Efficiency of seeds' germination in pre-sowing irradiation by UV- light of different spectral composition

Mykola Marenych[1], Anatoliy Semenov[2], Tamara Sakhno[1], Nikolay Barashkov[3]

1.Poltava State Agrarian Academy, Poltava, 36003, Ukraine

2.University of Economics and Trade, Poltava, 36014, Ukraine

3.Micro-Tracers, Inc, San Francisco, CA, USA

INTRODUCTION

One of the main tasks of the agricultural complex is to increase the quantity and quality of crop production. Great interest in stimulating growth and increasing the resistance of plants to external factors and increasing the productivity of agricultural crops is the pre-sowing processing of seeds of crops by UV radiation. The influence of UV-light with three different spectral regions C (200–280 nm), B (280–320 nm) and A (320–400 nm) of irradiation on the biological processes in seeds has been investigated. In series of laboratory experiments it has been shown that UV irradiation positively affects vigor and germination capacity. Particularly, it has been demonstrated that UV-light with a dose of 120 J/m^2 increases the vigor and germination capacity by 23–31 % and by 14–25 % (depending on the chosen spectral region), correspondingly, compared to control samples.

The purpose of the study was to investigate the pre-sowing effects of three different regions of C (200-280 nm), B (280-320 nm) and A (320-400 nm) of seed irradiation on biological processes (vigor, germination capacity and germination) in laboratory conditions. Ensuring high yield of agricultural crops is an important task of the agro-industrial complex in the near future. To solve this problem, specialists improve and develop new agro-measures aimed at improving the quality of seed material and yield [1,2]. In modern conditions, in order to improve the sowing qualities of seeds, physical methods are used to bring their biological systems out of rest [3]. The physical factors influencing the seed

include the use of X-ray, ultraviolet, optical and infrared radiation. The spectral composition of radiation and its intensity affect the physiological processes in the pre-sowing treatment of seed material and in the process of plant development and growth.

A large number of experimental studies are devoted to this problem [4-10]. In work [4], the effect of ultraviolet radiation (UV-C) on the germination percentage, germination rate, root length and plume length of corn seeds and sugar beet was studied. The UV-C radiation treatments did not significantly affect the germination percentage of the seeds. However, the seeds germination rate was significantly affected by the UV-C radiation treatments. The treatments of 8 h and 12 h exposure duration led to the highest seed germination rates in maize and sugar beet, respectively.

The relevance of the work is determined by the search and development of technologies for obtaining effective physical bio stimulants for pre-sowing treatment of seeds, contribute to the improvement of sowing qualities, enhancement of photosynthetic activity, survival and yield [3]. The seeds of different wheat varieties exposed for 3 h to UV A, B, and C radiation at dosage of 1.19,1.3 and 1.84 mW/cm^2 respectively and then further treated with acid spraying exhibited varied responses depending on the UV-light to which it was exposed. The varieties of wheat used for the study included the soft wheat (Triticum aestivum var. ferrugineum); durum wheat (T. durum); macha wheat (T. macha); and three varieties of the dika wheat. The treatment enhanced the chlorophyll synthesis, photosynthetic rate and protein content [5-7].

UV-C radiation is non-ionizing and it penetrates superficially into the plant tissues, which supports its potential as a germicidal agent. Seed treatments with low doses of UV-C (3.6 kJ m^{-2}) were used to elicit host resistance to black rot in cabbage (Brassica oleracea L.) [8]. This UV-C seed treatment also improved the quality and growth response of cabbages under greenhouse conditions.

In another study, Ouhibi et al. [9] investigated the impact of UV-C pre-sowing treatments in lettuce (Lactuca sativa L. 'Romaine'). Lettuce seeds were UV-C- treated by exposure to 0.82 and 3.42 kJ m-2 doses and resulting seedlings were challenged with salt stress. The results showed that UV-C treated seedlings were able to mitigate the impact of excessive salinity, possibly as result of the enhanced free radical scavenging activity detected in their leaf tissues. Additionally, the authors also showed that a dose-dependent response occurs: seedlings derived from seeds treated with the lowest UV-C dose showed higher tolerance to salinity conditions.

In work [10], the effect of ultraviolet radiation on seed germination, seedling growth, and peanut productivity was studied. The results indicate that UV-C irradiation up to 60 min increased the growth parameters of groundnut plant. The UV-C irradiation produces significant increase in seedling vigor and biomass production as compared to control and other treatments.

The object of the current study was to investigate the pre-sowing effect of UV irradiation on biological processes, such as vigor and germination capacity of the seeds (wheat, barley, rapeseed and carrots) in laboratory conditions.

EXPERIMENTAL SECTION

Vigor, germination ability and germination of seed were determined in laboratory conditions according to the published methods [11,12]. These parameters were compared for seeds irradiated in different energy regions A, B, C of ultraviolet radiation at the same irradiation doses of 120 J/m^2, with control samples (without irradiation).

Vigor means the percentage of sprouted seeds in 72 hours, the ability to germinate - the percentage of germinated seeds in 120 hours, germination of seeds - the percentage of germinated rapeseed in 7 days. For the experimental studies, 200 seeds for the control sample and 200 seedss for irradiation in the different energy regions of the UV spectrum were deduced from the obtained samples. The seeds were deposited into several layers of moisturized filter paper in Petri dishes and kept in a thermostat at 7-20^{o}C for 24 hours.

The choice of the used UV lamps included the following[13]:

1. UV-A range: LUF lamp 65/80, 80W power.

2. UV-B range: LES-30 W, 30 W power.

3. UV-C range: ZW20D15W lamp, 20W power.

Dose measurements of UV radiation in different energy range were performed using a Tensor-31 radiometer using the technique [14]. The irradiated and control samples of seeds

were germinated in Petri dishes at an air temperature of 25^{0}C. Table 1 shows the technical characteristics of the low pressure discharge UV lamps [15] used in the described experiments. The setup for pre-sowing seed irradiation was the same as in our previous publications[16,17].

Table 1. Characteristics of quartz glass lamp Jiangyin Feiyang Instr.Co.,Ltd. (China)

Lamp type	*P*, W	*I*, mA	*U*, V	UV irradiation at a distance of 1 m, W/cm^2
ZW80D19W-846	80	800–1200	120	240–270
ZW37D15W-793	37	350	78–101	110
ZW23D15W-436	23	420	40–55	62–69

The distance from the source of UV radiation with seed samples is 250 mm.

RESULTS AND DISCUSSION

The results of the study of the vigor of rapeseed, depending on the energy dose of ultraviolet radiation in range A, B, C show the following (Table. 2):

- the vigor increases, compared with the control sample, by 31.1% for range C, by 23% for range B increases, 26.2% for range A;

- the ability to germinate increases, compared with the control sample, by 25.0% for range C, by 14.7% - for range B, by 16.2% - for range A;
- the similarity level increases, compared to the control sample, by 17.1% for range C, 7.9% - for range B, by 10.5% - for range A.

Table. 2. Germination energy (vigor), germination capacity and germination of irradiated in the UV-C, UV-B and UV-A range at 120 J/m^2 dose and rapeseed control samples

%	Control sample	The sample irradiated in the range		
		UV-C	UV-B	UV-A
Germination energy	61	80	75	77
Percentage increase	-	31.1	23.0	26.2
Germination capacity	68	85	78	79
Percentage increase	-	25.0	14.7	16.2
Similarity level	76	89	82	84
Percentage increase		17,1	7,9	10,5

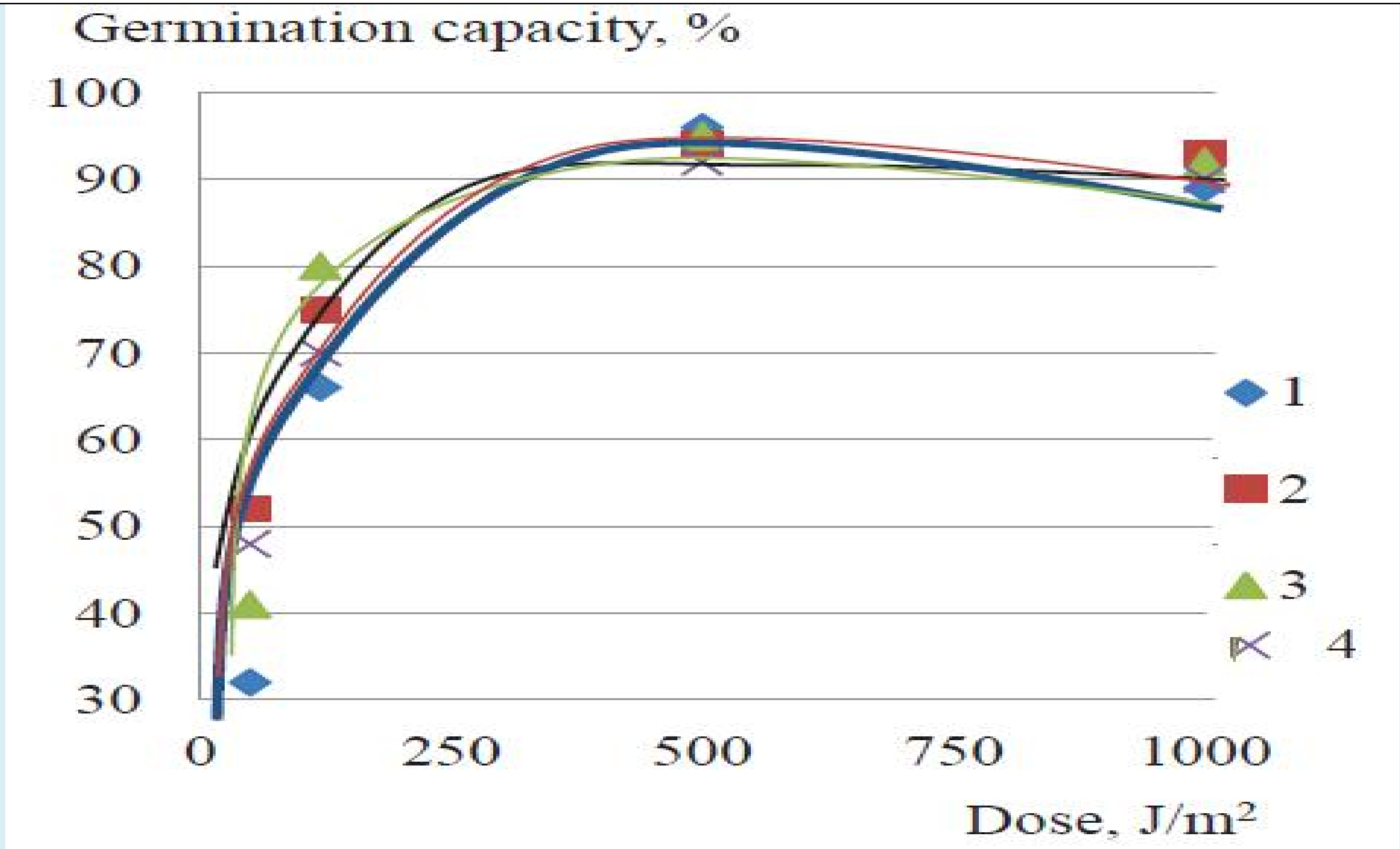


Fig. 1. Germination capacity determined for 4 wheat samples.

Samples of soft winter wheat and winter and spring barley were presented by the laboratory of grain crops of Ustytim experimental plant growing station (Ustymivka, Poltava region, Ukraine). The following wheat samples (harvest 2018) were investigated:

No. 1 – Podolianka (UDS02111), No. 2 – Taras (UDS05054), No. 3 – Astra (UDS04766), No. 4 – Yuzhanka (UDS04779) after UV irradiation with doses of 50, 120, 500, 1000 J/m^2 (Fig. 1).

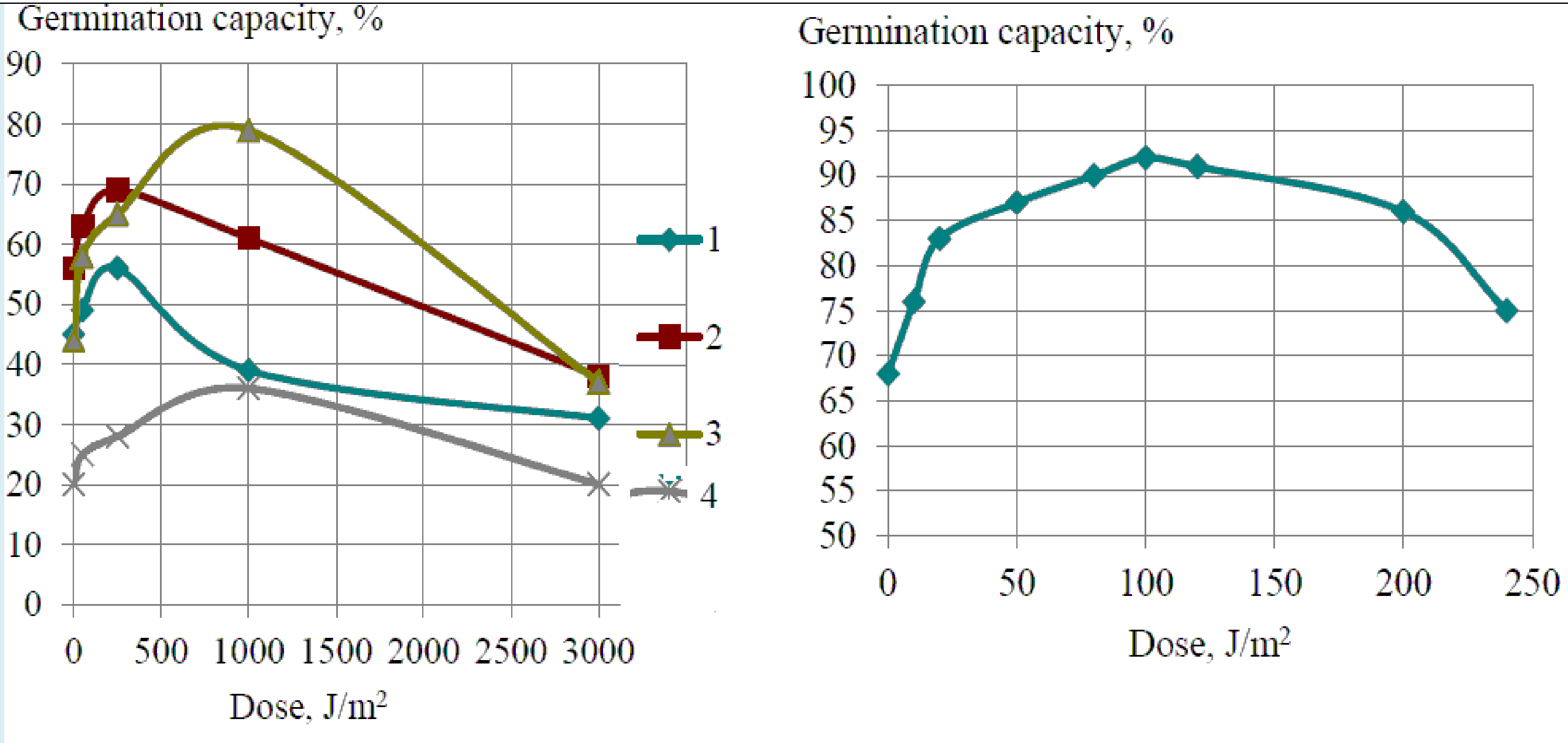
From the presented dependence (Fig. 1) of the germination capacity from the dose of UV irradiation, it was determined that the optimal dose for irradiating wheat seeds is 400–600 J/m^2, at which the number of germinated seeds is maximum. Doses close to 1000 $J/m^2$and more cause a decline in this parameter. The results of studies of vigor and germination capacity of wheat seeds of various varieties with a dose of UV-C exposure of 500 J/m^2 showed that vigor increases compared with control samples by 7–12 %, and germination capacity by 9–15% [15].

The following samples of barley were also investigated:

No. 1 – Zymovyi (var. Pallidum) winter (UKR), No. 2 – Osnova (var. Pallidum) winter (UKR), No. 3 – Rytsar (var. Submedicum) spring (RUS), No. 4 – Vzirets (var. Nutans spring (UKR) reproduction of 2018 after UV irradiation with doses of 50, 250, 1000, 3000 J/m^2 (Fig. 2).

The results of studies of vigor and germination capacity of barley seeds of different varieties showed that the germination capacity for winter barley with UV doses of 250 J/m^2 increased by 23% compared with control samples. Besides, the germination capacity for spring barley at doses of 900–1000 J/m^2 increased by 80% (Fig. 2A).

We investigated as well the behavior of rape’s samples after irradiation with doses of 50, 120 and 240 J/m^2. The results of seed germination capacity as a function of the dose of UV-C irradiation are shown in Fig. 2B.



A **B**

Fig. 2. Germination capacity: A– barley samples No. 1, 2, 3, 4; B – rapeseed sample

If was found that for the barley samples the vigour increases compared with the control sample by 20–26%, and the germination capacity – by 16 %, and for genetically modified seed plants – the germination capacity decreased by 7–10% [16]. A decrease in the «activity» of the germination of rapeseed was also observed when irradiated with higher doses of 240 J/m^2 (Fig. 2B). The following samples of carrots were investigated after UV irradiation with doses of 120, 200, 500, 1000 J/m^2: 1 – Perfection; 2 – Shantane Royal; 3 –

Dolianka; 4 – Jaskrava; 5 – Nantska. The experimental results showed that the UV irradiation of carrot seeds of all the studied varieties results in active stimulation of growth processes at a dose of 120J/m^2 (Fig. 3).

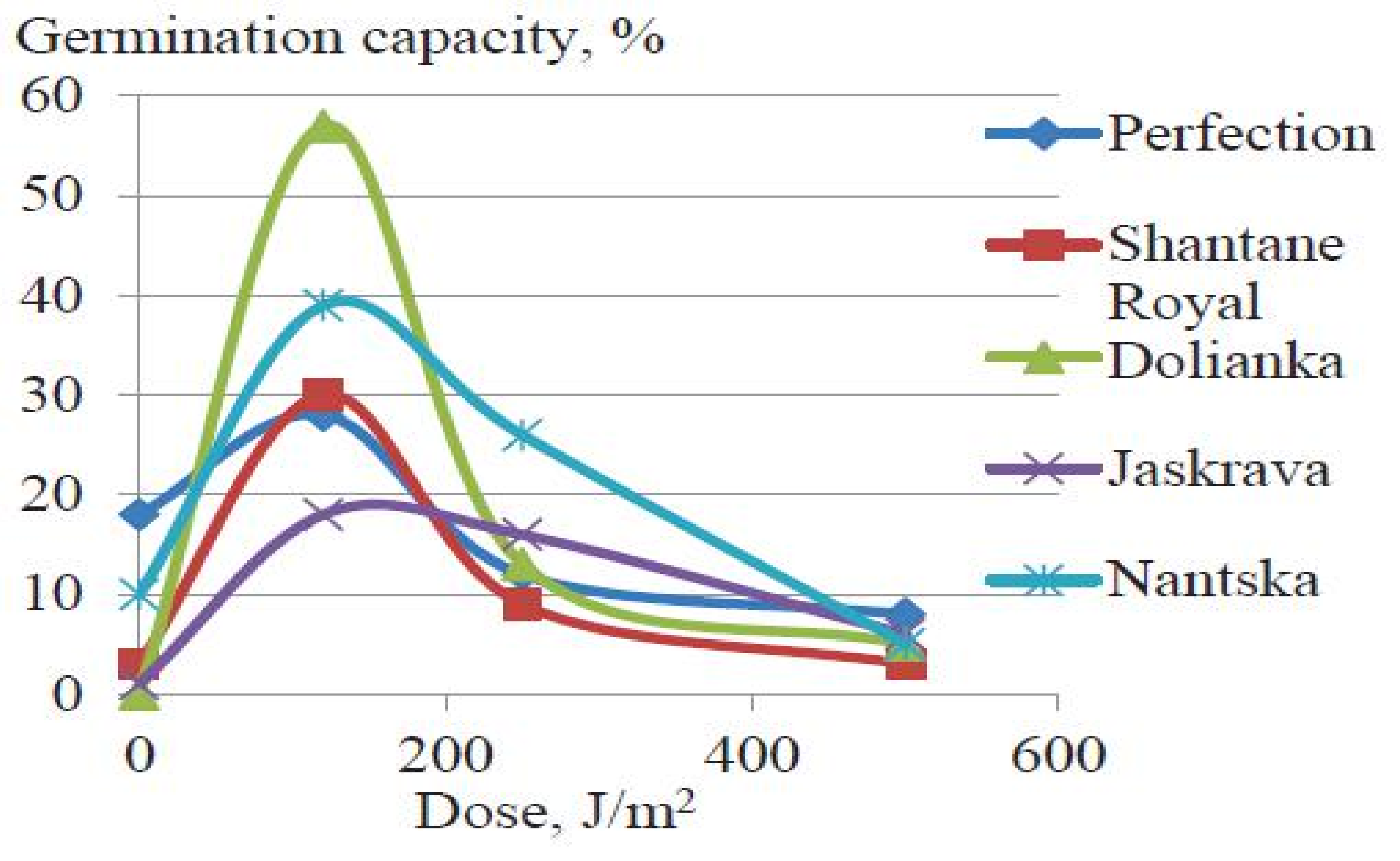


Fig. 3 Germination dependence on irradiation dose for samples of carrots.

According to data presented in Fig. 3, the dose of UV irradiation of 120–150 J/m^2 can be

determined as the most optimal, at which the percentage of germination of carrot seeds has the maximum value for all studied varieties. The greatest increase in germination capacity (the difference between the irradiated and the control sample) was 57% for the variety Dolianka, the same growth – 27–29% is shown by the varieties Shantane Royal and Nantska. At radiation doses of more than 200–250 J/m^2, a decrease in the studied parameters was observed.

These results are confirmed in the field conditions where the UV-C (dose of 120 J/m^2) irradiated samples of carrot seeds have risen earlier by 9 days compared to non-irradiated seeds. At the same time, the number of germinated seeds was 43 % higher, compared with the control samples. In the process of growth, a healthier development of the plants of irradiated seeds has been noted, which influenced the increase in yield.

Conclusions

1. **The positive effect of UV-irradiation in different spectral region on vigor, germination capacity and germination ability of rapeseeds has been demonstrated.**
2. **The pattern of positive influence of UV irradiation on the growth processes of crops has been observed in the field conditions when growing preliminary irradiated rapeseeds and carrot seeds contributed to an increase in yield.**
3. **Pre-sowing irradiation of seeds with ultraviolet in the area of C (200–280 nm) can find practical use in growing plants without the use of chemicals and growth stimulants.**

REFERENCES

1. Rifna E. J., Ratish Ramanan K., Mahendran R. Emerging technology applications for improving seed germination // Trends in Food Science & Technology. 2019. v. 86, 95–108.

2.Dhanya T.T, et al. "UV radiation priming: A means of amplifying the inherent potential for abiotic stress tolerance in crop plants". Environ. & Exper. Botany, 2017, v. 138, 57-66.

3. Araújo S., et al "Physical Methods for Seed Invigoration: Advantages and Challenges in Seed Technology". Front Plant Sci. 2016;v.12(7), 646.

4.Neelamegam, R., et al. "UV-C irradiation effect on seed germination, seedling growth and productivity of groundnut ". Int. J.Current Microbiol. & Applied Science, 2015, v.4 (8), 430-443.

5.Badridze, G., et al. "Influence of ultraviolet irradiation and acid precipitations on the content of antioxidants in wheat leaves". Appl. Ecol. Environ. Res. , 2015 v.13 (4), 993–1013.

6.Badridze, G., et al. "Effect of UV radiation and artificial acid rain on productivity of wheat", Russ. J. Ecology, 2016, v. 47, 158–166.

7.Pouria S., et al. "Exposure to Ultraviolet (UV-C) Radiation Increases Germination Rate of Maize (Zea maize L.) and Sugar Beet (Beta vulgaris)", Seeds Plants 2019, 8(2), 49

8.Brown, J.E., et al "The effect to flow dose ultraviolet light-C seed treatment on induced resistance in cabbage to black rot". Crop Prot., 2001, v. 20, 873–883.

9. Ouhibi C., et al. "Salt stress mitigation by seed priming with UV-C in lettuce plants, growth, antioxidant activity and phenolic compounds". Plant Phys. Biochem. 2014, v.83, 126–133.

10. Siddiqui A., et al. "Role of ultra violet (UV-C) radiation in the control of root infecting fungi on groundnut and mung bean". Pakistan J. Bot. , 2011, v.43 ,2221–2224.

11. "International Rules for Seed Testing". International Seed Testing Association, ISTA, Bassersdorf

, Switzerland, 2011.
12. DSTU 4138-2002. “Seeds of agricultural plants: Methods of quality determination. “Valid since 2004.01.01. Kyiv: Derzhstandart Ukrayiny, 2003. 173 p.
13. Semenov A. O., et al. “Non-ozone germicidal lamps for units of photochemical and photobiological action” // Technology Audit and Production Reserves. 2015. v. 4, Issue 1 (24). 4–7.
14. Semenov A. O., et al. “ Effects of preventive UV-inflammation on the development and productivity of potatoes” // Bulletin of Poltava State Agrarian Academy. 2018. Issue 1, 18–22.
15. Semenov A. O. et. al. “Influence of ultraviolet radiation on germination, sprouting and growth processes of wheat” / // Bulletin of Poltava State Agrarian Academy. 2018. Issue 4, 70–75.
16. Semenov A. O., Kozhushko H. M., Sakhno T. V. “Efficiency of germination of seeds in pre-sowing irradiation by its UV radiation of different spectral composition” // Bulletin of Poltava State Agrarian Academy. 2018. Issue 3. 27–31.
17. Semenov A., Kozhushko G., Sakhno T. “Influence of pre-sowing UV-radiation on the energy of germination capacity and germination ability of rapeseed” // Technology Audit and Production Reserves. 2018. V. 5, Issue 1 (43). 61–65.