JOURNAL OF PLANT PROTECTION RESEARCH
Vol. 46, No. 1 (2006)

APPLICATION OF SPECTRAL MEASUREMENTS TO THE ASSESSMENT OF POTATO PLANTS INFECTION BY *PHYTOPHTHORA INFESTANS*, THE CAUSAL AGENT OF POTATO LATE BLIGHT

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Accepted: March 24, 2006

Abstract: Measurements of spectral reflectance from potato plants were carried out in the years 2000 and 2001 using the field radiometer CE 313 of Cimel Electronique Company. Field experiments permitted to perceive differences in the reflectance of electromagnetic radiation from potato plant cultivars Bekas and Mila as well as differences between the plants treated with fungicides providing the protection against *Phytophthora infestans* and the untreated plants.
A differentiation of the values of vegetative indices between potato cultivars resulted from the unequal development rate of the cultivars and from their different susceptibility to *Phytophthora infestans*. The assessment of potato plants infection by the studied pathogen using spectral measurements agreed with the results of field inspection.

Key words: *Phytophthora infestans*, vegetation index

INTRODUCTION

Spectral measurements aim at the identification of differences in the amount of electromagnetic radiation absorbed and reflected by the studied objects. Spectral characteristics of plants highly depend on plant leaves and their optical properties and are determined primarily by chlorophyll, water contained in the tissues and by cellular structures. The phenomenon of a big contrast between the visible reflection and the near infrared reflection occurring in plants was utilised in the development of the so called vegetative indices which are defined as dimensionless radiometric measures used to assess the vegetative activity of plants.

The vegetative index is expected to perform two basic functions. Firstly, it has to be characterised by a high correlation with biophysical parameters of plants, most frequently including such data as biomass, index of leaf area and the photosynthetically absorbed active radiation. Secondly, the index should limit the effect of factors impeding the interpretation of spectral measurements both those connected with the object and the external ones. The first category of factors includes soil, land topography and photosynthetically inactive plant elements. The second category includes atmosphere, sun rays incidence angle and the angle of measurements being carried out. The vegetative indices are used among others in the monitoring of cultures, for the assessment of plant biomass and in yield prognoses (Asrar et al. 1984; Bausch 1993; Benefetti and Rossini 1993; Wanjura and Hatfieid 1987). They are also useful in the evaluation of soil erosion (Dejong 1994), in monitoring of water and energy circulation (Wood and Lakshmi 1993) and in the assessment of pasture degradation (Dymond et al. 1992).

The vegetative indices have been also applied in the studies on plant protection. Nilsson (l985) showed the usefulness of the vegetative indices in the evaluation of the effectiveness of barley protection against *Pyrenophora graminae* and in the assessment of the intensity of winter rape infection by *Sclerotinia sclerotiorum* and *Verticilium albo-atrum*. Sharp et al. (1985) used the vegetative indices for the assessment of wheat protection against *Puccinia graminis* and *Puccinia striiformis*, other researchers: Hickrnan et al. (1991) and Lamb and Weedon (1998) found the possibility to apply the vegetative indices to the evaluation of the correctness of chemical treatments with the use of herbicides.

The objective of the study was to evaluate the opportunity of spectral measurements in assessment of effectiveness of potato chemical protection against *P. infestans*.

MATERIALS AND METHODS

An experiment was established in random sub-block design in four replications in Winna Góra (N 52°23′ E 17°28′). Each plot consisted of 4 drills 20 m long. The drill width was 0.75 m and a distance between tubers was 0.20 m. Potato cultivars and chemical protection program were the experimental factors. The spectral measurements were carried out on chemically protected plots and on control plots without any chemical treatments against *P. infestans*. The studies were performed on two potato cultivars differing in their susceptibility to the pathogen. Cultivar Bekas is rated as susceptible to *P. infestans* infection, while cv. Mila belongs to the moderately resistant group. The following variants of chemical protection were applied in the experiment: Simphyt – chemical treatments carried out at the date indicated by Simphyt system; NegFry – chemical treatments applied according to the schedule predicted by NegFry; Stephan – chemical treatments according to the date defined by Stephan system; routine protection – treatments performed at 7-day intervals except for the second treatment which was applied 10 days after the first one which took place 60 days after the date of potato planting.

Measurements of spectral reflectance from potato plants were carried out in the years 2000 and 2001 using the field radiometer CE 313 of Cimel Electronique

Company. The apparatus permits the measurement of absolute monochromatic energetic luminance values in five ranges of spectrum whose maximal sensitivity falls to the waves of 450, 550, 650, 850 and 1650 nm length. The vegetative indices were calculated according to the following formulae:

$$NDVI = \frac{R_{850} + R_{650}}{R_{850} - R_{650}}, \quad NIR/RED = \frac{R_{850}}{R_{650}} \qquad \text{(Nilsson 1985)}$$

$$GREEN/RED = \frac{R_{550}}{R_{650}}, \quad ELAI = -0.441 + 0.285 \cdot \frac{R_{850}}{R_{650}} \qquad \text{(Nilsson 1985)}$$

The spectral measurements were carried out before noon, except on 13.07.2000. On each plot, three places were randomly selected for spectral measurements.

On all experimental plots, the infection of *P. infestans*, the cause of potato late blight was assessed on potato plants using the key presented in Table 1. The key is a compilation of scales proposed by the British Mycological Association (Anonymous 1947) and that prepared by Jörg and Kleinhenz (1999)

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

Table 1. Late blight assesment key for potato plants

Disease severity [%]	Plants decsription
0	no infection
0.1	a few scatered plants blighted; no more than 1 or 2 spots in 12-yard radius
1	up to 10 spots per plant
5	around 50 spots per plant; up to 1 leaflet in 10 attacked
10	up to 4 leaflets in 10 affected; plants still retaining normal form
25	nearly each leaflet with lesions but plants still retaining normal form; plot may look green though every plant is affected
50	every plant is affected and about half of lesf area destroyed by blight; plots looks green, flecked with brown
75	about 75% of leaf area destroyed; field appears neither predominantly brown nor green
95	only a few leaves on plants, but stems green
100	all leaves dead, stems dead or dying

RESULTS

Development of disease symptoms on the aboveground parts of plants

In the year 2000, the first disease symptoms characteristic for *P. infestans* infection were observed on the studied cultivars on July 15. Until August 2, on the protected plants of cv. Bekas the disease symptoms were developing slowly. On the other hand, during the next three weeks, the development rate of disease symptoms increased significantly and the destruction of potato plants increased from 1% to 95%. After August 23, the development rate of potato late blight declined again. On the unprotected plots, the development of disease symptoms was significantly faster than on the plots treated with fungicides against *P. infestans*. Within 12 days, from July 21 to August 7, the infection of potato plants on control plots increased from 5% to 95%. After that period, the development rate of disease symptoms slowed down.

On plants of cv. Mila, the development rate of disease symptoms was slower than on cv. Bekas. On the untreated plots, the infection was negligible until July 21. Then, the development of symptoms rapidly increased, but after August 16, it slowed down again. On protected plots, the disease developed with a 3-week delay in comparison with the unprotected plants.

Table 2. Development of disease symptoms on cultivars Bekas and Mila in Winna Góra in the years 2000 i 2001 [%]

Date of disease assesment	Bekas					Mila				
	Simphyt	NegFry	Stephan	Routine	Untreated	Simphyt	NegFry	Stephan	Routine	Untreated
17.VII.2000	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
21.VII.2000	0.1	0.1	0.1	0.1	5	0.1	0.1	0.1	0.1	1
26.VII.2000	0.1	0.1	0.1	0.1	25	0.1	0.1	0.1	0.1	10
31.VII.2000	0.5	0.5	0.5	0.5	50	0.1	0.1	0.1	0.1	25
2.VIII.2000	1	1	1	1	75	0.1	0.1	0.1	0.1	50
7.VIII.2000	10	10	10	10	95	5	5	5	5	75
16.VIII.2000	75	75	75	75	100	25	25	25	25	95
23.VIII.2000	95	95	95	95	100	50	50	50	50	100
30.VIII.2000	100	100	100	100	100	75	75	75	75	100
9.IX.2000	100	100	100	100	100	95	95	95	95	100
13.IX.2000	100	100	100	100	100	100	100	100	100	100
2.VII.2001	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0
10.VII.2001	0.5	0.5	0.5	0.5	13.75	0	0	0	0	0.1
17.VII.2001	5	5	5	5	50	0.1	0.1	0.1	0.1	1
24.VII.2001	5	5	5	5	95	0.1	0.1	0.1	0.1	5
31.VII.2001	25	25	25	25	100	5	5	5	5	50
7.VIII.2001	50	50	50	50	100	5	5	5	5	75
14.VIII.2001	75	100	95	75	100	10	25	25	10	95
21.VIII.2001	100	100	100	100	100	25	75	75	25	100
28.VIII.2001	100	100	100	100	100	50	95	95	50	100
4.IX.2001	100	100	100	100	100	75	100	100	75	100
11.IX.2001	100	100	100	100	100	100	100	100	100	100

In the year 2001, on plants of cv. Bekas the first disease symptoms appeared already on June 26, while on July 2, the degree of infection of this cultivar reached 0.1% (Table 2). Until July 24 on the protected combinations, the disease development rate was not great. On the other hand, on the unprotected plots, the disease progressed rapidly. On July 10, plant infection reached 13%, on July 17 it increased to 50% and on July 24, it was as high as 95%. In the period from July 24 to August

14, a rapid development of disease was observed on the protected plots. Until August 7, the disease development rate was equal on all protected combinations. On August 14, a slight differentiation of the infection was observed between the plots protected according to the recommendations of the studied protection systems. On the plots protected by the Simphyt system and the Routine system, the infection was 95%, while on plots protected by NegFry and Stephan's systems, the infection reached 100%. On August 21, plant infection of all experimental combinations was 100%.

Similarly as in the year 2000, the disease developed slower on plants of cv. Mila than on plants of cv. Bekas. (Table 2). On all protected plots, an equal development of disease symptoms was observed until August 7, and the infection degree of potato plants in that period did not exceed 5%. However, after that date a significant acceleration of disease symptoms development rate was observed. Furthermore, since August 14, a differentiation of disease development rate was visible between the investigated systems. In combinations protected according to NegFry and Stephan's systems, the disease developed faster than in the plots protected according to Simphyt and Routine systems. On the unprotected plots, a slow development of disease symptoms was observed until July 24. After that date, there followed an acceleration of disease development rate and it lasted until August 28.

Results of spectral measurements

In the vegetation season of 2000, the spectral measurements were carried out on the following dates: June 1, June 13, June 20, July 2, July 9 and July 26. On June 1, i.e. 24 days after emergence, cv. Bekas plants were at the inflorescence development stage, while the plants of cv. Mila were at the stage of the main stem growth. Significant differences in the spectral reflection were shown using the vegetative indices: NIR/RED and ElAI (Table 3). On the other hand, GREEN/RED index did not show at that stage any significant differences in the electromagnetic radiation reflectance between the cultivars. Mean values of NIR/RED, GREEN/RED and ELAI indices characterising Bekas cultivar were higher than the values of these indices calculated for cv. Mila. The system of chemical protection did not significantly differentiate the radiation reflectance from the surface area of potato plants.

On June 13, potato plants were at the blooming stage. Plants of cv. Bekas were more advanced in the development than cv. Mila plants. The differences in the spectral reflectance of the studied cultivars were so great that it was possible to identify them with the help of all analysed indices (Table 3). The values of all analysed indices calculated on the basis of the measurements of radiation reflectance from plants of cv. Mila were higher than the corresponding values referring to cv. Bekas cv. (Table 3). No significant differences were recorded between the spectral reflectance from plants representing different protective systems.

On June 20, potato plants continued to be at the blooming stage and statistical analysis based on the results of spectral measurements carried out that day, showed again the significant differences in electromagnetic radiation reflectance between cultivars Bekas and Mila (Table 3).

On August 2, potato plants were at the stage of fruit and seed ripening. Statistical analysis of the vegetative indices confirmed the differentiation of the studied cultivars regarding the reflectance of electromagnetic radiation (Table 3). The values of all vegetative indices calculated on the basis of measurements referring to cv. Mila were significantly higher than those of cv. Bekas. For the first time in the vegetation season, the occurrence of significant differences in the reflectance of electromagnetic radiation was found between the not protected plants and those protected with fungicides. However, the chemical protection according to different systems did not differentiate the values of vegetative indices (Table 4).

On August 9, the potato plants were still at the stage of fruit and seed ripening. The values of all the vegetative indices obtained on the basis of spectral measurements of cv. Mila. were significantly higher than the values characterising cv. Bekas (Table 3). Significant differences occurred also between the protected and the unprotected plants (Table 4).

Table 3. Comparision of cultivars Bekas and Mila with the help of vegetative inndices calculated on the basis of spectral measurements carried out in the years 2000 and 2001

Date of measurement	Cultivar	NIR/RED	GREEN/RED	ELAI
1.VI.2000	Bekas	21.984 a	2.871 a	5.824 a
	Mila	17.737 b	2.852 a	4.614 b
13.VI.2000	Bekas	16.626 b	2.414 b	4.297 b
	Mila	22.272 a	2.844 a	5.907 a
20.VI.2000	Bekas	12.793 b	2.106 b	3.205 b
	Mila	17.939 a	2.418 a	4.672 a
2.VIII.2000	Bekas	12.725 b	2.285 b	3.186 b
	Mila	16.354 a	2.672 a	4.220 a
9.VIII.2000	Bekas	9.517 b	2.030 b	2.271 b
	Mila	13.427 a	2.460 a	3.386 a
26.VIII.2000	Bekas	3.704 b	1.321 b	0.615 b
	Mila	9.610 a	2.069 a	2.298 a
5.VII.2001	Bekas	22.806 a	2.955 a	6.059 a
	Mila	24.839 a	2.924 a	6.638 a
28.VII.2001	Bekas	8.008 b	1.789 b	1.841 b
	Mila	25.837 a	3.069 a	6.923 a
9.VIII.2001	Bekas	6.318 b	1.657 b	1.360 b
	Mila	22.254 a	2.906 a	5.901 a

Means within columns followed by the same letter do not differ at p=0.05 according to Fisher's and Tukey's tests

On August 26, the potato plants were at the initial stage of plant senescence. Because of the complete withering of plants on unprotected plots, spectral measurements were carried out only on the protected plots. Again, significant differences were found in the reflectance of spectral radiation between the plants of the two studied cultivars (Table 3). The values of indices referring to cv. Mila.

were by 1.6 (GREEN/RED) to 3.7 (ELAI) times higher than the values referring to cv. Bekas. On the basis of a comparison of the p coefficient of significance, one can state that the vegetative indices very distinctly differentiated the investigated cultivars. On the other hand, no significant differences were found in the reflectance of electromagnetic radiation between the plants protected with the help of fungicides according to the recommendations of the studied protection systems.

Table 4. Comparision of decision support systems with the help of vegetative inndices calculated on the basis of spectral measurements carried out in the years 2000 and 2001

Date of measurement	System	NIR/RED	GREEN/RED	ELAI
2.VIII.2000	Simphyt	15.627 b	2.660 b	4.013 b
	NegFry	16.368 b	2.727 b	4.223 b
	Stephan	17.576 b	2.697 b	4.568 b
	Routine	17.270 b	2.694 b	4.481 b
	Untreated	5.857 a	1.615 a	1.228 a
9.VIII.2000	Simphyt	13.760 b	2.503 b	3.481 b
	NegFry	13.304 b	2.396 b	3.351 b
	Stephan	15.105 b	2.546 b	3.864 b
	Routine	14.791 b	2.508 b	3.775 b
	Untreated	3.417 a	1.233 a	0.533 a
16.VIII.2001	Simphyt	17.919 a	2.661 a	4.666 a
	NegFry	10.326 b	2.045 b	2.502 b
	Stephan	10.779 b	2.135 b	2.631 b
	Routine	17.829 a	2.702 a	4.640 a

Means within columns followed by the same letter do not differ at $p=0.05$ according to Fisher's and Tukey's tests

In the year 2001, the spectral measurements on all experimental plots were carried out on July 5 and July 28. On August 9, because of plant senescence on the experimental plots, the measurements were carried out only on plots treated with fungicides. On August 16, the measurements of electromagnetic radiation reflectance were performed only on protected plants of cv. Mila, because the plants on the remaining plots were almost completely decayed. The highest values of ELAI index in case of both cultivars were recorded on July 5.

On July 5, when the potato plants were at the stage of blooming, no significant differences were shown in the reflectance of electromagnetic radiation between the plants of cultivars Bekas and Mila. The Decision Support System (DSS) also did not significantly differentiate the values of the analysed vegetative indices (Table 3).

On July 28, the potato plants were at the stage of fruit and seed ripening. Because of a strong infection of plants on the unprotected plots, the spectral measurements were carried out only on the protected plots. In that term, using all indices, the occurrence of significant differences in the reflectance of electromagnetic radiation was found between the studied cultivars (Table 3). The values calculated for cv. Mila cv. were by 1.7 to 3.7 times higher than the corresponding values of cv. Bekas. On the other hand, no differences were recorded between the plants representing different protection systems.

On August 9, the plants of cv. Bekas were at the end of senescence i.e. leaves and stems dead, while plants of cv. Mila were at the stage of fruit and seed ripening. Significant differences were shown between the cultivars, but there was no difference between the protection systems. The values of all indices calculated on the basis of spectral measurements for plants of cv. Mila exceeded by 1.8–4.3 the indices calculated for cv. Bekas (Table 3).

On August 16, because of a very bad condition of cv. Bekas plants and the unprotected plants of cv. Mila spectral measurements were carried out on the remaining plots. With the help of all indices, the significant differences were shown between the plants protected with different protection systems (Table 4). The index values were different for Simphyt and Routine systems and for NegFry and Stephan's systems.

In both experimental years, no significant interactions between the cultivar and the protection system were found.

DISCUSSION

The studies carried out in the years 2000–2001 showed that the spectral measurements can be successfully utilised for the assessment of effectiveness of potato chemical protection against *P. infestans*. The applied vegetative indices permitted in the majority of cases to detect differences in the development of disease symptoms caused by *P. infestans* resulting from the resistance of potato cultivar as well as from the activity of fungicides. Such a conclusion was also drawn from the work of Wójtowicz and Piekarczyk (2001). The collected evidence materials indicate also that in the analysis of spectral measurements, next to the intensification of the development of disease symptoms, also the plant morphology should be taken into consideration.

In 2000, in Winna Góra, the spectral measurements permitted to detect differences in the reflectance of electromagnetic radiation from the plants of cultivars Bekas and Mila as well as between the plants protected against *P. infestans* and the untreated plants. The differences recorded on June 1 in the reflectance of electromagnetic radiation between cultivars Bekas and Mila did not result from plant infection by *P. infestans*, but from the fact that cv. Bekas was more advanced in the development than cv. Mila. The differences in the reflectance of electromagnetic radiation between cultivars Bekas and Mila were shown with the help of NIR/RED and ELAI indices. On the other hand, GREEN/RED index did not permit to detect these differences.

In the first half of June, plants of cv. Mila developed much more intensively than cv. Bekas plants and this resulted in greater abundance of plants. This fact was recorded on June 13. This situation found an expression in the spectral measurement results, and the values of all vegetative indices characterising cv. Mila were significantly higher than the corresponding values of cv. Bekas. The values of indices calculated on the basis of the measurements of June 20 were also the result of the absence of plant infection by *P. infestans* and the domination of cv. Mila over Bekas cv. regarding the abundance of plants. On the other hand, differences in the values of vegetative indices shown on the basis of the spectral measurements carried out on August 2 and August 9 resulted primarily as derivatives of the disease symptoms development induced by *P. infestans*. This is supported by the fact that the indicated differences in the spectral reflectance occurred not only between potato cultivars but also between plants protected against *P. infestans* and those which were not covered with protective treatments. It agrees with the results of field inspection carried out at the end of August. On August 2, on the protected plots, the infection of cv. Bekas plants was 1% and the infection of cv. Mila plants was 0.1%. Consecutively, on August 7, the infection of cv. Bekas was 10% and that of cv. Mila was 5%.

The differences shown on August 26 in the values of vegetative indices characterising the cultivars Bekas and Mila protected with fungicides resulted also from the infection degree by *P. infestans*. The infection of potato plants recorded on August 23 on plots with cv. Bekas amounted to 95% and on the plots with cv. Mila 50%.

Because of a high cloudiness dominating for a long time in spring 2001, it was not possible to carry out the early measurements of the reflectance of electromagnetic radiation from the potato plants in Winna Góra. Such possibility came finally on July 5 when the infection of cv. Bekas plot amounted to 0.1%, while on cv. Mila there were not yet disease symptoms characteristic of potato blight. On that day (July 5), the plants of both cultivars appeared to be equally abundant. It could have indicated that any possible differences in the values of indices would follow from the differences in the disease symptoms intensity. However, because of a small intensity of disease symptoms as well as due to the fact that the symptoms occurred only on Iower parts of plants and were not visible without drawing the plant leaves aside, it seems not probable that in this case, plant infection by *P. infestans* was the dominating factor differentiating the vegetative indices.

On the other hand, the results of spectral measurements carried out on July 28 and August 9 showed significant differences in the intensity of disease symptoms caused by *P. infestans* between cultivars Bekas and Mila. In each measurement, the values of all analysed indices characterising cv. Mila were higher than the indices characterising cv. Bekas being the more susceptible one to *P. infestans*. The assessment of the infection of cultivars by *P. infestans* with the help of vegetative indices agreed with the results of field inspection carried out on July 24 and July 31 as well as on August 7 and August 14.

Interesting results were obtained on July 18, when due to the withering of cv. Bekas plants, the spectral measurements were applied to cv Mila. only. On that date, the differences in the infection of potato plants between the plots representing different Decision Support Systems were successfully detected with the help of all applied vegetative indices.

The results of own studies are similar to the reports of Nilsson (1985) who studied the infection of barley by *Pyrenophora graminea* and showed the occurrence of significant differences in the values of vegetative indices defining the reflectance properties of plants treated with fungicides and those of control plants.

Sharp et al. (1985), in their studies on the utilisation of vegetative indices to the assessment of the effectiveness of chemical protection of wheat against *Puc-*

cinia graminis and *Puccinia striiformis* have also found that the values of indices calculated on the basis of the measurement results of electromagnetic radiation reflectance from treated plants were higher than in case of plants from the control plots. A significant effect of the pathogen on the spectral characteristics of plants was also shown by Pennypacker et al. (1982) who analysed the reflectance of electromagnetic radiation from healthy plants of barley and wheat and those infested by barley yellow dwarf virus and brown rust of wheat.

REFERENCES

Anonymous 1947. The measurement of potato blight. Trans. British Mycol. Soc. 31: 140–141.

Asrar G., Fuchs M., Kanemasu E.T., Hatfield J.L. 1984. Estimating absorbed photosynthetic radiation and leaf area index from spectral reflectance in wheat. Agron. J. 76: 300–306.

Bausch W.C. 1993. Soil background effects on reflectance-based crop coefficients for corn. Remote Sens. Environ. 46: 213–222.

Benedetti R., Rossini P. 1993. On the use of NDVI profiles as a tool for agricultural statistics: The case study of wheat yield estimates and forecast in Emilia Romagna. Remote Sens. Environ. 45: 311–326.

Dejong S. M. 1994. Derivation of vegetative variables from a Landsat TM image for modelling soil-erosion. Earth Surf. Process. Landforms. 19: 165–178.

Dymond J.R., Stephens P.R., Newsome P.F., Wilke R.H. 1992. Percentage vegetation cover of a degrading rangeland from SPOT. Int. J. Remote Sens. 13: 1999–2007.

Hickman M.V., Everitt J.H., Escobar D.E., Richardson A.J. 1991. Aerial photography and videography for detecting and mapping dicamba injury patterns. Weed Technol. 5: 700–706.

Jörg E., Kleinhenz B. 1999. Proposal for validation of the late blight DSS in field trials. PAV-Special Report No. 5: 30–41.

Lamb D., Weedon M. 1998 Evaluating the accuracy of mapping weeds in fallow fields using airborne digital imaging: *Panicum effusum* in oilseed rape stubble. Weed Research 38: 443–451

Nilsson H. 1985. Remote sensing of 6-row barley infected by barley stripe disease. Vaxtskyddsrapporter Jordbruk 36, 49 pp.

Pennypacker S.P., Scharpen A.L., Sharp E.L., Sands D.C. 1982. Spectral classification of wheat infected with barley yellow dwarf and stripe rust. Phytopathology 72, p. 1006

Sharp E.L., Perry C.R., Scharen A.L., Boatwright G.O., Sands D.C., Lautenschlager L.F., Yahyaoui C.M., Ravet F.W. 1985. Monitoring cereal rust development with a spectral radiometer. Phytopathology 75: 936–939.

Wanjura D.F., Hatfield J.L. 1987. Sensitivity of spectral vegetation indices to crop biomass. Trans. ASAC 30: 810–816.

Wójtowicz A., Piekarczyk J. 2001. Monitoring of *Phytophthora infestans* development with a luminancemeter. J. Plant Protection Res. 41: 256–265.

Wood E.F., Lakshmi V. 1993. Scaling water and energy fluxes in climate systems-3 land atmospheric modeling experiments. J. Climate 6: 839–857.

POLISH SUMMARY

ZASTOSOWANIE POMIARÓW SPEKTRALNYCH DO OCENY PORAŻENIA ŁANU ZIEMNIAKA PRZEZ *PHYTOPHTHORA INFESTANS*, SPRAWCĘ ZARAZY ZIEMNIAKA

Istotą pomiarów spektralnych jest uchwycenie różnic w ilości promieniowania elektromagnetycznego pochłanianego i odbijanego przez badane obiekty. O charakterystykach spektralnych roślin w dużym stopniu decydują liście, a ich właściwości optyczne determinowane są w pierwszej kolejności przez chlorofil, zawartą w tkankach wodę oraz struktury komórkowe. Charakterystyczne dla roślin zjawisko występowania dużego kontrastu pomiędzy odbiciem promieniowania widzialnego i promieniowania z zakresu bliskiej podczerwieni, zostało wykorzystane przy opracowywaniu tzw. wskaźników wegetacyjnych, które definiowane są jako bezjednostkowe miary radiometryczne służące do oceny aktywności wegetacyjnej roślin.

Celem przeprowadzonych badań było stwierdzenie czy zastosowane wskaźniki wegetacyjne nadają się do oceny porażenia łanu ziemniaka przez *Phytophthora infestans*. Pomiary odbicia spektralnego od roślin ziemniaka wykonano w latach 2000 i 2001, w Winnej Górze koło Środy Wlkp., przy użyciu polowego radiometru CE 313 firmy Cimel Electronique.

W pracy oceniono wpływ odmiany ziemniaka i ochrony chemicznej prowadzonej przeciwko *P. infestans* na spektralne charakterystyki łanu ziemniaka. W 2000 roku wykazano istotne zróżnicowanie wartości wskaźników wegetacyjnych NIR/RED i ELAI pomiędzy badanymi odmianami ziemniaka od fazy wzrostu pędu głównego do fazy zamierania. Ponadto w fazie dojrzewania owoców i nasion stwierdzono istotne różnice w wartościach analizowanych wskaźników pomiędzy roślinami ziemniaka chronionymi za pomocą fungicydów i nie podlegającymi ochronie chemicznej. Natomiast w 2001 roku istotne różnice w wartościach wskaźników NIR/RED i ELAI pomiędzy badanymi odmianami stwierdzono w fazie dojrzewania owoców i nasion oraz w fazie zamierania.