Stimulation of the Growth of *Trifolium pratense* following Exposure to Low Doses of Chronic Gamma Irradiation

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Summary

Results of the action of low doses of gamma irradiation, intensity 1-80 to 0-24 r/day, are recorded in this paper. Irradiation was carried out on a gamma field with a 0-50 g. equiv. Ra Co⁶⁰ source throughout the whole vegetative cycle. *Trifolium pratense* var. Jičínský was chosen as the experimental material. Growth and the yield of green matter was followed both on individually bedded out plants and on sown plots. Results of the measurement and weighing of the plants were statistically evaluated by means of the t-test and analysis of variation. Small, daily radiation doses (1·80—0·30 r per day)
produced a significant stimulatory effect which was evidenced in the greater height of the irradiated plants as compared with the controls and a higher yield of green matter. In conclusion the paper deals with work that has already been carried out in this field. Experiments and measurements have shown that low doses of chronic gamma radiation are capable of stimulating plant growth. This work is confirmed by result obtained by Breslavets, Berezina and Shchibrya (1956) on other material.

**Introduction**

The cultivation of plants on cobalt fields made it possible to follow the effects of radioactive radiation throughout the whole vegetative cycle. It was observed that strong doses of 50—6,000 r/day applied throughout the vegetative cycle inhibited growth and caused morphological and anatomical changes (Sparrow and Gunckel 1955, Biebel 1956) and finally genetic changes (Nybom 1956, Nybom, Gustafsson, Granhall and Ehrenberg 1956), nor does gamma radiation of low intensity applied in doses of a few r a day remain without effect. Granhall, Ehrenberg and Borrenius (1953) consider that daily doses of 0.25—0.58 r reduce fertility in barley. Sparrow and Pond (1956) found chromosome aberrations in *Lilium longiflorum* following daily doses of 0.60 r.

The stimulatory effects of low doses of gamma radiation noted by Breslavets, Berezina and Shchibrya (1956) are of a special nature. The authors found that daily doses of 0.019—0.036 r/day evoke stimulation of growth and development of maize. Similar results with buckwheat were produced by doses of 0.460—2.496 r/day.

**Methods and Evaluation**

The experimental plants were planted out on a field of 0.25 hectares in the middle of which a cobalt source Co	extsuperscript{60} of 0.50 g. equiv. Ra was placed.

The radiation apparatus was constructed as follows (fig. 1): On a steel frame (1) 150 cm. high control pulleys (3) were fixed. A cobalt source (6) was attached to the lower part of the lead stopper of the container (5) with polyacrylate. This method of attachment was found to be very satisfactory. During construction it was found that it was necessary to place a lead shade (7) above the source. The intensity of radiation without the shade, particularly behind the protective screen, was ten times greater owing to secondary reflected radiation. The control cable (2) was laid underground for a distance of 4 metres to the other side of a 30 cm. thick concrete protective wall. This radiation apparatus is portable and safe. During manipulation and field work the cobalt was passed into a protective container (4) buried underground.

One section of the field was planted with *Trifolium pratense* var. Jičinský in circles 40 cm. from each other, the plants being 25 cm. apart. The plants were one month old. At the same time the second section of the field was sown with the same variety in rows at intervals of 20 cm. During the whole period of vegetation the plants were exposed to radiation of 1.80—0.12 r/day. The control plants were placed behind the protective wall, where the radiation intensity did not exceed 0.010 r/day. In the case of the bedded out plants each plant was evaluated separately.
from the isodosic points. In the case of the sown crop three areas at one metre from the isodosic points were mown and the crop from each area was weighed separately. Measurements were made when the plants were in full flower by means of t-test and analysis of variation.

Dosimetry was carried out by means of Opit's intentdosimeter and Siemens Gamma Meter.

Results

Height of plants. 40—70 plants in full flower from the bedded out section were measured (see table 1).

For plants which had been irradiated with a daily dose of 1·80 r (total dose during the vegetative period 100·6 r) the average height was 5·35 cm. greater than for the controls. This difference was statistically significant ($5\cdot10^{-2} > P > 2\cdot10^{-2}$). In the case of daily doses of 0·46 r (total dose 28·58 r) and 0·30 r (total dose 18·60 r) the average height of the plants was 8·55 and 8·60 cm. greater than for the controls. These differences are highly statistically significant. In the case of the daily dose of 0·24 r (total dose 14·88 r) the difference was not statistically significant. The results of measurements of plants receiving doses of 1·80 r per day to 0·30 r per day show that growth had been stimulated.

Weight of plants. The weight of green matter from one mowing of plants
Table 1. Height of bedded out plants in cm.

| r/day | $\bar{x} \pm 3s_{\bar{x}}$ | $|d|$ | n | t | P |
|-------|----------------|-----|---|---|---|
| 0     | 55.00 ± 3.1.65 | —   | 47 | — | — |
| 1.800 | 60.35 ± 3.1.49 | 5.35 | 42 | 2.31 | $5.10^{-2} > P > 2.10^{-2}$ |
| 0.460 | 60.55 ± 3.0.99 | 8.55 | 55 | 4.45 | $1.10^{-3} > P > 1.10^{-6}$ |
| 0.300 | 63.60 ± 3.1.80 | 8.60 | 57 | 4.47 | $1.10^{-6} > P > 1.10^{-7}$ |
| 0.240 | 53.60 ± 3.0.84 | 1.40 | 74 | 0.15 | $9.10^{-1} > P > 8.10^{-1}$ |

$x$ average
$s_{\bar{x}}$ median error of average
$|d|$ absolute value of difference compared with control
n number of plants
t test of statistical significance
P probability

In full flower was determined in a similar way to the height. The results are given in table 2. Following daily doses of 1.80 r the average weight of plants increased by 19.94 g. per plant. The results are not statistically significant. Statistically significant results were obtained following daily doses of 0.46 and 0.30 r. Plants exposed to these intensities had average weights of 21.84 and 24.11 g. higher than the controls. Following these doses highly significant differences in height as compared with controls were also observed.

Table 2. Weight of green matter from one mowing of bedded out plants in g.

| r/day | $\bar{x} \pm 3s_{\bar{x}}$ | $|d|$ | n | t | P |
|-------|----------------|-----|---|---|---|
| 0     | 116.66 ± 3.6.87 | —   | 47 | — | — |
| 1.500 | 136.60 ± 3.9.40 | 19.94 | 42 | 1.72 | $1.10^{-1} > P > 5.10^{-2}$ |
| 0.460 | 138.50 ± 3.6.32 | 21.84 | 55 | 2.37 | $2.10^{-2} > P > 1.10^{-2}$ |
| 0.300 | 140.80 ± 3.6.70 | 24.11 | 57 | 2.51 | $1.10^{-1} > P > 1.10^{-3}$ |
| 0.240 | 103.20 ± 3.4.75 | 13.46 | 74 | 1.62 | $1.10^{-1} > P > 5.10^{-2}$ |

Table 3. Average crop from 1 m. of sown field in g.

<table>
<thead>
<tr>
<th>r/day</th>
<th>$\bar{x}$</th>
<th>P</th>
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<tr>
<td>0</td>
<td>50</td>
<td>—</td>
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| 2.400 | 48.3 | $P < 0.05$
| 0.700 | 51.0 | $P < 0.05$
| 0.260 | 71.0 | $P > 0.01$
| 0.240 | 69.3 | $P > 0.01$
| 0.120 | 48.9 | $P < 0.05$

$s_{\bar{x}} = ± 1.9$
$sd = ± 2.6$

sd median error of difference
In order to check this experiment we evaluated the sown crop of three areas each a metre from the isodosic points. (Table 3) This sown crop was exposed to radiation for 18 days longer than the bedded out plants. Statistically significant values were obtained following daily doses of 0.26 r/day (total dose 20.80 r) and 0.24 r/day (total dose 18.40 r), in which cases the increases in weight of the mowings from metre sections were 21.0 g. and 19.3 g. respectively, that is a percentual increase in weight of 40%. These results correspond to those obtained in the case of the bedded out plants. The high ratio of variation for doses obtained by variation analysis shows that the statistically very significant differences are caused by differences in dosage.

Discussion

The question of whether ionizing radiation can act as a stimulant besides causing harmful changes has been under discussion for a long time. To all intents this discussion started following the publication of MALDINAY and THOUVENIN’S work (1898), in which they demonstrated that X-rays stimulate the germination of Convolvulus arvensis, Lepidium sativum and Panicum miliaceum seeds. Immediately afterwards work appeared contradicting these results (PITHERS 1923, SCHWARTZ, CZEPA and SCHINDLER 1923) and, on the other hand, work confirming the experiments (MIÈGE and COUPÉ 1914). There then followed a considerable volume of work giving varying results. A detailed survey of such work has been made by BRESLAVETS (1956).

In an attempt to use these results in agricultural practice, ZHEZHEL (1955) carried out extensive experiments involving the addition of radioactive radium and uranium salts to manures. Over a period of 8 years these substances increased crops by 20—30%. In the opinion of the author, however, this method of increasing agricultural production is extremely inadvisable, because it involves the long-term contamination of the soil with radioactive substances, which in view of the present increase in radioactivity could in time represent a grave threat. The stimulatory effects of low concentrations of the fission products of uranium were noted by TIMOFEEV-RESSOVSKY (1956). TIMOFEEV-RESSOVSKY and LUCHNIK (1958) give a biophysical description of the process of stimulation by ionizing radiation. The authors show that the basis of stimulation is the influence of low doses on accelerating cell division. They also show that the stimulatory effect of radiation is in inverse ratio to the linear density of ionization. Alpha particles do not cause stimulation at all. Of beta particles the most effective were found to be high energy particles. As regards electromagnetic quanta the short-wave rays were the most effective.

The present paper confirm the results of BRESLAVETS, BEREZINA and SHECHIBRYA (1956), pointing to the stimulatory effect of low doses of chronic gamma irradiation.

References

Действие низких доз хронического гамма-облучения на рост

РОБЕРТ ГОНЧАРИВ

Резюме

В работе приведены результаты изучения действия низких доз гамма-облучения интенсивностью 1,800—0,240 р/день. Растения облучались на кобальтовом пеле источником 0,50 гр. эвк. Co⁶⁰ в течение всего вегетационного периода. Подопытным объектом являлся кленер Trifolium pratense L. сорта Йичинский (Йичинское). Результаты измерений и взвешиваний растений статистически обрабатывались методом t-теста и анализа вариации. Низкие дозы излучения (1,8—0,3 р/день) вызывали значительный стимуляционный эффект, проявляющийся более высокой общей облученными растениями по сравнению с контрольными и большим урожаем зеленой массы. В посеве наблюдалось повышение зеленой массы на 40%.

В заключении обсуждаются некоторые работы, проведенные в этой области. Опыты и измерения показали, что низкие дозы хронического облучения вызывают стимуляцию роста растений. Работа является подтверждением результатов Бреславец, Березиной и Щибры (1956) на другом материале.