Effect of Impulse Pressure on the Crop Productivity and Germinating Power of Cucumber (*Cucumis sativus*) Plants

Elena Edwardovna Nefedieva (Atrosechenko), Ph.D.

Department of Botany, Penza State Pedagogical University,
37 Lermontov Street, Penza 440026, Russia

ABSTRACT

The influence of pre-sowing treatment of cucumber *(Cucumis sativus)* seeds by impact wave generating impulse pressure on the seed germination and crop productivity in plants were studied. Two stress strategies, such as the damage of "week" seeds and the stimulation of physiological processes in others were shown.

(Key words: impact wave, stress, hothouse, mid-season hybrids, and normal distribution)

INTRODUCTION

Plant productivity is an integrative index determined by a whole complex of physiological processes (Mokronosov 1983). The development and maturation of fruits has received considerable scientific scrutiny because of both the uniqueness of such processes to the biology of plants and the importance of fruit as a significant component of the human diet (Giovannoni 2001).

Small doses of physical or chemical factors may be used as growth regulators due to the existence of non-adaptive (damage) or adaptive reactions to the influence. In case of an adaptive reaction the factor ("signal") initiates the programmed response, which provides the basis for accommodation to the environment (Wareing and Phillips 1978). However, many mechanisms of plant reaction to stress have not yet been investigated and practical utilization of those methods remains difficult.

We have described the method of pre-sowing seed treatment by impulse pressure (IP) generated by an impact wave (Atroschenko et al. 1995; Nefedieva 2002). Plant productivity depended on the value of IP. The aim of the work was to estimate if the increase of plant productivity depended on the mortality of seeds with poor overall performance or if this effect was based on the stimulation of physiological processes in plants.

MATERIALS AND METHODS

The subjects of the research presented here were hothouse hybrids F_1 of cucumber plants *(Cucumis sativus)*. The plants were grown in hothouses of State Unitary Enterprise "Teplichnoye", Penza, Russia. The choice of the agricultural enterprise was conditioned by the technology of plant cultivation that allows taking into account the specific character of impact wave treatment. The small mass of sown seeds (800-1,500 g of cucumber seeds per 10,000 m^2) is convenient for treatment. The seedling technology allows avoiding the rarefaction of crops after the decrease of germination. The cultivation conditions provide valuable harvests.

The seeds were treated by IP (Nefedieva 2002; Atroschenko 1997). The seeds experienced the volumetrical pressing during a 15-20 μsecond period. There were about 10,000 seeds treated simultaneously; and this mass of seeds was one of four biological series in each test.

Plants were grown in a wintry-spring rotation and an extended rotation (Table 1) by standard agricultural technology. The experiments were dated 1994 - 2002.

Table 1. Dates of Agricultural Measures.

Rotation	Date of Sowing	Date of Planting	Date of Last Harvesting
Wintry-Spring	November 25-30	December 25-30	June 10-15
Extended	December 15-20	January 10-20	September 20-25

We used cucumbers of hybrids F_1 NIIOH-416 (Scientific Research Institute of Vegetable Growing, Russia), and Estafeta ("Manul", Russia).

Hybrid F1 NIIOH-412 was bred at the Scientific Research Institute of Vegetable Growing, Russia. This mid-season hybrid enters into fructification on 56-57th day after the sprouting. It is a parthenocarpic autogamous hybrid with feminizing type of flowering. The plant is branchy, it possesses the potential resources in growth and ramification. Fruits are 28-39 cm long. Yield is 25-30 kg·m $^{-2}$ in hothouses. Plants are sensitive to some diseases.

Hybrid F1 Estafeta was bred at the Vegetable Experimental Station of Moscow Agriculture Academy, Russia. The mid-season hybrid enters into fructification on 53-66th day after the sprouting. It is a zoidiophilous hybrid with feminizing type of flowering. The branching is week or middle. Fruits are 15-20 cm long. Yield is 24-44 kg·m^{-2} in hothouses. Plants are resistant to shade and to infection.

The productivity of treated plants was examined in comparison with the control. There were four biological series (four plots per variant); they varied in area each year (the areas are indicated in tables below). We weighed the mass of fruit from each plot. An ANOVA was used for calculation of plant productivity (Lane 2001).

We determined if our data are approximately normally distributed or not. We built and inspected an empiric curve and divided the data into *k* classes:

$$k = 1+3,3 \log n,$$

where *n* is the amount of sampling. The size of class interval (*i*) in control was calculated as:

$$i = \frac{x_{max} - x_{min}}{k}$$

The sizes of class intervals in other tests were equal to control. The general formula of the normal curve equation was:

where *x* is a variable corresponding to the score value. The height of the curve at any point is a function of *x* (*P(x)*);

n is the amount of sampling;
i is the size of class interval;
M is the mean;
σ is the standard deviation
(Stockburger 1996).

The correspondences of empiric and theoretical curves were shown with the χ^2 criteria (Lane, 2001).

RESULTS AND DISCUSSION

The optimal pressures for the stimulation of growth, development and plant productivity were found in 1994. We treated the seeds of cucumber plants (hybrids F_1 NIIOH-416 and Estafeta) with pressures from 3 to 23 MPa, so the germinating power of seeds and plant productivity depended on the treated pressure (Table 2). The pressures 5 - 23 MPa decreased the germination of cucumber plants (to 22-75%).

IP had an influence on the plant productivity (Table 2). The productivity was estimated in wintry-spring rotation of 1994 as a mean from four groups of 25 plants (area 10 m^2). The productivity of plants of hybrid F_1 NIIOH-416 was enhanced to 15.4% with the pressure 4 MPa. The pressures 4, 5 and 11 MPa increased the productivity to 15.4%, 18.4% and 26.8% respectively. The yield was not changed after the treatment of pressures 3 and17 MPa. The plant productivity under the pressure 23 MPa increased to 19.7%.

The productivity of hybrid F_1 Estafeta plants raised significantly under the treatment by IP 4, 5, and 23 MPa (to 16.5%, 20.9%, and 43.0% correspondingly). The IP 3, 11 and 17 MPa did not influence the plant productivity. So we can note that the changes of plant productivity depended on the IP. They were represented the curved line with 2 maxims corresponded to IP 4-11 MPa and 23 MPa. The positions of extremes were specific for the hybrids.

The growth of plant productivity was observed in parallel with the diminution of germination power. There are genotypic and phenotypic "off-types" with low levels of physiological processes, so it our examination was actually to estimate if the increase of plant productivity depended on the death of seeds with poor overall performance (Nefedieva 2002) or if this effect was based on the stimulation of physiological processes in plants.

Table 2. Germinating Power of Seeds (%) and Yield of plants (kg × m $^{-2)}$, Treated by Impulse Pressure, 1994.

Hybrid F_1	Control	Pressure, MPa					
		3	4	5	11	17	23
Germinating Power of Seeds, %							
NIIOH-416	96 ± 2	95 ± 2	90 ± 3	78 ± 2	29 ± 4	21 ± 3	17 ± 5
F	540,61						
Estafeta	95 ± 1	96 ± 3	92 ± 2	74 ± 3	25 ± 3	19 ± 2	14 ± 4
F	786,73						
Yield, kg × m $^{-2}$							
NIIOH-416	22.8 ± 0.1	23.6 ± 0.2	26.3 ± 0.1	27.0 ± 0.1	28.9 ± 0.2	23.5 ± 0.2	27.3 ±0.3
F	750,38						
Estafeta	15.8 ± 0.1	16.2 ± 0.1	18.4 ± 0.2	19.1 ± 0.1	16.0 ± 0.2	16.8 ± 0.1	22.6 ± 0.2
F	1125,46						

Note: N = 4. F represents F distribution values (ANOVA).

We have built empiric curves of plant productivity distribution. To help visualize the problem, we have prepared curves of normal distribution P(x) with the same mean and standard deviation.

The empiric distribution of control plant productivity (Figure 1) corresponded to the normal distribution with the significance level 0.99 (χ^2 = 3.33, 7 class intervals). The minimal foetus mass was 4.1 kg, the maximal mass was 8.9 kg. The tails of curve were low and the peak was higher than in normal curve, so the distribution was leptocykurtic. The peculiarity of industrial hybrids is the grouping of most values of productivity near the mean. The curve was a little skewed right, so plants with reduced productivity were taken out during the breeding.

The empiric distribution of productivity of plants, treated with IP 5 MPa (Figure 2), corresponded to the normal distribution with the significance level 0.30 (χ^2 = 8.45, 10 class intervals). The curve was expanded when compared to the control. The minimal foetus mass was 4.5 kg, the maximum mass was 11.0 kg. Also the curve was skewed right, the peak was skewed right too. Table 2 shows the diminution of germination power of seeds after the treatment, but the amount of plants with low productivity was not reduced. So the displacement of peak depended on the appearance of plants with increased productivity, topped the control.

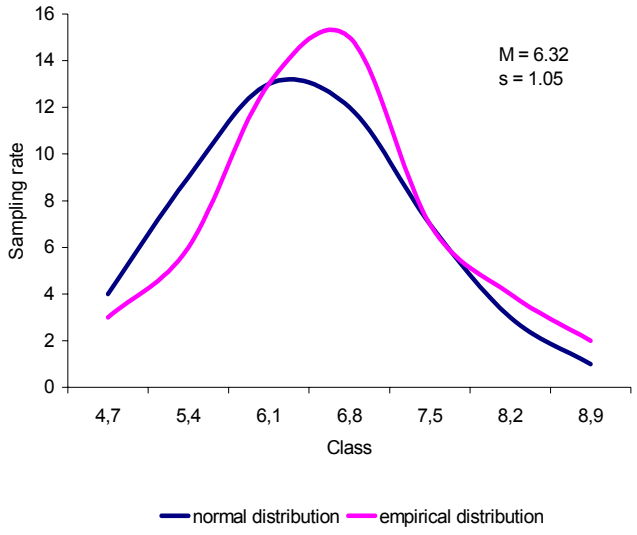

Fig. 1. Empiric and normal distribution of plant productivity in control. Estafeta, 1994.

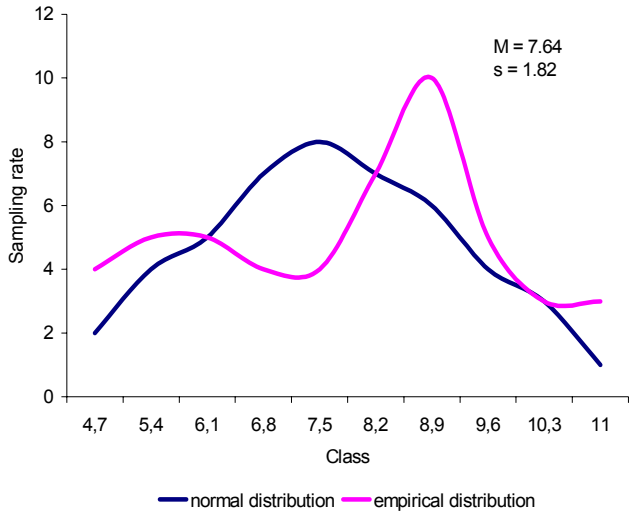

Fig. 2. Empiric and normal distribution of plant productivity, 5 MPa. Estafeta, 1994.

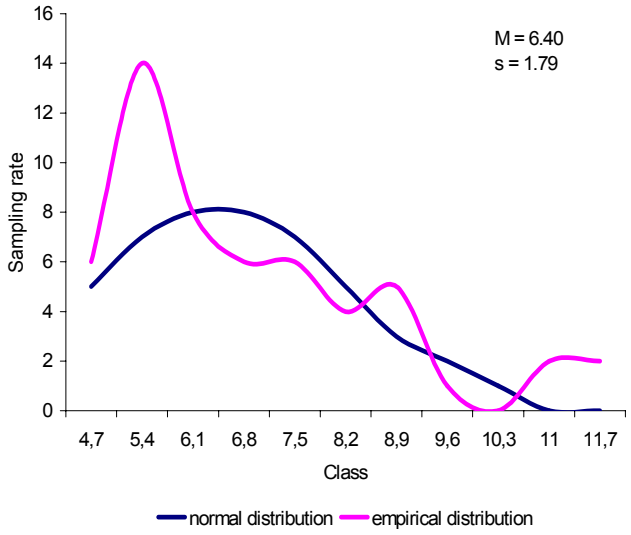

Fig. 3. Empiric and normal distribution of plant productivity, 11 MPa. Estafeta, 1994.

The empiric distribution of plant productivity after the treatment of IP 11 MPa (Figure 3) corresponded to the normal curve with the significance level 0.30 (χ^2 = 10.88, 11 class intervals). The irregular peak appeared in the left tail of the curve. The minimal plant productivity was 4.0 kg. The decrease of productivity of plants after the treatment of IP 11 MPa versus 5 MPa was promoted the increase of amount of plants with low productivity (1st, 2nd, and 3rd interval). Also the curve was significantly expanded and skewed right, because its right tail was long. The maximal plant productivity was 11.3, so plants with productivity exceeded the control appeared after the treatment. The extraction pressure was directed to individuals near the arithmetic mean. Described features showed the "transitional reaction" of plants.

The empiric distribution of productivity of plants, treated with IP 23 MPa (Figure 4), corresponded to the normal distribution with the significance level 0.99 (χ^2 = 11.70, 14 class intervals). The height of the probability density at one standard deviation above and below the mean was larger than the normal distribution's, then the distribution was platycykurtic. The minimal foetus mass was 5.3 kg, the maximal mass was 13.8 kg. Long tails approved that the curve was platycykurtic and not skewed. Simultaneously plants with productivity exceeded the control appeared and plants with reduced productivity vanished after the treatment. The decrease of seed germination may be a factor of extraction

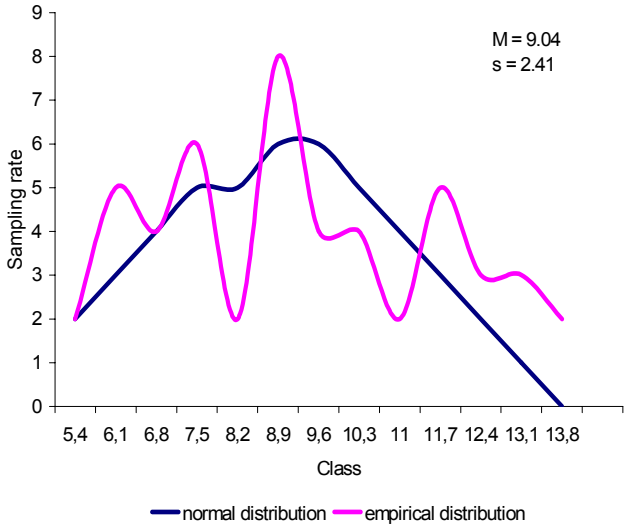

Fig. 4. Empiric and normal distribution of plant productivity, 23 MPa. Estafeta, 1994.

pressure. So genotypic and phenotypic "off-types" were the target of damage from the IP treatment. The increase of plant productivity is partly the result of the mortality of "week" seeds. Also there were highly productive plants appeared after the treatment. There are at least two stress strategies: the damage of "week" seeds and the stimulation of physiological processes in others.

Table 3. Productivity of Plants after the Impulse Pressure Treatment

Hybrid F_1	Pressure, MPa	Year	Rotation	Plots	Plot Area	Plants per Plot	Yield, kg/plot	F	Yield, kg/ m^2	% Crop Increase
NIIOH-416	0	1996	2	4	2,500	6,250	46,750	46.5	18.7	–
	5						53,250		21.3	14
Estafeta	0	1997	2	4	10,000	25,000	12,300	42.9	12.3	–
	4						14,000		14.0	14
Estafeta	0	1998	1	4	12,500	31,250	198,750	29.9	15.9	–
	4						226,250		18.1	14
Estafeta	0	1999	1	4	5,000	12,500	90,500	95.4	18.1	–
	5						103,000		20.6	14
Estafeta	0	2000	2	4	17,500	45,500	393,750	44.8	22.5	–
	5						449,750		25.7	14
Estafeta	0	2001	2	4	20,000	52,000	494,000	99.9	24.7	–
	5						568,000		28.4	15
Estafeta	0	2002	2	4	17,500	47,250	444,500	80.7	25.4	–
	5						505,750		28.9	14

Note: Rotation codes are as follows: 1) wintry-spring rotation; and 2) extended rotation. Plot area measured in square meters. N = 4. F represents F distribution values (ANOVA).

CONCLUSIONS

On the grounds of obtained data we recognize the influence of pressures from 4 to 5 MPa as optimal for cucumber plants. It does not lead to the significant lowering of seed germination. These parameters were used for preparation of agricultural productions since 1996 (Table 3). The application of the impact wave treatment was recognized as the perspective method.

At present the effect of the method of impact wave treatment of seeds is recognized. The introduction of the method on whole area of the state unitary enterprise "Teplichnoye" was carried out. Thus, the method was approved, recognized and recommended for the wide use.

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ABOUT THE AUTHOR

Elena Nefedieva, Ph.D. is a Senior Lecturer at Penza State Pedagogical University, Russia and she also serves as an adjunct professor at Greenwich University. She has research and pedagogical experience in the field of plant physiology and has investigated the stress of plants and the influence of pressure on plants. She is also interested in research and applications in plant growth regulation. Dr. Nefedieva has more than 40 scientific publications to her credit. Her biography is published in "Marquis Who's Who in the World", 2001.

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