mean	40.6	7.0	30.8	0.626	4.47
				SD	0.5	3.3	0.04	0.63
30th April	37	yellow bud	40	88.4	3.2a	50.5b	0.878a	15.62a
			80	86.2	3.3a	53.8ab	0.884a	16.32a
			120	89.0	3.3a	51.8ab	0.880a	15.79a
			160	86.3	3.4a	55.7a	0.886a	16.54a
			Mean	87.5	3.3	53.0	0.882	16.07
				SD	0.3	4.5	0.009	1.21

Means followed by the same letter within each date are not significantly different.

Table 2 shows that the agronomic parameters of an individual plant were inversely related to SR. Competition between plants determined their morphology and densely sown plants had fewer leaves (NLR) and branches (NBP) and smaller diameter of root collar (DRC) than plants from the plots with lower SR. Also, average fresh matter of a plant (FMP) from the plots with the highest SR was almost two times less than FMP of plants from the plots with the lowest SR. Among the agronomic parameters of individual plant, DRC showed the strongest correlation with SR. The experiment showed that the plant density had no significant influence on HAGP.

Table 2. Mean values of seven winter oilseed rape agronomic parameters: number of plants per square meter after emergence (NPE), and after winter (NPW), number of leaves per rosette (NLR), fresh matter of a plant (FMP), number of branches per plant (NBP), height of apical growing point (HAGP) and diameter of root collar (DRC) from plots with four different seeding rates, and correlation coefficients (r^2) between these parameters and seeding rates

Seeding rate (seeds m^{-2})	NPE (plants m^{-2})	NPW (plants m^{-2})	NLR (leaves rossette^{-1})	FMP (g)	NBP (branches plant^{-1})	HAGP (cm)	DRC (cm)
40	35.2	34.2	4.7	44	7.9	1.4	0.7
80	78.6	78.4	4.2	36	6.6	1.1	0.7
120	108.8	108.2	4.3	36	5.9	1.3	0.5
160	157.2	156.4	3.6	24	5.8	1.5	0.5
r^2	0.99**	0.99**	–0.47*	–0.57**	–0.55*	0.21	–0.68**

*Significant difference at P = 0.05, ** Significant difference at P = 0.01.

The simple linear correlation coefficients calculated between reflectance factors R_{650}, R_{850}, vegetation indices NDVI and RVI, and seven agronomic parameters on four spectral measurement dates, are presented in Table 3. In general, on all measurement dates, both vegetation indices were higher correlated with agronomic parameters than with reflectance factors. Both agronomic parameters of the crop, (NPE and NPW) were significantly correlated with spectral data only in the autumn, while all individual plant parameters, except HAGP, were significantly correlated in the autumn and thirty days after the onset of plant regrowth in the spring (30th April).

The highest correlation was observed between vegetation indices and agronomic parameters of the crop (NPE and NPW) when spectral data were collected early in the autumn growing season (24th September). At that time both indices showed similar correlation coefficients. The correlation decreased on 23rd October. Among the individual plant agronomic parameters, DRC was best correlated with NDVI on 24th September and with NBP on 30th April. The lowest correlation of all agronomic parameters was indicated with spectral data gathered in the beginning of spring (3rd April). Since there were no significant relationships between SR and HAGP, the correlation coefficients between this parameter and spectral data were not significant on any measurement date.

Table 3. Correlation of reflectance factors (R_{650} and R_{650}) and vegetation indices (NDVI and RVI) with seven agronomic parameters of winter oilseed rape for two dates in the autumn and two in the spring season

Parameter/Index		24th Sep.	23rd Oct.	3rd April	30th April
Number of plants per square meter after emergence (NPE)	R_{650}	–0.81**	–0.53*	–0.35	0.32
	R_{850}	0.59**	0.62**	–0.14	0.54*
	NDVI	0.92**	0.77**	0.09	0.41
	RVI	0.91**	0.79**	0.02	0.37
Number of plants per square meter after winter (NPW)	R_{650}	–0.82**	–0.53*	–0.36	0.32
	R_{850}	0.59**	0.62**	–0.14	0.54*
	NDVI	0.92**	0.78**	0.09	0.41
	RVI	0.91**	0.79**	0.02	0.37
Number of leaves per rossette (NLR)	R_{650}	0.63**	0.44*	0.33	0.22
	R_{850}	–0.17	–0.62**	0.12	–0.37
	NDVI	–0.61**	–0.66**	–0.14	–0.62**
	RVI	–0.63**	–0.64**	–0.02	–0.63**
Fresh matter of a plant (FMP)	R_{650}	0.65**	0.41*	0.24	0.02
	R_{850}	–0.32	–0.26	0.35	–0.55*
	NDVI	–0.66**	–0.46*	0.07	–0.67**
	RVI	–0.64**	–0.49*	0.18	–0.67**
Number of branches per plant (NBP)	R_{650}	0.63**	0.35	0.46*	0.05
	R_{850}	–0.30	–0.44	0.02	–0.53*
	NDVI	–0.64**	–0.53*	–0.28	–0.70**
	RVI	0.62**	–0.56*	–0.14	–0.66**
Height of apical growing point (HAGP)	R_{650}	–0.19	0.19	–0.31	0.04
	R_{850}	0.38	0.48*	0.03	0.12
	NDVI	0.35	0.15	0.14	0.09
	RVI	0.40	0.17	0.16	0.11
Diameter of a root collar (DRC)	R_{650}	0.64**	0.44	0.53	–0.18
	R_{850}	–0.39	–0.34	0.03	–0.63**
	NDVI	–0.69**	–0.55	–0.28	–0.63**
	RVI	0.67**	0.57**	–0.18	–0.58**

Significant difference: *SD = 0.444 at P = 0.05. **SD = 0.561 at P = 0.01.

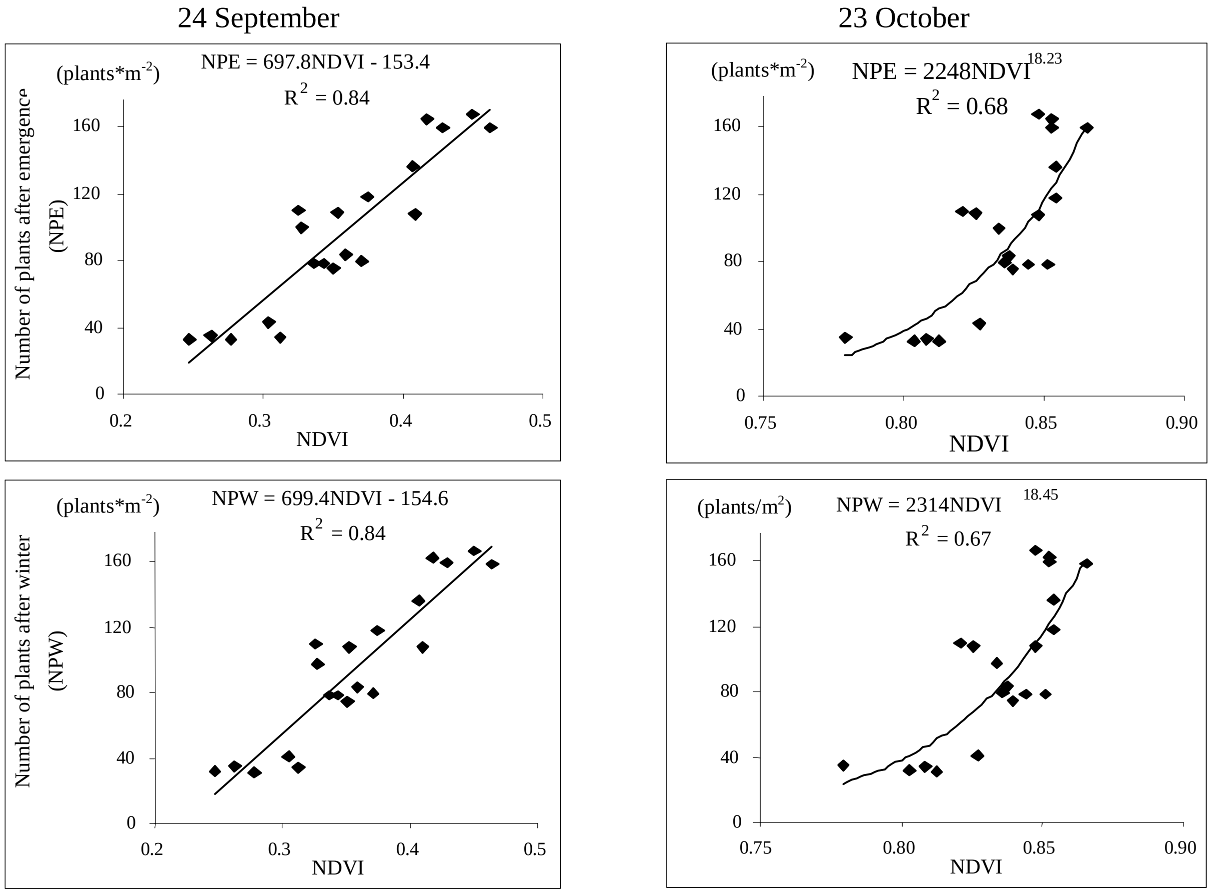

Fig. 1. The relationship between NDVI and six agronomic parameters of winter oilseed rape for plot averaged data (n = 20) on two measurement dates in the autumn season

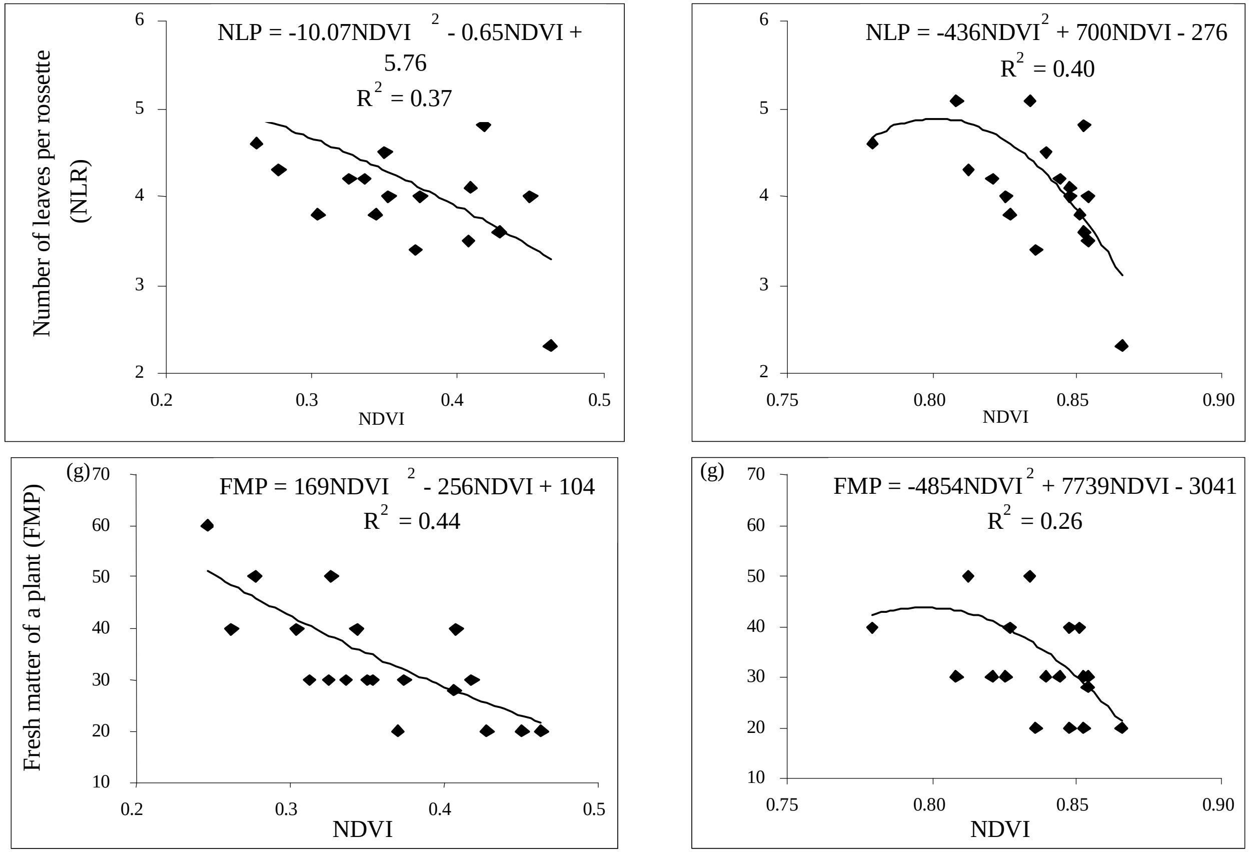

Fig. 1. Cont. The relationship between NDVI and six agronomic parameters of winter oilseed rape for plot averaged data (n = 20) on two measurement dates in the autumn season

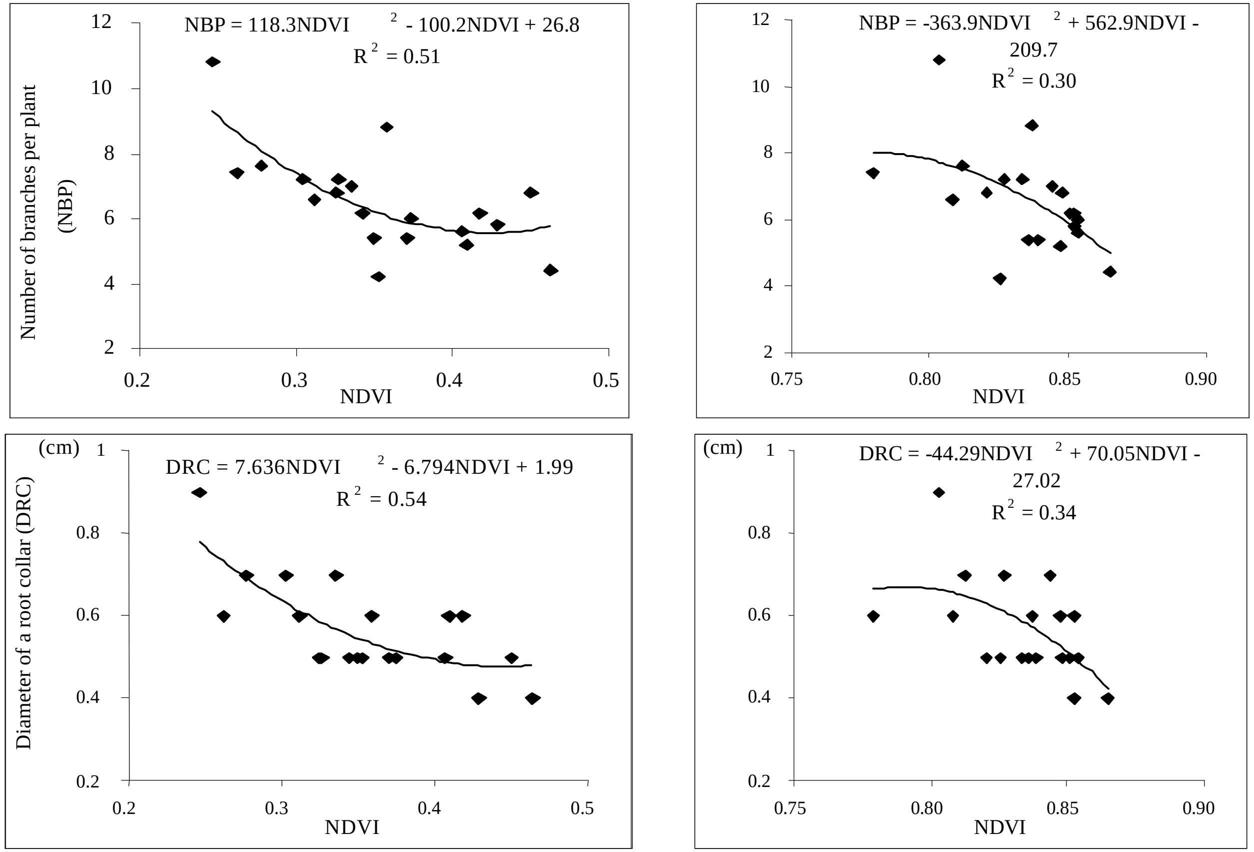

Fig. 1. Cont. The relationship between NDVI and six agronomic parameters of winter oilseed rape for plot averaged data (n = 20) on two measurement dates in the autumn season

Simple linear regression models were used to characterize the relationship between two spectral vegetation indices and seven agronomic parameters of winter oilseed rape. Regression statistics for analysis were generated using n = 20 pairs of observations. Variation in six winter oilseed rape agronomic parameters is represented in Figure 1 in relation to NDVI calculated from measurements taken on 24th September and 23rd October. Earlier in the autumn season the best fitting relationships were linear for crop agronomic parameters (NPE and NPW), later, the best fitting relationships were quadratic (near-linear). For all individual plant agronomic parameters the best relationships were polynomial on both autumn measurements dates.

DISCUSSION

Both vegetation indices calculated from reflectance measurements in red and near-infrared wavelengths have potential for monitoring vegetation development at early phenological phases of winter oilseed rape. Since the commonly used ratio vegetation indices are based upon the reflectance in both the red and near-infrared bands, they behave equally as indicators of plant biophysical parameters [1]. However, in our study, at low amount of vegetation, NDVI showed better ability than RVI to follow vegetation dynamics and to differentiate plots with various SR. The latter index was more useful at higher vegetation densities, which is consistent with conclusion of [8].

Plant density has a great influence on winter oilseed rape plant development [11]. Variations in seeding rate determine vegetation amount per unit area and plant competition and, consequently, affect spectral properties of a crop. As many authors report, increased oilseed rape plant density reduces the number of pods per plant [11], the number of fertile branches [7], and the number of seeds per pod [19]. These findings are in agreement with our results. The agronomic parameters of an individual plant (NLR, FMP, NBP and DRC) were inversely correlated with SR and, consequently, were directly related to R_{650}, and inversely to R_{850}, NDVI and RVI.

Among the agronomic variables, crop parameters are, on the whole, better correlated with spectral reflectance while individual plant parameters are less well correlated to it. The strength of the correlation depends on the date of spectral measurements. Weaker relationship observed later in the autumn season resulted from saturation of vegetation indices and poorer illumination conditions. Saturation in the vegetation index, like NDVI, has been reported by many authors [12], [23]. They noticed that vegetation indices used as estimators of biophysical plant parameters (e.g. LAI and biomass), perform better when the vegetation amount gradually increases up to a certain value. Further on, at dense vegetation, this relationship becomes asymptotic, because with plant growth near-infrared reflectance continues to increase while red reflectance shows only a slight decrease. Thus, vegetation indices change slightly. The upper asymptote of NDVI versus vegetation density usually occurs near 0.5-0.8 [3].

The second reason for better relationship between agronomic parameters of winter oilseed rape and vegetation indices earlier in the autumn season was better illumination conditions at that time. For incomplete canopies with row structure, spectral reflectance is highly dependent on solar zenith angles [9]. Higher solar position (θ_s = 53°) on 24th September ensures better illumination conditions than on 23rd October (θ_s = 63°). Some vegetation indices reduce the effect of sun angle over the plant canopies, although they do not eliminate it [5,16]. According to [6], reliable spectral data should be gathered at $\theta_s < 60°$.

Very poor relationship between spectral data and all agronomic parameters of oilseed rape at the beginning of the spring growing season was caused by the presence of leaf litter on the ground. The spectral properties of plant litter affect vegetation indices and can cause errors in their response to green vegetation cover [22].

CONCLUSIONS

1. The results of the study show that oilseed rape plants are detectable in the spectral data early in the autumn growing season: four weeks after emergence. At that time it is possible to differentiate crops with various plant densities.
2. Number of plants in the crop can be predicted in the early autumn with relatively high accuracy (R^2 = 0.84), however, the precision of this estimation decreased further with plant development.
3. The best time for remote sensing observation of winter oilseed rape in western Poland is in the first half of October, when solar zenithal position is relatively high (<60°) and vegetation indices are not saturated yet due to high vegetation amount.
4. Data presented in this paper should be of interest to investigators developing rapeseed crop models. Spectral data can be used for "recalibration" of such models and improve them by describing phenological development and dynamics of plant characteristics.
5. Since the relationship between spectral data and agronomic parameters presented in this study is relatively high at low vegetation cover, further investigations are needed to test the influence of various soil backgrounds. NDVI and RVI are heavily influenced by soil, and to overcome this problem "soil adjusted" vegetation indices should be tested.

REFERENCES

1. **Ahlrichs J.S., Bauer M.E.:** Relation of agronomic and multispectral reflectance characteristics of spring wheat canopies. Agron. J., 75, 987-993, 1983.
2. **Broge N.H., Leblanc E.:** Comparing prediction power and stability of broadband and hyper-spectral vegetation indices for estimation of green leaf area index and canopy chlorophyll density. Remote Sens. Environ., 76, 156-172, 2000.
3. **Carlson T.N., Ripley D.A.:** On the relation between NDVI, fractional vegetation cover, and leaf area index. Remote Sens. Environ., 62, 241-252, 1997.
4. **Daughtry C.S.T., Walthal, C.L., Kim M.S., Brown de Colstoun E., McMurtrey J. E.:** Estimating corn leaf chlorophyll concentration from leaf and canopy reflectance. Remote Sens. Environ., 74, 229-239, 2000.
5. **Epiphanio J.C.N., Huete A.R.:** Dependence of NDVI and SAVI on sun/sensor geometry and its effect on fAPAR relationships in alfalfa. Remote Sens. Environ., 51, 351-360, 1995.
6. **Frulla L.A., Milovich J.A., Gagliardini D.A.:** Illumination and observation geometry for NOAA-AVHRR images. Int. J. Remote Sens., 12, 2233-2253, 1995.
7. **Geisler G., Henning K.:** Untersochungen zur Ertragsstruktur von Raps (*Brassica napus* L.). II. Die generative Entwicklung der Rapspflanze in Abhaingigkeit von der Bestandesdichte. Bayer. Landw. Jahrb., 58, 322-332, 1981.
8. **Huete A.R., Jackson R.D., Post D.F.:** Spectral response of a plant canopy with different soil backgrounds. Remote Sens. Environ., 17, 37-53, 1985.
9. **Jackson R.D., Pinter P.J., Idso S.B., Reginato R.J.:** Wheat spectral reflectance: interactions between crop configuration, sun elevation, and azimuth angle. Appl. Optics, 28, 3730-3732, 1979.
10. **Kuusk A.:** The angular distribution of reflectance and vegetation indices in barley and clover canopies. Remote Sens. Environ., 37, 143-151, 1991.
11. **Leach J.E., Stevenson H.J., Rainbow A.J., Mullen L.A.:** Effects of high plant populations on the growth and yield of winter oilseed rape (*Brassica napus*). J. Agric. Sci. Camb., 132, 173-180, 1999.
12. **Major D.J., Baret F., Guyot G.:** A ratio vegetation index adjusted for soil brightness Int. J. Remote Sens., 11, 727-740, 1990.
13. **Mendham N.J., Shipway P.A., Scott R.K.:** The effects of delayed sowing and weather on growth, development and yield of winter oil-seed rape (*Brassica napus* L.). J. Agric. Sci. Camb., 96, 389-416, 1981.
14. **Muśnicki Cz.:** Botanical-agricultural characterisation of winter oil-seed rape and its yield under variable environmental and agricultural conditions (in Polish). Rocz. Akademii Rolniczej w Poznaniu, Rozprawy Naukowe, 191, 1-154, 1989.
15. **Piekarczyk J.:** Temporal variation of the winter rape crop spectral characteristics. Int. Agrophysics, 15, 101-107, 2001.
16. **Qi J., Cabot F., Moran M.S., Dedieu J.:** Biophysical parameter estimations using multidirectional spectral measurements. Remote Sens. Environ., 54, 71-83, 1995.
17. **Ridao E., Oliveira C.F., Conde J.R., Mlnguez M.I.:** Radiation interception and use, and spectral reflectance of contrasting canopies of autumn sown faba beans and semi-leafless peas. Agric. For. Meteorol., 79, 183-203, 1996.
18. **Robinson B.F., Biehl L.L.:** Calibration procedures for measurements of reflectance factor in remote sensing field research. In: Proc. SPIE, 196, 16-26, 1979.
19. **Sierts H.P., Geisler G., Leon J., Diepenbrock W.:** Stability of yield components from winter oil-seed rape (*Brassica napus* L.). J. Agron. Crop Sci., 158, 107-113, 1987.

20. **Thenkabail P.S., Smith R.B., De Pauw E.:** Hyperspectral vegetation indices and their relationship with agricultural crop characteristics. Remote Sens. Environ., 71, 158-182, 2000.
21. **Vaesen K., Gilliams S., Nackaerts K., Coppin P.:** Ground-measured spectral signatures as indicators of ground cover and leaf area index: the case of paddy rice. Field Crops Res., 69, 13-25, 2001.
22. **van Leeuwen W.J.D., Huete A.R.:** Effects of standing litter on the biophysical interpretation of plant canopies with spectral indices. Remote Sens. Environ., 55, 123-138, 1996.
23. **Wiegand C.L., Maas S.J., Aase J.K., Hatfield J.L., Pinter P.J., Jackson R.D., Kanemasu E.T., Lapitan R.L.:** Multisite analyses of spectral-biophysical data for wheat. Remote Sens. Environ., 42, 1-21, 1992.

ZASTOSOWANIE POLOWYCH POMIARÓW SPEKTRALNYCH DO OCENY AGRONOMICZNYCH PARAMETRÓW RZEPAKU OZIMEGO

Jan Piekarczyk[1], Marek Wójtowicz[2], Andrzej Wójtowicz[3]

[1]Instytut Geografii Fizycznej i Kształtowania Środowiska Przyrodniczego
Uniwersytet im. Adama Mickiewicza
ul. Dzięgielowa 27, 61-680 Poznań
e-mail: piekjan@amu.edu.pl
[2]Instytut Hodowli i Aklimatyzacji Roślin, ul. Strzeszyńska 36, 60-479 Poznań
[3]Instytut Ochrony Roślin, ul. Miczurina 20, 60-318 Poznań

Streszczenie. W przeprowadzonych badaniach określono wpływ gęstości siewu na charakterystyki spektralne rzepaku ozimego. Pomiary odbicia spektralnego od roślin wykonano za pomocą polowego luminancjometru CIMEL CE 313. Na podstawie wartości współczynników odbicia fal o długości 650 i 850 nm obliczono wskaźniki wegetacyjne NDVI i RVI. W doświadczeniu wykazano istotne zróżnicowanie charakterystyk spektralnych pomiędzy zastosowanymi kombinacjami doświadczalnymi. Współczynniki odbicia i wskaźniki wegetacyjne porównano z następującymi parametrami agronomicznymi rzepaku ozimego: liczbą roślin po wschodach i po zimie, liczbą liści w rozecie, świeżą masą roślin, liczbą pędów bocznych, wyniesieniem pąka wierzchołkowego oraz średnicą szyjki korzeniowej. Pierwsze dwa z wymienionych parametrów były silniej skorelowane z wartościami współczynników odbicia i wartościami wskaźników wegetacyjnych od pozostałych czterech. Uzyskane wyniki potwierdzają duże możliwości wykorzystania polowych pomiarów spektralnych w szacowaniu stanu upraw rzepaku ozimego.

Słowa kluczowe: rzepak ozimy, teledetekcja, spektroskopia polowa, wskaźniki wegetacyjne