radiation and the green revolution

An important contribution to plant breeding is now being made by using radiation techniques to induce mutations. Benefits have been seen in a number of food crop varieties, and in some cases threats of shortages caused by disease have been averted. In addition to the fact that it is one aspect of the Green Revolution which is alleviating many food problems, the technique is proving of value to breeders of flowers and ornamental plants.

Some of the results which have been achieved were given at a symposium organized by the International Atomic Energy Agency (IAEA) and the Food and Agriculture Organization of the United Nations (FAO) held in Pullman, Washington, USA, from 14-18 July, and 65 new varieties of plants evolved by the method were named.

Since the symposium was held further information has increased this figure to 77, of which 74 have been released to growers, nearly 50 of them during the past five years. They include rice and wheat varieties with improved qualities of resistance to disease and weather, higher protein content and increased yield. Economic gains have been made in producing castor oil in India and peppermint, the yield of which had been seriously threatened, in USA. An interesting, and commercially valuable, aspect has been the successful introduction of the technique into breeding ornamental plants.

Practical demonstrations of results obtained were provided by Washington State University, where the symposium was held. A large variety of plants bred by the method had been grown and were on view in the grounds.

Success in Five Years

Dr. Björn Sigurbjörnsson, of the FAO/IAEA Joint Division of Atomic Energy in Food and Agriculture, spoke of the progress made in the five years since the last symposium on the subject. At that time many doubts were expressed, but now success had been achieved. The efforts of dedicated scientists over four decades were now paying off in millions of hectares of superior crops throughout the world. He quoted as examples the highest-yielding rice variety in Japan, Reimei, a mutant which

Experts from IAEA, Ceylon, Guyana, India, Korea, the Philippines, Sweden, Thailand, and USSR, inspecting the All-India rice trial fields during a research co-ordination meeting.

succeeded in competition with varieties resulting from the most intensive conventional breeding efforts. Doubling of the protein content of rice, which had been reported, also indicated the potential of the method for quality improvements.

The recent shortening by three weeks of the growing period of rice in Hungary of a neutron-induced mutant could have far-reaching effects on the extent of rice cultivation in Europe.

Mutant varieties of durum wheat had shown superior performance in trials in more than a score of countries in Asia, Africa and Europe. The FAO was recommending that some countries replace their wheat acreage with the new mutants.

Ingenious applications had, he said, successfully adapted one of the high-yielding Mexican dwarf wheats to local preferences in India, drastically speeding up acceptance by Indian consumers.

Mutation breeding had made a great contribution to the breakthrough called the Green Revolution, which had alleviated the problem of providing enough high-quality food to keep pace with the population growth. More important, it had drawn attention to the significance of plant breeding and the number of characteristics of high-yielding varieties which needed improvement. This was a role for which induced mutations were especially suited.

150 Days a Year Saved

M. S. Swaminathan (India), one of the world leaders in the work, drew attention to a problem in growing castor oil seeds which had severely affected growers. This was that it took 270 days to mature and thus was at the mercy of changes in the rainy season. As a result of inducing mutants by radiation a new variety had been evolved maturing in 120 days and was now being grown by farmers. They were now assured of a good crop every year. In addition the soil used was released for an extra 150 days for other crops such as rice, of which some varieties mature also in 120 days.

First positive results of applying the method to maize were reported by C. O. Gardner (USA), who said that yield might possibly be increased beyond the highest yet known. This could be the most important development with maize since the 1920's and was the first example of using the method effectively on open pollinated, rather than self-pollinating, crops.

One of the best-known flavours in the world, peppermint, might have been lost but for use of the radiation method to develop resistance against disease. M. J. Murray (USA) reported that after fourteen years of fighting against a disease which could destroy whole crops it was found that use of radiation to produce plants to resist it was the only possible solution. Other methods had produced plants which resisted the disease but altered the flavour to spearmint. Use of the radiation method had saved an extremely important market.

New varieties listed, according to information available to the FAO/IAEA Joint Division up to 1 July, are in types of bread and durum wheat, barley, oats, rice, soybean, peas, beans, peanuts, rape, mustard, tobacco, peach, and a number of flowers. The countries where they have been developed are Argentina, Austria, China, Czechoslovakia, India, Indonesia, Italy, Japan, the Netherlands, Sweden, USSR, UK and USA.

List of Plant Mutants

This list of released or approved varieties produced with induced mutations or having induced mutations in their background is based on information received by 1 July 1969

Name	Place, date, principal worker, institute	Treatment [Parent variety]	Improved Attributes
Bread wheat			
NP 836	India, 1961 M.S. Swaminathan	Dry seeds (12%), 16 krad of X-rays (1955) [NP 799]	Fully awned; higher yield (10%); medium early maturity (140 days); high leaf rust resistance. Grows better than the parent in unirrigated areas.
Sharbati Sonora	India, 1967 M.S. Swaminathan IARI, New Delhi, India	Dry seeds (12%), 1 hour of 2600 A UV + 20 krad gamma rays from ^{60}Co (1963) [Sonora 64]	Amber grain color (preferred in India). Short straw, early maturity, high protein (16.5%) and high [lysine] (3.4 g lysine/ 100 g protein, in comparison to 2.2 g lysine in the parent strain).
Lewis	U.S.A., 1964 Missouri Agricultural Experiment Station	Thermal neutrons [Mo.W6185]	Lodging resistant; early maturity; high yielding.
Stadler	U.S.A., 1964 Missouri Agricultural Experiment Station	Thermal neutrons [Mo.W6243]	Early maturity; strong straw; good yielding ability; excellent soft quality grain; good disease resistance and winter hardiness.
Sinvalocho Gama	Argentina, 1962 E.A. Favret and G. Ryan Instituto de Fitotecnia, INTA, Castelar, Argentina	20 krad of ^{60}Co gamma rays (1956)	More resistant to black stem rust and leaf rust.
Zenkouzi-Komugi	Japan, 1969 M. Toda, T. Nakada, S. Miki and T. Tsukada Nagano Prefectural Acric. Experiment Station, Japan	^{60}Co gamma rays (1959) [Igachikugo-Oregon]	Earlier maturity (one or two days); shorter culm (15-20 cm); higher yield (10-15%).

Clear demonstration of resistance to the rice disease known as leaf blast. The unaffected plants were developed by Jeung Haeng Ree (Korea) using thermal neutron irradiation. Photo: J.H.Ree

Name	Place, date, principal worker, institute	Treatment [Parent variety]	Improved Attributes
Novo-sibirskaia 67	USSR, 1969/70 I.V. Cherny Institute of Cytology and Genetics Novosibirsk, USSR	^{60}Co gamma rays, 5 krad air-dry seeds	Lodging resistance, baking quality
Durum wheat			
Castel-porziano	Italy, 1968 G.T. Scarascia-Mugnozza, A. Bozzini and C. Mosconi C.N.E.N., Rome, Italy	Thermal neutrons at the dose of 8.38 × 10^{12}/cm^2 (1956) [Cappelli]	Lodging resistance; yielding ability.
Castelfusano	Italy, 1968 G.T. Scarascia-Mugnozza, A. Bozzini, C. Mosconi and F. D'Amato C.N.E.N., Rome, Italy	Thermal neutrons at the dose of 1.05 × 10^{13}/cm^2 (1956) [Cappelli]	Lodging resistance; yielding ability.
Castel del Monte	Italy, 1969 G.T. Scarascia-Mugnozza C.N.E.N., Rome, Italy	Fast neutrons, 100 reps [Garigliano]	Lodging resistance; high yield.
Barley			
Vienna	Austria, 1959 H. Hänsel Probstdorfer Saatzucht, N.O., Austria	9400 rad X-rays on dry seeds (1951) [Probstdorfer Vollkorn VK 41]	High yield; high 1000-kernel weight; mildew resistant; lodging resistant.
Pennrad	U.S.A., 1963 R.P. Pfeifer and R.I. Schein Pennsylvania Agricultural Experiment Station, Pennsylvania, U.S.A.	Thermal neutrons (dosage to cause 50% germination) (1956) [Hudson]	Increased winter hardiness; awnleted, recessive gene mutant.
Jutta	Germany (Democr. Rep.), 1955 N. Mews Institut für Pflanzenzüchtung Akademie der Land-wirtschaftlichen Wissen-schaften Berlin, Kleinwanzleben	X-rays, 5000 r (1944) [Peragis mittelfrühe II]	Higher yield, lodging resistance, increased winter hardiness.
Milns Golden Promise	United Kingdom, 1966 David Miln & Co. (Seedsmen) Ltd. Chester, England	Gamma rays, 6-24 krad (1956) [Maythorpe]	Shorter and stiffer straw with good grain yield and malting properties, but mildew-susceptible.
Midas	United Kingdom (to be released in 1970) David Miln & Co. (Seedsmen) Ltd. Chester, England	RM.759/10 × Miln Golden Promise	Short, stiff straw; erectoides habit; mildew resistance.
Luther	U.S.A., 1967 R.A. Nilan Washington State Agric. Experiment Station Pullman, Wash., U.S.A.	Seeds soaked in diethyl sulfate (dES) at .0038 M (conc.) for 3.5 hrs. at 30° C with solution changed every half hour (1960) [Alpine]	Shorter straw; increased grain yield and lodging resistance, especially with heavy fertilization.

Name	Place, date, principal worker, institute	Treatment [Parent variety]	Improved Attributes
Diamant	C.S.S.R., 1965 J. Bouma Breeding Institute Branisovice, C.S.S.R.	Seeds (14% moisture) treated with 10 krad of X-rays (1956)	Very high yield, short stem, very good grain and malting quality, lodging resistant.
Hellas	Sweden, 1967 A. Hagberg Swedish Seed Association Svalöf, Sweden	Selection from Pallas x Herta	Resistant to lodging and straw breakage; increased yield, especially with heavy fertilization; resists sprouting at harvest time.
Pallas	Sweden, 1960 A. Gustafsson Swedish Seed Association Svalöf, Sweden	Presoaked seeds X-rayed with 7350 rad (1946) [Bonus]	Stiff straw.
Mari	Sweden, 1962 A. Gustafsson Swedish Seed Association Svalöf, Sweden	Dry seeds X-rayed with 20 krad (1949) [Bonus]	Early maturity (by 8 days); stiffer straw.
Kristina	Sweden, 1969 A. Hagberg Swedish Seed Association	Selection from Domen x Mari	Resistant to lodging and straw breakage; very high yield; outstanding malting quality.
Oats			
Florad	U.S.A., 1959 W.H. Chapman, H.H. Luke and A.T. Wallace Florida Agricultural Experiment Station Gainesville, Fla., U.S.A.	Thermal neutrons to seeds (1954) [Floriland]	Resistant to stem rust, superior grain quality and straw stiffness.
Alamo-X	U.S.A., 1961 I.M. Atkins, M.C. Futrell and Q.J. Raab Texas Agricultural Exp. Station Texas, U.S.A.	Seeds X-rayed with 25 krad (1953) [Alamo]	Resistant to Victoria blight and crown rust.
Florida 500	U.S.A., 1965 D. Sechler and W.H. Chapman Florida Agricultural Experiment Station Gainesville, Fla., U.S.A.	Selection from Florad x Coker 58-7	Improved agronomic type combined with rust resistance of mutant Florad.
Florida 501	U.S.A., 1967 D. Sechler and W.H. Chapman Florida Agricultural Experiment Station Gainesville, Fla., U.S.A.	Selection from Florad x Coker 58-7	Improved agronomic plant and kernel type combined with crown rust resistance.
Rice			
SH 30-21	Rep. of China, 1957 H.W. Li Institute of Botany, Academia Sinica, Taipei; J.H. Hu Department of Agronomy Chung-hsing University, Taiwan, Rep. of China	X-rays (1957)	Higher yield, short growing period.

Name	Place, date, principal worker, institute	Treatment [Parent variety]	Improved Attributes
KT 20-74	Rep. of China, 1957 H.W. Li Institute of Botany Academia Sinica, Taipei; J.H. Hu Department of Agronomy, Chung-hsing University, Taiwan, Rep. of China	X-rays (1957)	Higher yield, short growing period.
YH 1	Rep. of China, 1963 H.W. Li Institute of Botany Academia Sinica, Taipei; J.H. Hu Department of Agronomy, Chung-hsing University, Taiwan, Rep. of China	Selection from Taichung No.1 x SH 30-21	Higher yield, short growing period.
Reimei	Japan, 1966 K. Toriyama, I. Futsuhara Fujisaka Branch Station Aomori Prefectural Agric. Experiment Station, Japan	Dry seeds treated with 20 krad of ^{60}Co gamma rays (1959) [Fujiminori]	Short straw, lodging resistant, especially with heavy fertilizer; less variation with location and year; tolerates lower temperatures, especially during germination and seedling stages.
Soybean			
Tainung No. 1 (R)	Rep. of China, 1962 Y.W. Cheng Taiwan Province Agricultural Research Institution, Taiwan, Rep. of China	Thermal neutrons	Vigorous, dropping-resistant variety with the characteristics of long branches and higher yield.
Tainung No. 2 (R)	Rep. of China, 1962 Y.W. Cheng Taiwan Province Agricultural Research Institution, Taiwan, Rep. of China	X-rays	Vigorous, dropping-resistant variety with short internode, large seed, and adapted to acid or alkaline soil.
Raiden	Japan (Tohoku district), 1966 M. Ishikawa et al. Kariwano Branch, National Regional Tohoku Exper. Sta. Japan	Dry seeds irradiated with 10 krad of ^{60}Co gamma rays (1960) [Nemashirazu]	Earlier maturity, shorter stem (resists lodging); maintains high yield and nematode resistance of original variety.
Raiko	Japan (Tohoku district), 1969 M. Ishikawa et al. Kariwano Branch, National Regional Tohoku Exper. Sta. Japan	Dry seed treatment with 10 krad of ^{60}Co gamma rays (originated from the same R_2 population which gave "Raiden"). (1960) [Nemashirazu]	Earlier maturity, shorter, stem, resists lodging, higher yield; maintains nematode resistance of the original variety. (Raiden, Raiko and their original variety form a set of varieties of different maturities but of similar grain quality, covering a wide area.)
Pea			
Stral-ärt	Sweden, 1954 O.E.V. Gelin Weibullsholm Plant Breeding Institution Landskrona, Sweden	Presoaked seeds irradiated with 15 krad X-rays (1941) [Kloster]	Vigorous development, 2-6% higher seed yield, high regenerative capacity; stable yield.

Name	Place, date, principal worker, institute	Treatment [Parent variety]	Improved Attributes
Navy pea beans			
Sanilac	U.S.A., 1956 A.L. Andersen Michigan State University and U.S.D.A.; E.E. Down, Michigan State U. East Lansing, Mich., U.S.A.	X-rays (1938) [Michelite]	Bush type, early maturity, resistant to alpha, beta and gamma races of *Colletotrichum lindemuthianum* (anthracnose) and bean common mosaic virus 1 and 123. Tolerant to *Sclerotinia sclerotiorum* (wilt or white mold).
Seaway	U.S.A., 1960 A.L. Andersen Michigan State University and U.S.D.A.; M.W. Adams, Michigan State U. East Lansing, Mich., U.S.A.	X-rays (1938) [Michelite]	Short-season, upright bush-type, resistant to bean common mosaic races 1, 15 and 123.
[illegible]iot	U.S.A., 1962 A.L. Andersen Michigan State University and U.S.D.A.; M.W. Adams, Michigan State U. East Lansing, Mich., U.S.A.	X-rays (1938) [Michelite]	Same as for Sanilac except stiffer straw and added resistance to bean common mosaic 15. Higher protein content than Sanilac.
Seafarer	U.S.A., 1967 M.W. Adams, Michigan State U.; A.L. Andersen, U.S.D.A. and Michigan State University, A.W. Saettler, Michigan State U. East Lansing, Mich., U.S.A.	X-rays (1938) [Michelite]	Very early maturity, bush-type, resistant to alpha, beta, gamma races of *Colletotrichum lindemuthianum* and bean common mosaic races 1, 15 and 123.
Haricot bean			
Saparke 75	U.S.S.R., 1967 S.G. Tedoradze Georgian Plant Breeding Station Georgia, U.S.S.R.	Seeds irradiated with 7 kRad of gamma rays (1958) [Tzanava-3]	Surpasses the initial variety on average by 55 dt/ha in green pod yield and 5.2 dt/ha in seed yield. Green pods are devoid of fibre and fixed on the stem 5-5 cm higher, making mechanical harvesting possible. Improved resistance to bacterial diseases.
String bean			
Universal	Germany (Fed.Rep.), 1950 K. Schäfer Samenzucht Göttingen	X-rays, 300 r (1938) [Granda]	Early maturity, higher yield, good resistance to *Colletotrichum lindemuthianum.*
Unima	Germany (Fed.Rep.), 1957 K. Schäfer Samenzucht Göttingen	Selection from Granda x Universal	Immune against *Colletotrichum lindemuthianum,* resistant to *Pseudomonas phaseolicola.*
Peanut			
N.C.4-X	U.S.A., 1959 W.C. Gregory North Carolina Agricultural Experiment Station, U.S.A.	X-rays to dry seeds (1949) [N.C.4]	Tougher hull (resists damage during harvest and transport), high yield, good quality.

Name	Place, date, principal worker, institute	Treatment [Parent variety]	Improved Attributes
Spring rape			
Regina vårraps elite A	Sweden, 1953 Swedish Seed Association Svalöf, Sweden	Seeds X-rayed with 35 krad (1941) [Svalöf's Regina]	Higher seed yield and percent oil.
Regina vårraps elite F	Sweden, 1962 Swedish Seed Association Svalöf, Sweden	Seeds X-rayed with 45 krad (1945) [Svalöf's Regina]	Higher seed yield and percent oil.
White mustard			
Svalöf's Primex	Sweden, 1950 Swedish Seed Association Svalöf, Sweden	Seeds X-rayed with 35 krad (1941) [Svalöf's White Mustard]	Higher seed yield and percent oil.
Castor bean			
Aruna	India, 1969 L.G. Kulkarni Indian Agricultural Research Institute New Delhi, India	Thermal neutrons, 1400 rad (1965)	Very early (120 days vs. 270 days for mother variety). Yield slightly higher.
Tobacco			
Chlorina F_1	Indonesia, 1934 D. Tollenaar Proefstation Vorstenland (Netherl. East Indies)	X-rays (1930) [Vorstenland]	Pale color, high quality of leaf.
Peach			
Magnif 135	Argentina, 1968 L.B.C. de Terraciano Instituto de Fitotecnía INTA, Castelar, Argentina	Chronic irradiation in gamma field (1962-63) [Magnif 43]	Bigger fruits with deeper red skin color; 7 days earlier maturity.
Lespedeza			
Hi-way	U.S.A., 1970/71 E. Donnelly Department of Agronomy Auburn University Alabama, U.S.A.	Thermal neutrons, 2 hrs (1957) [Sericea Lespedeza]	Compact, fine-stem, leafy, good tillering and seedling vigor.
Ornamentals			
Rose			
Desi	Germany (Democr.Rep.), H. Rupprecht Institut für Zierpflanzenbau Humboldt-Universität Berlin	X-rays, 3000 r (1956) [Gloria Dei]	Intensive colors, dark red stripes on yellow petals.

Name	Place, date, principal worker, institute	Treatment Parent variety]	Improved Attributes
Carnation			
UConn White Sim No. 1	U.S.A., 1962 G.A.L. Mehlquist Connecticut Agric.Exp.Sta. New Haven, Conn., U.S.A.	Gamma rays to rooted cuttings White Sim]	Fewer ray flowers, "holds" longer after cutting.
Chrysan-themum			
Dr. X	U.S.A., 1966 P.C. Crandall, W.J.Clore and R.A. Nilan Washington State Agric. Exp. Sta. Vancouver, Prosser and Pullman, Wash., U.S.A.	Rooted cuttings X-rayed with 1200 rad (1963) Dr. Dave]	Darker purple-red flower color.
Izetka Köpenicker Bronce Vogue	Germany (Democr.Rep.), 1962 H. Jank Institut für Zierpflanzenbau Humboldt-Universität Berlin	X-rays, 1000-2500 r (1956) Vogue]	Red-bronze color, incurved type, 15 cm flower diameter.
Izetka Filmstar Bronce	Germany (Democr.Rep.), 1966 H. Jank Institut für Zierpflanzenbau Humbold-Universität Berlin	X-rays, 1000-2500 r (1958) Filmstar]	bronze color, 6-8 flowers per stem, sturdy, dark green foliage.
Izetka Marienhain dunkelrosa	Germany (Democr.Rep.), 1966 Institut für Zierpflanzenbau M. Knuth Humboldt-Universität Berlin	X-rays, 1000-2500 r (1957) Izetka Marienhain]	dark pink, 20 cm flower diameter, 6-8 flowers per stem, weather-resistant.
Izetka Marienhain cremeweiss	Germany (Democr.Rep.), 1966 M. Knuth Institut für Zierpflanzenbau Humboldt-Universität Berlin	X-rays, 1000-2500 r (1957) Izetka Marienhain]	cream white, other attributes as above.
Izetka Marienhain hellgelb	Germany (Democr.Rep.), 1966 M. Knuth Institut für Zierpflanzenbau Humboldt-Universität Berlin	X-rays, 1000-2500 r (1957) Izetka Marienhain]	bright yellow, other attributes as above.
Izetka Herbstgold	Germany (Democr.Rep.), 1964 M. Knuth Institut für Zierpflanzenbau Humboldt-Universität Berlin	X-rays, 1000-2500 r (1959) Izetka Köpenicker Rayonnante]	yellow bronze, ray-shaped petals, sturdy stem, 20 cm diameter.
Izetka Köpenicker Barbarossa Goldkissen	Germany (Democr.Rep.), 1962 H. Jank Institut für Zierpflanzenbau Humboldt-Universität Berlin	X-rays, 1000-2500 r (1958) Barbarossa]	bordeau-red with bright yellow center, windflower-shaped petals, good stem, slightly susceptible to sprays.

Name	Place, date, principal worker, institute	Treatment [Parent variety]	Improved Attributes
Izetka Köpenicker Barbarossa Rotstern	Germany (Democr.Rep.), 1962 H. Jank Institut für Zierpflanzenbau Humboldt-Universität Berlin	X-rays, 1000-2500 r (1958) [Barbarossa]	dull-red with yellow center, other attributes as above.
Dahlia Gracieuse	Netherlands, 1966 C. Broertjes, Association EURATOM-ITAL, Wageningen; J.M. Ballego, Fa. Ballego en Zonen, Leiden, Netherlands	1-4 krad X-rays to dormant tubers (1963) [Salmon Rays]	Violet mauve colored spider-cactus type.
Selection	Netherlands, 1966 C. Broertjes, Association EURATOM-ITAL, Wageningen; J.M. Ballego, Fa. Ballego en Zonen, Leiden, Netherlands	1-4 krad X-rays to dormant tubers (1963) [Salmon Rays]	Larger blooms and longer stems than its parent, but with the same flower color.
Rotonde	Netherlands, 1966 C. Broertjes, Association EURATOM-ITAL, Wageninger; J.M. Ballego, Fa. Ballego en Zonen, Leiden. Netherlands	1-4 krad X-rays to dormant tubers (1963) [Salmon Rays]	Vivid color-true pink flowering mutant with larger blooms than its parent.
Ornamental Rays	Netherlands, 1966 C. Broertjes, Association EURATOM-ITAL, Wageningen; J.M. Ballego, Fa. Ballego en Zonen, Leiden, Netherlands	1-4 krad X-rays to dormant tubers (1963) [Salmon Rays]	Apricot-colored mutant with larger blooms than its parent.
Holland Jubilee	Netherlands, 1967 C. Broertjes, Association EURATOM-ITAL, Wageningen; J.M. Ballego, Fa. Ballego en Zonen, Leiden, Netherlands	1-4 krad of X-rays (1963) [Arthur Godfrey]	Light orange throughout; blooms more firm and regular than the original cultivar.
Progression	Netherlands, 1967 C. Broertjes, Association EURATOM-ITAL, Wageningen; J.M. Ballego, Fa. Ballego en Zonen, Leiden, Netherlands	1-4 krad of X-rays (1963) Arthur Godfrey]	Brick red throughout.
Rosy Mist	Netherlands, 1967 C. Broertjes, Association EURATOM-ITAL, Wageningen; J.M. Ballego, Fa. Ballego en Zonen, Leiden, Netherlands	1-4 krad of X-rays (1963) [Arthur Godfrey]	Empire rosé throughout.

Name	Place, date, principal worker, institute	Treatment [Parent variety]	Improved Attributes
Autumn Harmony	Netherlands, 1967 C. Broertjes, Association EURATOM-ITAL, Wageningen; J.M. Ballego, Fa. Ballego en Zonen, Leiden, Netherlands	1-4 krad of X-rays (1963) [Arthur Godfrey]	Cadmium-orange with scarlet center.
Explosion	Netherlands, 1967 C. Broertjes, Association EURATOM-ITAL, Wageningen; J.M. Ballego, Fa. Ballego en Zonen, Leiden, Netherlands	1-4 krad of X-rays (1963) [Arthur Godfrey]	Bloodred with bright yellow center; massive bloom, full at center and having a very fine habit.
The [illegible]vernor	Netherlands, 1968 C. Broertjes, Association EURATOM-ITAL, Wageningen; K. Maarse, Aalsmeer, Netherlands	2 krad X-rays to dormant tubers (1964) [Authority]	Bloom 18 cm diameter, plant 150 cm tall, deep copper-red flower color.
Dutch Visit	Netherlands, 1968 * Ballego en Zonen, Leiden (in cooperation with EURATOM-ITAL, Wageningen), Netherlands	2 krad of X-rays to dormant tubers (1963) [Arthur Godfrey]	Orange-red flower color; bloom 30 cm diameter (rest of the genotype unchanged).
Temptation	Netherlands, 1968 * Ballego en Zonen, Leiden (in cooperation with EURATOM-ITAL, Wageningen), Netherlands	2 krad of X-rays to dormant tubers (1963) [Arthur Godfrey]	Dark lacquer-red color; giant flower.
Streptocarpus Purple Nymph	Netherlands, 1969 * Institute of Atomic Sciences in Agriculture, Wageningen Netherlands	X-irradiation, colchicine treatment and combined treatment of leaves (1966) [Constant Nymph]	Larger flower and more purple flower color; plant more sturdy. Rest of the genotype unchanged.
[illegible]ni Nymph	Netherlands, 1969 * Institute of Atomic Sciences in Agricuture, Wageningen, Netherlands	X-irradiation of leaves (1966) [Constant Nymph]	Compact growth; very free flowering. Rest of genotype unchanged.
Blue Nymph	Netherlands, 1969 * Institute of Atomic Sciences in Agriculture, Wageningen, Netherlands	X-irradiation of leaves (1966) Constant Nymph]	Light blue flower color, finer plant growth. Rest of genotype unchanged.
Netta Nymph	Netherlands, 1969 * Institute of Atomic Sciences in Agriculture, Wageningen, Netherlands	X-irradiation of leaves (1966) [Constant Nymph]	Dark blue netted and picotee flowers, extremely free flowering.
Cobalt Nymph	Netherlands, 1969 * Institute of Atomic Sciences in Agriculture, Wageningen, Netherlands	Combined treatment of colchicine and X-irradiation (1966) [Constant Nymph]	Compact plant, dark blue flowers, tetraploid.

* C. Broertjes