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Presowing XeCl excilamp irradiation of crops: field research and prospects

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ABSTRACT

Here we present research data demonstrating how crop seeds response to ultraviolet produced by a barrier-discharge XeCl* excilamp with a wavelength of 290–320 nm (82–88 %). The data show that presowing ultraviolet treatment is stimulatory to seed germination and plant growth. Ultraviolet treatment increases the seed germinability by 20–30 % and the plant fresh weight by 54 %, compared to untreated control samples, and provides a developed root system with long twisted segments. The research results are encouraging for upgrading the UV technology to larger-scale seed irradiation.

Keywords: crops, excilamp, presowing UV treatment, XeCl

1. INTRODUCTION

Now, agriculture strives for advanced technologies that would speed up the seed germination, reduce the plant disease incidence, and enhance the crop yield. In this connection, more and more studies address ultraviolet irradiation of seeds and plants as a way to increase their sowing quality[1–5].

It has been demonstrated that the radiation produced by XeCl excilamps exerts a positive effect on seeds[6–8], but the effect needs statistical validity for which it should be proven by large-scale experiments covering various crops.

Here we present recent comparative data on the response of different crops to presowing short-wave ultraviolet treatment with a XeCl excilamp (308 nm) in different irradiation modes.

2. IRRADIATION MODES

Figure 1 shows setup schematics for the irradiation modes used. The mode of external irradiation (Fig. 1a) was used in our earlier studies[6,8]. For irradiation in this mode, seed grains are placed at some distance from the output window of a XeCl excilamp equipped with a reflector. Such external irradiation, hereinafter mode I, is convenient and provides the possibility to irradiate seed grains of different shapes and sizes from small flax seeds to large potato tubers. The shortcoming of this mode is its low efficiency because irradiance drops with distance from the excilamp surface by the hyperbolic law and it takes time to attain a desired irradiation dose. Thus, its efficiency is sufficient on small scales but insufficient on large-scales.

To eliminate the above shortcoming, another mode was proposed (Fig. 1b). In this mode, hereinafter mode II, seed grains 8 are placed in quartz tube 10 of diameter d = 11 mm and wall thickness h = 1 mm, allowing a manifold increase in radiant excitance and a proportional decrease in irradiation time. Besides, inner tube 10 provides uniform irradiation of air-dry seed mixtures at the tube periphery and improves the reproducibility of results. In addition, an optical meter serves to control the irradiation dose[9].

It was also proposed to use a mode similar to mode II but with periodic vibrations of seeds in tube 10 (mode III). Thus, the seeds are mixed during irradiation, and this shortens the time to a desired irradiation dose. Besides, the setup was

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equipped with control unit 4 and reducer 3 (Fig. 2), allowing control of the feeding and mixing rates and increasing the setup efficiency and the irradiation quality.

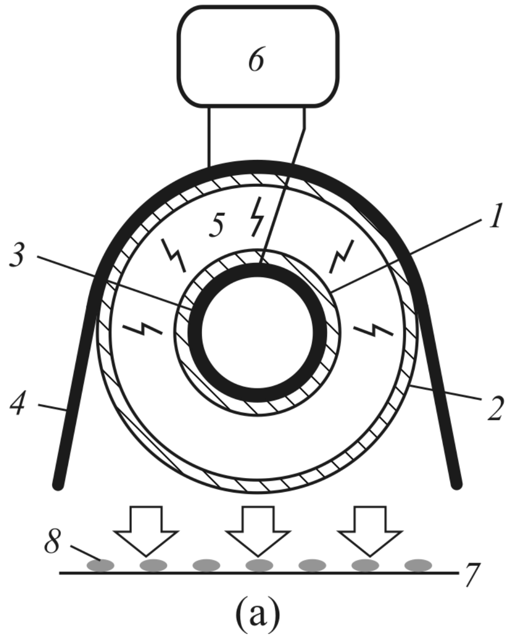

Figure 1. Setup schematics for external (a) and internal seed irradiation (b) with its direction marked by white arrows: *1*,*2* – excilamp quartz tubes; *3* – inner cylindrical electrode-reflector; *4* – outer segmented electrode with reflector; *5* – gas discharge gap with discharge zones indicated by lightning symbols; *6* – power supply; *7* – seed holder; *8* – seeds; *9* – perforated electrode; *10* – quartz tube.

Figure 2. Setup with enhanced efficiency for internal seed irradiation: *1* – excilamp case with cooling system; *2* – seed funnel; *3* – reducer-drive for seed supply; *4* – control unit

3. RESULTS AND DISCUSSION

Wheat seeds (Irgina cultivar) were exposed to XeCl exilamp ultraviolet in mode I for 80 s: 50 seeds uniformly distributed in each of two Petri dishes and a control group of 25 seeds (sample 1). Table 1 presents irradiation results for mode I.

The results in Tab. 1 suggest that ultraviolet treatment increases the germinability of wheat seeds by 20 %, compared to their control samples, and that the difference levels off only after six days but remains 2 % higher for treated seeds. Figures 3 and 4 show photos of control and treated seeds. The fresh weight of treated seeds is 54 % higher than that of untreated ones (Tab. 2).

Table 1. Effect of irradiation mode I

State	**Number of days**	**Germinated seed number**		**Germinability, %**		**Average germinability, %**
		Sample		**Sample**		
		1	**2**	**1**	**2**	
Control	3	19		76		76
Ultraviolet	3	24	24	96	96	**<u>96</u>**
Control	6	24		96		96
Ultraviolet	6	24	25	96	100	**<u>98</u>**

Table 2. Weighing results for treated seeds

Weight, g	**Number of days**	**Control**	**Ultraviolet**	
			Sample	
			1	**2**
Total fresh	8	14.6	17.8	27.0
Average total fresh	8	14.6	22.4	
Fresh per 1 pcs	8	1.46	**<u>2.24</u>**	
Total dry	13	4.6	4.2	5.0
Average total dry	13	4.6	4.6	
Dry per pcs	13	**<u>0.46</u>**	**<u>0.46</u>**	

Figure 3. Control seeds after three (a) and six days (b)

Figure. 4. Treated seeds after three (a) and six days (b)

Tables 3 and 4 presents data for wheat seeds (Omskaya 33) treated in mode II. It is seen from Tabs. 3 and 4 that ultraviolet treatment in mode II is also beneficial for wheat germinability and growth, and the question arises of whether such treatment is beneficial for other crops.

Reasoning that laboratory UV treatment demonstrates a good effect on crops, reliable statistics, and hence much promise for field applications, it is reasonable to advance the technology to provide ultraviolet treatment of large seed amounts in the shortest time. For this purpose, a modified XeCl excilamp has been designed at IHCE SB RAS. The excilamp operates in mode III (Fig. 2).

Table 3. Irradiation in mode II

Germinability, %					**Root length, cm per 7 days**					**Germ height, cm per 7 days**				
1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
98	88	90	92	92	11.4	6.8	10.2	8.6	9.25	6.9	2.8	5.6	3.8	4.77
94	90	86	90	90	13.5	6.6	10.9	9.8	**10.2**	8.5	3.5	6.4	4.9	**5.82**
100	82	92	98	95	12.3	6.9	10.1	9.3	9.65	7.3	3.7	6.0	4.1	5.28
94	96	92	98	95	13.3	6.4	9.5	9.2	9.6	8.8	3.4	5.0	4.0	5.30
HCP_{05} = 6.19					HCP_{05} = 0.90					HCP_{05} = 0.85				

Table 4. Weighing results for treated seeds

Root weight,g								**Germ weight,g**							
Fresh					**Air-dry**			**Fresh**					**Air-dry**		
1	2	3	4	$\bar{x}$	1	2	3	1	2	3	4	$\bar{x}$	1	2	3
0.20	0.10	0.20	0.14	0.16	0.05	0.03	0.05	0.45	0.16	0.36	0.22	0.30	0.06	0.02	0.05
0.50	0.07	0.28	0.17	0.25	0.05	0.04	0.05	0.51	0.23	0.42	0.29	**0.36**	0.07	0.03	0.05
0.46	0.08	0.25	0.16	0.24	0.05	0.03	0.05	0.52	0.22	0.39	0.24	**0.34**	0.06	0.03	0.05
0.54	0.13	0.25	0.19	**0.28**	0.05	0.04	0.05	0.52	0.26	0.36	0.24	**0.34**	0.07	0.03	0.04
HCP_{05} = 0.11								HCP_{05} = 0.04							

The modified exilamp has been tested, in addition to wheat, on cucumber seeds (Zasolochny) and on buckwheat (No. 9). The seeds were exposed to ultraviolet for 4.5, 6, 8.5, 16, and 34 s (eight seeds for each time period) and then were bedded in peat pots (two seeds per pot). The results are presented in Tabs. 5 and 6.

Table 5. Ultraviolet effect on seeds after 4 days

State Control/UV treated, s	**Germinated seed number**				**Germinability, %**				**Average germinability, %**
	Sample				**Sample**				
	1	2	3	4	1	2	3	4	
Control Cucumber	0	1	1	1	0	50	50	50	37.5
UV cucumber, 4.5	2	1	2	1	100	50	100	50	75
Control Buckwheat,	2	2	2	1	100	100	100	50	87.5
UV buckwheat, 4.5	2	2	1	2	100	100	50	100	87.5
UV buckwheat, 6	2	2	0	1	100	100	0	50	62.5
UV buckwheat, 8.5	2	2	2	2	100	100	100	100	**100**
UV buckwheat, 34	2	2	2	1	100	100	100	50	87.5
Control buckwheat$_2$	1	0	2	2	50	0	100	100	62.5
Control cucumber$_2$	2	2	1	2	100	100	50	100	87.5
UV cucumber, 16-s	2	2	2	2	100	100	100	100	**100**

The data in Tabs. 5 and 6 confirm the ultraviolet efficiency for presowing seed treatment: the treatment increases the seed germinability by at least 13 % and the plant height, on average, by 15 % compared to control samples. The UV treated plants a developed root system and one or two true leaves.

Table 6. Ultraviolet effect on seeds after 6 and 8 days

State Control/ UV treated, s	Germinated seed number				Average height, cm					Germinability, %				Average germina bility, %
	Sample				Sample					Sample				
	1	2	3	4	1	2	3	4	Общее среднее	1	2	3	4	
6 days														
Control cucumber	0	2	0	1	0	4.5	0	7	2.875	0	100	0	50	37.5
UV cucumber, 4.5	2	0	2	1	5	0	4.5	6	3.875	100	0	100	50	62.5
Control buckwheat	2	2	2	1	5.5	6.5	6.5	7	6.375	100	100	100	50	87.5
UV buckwheat, 4.5	2	2	1	2	6	7	6	7	6.5	100	100	50	100	87.5
UV buckwheat, 6	2	2	1	2	4	8	10	7	**7.25**	100	100	50	100	87.5
UV buckwheat, 8.5	2	2	2	2	6	8	7	6.5	6.875	100	100	100	100	**100**
UV buckwheat, 34	2	2	2	1	6.5	6.5	7	6.5	6.625	100	100	100	50	87.5
Control buckwheat$_2$	1	2	2	2	6	1	6	4.5	4.375	50	100	100	100	87.5
Control cucumber$_2$	2	2	2	2	8	8.5	4.5	5.25	**6.5625**	100	100	100	100	**100**
UV cucumber, 16	2	2	2	2	5.5	9	5	6	6.375	100	100	100	100	**100**
8 days														
Control cucumber	0	2	0	1	0	7.5	0	10	4.375	0	100	0	50	37.5
UV cucumber,.5	2	0	2	1	9	0	7.5	9	6.375	100	0	100	50	62.5
Control buckwheat	2	2	2	1	8.5	10.5	8.5	10	9.375	100	100	100	50	87.5
UV buckwheat, 4.5	2	2	1	2	12.5	10	9	8.5	10	100	100	50	100	87.5
UV buckwheat, 6	1	2	1	2	10	10.5	12.5	10	**10.75**	50	100	50	100	75
UV buckwheat, 8.5	2	2	2	2	8.5	11.5	8.5	10.5	9.75	100	100	100	100	**100**
UV buckwheat, 34	2	2	2	1	9.5	8.5	10.5	9.5	9.5	100	100	100	50	87.5
Control buckwheat$_2$	1	2	2	2	9	4.5	6.5	6.5	6.625	50	100	100	100	87.5
Control cucumber$_2$	2	2	2	2	9.75	10.25	7.5	8.75	**9.0625**	100	100	100	100	**100**
UV cucumber, 16	2	2	2	2	7.25	10.5	6.5	9	8.3125	100	100	100	100	**100**

4. CONCLUSION

Thus, we can see that ultraviolet XeCl excilamp treatment holds much promise as a presowing technology for large-scale field use. To advance the technology and provide its better efficiency, it is desired to extend the range of crops and to optimize the parameters of UV treatment.

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