საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 175, №4, 2007
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 175, no. 4, 2007

Plant Physiology

Influence of the Regimen of Ultraviolet Irradiation on the Development of Soybean and Pea Seedlings

Nani Kacharava, Eva Chkhubianishvili, Luiza Kobakhidze*

* *N. Ketskhoveli Institute of Botany, Tbilisi*

(Presented by Academy Member N. Nutsubidze)

ABSTRACT. The effect of different doses of ultraviolet irradiation (UV) on seedlings of legume plants: soybean (*Glycine hispida* (Moench) Max.) and pea (*Pisum sativum* L.) has been investigated by means of modeling experiments. The short wave section of the irradiation source (lamp DPT-400) was separated by means of glass filter (УФС-2). The effect of total spectrum of irradiation has been also studied. Differences in sensitivity towards irradiation were established not only between species but among the plant organs too. 15′ irradiation abated all growth parameters in soybean seedlings, while 60′ irradiation appeared to be stimulating. In pea seedlings stimulation induced by 15′ irradiation changed to a negative effect with the increase of radiation dose. High sensitivity of roots and resistance of cotyledons to inhibiting doses of UV irradiation was revealed (for soybean 90′ and for pea – 120′). Neutralization of the inhibitory effect of high doses of UV irradiation by using the integrated irradiation spectrum may be induced by long wave radiation. The supposition on neutralization of the negative effect of the UV irradiation and increasing the ranges of tolerance by switching on the "stress-defending" mechanisms is presented. © *2007 Bull. Georg. Natl. Acad. Sci.*

Key words: *ultraviolet radiation, growth, seedlings, soybean, pea.*

Enhancement of ozone concentration in the atmosphere and intensity of solar ultraviolet irradiation (together with other anthropogenic factors) are the stress factors which negatively influence plants, limiting the ranges of their tolerance towards the environmental factors [1-3]. Under these circumstances plants survival is closely associated with adaptivity to unfavorable conditions. Recently to predict the possible results of climate global changes investigation of the role of ultraviolet (UV) rays in the formation of morpho-physiological peculiarities and adaptive mechanisms of plants to extreme conditions assumes great importance [3,4].

According to experimental data the reaction of plants to UV irradiation is not similar and varies in a large range, beginning from inhibitory effect and ending with stimulation. The existence of a large amount of cell metabolites, actively absorbing UV energy, and responsible for diverse effects, complicate the interpretation of diametrically different results [5,6].

Most of the investigations were performed on grown-up plants, while in natural conditions seedling phase seems more sensitive to stress. In spite of the great attention paid to UV-B radiation, such studies are incapable of giving a full picture, because the progressive destruction of ozone screen is not limited to UV-B intensification [7, 8]. Accordingly, investigation of the influence of UV radiation on seedlings, using modeling experiments seems to be more informative.

Modeling makes possible to elaborate a method directed towards increasing the plant adaptivity by means of realization of the potential abilities of genotype [9].

The objective of the given study was to determine the stimulating, inhibiting and lethal doses of different radiation regimen, also to investigate the role of the full

Table 1

Intensity of irradiation of the ДРТ-400 lamp in short wave section of the spectrum (μwt·cm^{-2}, distance 50cm)

Variant	C section, <280nm	B section, 280-320nm	A section, 320-400nm
Under the УФС-2 filter	460	760	495
Without filter	491	802	540

spectrum of UV radiation in reactivation of the inhibitory effect of short wave radiation, and to determine the morphometric characteristics of seedlings, revealing the resistant and competitive species.

Popular annual legumes with high edibility characteristics - soybean (*Glycine hispida* (Moench) Max.) and pea (*Pisum sativum* L.) were selected for testing. Experiments were set according to the modified scheme after Borisova et al. [8].

Preliminarily soaked seeds of experimental plants were placed on wet filter paper for germination, in dark at 27°C. Two day-old seedlings were placed under permanent illumination (LB-100 lamps) at 26°-27°C. Part of 3 day-old seedlings stayed at day illumination (as control), while the second part (experimental variant) was irradiated from an artificial source of UV rays (lamp ДРТ-400). Distance from the lamp 50cm. To separate the short wave section of irradiation the glass filter УФС-2 was used, with transparence in the range of 250-400mkm and blocking the visible infrared rays. Intensity of irradiation was measured with radiometer (UVP radiometer, Inc. USA) (Table 1). To avoid evaporation, the seedlings were covered with polyethylene film. Different doses of irradiation were applied.

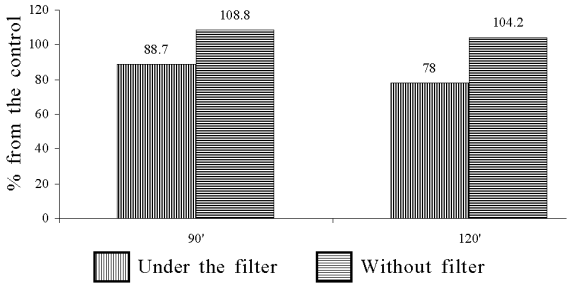
In the second variant of experiment the material was exposed to full spectrum of radiation, i.e. comprising the visible light (39.5%) together with UV section.

After the above mentioned treatment with radiation, control and affected variants of seedlings were placed under day light conditions as water cultures. In seven

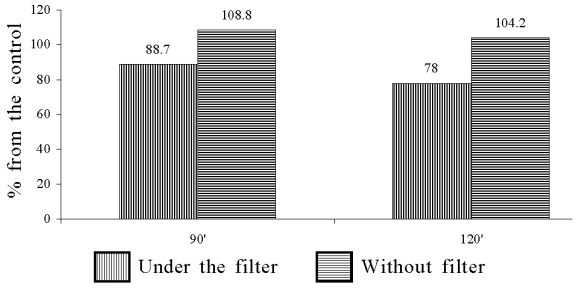
Table 2

Influence of different doses of UV radiation on the growth of soybean and pea seedlings (3 day-old seedlings were irradiated and 7 day-old seedlings were analyzed)

Plant	Seedlings organ	Index	Control	Duration of irradiation (min)			
				15′	60′	90′	120′
Soybean	Main root	Length, mm	124.4±18.1	103.2±10.4	155.0±12.4	54.6±8.5	died
		Biomass, mg	180.0±0.5	179.2±7.5	208.4±11.1	150.0±11.0	-
	Lateral root	Maximal length, mm	68.5±9.3	60.1±7.1	78.4±8.5	55.6±8.5	died
	Hypocotyls	Length, mm	9.5±9.9	90.0±10.3	80.3±10.3	81.5±6.4	died
		Biomass, mg	275.0±1.6	3.5.3±8.8	200.1±9.8	266.9±6.1	-
	Epicotyls	Length, mm	81.6±7.9	71.7±6.4	91.9±6.4	58.6±4.4	died
		Biomass, mg	140.7±2.2	138.4±0.7	147.8±3.9	102.3±0.9	-
	Cotyledons	Length, mm	18.1±0.9	17.8±1.4	21.2±1.3	16.3±0.8	died
		Width, mm	11.5±0.6	11.3±0.6	16.3±0.6	9.9±1.2	-
		Biomass, mg	561.5±4.1	583.0±7.7	630.0±7.0	514.6±5.3	-
Pea	Main root	Length, mm	67.8±9.3	80.8±11.3	67.1±0.5	60.3±0.8	49.0±1.9
		Biomass, mg	133.8±0.9	205.0±3.7	186.6±1.9	178.0±0.07	111.5±0.7
	Lateral root	Maximal length, mm	37.7±7.0	40.1±4.8	37.0±0.8	32.6±7.6	21.0±5.4
	Hypocotyls	Length, mm	13.0±1.4	13.9±5.3	13.2±1.8	9.2±1.3	9.0±0.7
		Biomass, mg	116.1±1.3	123.5±4.0	103.3±10.0	103.0±11.0	90.6±11.0
	Epicotyls	Length, mm	36.6±5.8	42.4±5.0	36.6±8.8	29.3±6.4	25.6±4.6
		Biomass, mg	40.0±4.0	41.2±2.3	37.8±13.0	37.5±10.1	31.5±9.0



Length of the main root



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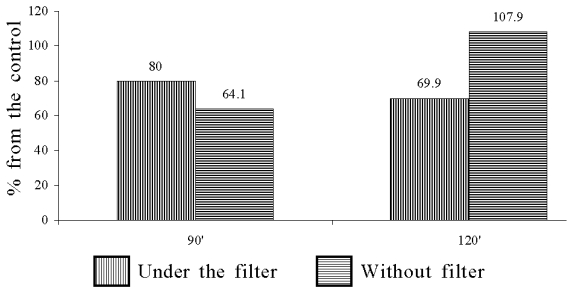
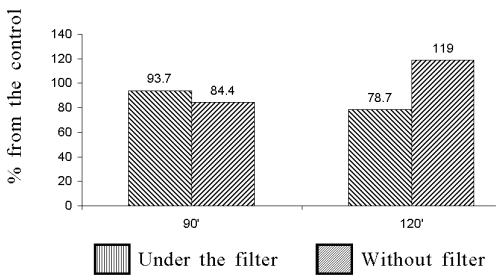
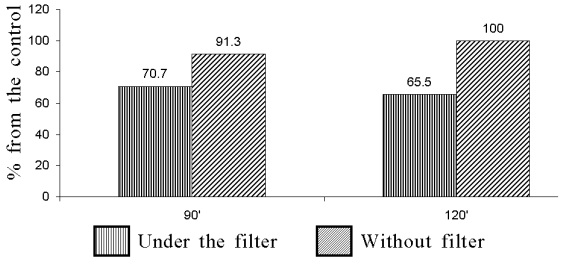


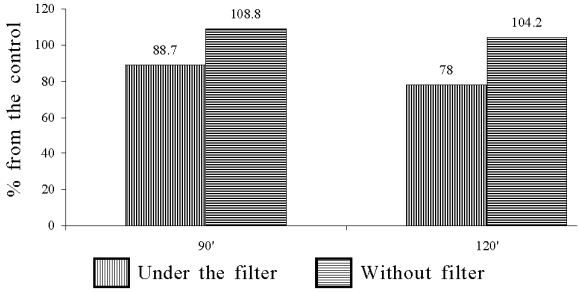
Length of hypocotyles



Biomass of hypocotyls



Length of epicotyls



Biomass of epicotyls

Fig. Growth parameters of pea seedlings

day-old seedlings morphometric analysis was made, the length of the main and lateral roots, also that of hypocotyls and epicotyls was measured. The length and width of cotyledons were determined only in soybean seedlings, because in pea this part of the plant remains underground. Besides this, the water content and biomass of particular organs (using gravimetric method) was measured.

Each experimental variant was done in three replications. The number of seedlings for each variant totalled 10-12. The obtained results were calculated statistically by means of Excell program. Tables and pictures present the mean values and standard deviation.

Investigation of the influence of different doses of UV radiation on experimental seedlings has shown that the effect of treatment depended on the dose of irradiation. The results differed not only for species, but for particular organs too (Table 2).

From the obtained results it is clear that 15′ irradiation retarded the development of soybean seedlings by all parameters studied, while 60′ doses were stimulating. According to literary data the initial stages of seedlings development is closely linked with the function of phytochrome [5, 10]. During photomorphogenesis it causes involvement of the growth stimulating hormones in the process of growth. The hormonal status of the plant is affected by the qualitative composition, intensity and duration of illumination. It is clear that 60′ irradiation was optimal for auxin activation in cotyledons, stimulating

Table 3

Influence of different doses of UV radiation on the water content in organs of soybean and pea seedlings

Variants	Root	Hypocotyls	Epicotyls	Cotyledons
Soybean				
Control	91.7±0.6	93.8±2.2	89.0±0.3	84.7±1.7
15′	90.1±0.2	93.4±0.9	89.9±5.5	84.4±4.4
60′	91.0±1.4	92.9±2.7	89.1±6.7	80.0±6.8
90′	90.9±1.1	92.3±2.2	90.2±9.1	70.1±2.0
Pea				
Control	88.5±10.2	92.7±8.8	81.2±12.0	-
15′	87.9±7.7	92.0±3.1	89.3±6.6	-
60′	87.7±1.9	91.9±3.3	94.3±0.7	-
90′	88.0±1.9	91.0±6.0	95.5±0.9	-
120′	88.1±1.0	92.0±2.7	95.7±11.1	-

their growth intensity, while inhibition of the development of hypocotyls may be explained by the decrease of auxin activity. 90′ irradiation of seedlings inhibited their growth, and higher dose (120′) was lethal, resulting in the death of seedlings. Biomass and size of cotyledons reduced, which negatively reflected on the development of other organs of developing seedlings.

Unlike soybean, irradiation of pea seedlings for 15′ appeared to be stimulating, but further increase of the dose revealed a negative effect. Irradiation for 120′ diminished growth by 55-83%, while for soybean seedlings it was lethal. The obtained results indicate a higher resistance of pea seedlings to UV radiation. The comparison of growth reactions of particular organs has revealed the high sensitivity of the rootage and the especial resistance of cotyledons to the inhibiting doses of UV radiation.

Maintaining the water balance is of great importance for the adaptivity of the plant to unfavorable conditions. From Table 3 it is clear that low doses of irradiation did not reveal an essential influence on the water content of seedlings. High doses caused a decrease of the moisture content in soybean cotyledons (Table 3). Roots and hypocotyls of pea revealed relatively small reaction to different doses of irradiation, while in epicotyls increasing of water content was noticed, with intensification of the effect. This may have been the reason for the survival of seedlings in spite of the growth inhibition.

It is known that the effect of UV radiation depends not only on doses but on the spectral composition of irradiation as well. The second variant of the experiments implied the study of the effect of the total spectrum of the ДРТ-400 lamp irradiation on the seedlings of experimental plants. In this case seedlings were subjected to visible radiation, together with UV rays. For the comparative studies the parameters of the development of pea seedlings both using УФС-2 filter and the total spectrum of irradiation are demonstrated in the Figure. It was found that exposure to the total spectrum of irradiation for 90′ caused activation of root and epicotyls growth and hypocotyls length diminishing to a grater extent compared with filtered irradiation. Treating for 120′ fully blocked the inhibitory effect of short rays, in spite of the high intensity of short wave irradiation (compared with filtered one) (Table 1). The effect of 120′ variant was so negative compared with 90’ exposure that the process of reactivation was expressed very weakly.

According to the obtained data it may be assumed that the inhibitory influence of high doses of UV radiation on the development of seedlings was neutralized by visible irradiation. According to some authors, this effect is the result of flavonic phytochrome activation which supplies the UV-damaged molecules with electrons [11, 12]. This type of molecular mechanism may be responsible for the induction of stress-proteins in the case of high doses of UV radiation, recovering the damaging effect of stress and stimulating resistance [13, 14].

მცენარეთა ფიზიოლოგია

ულტრაიისფერი დასხივების რეჟიმის გავლენა სოიასა და ბარდას აღმონაცენების ზრდა-განვითარებაზე

ნ. კაჭარავა, ე. ჩხუბიანიშვილი, ლ. კობახიძე*

* *ნ. კეცხოველის ბოტანიკის ინსტიტუტი, თბილისი*

(წარმოდგენილია აკადემიკოს ნ. ნუცუბიძის მიერ)

ნაშრომში შესწავლილია პარკოსანი მცენარეების – სოიისა (*Glycine hispida* (Moench) Max.) და ბარდის (*Pisum sativum* L.) აღმონაცენებზე ულტრაიისფერი (უი) დასხივების განსხვავებული რეჟიმის გავლენა. დასხივების წყაროდან (ნათურა DPT-400) ფილტრის საშუალებით გამოყოფილია სპექტრის მოკლეტალღიანი უბანი. ერთდროულად შესწავლილია ინტეგრალური დასხივებით გამოწვეული ეფექტები. დადგენილია, რომ დასხივებისადმი მგრძნობელობის მიხედვით განსხვავდებიან არა მხოლოდ სახეობები, არამედ აღმონაცენების ორგანოებიც. 15′ დასხივებამ შეაფერხა სოიის აღმონაცენების ზრდა ყველა პარამეტრის მიხედვით, მაშინ როდესაც 60′ დასხივება მასტიმულირებელი აღმოჩნდა. ბარდის აღმონაცენებში 15′ დასხივებით გამოწვეული სტიმულაცია დოზის შემდგომი გაზრდისას უარყოფითი ეფექტით შეიცვალა. გამოვლენილია ფესვთა სისტემის მაღალი მგრძნობიარობა და ლებნების მაღალი მდგრადობა უი დასხივების დამთრგუნველი (სოიისათვის 90′, ბარდასთვის – 120′) დოზების მიმართ. აღმონაცენის ზრდაზე უი დასხივების მაღალი დოზების მაინჰიბირებელი მოქმედების გაუვნებლება ინტეგრალური დასხივებისას გამოწვეულია გრძელტალღიანი სხივებით. გამოთქმულია მოსაზრება, რომ უი დასხივების სტრესული მოქმედების პირობებში ამოქმედებული ე.წ. "სტრესდამცველი" მექანიზმი ხსნის არა მხოლოდ ნეგატიურ ეფექტს, არამედ შეიძლება გამოიწვიოს ტოლერანტობის ფარგლების გაზრდა.

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Received January, 2007