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Larger-scale irradiation and marketing studies on onions (part of a coord.progr. on pre-commercial scale radiation treatment of food)

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LARGER-SCALE IRRADIATION AND MARKETING STUDIES ON ONIONS

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SUMMARY

The irradiation tests for onion conducted for several years in Hungary have already attained farm-level application.

The operation in 1979 of the irradiating equipment installed at the Agricultural "Rákóczi" Production Cooperative, and presently the assessment of storage losses in 1980 have justified the economic value of the method on a large scale.

The materials handling system modified on basis of experiences attained during the previous years proved to be feasible without leaves or short leaves irradiated in September 1980. The onion harvested by the new technique presented problems, because the onion was not completely freed from weeds and the foliage was not romoved and therefors the flow by gravity of the crop in the equipment was hampered and it stopped in its motion.

In the knowledge of the inputs /Tables 1 and 2/ it has become clear that this treatment could turn out to be economically profitable only if the equipment had a sufficient capacity or throughput. A good manpower and operation management could results in an at least 80 % capacity usage, and in this case, the combined costs of the treatment will not exceed 10 % of the current purchase price /3,20 Ft./kg./.

The experiments and tests proved that irradiation reduced storage losses, but the occurring losses were found to be depending on the initial quality.

The texture and density greatly affecting the marketing quality of the treated material was better than the untreated one under the effect of irradiation. In the spring months, a significantly greater force /$P \geq 99.9$ %/ was required to compress irradiated samples than untreated ones /Table 2/. Density, which is a function of texture was also significantly different /$P \geq 99.9$ %/ in favour of the irradiated sample /Table 6/. The investigation of interdependence between sprout inhibition, texture and density also indicated that irradiation over the period of storage promoted

a favourable alteration of these features /Tables 7 and 8./

The disputed internal discoloration caused by irradiation was shown to be exaggerated by our tests in comparison to previous experiments conducted abroad /Table 5/. The quality was improved by the treatment because the discoloration of the top was minimal, whereas in the untreated onion, a vigorous alteratio in colour was experienced, parallel with the inner bud growth /Table 5 and Figures 11 and 13./.

The favourable qualitative effect of radiation treatment was also confirmed by the HUNGAROFRUCT Company.

Summing up, it may be stated that irradiation, in addition to reduced storage losses, positively affects the quality of treated samples in the spring period, as compared to untreated batches.

Based on experiments thus far, it is considered necessary to repeat the investigations in 1980-81 in the framework of carefully prepared plans, before application on farm-level.

INTRODUCTION

Subsequent to the storage experiments in 1980-81 and their assessment, it appeared necessary to undertake repeated irradiation and storage tests on a partly farm-scale application at Rákóczifalva.

This was justified by the production cooperative having altered its harvesting technology; i.e mechanically picked onion without leaf removal was delivered for storage.

Onion with leaves harvest is also applied in the Netherlands, but there the lenght of leaves never exceeds 60-70 mm. The repeated radiation experment was conceived to to allow the collection of data on storage losses in case of onion harvested by large scale methods.

But the original objective had to be modified for the irradiation experiment scheduled for the fall of 1980, because the onion harvested with leaves failed to pass through the irradiating device by its gravity. Besides the whole leaf aspect, the problem was still enhanced by the material to be radiated being greatly polluted with weeds and earth clots. Thus, upon unloading from the transport tilting-type vehicle, the onion fell in one block into the hopper of the receiving part of the irradiator device.

Due to the above indicated problems, the irradiation and storage of the envisaged 1000 tons of onion were not undertaken, and experiments in the period 1980-81 were repratadly performed with manually defoliated and bagged onion. This resulted in only about 150 tons of onion being radiation-treated.

1. MATERIALS AND METHODS

1.1. Experimental material

For the experiment, the "Rákóczi" agricultural production cooperative provided seed grown onion of the "Alsógödi" variety.

The onion selected for radiation treatment was manually picked and the leaves was cut the material was then delivered for irradiation, packaged in bags of 20-25 kgs.

In the first week of September the weather was rainy over the production area, which delayed the harvest and the radiation treatment.

According to certificates of the cooperative and the capacity measurements 150 Mg onion were irradiated and stored. In the same conditions as for the treated onion, another lot of 150 mg onion were also put in store.

1.2. Irradiation

The 150 Mg seed grown onion were readiation treated from 1st. September 1980 to 19th. September, with a prototype onion irradiator device designed and installed by the Isotope Institute of the Hungarian Academy of Sciences. In accordance with experiences from 1979, certain modifications were made on the iradiator and on its loading and unloading section.

The onion arriving in sacks was first dumped into an EMG-6 type mobile hopper, from which it was forwarded into the irradiator device by means of a 12 m long ribbed conveyor belt.

The radiation device was also modified on the basis of findings from operations in the preceding years.

Safety and radiation level indicating automatic system

Its purpose:

Since the irradiation equipment is installed in the oper air, the following safety technoque installations were applied in order to prevent access by unauthorized persons, to permanently control protection efficiency, to rule out accidents by radiation, and to adjust and control radiation technological parameters.

Its major components:

1. Safe distance and protection against intrusion by unauthorized persons by wire fence and closeable iron gate.

2. System of signal lamps with red and green light located at four points of the fence in such a way as to render the light signals visible along the entire circumference of the irradiator.

3. Safety lifter and operating automatic system located outside the wire fence.

4. Level indicating gamma relay with GM-tube mounted on the container loading place of the irradiator device, inside the wire fence.

5. Protective grounding against lightning, connected to the lightning conductor system of the onion storage facility.

The automatic control and signal lamp systems operate at low voltage /24 V/.

Description of operation:

1. The padlock was removed from the K-1 main switch of the switchboard coase, and the device was put under voltage. /The presence of three phases is indicated by 3 red signal lamps/.

2. The safety key of the control board was inserted into the lock switch and the board was put into operation. In a pressed down position, the key was turned to the right, which could then be removed and the control table remaines operational. There were green singlan lights turned on on the control table and on the fence. The lift-up of the radiation source is possible only when the iron gate is closed.

3. Before lifting up the radiation source, the irradiator device was filled up with onion. The loader conveyor belt was started up, from the control table, and the process of filling up was monitored by television.

Simultaneously with the continual supply of onion, the flow control unloader and removal transport belt of the irradiator device was also started up.

4. The control of the radiation source in radiating position was performed as follows:

Pressing down the "Start" /N7/ button, the signal horn sounded. This signal disappeared after 20+10 seconds, the green light on the control board went out, and a yellow signal lamp lit up instead, indicating that the magnetic clutch of the device moving the radiation source is induced; the radiation source could then be lifted up into its irradiating position. By turning the manual driving shaft to the right, the radiation source was pulled up into its irradiating position. At the moment the lifting apparatus was set into operation, the green lights on the fence went out, and red lights appeared instead. The yellow and red lights on the control board were si,ultaneously gleanring.

The induction of the magnetic cloutch of the lifting device went on for 20 seconds, during which time the radiation source could be pulled up. In case it failed to be pulled up, the whole starting up had to be repeated.

Upon completion of the pull-up operation, the magnetic lock grasped the source-moving wire rope device and kept it in its irradiating position. /The radiation sources could only be pulled up if the loader part of the irradiator device was strated up by pressing the M-15 starter button./

5. At the termination of irradiation, the button "radiation down" on the control board had to be pressed, and thus the radiation source automatically went back to storing position. Then, the onion transporting and feeding belts were stopped. The safety key was inserted into the control table, it was then turned left and removed. /The low current control circuits were unloaded to no-voltage/.

The main switch on the switchboard was turned off and the board box was locked again. The chief operator had to keep on himself the padlock key of the switchboard, the key of the control table, and the key to the iron gate of the fence; he was in charge of guarding them.

Protection against failure

Should the radiation source not return to its storing position /due to undesirable and excessive friction of the torpedo/, then a specifically mounted steel wire strand moved it to this position.

The safety automatism moved the radiation source into its storing position in the following cases:

a./ if the "radiation source" button on the control table was pressed down /in case of end of irradiation or of protection failure againts/;

b./ if there was a failure in mains voltage;

c./ if the engine of the flow control or unloading device broke down /protection against excessive radiation/;

d./ if the iron gate of the wire fence was opened;

e./ if any of the alarm buttons were pressed inside the fence /if any of the alarm buttons is pressed during the pull-up of the radiation source, the radiation soruce can not be moved into its irradiating position/.

f./ personal dosimetric and management order

On the part of the Isotope Institute of the Hungarian Academy of Sciences, Mr. Vilmos Stenger, was responsible for the smooth performance of the active operation of the equipment; he is in charge of the Section for Irradiation Technique; he was aided by a liaison person appointed by the agricultural production cooperative of Rákóczifalva.

1.3. Measuerement of radiation treatment dosage

The dosage of irradiation was controlled by a Fricke-type dosimeter.

The measuring solutions applied in the measurements were filled into plastic ampoules and the ampoules were sealed by soldering.

Tennis balls were filled with a 1 kg.dm^{-3} densitiy material, with enough room left out for the desometric ampoules, where the ampoules were inserted upon measurement.

The balls containing the dosimeters were put among the onion passing through the irradiator. Dosages were measured each hour in case of permanent operation.

1.4. Study of storage and losses

In planning the experiments, we considered to use the storage facilities of the agricultural production cooperative which were operational by 1981; but due to those mentioned in the "Introduction" and to the small quantity of the radiation treated sample, this alternative was abandoned.

The irradiated lot was dimped into a shed in bulk in the autumn of 1981; the shed was adjacent to the treatment equipment.

The artificial aeration of the stored sample was not resolved, and our quality tests indicated that as early as the time of storing-in the irradiated batch comprised 15.3 % of damaged, spolied and valueless onion.

The same quality, untreated onion was stored in bags.

Quality tests on the experimental samples were undertaken three times, while in early April of 1981 the "Rákóczi" agricultural production cooperative sorted out and graded the irradiated onion by industrial methods and delivered it for marketing to the ZÖLDÉRT Company in county Szolnok. No assesment of loss was performed by the cooperative as regards the similar quality, untreated batch during the large-scale sporting and grading.

1.5. Texture measurement

Based on our previous investigations /KÁLMÁN, 1979. a,b.; KÁLMÁN, 1980, a,b./, it was established that the structure of the onion's body is loosened up by the developing bud in it and its structural constitution is therefore changed. In commercial marketing, onion with compacted and solid strukture is of better quality; this property is measured by specialists through compressing the onion.

In the experiment, we measured by instrument the force required to compress the stored treated and untreated onion, and thereby determined the density of various onions and the size of their inner bud.

For texture measurement, the "Instron 1140" tipe instrument operated at the development laboratory of the Hungarian Refrigeration Industry was used; the following instrumental constants were applied in the course of measurements:

Speed of the registrating paper	3.33 mmsec^{-1}
Speed of the measuring head	3.33 mmsec^{-1}
Spacing of measuring head	75, 80 and 65 mm
Measuring head applied	N^{o} . 100 and 500
Maximum of sensitivity	98.1, 491 and 981 N

In each case, 50, fully sound, first class quality onions were used for the measurements as samples.

The onion heads were all compressed to the limit of elastic deformation, at which point the samples collapsed.

From the data obtained, the ratio of the measured force and the path lenght covered by the measuring head was calculated whose value provided the value of force required to compress the sample by 1 mm within the range of elastic deformation.

1.6. Density measurement

The density of samples used for texture survey was measured in each cose.

This measurement was carried out by the method specified in the previous years /KÁLMÁN, 1979.a,b./, that is the weight of the onion was measured and its volume was then determined by the volume of poppy seeds displaced.

1.7. Study of growth of the inner bud

A feature of the so-called first class, impeccable onion suitable for sale is perfectly closed at the neck part and has no emerged shoot.

But in springtime, the onion corresponding to the above requirements might already comprise a very developed bud in its interior whose size can not be neglected.

Even the most modern storage techniques can only slow down the growth of the inner bud and not to prevent its development. On the other hand, the applied irradiation inhibits the shoot growth, whereby in springtime, the growht of the inner bud leading to reduced quality results in a favourable trend in case of treated samples during storage.

To determine the size of the inner bud, a method developed in KÉKI /Central Research Institute for Food Industry/ has been applied /KÁLMÁN, 1978.b./. Study was made into the samples used for texture measurement and into the samples used for colur determination.

This was justified by our intention to prove the interdependence between bud growth and softening and the interrelation between bud colour its size.

1.8. Colour measurement over the cut surface of the onion

Irradiation experiments and tests in Hungary and abroad have already unanimously proved the fact of sprout inhibition induced by treatment and of its favourable effect on loss reduction /DALLYN & SAWYER, 1959.a,b.; FRANKLIN,1963; FARKAS, 1971; SKOU, 1971; KÁLMÁN & KISS, 1971, KÁLMÁN, 1974, 1975, 1976, 1977.a,b., 1978.a,b,c, 1979.c., 1981; LOAHARANU, 1974; SUDARSAN, 1975; UMEDA, 1975/.

In addition to the favourable loss reducing effect, the discoloration of the growing part of onion caused by the treatment was described in a number of investigations /MACQUEEN, 1965; KHAN & TEMKIN-GORODEISKI, 1968; NAIR et al., 1973; GRÜNEWALD, 1978./.

Naturally, the large-scale introduction of onion irradiation has made it very important for us to consider the accidentally observable sprout discoloration for treated onion because this fact might present quality objections to this treatment. The use of the NEOTEC colour meter was also raised as an idea, since the damage-free method would have provided a possibility to investigate the same samples in the entire process of storage. But the possibility to use the NEOTEC instrument had to be dispensed with, due to technical problems. The application of surface colour measurement appeared to be much more convenient, but this involved that samples could be measured only once. Our opinion was that if a sufficiently large number of samples can be measured, results will be obtained with adequate accuracy.

Monthly samples were taken for the tests; 50-50 onions were selected in each case according to the law of random numbers. The onion sampies taken for measurements corresponded to our domestic, first class commercial standard and were 50-70 mm across.

The colour measurement was performed with the tri-stimulus colour measuring instrument available at the Section for Measure and Control Technique of the KÉKI. Onions were cut open along their axis through the neck and the base; colour was then measured over the cut surface at points indicated in Figure No. 1.

The colour of tunic leaves is indicated by point I, the peak of the nescent bud by II, and the basel part by point III, where the occasional occurrence of altered colour was expected. The location of point II has naturally changed with the advance of the sprouting process.

The measuring attachment of the instrument lit the surface of the onion through a diaphragm of 10 mm dia. Parallel investigations were made in the course of colour determination in order to reduce random errors as regards bot the point of measurement and the instrument itself. The inner bud ratio was also determined for each onion together with the colour measurement.

In evaluating measurement data, the inner bud ratio, the value of colour difference, ΔE, between the tunic leaves and bud tip, and between the tunic leaves and the base, as well as the xy colour coordinates were calculated. In determining colour differences, these features were chosen because in of the untreated sample, as the storage period advanced, a discoloration of the bud tip, and in case of the treated sample, a discoloration of the growing part was expected. Alteration in the colour of tunic leaves is, however, expected to be of such a small measure that it does not affect appreciably either the quality of onion or the measurement results.

From data obtained for the 50-50 onions, mean and standard diviation were computed. For the evaluation such a programme was compiled for an HP-97 computer through which the actual ΔE values could be calculated by one single data input and computer run; their average, standard deviation and the average of the colour coordinates for each points were also calculated in this same machine operation. These mean values were then used to investigate the relations between various variables.

2. RESULTS

2.1. The technological and economic assessment of radiation treatment

In the course of irradiation, keeping in mind the required treatment dosage /50±20 Gy/, capacity measurements were conducted by the Isotope Institute of the Academy.

The regular performance measurements justified the envisaged data because the treatment installation operated at a capacity of 9.96 Mgh^{-1}, and the average irradiation dosage, in this case, was 70,4 Gy on the basis of 114 measurements.

Bases on capacity data and the actual inputs, we have summed up the costs of radiation treatments, and calculated the operational and handling costs of the irradiation treatment installed in the storage line which operates as a service unit.

The results and findings obtained with respect to the above facts and considerations are tabulated in Tables 1, 2 and 3.

Table 1.

Table 2.

Table 3.

2.2. Storage loss aspects

The primary objektive of the experiment was to provide information on the trend of storage losses. Data for this are illustrated in Table 4.

Table 4.

Investigation results measured at the date of treatment and at the date of vigorous **sprout** growth are shown in Table 1; the same Table contains indications on losses of treated and untreated samples which were further stored after industrial grading and sorting as "commodity" quality.

2.3. Changing of texture

Table 5 and Figure 2 indicate results from instrumental texture measurements performed during the whole storage period.

Table 5.

Figure 2.

In Table 2, average values of the force needed to compress the measured onion samples by 1 mm and their standard deviations in the course of storage are illustrated, while Figure 2 shows the temporal trend of average values in a graphical manner.

2.4. Results from density measurements

Findings from density measurements conducted during storage may be seen in Table 6 and Figure 3.

Table 6.

Figure 3.

Average values of density measurements and pertaining standard deviations are shown in Table 3 at the date of investigation, while Figure 3 illustrates the regression line for the relation between density and duration of storage.

It was considered necessary to find out the relation between densitiy and stock at the date of investigation. Figure 4. indicates the regression line between the above specified two physical features during storage.

Figure 4.

2.5. Growth of the inner bud

It has already been mentioned in reviewing the ecperimental methods that the inner bud ratio was determined in our investigations from samples of texture and density measurements /I/, as well as from the onions utilized /II/ for colour measurements.

The mean values of the inner bud ratio for the two sample populations and the related standard deviation values are tabulated for convenience of a better comparison. /Table 7/.

Table 7.

Depending on the duration of the storage, the variations of the inner bud was represented graphically as well, and the thus obtaindd regression lines are shown in Figs. 5 and 6.

Figure 5

Figure 6

The relation between texture and density heavily affecting quality and their relation to the size of the inner bud is illustrated in Figs. 7 and 8 by drawing regression lines.

Figure 7.

Figure 8.

2.6. Results from colour measurements on the cut surface of onion

The summarized rasults of the colour measurements conduct are contained in Table 9.

Table 9.

In Table 5 the colour differences, ΔE, during storage between the tunic leaves bud tip /ΔE_{BL-CS}/, the tunic leaves and the growing ~~basal~~ part /ΔE_{BL-T}/, are indicated according to the new CIELAB system.

For a better visualization and evaluation of the findings from colour measurements, Figures 9, 10, 11, 12, 13 and 14 were compiled.

Figure 9.

Figure 10.

Figure 11.

Figure 12.

Figure 13.

Figure 14.

Figure 9, 10, 11 illustrate the regression lines for colour difference for the relation between ΔE_{BL-CS} and storage period, between ΔE_{BL-T} and the storage period, and between ΔE_{BT-CS} and inner bud ratio.

The direction of colour alteration over the measured points of the onion surface is illustrated by the colour triangle shown in Figs. 12, 13 and 14.

Figure 12 showhs measured results for tunic leaves, Figure 13 those for the bud tip, while Figure 14 those for the growing part, all of them during the storage of treated and untreated samples.

CONCLUSIONS

Experimental results and findings obtained over recent years in Hungary and abroad have already proved that ionizing radiation inhibits sprouting in case of onion /DALLYN & SAWYER, 1959.a,b; HARTMAN, 1971; FRANKLIN, 1972; KHAN & TEMKIN-GORODEISKI, 1968; FARKAS, 1971; KÁLMÁN & KISS, 1971; SKOU, 1971; KÁLMÁN, 1974, 1975, 1977.a,b./.

Most of the investigations undertaken have, however, searched only the occurrence of sprouting caused by treatment and its assumed causes, and only a few data reports were limited to the technical performance of the treatment technology, to the arising economic result, and to the subsequent commercial market-ability.

The possibility of its introduction on an industrial scale was analyzed primarily in Hungary and in Japan /UMEDA, 1975; KÁLMÁN, 1978; KÁLMÁN et al.; 1978; KÁLMÁN, 1979.c.; KÁLMÁN, 1980./, the investigations performed examined the technical and technological implementation from the viewpoint of the economics of the method.

The first experiment conducted with the prototype onion irradiator installed at Rákóczifalva in 1979 was aimed at giving answers to all the issues raised above, in spite of the fact that no decision may be taken on the basis of one single experiment in case of a farm-scale test.

The irradiation test conducted between 5 Sept. and 15 Oct. 1979 has sufficiently clarified one of the fundamental issues of the profitability of the method, i.e. to avoid any superfluous transport operation.

It has also become clear that in case of treatment with a well designed targeted irradiating device both the homogeneity of the dosage and the utilization degree of available radiation remain within the expected value.

After an adequate development of treatment technology, of a viable set-up of the loading and unloading system, the specific handling cost may still be reduced in comparison to the last year's 0.59 Ft per kg level.

In order to resolve the problems ariseen during the operation in 1979, the "Rákóczi" agricultural production cooperative made modifications on the loading or feeding line and a mobile hopper was installed of the type ÉMG 6 to receive the bulk of onion arriving for treatment.

According to the original plan, the onion must have been mechanically harvested and it would have been delivered for treatment with short leaves /max. 8 cm/ and in bulk by means of a tilting method. The delivery of onion with leaves is very favourrable in view of labour shortage problems and partly of its independence on weather, and in this system the desiccation of the onions' neck part occurs in the storage facility after intensive aeration. This storing method, due to its favourable effects /ANNON 1978.a,b/, is recommended for producers in the Netherlands with a developed onion producing technology and in other countries as well, such as U.K.

In the course of the experiment, the Rákóczi agricultural production cooperative tried to irradiate onion with leaves but the flow-through of the crop came to a stop in the equipment and a complete vaulting occured in the interior. It could be established that due to leaves bulk and admixed weeds, the received onion got compacted or caked in large lumps an it fell as one block into the receiving hopper when the delivery vehicle was tilted over at 90^{o} angle or so.

From the viewpoint of the experiment it is utterly important that the mass of onion in the irradiator should have a uniform and continual flow, which can scarcely be ensured by directly picked onion crop with full foliage and in many cases containing weeds.

There was no possibility for pre-cleaning in the supply line of the production cooperative at the location in question; thus the irradiation of manually picked onions delivered in bags was again udertaken.

Table 1, comprising costs by the cooperative, presents a most unfavourable picture in this case, but one should consider the fact that the radiation source operated for a maximum of only 19 hours instead of the envisaged 15-day long continual working time.

Compared to the scheduled 108 hour long irradiation duration, the actual 19 hours operation amounted to only 18 % of the envisaged period, which considerably raised the level of specific costs.

Besides the quality of the received bulk onion, there were naturally other problems as well which could be ascribed to shortcomings in labour organisation and management.

Table 2, containing the total cost inputs involved by the experiment, can also be assessed if attention is paid to the above considerations.

Table 3, was also compiled on the basis of the actual costs but here an 80 % utilization level was reckoned with as regards operational hours and capacity. It can be clearly seen that in case of a treatment price of 25 Fillers per kilogram as service provision, even the inputs completed with costs arising in the storing company are below 10 % of the purchasing price /3,2 Ft.kg^{-1}/.

Prior to the experiment under study here, the Commissioner advocated the opinion that in the repeated farm-scale experiment the investigations should deal with variations in the major qualitative features which are of great importance for the buyers. The assessment performed and the conclusions drawn from the results are therefore aimed at primarily considering these points.

Naturally, the measure of loss reduction is important for the storing company, but the level of sales is mainly a function of quality on both domestic and export markets.

In our experiments in the current year we investigated storage losses as well for both treated and untreated samples. The quality of the initial raw material was established to be rather defective because almost 15 % reject material was found in the lot chosen for irradiation /Table 4/. After five months' storage, the percentual amount of rejected material did not alter appreciably, and one month later, the industrial scale sorting and grading by the cooperative led to much the same amount of discard onions for treated and untreated alike.

Subsequent to the industrial sorting and grading in April, the storage of about 300 kg of treated and untreated onion went on in the cooperative, which was still of "commodity" quality in early April, i.e. suitable for marketing.

Investigation of the lot which was further stored was undertaken in mid-May of 1981, and results indicated that from the sample which was still marketable in early April, 55,3 % for the untreated and 9.8 % for the treated onion were found to be of reject quality. The investigation showed that for the sample stored from early April until mind-May, the irradiation treatment resulted in a loss reduction of 45,5 %, in comparison to the untreated sample.

Te result of loss assessment in early March and early April was substantially deteriorated for treated samples by the fact that the initial quality of irradiated onion was very bad and that the conditions of storage were also ectremely unfavourable.

As described earlier, for both irradiated and untreated samples, investigation was primarily made into the two major variations from the viewpoint of marketing: adequate internal texture and internal colour.

Our previous studies confirmedthat an optimum choice of the date of irradiation greatly affects the effect of sprout emergence inhibition and influences the quality of the sprout part in the onion body. In case of selling, the buyer judges the product first by its external quality, but the internal texture, the size of the bud in the onion body and the colour of the internal onion body also of great importance.

Similarly to earlier findings, it was established that in spring months and for treated onions, the growth of the internal sprout presents a significant difference /$P \geq 99.9$ %/ as compared to the untreated ones /Table 7/.

The relation between storage period and internal bud ratios in Figures 5 and 6 visualizes in a more striking way the favourable effect of irradiation since the regression lines for treated onions indicate a susbstatially lower growth than the lines for untreated samples.

Variations in texture and density in the course of storage can be seen in Tables 5. and 6, and in Figures 2 and 3. Data prove that both texture and density are better for irradiated samples, and that in spring months the difference is already markedly significant /P $\geq$ 99.9 %/in comparison to the untreated ones.

The findings thus far demonstrate the temporal evolution of the various measured variables /inner bud, texture, density/, while Figures 7. and 8. illustrate interrelations between bud growth, texture, and density as a result of inhibited sprouting.

In Figures 7. and 8, essentially the effect of radiation treatment can be measured for texture and density in the course of storage in comparision to the untreated samples.

It appears excellently that for both cases the extensive sprouting in untreated samples had an adverse effect on compressibility and density and that this quality deteriorating effect occurred more quickly as well.

Table 8 represents the measured colour data on the cut surface of onions. It can be seen that in comparision to the more or less same colour of the tunic leaves, the bud tip colour of untreated samples has greatly changed, while that of the irradiated samples remained about the same during storage /Table 8./. The alteration of colour relative to that of the tunic leaves in the base occurred for both treated and untreated samples, and this alteration was more pronounced in the spring months.

Figures 12, 13 and 14 illustrate the measurement data in colour trianles for the duration of storage. Representation in the colour triangle visualize very well the results of colour determinations on the cutting surface of onion.

Figure 12 illustrates excellently that the colour of tunic leaves did not change appreciably over the period of storage for either treated or untreated samples.

Based on our former obeervations, the colour alteration on tunic leaves was not expected and for this reason, the colour differences between bud tip and basal part were computed in our work.

Figure 13 provides adequate information on the extent and direction of colour alterations accurring in the bud tip during storage, and proves that the measured Δ E tunic leaves bud tip colour difference for untreated samples results from the apparence of a greenish-yellow, yellowish-green colour. Bud tip colour for treated samples varies inappreciably between the beginning and end of storage; this is confirmed by the ΔE_{BL-CS} value in Table 5.

Figure 14 shows colour variations on the growing part of onion in the course of storage. There is a minimum colour change towards the orange red on the growing part for untreated samples, while the same change is more pronounced for treated samples.

Through the measurements it could also be established that the slightly orange-like colour for treated onion starts to appear after March and it constitutes a maximum 2-3 mm thick narrow stripe at the upper part of the base.

The effect of treatment can be very well measured through the growth of the inner bud; thus, the relation between tunic leaves bud tip colour difference Δ E and sprout growth provides also data on colour changes under the effect of treatment /Figure 11/.

It is strikingly apparent that bud growth in untreated samples is vigorous and that the increasingly greeninsh colour of the developing embryo tip is closely related to size.

Variation in the ΔE_{BL-CS} value for treated samples is small, which is related to the fact that the treatment induces inhibition of sprouting.

To summarize what has been said above, the following conclusions may be drawn:

The farm-scale experiment conducted in 1980-81 provided information on very important issues and its findings should be put to use in the future.

Harvested onion without leaves should be treated with the irradiating equipment; only onion with partial foliage and free from weeds can be used in this process.

The latter consideration is further supported by the requirement that the irradiator should constitute an integral part of the loading-conveyor line and that the treatment device should follow the cleaning apparatus after the receiving hopper.

This year's experiences make it necessary that the Isotope Institute of the Academy should develop the flow models on the basis of dry onion, and the farm-level equipment should be installed and designed accordingly.

It seems advisable to satisfy domestic demand for irradiation on a service basis, which would require the development of a suitable organisational framowork.

Based on experiences in the current year, an adequate labour organisation is necessary on storage units demanding the installation of irradiation equipment in order to be able to secure a minimum of 80 % usage level for the operation of the very expensive mechanical equipment.

Irradiation considerably reduces storage-related losses but in the occurrence of the actual losses and their magnitude the decisive role is played by the initial quality and the method of storage.

It has been unambiguously proved that the treatment has a favourable effect on the texture and density of onion in the storage period in comparision to the untreated control samples;

Based on oolour determination examinations it could be established that in case of treatment, no internal discoloration occurred on the bud tip, while for untreated samples a greening of the internal shoot appeared, which was related to the size of the bud.

The previously described discoloration of the growing part for irradiated onion proved to be exaggerated since its occurrence affected the usage value only to an inappreciable degree. This statement is confirmed by the opinion of the HUNGAROFRUCT Company which runs like this:

> "We are pleased to inform you that all our onion deliveries in April, but particularly the shipment from the freezer unit of Zalaszentgrót and the radiation treated commodity from Rákóczifalva, were very well received on the market and were competitive with the recently produced overseas supply."

On the basis of the considerations specified above, we suggest to repeat the large-scale experiment with onion of adequate quality, in the course of which the good quality samples would be accommodated in the existing farm storage facility.

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Table 1: Input outlys of the "Rákóczi" Agricultural Production Cooperative in relation to the onion irradiation in 1980.

Cost factor	Cost /Ft/
1. Wages + 20 % communal and other taxes	11.376
2. Energy	4.551
3. Depreciation	
a. engineering installation, 8 %	50.200
b. construction facilities, 4 %	12.800
4. Usage charge on sacks	7.200
5. Expendable items	5.300
6. Transport and haulage	48.000
Total:	139.427
General plant unit costs, 10 %	13.943
Total inputs:	153.370

Table 2: Total costs for the irradiation experiment in 1980 at Rákóczifalva. Costs by KÉKI and the Isotope Institute of the Hungarian Academy of Sceinces were stated on the basis of the irradiation of the envisaged 1000 Mg onion

Cost factor	Cost /Ft/
1. Rákóczi Agricultural Production Cooperative	153.370
2. KÉKI	400.000
3. Isotope Institute of the Academy	330.000
Total inputs:	883.370

Table 3: Costs involved for the storage in bulk of 2000 Mg onion and its irradiation at 80 % capacity usage. The calculations here under are based on basic data obtained from the experiment in 1980 at Rákóczifalva. The treatment is carried out on a service provision basis; duration: 12 days

Cost factor	Cost /Ft/
I. Costs by the storing company	
1. Wages + 20 % communal etc. taxes	47.300
2. Energy	10.000
3. Depreciation	
a. constructional facilities, 4%	12.800
b. engineering installations, 8%	10.000
4. Expendable items	10.500
5. 10% as general on-plant costs after items No. 1 and 4	9.000
Total:	
II. Costs by the body carrying out irrad.	99.600
Irradiation cost, 2,5 Ft/Mg	500.000
Total inputs:	599.600
Irradiation costs for 1 Mg	300

Table 4: Losses in the onion irradiated between 1st and 19 th Sept. 1980 at the beginning of the experiment, when vigorous sprouting started and at the end of the experiment. Analyses in September and in May were made with two bags of samples. In May, one bag was investigated, from a sample which was taken from "commodity" quality onion. This onion was industrially sorted and further stored. During the period of storage, the samples were kept at a temperature identical to that of the external environment

Date of analysis	Radiation dosage	Quantity of the sample investigated /kg/	Loss /reject/ referred to the sample studied /weight %/	Difference between treated and untreated lots /weight %/
10 Sept. 1980	0	64.50	11.20	- 4.10
	50	56.30	15.30	
4. March 1981	0	55.90	17,17	+ 7.25
	50	59.50	9.92	
14 May 1981	0	283.90	55.30	+45.50xxx
	50	270.10	9.80	

xxx = $P \geq 99{,}9$ % based on the Student "t" test.

50Gy

Table 5: Results of stock and texture -measurements during storage of the seed-grown, Alsógöd variety onion which was irradiated between 1st. and 19 September 1980 or which was untreated. Storage was performed at the external air temperature. Significant differences for treated and untreated lots were indicated for irradiated samples. The values $\bar{x}$ present measurement averages, and s are standard deviations from the averages

Date of analyses	Radiation dosage /Gy/	Number of samples analysed /pieces/	Specific compressibility $/N.mm^{-1}/$	
			$\bar{x}$	s
September 1980	0	5x10	47.368	9.342
	50	5x10	45.734	10.863
October 1980	0	5x10	49.525	7.916
	50	5x10	51.973	8.598
November 1980	0	5x10	40.474	9.369
	50	5x10	47.353	9.582
January 1981	0	5x10	34.768	8.338
	50	5x10	42.094	6.931
February 1981	0	5x10	36.320	5.890
	50	5x10	37.572	6.511
March 1981	0	5x10	34.483	6.510
	50	5x10	49.764^{xxx}	11.125
May 1981	0	5x10	29.181	6.598
	50	5x10	38.607^{xxx}	6.994

xxx = P $\geq$ 99,9% based on the Student "t" test.

 0 Gy

x / x

Table 6: Average value /$\bar{x}$/ and related standard deviation /s/ during storage for the Alsógödi variety of seed grown onion and treated with radiation between 1st and 19 September 1980 or untreated. The crop was stored at external temperature, and the significant deviations between average values of density for treated and untreated samples are indicated under the irradiated sample sections

Date of analysis	Radiation dosage /Gy/	Number of samples examined /pieces/	Density /gcm^{-3}/	
			$\bar{x}$	s
15-19 September 1980	0	5x10	0.926^{x}	0.037
	50	5x10	0.926	0.037
23-27 October 1980	0	5x10	0.920	0.029
	50	5x10	0.959	0.016
16-21 January 1981	0	5x10	0.806	0.049
	50	5x10	0.909^{xxx}	0.036
February 17-27 1981	0	5x10	0.755	0.057
	50	5x10	0.909^{xxx}	0.022
9-16 March 1981	0	5x10	0.878	0.030
	50	5x10	0.906^{xxx}	0.024
14-20 May 1981	0	5x10	0.720	0.048
	50	5x10	0.889^{xxx}	0.041
26-30 November 1980	0	5x10	0.872	0.037
	50	5x10	0.953^{xx}	0.022

x = P $\geq$ 95.0 %

xx = P $\geq$ 99.0 %

xxx = P $\geq$ 99,9 %

Based on the Student "t" test.

* STARTING STATE

Table 7: Average values /$\bar{x}$/ for inner bud ratio and standard deviations for averages during storage in case of the Alsógöd variety for seed grown onion, for its treated and untreated batches. The results marked by I are samples for texture and density measurement, and those marked by II are samples for colour determination. Storage temperature coincided with the external one, and significant deviations between treated an untreated samples are indicated under the section of irradiated samples

Date of analysis	Radiation dosage /Gy/	Number of samples examined /pieces/	Inner bud ratio, I		Inner bud ratio, II	
			$\bar{x}$	s	$\bar{x}$	s
15-19 Sept. 1980	0	5x10	0.446	0.066	0.467	0.094
	50	5x10	0.427	0.051	0.467	0.094
23-27 Oct. 1980	0	5x10	0.511	0.056	0.541	0.119
	50	5x10	0.376	0.056	0.422	0.076
26-30 Nov. 1980	0	5x10	0.563	0.071	0.563	0.080
	50	5x10	0.455xx	0.074	0.475xx	0.088
16-21 January 1981	0	5x10	0.751	0.094	0.781	0.140
	50	5x10	0.535xxx	0.043	0.557xxx	0.051
17-27 February 1981	0	5x10	0.754	0.094	0.723	0.099
	50	5x10	0.513xxx	0.038	0.560xxx	0.059
9-16 March 1981	0	5x10	0.805	0.097	0.815	0.097
	50	5x10	0.567xxx	0.047	0.572xxx	0.036
14-20 May 1981	0	5x10	0.938	0.081	0.939	0.061
	50	5x10	0.581xxx	0.058	0.589xxx	0.049

xx = $P \leq 99.0$ %

xxx = $P \leq 99.9$ % based on the Student "t" test.

STARTING STATE

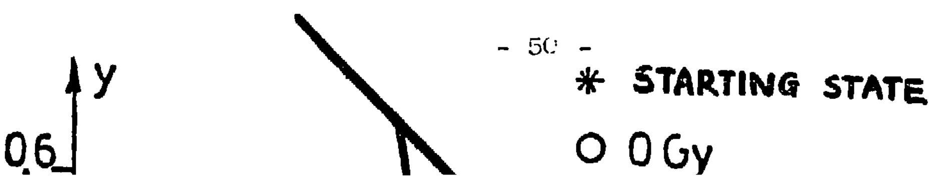
Table 8: Results of colour measurements during storage over the cut surface of Alsógöd variety of seed grown onion and irradiated between 1st and 19th September 1980. The ΔE_{BL-CS} values represent colour differences between tunic leaves and bud tip, while ΔE_{BL-T} represent colour differences for tunic leaves and growing part. Storage temperature was the same as the outdoor one

Date of analysis	Radiation dosage /Gy/	Number of measurements /pieces/	ΔE_{BL-CS}		ΔE_{BL-T}	
			$\bar{x}$	s	$\bar{x}$	s
15-19 Sept. 1980	0	5x10	5.6026	2.9308	14.0067	3.2422
	50	5x10	-	-	-	-
23-27 Oct. 1980	0	5x10	8.5778	4.4290	15.0352	2.6569
	50	5x10	7.5461	3.1914	13.2481	2.4693
26-30 November 1980	0	5x10	9.1816	4.2204	13.6305	3.2767
	50	5x10	7.4051	3.4913	13.2481	2.4693
16-21 January 1981	0	5x10	14.1014	5.0644	10.7784	2.9578
	50	5x10	6.1611	2.6569	15.1678	3.5011
17-27 February 1981	0	5x10	14.5332	6.0697	9.4045	5.6466
	50	5x10	6.5362	4.9455	17.5581	4.0518
9-16 March 1981	0	5x10	17.6848	6.7739	12.1321	2.2782
	50	5x10	6.7592	3.0732	18.1404	3.8274
14-20 May 1981	0	5x10	18.7422	5.9315	11.2245	3.3451
	50	5x10	6.6941	2.1516	19.4320	4.4256

$\bar{x}$ = átlag érték

s = standard eltérés

- 50 -



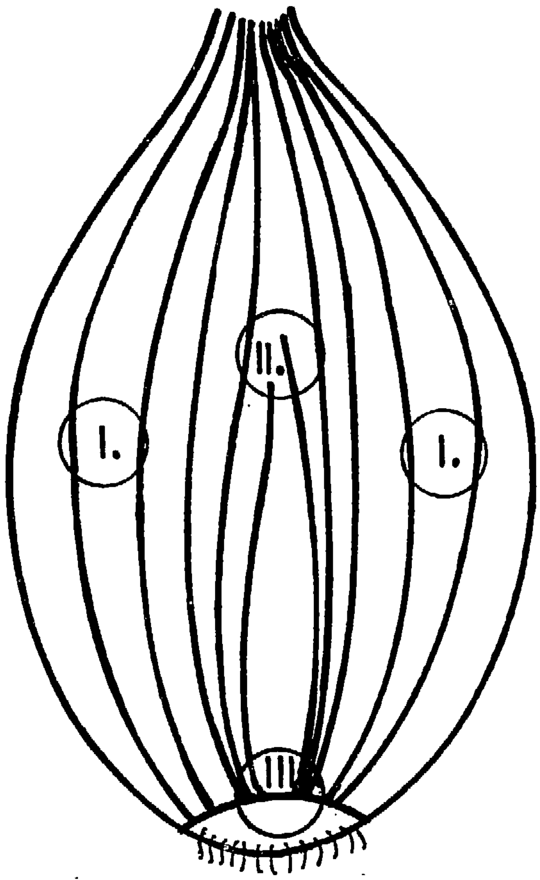


Figure 1: Location of measurement points over the cut surface of onion in case of colour determination

1. 1st. point of measurement = tunic leaves
2. 2nd. point of measurement = bud tip
3. 3rd. measuerement point = growing

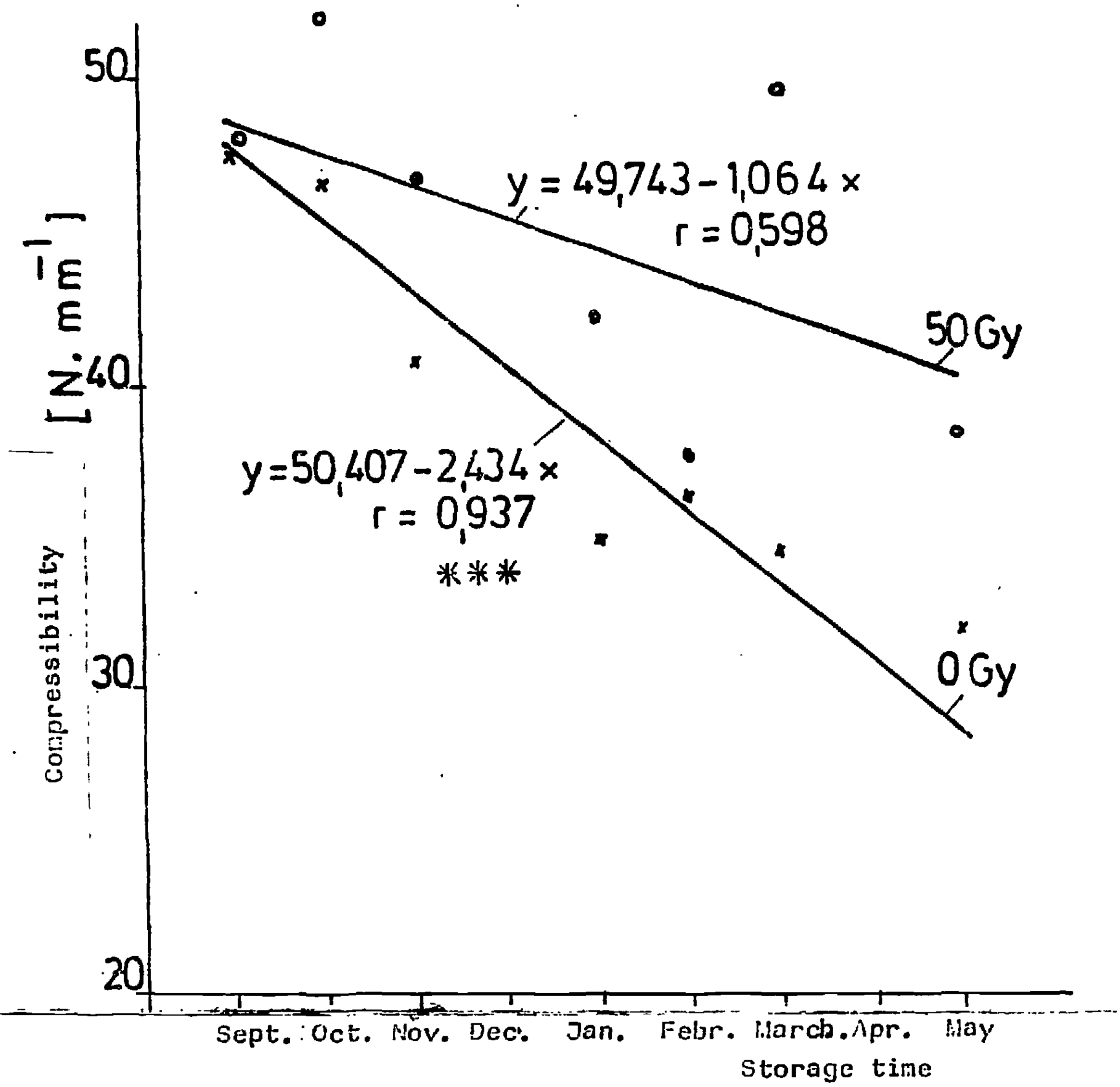


Figure 2: Texture changes during storage in seedgrown, Alsógöd variety onion for the untreated and treated cases; irradiation period; 1st, Sept. and 19 Sept. 1980. The storage temperature was equal to the enviromental temperature

xxx = P $\geq$ 99.9 % isthe significance of "r" for FG=7

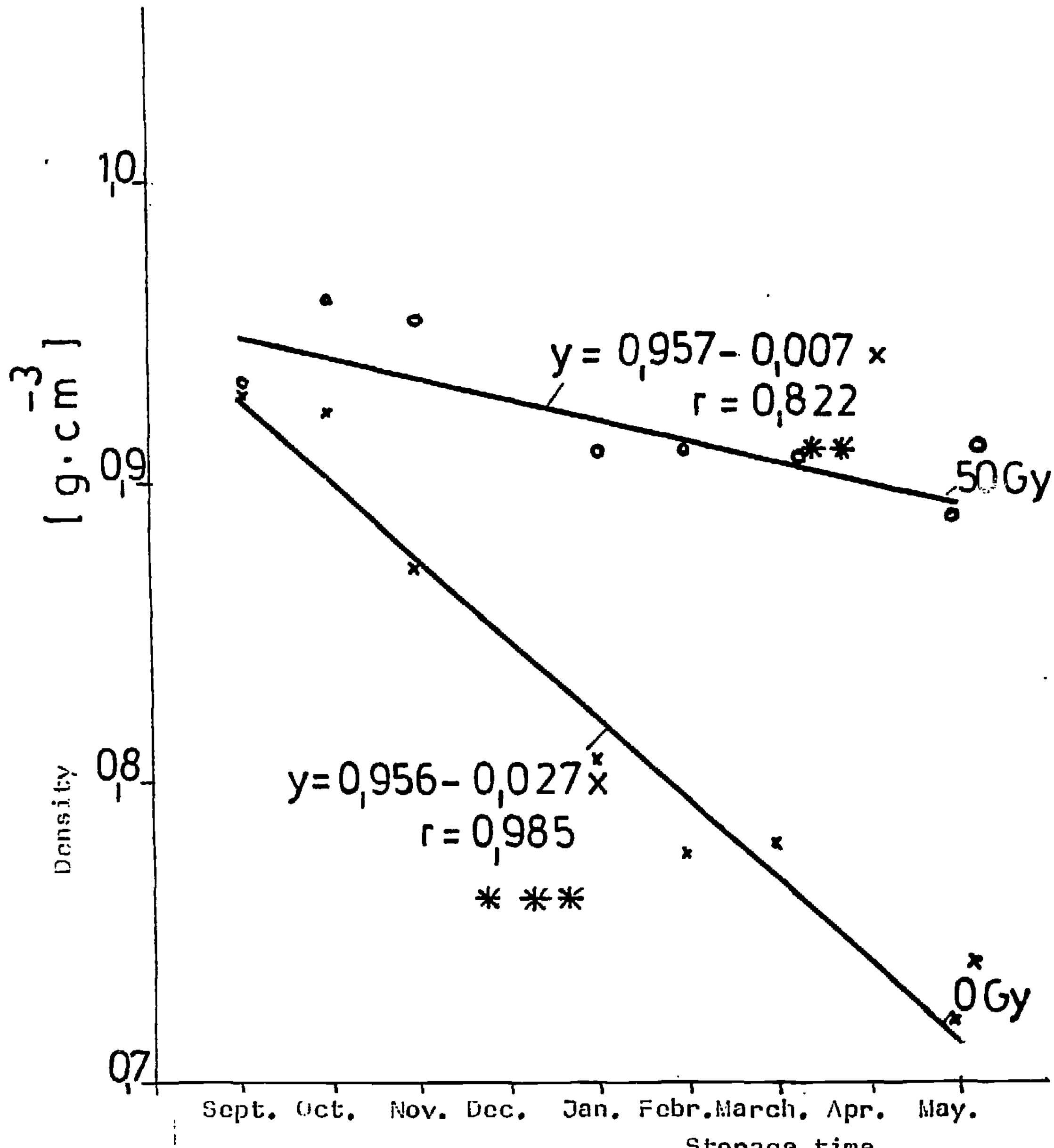


Figure 3: Densitiy changes during storage for the Alsógöd variety, seed-grown, treated and untreated onion; radiation period: 1-19 Sept. 1980. Storage temperature the same as the outdoor one

xx = P ≥ 99.0 %
xxx = P ≥ 99.9 % is the significance of "r" for FG=5.

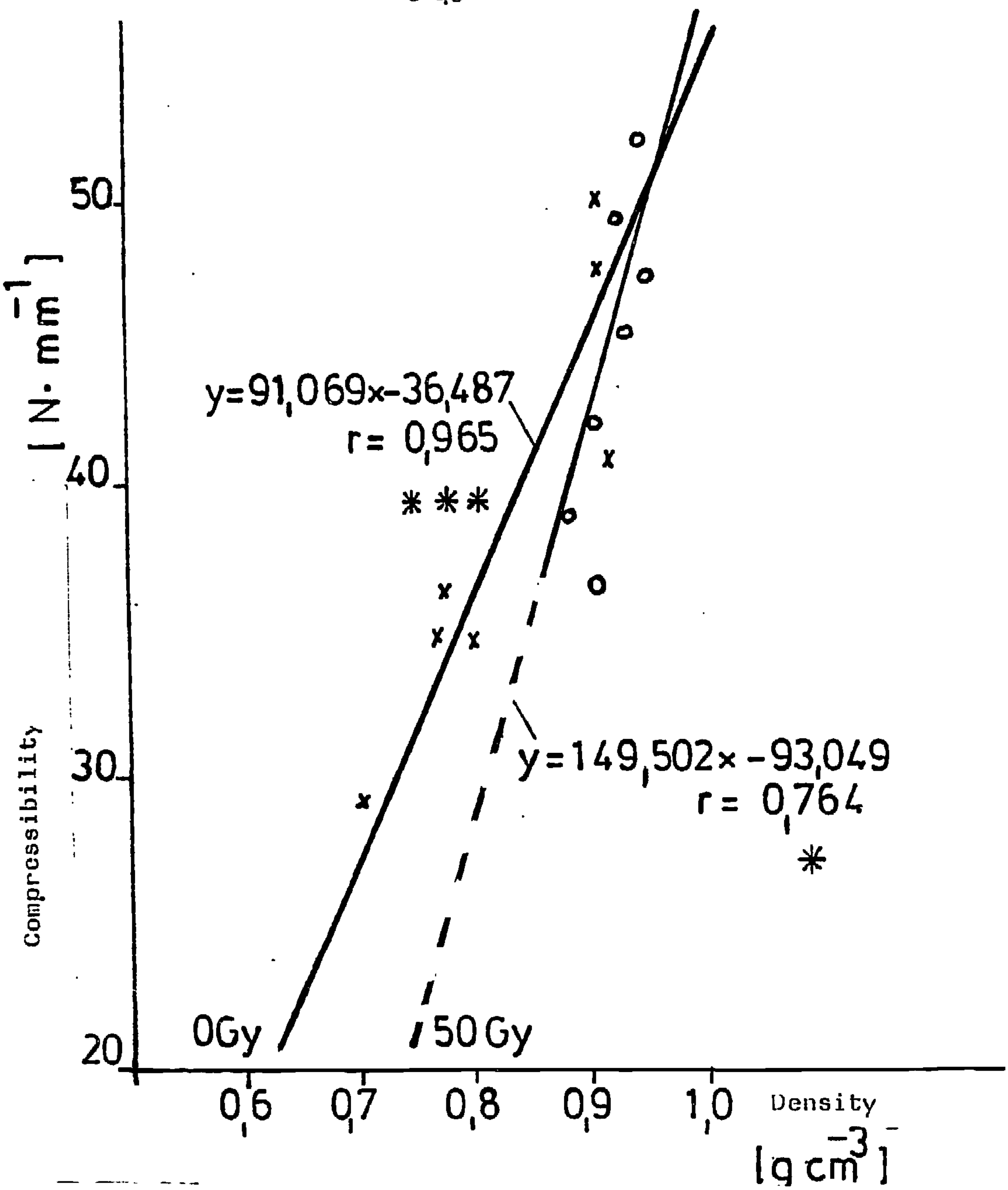


Figure 4: Relations between the texture and density of treated and untreated Alsógöd variety seed grown onion stored until mid-May; time of irradiation: 1-19 Dept. 1980. Storage temperature was the same as the external one

xx = P ≥ 99.0 % is the significance of "r" for FG=5
xxx = P ≥ 99.9 %

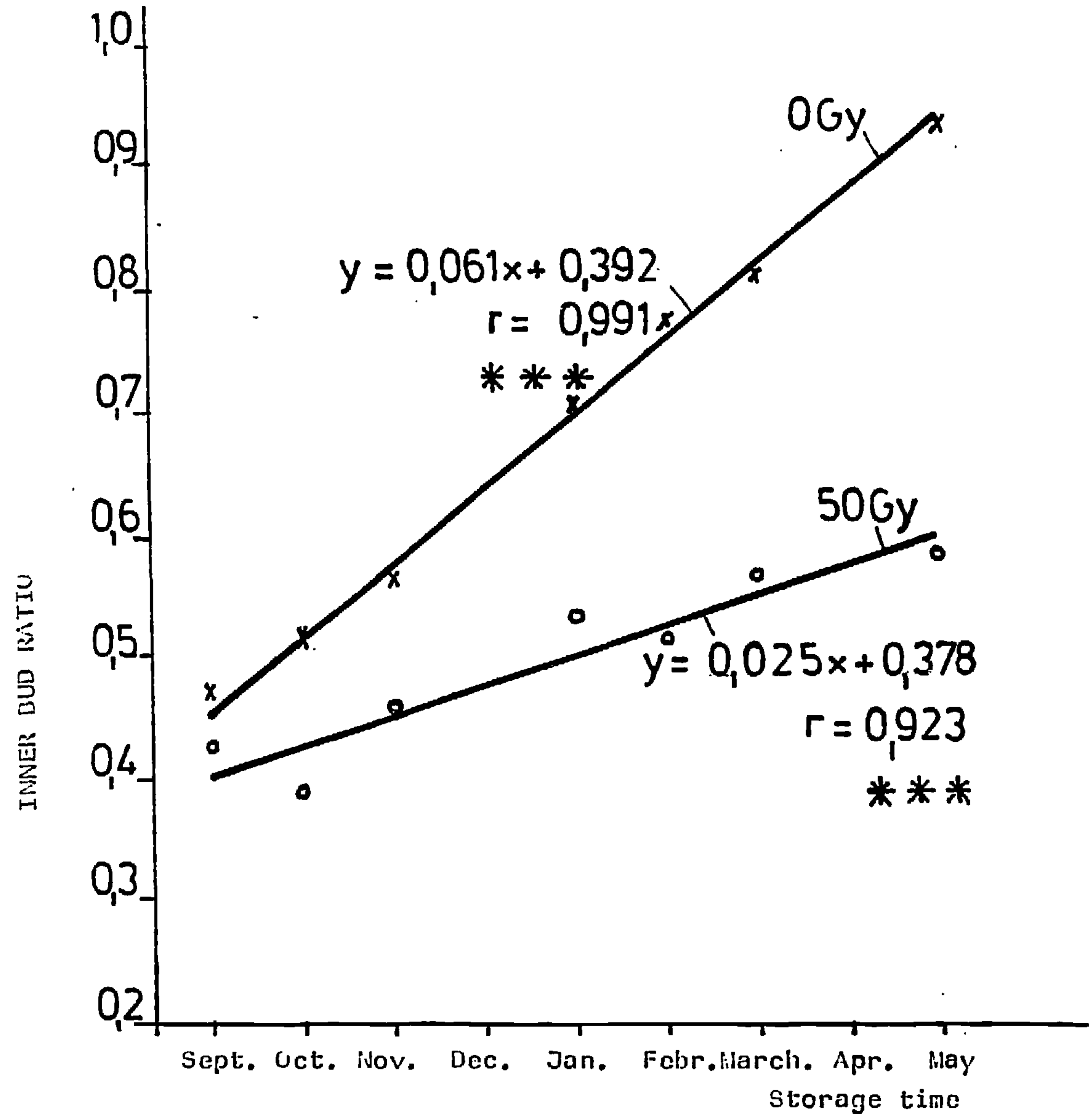


Figure 5: The growth of inner bud during storage for treated and untreated, Alsógöd variety, ~~seed-grown onion.~~ Irradiation period: 1-19 Sept. 1980. The samples were always stored at the external air temperature. Data for the inner bud are obtained from measurement samples for texture and density

xxx = P $\geq$ 99.o % is the significance of "F" for FG=7.

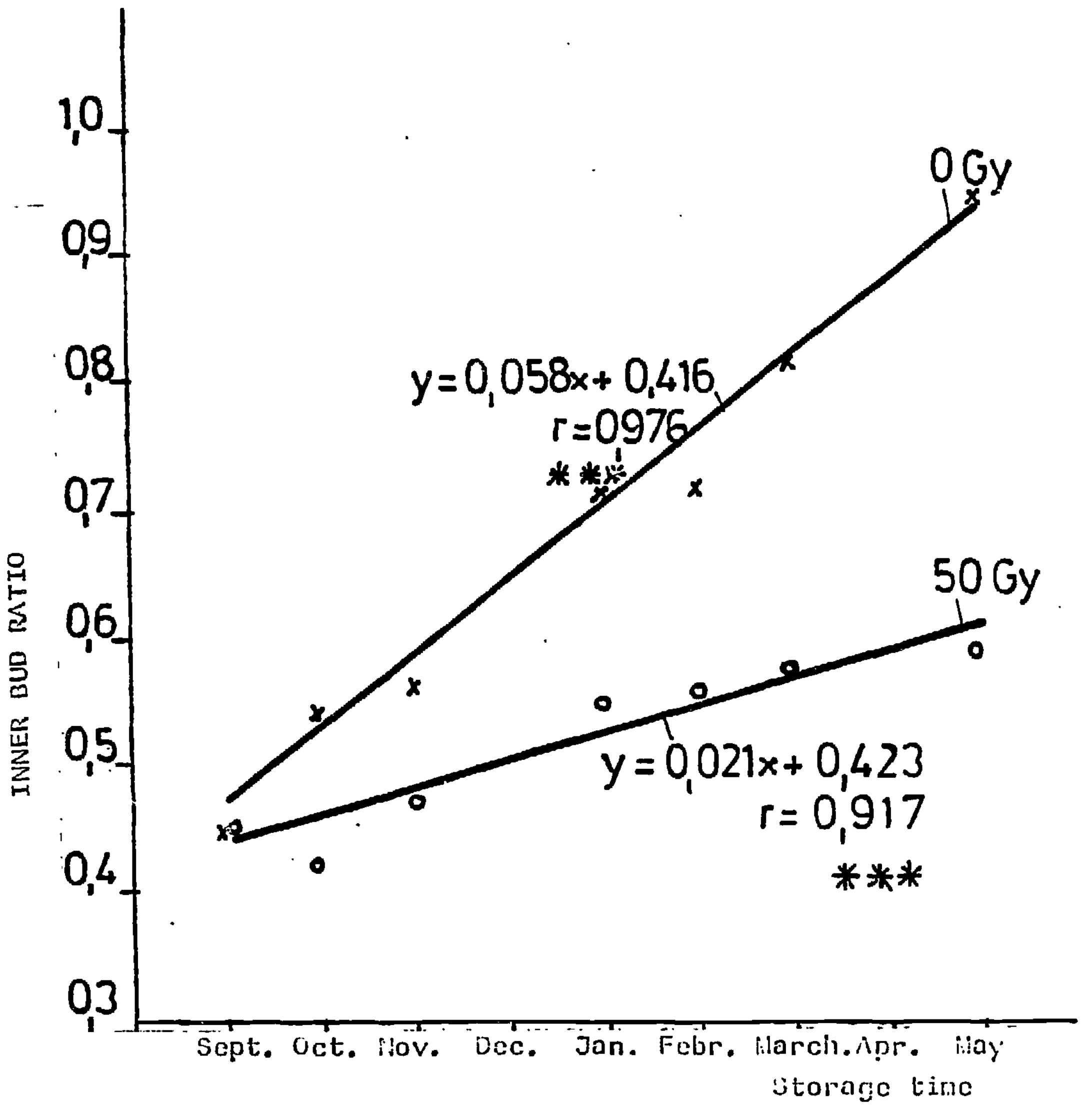
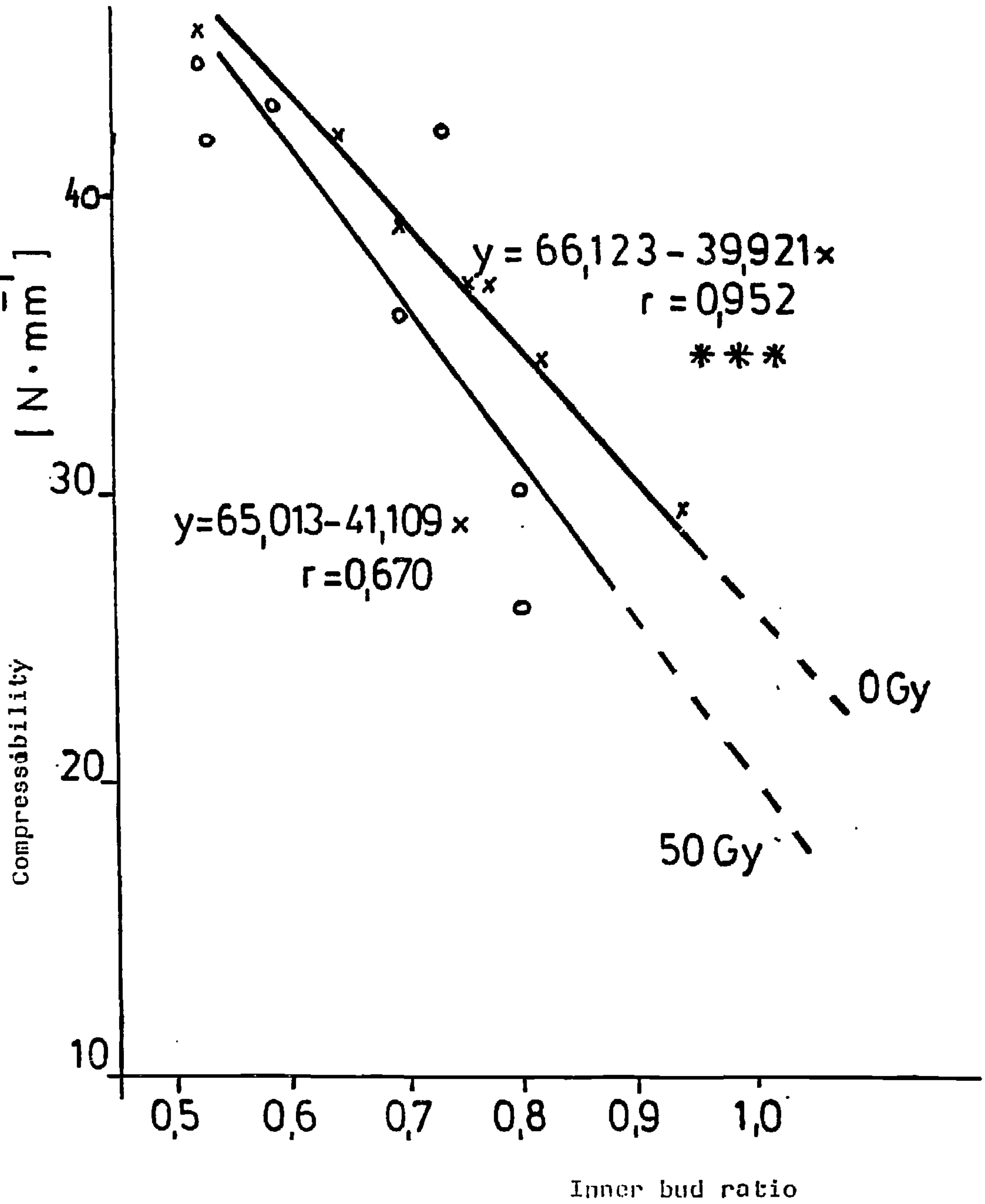


Figure 6: Changes in the inner bud during storage in case of treated and untreated, Alsógöd variety, seed grown onion; period of irradiation: 1-19 Sept. 1980. Storage temperature was the same as that of the external air. Data for the inner buds are obtained from the samples used for colour determination.

xxx = P ≥ 99.9 % is the significance of "r" for FG=7.



<u>Figure 7:</u> Relation between the inner bud growth and texture of treated and untreated, Alsógöd onion variety; the onion was stored until mid-May 1981; irradiation period; 1-19 Sept. 1980. The storage temperature was always the same as the external air temperature.

xxx = P ≥ 99.9 % is the significance of "r" for FG=5

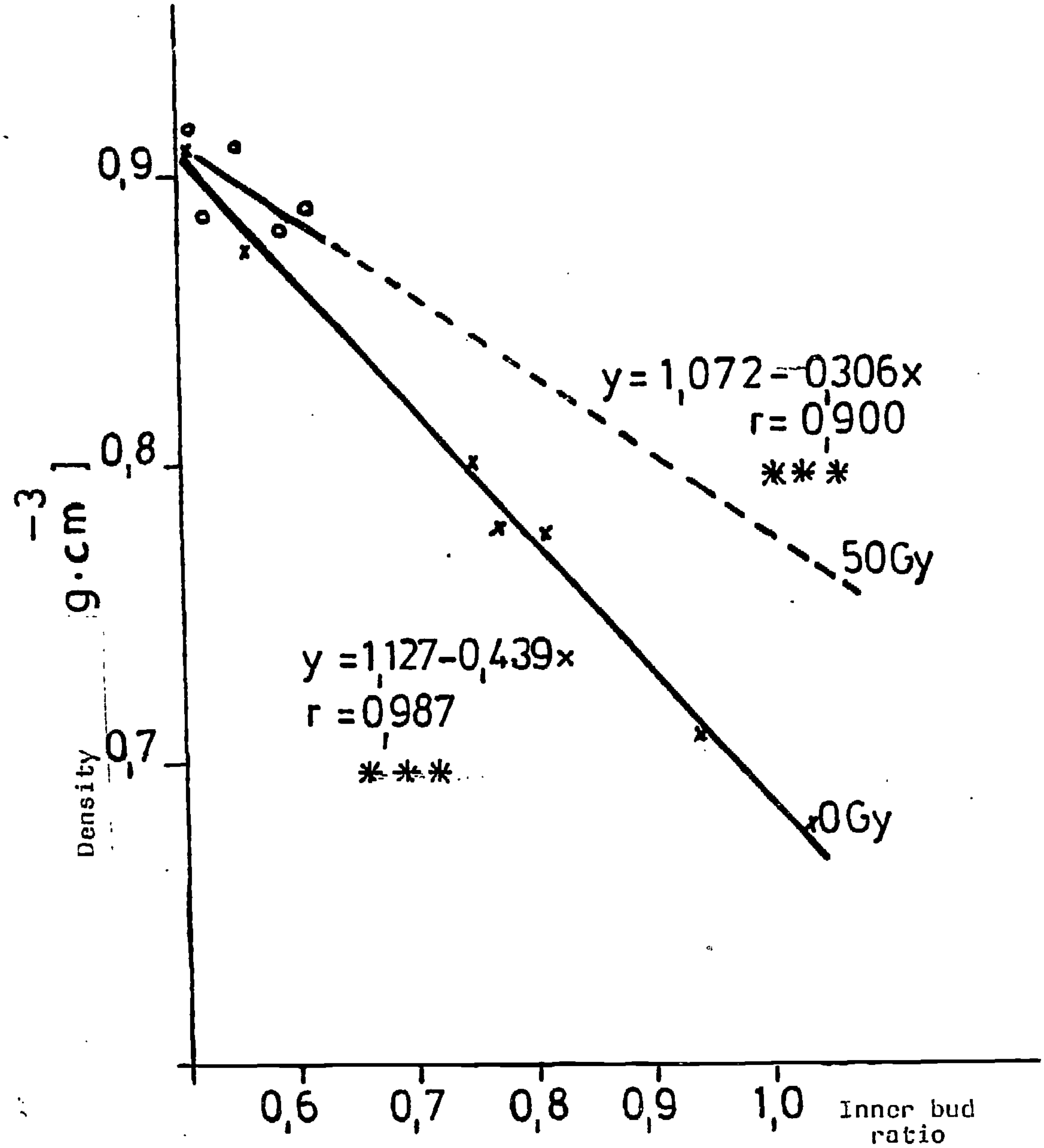


Figure 8: Interrelation of inner bud growth and density for treated and untreated samples of Alsógöd variety; onion stored until mid-May; treatment period: 1-19 September. Storage temperature was the same as that of the outdoor ambient air

xxx = P ≥ 99.9 % is the significance of "r" for FG=5

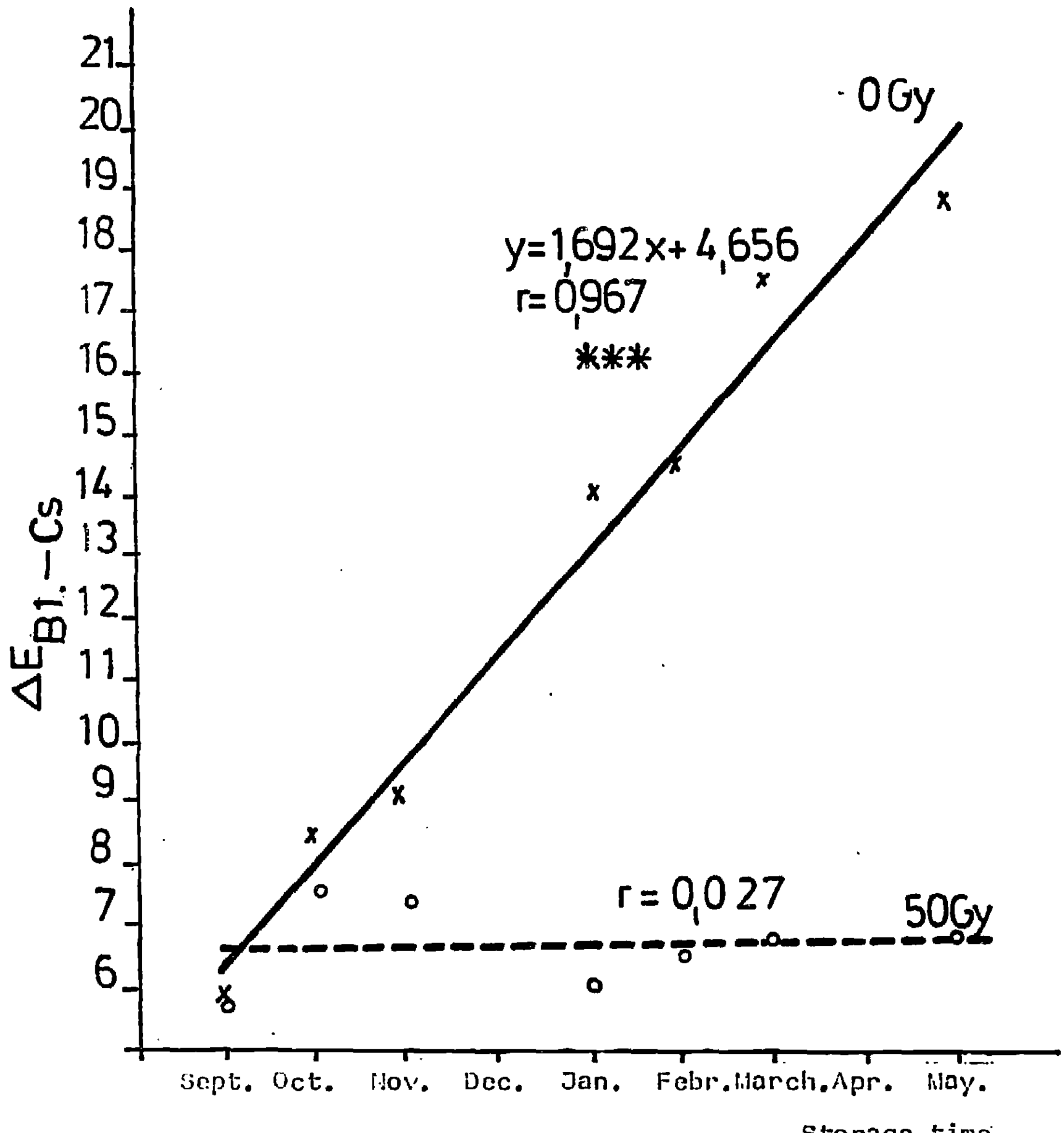


Figure 9: The colour difference, Δ E, between bud tip and tunic leaf during storage for treated and untreated, Alsógöd variety onion; radiation treatment period: 1-19 September 1980. The storage temperature was always identical with ambient air temperature

xxx = P $\geq$ 99.9 % is the significance of "r" for FG=7.

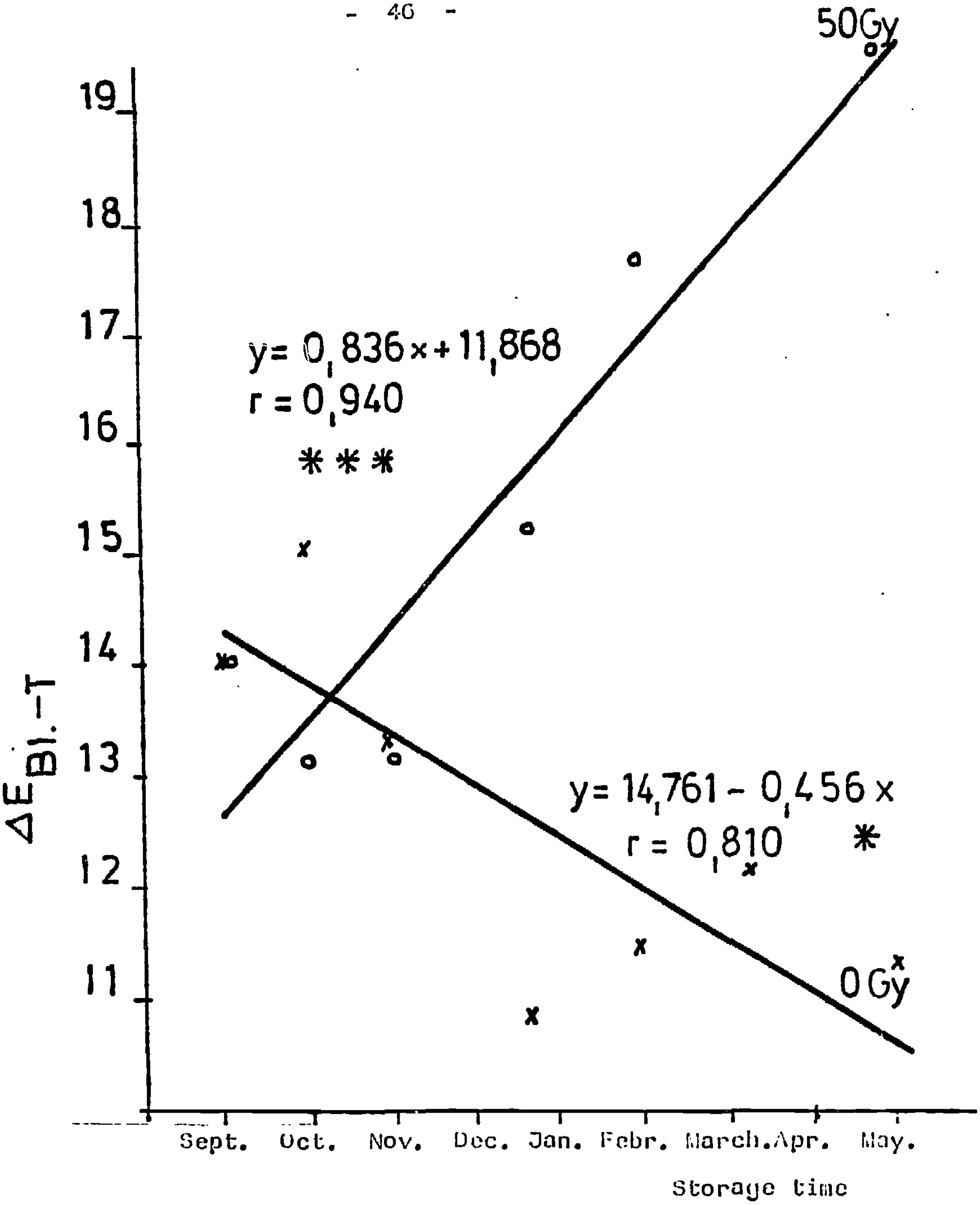


Figure 10: The colour difference, Δ E, during storage between the tunic leaves and the growing part of treated and untreated Alsógöd variety, onion stored until mid-May; radiation treatment period: 1-19 Sept. 1980. The storage temperature was the same as that of the same of the ambient environment.

$*$ = P $\geq$ 95.0 % is the significance of "r" for FG=7

$***$ = P $\geq$ 99.9 %

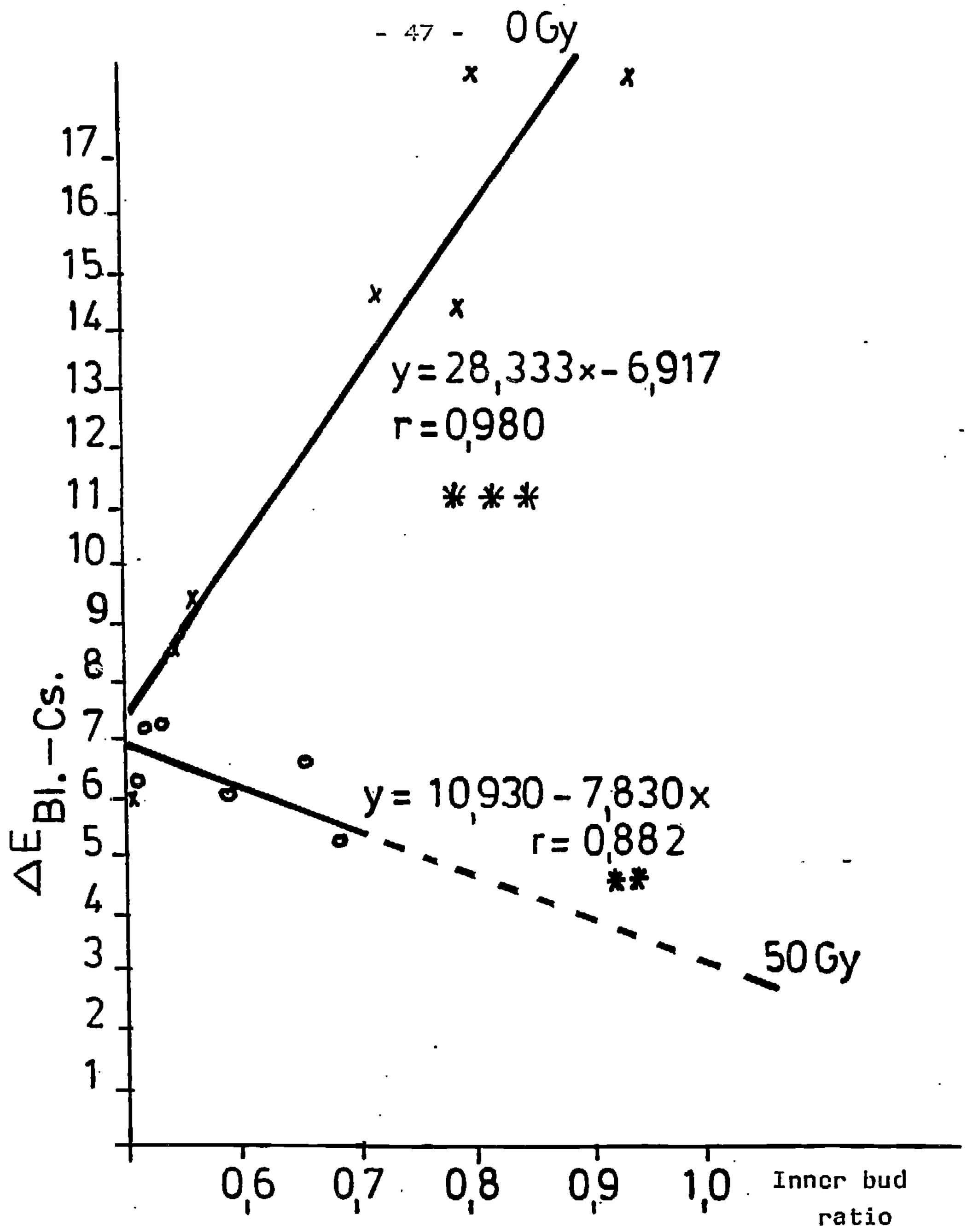
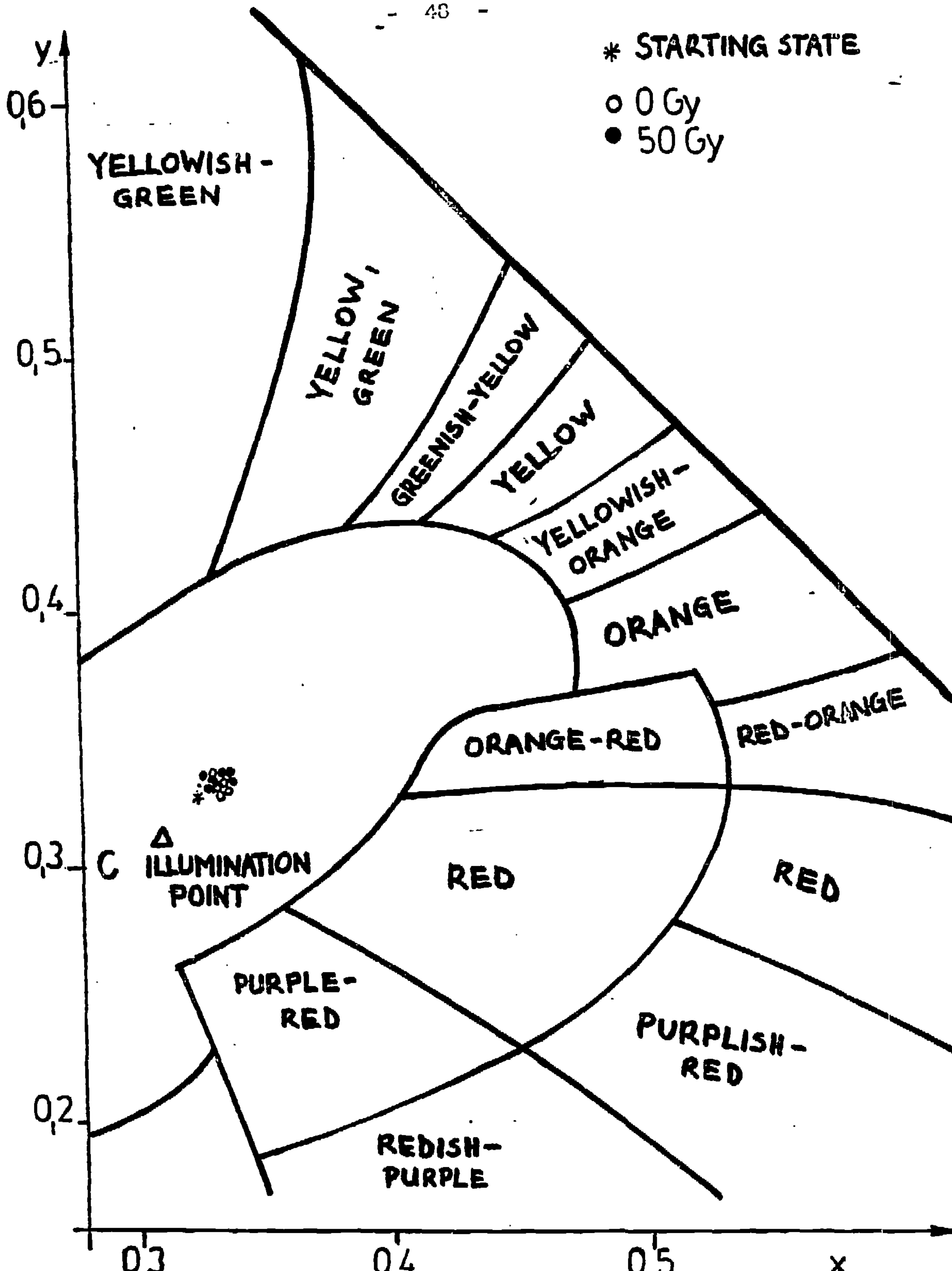


Figure 11: Relation between the colour difference, ΔE, the bud tip and inner bud ratio for treated and untreated Alsógöd onion stored until mid-May 1981; radiation treatment period: 1-19 September 1980. The storage was made at a temperature indentical to the external air temperature

xx = P ≥ 99.0 % is the significance of "r" for FG=5
xxx = P ≥ 99.9 %



igure 12: The result of colour measurement on the tunic leaves during storage of treated and untreated, Alsógöd variety onion: radiation treatment period: 1-19 Sptember 1980. Storage was performed at the outdoor air temperature

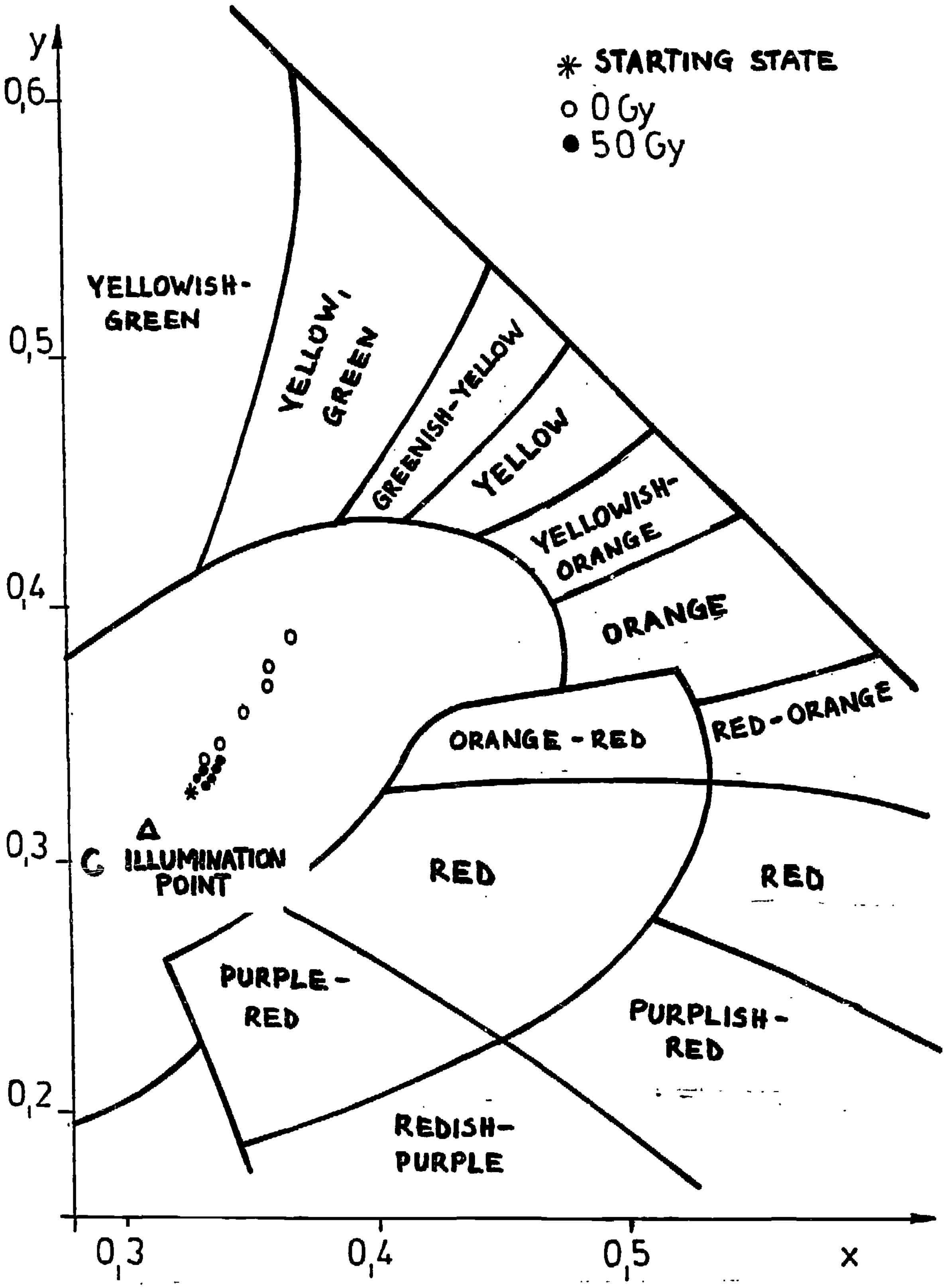
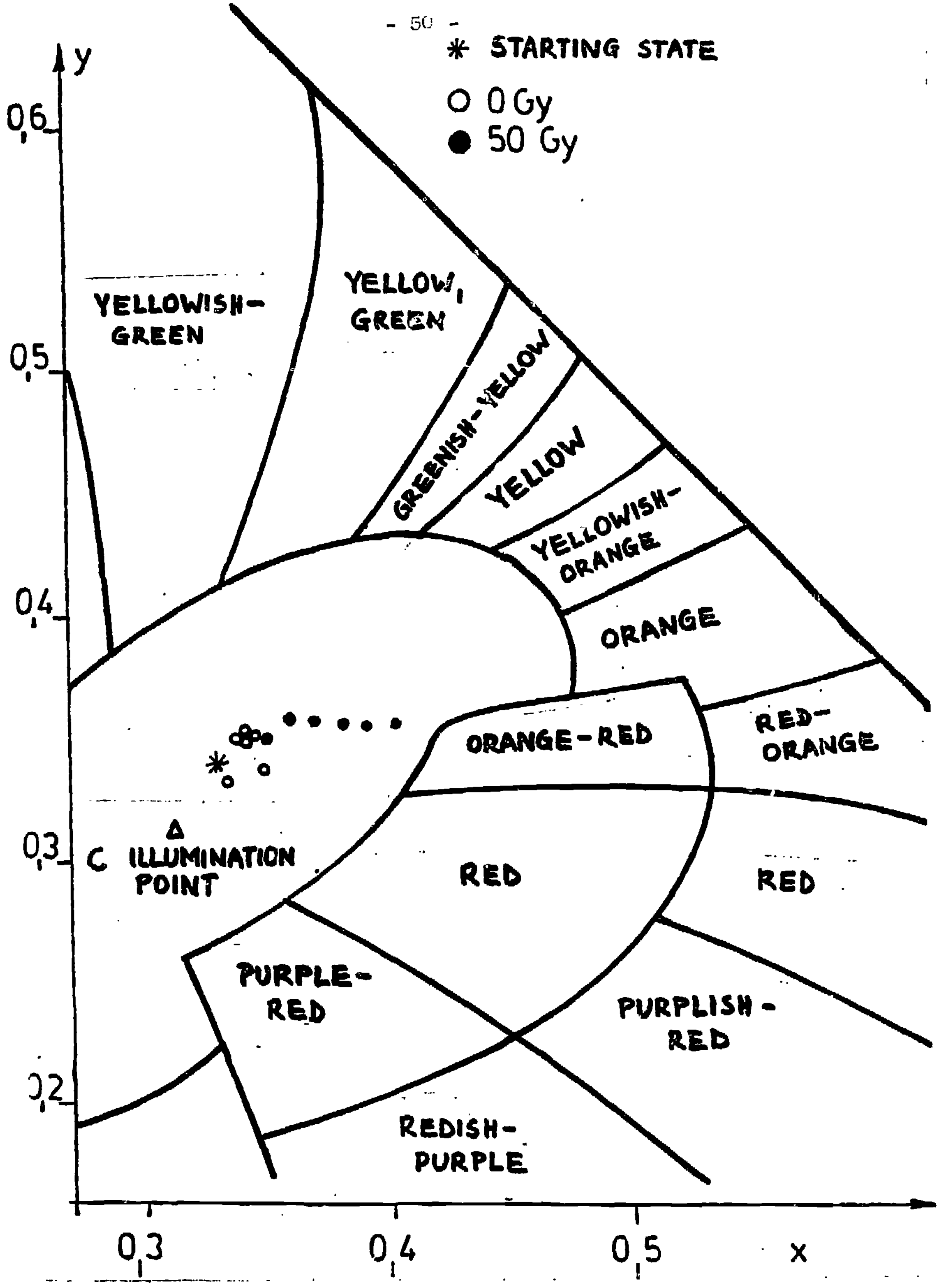


Figure 13: Colour changes measured on the bud tip of treated and untreated, Alsógöd variety onion during storage; radiation treatment period: 1-19 September 1980. Storage temperature was indentical with the ambient air temperature.



igure 14: Colour changes measured during storage on the growing part of treated and untreated samples of the Alsógöd variety onion: radiation treatment period: 1-19 September 1980. Storage was made at a temperature indentical that of the external air temperature.