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EFFECTS OF FOIL COVERS OF DIFFERENT COLOURS ON THE TISSUE STRUCTURE OF THE LEAVES OF LETTUCE, SPINACH, AND GARDEN SORREL

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Introduction

Of late years, plastic foils have been used increasingly for growing garden plants. In Hungary, the surface of foil beds was 1 million sq. m. in 1965, and their use has considerably grown from year to year (SOMOS, 1967). With foil covering the vegetation time can be prolonged considerably both in spring and autumn months, in this way providing an opportunity of producing early and late primeurs under field conditions.

Somos and co-workers have dealt with the theoretical and practical problems of foil covering for some decades. They have elaborated several „foil tent" types and agricultural techniques for growing certain garden plants.

For covering they have used colourless PVC and polyethylene foils. Since the 1950s, more and more researchers have atempted to apply coloured plastic foils under experimenthal conditions. In Hungary, these investigations were begun by HORVÁTH (1965) in 1962. The theoretical basis is the old recognition (SENEBIER, 1785; later TIMIRYAZEV, 1875) that lights of different colours exert different effects on plants.

Literature survey

A change in the strength and quality of the light is very important in the case of plants, as by means we can exert an influence on the photosynthesis, the fundamental plant function. As a result, there is a change in the amount and composition of the organic matter in the plant, and, as shown by the results of several researches, the metabolic changes taking place in this way bring about external morphological, phenomenological, anatomical, etc. alterations.

By prolonging the time of illumination, we generally increase the production of organic matter and, parallel with this, the growth of the plant as well. Illumination providing intense photosynthesis usually also makes good growth possible.

According to the findings of PÁL (1966) and HORVÁTH and KOLTAY (1967), the plant height is influenced rather by the strength of illumination than by the spectral range. The stem length and leaf size are increased by a decreased energy level. The optimum strengths of illumination are very different for the individual plant species: in most cases, full natural sunshine is not necessary.

In the development of the intensity of photosynthesis the leaf thickness too plays an essential part. If the leaves are very thick, the more absorptive light is absorbed already in the surface cells. For these leaves, the effect maximum is shifted towards the orange. Apart from the leaf thickness, the intensity of photosynthesis is considerably influenced by the structure of the assimilating parenchyma, the number of leaf vessels and the quantity of supporting tissues (McCLEDON, 1962).

For the cabbaging (heading) of lettuce, a balance of illumination and temperature is essential. DULLFORCE (1969) investigated under conditioned circumstances the light and temperature values that are critical for cabbaging. At a permanent temperature of 13 °C they could achieve cabbaging if the visible energy was 10 cal/sq. cm/day. The leaf surface of the seedlings developing at 21 °C being larger, these plants make better use of the decreased winter light amount.

The morphological effects of lights of different qualities and intensities are strongly interdependent. The interdependence may be so strong that the effect of a ligth of a given quality becomes the opposite at a different energy level. Red light, for example, increases the longitudinal growth of leaves at a low energy level but decreases it at a high energy level (NUERNBERGK, 1966). According to VINCE (1956), at the same energy level the size of leaf blades grows at a rate depending upon the spectral band, but there are important differences between individual plants. With regard to the leaf surface, HORVÁTH (1965) emphasizes the marked influence of the spectral composition but this differs according to the plant species. For pea, an increase in the proportion of the blue spectral range enralges, whereas that of the red spectralband reduces the leaf surface, while for paprika the blue reduces and the yellow enlarges it.

According to FORTANIER (1954), the number of leaves is not affected by the quality of the light. On the other hand, HORVÁTH (1965), investigating the effects of different spectral ranges, obtained a significant difference: for paprika, considerably more leaves developed in the phytotrone under yellow fluorescence than under F_{33} „orange" lamps.

The effect exterted by the spectral composition of the light on the stem lengthening changes according to the plants, too depending upon the intensity of illumination. In connection with the lengthening of the internodes too, as for the size of the leaf blades VINCE (1956), generalizes the finding that at an identical energy level the length of the internodes increases depending on the wavelength.

HORVÁTH (1965), investigating the dry matter production of plants under colourless and yellow foils and of control plants, achieved higher values than for plants grown under red and blue foils. In his opinion, with the exception of highly light-demanding plants the organic matter production can be increased by decreasing the level of light energy (applying plastic foils) and ensuring the suitable spectral range. Concerning the organic matter production, he regards the quality of the light as more important than its intensity. NUERNBERGK (1966) relates the effect of the spectral composition on the organic matter production with the tissue structure of the leaf. Intensification of the strongly absorbing spectral ranges, i. e. the blue and red increases the productivity of photosynthesis only in the case of thin leaves.

The quality of the light influences the plant tissues, too in a differentiated way. LÁSZLÓ–SZALKAI (1964), HORVÁTH (1965) and SIMON–SZEGEDI (1969, 1970) studied and evaluated the morphological, anatomical and productivity changes of some domesticated plants, under lights of different intensities and spectral ranges. The change could be evaluated above all in the supporting tissue system and in the size-fluctuation of the ligneous part of the conductive tissue; the least change was in the phloem and cambium. The increase in the proportion of the ligneous part and the supporting tissue system takes place to the detriment of the medullary parenchyma. The proportion of the ligneous part and the supporting tissue system is the highest in a light of spectral composition shifted towards the blue. Therefore, a relation of positive direction is achieved between both tissue systems as well as the increase in the ratio of the carbohydrate compounds (HORVÁTH, 1965).

SIMON and SZEGEDI (1969, 1970), analysing the stem tissue structure of pea grown under foil tents of different colours, established that the largest phloem developed in the plants in uncovered plots, and the smallest in those covered with red foil. The uncovered, colourless and yellow variations accumulated almost twice as much ligneous element as developed under green, blue and red foils.

The results of several investigations show that the effects of varying the spectral composition of the light by means of plastic foils are not the same for different species. It is important therefore, to investigate these changes for the most important garden plants.

Lactuca, *Spinacia* and *Rumex* species were first investigated, with regard to the effects of light of different intensities and spectral compositions on the external morphology and tissue structure of the leaf.

Materials and Methods

The investigations took place in 1970, under field conditions, in the Botanical Gardens of the Attila József University, Szeged. The following economically important primeur plants were investigated:

Lactuca sativa L. var. *cap.* convar. Cabbage-lettuce „King of May", „Budai" and „Soroksári".

Spinacia oleracea L. var. *glabra* convar. Spinach „Eskimo", „Matador", „Viroflay".

Rumex acetosa L. var *hortensis* convar. „Largeleaved" Sorrel.

The seeds were sown on May 14th (May—June experiment) and on June 25th (June—July experiment). Spinach was grown for five weeks, cabbage-lettuce for six weeks, and sorrel for seven weeks. (Sorrel was investigated only during the May—June growing.)

The plants were grown under field conditions, in plots of 4 sqm. There were five variants, each duplicated. Lights of different spectral compositions were provided by means of coloured foil covers. The foils were perforated in 25 per cent of the total surface.

The experimental area was an irrigated meadow soil. The covering with a perforated foil (HORVÁTH, 1965) changed the air temperature to only a comparatively low extent (Table 1)

The total radiation is decreased by the different means of covering to different degrees and the permeability is different in the individual spectral ranges. In the case of coloured foils (HORVÁTH, 1965), the shifting of the spectral composition of the towards the foil colour can be well proved in every case (Table 2).

Table 1

variant	total radiation	air temperature
uncovered control	100%	29,2 °C
colourless foil	75%	29,4 °C
blue foil	38%	29,0 °C
yellow foil	62%	28,6 °C
red foil	37%	27,6 °C

Table 2

variant	energy distribution as a percentage of the energy in the spectral range 400—700 nm.					
	1	2	3	4	5	6
uncovered control	14	25	25	7	10	19
blue foil	22	32	22	5	5	14
colourless foil	14	24	26	8	12	19
yellow foil	10	22	26	9	12	21
red foil	11	14	11	4	14	46

1 = violet (400—436 nm) 4 = yellow (566—589 nm)
2 = blue (436—495 nm) 5 = orange (589—627 nm)
3 = green (495—566 nm) 6 = red (627—700 nm)

Table 3

Month	mean temperature °C			precipitation mm			number of sunny hours		
	1970	mean	deviation	1970	mean	deviation	1970	mean	deviation
May	14,9	16,8	−1,9	35	61	−26	184	258	−74
June	20,9	20,0	+0,9	61,2	63	−6,8	261	271	−10
July	21,8	22,3	−0,5	50,1	51	−0,9	284	309	−25

Mean = 50-year average

The main meteorological data during cultivation are given in Table 3. compared with the 50-year mean (placed at our disposal by the Department of Climatology, Attila József University, Szeged).

In the course of the outside morphological and phenological investigations the following characteristic were taken into consideration:

1. number of leaves
2. height of the plant
3. maximum width and length of the leaf-blades
4. fresh weight of leaves
5. appearence of flowers and shooting of the seed-stalks

The maximum length of the leaf-blade (lamina) was measured along the main vessel, and its at the widest part of the leaf. The values obtained in this way are approximately suitable for characterizing the size of the lamina. On collection of the material for investigation, we recorded the fresh weight of the vegetative organs. From under foils of identical colours, we weighed 20 individuals, each of average development. The number of leaves and the size of leaf-blades were investigated on five occasions (2, 3, 4, 5, 6. — weeks old).

For histological processing five to ten well-developed leaves were collected from nods 3—4—5 for every treatment. The middle third of the leaves was used for dissections. The material collected was fixed until processing in a mixture of absolute alcohol, formalin and distilled water in a ratio of 3 : 1 : 1, or stored in 40% ethanol. The leaves were prepared by maceration, and embedded in celioidin. The section were made with a microtome; after being cleaned they were stained progressively with Ehrlich's iron haematoxylin and fixed in Canada balsam.

On the adaxial and abaxial surfaces of the leaves and the leaf cross-section the following recordings/50 fields of sight each were carried out:

1. stoma number per sq. mm,
2. thickness of leaf-blade,
3. thickness of adaxial epidermis and palisade parenchyma
4. thickness of abaxial epidermis and spongious parenchyma
5. proportion of phloem and cambium in the main vessels
6. proportion of the ligneous part in the main vessels.

Projected on transparent paper, the tissue parts of the conductive bundles in the main vessel were drawn round. The proportions of the ligneous and phloem tissues were estimated on the basis of the weight of the transparent paper, corresponding to the surface size of the tissue regions.

The properties recorded show a curve of normal distribution. The reliability of the data was evaluated, therefore, by variance analysis, F and T tests. The calculations were carried out with an M : 3 computer in the Cybernetic Laboratory, Attila József University, Szeged.

Discussion and evaluation of results

The changes taking place as a result of the foil covers of different colours have been evaluated with regard to the intensity of illumination, and the spectral composition of the light. In the evaluation of the results, we have taken into consideration the favourable properties of the edible primeurs.

1. Number of leaves

In the May–June growing, the most leaves were produced by the plants under yellow and colourless foils, except for sorrel. The fewest leaves found under the blue and red foils.

For garden sorrel, covering with foil is not favourable as most leaves develop in full sunshine. For this plant there is a linear relation between the intensity of illumination and the number of leaves (Table 4).

Table 4. May—June experiment

variant	*L. sativa* var. *cap.* convar.			*S. oleracea* var. *glabra* convar.			*R. acetosa* var. *hort.* convar.
	„King of May"	Buda	Sorok-sár	Eskimo	Matador	Viro-flay	Large-leaved
uncovered control	20	18	15	10	9	20	15
colourless	22	23	22	12	12	12	12
yellow	18	22	20	13	15	15	11
blue	8	12	8	10	12	25	7
red	10	15	12	8	10	12	10

Table 5. June—July experiment

variant	*L. sativa* var. *cap.* convar.			*S. oleracea* var. *glabra* convar.		
	„King of May"	Buda	Sorok-sár	Eskimo	Matador	Viro-flay
uncovered control	15	14	16	14	11	11
colourless	16	11	13	16	15	9
yellow	11	11	10	10	10	14
blue	10	11	9	16	9	13
red	15	12	15	12	15	12

For spinach, we have observed a reaction differing according to the species. In the case of Eskimo and Matador, similarly to the three lettuce species, the number of leaves is increased by the yellow and colourless foils. In the case of Viroflay, however, the leaf number is increased by the blue foil.

In the period June–July, for cabbage lettuce the most leaves are produced for the control and under the colourless foil but this value is also approached with red the foil covering. Spinach gave more leaves as a result of covering, but this effect was exerted with foils of different colours, depending on the species, (blue and yellow for Viroflay, colourless and red covers for Matador and Eskimo.)

The number of leaves developing under different foil covers are listed in Tables 4 and 5.

2. Height of plants

Under the foils, increase in the intensity of illumination leads to a longer stem; under a colourless foil it is even longer than that of the uncovered control. The degree of lengthening differs according to the species. For the lettuce „King of May", the lengthening of the internodes is not extensive, with the important result of the „lettuce heads" thus being more compact. A major lengthening of the stem is associated with smaller leaves, which in the case of lettuces, is disadvantageous from a practical point of view.

In the June–July experiment, the stem was the longest under red foil; as compared with the firts experiment, however, the plants were lower.

In the early period the blue and red foils, i. e. low light intensity, are favourable to lettuce from the point of view of heading.

3. Size of leaf-blades

It can be established from the results of the first experiment that the leaf size grows in linear proportion to the intensity of illumination, but the degree of growth differs for the individual species. The leaf surface of the lettuce species is enlarged the most by an increase in the intensity of illumination. For sorrel, during the foil covering, a contrary tendency may be observed: the leaf size is increased by a decrease in the intensity of illumination.

In the June–July growing, of the coloured foils the red ones show a marked spectral effect. The lettuce increases its leaf surface to about twice that of control. This spectral effect is manifested in the case of spinach during both cultivations, but in the first experiment the activity of the meristems is increased to a higher degree by the red spectral range.

4. Fresh weight

We have recorded the fresh weight of the cabbaging lower leaves, as from a practical point of view this is more important than the dry weight. In the first experiment, there is a close, positive correlation between the intensity of illumination and the fresh weight. From among the three sorts of cabbage lettuces, the fresh weight of the leaves of „King of May" was increased the most by the higher energy level. At a low light intensity, the loss of weight as a result of increasing the blue spectral range is very considerable. In the second experimental series, the effect of the energy level does not exert any essential change. Here the spectral effect comes to the front; the weight increases progressively in the direction of the enhanced long-wave red rays. These results can be correlated with the number of leaves and their size, where the degree and direction of the changes are similar to these. The difference between the two experimental periods is great; in May–June, owing to the increasing light intensity, the leaf production generally also increases, but July it decreases. The contradiction that, as a result of being overshadowed by the foils, in June–July at the lower energy level there is more fresh weight than with the full light of the sun, can be explained in that the high energy level of the natural light is not optimum for these plants if not coupled with appropriate temperature and water supply. This was proved by Mattei (1967), who investigated the effect of shade on cabbage lettuce. The highest leaf production was given by a 50% decrease of the light intensity.

„King of May" is worth mentioning because the proportion of the marketed cabbaging stem-leaves in the total weight (stem + leaf) is the highest. In the other two species, the leaf production is lower because of the increased stem elongation.

5. Phenological properties

The species investigated also have some different properties from a phenological point of view. As regards the cabbage lettuces sown in May, at the time of collecting (sixth week), the reproductive organs of „King of May" had not developed fully in any of the variants. For „Buda" the flower-buds appeared during every treatment. In the case of „Soroksár", under blue and red foils, the reproductive organs developed five to seven days later. We have followed the shooting of the seed-stalks of spinach, too. The favourable effect of the red foil is manifested in the retardation of the formation of the reproductive organs. No species developed any seed- stalks in the course of the first experiment.

6. Number of stomata per sq. mm.

On the abaxial epidermis of all the seven species investigated there are about 40–50% more stomata than on the surface, and this ratio was hardly changed by the treatment. The stomata numbers of lettuce and spinach were

Fig. 1. *Lactuca s.* var. *cap.* convar. „King of May", May—June experiment, abaxial epidermis (x200)

1. uncovered control
2. colourless foil cover
3. blue foil cover
4. yellow foil cover
5. red foil cover

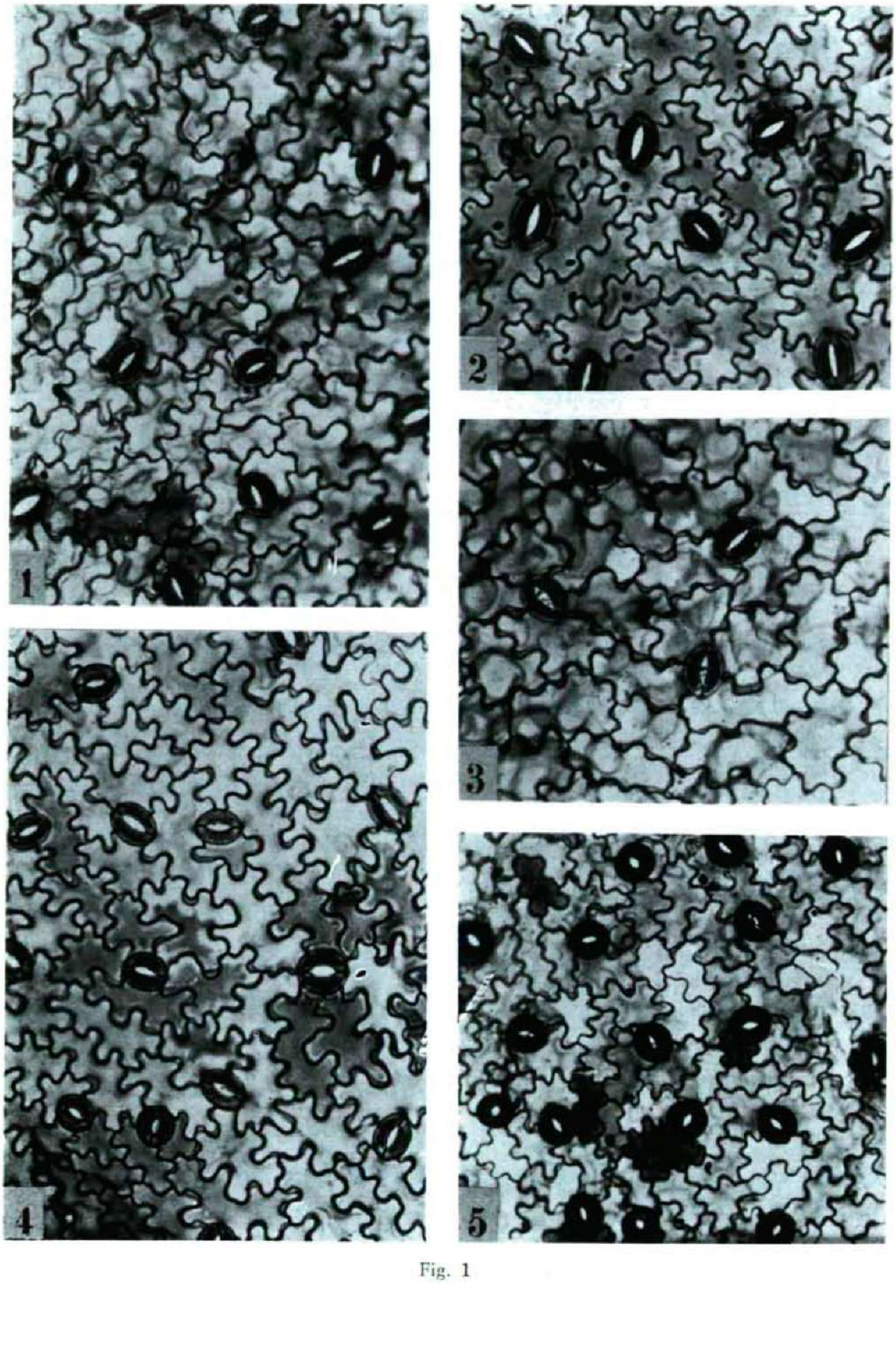

Fig. 1

increased by a higher intensity of illumination, the maximum value being given by the control. This effect can be observed in the case of sorrel, too, but the most stomata appear for the colourless variants. The stomata number is increased by raising the proportion of short-wave rays if it is connected with a high energy level. For „King of May", the spectral effect is manifested after enhancement of the red rays, with a high value exceeding even a 0,1% significance level (Fig. 1). Sorrel, however, responds more sensitively to the rays of short wave-length in the case of a low intensity of illumination, because after the colourless variants the epidermis of the blue variants is the most densely stomatized (Table 6).

In the June–July experiment, the most stomata developed under yellow foil. No spectral effect was manifested; for instance, there was no significant difference between the plants under red and blue foils. For spinach, similarly, an increase in the proportion of the yellow-orange-red spectral ranges increases the frequency of stomata.

The specific effect of the red foil must be emphasized, as the stoma number in 1 sq. mm. of the red-covered individuals of Lactuca, that has a small leaf surface, was very high in May–June (Fig. 1). In July, on the other hand, the individuals of largest leaf surface grew under red foil but the stoma number per unit surface was the lowest (Table 7).

Table 6. May—June experiment

variant		*L. sativa* var. *cap.* convar.			*S. oleracea* var. *glabra* convar.			*R. acetosa* var. *hort.* convar.
		„King of May"	Buda	Sorok-sár	Eskimo	Matador	Viro-flay	Large-leaved
uncovered control		123	167	201	195	265	152	76
colourless		140	153	151	143	181	169	108
yellow		148	139	155	157	156	106	87
blue		150	142	162	159	67	95	92
red		259	127	169	156	203	122	67
S. D. %	0.1	26	6,3	8,4	10,5	46,5	13,1	3,3
	1	20	4,9	6,6	8,3	37	10,3	2,5

Table 7. June—July experiment

variant		*L. sativa* var. *cap.* convar.			*S. oleracea* var. *glabra* convar.		
		„King of May"	Buda	Sorok-sár	Eskimo	Matador	Viro-flay
uncovered control		160	149	180	168	259	165
colourless		155	142	133	164	194	187
yellow		162	161	140	216	225	193
blue		128	122	114	—	183	143
red		127	105	124	169	206	162
S. D. %	0.1	6,7	6	7.7	8,8	12,8	10,3
	1	5,3	4,5	6,1	6,9	9,9	8,1

7. Thickness of the leaf-blade

For lettuce and sorrel, the quantity of the assimilating tissue and, at the same time, the actual thickness of the leaves are the largest (exceeding the control) under colourless and yellow foils (Fig. 2). In the Figure, the joint mean values of the three species in the May–June experiment are given.

For the spinach species, not only the yellow foil cover, but also the red one yielded thicker leaves. The enhanced red spectral range increased the thickness of the leaf in a linear way for spinach. In the case of lettuce and sorrel, there is no spectral effect on the optimum curve (Fig. 2).

In the June–July production, the plants developed in full sunshine and under yellow foils have the thickest mesophyllum (Fig. 3).

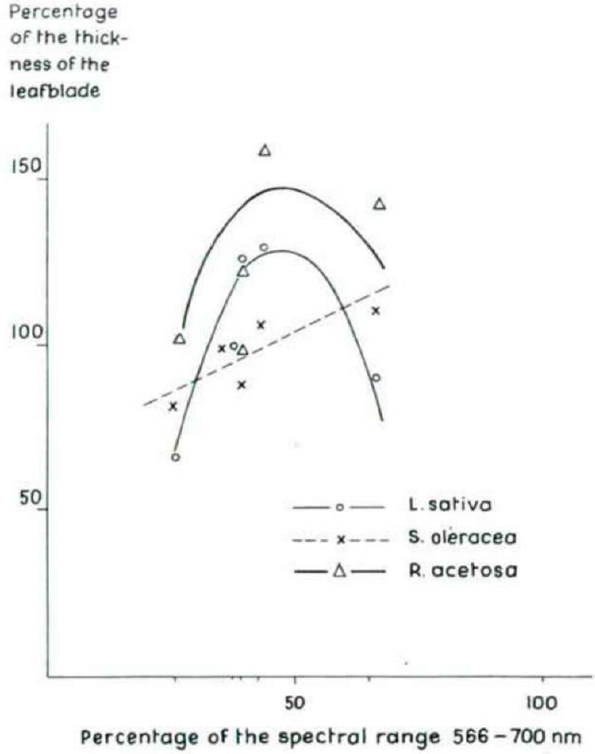

Fig. 2. Thickness of the leaf-blade as compared to the uncovered control

Fig. 3. *Spinacia o.* var. *glabra* convar. Viroflay June—July experiment, palisade and spongious parenchyma (x200)

1. uncovered control
2. colourless foil cover
3. blue foil cover
4. yellow foil cover
5. red foil cover

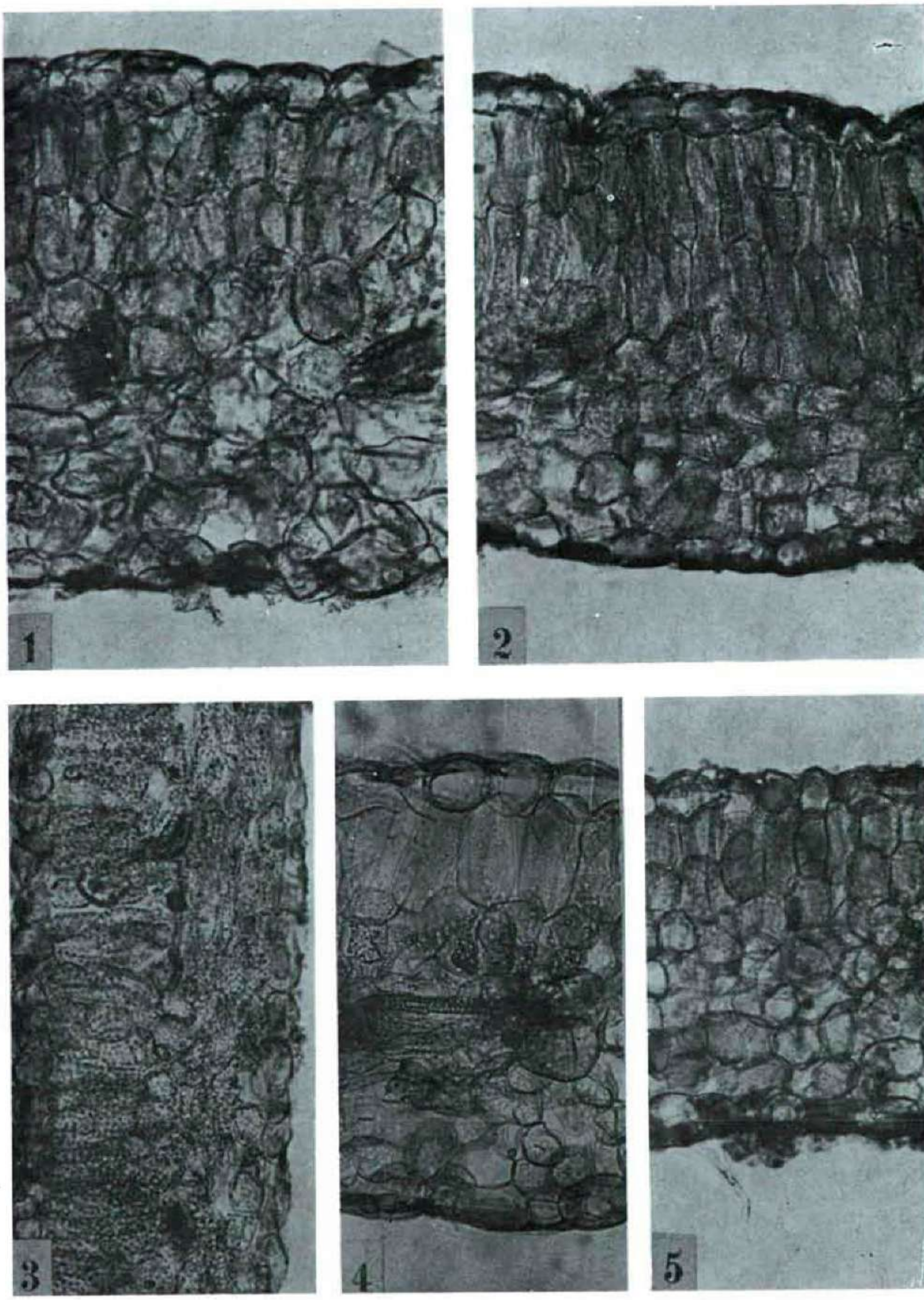

Fig. 3

8. Palisade parenchyma

The tissue of the *Lactuca* and *Rumex* palisade parenchyma is unilinear and the number of layers was not affected by the various covers. For *Spinacia*, in the case of a high intensity of illumination (control and colourless foil) cover even a three-layer palisade tissue developed. The other treatments resulted in a palisade parenchyma of double cell lines (Fig. 3). For *Spinacia*, the most developed palisade was brought about by different foil covers for different species (Viroflay – control, Matador – colourless foil, Eskimo – red foil). In the June–July production, a rise in the energy level of the light increases the development of the palisade tissue. For spinach, this effect is manifested in the change in layer number, while for lettuce it appears only in the lengthening of the cells. No spectral effect was shown: the thickness of the palisade tissue was reduced by the high proportion of both the blue and red spectral ranges. Sorrel is the most sensitive to the rays of short wave-lengt. The diameter of its palisade cells perpendicular to the surface is 90 μ in the control plants, that is one-third of the leaf cross-section. In comparison, in plants under blue foil this falls to 65 μ, the difference exceeding the 0,1% significance level.

9. Spongious parenchyma

In the earlier experiment the (colourless, yellow) foil covering was more favourable, but in June–July the control individuals had the thickest spongious parenchyma. For spinach, the enhancement of the long-wave under the red foil of low intensity illumination brought about a spongious parenchyma that athained and even exceeded the development of the control parenchyma (Fig. 4 illustrates the results of the May–June experiment, according to species, as a function of the proportion of the red spectral range).

The layer number of the spongious parenchyma changes, too, under the different foils. The control lettuce and its colourless and yellow variants have 7 to 8 cell-layers; under blue and red foils, however, there are 5 to 7 layers. For the blue variants of spinach, the layer number of the spongious parenchyma varies between 4 and 6, and the thickness of the spongy tissue is also the smallest here. The change of the layer numbers between 5 and 8 in the course of the treatment is accompanied by a considerable increase in the direction of the enhanced red spectral range (Fig. 4).

In the June–July experiment, too, the thinnest spongy tissue was a result of the blue foil coverage. For spinach, the thickness of the spongious parenchyma decreases in a linear way as a result of an increases in the proportion of the energy in the violet-blue-green spectral range. In the lettuce and sorrel leaves, the amount of the spongious parenchyma changes according to an optimum curve as a function of the enhancement of the red spectral range (Fig. 4).

10. Phloem tissue

In the May–June experiment, both the smallest and largest intensity of illumination developed only a small number of phloem elements. For lettuce, there is no spectral effect as there is hardly any difference under blue and red foil covers. The largest amount of phloem was brought about by yellow foil (two or three times more than for blue and red variants). For the sorrel and spinach species, the phloem part of the conducting tissue was enlarged to the highest degree by the red foil covering; for Eskimo it is nearly twice that in the control (Fig. 5). The smallest phloem was produced by a low energy level and by the most enhanced violet-blue-green spectral range.

In the June–July experiment, we again meet the increased development of the phloem elements as a result of enhancing the red spectral range. For spinach this is manifested more intensely than for lettuce, because it produced an amount of phloem tissue that exceeded all the other variants. For lettuce,

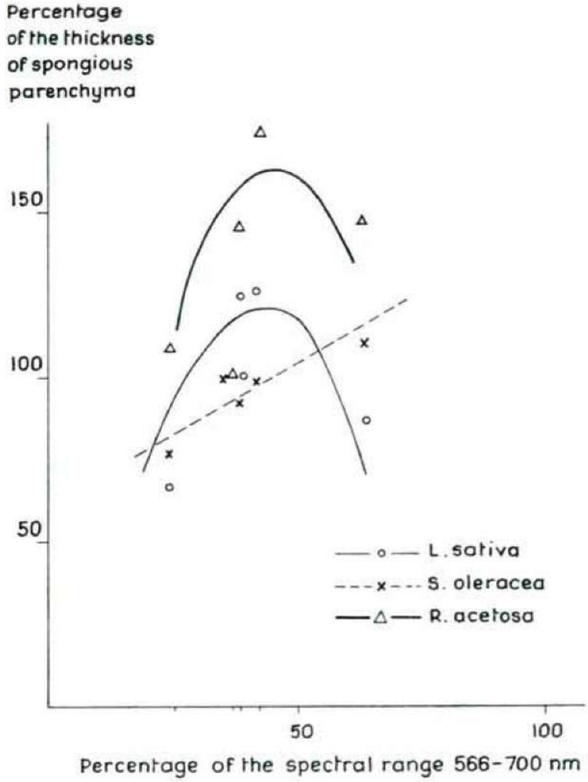

Fig. 4. Thikness of the spongious parenchyma apared to the uncovered control

there is a great difference according to species. Our results confirm the findings of JANKOVICH (1956), who lays down as a rule that on proceeding from blue towards red light, the amount of conducting tissue keeps on growing.

Fig. 5. *Spinacia o.* var. *glabra* convar. Eskimo May—June experiment, cross-section of the main vascular bundle (x200)

1. uncovered control
2. red foil cover

Lactuca s. var. *cap.* convar. Buda, June—July experiment, cross-section of the main vascular bundle (x200)

3. uncovered control
4. blue foil cover
5. red foil cover

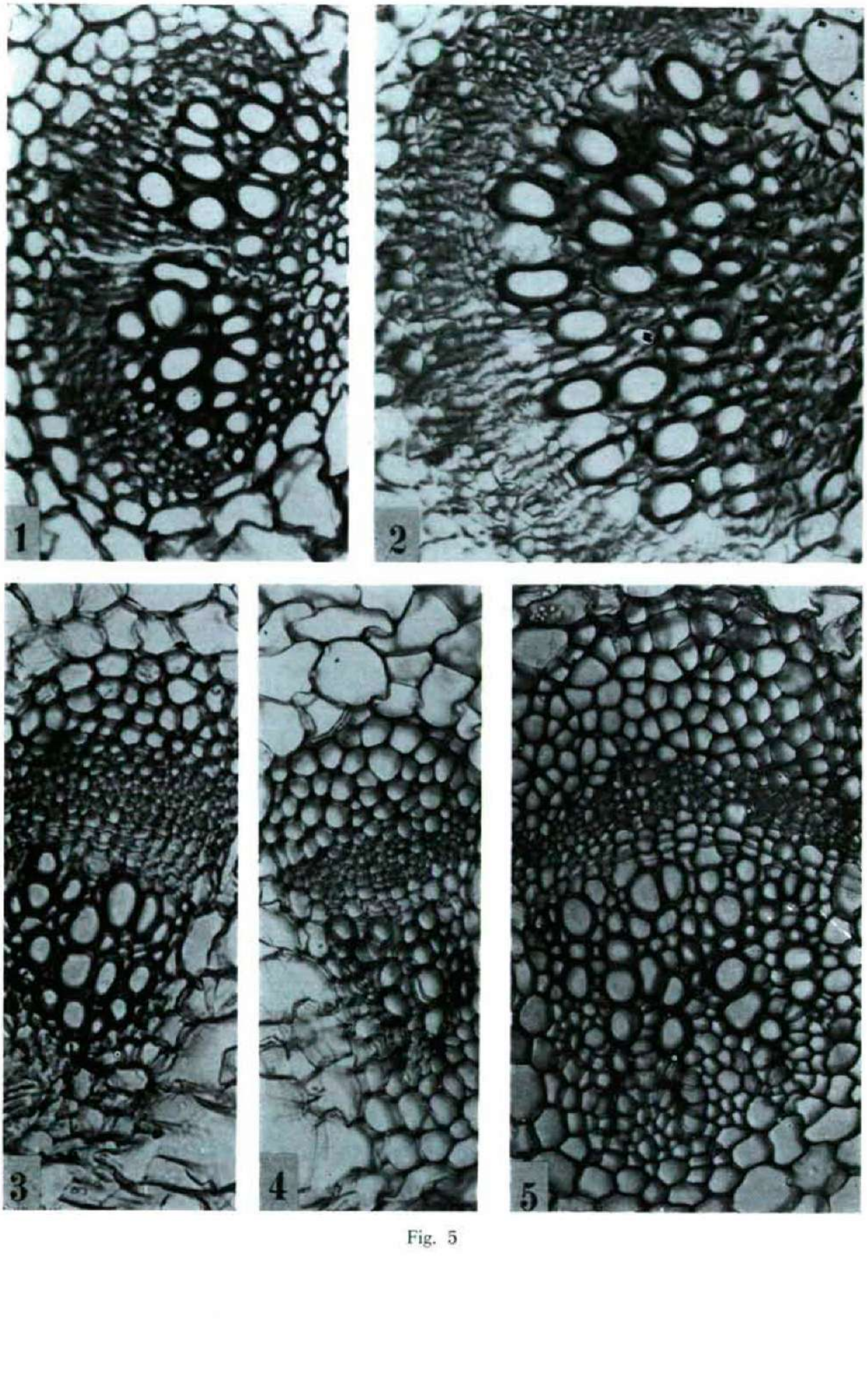

Fig. 5

11. Ligneous part

The lettuces grown in the period May–June developed three or four times more ligneous elements under colourless and yellow foils than under blue and red foils. It is shown by the optimum curve that the spectral effect has no influence on the ligneous part, because there is no considerable enhanced (Fig. 6 – shows the change in the amount of ligneous elements, in the average of three species each, in the period of the May–June production).

For sorrel, on the increase of the light energy, the ligneous part decreases, being the smallest for the control. The spectral effect is expressed in that an increase in the proportion of the red spectral range produced a more developed ligneous part (Fig. 6).

For spinach, as compared to the control, the development of the ligneous part was reduced by the colourless and blue covers, but considerably increased by the yellow and red covers (Fig. 5).

In the June–July experiment, the growth of the ligneous part is of a higher degree in the direction from the blue to the red spectral range. This effect is manifested for lettuces, too.

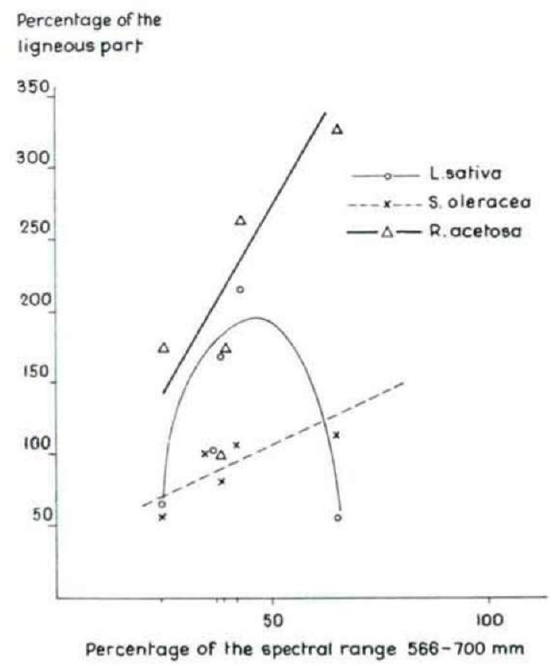

Fig. 6. Development of the ligneous part of the main vessel as compared to the uncovered control

Summary

We have investigated the morphological, phenological, and leaf-anatomical changes in cabbage lettuce, spinach, and sorrel species as functions of the intensity of illumination and spectral energy distribution. The field experiments

were carried out in May–June and June–July. Colourless, blue, yellow and red perforated foil covers were applied.

Epidermis preparations were made by maceration and sectioning of the leaves, and the quantitative properties of the tissue elements were evaluated by biometric methods. The treatments induced significant changes in a great part of the features investigated.

1. The effect of the intensity of illumination can be summed up as follows:

In the May–June period, increase in the light energy leads to the parallel increase of the fresh leaf weight of cabbage lettuces, the surface of the leaf, the leaf number and the stem length. In the June–July production, on the other hand- the higher temperature being, associated with less precipitation – the leaf surface, leaf production and stem length of cabbage lettuces growing in full sunshine are less.

The correlation between the number of stomata per unit area and the increase in energy level is generally positive.

In the June–July experiment, for all the three cabbage lettuces, there was a positive correlation between the increase of the intensity of illumination, the length of the palisade parenchyma cells, and the thickness of the leaf, as well as the amount of lignaceous elements. Further in the case of „King of May", the effect of the light intensity is proved by the stomata number and the tissue thickness of the spongious parenchyma tissue increasing. In the case of Spinacia, the layer thickness and layer number of the palisade parenchyma similarly increase in the direction of a higher energy level. The leaf surface of sorrel was increased by the reduced light intensity, but the leaf number was lower.

2. The spectral effect of the light:

The role of the spectral composition is shown by the fresh leaf weight, the increase in the thickness of the leaf-blade, the increase of the leaf surface, and a major lengthening of the cells of the palisade parenchyma. The thickness of the leaf-blade and, closely connected, the amount of the spongious tissue in the lettuce and sorrel leaves increase according to an optimum curve, but for spinach in a linear way, together with the increase in the proportion of the red spectral range.

A different change is also induced, in the three species by enhancing the yellow-orange-red spectral range (primarily in the ligneous part). In the leaves of sorrel and spinach a linear growth appears, while in lettuce the change takes place according to an optimum curve.

From among the phenological properties, the shooting of the seed-stalks of spinach is inhibited by red light.

The stomata number per unit area is very high on enhancing the proportion of the violet-blue-green spectral range. In addition, the increase in the proportion of the short-wave rays decreased the surface of the leaf-blade, the leaf thickness and the amount of conductive tissues (particularly of the phloem) and inhibited the lengthening of the palisade cells. The mesophyllum tissue of the blue variants are therefore very undeveloped.

3. Taking into consideration some practical points of view, the following conclusions can be drawn:

a) In the earlier production of lettuce, the features determining the „production" (leaf number, size of leaf-blade, thickness of the leaf) were mostly increased by yellow and colourless foil covers. The yellow foil also has a favourable influence on the anatomical properties (development of mesophyllum, conductive tissue).

In the later (June–July) production, on the basis of the above points of view, a red foil too can be taken into consideration.

b) For spinach, the production is increased by the red and yellow foils in both experimental periods.

c) The fresh weight of sorrel (leaf number, leaf size) is the highest in full sunshine. However, taking into consideration the anatomical properties (mesophyllum, conductive tissue system), too, yellow and red foil covers can also be taken into consideration.

d) In the case of these garden plants, a blue foil cover is not advisable as the production of leaves is markedly decreased.

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