SPECIAL TECHNIQUES IN MUTATION BREEDING FOR IMPROVING DISEASE RESISTANCE AND NUTRITIONAL QUALITY OF CROPS

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DISEASE RESISTANCE

Introduction

Improvement of disease resistance is a complicated problem because disease manifestation is a result of interaction between two organisms, the plant and the disease.

A disease becomes apparent only when both the organisms have established contact.

Disease-resistant varieties are key factors in increasing yield and keeping crop production safe.

Development of resistant varieties is necessary because chemical control does not always solve the problems due to:

- Cost of fungicide and spraying
- Lack of effective chemicals for many bacterial diseases.
- Complete lack of effective chemical for viruses and viroids.

Genetical considerations

(1) Resistance is often found to be governed by simply inherited Mendelian factors, specially dominant ones.

(2) Resistance is not always controlled by a single pair of genes.

(3) Even if it is, inducing a single mutation for a dominant

allele is far more formidable than inducing a recessive mutation in one of the complementary genes for a single characteristic.

(4) However, many instances of successful mutation breeding for disease resistance have been reported (Induced Mutations against Plant Diseases, STI/PUB/462 and Induced Mutations for Disease Resistance in Crop Plants II, STI/PUB/633, I.A.E.A. Vienna).

Why mutation breeding?

1 - Sources of resistance in germplasm collection may be available but may not be feasible to incorporate into a high performance variety.

2 - Resistance genes are found usually in a limited number of genotypes e.g. Bacterial leaf blight resistance in only 20 out of 1747 accessions (Uchiyamada et al 1977) originating in various corners of the world.

3 - Crossing of acc essions of remote origin with a commerciial variety is difficult because of incompatibility in various stages of sexual reproduction.

4 - Incorporation of a desired gene from a remote origin without bringing in undesirable characters is difficult.

5 - Mutation breeding may be relied upon as another potential gene source.

<u>Some terms and definitions</u> (A.Micke, FAO/IAEA Joint Divn.,IAEA)

1 - A plant is <u>diseased</u> when it is affected by a <u>pathogen.</u> This may be visible <u>symptoms</u> or <u>damage.</u>

2 - A plant may be <u>resistant</u> if it is less affected by a pathogen than another plant of the same species. There are many reasons why a plant may be less affected. We only call it <u>resistance</u>, if the difference to other plants is <u>heritable.</u>

3 - Resistance may be assessed on a <u>plant</u>, or a <u>plot</u> or a <u>field basis</u>. Check in different <u>growth stages</u> and look at different <u>organs</u> or determine the <u>yield</u> to decide whether a plant possesses resistance or not.

4 - If there is no disease, the host plant may be resistant or the pathogen a - virulent. Types of <u>pathogens differing in pathogenicity</u> or <u>virulence</u> are better called <u>pathytypes</u> and not <u>races</u>. Disease development in a field is called <u>epidemic.</u>

5 - A genotype may be diseased but showing less reduction in yield than others; it is <u>tolerant.</u> A plant that is <u>infected</u> but does not develop a disease is not tolerant but <u>latently infected.</u>

6 - Selection for resistance is done by <u>quantifying disease symptoms</u> (e.g. No. of lesions, % leaf area damaged, % plants killed, etc.).

7 - Yield losses passing an economic threshold level require plant protection or resistance breeding.

<u>Inoculation:</u> Job of plant pathologist. He should be a co-worker in the program.

For practical mutation breeding, field screening of the segregating population (M_2 & M_3) is suggested.

Ensure disease development in the field by:

1 - Selecting a piece of land (experimental farm on farmer's field) with previous history of the disease.

2 - Increase probability of disease development by growing same crop in that piece of land in the previous season and also by leaving plant parts (stem, branch, leaf, etc.) in the field.

3 - Sow a few rows of "Spreader" or "bombardment" varieties i.e. susceptible varieties all around the experimental plot and also after each 10th row of the test material. Sow also the motherline beside it.

4 - Create micro-climate in the field conducive to disease development i.e. through irrigation, allowing thick canopy, increasing humidity by covering with plastic etc.

5 - Spray spore suspensions/other crude inoculum on the plants.

6 - In case of YMV, introduce white fly vector (<u>Be missia tabbaci</u>) if population of the fly is not sufficient.

7 - Induce mechanical or other forms of maceration for quick infection of the disease.

Selection and evaluation

- Select resistant/tolerant types
- Repeat same procedure in the next generation and sow plant to progeny rows.
- Select resistant/tolerant lines.
- Take help of a pathologist and inoculate the resistant/tolerant genotypes for reconfirmation. Population will be within a manageable size now.
- Declare/publish.

Two avenues left:

(a) Evaluate for yield. Continue for 2/3 years if equal or higher yield than the motherline.

(b) Cross with the motherline and select for higher yield and disease resistant type.

NUTRITIONAL QUALITY IMPROVEMENT

Two ways

1 - Start screening from M_2/M_3 generation.
- Select about 1000 normal/better looking M_2 or M_3 plants;
- analyze part of the seed from each plant for protein content by fast screening methods like DBC etc.
- select those with higher % of protein than the motherline.
- Grow plant progeny rows and harvest all plants of the row together.

- Samples are big enough, use Kjeldahl method for protein determination.

  Calculation:

  For legumes multiply N% x 6.25

  rice " N% x 5.85

2. Screening from M_4 or M_5 generation.

   - First select for better agromic characters.
   - Then start analyzing seeds for protein content.
   - Select lines with higher yield and equal/better content of protein.
   - It has been possible to select and release a chickpea variety with the fortuitous combination of both increased yield and higher content of protein following this method. (Shaikh et al. 1982).

Table 1. Genetic improvement of grain legumes by mutation breeding: species and countries. (Source: FAO/IAEA Mutation Breeding Newsletter and other IAEA publications)

Target Species	Countries
Arachis hypogaea L. (groundnut)	Argentina, Bangladesh, Burma, China, India, Indonesia, Israel, Malaysia, Philippines, Sri Lanka, Uganda, USA
Cajanus cajan (L.) Millsp. (pigeon pea)	India, Jamaica, Kenya, Sri Lanka
Cicer arietinum L. (chickpea)	Bangladesh, Chile, India, Pakistan
Glycine max L. (soybean)	Algeria, Brazil, Bulgaria, China, CSSR, GDR, Hungary, India, Indonesia, Jamaica, Japan, Korea, Malaysia, Pakistan, Philippines, Poland, Romania, Singapore, Sri Lanka, Thailand, Uganda, USA, USSR, Vietnam, Zaire
Lablab purpureus (L.) Sweet. (hyazinth bean)	India
Lathyrus sativus L. (grass pea)	Bangladesh, India
Lens culinaris Medik. (lentil)	Bangladesh, Chile, India, Pakistan
Lupinus albus L. (white lupin)	USSR
Lupinus angustifolius L. (blue lupin)	Australia
Lupinus cosentinii Guss. (sandplain lupin)	Australia
Lupinus luteus L. (yellow lupin)	Poland
Lupinus mutabilis Sweet. (tarwi)	South Africa
Phaseolus vulgaris L. (bean)	Brazil, Bulgaria, Chile, Costa Rica, CSSR, Egypt, FRG, Guatemala, Italy, Jamaica, Kenya, Malaysia, Peru, Sweden, Uganda, USA, USSR
Pisum sativum L. (pea)	Argentina, Bulgaria, CSSR, Egypt, Finland, FRG, India, Italy, Peru, Poland, Sweden, UK, USSR

Target Species	Countries
Psophocarpus palustris Desv. (Goa bean)	Zaire
Psophocarpus scandens (African winged bean)	Zaire
Psophocarpus tetragonolobus (L.) DC. (winged bean)	Ghana, Malaysia, Papua New Guinea, Philippines Zaire
Vicia faba L. (faba bean)	Austria, Egypt, GDR, Greece, Italy, Poland, Norway
Vigna angularis (Willd.) Ohwi & Ohashi (adzuki bean)	Japan
Vigna mungo (L.) Hepper (black gram)	Bangladesh, India, Pakistan, Sri Lanka, Thailand
Vigna radiata (L.) Wilczek (mungbean)	Bangladesh, India, Indonesia, Korea, Pakistan, Sri Lanka, Thailand, Venezuela
Vigna unguiculata (L.) Walp. (cowpea)	Ghana, India, Kenya, Nigeria, Sri Lanka, Venezuela
Vigna vexillata (L). A. Rich. (Zombi pea)	Zaire
Voandzeia subterranea (L.) Thou (bambarra groundnut)	Ghana

Mieke, 1987.

Table 3. Grain legume cultivars developed with the help of induced mutations

Name of variety	Place and date of release (or approval) and name of principal worker & institute	Kind and date of mutagenic treatment [parent variety] or mutant crosses (mutant underlined)	Main improved attributes of variety
Arachis hypogaea L. (groundnut)			
N.C.4-X	USA, 1959 W.C. Gregory North Carolina Agr.Exp.St. Raleigh	seed, x-rays, 1949 [N.C.4]	tougher hull-resists damage during harvest and transport, high yield, good quality
Yueyou No. 22	China, 1968 Guangdong Acad.Agr.Sci. Guangzhou	_Fushi_ (Beta ray induced mutant) x Fuhuasheng	dwarf type, higher pod number, higher yield, cultivated on more than 100 000 ha
Changhua No. 4	China, 1972 Changwei Regional Inst. of Agric.Sci. Shandong Prov.	seed, 1.5 krad gamma rays (recurrent irradiation) [Fuhuasheng]	early flowering, cold and drought tolerant, dense pods
Colorado Irradiado	Argentina, 1972 Manfredi Experimental Station	20 kR x-rays [Colorado de Cordoba]	higher yield, higher oil content, better resistance to disease
Yueyou No. 551	China, 1972 Guangdong Acad.Agr.Sci. Guangzhou	_Yueyou No. 22_ x Yueyou No. 431	dwarf type of mutant, higher pod number, higher yield, cultivated on more than 100 000 ha

Vikram (TG 1)	India, 1973 S.H. Patil Biology and Agriculture Div. BARC, Trombay, Bombay	55 kR, x-rays [Spanish improved]	large kernels, (TKW 8800 g) particularly suitable for export, 130-135 d till maturity, yield up to 4 t/ha under irrigated conditions
TG 3	India, 1973 S.H. Patil Biology and Agriculture Div. BARC, Trombay, Bombay	15 kR x-rays, 1958 [Spanish improved]	more pods, higher yield, esp. under rainfed conditions
TG 4	India, 1976 S.H. Patil Biology and Agriculture Div. BARC, Trombay, Bombay	15 kR x-rays, 1958 [Spanish improved] Intercross of mutants	uniform maturity, higher yield, esp. under irrigated conditions
TG 17	India, 1977 S.H. Patil Biology and Agriculture Div. BARC, Trombay, Bombay	15 kR x-rays, 1958 [Spanish improved] Intercross of mutants	higher yield, short plants without secondary branching, higher harvest index
Virginia No. 3	Argentina, 1980 Manfredi Experimental Station INTA	gamma irradiation [NC 2]	higher yield of oil
Fu 21	China, 1981 Jiang Xienan Kotaru Asai Zhou Yongxing Agric. Science College of Guandong Province Guangzhou	seeds, 20 krad gamma rays 1968 [Yueyou 22]	higher yield (10% over Yueyou 22); short stem, more branched, better resistance to bact. wilt
Sin Pa detha 1	Burma, 1982 Tin Myint Agric. Res. Institute Yezin Pyinmana	gamma rays, 40 kR, 1977 [Magwe-10, Spanish Type]	10-15 days earlier (85-95 days)

Co 2	India, 1984 M.R. Sivaram S.R. Sree Rangasamy R. Appadurai Tamil Nadu Univ. Coimbatore 641003	soaked seeds 0,2% EMS	high yield
<u>Cajanus cajan</u> (pigeon pea)			
Trombay Vishakha-1	India, 1976 S.E. Pawar, R.G. Thakare, D.C. Joshua, BARC Bombay	fast neutrons, 1972 [T-21]	35% increase in seed size with other characters (yield, maturity time, disease reaction) equal to original variety
Co 3	India, 1977 Tamil Nadu Agric. Univ. Coimbatore	seeds, EMS 0,6% [Co 1]	high yield, bold seeded, higher shelling, field dormancy for 15-20 days
Co 5	India, 1984 Tamil Nadu Agric. Univ. Coimbatore	seeds, gamma rays 16 krad [Co 1]	early maturity, daylength insensitive, drought tolerant
TAT 5	India, 1984 S.E. Pawar, R.G. Thakare G.R. Fulzele, A.N. Patil, A.R. Kshirsagar K.B. Wanjan P.K.V. Akola Nuclear Agriculture Division BARC, Bombay	seed fast neutron, 1,5 krad 1972 [T-21]	ca. 50% larger seed size TKW 100-117 g early maturity (140 d)
TAT 10	India, 1985 S.E. Pawar, K.B. Wanjari A.R. Kshirsagar, G.R. Fulzele P.K.V. Akola Nuclear Agric. Division BARC, Bombay	cross of mutants <u>TT-2</u> (large seed compact) x <u>TT-8</u> (early) both induced by 2,5 krad fast neutron 1972 [T-21]	Medium large grain, extra early maturity (115-120 d)

Cicer arietinum (chickpea)

Hyprosola (M-699)	Bangladesh, 1981 M.A.Q. Shaikh Plant Genetics Division Institute of Nuclear Agric. Mymensingh	gamma rays, 20 kR 1971 [Faridpur-1]	matures 10 days earlier, more pods, higher harvest index, higher planting density feasible, ca. 19% higher yield
CM 72	Pakistan, 1983 A. Ahsanul Haq, A. Shakoor M. Sadiq, Mahmudul Hassan Nuclear Institute for Agric. and Biology (NIAB) Faisalabad	gamma rays, 15 Krad 1974 [6153]	resistant against chickpea blight (*Ascochyta rabiei*), high yield
Kiran (RSG-2)	India, 1984 C.P. Bhatnagar D.K. Saxena S.M. Bhatnagar Sukhadia Univ., Agr.Res.St. Durgapura, Jaipur 302015	seed neutrons $4,5 \times 10^{12} n/cm^2$ [RS-10]	erect habit with increased no. of pods/plant early maturity, salinity tolerant, high yield
Pusa 408 (Ajay)	India, 1985 M.C. Kharkwal, H.K. Jain IARI, New Delhi	60 krad gamma rays [G-130]	highest yielding in N.W. India average yield 2.28 t/ha, potential 3.5 t, resistant to Ascochyta blight, semi-erect, profuse branching; 140-155 days till maturity
Pusa 413 (Atul)	India, 1985 M.C. Kharkwal, H.K. Jain IARI, New Delhi	60 krad gamma rays [G-130]	highest yielding in N.E. India average 1.88 t, potential 3.5 t resistant to wilt, moder. res. to Ascochyta blight, stunt virus, foot rot, root rot; semi-erect, profusely branched, high no. of pods, more than 2 grains/pod, matures in 130-140 d

Pusa 417 (Girnar)	India, 1985 M.C. Kharkwal, H.K. Jain IARI, New Delhi	60 krad gamma rays 1977 [BG 203]	highest yielding in Central India, short, semi-erect, profusely branched, high pod no., matures 110-130 d. 2.1 t/ha, yield potential 3.6 t highly wilt resistant, moderately resistant to stunt virus, collar rot, foot rot, root rot; low pod borer and nematode damage
<u>Dolichos lablab L.</u> (hyacinth bean)			
Co 10	India, 1983 Tamil Nadu Agric. Univ. Coimbatore	seeds, gamma rays 24 krad [Co 6]	high yielding, bushy type with greenish white tubular pods
<u>Glycine max.</u> (soybean)			
Tainung No.1 (R)	China, 1962 Y.M. Cheng Taiwan Province Agricultural Research Institute	thermal neutrons	vigorous dropping resistant variety with long branches and higher yield
Tainung No.2(R)	China, 1962 Y.W. Cheng Taiwan Province Agricultural Research Institute	x-rays	vigorous, dropping resistant variety with short internode, large seed, and adapted to acid or alkaline soil
Universal I	USSR, 1965 Tedoradze S.G. Georgian Plant Breed. Station	gamma rays [Imeretinskaya]	surpasses initial variety by 500 kg/ha in grain yield, is lodging resistant, can be used as grain crop or as green fodder

Raiden	Japan, 1966 M. Ishikawa Kariwano Branch National Regional Tohoku Experiment Station	dry seeds, 10 krad ^{60}Co gamma-rays 1960 [Nemashirazu]	earlier maturity, shorter stem (resists lodging), maintains high yield and nematode resistance of original variety
Heinong No. 4	China, 1967 Heilongjiang Acad.of Agric.Sci. Harbin	seeds, gamma rays 10 kR [Mancangjin]	compact branched type
Heinong No. 5	China, 1967 Heilongjiang Acad.of Agric.Sci. Harbin	seeds, gamma rays 10 kR [Dongnong No. 4]	good root system, short internode, higher branch and pod number
Heinong No. 6	China, 1967 Heilongjiang Acad.of Agr. Sciences Harbin	seeds, gamma-rays 10 kR [Mancangjin]	tall plants, drought tolerant
Heinong No. 7	China, 1967 Heilongjiang Acad.of Agric.Sci. Harbin	seeds, gamma rays 10 kR [Dongnong No. 4]	good root system, short internode, higher branch and pod number
Heinong No. 8	China, 1967 Heilongjiang Acad.of Agric.Sci. Harbin	seeds, gamma rays 10 kR [Dongnong No. 4]	10 days earlier than original variety, humidity tolerance
Raiko	Japan, 1969 M. Ishikawa Kariwano Branch National Regional Tohoku Experiment Station	dry seeds, 10 krad ^{60}Co gamma-rays (originated from same M_2 population which gave "Raiden") 1960	earlier maturity, shorter stem (resists lodging), higher yield, maintains nematode resistance of original variety
Fengshou No. 11	China, 1970 Keshan Inst.of Agr.Sci. Heilongjiang Province	seeds, 14 krad gamma rays [Ke 56-4285]	30 days earlier than parent, strong stem, lodging resistant, high number of branches

Heinong No. 16	China, 1970 Heilongjiang Acad.of Agric. Sci. Harbin	seeds, gamma rays 10 kR [F_2 (Wudingzhu x Jingshanpu)]	higher branch number, short internode, drought tolerance, wide adaptability, cultivated on more than 100 000 ha
Tiefeng 18	China, 1973 Tieling Regional Inst.of Agr.Sci. Liaoning	seeds, gamma rays 12 kR [45-15/5621]	fertility tolerance, lodging resistance, higher yield, good quality, cultivated on more than 100 000 ha
KEX-2	Korea, 1973 S.H. Kwon, K.H. Im KAERI, Seoul	24 krad x-rays 1963 [Keum Kang-Dai-Rip]	earlier maturity (11 days), higher yield (16%), large seed size
Heinong No. 26	China, 1975 Heilongjiang Acad.of Agric. Sci. Harbin	HAR 63- 2294 x Xiaojinhuang No. 1	good stature, cold, drought and waterlogging tolerance, good quality, cultivated on more than 100 000 ha
Nanbushirome	Japan, 1977 S. Matsumoto, et al Tohoku Agric. Exp. Station Uenodai, Kariwano Nishisenpoku-machi Akita-ken 019-21	Raiden x Kitaminagaha	changed towards intermediate maturing time, long leaf, high yield, resistant to cyst nematode
Cerag Nr. 1	Algeria, 1979 I. Nicolae, B. Ougouag F. Nicolae, T.F. Benabaad CERAG El-Harrach	30 kR gamma rays 1972 [B 107/10]	(mutant selected in Romania 1974 by I. Nicolae) early, resistant against spring cold, very productive, drought resistant, short plant type, white flowers, yellow seeds

Mushi No. 6	China, 1980 Mudanjiang Normal College Heilongjiang	seeds, gamma rays 12 kR [F_2 (Fengshou No.10 x Jilin No.3)]	early maturity, lodging resistant, strong plants, high yield, high quality
Boriana	Bulgaria, 1981 A. Mehandjiev, P. Gecheva Inst. of Genetics Bulgarian Academy of Sciences Sofia	seeds, 12% moisture gamma-rays, 10 krad followed by 0.1% EMS 4h 1976 [Beeson]	maturing in 105-110 days, 30 days earlier than "Beeson" protein content 5% higher, yield 4000 kg/ha or 6% higher than Beeson
Liaodou No.3	China, 1983 Institute for Appl.of Atomic Energy Liaoning Acad.Agr.Sci.	seeds, gamma rays 6405 x Amuson	early maturing, strong stem, resistant to lodging, resistant to virus and Sclerophotora macrospora, tolerant to water logging
Aida (HM-S-78)	CSSR, 1984 Z. Hruby, B. Zdrahalova B. Hradil Res. and Breed. Inst. of Technical Crops and Leg. Sumperk-Temenice Plant Breed. Stat. of Legumes Horní Mostenice	seeds EMS 1974 [Smena]	18 days earlier than Dunajka (140 days) yield ca. 2.2 t/ha stem type
Bangsa-Kong (CB27-25-27)	Rep. of Korea, 1985 S.H. Kwon H.S. Song J.H. Oh KAERI Seoul	seeds x-ray 25 kR [CB-27]	due to higher no. of pods high seed yield 2.5 t/ha smaller seed to fit soybean sprout, resistance to SMV N
Heinong 28	China, 1986 Soybean Institute Heilongjiang Acad. of Agric. Sci. Harbin	seeds, thermal neutrons $5x10^{11}$ N/cm^2 [Heinong No. 16 x Zyuushoo Nagaka]	growth period 121 d, strong stem, yield high (2.79 t/ha), good quality (protein 38.7%, fat 21.3%)

Lens culinaris Medik. (lentil)

S-256 (Ranjan)	India, 1981 (West Bengal) S.N. Sen Pulses and Oil Res. Station Berhampora 742101	good radiation [B 77]	spreading type, high yield 110 days to mature

Lupinus albus L.(white lupin)

Kievsky	USSR, 1969 W.I. Golovchenko F.F. Juchimchuk, W.G. Kucherenko Ukrainian Institute of Agronomy, Kiev	(F_1) 25 krad 1958 (F_2) 25 krad 1959 (fractionally 300-400 rad) [Hvanchkoly x sample from Syria]	high grain and forage yields, less alkaloid, high protein (44%) and lysine (6.8%) contents
Gorizont	USSR, 1977	cross with alkaloid free mutant induced by EI	low alkaloid content
Dnepr	USSR, 1978	cross with mutant induced by EI	

L. angustifolius L.(blue lupin)

Chittick	Australia, 1982 J.D. Gladstones Div. of Plant Production Dept. of Agriculture South Perth 6151	seed treatment, 1961 0,24% EI [Borre] several crosses with selected early flowering mutant	early flowering

L. cosentinii Guss. (sandplain lupin)

Eregulla	Australia, 1972 J.S. Gladstones Department of Agriculture South Perth 6151	complex crossing of mutants [Chapman]	low alkaloid, early flowering, white flowers and seeds (non-shattering)

L. luteus L. (yellow lupin)			
Aga	Poland, 1981 J. Mikolajczyk E. Peikow, Plant Breeding Station, Przebedowo	seeds x-rays, 1956 (mutant population x Afus)	early maturing, resistant to Fusarium, high yield potential
Phaseolus vulgaris L. (bean)			
Universal	Fed. Rep. of Germany, 1950 K. Schäfer Samenzucht Göttingen	300 R x-rays 1938 [Granda]	early maturity, higher yield, good resistance to Colletotrichum lindemuthianum
Sanilac	USA, 1956 A.L. Andersen Michigan State University and USDA; E.E. Down, Michigan State University East Lansing, Mich.	x-rays 1938 [Michelite] selection from cross involving Michelite mutant, Robus, Crawford, Robus, Crawford, Emerson 847 and Emerson 53	bush type, early maturity, resistant to alpha, beta and gamma races of Colletotrichum lindemuthianum and bean common mosaic virus 1 and 123, tolerant to Sclerotinia sclerotiorum (wilt or white mould)
Unima	Fed. Rep. of Germany, 1957 K. Schäfer Samenzucht Göttingen	selection from Granda x Universal	immune to Colletotrichum lindemuthianum, resistance to Pseudomonas phaseolicola
Seaway	USA, 1960 A.L. Andersen Michigan State University and USDA; M.W. Adams Michigan State University East Lansing, Mich.	x-rays 1938 [Michelite] selection from cross involving Michelite, Michelite mutant and Topcross	short-season, upright bush-type, resistant to bean common mosaic virus 1, 15 and 123

Gratiot	USA, 1962 A.L. Andersen Michigan State University and USDA; M.W. Adams Michigan State University East Lansing, Mich.	x-rays 1938 [Michelite] selection from cross involving Michelite, Michelite mutant and B 1788	same as for Sanilac expect stiffer straw, added resistance to bean common mosaic virus 15, higher protein content
Seafarer	USA, 1967 M.W. Adams Michigan State University A.L. Andersen, USDA and Michigan State University; A.W. Saettler Michigan State University East Lansing, Mich.	x-rays 1938 [Michelite] selection from cross involving Michelite, Michelite mutant, Trag 279, Florida Belle and Emerson 847	very early maturity, bush-type, resistant to alpha, beta, gamma races of <u>Colletotrichum lindemuthianum</u> and bean common mosaic virus 1, 15 and 123
Saparke 75	USSR, 1967 S.G. Tedoradze Georgian Plant Breeding Station Georgia	seeds, 7 krad gamma-rays 1958 [Tzanava-3]	surpasses initial variety on average by 5.5 t/ha in green pod yield and 0.52 t/ha in seed yield, green pods devoid of fibre and 5-6 cm higher on stem, making mechanical harvesting possible, improved resistance to bacterial diseases
Pusa Parvati	India, 1970 H.S. Gill, V. Swarup Indian Agricultural Research Institute New Delhi	dry seeds (10%) x-rays 1959 [Wax Podded]	early bushy type with attractive round meaty, light-green pods, 40-45 days maturity, about 45% higher yield
Alfa	CSSR, 1972 A. Hanisova, M. Hanis, V. Nemec H. Slavickova, I. Branzovsky Plant Breed. Station Stupice	EMS 0,2% 1966 [Black bean]	white seed colour, improved seed and protein yield, earliness, resistance to <u>Colletotrichum lindemuthianum</u>, good cooking quality

Giza 80	Egypt, 1980 H.A.S. Hussein, J.A. Disunki Dept. of Genetics Faculty of Agriculture University of Cairo, Giza	10 kR gamma rays [Fin de Villeneuve]	rust resistant, 12% higher yield, higher TGW, white seed coat, higher protein content, cooking time for dry seeds reduced
Ouray	USA, 1982 D.R. Wood Colorado State University Fort Collins Co. 80523	cross (Sanilac x U.I.111) x rust resistant pinto selection	Bush habit derived from mutant variety "Sanilac". Resistance to bean common mosaic virus and some races of *Uromyces phaseoli*
Neptune	USA, 1986 M.W. Adams et al. Michigan State Univ. East Lansing	cross MSU 31906/ San Fernando/Seafarer	maintains plant architecture derived from Seafarer
Pisum sativum L. (pea)			
Stral-ärt	Sweden, 1954 O.E.V. Gelin Weibullsholm Plant Breeding Institution Landskrona	presoaked seeds, 15 krad x-rays 1941 [Kloster]	vigorous development, 2-6% higher seed yield, high regenerative capacity, stable yield
Moskovsky 73	USSR, 1974 G.A. Debeliy and O.I. Bezhanidze Agric. Inst. Central Regions of Noncherozem Zone Nemchinovka, Moscow Region	DES, 0.03%, 1967 [Nemchinovsky 766]	larger grain, higher protein content
Hans	India, 1979 B. Sharma Division of Genetics, IARI New Delhi	E.I. 1967 [P1163]	higher yield

Wasata	Poland, 1979 J.K. Jaranowski Inst. Gen. and Plant Breed. Acad. of Agric. Poznan J. Mikolajczyk, K. Korlub Plant Breeding Station Przebedowo	50 krad gamma rays, 1965 [line 5/2]	change of leaflets to tendrils (high harvest index), early maturing (ca. 103 days), high yield, lodging resistant, fodder pea. Suitable for combine harvest
Sum	Poland, 1979 J.K. Jaranowski Inst. Gen. and Plant Breed. Acad. of Agric. Poznan J. Mikolajczyk, M. Kielpinski Plant Breed. Station Przebedowo J. Styczynska, Inst. of Plant Breeding, Radzikow	Cross Porta x Wasata	shorter plant type, larger seed than Wasata, very high yield potential, edible pea
Esedra	Italy, 1980 F. Saccardo, C.M. Monti P. Vitale CNEN Lab. Agricoltura CSN Casaccia	x-rays, 750 rad pollen 1971 [Sprinter]	4 days later flowering, increased yield, more contemporary pod setting, better suitable for mechanical harvesting
Navona	Italy, 1980 F. Saccardo, C.M. Monti P. Vitale CNEN Lab. Agricoltura CSN Casaccia	x-rays, 750 rad, pollen, 1971 [Sprinter]	one week later flowering, reduced plant height, more contemporary pod setting, longer period for canning
Hamil	Poland, 1981 J. Jaranowski Inst. of Genetics Acad. of Agric. Poznan J. Mikolajczyk, H. Strykala Plant Breeding Station Przebedowo	Cross (Wasata x I.6L/78) x Porta	change of leaflets to tendrils, early maturity, high yield, lodging resistant; suitable for combine harvest

Wasata	Poland, 1979 J.K. Jaranowski Inst. Gen. and Plant Breed. Acad. of Agric. Poznan J. Mikolajczyk, K. Korlub Plant Breeding Station Przebedowo	50 krad gamma rays, 1965 [line 5/2]	change of leaflets to tendrils (high harvest index), early maturing (ca. 103 days), high yield, lodging resistant, fodder pea. Suitable for combine harvest
Sum	Poland, 1979 J.K. Jaranowski Inst. Gen. and Plant Breed. Acad. of Agric. Poznan J. Mikolajczyk, M. Kielpinski Plant Breed. Station Przebedowo J. Styczynska, Inst. of Plant Breeding, Radzikow	Cross Porta x Wasata	shorter plant type, larger seed than Wasata, very high yield potential, edible pea
Esedra	Italy, 1980 F. Saccardo, C.M. Monti P. Vitale CNEN Lab. Agricoltura CSN Casaccia	x-rays, 750 rad pollen 1971 [Sprinter]	4 days later flowering, increased yield, more contemporary pod setting, better suitable for mechanical harvesting
Navona	Italy, 1980 F. Saccardo, C.M. Monti P. Vitale CNEN Lab. Agricoltura CSN Casaccia	x-rays, 750 rad, pollen, 1971 [Sprinter]	one week later flowering, reduced plant height, more contemporary pod setting, longer period for canning
Hamil	Poland, 1981 J. Jaranowski Inst. of Genetics Acad. of Agric. Poznan J. Mikolajczyk, H. Strykala Plant Breeding Station Przebedowo	Cross (Wasata x I.6L/78) x Porta	change of leaflets to tendrils, early maturity, high yield, lodging resistant; suitable for combine harvest

Ti-Nova	GDR, 1986 R. Steuckardt M. Dietrich H. Griem VEG Pflanzenproduktion Gotha-Friedrichswerth	cross with x-ray induced ti mutant	terminal inflorescence 70-90 cm, improved lodging resistance; earlier and more uniform maturity; suitable for combine harvest

Vigna angularis Willd. (adzuki bean)

Beni-nambu	Japan, 1978 Iwate Prefect. Agric. Exp. Station Iwate-gun 020-01	gamma rays, 1969 [Mombetsu 26]	early maturing, shorter stem, good seed colour, uniform seed size, high yield

Vigna mungo L. (black gram)

Co 4	India, 1978 Tamil Nadu Agric.Univ. Coimbatore 641 003	seeds, MMS 0.02% [Co 1]	early maturing, erect, compact, determinate, day-length tolerant
TAU 1	India, 1985 S.E. Pawar, R.G. Thakare A.R. Kshirsagar, P.B. Ghawagawe G.R. Fulzele, K.B. Wanjari P.K.V. Akola	cross, T-9 x 4-196 (mutant induced by gamma rays 1976) [No. 55]	Yield 8,6% over T-9 and 24.4% over no. 55, larger seed size moderately resistant to powdery mildew

Vigna radiata L. (mungbean)

Co 4	India, 1982 Tamil Nadu Agric.Univ. Coimbatore	seeds, gamma rays 20 krad [Co 1]	high yield, matures in 85 days; drought tolerant

Pant Moong 2	India, 1982 D.P. Singh, B.L. Sharma Dept. of Plant Breeding G.B. Pant Univ. of Agric. and Techn. Pantnagar 263141	gamma rays, 10 kR, 1976 [ML 26]	moderately resistant to mungbean yellow mosaic virus, higher yield
TAP-7	India, 1982 S.E. Pawar, R.G. Thakare BARC Bombay B.T. Kshirsajar, G.R. Fulzele, Pulses Research Unit Punjabrao Krishi Vidyapeeth Akaya, Maharashtra	gamma rays, 1975 [S-8]	5-7 days earlier maturity, fairly tolerant to powdery mildew and leaf spot disease, 23% higher yield than cv Kopergaon
NIAB Mung-28	Pakistan, 1983 I. A. Malik, M. Sadiq, M.A. Haq, G. Sarwar Nuclear Institute for Agric. and Biology (NIAB) Faisalabad	gamma rays, seeds 20 krad, [Pak 17]	early and uniform maturity, high yield, better nitrogen fixation
NIAB Mung 19-19	Pakistan, 1985 I.A. Malik, G. Sarward, Y. Ali NIAB Faisalabad	gamma rays 40 kR [Pak 22]	takes 60-65 d instead of 90-95 d to harvest; determinate type, yields 35% more than standard variety 6601; recommended for spring and summer crop
NIAB Mung 121-25	Pakistan, 1985 I.A. Malik, G. Sarwar, Y. Ali NIAB Faisalabad	gamma rays 20 kR [RC 71-27]	takes 60-65 d instead of 90-95 d to harvest; determinate type, yields 44% more than standard variety 6601; recommended for spring and summer crop
NIAB Mung 13-1	Pakistan, 1986 I.A. Malik, G. Sarwar Y. Ali NIAB Faisalabad	seeds, gamma rays 10 krad [6601]	earlier (56 d), shorter, more pods, harvest index 28%; TGW 40.5 g, 44% higher yield than 6601 suitable as catch crop

NIAB Mung 20-21	Pakistan 1986 I.A. Malik, G. Sarwar Y. Ali NIAB Faisalabad	seeds, gamma rays 40 krad [Pak 22]	earlier (56 d), shorter than NMB-1, more pods, harvest index 31%; TGW 38.6 g. 65% higher yield than Pak 22, better tolerant to yellow mosaic and Cercospora leaf spot; suitable as catch crop
Vigna unguiculata L.(cowpea)			
V16 (Amba)	India, 1981 B. Sharma IARI, Div. of Genetics New Delhi	seeds DMS 1966 [Pusa Phalguni]	highest yielding variety of cowpea in India. Resistant to fungal and bacterial diseases
V37 (Shreshtha)	India, 1981 B. Sharma IARI, Div. of Genetics New Delhi	seeds DMS 1966 [Pusa Phalguni]	high yield, luxuriant vegetative growth, therefore also suitable as green fodder
V38 (Swarna)	India, 1981 B. Sharma IARI, Div. of Genetics New Delhi	seeds DMS 1966 [Pusa Phalguni]	high yield, early maturity, synchronous flowering, better quality pods and grain. Almost immune to most diseases of the region
V240	India, 1984 B. Sharma IARI, Div. of Genetics New Delhi	seeds DMS 1966 [Pusa Phalguni]	high yield, resistant to all major fungal, bacterial and viral diseases
ICV 11 (Reg. no. 62)	Kenya, 1985 R.S. Pathak J.C. Olela ICIPE Nairobi	seed, gamma radiation [ICV1]	Semi-erect, large leaves, green stems, green pods matures in 65 d, yield 1100 kg/ha, resistant to cowpea aphids

ICV 12 (Reg. no. 63)	Kenya, 1985 R.S. Pathak J.C. Olela ICIPE Nairobi	seed, gamma radiation [ICV 1]	Similar to ICV 11 but slightly higher yield, resistant to cowpea aphids
Co 5	India, 1986 Tamil Nadu Agric.Univ. Coimbatore 641003	seeds, gamma rays 30 krad [Co 1]	forage cowpea, more nutritive, 16% higher yield, compatible for intercropping with fodder cereals

Tab. 4. Number of mutant cultivars of grain legumes according to year of release

	Total	derived from cross with mutant
before 1952	1	0
1952–1956	2	1
1957–1961	3	2
1962–1966	5	1
1967–1971	13	2
1972–1976	13	4
1977–1981	25	7
1982–1986	38	12
	100	29

Tab. 5. Mutagens used for released mutant cultivars of grain legumes

Radiation	
Gamma rays	53
X-rays	24
fast neutrons	3
thermal neutrons	3
beta rays	1
Chemical mutagens	
EMS	4
EI	4
DMS	4
DES	1
MMS	1

Tab. 6. Main improved characters reported for mutant cultivars of grain legumes

Yield	
higher grain yield	57
higher pod number	12
larger seed	9
shattering resistant	2
smaller seed	1
better N_2-fixation	1
Plant architecture	
dwarf or bushy type	17
more lodging resistant	17
improved architecture	13
erect or tall type	8
higher "harvest index"	2
Maturity time	
earlier maturity	39
altered maturity time	5
more uniform maturity	4
daylength tolerant	2
Quality	
better grain quality	7
more grain protein	4
less alkaloid	3
more oil	2
Resistance	
more disease resistant	26
aphid resistant	2
nematode resistant	1
resistant to mechanical damage	1
Tolerance	
better tolerance to drought	7
better tolerance to cold	3
better tolerance to saline, acid or alkaline sols	2
better tolerance to high humidity	1
better tolerance to high soil fertility (N)	1