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Influence of magnetic field with chemomutagen and gamma rays on the variability of yielding parameters in barley (*Hordeum vulgare* L.)

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A b s t r a c t. The goal of performed investigations was estimation of magnetic field, chemomutagen and gamma rays influence on the level of biological injuries of M_1 barley plants, expressed by variation of yield structure parameters. Generally in both variants of the experiment, stationary and alternate magnetic field induced the biostimulation effect of analyzed traits as compared to control plants. The results obtained depended on the type of magnetic field used, their intensity, doses of gamma rays or chemomutagen and kind of analyzed trait. In contrast to the magnetic field, the doses of MNU used and particularly the gamma rays caused strong reduction of yields parameters. The reduction observed increased with the use of higher doses of irradiation and MNU treatment. In common treatments (magnetic field + gamma rays or magnetic field + MNU) the values of yield structures obtained were lower as for the separate use of magnetic fields but higher than for separate treatment of grains with gamma rays or MNU. This indicates the protected influence of magnetic fields on the level of biological injuries induced by mutagenic treatment of grains with gamma rays or MNU. This effect has undoubtedly a connection with the biostimulate influence of the magnetic field on the value of yield structure parameters.

K e y w o r d s: biological injuries, biostimulation, magnetic field, mutagens, spring barley

INTRODUCTION

Besides the recombination processes, the artificially induced mutation constituted an important factor for the induction of the variability of traits in agricultural plants. The use of ionizing radiation such X-rays, gamma rays and neutron and chemical mutagens for inducing variation, is well established. Induced mutations has been used to improve major crops, such as wheat, rice, barley, cotton, peanuts, and beans which are seed propagated [4]. As a result of this work more than 1800 cultivars were obtained either as direct mutants or derived from their crosses, worldwide in 50 countries.

For the high effective selection of mutated genotypes, it is necessary to obtain the broadest possible variation of desirable traits. This process has a close connection with frequency of induced mutations. On the other hand, the rate of mutations depends on many factors [6] among which the induction method used is particularly important. The use of strong doses of mutagens makes possible the increase in mutation frequency but this is connected with the appearance of many undesirable effects, one of which is the biological injuries of M_1 plants, increased with by using higher doses of mutagens. In extreme cases the survival of plants is so low that the number of harvested seeds is too small to obtain a sufficient number of M_2 plants and or an effective selection of mutated genotypes. From this point of view, it is interesting to choose such methods of mutation induction as will allow the use of relatively high doses of mutagens without markedly decreasing plant fertility.

The use of physical biostimulators could be interesting for mutation induction, used in combined treatment with mutagens [28] with the exception of the following different chemical biostimulators (gibberellin, cytokinins and auxins).

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In Poland, such biostimulators as the laser light is used for the commercial seed biostimulation before sowing of the major crops [8]. Similar effect showed too the microwave radiation [14] as well as white light [9]. Other literature data indicates the specific stimulatory propriety of magnetic field [11,17,20] suggesting that they be used for the mutagenic treatment of barley seeds with chemical and physical mutagen agents.

The aim of the studies carried out was the estimation of magnetic fields and the chemomutagen and gamma ray influence on the level of biological injuries of M_1 barley plants, expressed by the variation of yield structure parameters.

MATERIAL AND METHODS

The initial material for studies were the air dried grains of spring barley (*Hordeum vulgare* L.), of the commercial variety Bryl. The grains of this variety were used for two experiments with magnetic field. In both experiments, the grain was placed in stationary and alternating magnetic fields. The magnetic field was created by means of an electromagnet present at the Department of Physics of the Agricultural University, Lublin [15]. The required alternating magnetic induction was received by regulation of the intensity of the current flow in the insulation of coils feeding the electromagnet. For the alternating magnetic field, the grains were treated with magnetic induction 30 and 85 mT and exposure time t = 15 s (MF I and MF II), for stationary magnetic field by 100 and 600 mT and time exposure t = 60 s (MF III and MF IV). In the first experiment (E I) directly after treatment with both kinds of magnetic field, part of the grain was irradiated with gamma rays in doses of 150; 200 and 250 Gy. In the second experiment (E II) this same magnetic field parameter was used. After treatment with the magnetic field, the grains were pre-soaked in distilled water for 8 h and than submersed in a freshly prepared aqueous solution of mutagen agent – MNU (N-nitroso-N-methylurea) for 3 h at a dose of 0.9 and 1.2 mM MNU. After mutagenic treatment, the grains were thoroughly washed with running tap-water before sowing to remove the mutagen from the grain surfaces. In both experiments the seeds without magnetic field treatment, gamma rays and MNU, constituted control combination.

Immediately after treatment, a hundred treated control grains were sown into each plot (1.0 m^2) in a randomized-bloc design, with 3 replication and 25 cm spacing between rows. After harvesting the M_1 and control plants, the data was recorded for plant height (PH), length of spike (SL), number of spikelets per spike (SPS), number of fertile spikes per plant (FSP), number and weight of grains per main spike (NGMS, WGMS) and number and weight of grains per plant (NGP, WGP). The data obtained was used for the calculation of reduction (biological injuries) or stimulation effect of the analyzed traits as compared to the control combination according to the method given by Rybiñski *et al*. [25].

RESULTS

Experiment with magnetic field and gamma rays (EI)

The results of this experiment are presented in Table 1. Generally both kinds of magnetic field had an influence on the higher values of yield structure parameters as compared to the control combination. A particularly high effectiveness was observed for the stationary magnetic field (MF III and IV), the number of fertile spikes per plant and number and weight of grains per main spike and plant. For alternate magnetic field (MF I and II) 5.4 and 5.5 fertile spikes per plant was obtained, for stationary field: 6.1 and 6.4. Similarly, for grains number and weight per main spike and plant the results obtained were higher for stationary magnetic field. The doses of gamma rays used decreased the values of the analyzed traits and the reduction observed increased with the use of higher doses of gamma rays. A dose of 250 Gy was too strong for barley, caused very low emergence and the death of seedlings. The other doses (150 and 200 Gy) induced a strong decrease of fertile spike number per plant and number and weight of grains per spike and plant. In common treatment (magnetic field + gamma rays) the values of the traits obtained were lower as compared to exclusive treatment with a magnetic field but higher than for exclusive treatment with gamma rays. This was particularly true for the following combination: magnetic field + 200 Gy. For simple treatment with 200 Gy only one fertile spike per plant was obtained, in combination with the magnetic field, the number of fertile spikes increased as well as the number and weight of grains per main spike and plant.

The yield structure expressed in values of stimulation or reduction as compared to control is presented in Table 2. The results indicate the biostimulative influence of the magnetic field, particularly of a stationary field. For both doses of this field and number of fertile spikes per plant, 13.0 and 18.5% stimulation was noticed. For the number and weight of grains per plant, the stimulation level was above 10%. In common treatment (magnetic field + gamma rays) biostimulation was observed only for spike length and the spikelets number in the spike. For other traits, closely related to plant fertility, only the reduction effect was noticed. This effect was higher as compared to the single treatment with magnetic field but lower than with a single irradiation with gamma rays. The highest effectiveness showed in the combination of alternate magnetic field (MF II) + gamma rays for the number of fertile spikes and number and weight of grains per main spike and plant.

The estimation of yield structure parameters for magnetic field together with (MF I- MF IV), the single treatment with gamma rays and the combination of magnetic field with

T a b l e 1. Means of yield structure parameters in experiment with magnetic field and gamma rays

Combination	PH* (cm)	SL (cm)	SPS	FSP	NGMS	WGMS (g)	NGP	WGP (g)
Control	78.9	9.8	26.9	5.4	25.2	0.82	99.0	2.42
MF I**	88.5	10.8	28.5	5.4	26.3	0.90	102.5	2.49
MF II	81.0	10.9	28.2	5.5	26.6	0.87	103.9	2.56
MF III	77.3	10.6	27.7	6.1	26.2	0.90	113.1	2.74
MF IV	85.4	11.1	28.6	6.4	27.4	0.97	113.6	2.90
150 Gy***	71.9	9.6	26.8	2.7	16.0	0.43	19.9	0.33
200 Gy	62.0	9.2	22.0	1.0	4.0	0.09	4.0	0.09
250 Gy	–	–	–	–	–	–	–	–
MF I + 150 Gy	75.4	10.4	26.0	4.0	19.9	0.67	39.6	0.99
MF I + 200 Gy	69.0	10.8	27.0	2.3	11.6	0.35	19.6	0.32
MF I + 250 Gy	–	–	–	–	–	–	–	–
MF II + 150 Gy	73.0	10.3	26.4	4.8	21.6	0.69	57.2	1.50
MF II + 200 Gy	75.1	10.2	27.0	4.8	21.3	0.60	54.0	1.36
MF II + 250 Gy	–	–	–	–	–	–	–	–
MF III + 150 Gy	76.5	11.1	28.4	4.8	20.5	0.71	66.2	1.77
MF III + 200 Gy	77.0	11.0	26.2	3.0	13.7	0.41	17.1	0.31
MF III + 250 Gy	–	–	–	–	–	–	–	–
MF IV + 150 Gy	77.9	10.3	26.6	3.9	19.2	0.61	35.8	0.77
MF IV + 200 Gy	63.7	9.2	26.5	3.3	16.5	0.55	20.3	0.42
MF IV + 250 Gy	–	–	–	–	–	–	–	–

*plant height (PH), length of spike (SL), number of spikelets per spike (SPS), number of fertile spikes per plant (FSP), number and weight of grains per main spike (NGMS, WGMS) and number and weight of grains per plant (NGP, WGP); **MF I, MF – II – alternate magnetic field; MF III, MF IV – stationary magnetic field; ***150, 200 and 250 Gy – doses of gamma rays.

T a b l e 2. Reduction (–) or stimulation (+) of analyzed traits calculated as a percentage of control value in experiment with magnetic field and gamma rays

Combination	PH* (cm)	SL (cm)	SPS	FSP	NGMS	WGMS (g)	NGP	WGP (g)
MF I**	+12.6	+10.2	+5.9	0.0	+4.4	+9.7	+3.5	+2.8
MF II	+2.6	+11.2	+4.8	+1.8	+5.5	+6.1	+5.0	+5.8
MF III	– 2.9	+8.1	+2.9	+13.0	+4.0	+9.7	+14.2	+13.2
MF IV	+8.2	+13.3	+6.3	+18.5	+8.7	+18.3	+14.7	+19.9
150 Gy***	–8.9	–2.1	–0.4	–50.0	–36.5	–47.6	–79.9	–86.4
200 Gy	–21.5	–6.2	–18.2	–81.5	–84.1	–89.1	–96.0	–96.3
MF I + 150 Gy	–4.5	+6.1	–3.4	–26.0	–21.0	–18.3	–60.0	–59.1
MF I + 200 Gy	–12.6	+10.2	+0.3	–57.4	–54.0	–57.4	–80.2	- 86.8
MF II + 150 Gy	–7.5	+5.1	–1.9	–9.3	–14.3	–15.9	–42.3	–38.0
MF II + 200 Gy	–4.9	+4.0	+0.3	–11.1	–15.5	–26.9	–45.5	–43.8
MF III + 150 Gy	–3.1	+13.2	+5.5	–11.1	–18.7	–13.5	–33.1	–26.9
MF III + 200 GY	–2.4	+12.2	–2.6	–44.5	–45.6	–50.0	–82.7	–87.2
MF IV + 150 Gy	–1.3	+5.1	–1.1	–27.8	–23.8	–25.7	–63.8	–68.2
MF IV + 200 Gy	–19.3	–6.2	–1.5	-38.9	–34.5	–33.0	–79.5	–82.7

Explanations as in Table 1.

gamma rays is presented in Table 3. In common treatment, except for spike length, all the values obtained were lower compared to the magnetic field but higher than for simple irradiation. The combination of magnetic field with 200 Gy of gamma rays induced the markedly higher reduction of analyzed traits than in combination with 150 Gy.

Experiment with magnetic field and MNU (EII)

The values of yield structure parameters for the initial variety 'Bryl' in the experiment performed were similar to the results obtained in the experiment with gamma rays (Table 4). A small difference was observed in plant height, spike length and number and weight of grains per plant only. As with the experiment with gamma rays, both kinds of magnetic field influenced the higher values of analyzed traits compared to the control. Except for the higher values for plant height and spike length, the particularly positive influence of the magnetic field was also observed for the number of fertile spikes per plant. First of all it was visible for stationary magnetic field (MF III and IV). Also in the experiment with gamma rays, the highest number and weight of grains per main spike and plant were noticed for stationary magnetic field. The doses of MNU used for spike length and the number of spikelets increased the values of the results obtained. For other traits, only a reduction was noticed, increased with the higher dose of MNU. In common treatments (magnetic field + MNU) higher values when compared to the control were obtained for plant height, spike length and number of spikelets per spike. For other traits, directly connected with plant fertility (number of fertile spikes per plant and number and weight of grains per main spike and plant) the data scored was lower compared to simple treatment with a magnetic field but higher than for the simple treatment of grains with MNU. The same effect was observed in the experiment using gamma rays.

The results obtained expressed as a reduction or stimulation in comparison with the control are presented in Table 5. The simple treatment of grains with magnetic field

T a b l e 3. The estimation of yield structure parameters for magnetic field together (MF I – MF IV) and combination of magnetic field with gamma rays (150 and 200 Gy) expressed in percentage of control

Combination	PH* (cm)	SL (cm)	SPS	FSP	NGMS	WGMS (g)	NGP	WGP (g)
MF I – IV	105.2	110.7	105.0	108.3	105.6	110.9	109.2	110.4
150 Gy	91.1	97.9	99.6	50.0	63.5	52.4	20.1	13.6
200 Gy	78.5	93.8	81.8	18.5	15.9	10.9	4.0	3.7
MF I – IV + 150 Gy	95.9	107.1	99.6	81.4	80.1	81.8	50.2	51.6
MF I – IV + 200 Gy	90.6	105.1	98.9	62.0	62.3	57.3	27.9	24.8

Explanations as in Table 1.

T a b l e 4. Means of yield structure parameters in experiment with magnetic field and MNU

Combination	PH* (cm)	SL (cm)	SPS	FSP	NGMS	WGMS (g)	NGP	WGP (g)
Control	70.5	9.1	25.9	5.6	25.3	0.75	101.9	2.49
MF I**	76.2	10.0	27.4	6.0	27.1	0.86	103.9	2.56
MF II	82.0	9.6	27.1	5.8	25.7	0.79	104.3	2.58
MF III	77.6	9.4	26.6	6.0	25.6	0.76	106.5	2.69
MF IV	80.6	10.0	26.9	6.2	26.1	0.79	105.9	2.66
0.9 mM MNU	69.0	9.4	25.9	4.1	21.1	0.69	40.9	1.26
1.2 mM MNU	69.0	9.7	26.9	3.8	19.9	0.58	31.0	0.87
MF I + 0.9 mM	75.3	9.2	25.4	4.9	21.6	0.70	51.4	1.46
MF II + 0.9 mM	66.1	9.5	26.4	4.5	22.0	0.70	47.6	1.44
MF III + 0.9 mM	73.7	9.0	25.4	5.3	22.3	0.69	62.8	1.84
MF IV + 0.9 mM	81.4	9.8	27.0	6.3	23.3	0.76	72.6	2.08
MF I + 1.2 mM	82.2	10.3	26.4	3.8	19.3	0.62	30.8	0.92
MF II + 1.2mM	69.7	9.4	25.6	4.1	19.8	0.66	31.1	0.81
MF III + 1.2 mM	79.4	10.3	27.0	4.9	22.2	0.75	48.2	1.32
MF IV + 1.2 mM	71.1	9.2	25.3	4.1	20.0	0.63	29.3	0.79

Explanations as in Table 1.

for all analyzed traits induced biostimulation which was particularly high for plant height (8.0–16.3%). The magnetic field effectively stimulated the number of fertile spikes per plant (3.5–10.7%) which had a direct influence on the biostimulation obtained for number and weight of grains per plant. Similar as compared to gamma rays, MNU induced reduction exclusively which was higher for 1.2 mM as compared to dose 0.9 mM as well as for traits directly related with plant fertility. The use of 1.2 mM of MNU for grain number and weight per plant caused the appearance of reduction for 60 and 49.4%. For grain weight per plant and simple treatment of grains with stationary magnetic field (MF IV) biostimulation was noticed (6.8%), simple treatment with 0.9 mM MNU induced reduction in these traits (49.4%), but in common treatment (MF IV + 0.9 MNU) reduction reached only 16.5%. As with the experiment with gamma rays, the estimation of yield structure parameters for magnetic field together (MF I – MF IV) and combination of MF with MNU indicates that the data obtained for combined treatment decreased when compared to the magnetic field but increased in comparison with exclusive treatment with MNU (Table 6).

DISCUSSION

Barley is a main crop in Poland – for feeding and brewery purposes. Due to artificially induced mutations, not only was a broader variation of desirable traits obtained but also in the results of breeding many mutation varieties were released [4]. Besides mutagenic propriety, mutagen agents at low doses are able to stimulate M_1 progeny [2]. The markedly higher biostimulative propriety shows laser light, making possible the pre-sowing biostimulation of seeds of such crops as the faba bean [22], French bean [29], wheat [5], sugar beet [10], grasses [27], soyabean [21] and tomato [7]. In this last case, magnetic field is used in the same way as laser light [11,16,19].

One of the effects observed after treatment of seeds with magnetic field is the higher vigor of the seeds [1] particularly visible in maize and soybean germinated at lower temperatures, where the magnetic field improved germination by 20%, the emergence of seedlings as well as the development and vigor of plants [23]. In investigations with barley [12] and wheat [13], seedling growth was significantly stimulated. This biological response was closely related to

T a b l e 5. Reduction (-) or stimulation (+) of analyzed traits calculated as a percentage of control value in experiment with magnetic field and MNU

Combination	PH* (cm)	SL (cm)	SPS	FSP	NGMS	WGMS (g)	NGP	WGP (g)
MF I**	+8.0	+9.8	+5.8	+7.1	+7.1	+14.6	+2.0	+2.8
MF II	+16.3	+5.4	+4.6	+3.5	+1.6	+5.3	+2.3	+3.6
MF III	+10.0	+3.2	+2.7	+7.1	+1.2	+1.3	+4.5	+8.0
MF IV	+14.3	+9.8	+3.8	+10.7	+3.2	+5.3	+3.9	+6.8
0.9 mM MNU	–2.2	+3.8	0.0	–26.8	–16.6	–8.0	–60.0	–49.4
1.2 mM MNU	–2.2	+6.7	+3.8	–32.2	–21.6	–22.7	–69.6	–65.1
MF I + 0.9 mM	+6.8	+1.0	–2.0	–12.5	–14.6	–6.7	-49.6	–41.3
MF II + 0.9 mM	–6.3	+4.3	+1.9	–19.7	–13.0	–6.7	–53.3	–42.2
MF III + 0.9 mM	+4.5	–1.1	–2.0	–5.4	–11.9	–8.0	–38.4	–26.2
MF IV + 0.9 mM	+15.4	+7.6	+4.2	+12.5	–7.9	+1.3	–28.8	–16.5
MF I + 1.2 mM	+16.5	+13.2	+1.9	–32.2	–23.8	–17.4	–69.8	–63.1
MF II + 1.2mM	–1.2	+3.2	–1.2	–26.8	–21.8	–12.0	–69.5	–67.5
MF III + 1.2 mM	+12.6	+13.2	+4.2	–12.5	-12.7	0.0	–52.7	–47.0
MF IV + 1.2 mM	+0.8	+1.0	–2.4	–26.8	–21.0	–16.0	–71.3	–68.3

Explanations as in Table 1.

T a b l e 6. The estimation of yield structure parameters for magnetic field together (MF I – MF IV) and combination of magnetic field with MNU expressed in percentage of control

Combination	PH* (cm)	SL (cm)	SPS	FSP	NGMS	WGMS (g)	NGP	WGP (g)
MF I – IV	112.1	107.1	104.2	107.1	103.1	106.6	103.1	105.2
0.9 mM MNU	97.8	103.8	100.0	73.2	83.3	92.0	40.1	50.6
1.2 mM MNU	97.8	106.7	103.8	67.8	78.6	77.3	30.4	34.9
MF I – IV + 0.9 mM	105.1	102.9	100.4	93.7	88.1	94.6	57.5	68.2
MF I – IV + 1.2 mM	107.2	107.6	100.4	75.3	80.2	88.0	34.1	38.5

Explanations as in Table 1.

magnetic field strength level and exposure time. Experiments with onion [18], white cabbage [19] and wheat [17] confirm the positive effect of chosen doses of magnetic field on germination and the vigor of seeds. The biostimulation of plant height and spike length observed in both the performed experiments may have a connection with the vigor described above. Similar biostimulation was noticed for barley and laser light [24,25].

Except for the biostimulation of plant height and spike length, the magnetic field increased plant yielding ability. This same effect was obtained for wheat where magnetic field treatment increased grain yield per 1 m^2 for varieties Henika and Jara at 37 and 19% [16]. Among analyzed yield structure parameters in both experiments, particularly important was the influence of the magnetic field on fertile spike numbers per plant. This effect could be connected with the higher vigor of the plant to make possible the production of a higher number of productive tillers. The higher number of spikes per 1 m^2 for 12.6 and 16.7% was obtained for two wheat varieties after the use of the magnetic field [16]. For the experiment with the barley varieties Rudzik, Rambo and Boss, laser light stimulated production of fertile spikes per plant for 24.2, 4.0 and 26% [24], and decreased the number of underdeveloped tillers per plant [25]. In both of the experiments we performed, the magnetic field increased the number of grains per spike but the results obtained were lower than in the experiment with the wheat [16], where for varieties Henika and Jara the values obtained compared to the control ranged from 127.7 to 129.1%. Higher values for spike number per plant as well as for number and weight of grains per spike caused an increase in grain number and weight per plant as was observed for the experiment with gamma rays and MNU.

The mutagenic agents at low doses induced stimulation [2] but a higher dose caused the appearance of biological injuries in M_1 progeny [3]. In both experiments only this last effect was observed. It was particularly true for gamma rays. The reduction of grain number per plant for 150 Gy was 79.9% and for 200 Gy – 96%. The dose 250 Gy was absolutely lethal to barley and the majority of seedlings died directly after emergence. At a dose of 200 Gy the lupine plant survival reached only 20% of control value [26].

If the magnetic field induced bistimulation, MNU and gamma rays – the reduction of analyzed traits is undoubtedly interesting in using them for common treatment. The results obtained from this kind of treatment were lower compared to the simple treatment of seeds with a magnetic field but higher than for simple treatment with MNU or gamma rays. This indicates the 'protective' influence of the magnetic field on the level of biological injuries induced in common treatment by mutagens. For example a dose of 200 Gy caused a 96% reduction of grain numbers per plant but in combination with magnetic field (MF I – MF IV) the reduction ranged from 45.5 to 82.7%. This effect, visible in common treatment, may have a practical significance because it makes the use of higher doses of mutagens possible, causing in simple treatments, the strong reduction of grain numbers, harvested from the M_1 plant. This last situation can drastically limited the number of plants in the M_2 population and the efficiency of mutants selection. On the other hand, with the use of stronger doses of mutagens the probability of higher mutation frequency increases.

The number of fertile spikes per plant as well as the number and weight of grains per plant in both experiments indicates the higher effectiveness of the stationary magnetic field compared to the alternating field. Investigations of the ability of onion seeds to germinate [18] confirm the high biostimulation of the stationary magnetic field. In common treatment with MNU, the stationary magnetic field showed a more positive influence but such dependence was not observed in combination with gamma rays.

CONCLUSIONS

1. Treatment of grains with a magnetic field compared to a control caused the appearance of the biostimlation of analyzed traits. This was particularly visible for grain number and weight per plant.

2. Biostimulation observed after use of the magnetic field for grain yield per plant was probably due to the increase of fertile spike numbers per plant as well as grain number and weight per spike. Improvement of plant fertility expressed by the higher number of productive tillers per plant is one of the most desirable effects obtained as a result of magnetic field use.

3. Doses of MNU and gamma rays used induced a reduction of analyzed traits in M_1 progeny as compared to the control. The value of the reduction observed depended on applied doses and kind of mutagen agents. Chemomutagen –MNU caused a lower level of biological injuries to M_1plants than gamma rays. A dose of 250 Gy gamma rays was absolutely lethal to the barley.

4. In common treatment (magnetic field + MNU or gamma rays) the values obtained of yield structure parameters were lower as compared to the exclusive treatment of grains with the magnetic field but higher than for exclusive treatment with MNU or gamma rays. This effect in M_1 progeny can be explained by the stimulating properties of magnetic field which in the common treatment is limited by the appearance of biological injuries induced by MNU or gamma rays.

5. The improved yielding ability of plants expressed by grain number and weight per plant indicate the higher efficiency of stationary magnetic field compared to results obtained for the alternating field. For common treatment, a similar effect was observed for MNU but not for gamma rays.

REFERENCES

1. **Achremowicz B., Gruszecka D., Kornarzyński K., and Kulpa D., 2001.** Influence of alternating magnetic and electric field on vigor of hybrid kernels of triticale with aegilops (in Polish). Proc. First Int. Conf. 'Agrolaser 2001', Lublin 26-28.09. 2001, 127–128.
2. **Adamska E. and Małuszyński M., 1983.** The stimulation of growth in shoots of *Nicotiana rustica* and *Nicotiana tabacum* after N-Nitroso-N-methylurea treatment. Acta Biologica, 12, 174–184.
3. **Adamska E. and Rybiński W., 2000.** The analyse of quantitative traits of plants in M_1 progeny using of laser light and sodium azide. Biul. Instutu Hodowli i Aklimatyzacji Roślin, 216, 213–219.
4. **Ahloowalia B.S. and Małuszyński M., 2001.** Induced mutations – A new paradigm in plant breeding. Euphytica, 118, 167–173.
5. **Drozd D., Szajsner H., and Laszkiewicz E., 1999.** The utilisation of laser biostymulation in cultivation of spring wheat. Biul. Instutu Hodowli i Aklimatyzacji Roślin, 211, 85–90.
6. **Gottschalk W. and Wolff G., 1983.** Induced Mutations in Plant Breeding. Springer-Verlag, 1–231.
7. **Koper R., 1997.** Influence of laser pre-sowing stimulation of tomato seeds (in Polish). Owoce, Warzywa i Kwiaty, 21, 16.
8. **Koper R., 1999.** System for pre-sowing laser biostimulation of seeds. Praque, Proc. Conf. TAE, 2, 187–189.
9. **Koper R., Oleszczuk M., Truchliński M., and Zarębski W., 2001.** Pre-sowing biostimulation with natural light of sugar beet seeds (in Polish). Proc. First Int. Conf. 'Agrolaser 2001', Lublin 26-28.09.2001, 140.
10. **Koper R., Wójcik S., Kornas-Czuczwar B., and Bojarska U., 1996.** Effect of laser exposure of seeds the yield and chemical composition of sugar beet roots. Int. Agrophysics, 10, 103–108.
11. **Kornarzyński K. and Pietruszewski S., 1999.** Effect of stationary magnetic field on the germination of wheat grain. Int. Agrophysics, 13, 457–461.
12. **Martinez E., Carbonell M.V., and Amaya J.M., 2000.** A static magnetic field of 125 mT stimulate the initial growth stages of barley (*Hordeum vulgare* L.). Electro-and magnetobiology, 19(3), 271–277.
13. **Martinez E., Carbonell M.V., Socorro A., and Amaya J.M, 2001.** Biological response of wheat (*Triticum aestivum* L.) to magnetic treatment. Proc. First Int. Conf. 'Agrolaser 2001', Lublin 26-28.09.2001, 63–69.
14. **Olchowik G. and Gawda H., 2001.** Refining of the seminal material by microwave radiation (in Polish). Proc. First Int. Conf. 'Agrolaser 2001', Lublin 26-28.09.2001, 155–156.
15. **Pietruszewski S., 1998.** Stand of pre-sowing biostimulation of seeds with alternating magnetic field (in Polish). Inż. Roln., 2/98, 31–36.
16. **Pietruszewski S., 1999.** Influence of pre-sowing magnetic biostimulation on germination and yield of wheat. Int. Agrophysics, 13, 241–243.
17. **Pietuszewski S., Kornarzyński K., and Łacek R., 2001.** Germination of wheat grain in an alternating magnetic field. Int. Agrophysics, 15, 269–271.
18. **Pietruszewski S., Kornarzyński K., Łacek R., and Prokop M., 2001.** Germination of onion seeds in stationary magnetic field (in Polish). Proc. First Int. Conf. 'Agrolaser 2001', Lublin 26-28.09.2001, 160–161.
19. **Pietruszewski S., Kornarzyński K., Łacek R., and Prokop M., 2001.** Germination of white cabbage in stationary magnetic field (in Polish). Proc. First Int. Conf. 'Agrolaser 2001', Lublin 26-28.09.2001, 158–159.
20. **Pietruszewski S. and Wójcik S., 2000.** Effect of magnetic field on yield and chemical composition of sugar beet roots. Int. Agrophysics, 14, 89–92.
21. **Plesnik S., 1993.** The evaluation of some quantitative traits in M_1 generation of soybeen after laser emission and ethyleneimine. Genetica et Biologia Molecularis, 24, 105–113.
22. **Podleśny J., 1997.** Effect of pre-sowing seeds treatment by laser irradiation on morphological features formation and faba bean yielding (in Polish). Zesz. Probl. Post. Nauk Roln., 446, 435–439.
23. **Rochalska M., 2001.** Frequent magnetic field as method of seeds vigor improvement. Proc. First Int. Conf. 'Agrolaser 2001', Lublin 26-28.09.2001, 167–168.
24. **Rybiński W., 2001.** Influence of laser beams combined with chemomutagen (MNU) on the variability of traits and mutation frequency in spring barley. Int. Agrophysics, 15, 115–119.
25. **Rybiński W., Patyna H., and Przewoźny T., 1993.** Mutagenic effect of laser and chemical mutagens in barley (*Hordeum vulgare* L.). Genetica Polonica, 34, 337–343.
26. **Sawicka E., 1993.** Induced mutations in Andean lupine (*Lupinus mutabilis* Sweet.). Prace Ogrodu Botanicznego PAN, Monografie i Rozprawy, 3, 1–102.
27. **Sawicki B., 1995.** The yielding of some grasses after irradiation of seeds with helium-neon laser (in Polish). Annales Universitatis Mariae Curie-Skłodowska, 9, 59–63.
28. **Singh Ch., Olejniczak J., Hoppe P., and Patyna H., 1980.** The effect of growth regulators on sodium azide induced genetic damage in barley. Biologia Plantarium, 22, 91–96.
29. **Szyrmer J. and Klimont K., 1999.** The influence of laser biostimulation on the quality of French bean (*Phseolus vulgaris* L.) seeds (in Polish). Biul. Instutu Hodowli i Aklimatyzacji Roślin, 210, 165–168.