INVESTIGATION OF SPECTRAL CHARACTERISTICS OF NATURAL OBJECTS IN TESTSITES OF THE GDR

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ABSTRACT

Methodical investigations on the spectral characteristics of natural objects are carried out mainly on land use objects in the GDR. For this reason test sites were set up on which both the spectral reflectance curves and the object specific features (biomass, chlorophyll content, plant water content, leaf area index, soil cover, soil moisture content e. t. c.) are measured during the whole vegetation periode. The measurement of the spectral remission coefficient is carried out by a field laboratory, which consists of two parallel operating spectrometers, the first one operating nearly continously in the 0,4 - 1,1 μm waveband, the second one operating in the 0,4 - 2,5 μm waveband, using 7 channels. Relations between object specific characteristics and spectral reflectance curves are discussed. It turned out, that the density of chlorophyll content mg/m^2 is the most importent object specific feature to be obtained for grain and grassland areas.

1. Problems

In the course of the year land in cultivation is subjected to the rhythm of tillage, growth, ripening and harvest. It determines the way as reflected in remote sensing data. The attempt to cover in the framework of development of landscape diagnosis methods relations between agricultural object properties and object features which can be characterized by means of remote sensing must take into consideration the seasonal rhythm of agricultural crops. This requires multi-temporal methods of aquisition, as e. g. the comparison of photographs of the same region in different seasons. The more exact determination of relations between phenological phases of agricultural crops and remote sensing data, however, does not do without series of measurement which render possible the derivation of statistical models of the quantitative relation between plant development and remote sensing characteristics.

Additionally to the evaluation of aerial photographs from 1978 and 1983 for this reason since 1981 field experiments are carried out [2, 3, 4]. Insitu measurements concern the seasonal sequence of spectral reflectance of grain and grassland. In this paper, results of works carried out on a test area at Central part of GDR near by Potsdam in 1982 and 1983 will be presented and related to conclusions of aerial photographs of this area.

2. Conclusions of multispectral aerial photographs (taken by the camera MKF-6) on the development of winter rye and grassland cultures

Aerial photographs of the test site were taken from a height of 4000 m and 6500 m. On the colour synthesis pictures the orchards, the forests and the villages are distinguishable as distinctly as the winter rye field in the area under investigation. They contrast very clearly with the grassland fields. Comparing the photographs, distinct differences are to be seen.

The vigorous red colour of the winter rye in the beginning of May indicates a high chlorophyll contents of the plants in the phase of upward growth, the changeover to green in the beginning of July on the other hand, unsignificant chlorophyll contents during ripening. On May, in the grassland only the not ploughed up stock is growing, on July, however, after the first mowing all are growing. From this are resulting the high-contrast colour patterns both of the grassland fields in May and their poorer in colour contrast subdivision in July.

3. Parameters of phenological phases of winter rye and grassland (Dactylis glomerata)

For the aquisition of the development of winter rye (Janosz grade) and Dactylis glomerata 5 geotopes were selected:

- Location A is situated at the high slope of the edge of a plate on loam-underlain sand-rost soil in the winter rye field.
- Location B is situated at the low slope of the plate edge. There one finds sand-rost gley with ground water influx off 7 dm distance. This position belongs to the winter rye field, too.
- Location C represents the medium slope of the plate edge. The winter rye is here on sand-rost soil.
- Location D is situated on sand-humus gley, Dactylis glomerata has been sown. Ground water off 3 dm depth.
- Location E belongs to the central part with fen peat. There is Dactylis glomerata, too. The ground water sometimes reaches the surface.

In the harvesting periodes the following phenological phases were detected: beginning of the upward growth, bloom and ripening. See following table.

winter rye		grass	
phenological phase	time	state	time
seeding	1981	first growth phase	May
sprout formation	1981	first mowing	middle of June
beginning of the upward growth	beginning of May	2-nd growth phase	after that
		2-nd mowing	beginning of September
bloom	beginning of June		
ripening	middle of July		

On the described phenological terms were determined the chlorophyll contents, the leaf area index and the above ground biomass, which influence the spectral characteristics of the plants, too [1]. Comparing the chlorophyll contents of the plants in the course of the year [fig. 1], it is to be seen with winter rye that the chlorophyll contents slowly increased from the sprout formation up to the beginning of the growth phase in May 1982, and guide increased during the growth phase and after that it decreased as fast up to the ripening only unsignificantly above zero (mg/g plant mass). With Dactylis glomerata, the chlorophyll contents during the first growth phase in June was distinctly lower than during the 2-nd growth phase in July. At the end of the vegetation period it decreased again significantly. The altogether higher values first appeared in the moist spring 1982 at the less humid edge of the flat of location D, in the arid summer and autumn, however, in the still moist centre of the flat of position E. Difference caused by the location become distinct in the comparison of measured values at locations A and B, too. The loam-underlain sand at location A could store so much humidity that the biomass production was higher than 1000 g/m^3. Contrary to this on the deep sand of location B, which could in this arid summer be provided with nutrients even not by the ground water, only 400 g biomass/m^3 were left during harvest. Especially between bloom and ripening the biomass increased only unsignificantly at this location. In this period also the values for leaf area index and chlorophyll contents at location B are distinctly smaller than those of location A.

4. Spectrometric features of plants and soil determined under laboratory conditions

For comparison with field measurements the reflectance of plant material from location A, B, D and E was determined in the laboratory. The reflectance measurements were carried out in the range from 0,4 to 1,0 μm wave length at the spectrophotometer VSU 2 with additional reflectance attachment. By the beginning of June 1982, in the growth phase, the leaves showed clearly the reflectance minimum determined by the chlorophyll contents in the red range, a reflectance maximum (peak), however, in the infrared range [fig. 1] . A reflectance maximum in the green range of the visible light (green peak), howe ver, was here not to be determined. The ripe cereals displayed this chlorophyll contents curve only weak or not at all. Thus, in July 1982 significant differences between the reflectance values of Dactylis glomerata and winter rye occured.

For samples of the upper floor from 0,4 to 1,0 μm wave length the reflectance values increased approximately in the relation permanently 1 : 3. They were at dry locations (A, B) significantly higher than on humid ones (D, E). On the dryer areals the humus contents of the upper soil was, as expected, smaller than on more humid ones. The vegetationspecific behaviour of the reflectance curve could't be determined at no one soil sample. This facilitated the field experiments.

5. Spectral reflectance measurements under in-situ conditions

5.1. Experiment-technical suppositions for determination of spectral reflectance properties under in-situ conditions

Only the determination of spectral characteristics under in-situ conditions renders possible more founded assertions on the question whether specific object properties can be determined by means of multispectral remote sensing methods.

For carrying out these in-situ measurements, the Mobile measuring complex of the Central Institute for Physics of the Earth was used in 1982 and 1983 [fig. 2]. The basic equipment of the Measuring complex consists of a field spectrometer and a radiometer which are mounted pivot ing at an approx. 6 m long measuring cantilever. The carrier vehicle is a rebuilt GAS 69. By means of the field spectrometer the spectral directed reflectance coefficient is measured in the wave length range 0,4 to 1,1 μm in 35 channels. At each of the locations under investigation, measurements were carried out at several measuring points and from this the mean spectral directed reflectance coefficient per location was determined for further evaluation. The accuracy of the relative spectral course of the measured reflectance curves was therefore approx. 5 %. The absolute measuring accuracy, however, is much worse and under practical conditions it can scarcely be kept in such limits, so that an interpretation of absolute differences between the measured values would be ingenious.

5.2. Results of reflectance measurements under in-situ conditions

Season 1982:

The reflectance measurements were carried out synchronously for determination of the phenological growth phases of winter rye and Dactylis glomerata. Unsignificant temporal variations were due to the meteorological situation.

Figure 3 shows the mean behaviour of the directed spectral reflectance coefficient for each location under investigation. In all spectral curves the typical behaviour for vegetation is discernible. The growth behaviour of winter rye is clearly reflected in both locations A and B. By the beginning of June the represented curves do not yet have discernible differences in the state of the plants for locations A and B. The development was up to the bloom an approximately parallel one. The arid weather beginning after that caused the different plant growth at both locations as already described which is reflected in the spectral curves, too.

By the middle of July at location A both the biomass and the chlorophyll contents were distinctly higher than at location B. In the behaviour of the curve this is reflected by the fact that the spectral curve at location B has scarcely any more typical signs of the spectral behaviour of reflectance coefficients for vegetation. In its form it is nearly identical with the reflectance curve of dry soil. In the reflectance curve of rye at location A the typical green peak is still marked distinctly at 0,55 μm, and a clearly increasing reflectance is distinguishable in the near infrared range. Because of the higher biomass portion the spectral reflectance coefficient in the near infrared reaches higher values than in the curve for location B. By the end of July (3 days before harvesting) in both locations the typical behaviour of the spectral reflectance curve is not longer distinguishable. At location A, a still slight rise on the other side of the chlorophyll absorption band at 0,68 μm is outlined. Since at location A a significantly higher biomass was existing, the reflectance curve lies above that of the rye at location B. Thus, the annual variation of the development of rye on the area under investigation is distinct in the spectral reflectance ability, too. By measurements of spectral reflectance coefficients of the grassland area to the seasonal rhythm of the development of Dactylis glomerata is to be seen, too. It is clearly to be seen that in the 2-nd growth phase, in the middle of July, the chlorophyll absorption band is expressed deeper than in the first growth period, in the beginning of June. This is obviously caused by a higher chlorophyll contents in the 2-nd growth phase. Laboratory investigations confirm this [fig. 1] .

<u>Season 1983:</u>

In 1983 the change of spectral remission of the grain plants during their development has again been confirmed fig. 4 . It is apparent, that the characteristic changes in the spectral curve don't occur simultanously during the process of ripening. Instead the maximum of remission in the region of 560 nm respectively the minimum at 680 nm vanishs firstly while the characteristic sharp increase towards the infrared remission plateau at 720 nm keeps firstly preserved and only vanishs if the process of ripening is terminated. This behaviour concludes, that at the beginning of the ripening a rapid decline in the chlorophyll content takes place with the cell structure being unchanged by the end of the ripening process. The factor analysis has been used to investigate the spectral remission coefficient measured as to their information content. As a result of this analysis for the object considered here two factors could be extracted with factor 1 being valid for the wavelength region 400 - 720 nm and factor 2 for the 780 - 1100 nm region. This leads to the conclusion, that for investigationes on vegetation channel 4 and 6 of the multispectral camera MKF-6 contain most of the information. The phenological development of the test object is shown in fig. 5. The ordinate axis corresponds complexes of features the formation of which are based on factorial loadings. It is obvious, that the plants at location A attain the corresponding states of ripening to a significally later date as compared to those plants at location B. The temporal development of factor 2 presented in fig. 5 is to interpreted in such a way, that apparently an additional object feature acted whose influence could not be accounted for in the test scheme having used so far.

6. Summarizing interpretation of field experiments

The seasonal rhythm of plant development and the occuring differences caused by the location are reflected in the measured values. Growth periods are always characterized by a high chlorophyll contents, a high leaf area index and a distinct change of reflectance minima at 0,4 and 0,65 µm and reflectance maxima (peaks) at 0,55 µm and off 0,7 µm. In the ripening period chlorophyll contents and leaf area index decrease, the reflectance curve is smoothed. Thus, in the area under investigation the phenological growth phases could be determined from the spectral characteristics with an accuracy of less than 10 days. The locations more favourable for plant development are characterized by higher chlorophyll contents, higher specific leaf area index, greater biomass and more distinct vegetation-typical reflectance values. The higher fertility of these locations resulted less from their greater nutrient supply but predominantly from its more intense deposition. In general it can be stated that the relation between soil water, soil air and soil substance significantly influences the fertility in the area under investigation. The form of spectral curves characterizes the vitality state of vegetation. This fact can be the base for further investigations on these problems.

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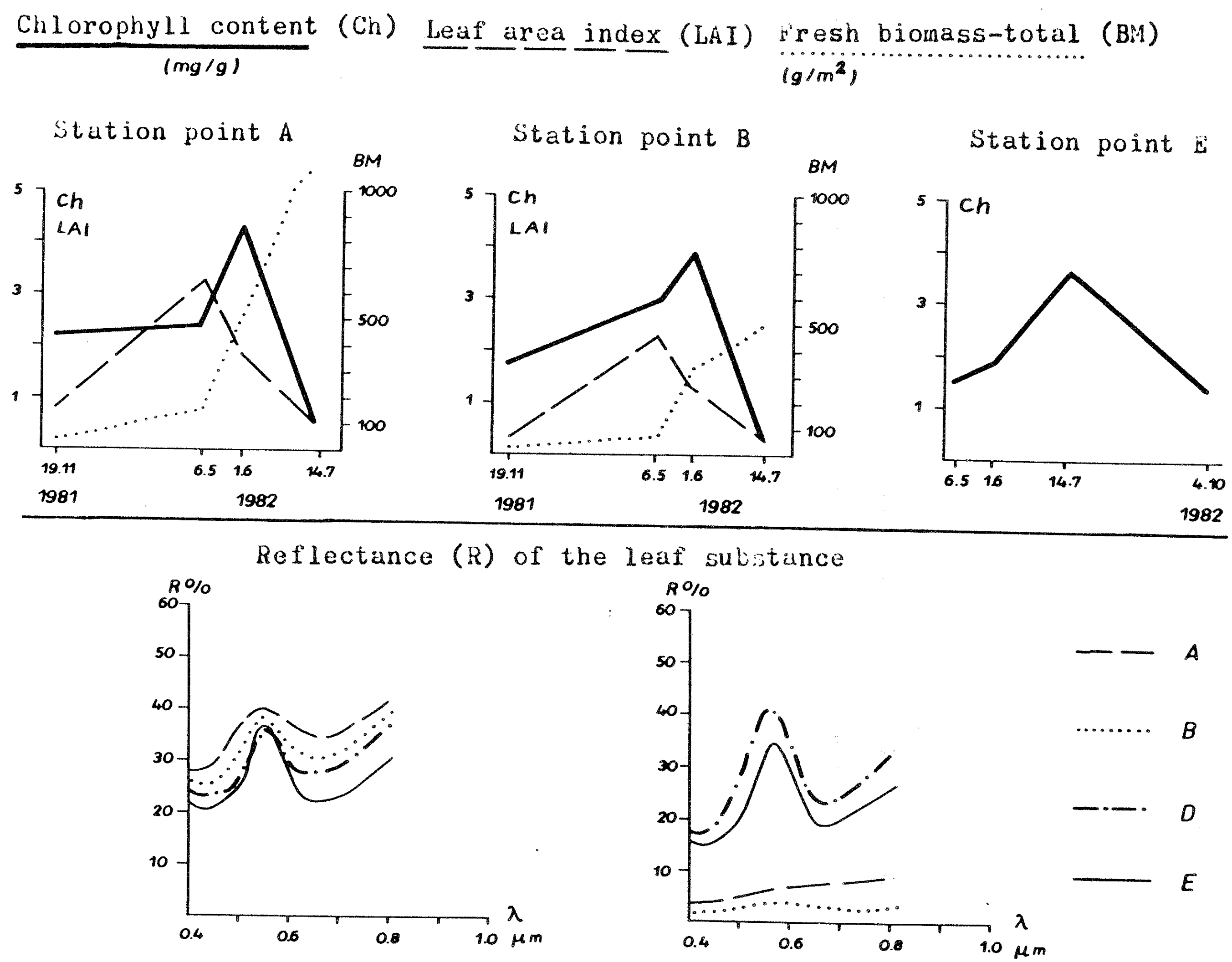


Fig. 1: Phenological phases and parameters of the development of winter rye crops and grassland; results of laboratory measurements

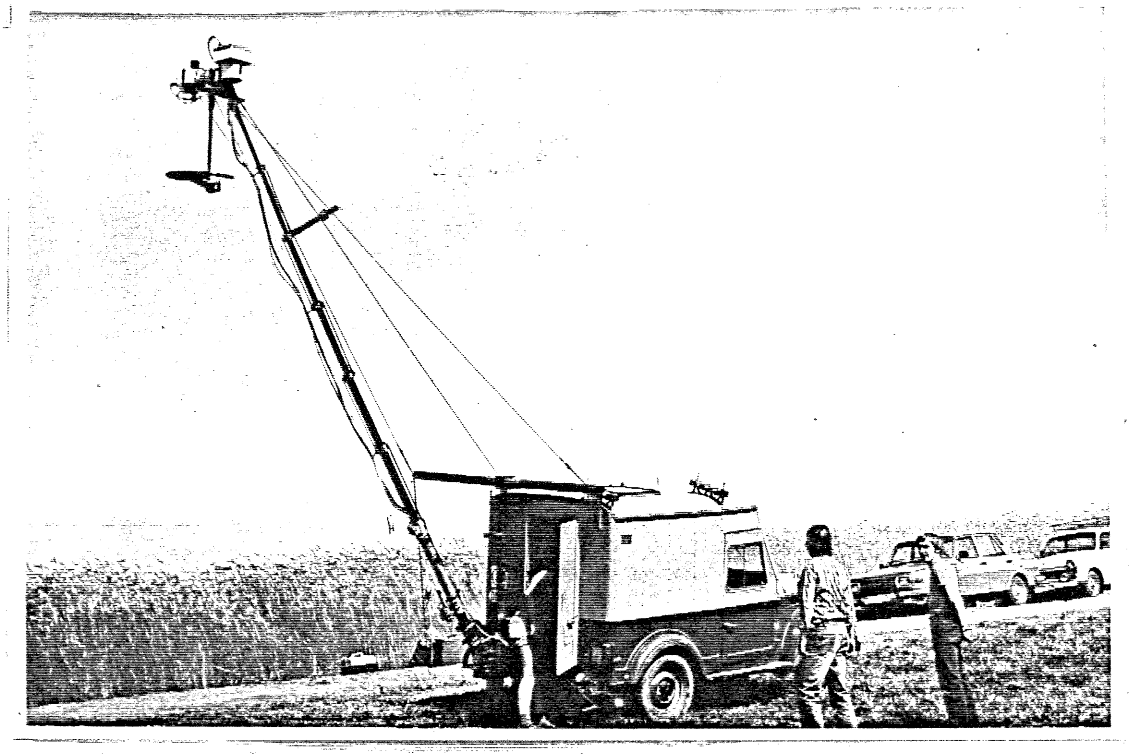


Fig. 2 Mobile complex for field measurements (field laboratory) of the Central Institute for Physics of the Earth of the Academic of sciences of the GDR

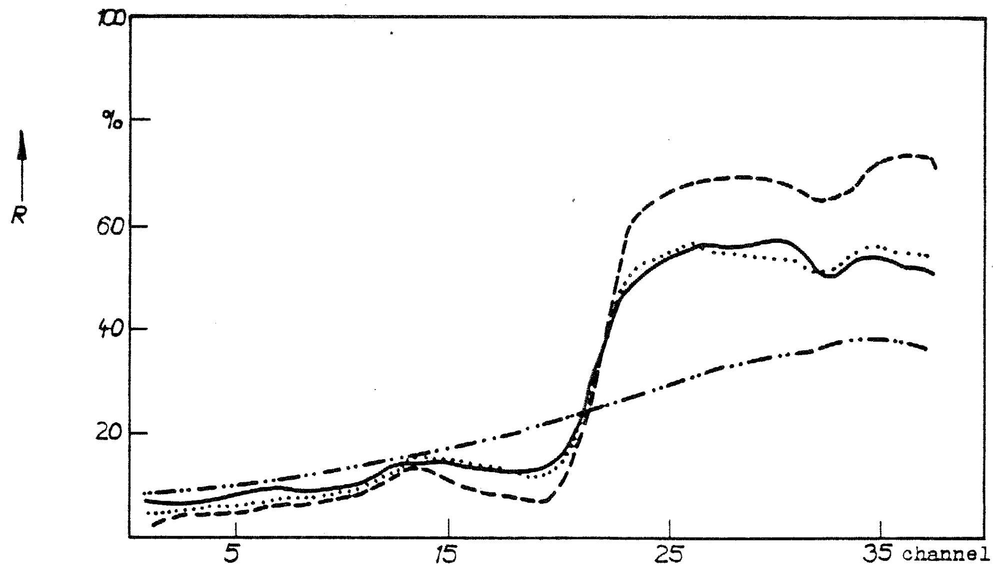


Fig. 3a

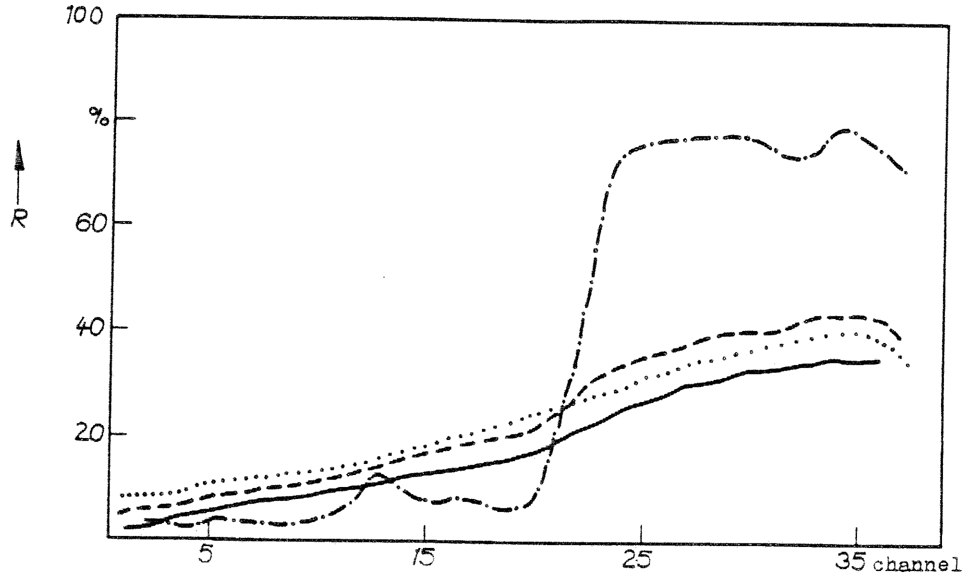


Fig. 3b

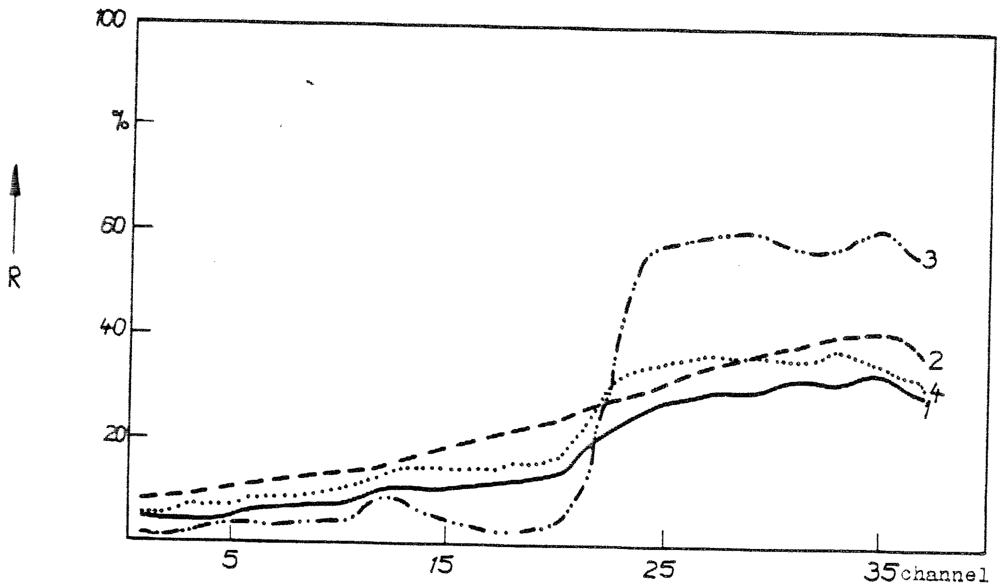


Fig. 3c

Fig. 3: Spectral reflectance curves of winter rye (1-location B, 4-location A) grassland (3) and soil (2) beginning of June (a), middle of July (b) and end of July (c)

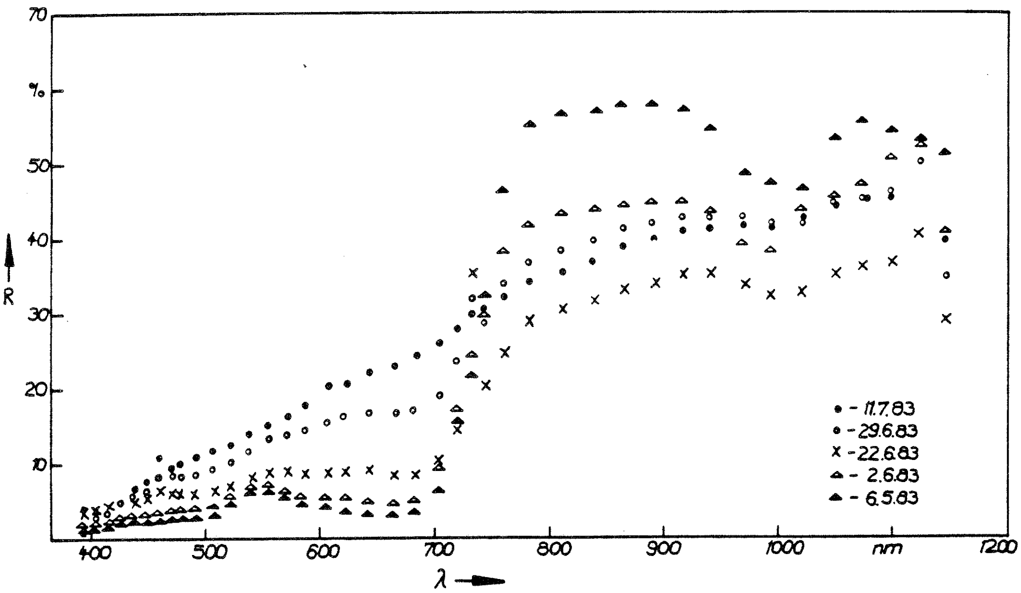
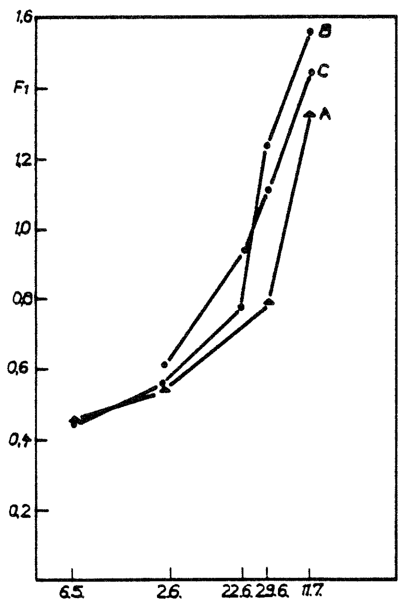


Fig. 4: Spectral reflectance curves of winter rye (location B) in various phenological phases 1983



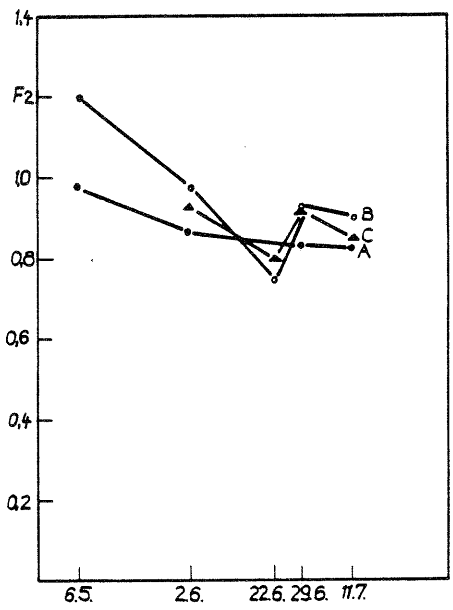


Fig. 5: Development of complexes of spectral features during the vegetation periode 1983 at the example of winter rye (A - location A, B - location B, C - location C)