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農研機構研究報告　次世代作物開発研究センター　第１号

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農研機構研究報告　次世代作物開発研究センター　第１号

（平成 29 年 7 月）

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「日本のコムギコアコレクション」の作成と評価

小島久代・藤田雅也・松中　仁[*1]・関　昌子[*2]・
蝶野真喜子・乙部(桐淵)千雅子・高山敏之・小田俊介

抄　　録

遺伝資源の有効利用を目的として、これまでに多くの主要作物でコアコレクションの開発が行われてきた。近年のゲノム研究の進展などから、日本のコムギにおいてもコアコレクションの選定が強く望まれてきた。著者らは日本の在来品種と最近の育成品種の来歴情報をもとに 96 品種を選定し、農業・食品産業技術総合研究機構（農研機構）遺伝資源センタージーンバンクに「日本のコムギコアコレクション」として登録し利用できるようにした。これら 96 品種について特性評価および育種上重要な形質を支配する遺伝子の遺伝子型の調査を行った結果を紹介する。

キーワード：コムギ、コアコレクション、遺伝資源、遺伝的多様性、特性評価

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Development and Evaluation of the Core Collection of Japanese Wheat Varieties

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Abstract

Core collections as a tool for effective utilization of genetic resources have been developed in many major crops. With the progress of plant genomics, the core collection of Japanese wheat varieties had been also required. The authors selected 96 varieties consisting of Japanese landraces and recent breeding varieties based on their geographical and genealogical information and registered them to Genetic Resources Center, NARO（NGRC）Genebank as 'Japanese wheat core collection'. In this article, we report evaluation data, including some genotypes important for breeding, of the core collection.

Key Words : wheat, core collection, genetic resource, genetic diversity, characteristic evaluation

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Ⅰ　緒　　言

保存されている膨大な数の遺伝資源の中から、全体の遺伝的多様性を反映するように最小限の品種・系統を選定して構成したコアコレクションは、遺伝資源を評価、利用する上で大変有効なものである（Frankel 1984）。農業特性、形態特性、来歴、DNA マーカー多型などの情報をもとに多くの主要作物でコアコレクションの作成が実施され（Odong *et al.* 2013）、日本においても農研機構遺伝資源センタージーンバンクがイネ、ダイズをはじめとするコアコレクションを開発した（https://www.gene.affrc.go.jp/databases-core_collections.php）。

コムギにおいても、容易に変異の程度を推定できるコアコレクションの選定が強く望まれてきたが、本コアコレクション作成時点ではコムギ遺伝資源のゲノム情報はまだ少なく、著者らは「麦類品種一覧」（農林省関東東山農業試験場 1959）と、近年の育成品種の系譜（福永・稲垣 1985）をもとに 96 品種を選定し、農研機構遺伝資源センタージーンバンクに「日本のコムギコアコレクション」として登録し利用できるようにした。

その内訳は在来品種もしくは純系選抜のみによる育成品種が 44 品種、近代の交配育種由来の育成品種が 51 品種で、将来的なゲノム情報の利用を想定して遺伝学標準系統である Chinese Spring を加え、計 96 品種とした。選定にあたって、在来品種および 1955 年以前の育成品種については、当時の農林省のジーンバンクに当たる関東東山農業試験場（埼玉県鴻巣市）の麦育種材料研究室がとりまとめた「麦類品種一覧」に掲載されている主要品種別作付面積の変遷をもとに、各地域をカバーするように作付面積の多い品種を年代別に選定した。また、1956 年以降の育成品種およびその系譜上の親は、福永・稲垣（1985）が作成した日本のコムギ育成系譜図をカバーできるように近縁度や系譜の出現頻度等を考慮して、最終的に 96 品種に絞り込んだ。なお、「NIAS コアコレクション」として配布するため、ジーンバンクが保有し、配布可能な品種から選定した。

ユーザーの利用を考え、これら 96 品種について出穂期、成熟期、稈長、穂型などの重要形質について特性評価および育種上重要な形質を支配する遺伝子の遺伝子型の調査を行った結果を紹介するとともに、品種が成立した場所と時代の視点から考察した。

Ⅱ　構成品種の成立地域・年代による区分

特性評価と遺伝子型調査の結果を品種が成立した地域と時代の視点から考察するために、各品種の成立地域を「北海道」、「東北・北陸」、「関東・甲信・東海」、「近畿・中国・四国・九州」の 5 区分に、成立した時代を「在来品種および純系選抜のみによる育成」、「1955 年以前の育成」、「1956 年 −1975 年の育成」、「1976 年以降の育成」の 4 区分に分類した（表 1）。

表 1　日本のコムギコアコレクションの構成品種一覧およびその品種成立地域と成立時代による分類

ID[1]	品種名	原産地	成立年もしくは栽培時期	地域区分[2]	成立時期[3]	ID	品種名	原産地	成立年もしくは栽培時期	地域区分[2]	成立時期[3]
JWC 01	赤皮赤	北海道	1906(明治39)年奨励品種	北海道	1	JWC 49	鴻巣25号	埼玉	1937(昭和12)年以前	関東・甲信・東海	2
JWC 02	白肌	北海道	不明	北海道	1	JWC 50	埼玉27号	埼玉	1918(大正7)年に交配	関東・甲信・東海	2
JWC 03	ドーソン1号	北海道	1923(大正12)年奨励品種	北海道	1	JWC 51	関東107号	茨城	1984(昭和59)年	関東・甲信・東海	4
JWC 04	札幌春小麦	北海道	1906(明治39)年奨励品種	北海道	1	JWC 52	伊賀筑後オレゴン	長野	1919(大正8)年奨励品種	関東・甲信・東海	2
JWC 05	相州2号	青森	1931(昭和6)年奨励品種	東北・北陸	1	JWC 53	極早生4-15	広島	1958(昭和33)年に交配	近畿・中国・四国・九州	3
JWC 06	資選1号	岩手	1920(大正9)年奨励品種	東北・北陸	1	JWC 54	小麦農林1号	岩手	1929(昭和4)年	東北・北陸	2
JWC 07	在来フルツ	岩手	不明	東北・北陸	1	JWC 55	春播小麦農林3号	北海道	1930(昭和5)年	北海道	2
JWC 08	西村	山形	1932(昭和7)年奨励品種	東北・北陸	1	JWC 56	小麦農林9号	愛知	1935(昭和10)年	関東・甲信・東海	2
JWC 09	白莢	茨城	不明	関東・甲信・東海	1	JWC 57	小麦農林10号	岩手	1935(昭和10)年	東北・北陸	2
JWC 10	富国	茨城	1912(大正1)年奨励品種	関東・甲信・東海	1	JWC 58	小麦農林16号	群馬	1936(昭和11)年	関東・甲信・東海	2
JWC 11	赤稈茨城1号	茨城	1906(明治39)年取り寄せ	関東・甲信・東海	1	JWC 59	小麦農林26号	奈良	1937(昭和12)年	近畿・中国・四国・九州	2
JWC 12	白三尺	茨城	不明	関東・甲信・東海	1	JWC 60	小麦農林27号	岩手	1937(昭和12)年	東北・北陸	2
JWC 13	赤ボロ1号	栃木	1921(大正10)年奨励品種	関東・甲信・東海	1	JWC 61	小麦農林39号	岩手	1939(昭和14)年	東北・北陸	2
JWC 14	新田早生	群馬	不明	関東・甲信・東海	1	JWC 62	硬質小麦農林42号	群馬	1939(昭和14)年	関東・甲信・東海	2
JWC 15	スネキリ15号	群馬	1922(大正11)年奨励品種	関東・甲信・東海	1	JWC 63	小麦農林50号	群馬	1942(昭和17)年	関東・甲信・東海	2
JWC 16	赤坊主	埼玉	不明	関東・甲信・東海	1	JWC 64	小麦農林53号	愛知	1943(昭和18)年	関東・甲信・東海	2
JWC 17	細稈	千葉	1915(大正4)年奨励品種	関東・甲信・東海	1	JWC 65	小麦農林55号	岩手	1943(昭和18)年	東北・北陸	2
JWC 18	白達摩	神奈川	1932(昭和7年)奨励品種	関東・甲信・東海	1	JWC 66	小麦農林61号	佐賀	1944(昭和19)年	近畿・中国・四国・九州	2
JWC 19	赤達摩	神奈川	1932(昭和7年)奨励品種	関東・甲信・東海	1	JWC 67	小麦農林67号	群馬	1944(昭和19)年	関東・甲信・東海	2
JWC 20	早生小麦	神奈川	1932(昭和7年)奨励品種	関東・甲信・東海	1	JWC 68	春播小麦農林75号	北海道	1947(昭和22)年	北海道	2
JWC 21	赤小麦	山梨	1916(大正5)年奨励品種	関東・甲信・東海	1	JWC 69	北栄	北海道	1954(昭和29)年	北海道	2
JWC 22	渋不知	長野	1916(大正5)年奨励品種	関東・甲信・東海	1	JWC 70	ムカコムギ	北海道	1968(昭和43)年	北海道	3
JWC 23	古志郡在来種	新潟	不明	東北・北陸	1	JWC 71	ホロシリコムギ	北海道	1974(昭和49)年	北海道	3
JWC 24	白チャボ	三重	不明	関東・甲信・東海	1	JWC 72	タクネコムギ	北海道	1974(昭和49)年	北海道	3
JWC 25	サコボレ	静岡	1932(昭和7)年奨励品種	関東・甲信・東海	1	JWC 73	ハルヒカリ	北海道	1965(昭和40)年	北海道	3
JWC 26	新中長	兵庫	1925(大正14)年奨励品種	近畿・中国・四国・九州	1	JWC 74	アオバコムギ	岩手	1951(昭和26)年	東北・北陸	2
JWC 27	畠田小麦	岡山	1919(大正8)年奨励品種	近畿・中国・四国・九州	1	JWC 75	ヒツミコムギ	岩手	1953(昭和28)年	東北・北陸	2
JWC 28	優勝旗347	岡山	不明	近畿・中国・四国・九州	1	JWC 76	フルツマサリ	岩手	1956(昭和31)年	東北・北陸	3
JWC 29	広島シプレー	広島	不明	近畿・中国・四国・九州	1	JWC 77	ユキチャボ	新潟	1952(昭和27)年	東北・北陸	2
JWC 30	無芒珍子	広島	1922(大正11)年奨励品種	近畿・中国・四国・九州	1	JWC 78	ヒカリコムギ	新潟	1952(昭和27)年	東北・北陸	2
JWC 31	ヒラキ小麦	鳥取	不明	近畿・中国・四国・九州	1	JWC 79	フクホコムギ	埼玉	1979(昭和54)年	関東・甲信・東海	4
JWC 32	中相州	香川	不明	近畿・中国・四国・九州	1	JWC 80	フクワセコムギ	広島	1983(昭和58)年	近畿・中国・四国・九州	4
JWC 33	宝満	栃木	不明	関東・甲信・東海	1	JWC 81	アブクマワセ	福岡	1992(平成4)年	近畿・中国・四国・九州	4
JWC 34	赤竹1号	愛知	1922(大正11)年奨励品種	関東・甲信・東海	1	JWC 82	ホクシン	北海道	1995（平成7)年	北海道	4
JWC 35	江島神力	福岡	大正奨励品種	近畿・中国・四国・九州	2	JWC 83	チホクコムギ	北海道	1981(昭和56)年	北海道	4
JWC 36	伊賀筑後	佐賀	不明	近畿・中国・四国・九州	1	JWC 84	ハルユタカ	北海道	1985(昭和60)年	北海道	4
JWC 37	白小麦	佐賀	不明	近畿・中国・四国・九州	1	JWC 85	ナンブコムギ	岩手	1951(昭和26)年	東北・北陸	2
JWC 38	筑前	佐賀	不明	近畿・中国・四国・九州	1	JWC 86	キタカミコムギ	岩手	1959(昭和34)年	東北・北陸	3
JWC 39	1号早小麦	熊本	1922(大正11)年奨励品種	近畿・中国・四国・九州	1	JWC 87	シラネコムギ	長野	1986(昭和61)年	関東・甲信・東海	4
JWC 40	白ブンブ	熊本	1916(大正5)年奨励品種	近畿・中国・四国・九州	1	JWC 88	バンドウワセ	茨城	1990(平成2)年	関東・甲信・東海	4
JWC 41	阿蘇在来（有芒褐ぷ）	熊本	不明	近畿・中国・四国・九州	1	JWC 89	シロガネコムギ	福岡	1974(昭和49)年	近畿・中国・四国・九州	3
JWC 42	外海	長崎	1923(大正12)年奨励品種	近畿・中国・四国・九州	1	JWC 90	チクゴイズミ	福岡	1993(平成5)年	近畿・中国・四国・九州	4
JWC 43	貞坊主	宮崎	不明	近畿・中国・四国・九州	1	JWC 91	小麦農林20号	佐賀	1935(昭和10)年	近畿・中国・四国・九州	2
JWC 44	延岡坊主小麦	宮崎	不明	近畿・中国・四国・九州	1	JWC 92	フジミコムギ	埼玉	1960(昭和35)年	関東・甲信・東海	3
JWC 45	魁1号	鹿児島	1925(大正14)年奨励品種	近畿・中国・四国・九州	1	JWC 93	シラサギコムギ	広島	1956(昭和31)年	近畿・中国・四国・九州	3
JWC 46	赤銹不知1号	北海道	1927(昭和2)年優良品種	北海道	2	JWC 94	ジュンレイコムギ	香川	1957(昭和32)年	近畿・中国・四国・九州	3
JWC 47	本系275号	北海道	不明	北海道	2	JWC 95	ハチマンコムギ	岩手	1973(昭和48)年	東北・北陸	3
JWC 48	北海240号	北海道	不明	北海道	2	JWC 96	Chinese Spring	不明	不明	不明	不明

1) 農研機構遺伝資源センタージーンバンクID
2) 北海道（北海道）、東北・北陸（青森・岩手・山形・新潟）、関東・甲信・東海（栃木・茨城・埼玉・群馬・千葉・神奈川・山梨・長野・静岡・愛知・三重）、近畿・中国・四国・九州（奈良・兵庫・岡山・広島・鳥取・香川・福岡・佐賀・長崎・熊本・宮崎・鹿児島）
3) 1（在来品種および純系選抜のみによる育成品種）、2（1955年以前の育成品種）、3（1956年-1975年の育成品種）、4（1976年以降の育成品種）

Ⅲ　材料と方法

1　特性評価

「日本のコムギコアコレクション」96 品種を農研機構作物研究所（現、次世代作物開発研究センター）の試験圃場（観音台地区）で、2008–2009 年と、2009–2010 年の 2 ヶ年栽培した。播種はそれぞれ 2008 年 11 月 6 日および 2009 年 11 月 5 日に行った。いずれの年も株間 8.5cm、1 区あたりの面積は畝幅 0.7m、畝長 1.7m の 1.19m^2 で、1 反復とした。施肥は化成肥料（N:P_2O_5:K_2O=6:9:6）7.0kg/a、重焼リン 10.0kg/a を播種前に施用した。特性評価の項目は以下の通りである。2008–2009 年には出穂期、成熟期、株の開閉、稈の太さ、倒伏程度、稈長、穂型、粒着の粗密、穂長、稃色、芒の有無・多少、芒の長さについて調査した。2009–2010 年には出穂期、成熟期、叢性、葉色について調査を行った。調査方法は「小麦調査基準」（農業研究センター　1986）に従った。

2　育種上重要な遺伝子型の調査

育種上重要な形質を支配する遺伝子について調査を行った。日本のコムギの半矮性育種を考える上で重要な半矮性遺伝子 *Rht-B1* と *Rht-D1*（Ellis *et al.* 2002, Yamada 1990）、製パン品質（Payne *et al.* 1987）を考える上で重要な高分子量グルテニンサブユニットをコードする *Glu-A1*（高田ら 2008）と *Glu-D1*（石川ら 2005）、低分子量グルテニンサブユニットをコードする *Glu-B3*（鈴木・竹内 2007）、子実のデンプン中のアミロース合成に関与するデンプン合成酵素の *Wx-A1*（Nakamura *et al.* 2002）と *Wx-B1*（Saito et al. 2009）、子実の硬軟質性を決定するピュロインドリン遺伝子をコードする *Pina-D1*（鈴木・竹内 2007）と *Pinb-D1*（Gabriela Tranquilli http://maswheat.ucdavis.edu/protocols/Hardness/index.htm）、種皮色に関与する *Tamyb10-A1*、*Tamyb10-B1*、*Tamyb10-D1*（Himi *et al.* 2011）、以上 12 個の遺伝子について上記の引用文献の情報をもとに遺伝子型を調査した。

温室でポット栽培した幼苗を、各品種 10 個体をバルクにして CTAB 法により DNA を抽出した（Murray and Thompson 1980）。各反応液に占める DNA が 10ng となるように濃度を調整して PCR 反応に供試した。PCR 反応液の組成とサイクルは、各引用文献に従った。PCR 反応は GeneAmp PCR System 9700 Thermalcycler（Applied Biosystems, Foster City, CA, USA）を使用し、PCR 産物を 10% アクリルアミドまたは 2%アガロースゲルで電気泳動し、SYBR® Green I Nucleic Acid Stain（Lonza, Rockland, ME, USA）で染色して遺伝子型を決定した。

Ⅳ　結果と考察

特性評価の結果を表 2 に、品種成立時期別の主要特性平均値を表 3 に示した。関東以西の品種における出穂期・成熟期と成立時期の関係を見ると、古い時代の品種では早生から晩生まで幅広く存在するが、成立時期が新しくなるにつれて早生の品種が多数を占めている傾向がある。藤田（2013）の総説にもあるように、特に温暖地において田植機の普及により稲作が早期化した作業上の理由と、収穫期の梅雨による穂発芽等の雨害の影響を避けるために早生品種が選抜されてきた結果と捉えられる。これに関して、温暖地の早生化は、不感光型の感光性遺伝子である *Ppd-B1a* と *Ppd-D1a* が関与していることが明らかにされている（Seki *et al.* 2011）。

稈長については古い時代の品種では稈長が高い

表２　日本のコムギコアコレクションの特性評価（2008-2009 年、2009-2010 年）

				2008-2009												2009-2010			
ID	品種名	地域区分	成立時期	出穂期	成熟期	株の開閉	稈の太さ	倒伏	平均稈長 (cm)	穂型	粒着の粗密	平均穂長 (cm)	稃色	芒の有無・多少	芒の長さ	出穂期	成熟期1)	叢性	葉色
JWC 01	赤皮赤	北海道	1	5/11	6/23	中	やや細	3	154.4	錐	やや疎	14.4	褐	中	やや長	5/17	-	中	中
JWC 02	白肌	北海道	1	5/11	6/20	やや閉	やや細	3	158.6	紡錘	中	12.9	淡黄	極少	極短	5/18	-	中	やや濃
JWC 03	ドーソン1号	北海道	1	5/5	6/20	中	細	4	154.8	錐	疎	14.2	黄	極少	短	5/13	-	中	やや濃
JWC 04	札幌春小麦	北海道	1	5/6	6/20	中	やや細	3	170.4	錐	疎	14.7	淡黄	中	やや長	5/13	-	中	やや濃
JWC 05	相州2号	東北・北陸	1	4/26	6/15	やや閉	中	1	140.0	棒	中	8.9	褐	極少	極短	5/4	-	やや匍匐	中
JWC 06	資選1号	東北・北陸	1	4/29	6/15	中	やや太	1	128.4	棍棒	やや密	7.5	淡黄	極少	極短	5/3	6/18	中	中
JWC 07	在来フルツ	東北・北陸	1	4/21	6/10	やや閉	細	0	90.0	紡錘	やや疎	10.8	褐	やや多	中	4/30	6/17	中	やや濃
JWC 08	西村	東北・北陸	1	4/25	6/12	中	中	1	138.2	紡錘	やや密	10.3	淡黄	中	中	5/3	6/13	やや匍匐	中
JWC 09	白莢	関東・甲信・東海	1	4/20	6/7	やや閉	中	1	115.8	棒	やや疎	11.1	黄	中	中	4/30	-	やや匍匐	中
JWC 10	富国	関東・甲信・東海	1	4/30	6/15	やや閉	やや細	1	142.2	棍棒	密	7.4	褐	無	無	5/8	-	中	中
JWC 11	赤稈茨城1号	関東・甲信・東海	1	5/1	6/16	やや閉	中	1	130.2	軍配	密	6.0	褐	極少	極短	5/8	-	やや匍匐	やや濃
JWC 12	白三尺	関東・甲信・東海	1	4/18	6/6	中	中	2	106.0	棒	疎	8.2	褐	中	中	4/26	-	やや匍匐	中
JWC 13	赤ボロ1号	関東・甲信・東海	1	4/22	6/11	やや閉	中	2	128.2	棒	中	8.3	褐	やや多	中	5/6	-	中	中
JWC 14	新田早生	関東・甲信・東海	1	4/19	6/9	閉	中	2	124.0	棒	中	8.5	褐	やや多	中	4/30	-	やや匍匐	中
JWC 15	スネキリ15号	関東・甲信・東海	1	4/21	6/9	中	細	1	86.4	紡錘	やや疎	9.8	黄	多	中	4/30	6/16	中	中
JWC 16	赤坊主	関東・甲信・東海	1	4/20	6/11	やや閉	中	4	118.0	棒	密	9.7	褐	無	無	4/30	6/16	やや匍匐	中
JWC 17	細稈	関東・甲信・東海	1	5/2	6/15	閉	やや太	5	143.8	錐	中	12.0	淡黄	中	やや長	5/6	-	中	やや淡
JWC 18	白達摩	関東・甲信・東海	1	4/19	6/10	中	やや細	0	80.4	紡錘	中	9.5	淡黄	やや多	中	4/29	6/16	やや匍匐	やや淡
JWC 19	赤達摩	関東・甲信・東海	1	4/17	6/9	中	中	4	98.8	紡錘	中	10.1	褐	中	中	4/27	6/15	中	中
JWC 20	早生小麦	関東・甲信・東海	1	4/18	6/3	中	中	0	107.0	棒	中	9.5	淡黄	やや多	やや長	4/27	6/15	中	やや淡
JWC 21	赤小麦	関東・甲信・東海	1	4/17	6/8	中	中	2	112.2	棒	中	8.1	褐	中	中	4/28	6/15	中	やや淡
JWC 22	渋不知	関東・甲信・東海	1	4/28	6/15	閉	やや太	1	138.2	紡錘	やや密	9.9	褐	中	やや長	5/6	-	中	中
JWC 23	古志郡在来種	東北・北陸	1	5/2	6/19	やや閉	やや細	5	156.4	錐	疎	12.8	褐	中	やや長	5/7	-	中	中
JWC 24	白チャボ	関東・甲信・東海	1	4/20	6/11	閉	やや細	2	110.0	錐	やや疎	10.6	淡黄	無	無	5/1	6/18	中	やや濃
JWC 25	サコボレ	関東・甲信・東海	1	4/22	6/10	開	やや細	4	138.2	錐	中	9.7	褐	やや少	やや長	5/1	6/17	中	中
JWC 26	新中長	近畿・中国・四国・九州	1	4/18	6/3	やや閉	中	1	116.8	紡錘	中	8.9	褐	やや少	中	4/28	6/13	やや直立	中
JWC 27	畠田小麦	近畿・中国・四国・九州	1	4/18	6/4	やや閉	中	1	111.4	紡錘	中	7.9	褐	中	中	4/27	6/16	中	やや淡
JWC 28	優勝旗347	近畿・中国・四国・九州	1	4/19	6/8	中	細	0	80.8	紡錘	中	9.3	黄	中	中	4/28	6/15	やや匍匐	中
JWC 29	広島シプレー	近畿・中国・四国・九州	1	4/20	6/12	中	やや細	1	110.6	錐	中	10.5	淡黄	無	無	5/1	6/17	中	やや淡
JWC 30	無芒珍子	近畿・中国・四国・九州	1	4/24	6/9	やや閉	中	1	109.4	錐	中	9.6	褐	無	無	5/4	6/16	中	やや淡
JWC 31	ヒラキ小麦	近畿・中国・四国・九州	1	4/26	6/9	中	中	1	112.6	軍配	極密	5.6	黄	中	中	4/24	6/18	中	中
JWC 32	中相州	近畿・中国・四国・九州	1	4/18	6/4	中	やや細	4	115.6	紡錘	やや疎	9.3	褐	やや多	中	5/6	6/12	やや直立	中
JWC 33	宝満	関東・甲信・東海	1	4/30	6/14	中	中	1	141.8	棍棒	中	8.8	褐	無	無	5/1	-	中	中
JWC 34	赤竹1号	関東・甲信・東海	1	4/21	6/8	やや閉	やや細	5	103.6	錐	やや疎	10.0	褐	無	無	4/25	6/16	中	中
JWC 35	江島神力	近畿・中国・四国・九州	2	4/15	6/7	閉	中	1	128.6	錐	疎	11.7	褐	多	やや長	4/25	6/16	中	やや淡
JWC 36	伊賀筑後	近畿・中国・四国・九州	1	4/18	6/10	中	中	1	111.2	棒	やや密	8.0	褐	中	中	4/28	6/16	中	やや淡
JWC 37	白小麦	近畿・中国・四国・九州	1	4/20	6/9	閉	やや細	1	136.8	紡錘	中	9.6	黄	中	中	4/29	6/17	中	中
JWC 38	筑前	近畿・中国・四国・九州	1	4/30	6/14	やや閉	中	2	145.0	棍棒	密	8.1	褐	無	無	5/6	-	中	中
JWC 39	1号早小麦	近畿・中国・四国・九州	1	4/16	6/3	中	中	1	117.0	紡錘	中	9.8	褐	中	中	4/18	6/11	中	やや淡
JWC 40	白ブンブ	近畿・中国・四国・九州	1	4/28	6/14	閉	やや細	1	126.6	棍棒	やや密	7.2	黄	無	無	5/5	-	やや匍匐	中
JWC 41	阿蘇在来（有芒褐ぷ	近畿・中国・四国・九州	1	4/30	6/15	中	やや細	2	152.0	錐	疎	13.2	褐	中	やや長	5/6	-	中	中
JWC 42	外海	近畿・中国・四国・九州	1	4/30	6/10	中	中	2	146.4	錐	疎	11.6	淡黄	無	無	5/5	-	やや匍匐	中
JWC 43	貞坊主	近畿・中国・四国・九州	1	4/29	6/13	やや閉	中	2	127.0	棍棒	やや密	7.4	淡黄	無	無	5/5	6/18	中	やや濃
JWC 44	延岡坊主小麦	近畿・中国・四国・九州	1	5/1	6/17	中	細	3	143.6	錐	やや疎	11.9	淡黄	無	無	5/6	-	中	中
JWC 45	魁１号	近畿・中国・四国・九州	1	4/22	6/11	中	中	4	122.0	紡錘	中	9.5	褐	やや多	中	4/30	6/17	中	中
JWC 46	赤銹不知1号	北海道	2	5/7	6/23	やや閉	やや細	4	159.6		中	11.4	淡黄	少	やや長	5/14	-	やや匍匐	やや濃
JWC 47	本系275号	北海道	2	4/16	6/9	閉	中	1	106.0	棒	やや密	8.9	淡黄	中	中	4/22	6/16	中	やや濃
JWC 48	北海240号	北海道	2	4/30	6/13	やや閉	太	0	104.2	棒	やや密	9.9	褐	無	無	5/9	-	中	中
JWC 49	鴻巣25号	関東・甲信・東海	2	4/13	6/6	やや閉	中	1	118.6	紡錘	中	9.7	淡黄	中	中	4/19	6/12	やや直立	やや淡
JWC 50	埼玉27号	関東・甲信・東海	2	4/18	6/8	やや閉	中	1	108.8	紡錘	やや疎	12.0	淡黄	中	やや長	-	-	-	-
JWC 51	関東107号	関東・甲信・東海	4	4/14	6/8	中	中	0	89.2	棒	中	11.1	黄	やや多	中	4/21	6/13	中	やや淡
JWC 52	伊賀筑後オレゴン	関東・甲信・東海	2	4/18	6/8	やや開	中	3	116.0	錐	疎	11.8	褐	やや多	中	4/28	6/13	中	やや淡
JWC 53	極早生4-15	近畿・中国・四国・九州	3	4/10	6/6	やや閉	やや細	3	108.2	紡錘	やや疎	9.0	淡黄	やや多	中	4/18	6/15	中	中

表 2　日本のコムギコアコレクションの特性評価（2008-2009 年、2009-2010 年）

				2008-2009												2009-2010			
ID	品種名	地域区分	成立時期	出穂期	成熟期	株の開閉	稈の太さ	倒伏	平均稈長 (cm)	穂型	粒着の粗密	平均穂長 (cm)	稃色	芒の有無・多少	芒の長さ	出穂期	成熟期[1]	叢性	葉色
JWC 54	小麦農林1号	東北・北陸	2	4/23	6/9	やや開	中	1	99.8	棒	中	10.5	淡黄	中	中	5/3	6/15	中	やや淡
JWC 55	春播小麦農林3号	北海道	2	5/9	-	やや閉	中	2	164.2	錐	疎	12.8	淡黄	やや少	長	5/17	-	中	中
JWC 56	小麦農林9号	関東・甲信・東海	2	4/17	6/10	中	やや細	1	82.6	紡錘	中	9.3	褐	やや多	中	4/25	6/17	中	中
JWC 57	小麦農林10号	東北・北陸	2	4/28	6/10	中	やや太	0	71.4	紡錘	やや疎	10.4	黄	中	やや長	5/4	6/18	中	やや濃
JWC 58	小麦農林16号	関東・甲信・東海	2	4/18	6/10	閉	中	0	90.8	紡錘	中	10.0	淡黄	中	中	4/30	6/17	中	中
JWC 59	小麦農林26号	近畿・中国・四国・九州	2	4/17	6/7	中	中	0	97.8	紡錘	中	9.6	淡黄	やや多	中	4/24	6/11	中	やや淡
JWC 60	小麦農林27号	東北・北陸	2	4/23	6/12	閉	中	1	119.4	紡錘	中	10.7	褐	やや多	やや長	5/3	6/18	やや匍匐	中
JWC 61	小麦農林39号	東北・北陸	2	5/1	6/15	やや開	中	1	137.2	錐	中	11.0	淡黄	無	無	5/7	-	やや匍匐	中
JWC 62	硬質小麦農林42号	関東・甲信・東海	2	4/17	6/8	やや閉	やや細	0	103.8	紡錘	やや疎	9.0	黄	中	中	4/26	6/16	中	中
JWC 63	小麦農林50号	関東・甲信・東海	2	4/20	6/9	中	中	1	91.8	紡錘	疎	10.8	褐	やや多	中	4/29	6/17	中	中
JWC 64	小麦農林53号	関東・甲信・東海	2	4/18	6/9	中	やや細	2	105.0	紡錘	中	10.5	褐	中	中	4/27	6/17	中	中
JWC 65	小麦農林55号	東北・北陸	2	4/22	6/8	やや閉	やや細	4	106.2	錐	やや疎	13.3	褐	少	やや短	5/1	6/17	中	中
JWC 66	小麦農林61号	近畿・中国・四国・九州	2	4/18	6/8	中	中	0	100.2	紡錘	中	10.1	褐	中	中	4/27	6/17	中	中
JWC 67	小麦農林67号	関東・甲信・東海	2	4/26	6/8	開	中	1	95.0	紡錘	中	10.7	黄	やや多	やや長	5/4	6/17	やや匍匐	中
JWC 68	春播小麦農林75号	北海道	2	4/30	6/12	やや閉	やや細	2	156.4	錐	疎	12.3	淡黄	やや多	やや長	5/8	-	中	中
JWC 69	北栄	北海道	2	5/7	6/23	やや閉	中	3	176.2	紡錘	中	13.0	淡黄	少	短	5/17	-	やや匍匐	やや濃
JWC 70	ムカコムギ	北海道	3	5/6	6/23	中	中	2	122.8	紡錘	中	12.5	褐	極少	短	5/15	-	やや匍匐	やや濃
JWC 71	ホロシリコムギ	北海道	3	5/7	6/20	やや閉	太	0	99.6	棒	密	11.9	黄	無	無	5/8	-	やや匍匐	やや淡
JWC 72	タクネコムギ	北海道	3	4/25	6/16	閉	やや太	0	78.4	棒	やや密	12.1	褐	無	無	5/5	6/18	中	中
JWC 73	ハルヒカリ	北海道	3	4/28	6/13	中	中	2	151.8	錐	中	12.4	淡黄	多	長	5/5	-	やや匍匐	中
JWC 74	アオバコムギ	東北・北陸	2	4/20	6/9	閉	中	1	102.0	紡錘	中	11.4	淡黄	極少	極短	4/30	6/16	中	やや濃
JWC 75	ヒツミコムギ	東北・北陸	2	4/30	6/20	開	中	1	107.4	棒	中	10.6	淡黄	無	無	5/7	-	中	中
JWC 76	フルツマサリ	東北・北陸	3	4/25	6/13	やや開	中	1	108.2	錐	やや密	11.5	褐	やや少	やや長	5/3	6/18	やや匍匐	中
JWC 77	ユキチャボ	東北・北陸	2	4/25	6/13	中	やや太	0	88.0	棒	中	8.6	淡黄	やや少	やや長	5/3	6/17	中	中
JWC 78	ヒカリコムギ	東北・北陸	2	4/22	6/7	閉	中	1	112.8	棒	やや密	11.4	淡黄	やや少	中	5/2	6/17	やや匍匐	やや淡
JWC 79	フクホコムギ	関東・甲信・東海	4	4/14	6/3	中	中	0	90.8	棒	やや密	10.6	褐	多	中	4/19	6/7	中	やや淡
JWC 80	フクワセコムギ	近畿・中国・四国・九州	4	4/10	5/31	やや閉	中	0	93.2	紡錘	中	9.4	褐	中	中	4/13	6/7	中	やや淡
JWC 81	アブクマワセ	近畿・中国・四国・九州	4	4/9	6/2	中	中	0	79.8	紡錘	やや密	8.5	淡黄	中	中	4/11	6/10	中	やや淡
JWC 82	ホクシン	北海道	4	4/29	6/13	中	太	0	92.6	棒	密	10.8	淡黄	無	無	5/6	-	中	中
JWC 83	チホクコムギ	北海道	4	5/7	6/15	中	やや太	0	99.4	棒	中	9.6	黄	無	無	5/8	-	中	中
JWC 84	ハルユタカ	北海道	4	5/2	6/23	閉	やや太	1	115.2	錐	やや疎	12.9	淡黄	多	長	5/10	-	中	やや濃
JWC 85	ナンブコムギ	東北・北陸	2	4/19	6/8	中	中	0	96.8	錐	やや疎	12.4	褐	少	極短	4/28	6/13	中	中
JWC 86	キタカミコムギ	東北・北陸	3	4/27	6/15	やや閉	中	1	101.0	棒	やや密	10.2	淡黄	多	やや長	5/5	-	中	中
JWC 87	シラネコムギ	関東・甲信・東海	4	4/20	6/8	中	中	1	93.4	紡錘	やや密	10.0	褐	多	中	4/30	6/15	中	やや淡
JWC 88	バンドウワセ	関東・甲信・東海	4	4/12	6/8	中	中	0	80.6	棒	中	11.2	褐	多	中	4/13	6/11	中	やや淡
JWC 89	シロガネコムギ	近畿・中国・四国・九州	3	4/12	6/4	やや開	やや細	0	81.4	紡錘	中	9.7	淡黄	多	中	4/13	6/8	中	やや淡
JWC 90	チクゴイズミ	近畿・中国・四国・九州	4	4/13	6/4	やや開	中	1	88.2	棒	中	10.8	黄	多	やや長	4/18	6/11	中	やや淡
JWC 91	小麦農林20号	近畿・中国・四国・九州	2	4/14	6/3	中	中	2	112.0	棒	中	10.1	褐	やや多	中	4/18	6/13	中	やや淡
JWC 92	フジミコムギ	関東・甲信・東海	3	4/15	6/9	中	中	1	101.0	紡錘	中	10.1	黄	多	中	4/19	6/16	中	中
JWC 93	シラサギコムギ	近畿・中国・四国・九州	3	4/17	6/4	中	やや太	0	102.4	紡錘	中	10.0	淡黄	多	中	4/21	6/11	中	やや淡
JWC 94	ジュンレイコムギ	近畿・中国・四国・九州	3	4/16	6/3	中	中	0	98.2	紡錘	中	11.0	褐	多	中	4/21	6/8	中	やや淡
JWC 95	ハチマンコムギ	東北・北陸	3	4/22	6/9	閉	太	0	92.6	錐	中	12.1	淡黄	少	極短	5/3	-	中	やや濃
JWC 96	Chinese Spring	不明	不明	4/30	6/9	極開	中	1	140.8	棍棒	中	8.5	淡黄	無	無	5/5	6/18	中	やや淡

1) 「-」は極晩生で、成熟期が判定できなかった。

ものから低いものまであるが、時代が新しくなるにつれて、稈長が80cmから100cm程度の品種が占める割合が多くなっている。コムギは稈長が高くなるほど倒伏しやすくなり（松山ら2014）、倒伏は収量と品質の低下を招くことから、倒伏しにくい短稈系統が選抜されてきた結果と考えられる。同時に、ドリル播栽培など、機械化と多肥栽培に適した品種が育成されてきたと考えられる。また、穂の形態と粒着の粗密については、成立時期が早い品種では「錘」・「紡錘」・「棒」・「棍棒」・「軍配」があり、粒着の粗密についても「極密」から「粗」まで多様な穂の形態を示しているが（図1）、成立時期が新しくなるほど「紡錘」・「棒」状の穂型割合が増え、それに伴って粒着の粗密は「中」を中心に「やや密」から「やや粗」を示すようになる。

育種上重要な形質を支配する12個の遺伝子の遺伝子型を表4に示した。

Yamada（1990）によれば、国内の半矮性育成品種のほとんどは、草丈を低くする半矮性遺伝子*Rht-B1*と*Rht-D1*の遺伝子型によって説明でき、重要であると考えられる。そこで本コアコレクションでは、パーフェクトマーカーで判定が可能な（Ellis *et al.* 2002）両遺伝子について調査した。在来品種では、「スネキリ」や「達磨」などの短稈を示す特性が名前の由来と考えられる在来品種以外はこれらの半矮性遺伝子を持たない品種の割合が多いのに対し、近年の品種ではほとんどの品種が*Rht-B1b*と*Rht-D1b*のいずれかを持っていることが分かる。前述のように稈長の低い品種を選抜する過程でこれらの半矮性遺伝子が選ばれてきた結果と考えられる。本コレクションにおいて*Rht-B1b*と*Rht-D1b*を併せ持つ品種は、コムギにおける緑の革命の原動力となった「農林10号」のみであった。*Rht-B1b*と*Rht-D1b*を併せ持つ品種は、日本で使われているような自脱型コンバインでは、短稈過ぎて収穫しづらく選抜されてこなかった可能性がある。また、「赤小麦」はヨーロッパなどで利用されている半矮性遺伝子*Rht8*を持つことが知られているが（Korzun *et al.* 1998）、本試験結果からは、赤小麦の稈長は112.2cmと*Rht-B1b*または*Rht-D1b*持つ品種より高めであった。

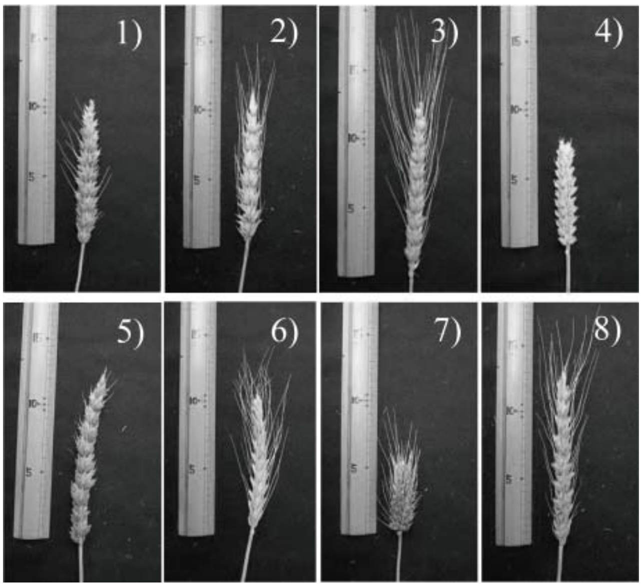

図1　穂の形態

1）小麦農林61号－紡錘、2）小麦農林10号－紡錘、
3）赤皮赤－錐、4) 資選1号－棍棒、
5）ナンブコムギ－錐、6）小麦農林67号－紡錘、
7）ヒラキ小麦－軍配、8）伊賀筑後オレゴン－錐

品質関連の遺伝子型について、*Glu-A1*遺伝子座の遺伝子型がaを示した（*Glu-A1a*）（サブユニット1）品種のほとんどが北海道と東北の品種であった。明治時代以降、外国品種が導入された（藤田2013）北海道や東北の品種にはこの遺伝子型を持つものが存在したが、奈良時代に九州地方に伝来したとされる関東以西の温暖地の品種にはこの遺伝子型を持つものが元々なかったと考えられる。これに対し、*Glu-A1b*（サブユニット2*）と*Glu-A1c*

表3　品種成立時期別の出穂期、成熟期、稈長、倒伏程度の平均値と穂型割合

成立時期	2008-2009 出穂期	成熟期	倒伏	稈長（cm）	紡錘・棒状の穂型割合	品種数
1（在来品種および純系選抜のみによる育成品種）	4/24	6/11	2.0	125.0	50%	44
2（1955年以前の育成品種）	4/23	6/10	1.2	111.8	76%	29
3（1956年-1975年の育成品種）	4/23	6/11	0.6	103.4	82%	11
4（1976年以降の育成品種）	4/18	6/8	0.5	93.7	91%	11

表4　育種上重要な形質を支配する遺伝子の遺伝子型

ID	品種名	地域区分	成立時期	*Rht-B1* [1]	*Rht-D1* [2]	*Glu-A1* [3]	*Glu-D1* [4]	*Glu-B3* [5]	*Wx-A1* [6]	*Wx-B1* [7]	*Pina-D1* [8]	*Pinb-D1* [9]	*Tamyb10-A1* [10]	*Tamyb10-B1* [11]	*Tamyb10-D1* [12]
JWC 01	赤皮赤	北海道	1	a	a	a	-	b	a	a	a	-	b	b	b
JWC 02	白肌	北海道	1	a	a	a	-	g	a	a	a	-	b	a	a
JWC 03	ドーソン1号	北海道	1	a	a	b	-	g	a	a	a	-	b	a	a
JWC 04	札幌春小麦	北海道	1	a	a	b	-	g	a	a	a	-	b	a	a
JWC 05	相州2号	東北・北陸	1	a	a	c	-	a	a	a	a	-	b	b	b
JWC 06	資選1号	東北・北陸	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 07	在来フルツ	東北・北陸	1	a	b (Rht2)	c	-	-	a	a	a	-	a(CS)	b	b
JWC 08	西村	東北・北陸	1	a	a	c	-	-	a	a	a	-	a(CS)	b	b
JWC 09	白莢	関東・甲信・東海	1	a	a	c	-	a	a	a	a	-	b	b	b
JWC 10	富国	関東・甲信・東海	1	a	a	c	-	-	a	a	-	-	b	b	b
JWC 11	赤稈茨城1号	関東・甲信・東海	1	a	a	c	-	-	a	a	-	-	b	Hetero[13]	b
JWC 12	白三尺	関東・甲信・東海	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 13	赤ボロ1号	関東・甲信・東海	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 14	新田早生	関東・甲信・東海	1	a	-	c	-	-	a	a	a	-	b	b	b
JWC 15	スネキリ15号	関東・甲信・東海	1	a	b (Rht2)	c	-	-	b	a	a	-	b	b	b
JWC 16	赤坊主	関東・甲信・東海	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 17	細稈	関東・甲信・東海	1	a	a	c	-	b	a	a	a	-	b	b	b
JWC 18	白達摩	関東・甲信・東海	1	a	b (Rht2)	c	-	-	b	a	a	-	b	b	b
JWC 19	赤達摩	関東・甲信・東海	1	a	b (Rht2)	c	-	-	a	a	a	-	a(Norin17)	b	b
JWC 20	早生小麦	関東・甲信・東海	1	b (Rht1)	a	c	-	-	a	a	a	-	b	b	a
JWC 21	赤小麦	関東・甲信・東海	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 22	渋不知	関東・甲信・東海	1	a	a	b	-	-	a	a	a	-	b	b	b
JWC 23	古志郡在来種	東北・北陸	1	a	a	c	-	-	b	a	a	-	b	b	b
JWC 24	白チャボ	関東・甲信・東海	1	a	b (Rht2)	c	-	-	a	a	a	-	b	b	b
JWC 25	サコボレ	関東・甲信・東海	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 26	新中長	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 27	畠田小麦	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 28	優勝旗347	近畿・中国・四国・九州	1	a	b (Rht2)	c	-	-	b	a	a	-	b	b	b
JWC 29	広島シプレー	近畿・中国・四国・九州	1	a	b (Rht2)	c	-	b	Hetero	a	a	-	b	b	b
JWC 30	無芒珍子	近畿・中国・四国・九州	1	a	b (Rht2)	c	-	-	b	a	a	-	b	b	b
JWC 31	ヒラキ小麦	近畿・中国・四国・九州	1	a	a	c	-	-	b	a	a	-	b	b	b
JWC 32	中相州	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 33	宝満	関東・甲信・東海	1	a	a	c	-	a	a	a	a	-	b	b	b
JWC 34	赤竹1号	関東・甲信・東海	1	a	b (Rht2)	c	-	a	b	a	a	-	b	b	b
JWC 35	江島神力	近畿・中国・四国・九州	2	a	a	b	-	-	a	a	a	-	b	a	b
JWC 36	伊賀筑後	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	a	-	b	Hetero	b
JWC 37	白小麦	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	-	-	b	b	b
JWC 38	筑前	近畿・中国・四国・九州	1	a	a	c	-	a	a	a	a	-	b	b	b
JWC 39	1号早小麦	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	a	-	b	a	b
JWC 40	白ブンブ	近畿・中国・四国・九州	1	a	a	c	-	-	b	a	a	-	b	b	b
JWC 41	阿蘇在来(有芒褐ぶ)	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 42	外海	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	a	-	b	a	b
JWC 43	貞坊主	近畿・中国・四国・九州	1	a	a	c	-	-	b	a	-	-	b	b	b
JWC 44	延岡坊主小麦	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	-	-	b	b	b
JWC 45	魁1号	近畿・中国・四国・九州	1	a	a	c	-	-	a	a	a	-	b	b	b
JWC 46	赤銹不知1号	北海道	2	a	a	a	-	b	a	a	a	-	b	b	a
JWC 47	本系275号	北海道	2	a	a	c	-	-	a	a	a	b	a(Norin17)	b	b
JWC 48	北海240号	北海道	2	a	b (Rht2)	a	-	b	a	a	a	-	a(CS)	b	a
JWC 49	鴻巣25号	関東・甲信・東海	2	a	a	c	-	b	a	a	a	b	b	b	b
JWC 50	埼玉27号	関東・甲信・東海	2	b (Rht1)	-	c	-	-	a	a	a	-	b	b	b
JWC 51	関東107号	関東・甲信・東海	4	b (Rht1)	a	c	-	g	b	b	a	-	b	b	a
JWC 52	伊賀筑後オレゴン	関東・甲信・東海	2	a	a	c	-	b	a	a	a	-	b	b	b
JWC 53	極早生4-15	近畿・中国・四国・九州	3	a	a	c	-	-	a	a	a	-	b	b	a
JWC 54	小麦農林1号	東北・北陸	2	a	b (Rht2)	c	-	-	b	a	a	-	b	b	b
JWC 55	春播小麦農林3号	北海道	2	a	a	c	-	-	a	a	a	-	b	b	a
JWC 56	小麦農林9号	関東・甲信・東海	2	a	b (Rht2)	c	-	-	a	a	a	-	b	a	b
JWC 57	小麦農林10号	東北・北陸	2	b (Rht1)	b (Rht2)	a	-	b	a	a	a	-	b	a	b

表4　育種上重要な形質を支配する遺伝子の遺伝子型

ID	品種名	地域区分	成立時期	*Rht-B1* [1]	*Rht-D1* [2]	*Glu-A1* [3]	*Glu-D1* [4]	*Glu-B3* [5]	*Wx-A1* [6]	*Wx-B1* [7]	*Pina-D1* [8]	*Pinb-D1* [9]	*Tamyb10-A1* [10]	*Tamyb10-B1* [11]	*Tamyb10-D1* [12]
JWC 58	小麦農林16号	関東・甲信・東海	2	a	b (Rht2)	c	-	b	a	a	a	-	a(Norin17)	b	b
JWC 59	小麦農林26号	近畿・中国・四国・九州	2	b (Rht1)	a	c	-	-	a	a	a	-	b	b	a
JWC 60	小麦農林27号	東北・北陸	2	a	a	c	-	b	a	a	a	-	a(CS)	b	b
JWC 61	小麦農林39号	東北・北陸	2	a	a	a	-	g	a	a	a	-	b	b	b
JWC 62	硬質小麦農林42号	関東・甲信・東海	2	a	a	b	-	-	a	a	a	b	b	b	a
JWC 63	小麦農林50号	関東・甲信・東海	2	a	b (Rht2)	c	-	-	a	a	a	-	b	b	b
JWC 64	小麦農林53号	関東・甲信・東海	2	b (Rht1)	a	c	-	-	a	a	a	-	b	Hetero	b
JWC 65	小麦農林55号	東北・北陸	2	a	b (Rht2)	c	-	b	a	a	a	b	b	a	a
JWC 66	小麦農林61号	近畿・中国・四国・九州	2	a	b (Rht2)	b	-	-	a	a	a	-	b	b	b
JWC 67	小麦農林67号	関東・甲信・東海	2	a	b (Rht2)	c	-	g	b	b	a	c	b	b	a
JWC 68	春播小麦農林75号	北海道	2	a	a	c	-	g	a	b	a	c	b	b	a
JWC 69	北栄	北海道	2	a	a	a	-	b	a	a	a	-	b	b	b
JWC 70	ムカコムギ	北海道	3	a	b (Rht2)	a	-	b	a	a	a	b	a(CS)	b	b
JWC 71	ホロシリコムギ	北海道	3	a	b (Rht2)	a	-	h	a	a	a	b	a(CS)	b	b
JWC 72	タクネコムギ	北海道	3	a	b (Rht2)	a	-	b	a	a	a	b	b	Hetero	b
JWC 73	ハルヒカリ	北海道	3	a	a	c	d	b	a	b	a	c	b	b	b
JWC 74	アオバコムギ	東北・北陸	2	a	b (Rht2)	c	-	b	a	a	a	b	a(CS)	Hetero	b
JWC 75	ヒツミコムギ	東北・北陸	2	a	b (Rht2)	a	-	g	a	a	a	-	a(Norin17)	b	b
JWC 76	フルツマサリ	東北・北陸	3	a	b (Rht2)	c	-	-	a	a	a	-	a(Norin17)	b	b
JWC 77	ユキチャボ	東北・北陸	2	a	b (Rht2)	a	-	b	a	a	a	-	a(Norin17)	b	a
JWC 78	ヒカリコムギ	東北・北陸	2	a	a	Hetero (a,b)	-	-	a	a	a	b	b	b	a
JWC 79	フクホコムギ	関東・甲信・東海	4	b (Rht1)	a	b	-	-	a	a	a	-	b	b	a
JWC 80	フクワセコムギ	近畿・中国・四国・九州	4	a	a	c	-	-	a	a	a	-	b	a	a
JWC 81	アブクマワセ	近畿・中国・四国・九州	4	b (Rht1)	a	c	-	-	a	a	a	-	b	a	a
JWC 82	ホクシン	北海道	4	a	b (Rht2)	a	-	g	a	b	a	-	b	b	a
JWC 83	チホクコムギ	北海道	4	a	b (Rht2)	a	-	g	a	b	a	-	b	b	b
JWC 84	ハルユタカ	北海道	4	b (Rht1)	a	a	-	h	a	b	b	-	b	b	a
JWC 85	ナンブコムギ	東北・北陸	2	a	b (Rht2)	a	-	b	a	a	a	-	b	a	b
JWC 86	キタカミコムギ	東北・北陸	3	a	b (Rht2)	c	-	g	a	a	a	-	a(Norin17)	b	b
JWC 87	シラネコムギ	関東・甲信・東海	4	a	b (Rht2)	a	-	-	a	a	a	-	a(Norin17)	b	a
JWC 88	バンドウワセ	関東・甲信・東海	4	b (Rht1)	a	b	-	-	a	a	a	-	a(Norin17)	b	a
JWC 89	シロガネコムギ	近畿・中国・四国・九州	3	b (Rht1)	a	c	-	-	a	a	a	-	b	a	b
JWC 90	チクゴイズミ	近畿・中国・四国・九州	4	b (Rht1)	a	b	-	-	b	b	a	-	b	b	a
JWC 91	小麦農林20号	近畿・中国・四国・九州	2	a	a	c	-	-	a	a	a	-	a(Norin17)	a	b
JWC 92	フジミコムギ	関東・甲信・東海	3	b (Rht1)	a	c	-	-	b	a	a	-	a(Norin17)	b	a
JWC 93	シラサギコムギ	近畿・中国・四国・九州	3	b (Rht1)	a	c	-	-	a	a	a	-	b	b	a
JWC 94	ジュンレイコムギ	近畿・中国・四国・九州	3	b (Rht1)	a	c	-	-	a	a	a	-	b	b	a
JWC 95	ハチマンコムギ	東北・北陸	3	a	b (Rht2)	c	-	b	a	a	a	-	a(CS)	a	b
JWC 96	Chinese Spring	不明	不明	a	a	c	-	a	a	a	a	-	a(CS)	a	b

1) 半矮性遺伝子。a（野生型）とb（変異型-Rht1-半矮性）を判別（Ellis et al. 2002）。
2) 半矮性遺伝子。a（野生型）とb（変異型-Rht2-半矮性）を判別（Ellis et al. 2002）。
3) 高分子グルテニンサブユニットをコードする。「a」、「b」、「c（欠失型）」を判別するマーカーで判定（高田ら 2008）。
4) 高分子グルテニンサブユニットをコードする。生地物性を強める「d」を判別するマーカーで判定。「d」以外については未分類で「-」と表記（石川ら 2005）。
5) 低分子グルテニンサブユニットをコードする。「a」、「b」、「g」、「h」を判別するマーカーで判定。それ以外については未分類で「-」と表記（鈴木ら 2007）。
6) 顆粒性デンプン合成酵素をコードする。「a（野生型）」と「b（欠失型）」を判別（Nakamura et al. 2002）。
7) 顆粒性デンプン合成酵素をコードする。「a（野生型）」と「b（欠失型）を判別（Saito et al. 2009）。
8) 粒の硬軟質を決定するピュロインドリンをコードする。「a（野生型）」と「b（変異型-硬質）」を判別（鈴木ら 2007）。
9) 粒の硬軟質を決定するピュロインドリンをコードする。「b」と「c」（ともに変異型-硬質）を判別（Gabriela Tranquilli　http://maswheat.ucdavis.edu/protocols/Hardness/index.htm）。
どちらでもない場合については「-」記載したが、このうちほとんどが野生型であるaのタイプだと推測される。
10) 種皮色を決定する遺伝子。「a（変異型-Norin17型とChinese Spring型の2つがある）」と「b（野生型)」を判別（Himi et al. 2011）。
11) 種皮色を決定する遺伝子。「a（変異型）」と「b（野生型）」を判別（Himi et al. 2011）。
12) 種皮色を決定する遺伝子。「a（変異型）」と「b（野生型）」を判別（Himi et al. 2011）。
13) 「Hetero」については遺伝子型が分離していたものを示す。

（null）の遺伝子型を持つ品種は全国的に広く存在していた。また、近年 *Glu-D1* 遺伝子座が小麦粉の生地物性に大きく影響し、その遺伝子型が d である（*Glu-D1d*）（サブユニット 5 ＋ 10）と製パン性が向上することが明らかになってきている（Payne *et al.* 1987、Takata *et al.* 2000）。コアコレクション 96 品種中、この *Glu-D1d* の遺伝子型を持つ品種は「ハルヒカリ」のみであった。「ハルヒカリ」の系譜を調べると「Mida/Pilot// 春播小麦農林 75 号」となっているが、「春播小麦農林 75 号」は *Glu-D1d* ではないことから、外国品種である「Mida」あるいは「Pilot」に由来するものと考えられる。本コアコレクションは、農研機構遺伝資源センタージーンバンクから配布可能な 2000 年以前に育成された遺伝資源で構成されている。近年、パン用コムギの育種が盛んになって以来、*Glu-D1d* 遺伝子を持つ品種を交配親に積極的に使用しているが、それ以前の日本の遺伝資源にはこの遺伝子型を持つ品種は、「ハルヒカリ」のような北海道の春播きパン用品種以外はなかったものと推測される。逆にいえば、ここ 15 年ほどで急速にパン用品質の改良がなされたと考えられる。

小麦粉のアミロース含量は麺の食感を左右する（Oda *et al.* 1980、Toyokawa *et al.* 1989）。コムギのアミロース含量は A、B、D、3 つのゲノム上にそれぞれ存在する *Wx* 遺伝子座（*Wx-A1*、*Wx-B1*、*Wx-D1*）に支配されており、*Wx-B1* の遺伝子型が b（欠失型）の場合は「やや低アミロース」、*Wx-A1* と *Wx-B1* の遺伝子型がともに b（欠失型）の場合は「低アミロース」になり、麺にしたときのなめらかさや粘弾性が優れる。しかし、本コアコレクションの 1975 年以前に育成された品種において *Wx-B1b*（欠失型）の品種は 3 品種しかないことから、*Wx-B1b*（欠失型）は麺としての品質を重視した育種の過程で近年になってから意識的に取り込まれたものと考えることができる。一方 *Wx-A1b*（欠失型）に関しては在来品種にも 9 品種存在していた。

コムギの種皮色はフラボノイド合成に関与する 3 つの *myb* 遺伝子（*Tamyb10-A1*、*Tamyb10-B1*、*Tamyb10-D1*）に支配されていることが分かっており（Himi *et al.* 2011）、3 つの遺伝子型すべてが a（劣性）の場合は白粒、それ以外は赤粒になることが知られている。一般的に白粒の品種は赤粒の品種に比べて穂発芽に弱いことが知られており、湿潤で成熟期が梅雨と重なる日本においては穂発芽に弱い白粒品種の栽培は難しい。「麦類品種一覧」（農林省関東東山農業試験場 1959）には白粒品種もわずかながら掲載されているが、本コアコレクションでは、主要な普及品種とその系譜上の重要な品種を選んだ結果、3 つの遺伝子型すべてが劣性の白粒品種は入らなかったと考えられる。

Hoshino *et al.*（2001）は、湿潤な気候で栽培される日本のコムギには早生で穂発芽に強い品種が多いと報告している。本コアコレクションにはこれらの特徴が反映されており、近年の育成品種は早生で、穂発芽に強いとされる赤粒の品種となっている。

最近、Kobayashi *et al.*（2016）により、本コアコレクションを利用してゲノムワイドな情報から、日本のコムギ品種成立の考察などがなされており、文献上から作成した本コアコレクションが、国内コムギ品種の広い変異をカバーしていることが明らかにされた。このような場面でも、このコアコレクションが今後の作物開発、進化研究に貢献することを期待したい。

「日本のコムギコアコレクション」は 96 品種のセットとして農研機構遺伝資源センタージーンバンクのホームページ（http://www.gene.affrc.go.jp/distribution-plant_core.php）から入手できる。

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早生で穂発芽に強い日本めん用小麦新品種「ふくあかり」の育成

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抄　　録

「ふくあかり」は、1997 年度に早生・良質を育種目標として、「谷系 RA4215」を母、「関東 119 号」（後の「あやひかり」）を父として人工交配を行い、世代促進栽培を用いた集団育種法により選抜・固定を図って育成した品種である。育成地では「農林 61 号」と比較して次のような特徴を示す。

１）播性程度はⅠ－Ⅱで、出穂期、成熟期とも 4 日早い。
２）褐ぷで稈長は短く、穂長はやや長い。穂数は少なく、耐倒伏性は優れる。
３）収量性は高く、容積重は同程度で、千粒重はやや小さい。
４）縞萎縮病とうどんこ病にはやや強く、赤かび病にはやや弱い。
５）ゆで麺の色は同程度だが、アミロース含量はやや低く、ゆで麺の粘弾性が優れ、合計点は優る。

栽培適地は南東北及び関東以西の平坦地である。福島県において早生で穂発芽性が難であることが評価され、2011 年に奨励品種に採用された。

キーワード：小麦、麺、早生、穂発芽、アミロース、新品種

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Breeding of a New Soft Wheat Cultivar “Fukuakari” with Pre-harvest Sprouting Resistance

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Abstract

“Fukuakari” was registered as a new wheat cultivar in 2010. It was bred by the bulk method at the NARO Institute of Crop Science, Tsukuba, Ibaraki, Japan, from a cross made in 1998 between “Tanikei RA4215” and “Kanto 119”.

“Fukuakari” is an awned, brown-glumed, soft wheat cultivar with red seeds. The degree of its winter habit is I–II（spring type）. Compared with “Norin 61”, the leading cultivar in central and southwestern Japan, “Fukuakari” has shorter culm length and superior lodging resistance. “Fukuakari” matures 4 days earlier and its yield is higher than that of “Norin 61”. “Fukuakari” is resistant to wheat yellow mosaic virus and powdery mildew but susceptible to scab. “Fukuakari” shows good noodle texture because its amylose content is lower than that of “Norin 61”.

Fukushima prefecture designated “Fukuakari” as a recommended cultivar in 2011, because its pre-harvest sprouting resistance is good with “difficulty” and it has early maturity.

Key Words : soft wheat, noodle, pre-harvest sprouting, amylose, new cultivar

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Ⅰ　緒　　言

日本では小麦の収穫時期が入梅時期と重なることから、世界的にみて穂発芽による被害を受けやすい栽培環境にある。穂発芽による被害を防ぐためには、穂発芽耐性の強い品種を育成、栽培することが最も有効な手段であり、「ゼンコウジコムギ」や「トヨホコムギ」の穂発芽耐性が強いことが知られている（Hoshino *et al.* 1989）。福島県における小麦の品質低下要因も収穫時期の雨害であり、これを回避するため早生品種「アブクマワセ」を採用しているが、この品種は穂発芽性が「易」である。そのため栽培面積が年々減少しており、穂発芽耐性が優れた早生品種に対する要望が高い。そこで、福島県と作物研究所（現　次世代作物開発研究センター）は2005年度から「小麦早生系統選抜」の課題で協定研究を行い、通常の配付世代より早い世代から福島県での選抜・評価を行った。その結果、「関東135号」が有望視され、2010年12月に「ふくあかり」の名称で品種登録出願を行った。その後、2011年4月に本品種は福島県の奨励品種に採用された。

Ⅱ　育種目標及び育成経過

両親の特性を表1に示す。また、「ふくあかり」の系譜を図1、選抜経過を表2、育成系統図を図2に示す。「ふくあかり」は、1997年度（1998年5月）、農業研究センター（現　次世代作物開発研究センター）において、早生・良質を育種目標として、「谷系RA4215」を母、「関東119号」（後の「あやひかり」）を父とした人工交配（関交2294）から育成された。

1997年度に2穂の人工交配を行い、37粒を得た。1998年度に雑種第1代（F_1）として36個体を栽培し収穫した。1999年度にF_2世代は国際農林水産業研究センター島嶼研究拠点（沖縄県石垣市）の秋播栽培、F_3世代は北海道農業研究センター（北海道河西郡芽室町）の春播栽培で世代促進栽培を行った。2000年度に雑種集団（F_4）3700個体を栽培し、全刈り収穫を行った。2001年度は雑種集団（F_5）4000個体を栽培し、200穂を穂摘みした。2002年度に穂別系統（F_6）とし200系統を栽培し、17系統を選抜した。2003年度に谷系RA9587－谷系RA9603の系統名をつけて17系統を栽培し、2系統（谷系RA9594、谷系RA9602）を選抜した。2004年度から生産力検定予備試験、2004年度は1か所のみ特性検定試験に供試し、その成績が良好であったので2006年度から「谷系RA9594」を「関系w503」として系統適応性検定試験に供試した。その結果、成績が良好であったので、2007年度から「関東135号」の系統名を付与し、関係各県で奨励品種決定調査に供試されて地域適応性が検討された。

福島県では2005年度に「小麦早生系統選抜」の課題で作物研究所（現　次世代作物開発研究センター）と協定研究を行い、通常の配付世代より

表1　両親の特性

品種・系統名	叢性	株の開閉	成熟期	稈長	穂長	耐倒伏性	播性	穂型	赤さび病抵抗性	うどんこ病抵抗性	穂発芽性
谷系RA4215（母）	中	やや開	やや早	中	やや長	やや強	II	紡錘状	中	やや強	－
関東119号（父）	中	中	やや早	中	やや長	やや強	I～II	紡錘状	強	やや弱	難
ふくあかり	中	中	やや早	中	中	やや強	I～II	紡錘状	中	やや強	難

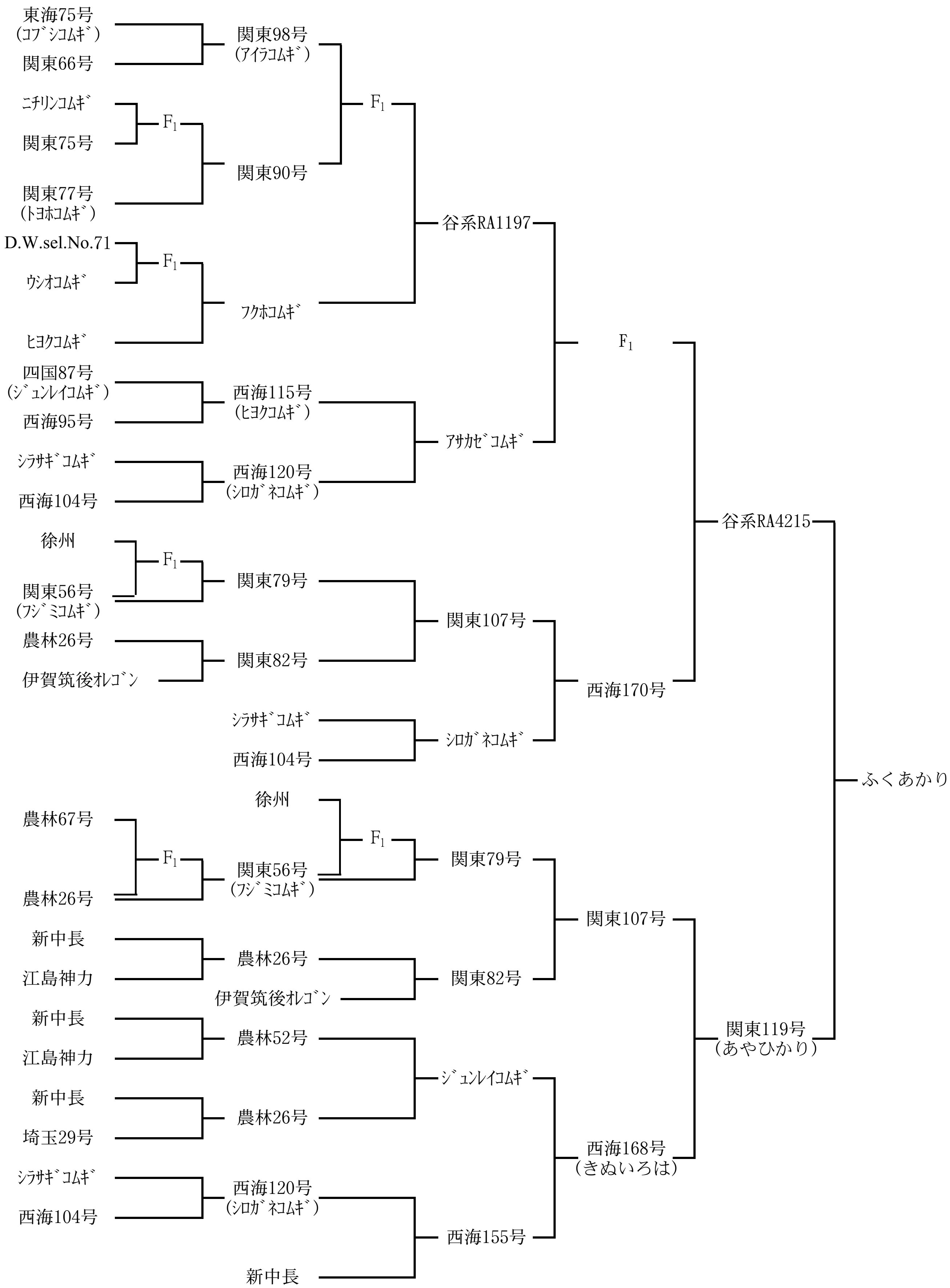
東海75号
（ｺﾌﾞｼｺﾑｷﾞ）
関東66号
関東98号
（ｱｲﾗｺﾑｷﾞ）
ﾆﾁﾘﾝｺﾑｷﾞ
関東75号
F1
関東90号
関東77号
（ﾄﾖﾎｺﾑｷﾞ）
F1
谷系RA1197
D.W.sel.No.71
ｳｼｵｺﾑｷﾞ
F1
ﾌｸﾎｺﾑｷﾞ
ﾋﾖｸｺﾑｷﾞ
F1
四国87号
（ｼﾞｭﾝﾚｲｺﾑｷﾞ）
西海95号
西海115号
（ﾋﾖｸｺﾑｷﾞ）
ｱｻｶｾﾞｺﾑｷﾞ
ｼﾗｻｷﾞｺﾑｷﾞ
西海104号
西海120号
（ｼﾛｶﾞﾈｺﾑｷﾞ）
谷系RA4215
徐州
関東56号
（ﾌｼﾞﾐｺﾑｷﾞ）
F1
関東79号
関東107号
農林26号
伊賀筑後ｵﾚｺﾞﾝ
関東82号
西海170号
ｼﾗｻｷﾞｺﾑｷﾞ
西海104号
ｼﾛｶﾞﾈｺﾑｷﾞ
ふくあかり
徐州
農林67号
F1
関東56号
（ﾌｼﾞﾐｺﾑｷﾞ）
F1
関東79号
農林26号
関東107号
新中長
江島神力
農林26号
伊賀筑後ｵﾚｺﾞﾝ
関東82号
新中長
江島神力
農林52号
関東119号
（あやひかり）
ｼﾞｭﾝﾚｲｺﾑｷﾞ
新中長
埼玉29号
農林26号
西海168号
（きぬいろは）
ｼﾗｻｷﾞｺﾑｷﾞ
西海104号
西海120号
（ｼﾛｶﾞﾈｺﾑｷﾞ）
西海155号
新中長

図１　「ふくあかり」の系譜

表２　選抜経過

	播種年度 世代	1997 交配	1998 F_1	1999 F_2	 F_3	2000 F_4	2001 F_5	2002 F_6	2003 F_7	2004 F_8	2005 F_9	2006 F_{10}	2007 F_{11}	2008 F_{12}	2009 F_{13}
供試	系統群数	２穂							17	2	2	1	1	1	1
	系統数	37 粒	36 個体			3700 個体	4000 個体	200	17	6	10	5	5	5	5
選抜	系統群数								2	2	1	1	1	1	1
	系統数							17	2	2	1	1	1	1	1
	個体数		36 個体			全刈	200 穂	17	6	10	5	5	5	5	5
生産力検定試験	予備試験									標準栽培（畑）					
	本試験										ドリル栽培（畑）	ドリル栽培（畑） 標準栽培（水田）	ドリル栽培（畑） 標準栽培（水田）	ドリル栽培（畑） 標準栽培（水田）	ドリル栽培（畑） 標準栽培（水田）
特性検定試験										1	3	6	7	7	6
系統適応性検定試験											(1)	3			
奨励品種決定調査試験													10	9	7
備考		関交 2294		世促 （国際農研沖縄）	世促 （北農試）			穂別系統	谷系 RA9594			関系 w503	関東 135 号		

特性検定試験の欄の数字は試験実施数を示す。
系統適応性検定試験、奨励品種決定調査試験の欄の数字は試験実施数を示す。
系統適応性検定試験の 2005 年度の（1）は、協定研究として福島県で系適番号付与前に行った試験である。

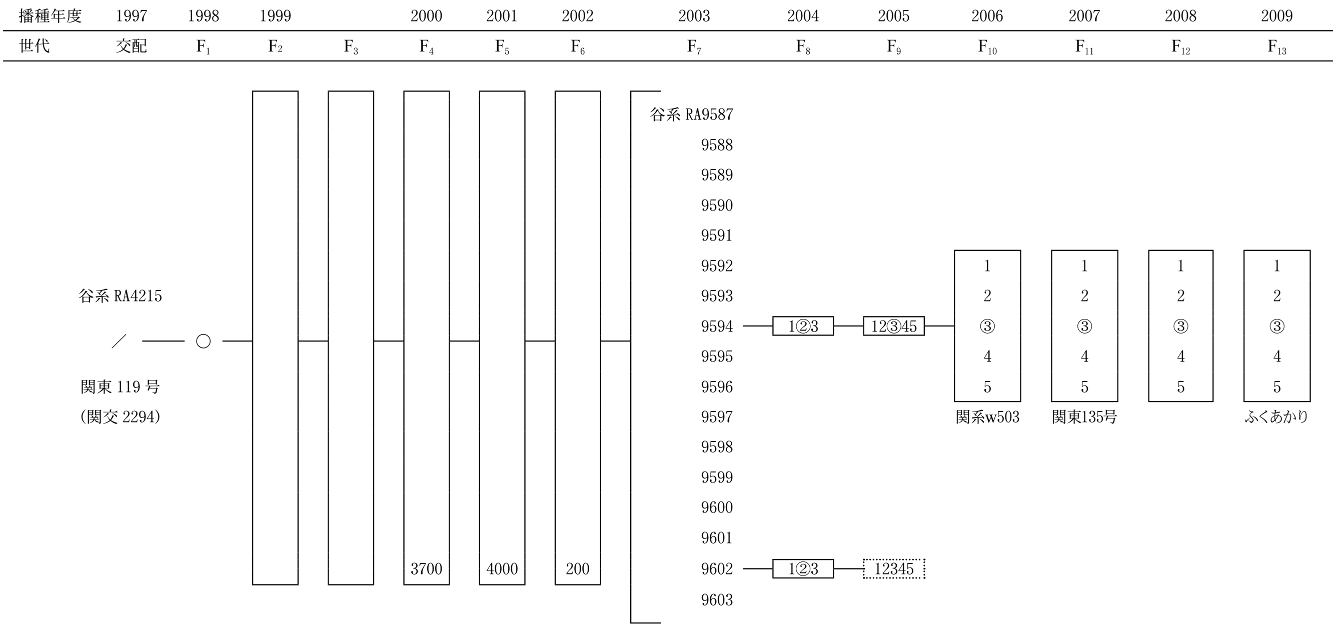

図２　「ふくあかり」の育成系統図

早期に「谷系 RA9594」の配付を受け、農業試験場本場で供試した。早生で、穂発芽耐性に優れることから、2006 年度に系統適応性検定試験（「関系 w503」）、2007 年度に奨励品種決定調査予備試験（「関東 135 号」）に供試し、2008 年度から農業総合センター本部および浜地域研究所で本調査に供試するとともに、白河市と広野町の奨励品種決定調査現地調査に供した。2009 年度から会津地域研究所でも本調査に供試した。

これらの結果、福島県では「関東 135 号」は「アブクマワセ」と成熟期が同程度で、穂発芽性が「難」で「アブクマワセ」に比べて多収であり、加工適性も問題が無かった。そこで、「関東 135 号」を導入することで「アブクマワセ」産地での小麦品質の改善が図られ、大規模麦作団地における収穫適期幅の拡大、さらには麦作付地帯の拡大も見込まれるため奨励品種候補となった。そこで、2010 年に「ふくあかり」の名称で品種登録出願を行った（出願日：2010 年 12 月８日、登録日：2014 年2月 12 日、登録番号：第 23008 号）。

Ⅲ 特　　性

育成地における試験成績をもとに判定した種苗特性分類調査報告書（平成 10 年 3 月）の基準による形態的特性及び生態的特性・品質特性の概要を表 3、4、5 に示す。その特性概要は次の通りである。

1　形態的特性

叢性は“中”で、株の開閉は“中”である。稈長は“中”で「農林 61 号」より短い。稈は“中”の太さで、“やや剛”である。葉色は“中”で、葉身の下垂度は“中”である。穂型は“紡錘状”、穂長は「農林 61 号」よりやや長いが特性分類では同じ“中”に区分される。粒着の粗密は“中”である。ふの色は“褐”である。粒の形は“中”、粒の大小は“やや大”で、粒の色は“褐”である。千粒重は「農林 61 号」よりやや小さいが特性分類では同じ“中”に区分される。容積重は“中”である。原麦粒の見かけの品質は“中の上”である。

2　生態的特性

播性の程度は“I − II”で、茎立性は“やや早”である。出穂期、成熟期は“やや早”で「農林 61 号」より早生である。耐倒伏性は“やや強”である。穂発芽性は“難”で、収量性は“やや多”である。「農林 61 号」に比べて、縞萎縮病、うどんこ病にはやや強い“ やや強”、赤さび病には同程度の“中”、赤かび病にはやや弱い“やや弱”である。

表 3　特性一覧（形態的特性）

形質	ふくあかり 階級（状態・区分）	農林６１号 階級（状態・区分）	アブクマワセ 階級（状態・区分）
叢性	中	やや直立	やや直立
株の開閉	中	中	やや開
鞘葉の色	無	無	無
稈長	中	やや長	短
稈の細太	中	中	中
稈の剛柔	やや剛	中	中
稈のﾜｯｸｽの多少	少	少	中
葉色	中	中	やや淡
葉鞘のﾜｯｸｽの多少	少	少	中
葉鞘の毛の有無・多少	無～極少	無～極少	無
葉身の下垂度	中	中	やや大
ﾌﾚｯｹﾝの有無・多少	無～極少	少	少
穂型	紡錘状	紡錘状	紡錘状
穂長	中	中	短
粒着の粗密	中	中	中
穂の抽出度	やや短	中	中
穂のﾜｯｸｽの多少	少	少	少
ふ毛の有無	無	無	無
葯の色	黄	黄	黄
芒の有無・多少	やや多	中	中
芒長	やや長	中	中
ふの色	褐	褐	淡黄
粒の形	中	中	やや円～中
粒の大小	やや大	やや大	中
粒の色	褐	赤褐	黄褐
頂毛部の大きさ	中	中	中
粒の黒目の有無・多少	無～極少	無～極少	極少
千粒重	中	中	中
容積重	中	中	中
原麦粒の見かけの品質	中の上	中の上	中の上

種苗特性分類調査報告書（平成 10 年 3 月）の基準による
アブクマワセのみ種苗特性分類調査報告書（昭和 55 年 3 月）の項目による

3　品質特性

粒質は“粉状質”で、製粉歩留は“やや高”で、ミリングスコアは“やや高”である。60％粉の粗蛋白質含量は「農林 61 号」よりやや少ないが特性分類では同じ“中”に区分される。灰分含量は“中”、アミロース含量は“やや少”である。粉色は「農林 61 号」に比べ、明度、赤色み、黄色み共に同程度の“中”である。吸水率は「農林 61 号」よりやや低いが特性分類では同じ“中”に区分される。バロリメーターバリュウは“中”である。

表４　特性一覧（生態的特性）

形質	ふくあかり 階級（状態・区分）	農林６１号 階級（状態・区分）	アブクマワセ 階級（状態・区分）
うるち・もちの別	うるち	うるち	―
播性の程度	Ⅰ－Ⅱ	Ⅱ	Ⅰ－Ⅱ
茎立性	やや早	中	やや早
出穂期	やや早	中	極早
成熟期	やや早	中	極早
耐湿性	やや弱	中	―
耐凍上性	弱	弱	―
耐倒伏性	やや強	やや弱	強
穂発芽性	難	難	やや易
脱粒性	中	中	やや易
収量性	やや多	中	やや少
縞萎縮病抵抗性	やや強	中	強
赤かび病抵抗性	やや弱	中	中
うどんこ病抵抗性	やや強	中	やや弱
赤さび病抵抗性	中	中	やや弱

種苗特性分類調査報告書（平成 10 年３月）の基準による
アブクマワセのみ種苗特性分類調査報告書（昭和 55 年３月）の項目による

表５　特性一覧（品質特性）

形質	ふくあかり 階級（状態・区分）	農林６１号 階級（状態・区分）	アブクマワセ 階級（状態・区分）
粗蛋白質含量	中	中	―
灰分含量	やや少	中	―
粒の硬軟	中	中	中
粒質	粉状質	粉状質	やや粉状
製粉歩留	やや高	中	やや高
ミリングスコア	やや高	中	高
60％粉粗蛋白質含量	中	中	やや多
60％粉灰分含量	中	中	―
60％粉ｱﾐﾛｰｽ含量	やや少	中	―
粉の白さ	中	中	やや高
粉の明るさ	中	中	中
粉の色づき	中	中	やや低
粉の明度	中	中	―
粉の赤色み	中	中	―
粉の黄色み	中	中	―
吸水率	中	中	やや高
ﾊﾞﾛﾘﾒｰﾀｰﾊﾞﾘｭｳ	中	中	中
生地の力の程度	中	中	―
生地の伸張抵抗	やや強	中	中
生地の伸張度	やや短	中	やや長
生地の形状係数	やや大	中	中
最高粘度	やや大	中	やや大
ﾌﾞﾚｰｸﾀﾞｳﾝ	やや大	中	―

種苗特性分類調査報告書（平成 10 年３月）の基準による
アブクマワセのみ種苗特性分類調査報告書（昭和 55 年３月）の項目による

Ⅳ　育成地における試験成績

１　生育調査成績及び収穫物調査成績

生産力検定試験における生育調査及び収穫物調査成績の結果を、表６、表７に示す。

「ふくあかり」は「農林 61 号」と比べて、出穂期で４日、成熟期で４日早生の品種である。稈長は15－17cm 短く、耐倒伏性は「農林 61 号」より優れる。穂長はやや長く、穂数は少ない。「農林 61 号」より、うどんこ病には強いが、赤さび病には同程度の抵抗性を持つ。粒色は褐で、千粒重はやや小さく、容積重は同程度である。収量は「農林 61 号」より多収となる。粒質は「農林 61 号」と同じ中間質であるが、種苗特性分類では「農林 61 号」が“粉状質”であるため“粉状質”に区分される。外観品質は同程度である。

表６　育成地における生育調査成績

品種名	栽培法	試験年度	出穂期（月．日）	成熟期（月．日）	稈長（cm）	穂長（cm）	穂数（本 /m^2）	倒伏程度	圃場発病 赤さび病	うどんこ病	赤かび病
ふくあかり	ドリル栽培（畑）	2005-2009	4.17	6. 6	81	9.3	716	0.0	1.2	0.6	0.0
農林 61 号			4.21	6.10	98	8.8	827	1.5	1.2	1.1	0.0
ふくあかり	標準栽培（水田）	2006-2009	4.19	6. 5	72	9.2	245	0.0	0.4	0.8	0.0
農林 61 号			4.23	6. 9	87	8.8	301	1.2	0.9	2.1	0.0

耕種概要　ドリル栽培（畑）：ドリル播、条間 15cm、播種量 222.5 粒 /㎡、１区面積 5.25m^2 または 4.2m^2、２または３区
標準栽培（水田）：条播、畦幅 70cm、播種量 7.1g/m^2、１区面積 7.0m^2、４区
倒伏程度　０（無）、１（微）、２（少）、３（中）、４（多）、５（甚）で表示。
発病程度　０（無）、１（微）、２（少）、３（中）、４（多）、５（甚）で表示。

表７　育成地における収穫物調査成績

品種名	栽培法	試験年度	子実重（kg/a）	標準比率（％）	容積重（g/l）	千粒重（g）	粒型	粒大	粒質	粒色	外観品質
ふくあかり	ドリル栽培（畑）	2005-2009	67.9	136	793	37.3	中	やや大	中間質	褐	中中
農林 61 号			51.2	100	789	38.4	中	やや大	中間質	褐	中中
ふくあかり	標準栽培（水田）	2006-2009	28.1	113	799	34.9	中	やや大	中間質	褐	中中
農林 61 号			26.0	100	796	37.2	中	やや大	中間質	褐	中中

耕種概要　ドリル栽培（畑）：ドリル播、条間 15cm、播種量 222.5 粒 /m^2、１区面積 5.25m^2 または 4.2m^2、２または３区
標準栽培（水田）：条播、畦幅 70cm、播種量 7.1g/m^2、１区面積 7.0m^2、４区

２　特性検定試験成績

特性検定試験の結果を表８、９に示す。

「ふくあかり」は「農林 61 号」に比べて、耐凍上性は同程度である。赤かび病と耐湿性は“やや弱”で「農林 61 号」よりやや劣る。うどんこ病は「農林 61 号」より1ランク強い“中”であるが、種苗特性分類では「農林 61 号」が“中”であるため“やや強”に分類される。縞萎縮病は“やや強”で、「農林 61 号」よりやや優る。播性はⅠ－Ⅱである。

穂発芽性は 2004 － 2009 年（2006 年を除く）でいずれも「農林 61 号」より1－3ランク優れており、総合判断は「農林 61 号」の“中”より2ランク優れる“難”である。しかし、種苗特性分類では「農林 61 号」が“難”であるため、10℃での検定という厳しい条件で2ランク優れているが、“かなり難”または“極難”までの差は無いと判断し、“難”に分類される。

表８　特性検定試験成績

品種名	耐凍上性（長野）	赤かび病抵抗性（長野）	耐湿性（三重）	うどんこ病抵抗性（育成地）	播性（育成地）	縞萎縮病抵抗性（育成地）	
						判定	ElISA 法
ふくあかり	弱	やや弱	やや弱	中	Ⅰ－Ⅱ	やや強	－
農林 61 号	弱	やや強	中	やや弱	Ⅱ	中	＋

注）原則として「小麦調査基準（昭和 61 年３月）」に基づいた７階級区分（極強、強、やや強、中、やや弱、弱、極弱）で表記しており、「種苗特性分類調査報告書（平成 10 年３月）」の９階級区分（極強、かなり強、強、やや強、中、やや弱、弱、かなり弱、極弱）と合わない場合もある。各特性検定の調査方法は以下の通り。
耐凍上性：10 月中旬、下旬の２回播種。越冬株歩合を重点に葉枯れ程度を参考にして強弱を判定。
赤かび病：ポット栽培により、開花期に菌株を接種し、発病程度を０～９のスコアにより評価して判定。
耐湿性：標準区と多湿区の子実重を比較して強弱を判定。
うどんこ病：春播き栽培でチクゴイズミをスプレッダーとする成体自然感染の発病程度により判定。
播性：３月上中旬より 10 日間隔で播種。出穂状況により判定。
縞萎縮病：汚染圃場での発病程度により強弱を判定。一部 ELISA 検定を実施。

表９　育成地における穂発芽性の評価

試験年度	穂発芽性	
	ふくあかり	農林 61 号
2004	難	やや難
2005	極難	中
2006	－	中
2007	極難	難
2008	難	中
2009	難	中
総合判定	難	中

成熟期前後に摘穂した穂を室温で乾燥させた後、２段階の温度（10℃、15℃）で雨濡れ処理を行い、穂発芽程度の経過により判定。
判定は「極難、難、やや難、中、やや易、易、極易」の７段階。

３　製粉及び粉質調査成績

製粉及び粉質調査の結果を表 10、11、12 に示す。製粉及び粉質調査は「小麦品質検定方法－小麦育種試験におけるー」（農林水産技術会議事務局　1968）に準拠して行った。製麺試験は「国内産小麦の評価に関する研究会報告－小麦のめん（うどん）適性評価法－」（食糧庁　1997）に準拠して行った。

「ふくあかり」は「農林 61 号」に比べて、製粉歩留はやや高くミリングスコアはやや高い。BM 率はやや低く、セモリナ生成率、セモリナ粉砕率はやや高い。60％粉の色は同程度である。60％粉の

表 10　育成地における原粒品質、製粉性及び小麦粉品質

品種名	栽培法	試験年度	製粉条件	原粒 灰分（％）	原粒 粗蛋白質含量（％）	製粉性 歩留（％）	製粉性 ﾐﾘﾝｸﾞｽｺｱ	製粉性 BM 率（％）	製粉性 ｾﾓﾘﾅ生成率（％）	製粉性 ｾﾓﾘﾅ粉砕率（％）	製粉性 灰分移行率（％）	60％粉 灰分（％）	60％粉 粗蛋白質含量（％）	60％粉 ｱﾐﾛｰｽ含量（％）	色差計 L*	色差計 a*	色差計 b*	色差計 W	平均粒度（μm）	粒度分布のタイプ
ふくあかり	ドリル栽培（畑）	2005-2008	ア	1.49	11.2	67.9	81.8	60.2	51.3	82.7	48.9	0.40	9.4	26.9	87.01	0.83	14.59	80.46	37.4	B
農林 61 号			ア	1.57	12.0	65.1	78.8	68.8	49.2	78.5	47.5	0.41	10.3	28.6	87.20	0.91	14.51	80.63	37.7	B
ASW			イ	1.29	10.3	71.4	82.8	28.8	64.2	86.4	45.3	0.45	9.6	27.4	89.30	0.47	14.56	81.92	50.7	B
農林 61 号(群馬)			ア	1.70	9.5	64.0	78.6	80.4	47.8	74.3	48.7	0.40	7.3	29.5	88.57	0.69	14.81	81.27	32.1	A'
ふくあかり	標準栽培（水田）	2006	ア	1.79	9.2	70.6	80.7	59.6	50.1	88.2	51.0	0.45	7.8	25.7	88.26	0.82	15.67	80.40	35.5	A'
農林 61 号			ア	1.73	8.9	67.9	79.4	62.7	49.7	83.9	49.5	0.45	8.5	27.2	88.70	0.71	15.35	80.93	34.3	A'
ASW			イ	1.27	9.2	73.2	84.7	28.9	63.8	89.0	46.1	0.43	9.6	26.7	89.54	0.51	14.58	82.05	50.6	B
農林 61 号(群馬)			ア	1.63	10.7	62.3	77.9	75.9	49.1	72.1	47.5	0.38	6.8	29.5	88.58	0.73	15.09	81.06	34.2	A'

注）製粉条件　ア：軟質中間質、イ：軟質硝子質
平均粒度（μm）　ﾚｰｻﾞｰ回折式粒度分布測定装置による測定。
粒度分布のﾀｲﾌﾟ　A（2 頂型で粒度の細かいﾋﾟｰｸがより高い）、A'（2 頂型で両ﾋﾟｰｸの高さがほぼ同じ）、B（2 頂型で粒度の粗いﾋﾟｰｸがより高い）、C（1 頂型）。
栽培法は表 6 と同じ

表 11　育成地における小麦粉品質

品種名	栽培法	試験年度	ﾌｧﾘﾉｸﾞﾗﾑ					ｴｷｽﾃﾝｿｸﾞﾗﾑ（45 分）				ｴｷｽﾃﾝｿｸﾞﾗﾑ（90 分）				ｴｷｽﾃﾝｿｸﾞﾗﾑ（135 分）				ｱﾐﾛｸﾞﾗﾑ			
			吸水率	生地の形成時間(分)	生地の弱化度(BU)	ﾊﾞﾛﾘﾒｰﾀｰﾊﾞﾘｭｳ	生地の安定度(分)	面積 (cm^2)	伸張抵抗 (BU)	伸長度 (mm)	形状係数	面積 (cm^2)	伸張抵抗 (BU)	伸長度 (mm)	形状係数	面積 (cm^2)	伸張抵抗 (BU)	伸長度 (mm)	形状係数	糊化開始温度 (度)	最高粘度時の温度 (度)	最高粘度 (BU)	ﾌﾞﾚｰｸﾀﾞｳﾝ (BU)
ふくあかり	ドリル栽培(畑)	2005-2008	57.3	2.4	95	46	2.1	89	334	202	1.7	96	370	205	1.9	103	385	209	1.8	71.8	89.8	1072	328
農林 61 号			58.2	2.4	90	47	2.1	96	313	226	1.4	93	336	211	1.6	82	273	209	1.3	70.0	88.5	927	163
ASW			58.3	4.5	55	60	4.7	152	553	228	2.4	157	615	217	2.9	166	684	208	3.3	69.3	89.5	863	197
農林 61 号(群馬)			53.6	1.4	107	41	1.2	86	350	189	1.8	88	407	171	2.3	92	433	170	2.6	69.5	90.0	953	140

栽培法は表 6 と同じ

表 12　育成地における製麺試験成績

品種名	栽培法	試験年度	麺帯の色				評点						
			色差計 L*	a*	b*	W	色 (20)	外観 (15)	かたさ (10)	粘弾性 (25)	なめらかさ (15)	食味 (15)	合計 (100)
ふくあかり	ドリル栽培（畑）	2005-2008	82.2	1.50	20.7	72.6	12.3	10.8	7.1	19.3	11.8	10.7	71.8
農林 61 号			81.2	1.85	21.7	71.0	12.3	10.1	6.9	17.7	10.2	10.6	67.6
ASW			83.2	0.90	23.3	71.6	17.0	11.8	7.4	19.5	11.8	11.0	78.4
農林 61 号（群馬）			85.0	1.06	20.0	74.9	14.0	10.5	7.0	17.5	10.5	10.5	70.0
ふくあかり	標準栽培（水田）	2006	83.4	2.36	21.9	72.4	14.7	11.3	7.5	19.9	12.3	11.0	76.7
農林 61 号			82.7	2.33	21.8	72.0	15.0	10.8	7.0	17.8	10.7	10.7	71.9
ASW			82.8	1.76	22.3	71.8	17.3	12.3	7.5	19.7	11.8	11.0	79.5
農林 61 号（群馬）			84.8	1.77	18.5	76.0	14.0	10.5	7.0	17.5	10.5	10.5	70.0

灰分含量は同程度で、粗蛋白質含量はやや低い。アミロース含量はやや低い。吸水率はやや低く、バロリメーターバリュウは同程度である。エキステンソグラムの面積、伸張抵抗、形状係数はやや大きく、伸長度は同程度である。アミログラムの最高粘度はやや高く、ブレークダウンは大きい。麺の色は同程度で、麺の粘弾性、なめらかさに優れる。

4　実需者による二次加工適性試験成績

関東ブロック品質評価協議会において行った製粉及び粉質調査と製めん試験を行った結果を表 13、14 に示す。

「ふくあかり」は「農林 61 号」に比べて、製粉歩留とミリングスコアは高い。60%粉の色は同程度で、灰分、粗蛋白質含量、アミロース含量はやや少ない。吸水率がやや低く、弱化度がやや大きい。バロリメーターバリュウは同程度で、生地の安定度はやや小さい。アミログラムの最高粘度はやや高い。麺の色と粘弾性は同程度で、なめらかさはやや優れる。

5　固定度調査成績

固定度調査の結果を表 15 に示す。

各系統の出穂期、稈長、穂長、1 株穂数の平均値及び変動係数から見て、「ふくあかり」は実用的に固定していると推定される。

表 13　実需者による二次加工適性試験（製粉及び粉質調査）

品種名	試験年度	原粒		製粉性		６０％粉						ﾌｧﾘﾉｸﾞﾗﾑ					ｱﾐﾛｸﾞﾗﾑ		
		灰分 (%)	粗蛋白質含量 (%)	歩留 (%)	ﾐﾘﾝｸﾞｽｺｱ	灰分 (%)	粗蛋白質含量 (%)	ｱﾐﾛｰｽ含量 (%)	ｶﾗｰｸﾞﾚｰﾀﾞｰﾊﾞﾘｭｳ	分光光度反射率 R455	R554	吸水率	生地の形成時間(分)	生地の弱化度 (BU)	ﾊﾞﾛﾘﾒｰﾀｰﾊﾞﾘｭｳ	生地の安定度 (分)	糊化開始温度 (度)	最高粘度時の温度 (度)	最高粘度 (BU)
ふくあかり	2007-2008	1.73	9.5	65.4	77.6	0.44	7.8	26.4	-1.5	60.9	78.5	53.3	1.5	93	44	2.0	57.5	88.8	1143
農林 61 号		1.80	10.2	61.5	72.5	0.47	8.7	28.2	-1.4	61.0	78.4	54.8	1.7	78	47	4.0	57.8	88.8	1003
ASW		1.21	10.5	71.5	83.0	0.40	9.4	27.7	-3.6	63.8	81.8	56.9	5.4	48	64	9.4	57.8	88.0	865
農林 61 号(群馬)		1.66	8.6	63.2	76.9	0.42	7.3	30.3	-2.8	63.2	80.8	53.4	1.4	113	39	2.0	58.3	89.5	960

供試材料：作物研究所における標準栽培（水田）の生産物
試験実施場所：製粉研究所

表 14　実需者による二次加工適性試験（製麺試験成績）

品種名	試験年度	評点 色 (20)	外観 (15)	かたさ (10)	粘弾性 (25)	なめらかさ (15)	食味 (15)	合計 (100)
ふくあかり	2007-2008	13.6	10.5	7.0	17.6	10.9	10.5	70.0
農林 61 号		13.6	10.5	7.1	17.5	10.5	10.5	69.6
ASW		15.4	10.7	7.5	19.2	11.4	10.5	74.5
農林 61 号（群馬）		14.0	10.5	7.0	17.5	10.5	10.5	70.0

供試材料：作物研究所における標準栽培（水田）の生産物
試験実施場所：製粉研究所

表 15　固定度

品種名	系統番号	出穂期（月．日）	稈長 平均 (cm)	稈長 変動係数 (%)	穂長 平均 (cm)	穂長 変動係数 (%)	穂数 平均 (本/株)	穂数 変動係数 (%)	調査株数
ふくあかり	1	4　14	77.4	4.0	10.4	6.1	13.1	26.6	30
	2	4　14	73.5	3.8	10.5	5.7	13.3	26.4	30
	③	4　15	75.5	3.9	10.6	6.2	14.3	26.1	30
	4	4　15	75.3	4.1	10.8	5.2	12.5	23.5	30
	5	4　14	76.2	4.4	10.7	6.1	14.3	38.7	30
	平均	4　14	75.6	4.0	10.6	5.9	13.5	28.2	
農林 61 号	1	4　20	94.0	5.5	10.8	5.5	15.4	31.1	26
	2	4　21	93.0	5.1	10.8	5.8	14.3	25.3	24
	3	4　21	95.7	3.5	10.6	4.6	15.6	18.9	30
	4	4　21	95.0	3.6	10.6	6.9	14.4	29.4	30
	5	4　21	93.7	4.5	10.6	5.4	13.6	27.1	30
	平均	4　21	94.3	4.5	10.7	6.0	14.7	26.4	

○印は選抜系統を表す。
耕種概要：畦幅 70cm、株間 10cm、1 点 1 粒播、2009 年 10 月 29 日播種。

V　配付先（福島県を除く）における試験成績

1　福島県農業総合センター及び現地試験における試験成績

福島県農業総合センターにおける成績を表 16 に示す。

標準播種では、「ふくあかり」は「アブクマワセ」に比べて、出穂期は 6 日遅く、成熟期は同程度である。稈長は同程度で穂長は長い。穂数は少ない。収量は多く、容積重はやや大きく、千粒重は同程度である。外観品質はやや劣る。

ドリル播種では、「ふくあかり」は「アブクマワセ」に比べて、出穂期は 5 日、成熟期は 1 日遅い。稈長は同程度で穂長は長い。穂数は少ない。収量は多く、容積重と千粒重は同程度である。外観品質はやや劣る。

現地圃場における成績を表 17 に示す。

「ふくあかり」は「アブクマワセ」に比べて、出穂期で 2 − 4 日、成熟期で 1 − 2 日遅い。稈長は同程度である。穂数は少ないが収量は多い。容積重と千粒重は同等−やや大きい。外観品質は同等−やや劣る。

「ふくあかり」は「きぬあずま」に比べて、出穂期と成熟期で 4 日早い。稈長は 6cm 短く、耐倒伏性に優れる。穂数は少ないが収量は多い。容積重と千粒重はやや大きい。外観品質はやや優れる。

表 16　福島県農業総合センターにおける奨励品種決定調査成績

系統名及び品種名	栽培法	試験年度	出穂期(月.日)	成熟期(月.日)	稈長(cm)	穂長(cm)	穂数(本/m²)	倒伏程度	赤さび病	うどんこ病	赤かび病	縞萎縮病	子実重(kg/a)	ｱﾌﾞｸﾏﾜｾ対比標準比率(％)	きぬあずま対比標準比率(％)	容積重(g/l)	千粒重(g)	検査等級
ふくあかり	標準播種(普通畑)	2005-2009	4.29	6.13	77	8.0	383	0.0	0.2	0.0	0.0	0.0	50.2	129	88	781	38.8	2上
アブクマワセ			4.23	6.13	77	7.0	455	0.0	0.0	0.2	0.0	0.0	40.6	100	70	766	38.5	1下
きぬあずま			5.3	6.17	82	8.5	414	0.0	0.2	0.0	0.0	0.0	57.5	147	100	780	40.7	1中
ふくあかり	ドリル(普通畑)	2007-2009	4.29	6.11	77	7.8	542	0.0	0.0	0.0	0.0	0.0	55.4	109	－	778	35.5	2上
アブクマワセ			4.24	6.10	76	6.7	628	0.0	0.0	0.0	0.0	0.0	51.7	100	－	775	36.3	1中

耕種概要　標準栽培（普通畑）：条播、播幅 70cm、播種量 0.5kg/a、1 区面積 7.0 又は 11m²、2 または 3 区
　　　　　ドリル栽培（普通畑）：ドリル播、播幅 30cm、播種量 1.0kg/a、1 区面積 40 または 50m²、2 区
倒伏程度　0（無）、1（微）、2（少）、3（中）、4（多）、5（甚）で表示。
発病程度　0（無）、1（微）、2（少）、3（中）、4（多）、5（甚）で表示。

表 17　福島県における奨励品種決定現地調査成績

場所	系統名及び品種名	試験年度	出穂期(月.日)	成熟期(月.日)	稈長(cm)	穂数(本/m²)	倒伏程度	赤さび病	赤かび病	縞萎縮病	子実重(kg/a)	標準比率(％)	容積重(g/l)	千粒重(g)	検査等級
白河市	ふくあかり	2008-2009	4.28	6.17	75	529	0.0	0.0	0.0	0.0	33.9	160	773	35.4	2上
	アブクマワセ		4.26	6.15	76	703	0.5	0.0	0.0	0.0	21.0	100	777	33.4	2上
広野町	ふくあかり	2008-2009	4.26	6.16	73	269	0.0	0.0	0.0	0.0	22.0	113	763	35.0	2下
	アブクマワセ		4.22	6.15	74	286	0.5	0.0	1.5	0.0	23.1	100	742	35.5	2上
二本松市	ふくあかり	2008-2009	5.05	6.22	85	453	0.5	0.0	0.0	0.0	51.0	112	802	35.6	2下
	きぬあずま		5.09	6.26	91	509	2.0	0.0	0.0	0.0	47.6	100	781	33.7	規格外

倒伏程度　0（無）、1（微）、2（少）、3（中）、4（多）、5（甚）で表示。
発病程度　0（無）、1（微）、2（少）、3（中）、4（多）、5（甚）で表示。

2　福島県における品質評価

福島県での栽培した収穫物の作物研究所及び東北農業研究センターで実施した品質評価成績を表 18、19 に示す。

「ふくあかり」は「アブクマワセ」に比べて、製粉歩留とミリングスコアは同程度である。BM 率はやや低い。60％粉の灰分は同程度、粗蛋白質含量、アミロース含量はやや低い。60％粉の色は明度 (L*) がやや低く、赤味 (a*) がやや高い。麺の色は劣り、粘弾性となめらかさは優り、合計ではやや劣る。製麺試験の共通標準である群馬産「農林 61 号」との比較では、麺の色はやや劣るが、その他の全ての項目で優る。

実需者による品質評価を表 20、21 に示す。

表 18　福島県における品質試験成績（製粉及び粉質調査）

品種名	試験年度	原粒		製粉性			60％粉						
		灰分(％)	粗蛋白質含量(％)	歩留(％)	BM 率(％)	ﾐﾘﾝｸﾞｽｺｱ	灰分(％)	粗蛋白質含量(％)	ｱﾐﾛｰｽ含量(％)	色彩色差計 L*	a*	b*	W
ふくあかり	2005-2007	1.73	9.4	70.3	44.4	81.8	0.44	8.1	27.1	88.4	0.54	14.6	81.4
アブクマワセ		1.61	10.0	69.1	50.9	81.9	0.42	8.9	29.8	89.1	0.41	14.1	82.2
農林 61 号（群馬）		1.69	9.5	66.0	56.4	80.8	0.38	7.3	29.5	88.5	0.60	14.7	81.4

栽培場所：福島県
試験実施場所：2005 ～ 2006 年度は作物研究所。2007 年度は東北農業研究センター。

表 19　福島県における品質試験成績（製麺試験）

品種名	試験年度	評点 色(20)	外観(15)	かたさ(10)	粘弾性(25)	なめらかさ(15)	食味(15)	合計(100)
ふくあかり	2005-2007	13.4	11.0	7.6	19.7	11.9	10.8	74.3
アブクマワセ		16.0	11.5	7.3	18.6	11.1	10.7	75.3
農林 61 号（群馬）		14.0	10.5	7.0	17.5	10.5	10.5	70.0

栽培場所：福島県
試験実施場所：2005 ～ 2006 年度は作物研究所。2007 年度は東北農業研究センター。

表 20　福島県における実需者評価（製麺試験）

試験名		評点 色 (20)	外観 (15)	かたさ (10)	粘弾性 (25)	なめからさ (15)	食味 (15)	合計 (100)
試験 1	ふくあかり	16.1	11.5	7.2	18.6	12.1	11.3	76.5
	(F) J-1 斜里	14.0	10.5	7.0	17.5	10.5	10.5	70.0
試験 2	ふくあかり（1 等粉）	16.1	11.5	7.2	18.6	12.1	11.3	76.5
	ふくあかり（2 等粉）	9.9	9.2	6.9	17.8	10.8	11.0	66.5
	ふくあかり（1 等粉＋2 等粉）	13.7	10.0	7.1	17.8	10.9	10.7	69.5
	ASW（総合食料局無償譲与）	18.4	12.6	7.0	17.7	12.3	10.9	77.5
	農林 61 号（群馬）	14.0	10.5	7.0	17.5	10.5	10.5	70.0

材料－ 2008 年度福島県で栽培したふくあかりの江別製粉株式会社の F-Ship で製粉した 1 等粉及び 2 等粉江別製粉株式会社製小麦粉の「(F) J-1（斜里)」
試験 1 は（F）J-1 斜里を標準に江別製粉株式会社にて実施。
試験 2 は農林 61 号（群馬）を標準に福島県農業総合研究センターにて実施。
江別製粉株式会社の F-Ship で製粉した 1 等粉及び 2 等粉の特性

品種名	原粒蛋白質含量（%）		製粉歩留（%）	灰分（%）	粉蛋白質含量（%）	ﾌｧﾘﾉｸﾞﾗﾌ ﾊﾞﾛﾘﾒｰﾀｰﾊﾞﾘｭｳ	ｱﾐﾛｸﾞﾗﾌ 最高粘度（BU）
ふくあかり	9.6	1 等粉	44	0.39	7.6	43	1040
		2 等粉	18	0.55	8.7	44	870

表 21　福島県における実需者評価（ゆで麺の保存試験）

	加水量（%）	保存日数（日）	評点 色 (20)	外観 (15)	かたさ (10)	粘弾性 (25)	なめからさ (15)	食味 (15)	総合評価 (100)
基準（各材料保存 1 日目の麺）			14.0	10.5	7.0	17.5	10.5	10.5	70.0
ふくあかり A	37	4	11.9	9.5	6.6	17.4	10.3	10.4	67.6
		7	12.6	9.9	7.0	17.8	10.7	10.7	71.8
		11	13.5	10.2	7.4	17.5	10.7	10.7	70.6
ふくあかり B	39	4	14.3	10.6	7.2	17.2	11.1	10.5	71.9
		7	13.9	10.6	6.9	17.7	11.0	10.2	68.8
		11	13.5	10.7	7.4	18.3	11.2	10.8	71.9
あぶくま	37	4	12.4	10.0	6.8	17.8	10.1	10.3	70.0
		7	12.6	9.9	6.7	17.6	10.7	10.5	72.4
		11	12.4	9.4	6.3	16.9	9.9	10.3	68.2
きぬあずま	37	4	12.9	10.0	6.9	17.7	10.3	10.2	69.4
		7	12.0	9.9	7.1	18.4	11.0	10.4	72.5
		11	11.2	7.5	6.4	15.6	10.0	9.5	58.8

材料－江別製粉株式会社の F-Ship で製粉したふくあかりの 1 等粉
阿部製粉株式会社製小麦粉の「あぶくま」（シラネコムギ＋アブクマワセ）及び「きぬあずま」
保存試験－阿部製粉株式会社にて実施。3% 食塩と 1% アルコールをを加えてゆで麺を作成し、ポリ袋に入れて所定日数 5℃で保存。
保存 1 日の麺を基準に官能評価を行った。

供試材料は江別製粉株式会社が開発した小型製粉プラント F − Ship で製粉した 1 等粉と 2 等粉である。「ふくあかり」は「(F) J-1 斜里）より、麺の色、外観、粘弾性、なめらかさで優れている。また、1 等粉は 2 等粉より、麺の色、外観、粘弾性、なめらかさで優れている。ゆで麺の保存日数 11 日の総合評価では、「あぶくま」は少し低下、「きぬあずま」は著しく低下するが、「ふくあかり」は低下せず、「ふくあかり」の保存性は「きぬあずま」より明らかに良く、「あぶくま」よりも優っている。

3　福島県における穂発芽耐性

穂発芽性の調査結果を表 22 に示す。

2005 − 2008 年の 4 年間いずれも、「ふくあかり」は「アブクマワセ」より穂発芽粒率が明らかに低く、穂発芽耐性が強い。

表 22　福島県における穂発芽性の評価

試験年度	穂発芽粒率（%） ふくあかり	アブクマワセ
2005	1	80
2006	5	93
2007	17	91
2008	1.2	90

サンプルは成熟期に各区より 10 穂を無作為に採取し、採取後室温で風乾保管し、流水中に５時間浸漬後、温度 20℃の接種箱に搬入。
４日後に 80℃で乾燥した後に発芽粒率（発芽粒数／調査粒数）を調査。

Ⅵ　配付先（福島県を除く）における試験成績

配付先（福島県を除く）における成績を表 23、24 に示す。

「ふくあかり」は「農林 61 号」と比べて、出穂期で２－６日、成熟期で２－７日早い。稈長は 15 － 19cm 短く、耐倒伏性に優れる。穂長は愛知で 1.4cm 短いが、その他は同等である。穂数は滋賀を除きやや少ない。収量は埼玉、千葉、三重、滋賀では多いが、岐阜、愛知、山口では少ない。容積重は埼玉、神奈川ではやや大きいが、愛知、滋賀ではやや小さい。千粒重は埼玉ではやや大きいが、その他ではやや小さい。外観品質は埼玉ではやや優れるが、その他ではやや劣る。

長野県では「ふくあかり」は「シラネコムギ」に比べて出穂期と成熟期で４日早い。稈長は 11cm 短く、耐倒伏性は同程度である。穂長は同程度である。穂数はやや少ないが、収量は多い。容積重はやや大きい。千粒重はやや小さい。外観品質はやや優れる。

「ふくあかり」は「シロガネコムギ」と比べて、出穂期と成熟期で１日遅い。稈長は兵庫で 3cm 短く、

表 23　配付先（除く福島）における試験成績

場所	試験年度	品種名	発芽の良否	叢性	出穂期 (月.日)	成熟期 (月.日)	稈長 (cm)	穂長 (cm)	穂数 (本/m^2)	株の開閉	倒伏程度	赤さび病	うどんこ病	赤かび病	縞萎縮病	子実重 (kg/a)	標準比率 (%)	容積重 (g/l)	千粒重 (g)	外観品質
埼玉	2007	ふくあかり	1.0	2.0	4.14	6.08	95	8.3	655	－	4.3	0.0	0.3	0.0	0.0	78.9	135	842	34.5	5.0
		農林 61 号	1.0	2.0	4.18	6.10	110	8.4	745	－	5.0	0.0	1.5	0.0	0.0	58.3	100	830	33.2	6.0
千葉	2007-2009	ふくあかり	－	－	4.13	6.04	86	8.9	351	3.2	0.5	0.0	－	0.0	0.0	42.5	110	801	34.6	4.0
		農林 61 号	－	－	4.18	6.08	101	9.1	398	3.0	2.8	0.0	－	0.0	0.0	39.2	100	796	36.8	3.7
神奈川	2007-2008	ふくあかり	1.0	3.0	4.17	6.02	81	9.0	319	3.0	0.0	0.5	0.0	0.0	0.0	45.7	101	802	37.8	4.3
		農林 61 号	1.0	3.0	4.21	6.08	96	9.2	398	3.0	1.8	0.5	0.3	0.0	0.0	45.3	100	793	38.7	3.5
長野	2007-2008	ふくあかり	1.0	－	5.03	6.20	83	8.2	568	4.0	0.0	0.0	0.3	0.0	0.0	87.3	114	839	41.6	4.0
		シラネコムギ	1.0	－	5.07	6.24	94	8.0	593	4.0	0.2	0.5	0.8	0.0	0.0	77.3	100	823	42.3	4.5
岐阜	2007-2009	ふくあかり	1.0	－	4.07	5.30	70	8.2	298	3.0	0.0	0.0	0.0	0.0	0.0	36.3	81	810	36.5	4.3
		農林 61 号	1.0	－	4.11	6.04	87	8.1	471	3.5	1.3	0.0	0.0	0.0	0.0	45.4	100	816	42.6	3.2
愛知	2007	ふくあかり	2.8	3.8	4.13	5.31	79	9.5	247	2.8	0.0	－	－	－	－	34.7	84	794	34.3	5.3
		農林 61 号	1.5	2.0	4.15	6.06	94	8.2	445	3.0	0.4	－	－	－	－	41.0	100	825	40.6	1.9
三重	2007	ふくあかり	3.0	－	4.11	5.31	85	9.2	480	－	0.0	0.0	0.0	0.0	0.0	68.4	110	807	35.6	6.0
		農林 61 号	3.0	－	4.14	6.04	104	8.7	599	－	1.7	0.0	0.0	0.0	0.0	62.1	100	806	40.1	5.0
滋賀	2008-2009	ふくあかり	1.0	－	4.10	6.02	76	8.1	565	3.2	0.0	0.0	0.0	0.0	0.0	50.1	109	819	39.0	5.3
		農林 61 号	1.0	－	4.13	6.09	95	7.8	490	3.2	0.3	1.5	0.0	0.4	0.0	45.5	100	831	43.4	2.7
兵庫	2008-2009	ふくあかり	1.0	－	4.11	6.01	77	8.6	503	－	0.0	0.0	0.0	0.0	0.0	48.4	112	796	33.5	3.5
		シラネコムギ	1.0	－	4.10	6.02	80	7.4	650	－	0.0	0.0	0.0	0.0	0.0	43.7	100	802	35.2	1.8
山口	2008-2009	ふくあかり	4.5	－	4.09	6.03	71	8.8	269	－	0.3	0.0	0.0	0.0	0.0	32.2	76	824	35.8	3.9
		農林 61 号	5.0	－	4.15	6.07	92	9.0	418	－	2.1	0.0	0.0	0.0	0.8	42.9	100	818	39.5	2.6
香川	2008	ふくあかり	3.0	4.5	4.05	5.25	69	8.7	341	－	0.0	－	－	0.0	－	40.5	96	835	39.5	3.5
		さぬきの夢 2000	1.0	3.0	4.06	5.25	77	6.8	469	－	0.0	－	－	0.0	－	42.4	100	845	41.1	1.0
佐賀	2008-2009	ふくあかり	1.0	3.0	4.13	6.02	80	8.6	388	2.3	0.0	0.0	0.0	0.0	0.0	49.0	103	821	33.7	3.5
		シロガネコムギ	1.0	3.0	4.12	6.03	74	7.5	476	3.5	0.0	0.0	0.0	0.0	0.0	47.4	100	820	33.8	2.0

発芽の良否　1（良 80%以上）、3（中）、5（否 60%以下）で表示。
叢性　1（直立）、2（やや直立）、3（中間）、4（やや匍匐）、5（匍匐）で表示
株の開閉　1（閉）、3（中）、5（開）で表示。
倒伏程度　0（無）、1（微）、2（少）、3（中）、4（多）、5（甚）で表示。
発病程度　0（無）、1（微）、2（少）、3（中）、4（多）、5（甚）で表示。
外観品質　1（上の上）、2（上の中）、3（中の上）、4（中の中）、5（中の下）、6（下）で表示。

佐賀で6cm長い。耐倒伏性は同程度である。穂長はやや長い。穂数は少なく、収量は兵庫でやや多いが佐賀では同等である。容積重は同等である。千粒重は兵庫ではやや小さいが佐賀では同等である。外観品質はやや劣る。

香川では「ふくあかり」は「さぬきの夢2000」と比べて、出穂期で1日早く、成熟期で同程度である。稈長は8cm短い。耐倒伏性は同程度である。穂長は長い。穂数は少なく、収量は同等である。容積重と千粒重はやや小さい。外観品質はやや劣る。

表24　配付先（除く福島）における概評一覧

県名	2007		2008		2009		標準品種
埼玉	△※	135					農林61号
千葉	△	122	△	82	※	127	農林61号
神奈川	△	106	×	96			農林61号
長野	△	124	△	103			シラネコムギ
岐阜	△	90	△	109	※	44	農林61号
愛知	△×※	84					農林61号
三重	×	110					農林61号
滋賀			△	127	△	92	農林61号
兵庫			△	124	△	99	シロガネコムギ
山口			△	100	×	79	農林61号
香川			×	96			さぬきの夢2000
佐賀			△	111	×	96	シロガネコムギ

注）数字は子実重の対標準比（%）。○：有望、△：再検討、×：打ち切り、※：特性把握

Ⅶ 考　　察

小麦の収穫時期が入梅時期と重なるため穂発芽の被害を受けやすい日本では、ゼンコウジコムギやトヨホコムギの穂発芽耐性が強いことが知られている（Hoshino *et al.* 1989）。穂発芽耐性を強くするためには、種子休眠性を高めることが必要であり、ゼンコウジコムギの強い休眠性を担う3A染色体の種子休眠QTL: *QPhs.ocs-3A.1* が同定されている（Mori *et al.* 2005）。近年、Nakamura *et al.*（2011）によりこのQTLの原因遺伝子が *Mother of FT and TFL1*（*MFT*）遺伝子であることが報告された。穂発芽耐性が強いゼンコウジコムギと弱いChinese Springの間の種子休眠程度の差は、MFT遺伝子のプロモーター上の一塩基置換により生じており、*Cla*I制限酵素サイトをゼンコウジコムギ（休眠性強）型は持たないのに対して、Chinese Spring（休眠性弱）型は持っている。この *Cla*I制限酵素サイトの有無を利用したDNAマーカーにより *MFT* 遺伝子の遺伝子型を判定したところ、「ふくあかり」と「アブクマワセ」はいずれも温暖地・暖地で育成された品種に多く見られるゼンコウジコムギ（休眠性強）型であった（Chono *et al.* 2015）。しかし、「ふくあかり」は「アブクマワセ」より、明らかに穂発芽耐性が強くなっている。これは、育成の過程で、*MFT* 遺伝子以外の遺伝的要因が導入された結果であると考えられる。ただし、両親のいずれから導入されたかは断定出来ない。

日本めんの食感には、小麦粉に含まれるデンプン組成が大きく影響している。小麦粉中のデンプンは直鎖構造を持つアミロースと枝分かれ構造を持つアミロペクチンで構成され、アミロースの比率（アミロース含量）が22－24%程度（低アミロース）までは、アミロース含量が低い小麦粉で作られた日本めんの食感はモチモチ感が増し、粘弾性が向上する。日本めん用として高い評価を得ている輸入銘柄「ASW（オーストラリア・スタンダード・ホワイト）」はアミロース含量が25－27%程度（やや低アミロー

ス）である。

「ふくあかり」は製麺試験において「農林61号」や「アブクマワセ」に比べて、麺の粘弾性と滑らかさが優れている。これは、アミロース含量が「農林61号」「アブクマワセ」などの28－30%程度（通常アミロース）より少し低いやや低アミロースであるためである。アミロース合成を支配する酵素であるWxタンパク質は小麦では3種類（Wx-A1、Wx-B1、Wx-D1）あり、「農林61号」や「アブクマワセ」などの通常アミロースの品種は3種類すべてを持っている。「ふくあかり」はWx-B1を欠失しているためやや低アミロースである。交配親である「あやひかり」はWx-A1とWx-B1を欠失しているため低アミロースであり、もう一方の交配親である「谷系RA4215」はWx-B1を欠失しているためやや低アミロースである。このことから、「ふくあかり」は「あやひかり」のWx-A1欠失という性質は引き継がなかったことにより、低アミロースではなく、やや低アミロースの特性を持っている。

作物研究所（現　次世代作物開発研究センター）では、日本めん用として低アミロースの小麦品種「あやひかり」（吉田ら　2001a）と「きぬあずま」（吉田　2001b）、やや低アミロースの小麦品種「あおばの恋」（乙部ら　2011）を育成した。このうち、「あおばの恋」は日本めん用でありながら硬質で製粉歩留が高いという特徴を持っている。今回育成した「ふくあかり」は、作物研究所としては初めて育成した「農林61号」より製粉歩留の高い軟質のやや低アミロースの小麦品種である。

福島県以外の配付先での「ふくあかり」の試験成績では、「農林61号」と比べて岐阜、愛知、山口では収量が少ない。岐阜は2009年度が雀害（備考の記述）で標準比率が44%になっている影響が大きい。愛知は「出穂期の割に登熟が早く未熟粒が多い」、山口は「湿害で穂数が少ない」と備考がある（データ省略）。愛知での登熟の早さも湿害により根の活性が低下したことで正常に登熟出来なかった可能性がある。従って、「ふくあかり」の耐湿性が“やや弱”で「農林61号」よりやや劣ることから、栽培では湿害対策に配慮する必要がある。

福島県は、「ふくあかり」を穂発芽耐性が弱い「アブクマワセ」の産地（中通り、浜通りの平坦地）に導入することで、小麦品質の改善、収穫適期幅と麦作付地帯の拡大が見込めるとの理由で、2011年4月に「ふくあかり」を奨励品種に採用した。しかし、2011年3月11日に東日本大震災が発生し、東京電力福島第1原子力発電所の事故の被害を普及予定地域が受けたため、普及は当初の予定より大幅に遅れている。しかし、「ふくあかり」の普及が今後進められ、東日本大震災の被害からの復興の一助になることを期待したい。

Ⅷ　栽培適地と栽培上の注意

栽培適地は南東北及び関東以西の平坦地である。

穂発芽性は“難”であるが、刈り遅れによる品質低下を避けるため適期収穫に努める。赤かび病抵抗性は“やや弱”であるので、適期防除に努める。耐湿性は“やや弱”で「農林61号」よりやや劣ることから、湿害対策に努める。

Ⅸ　命名の由来

地域農業、地場産業、消費者に「福」をもたらし、小麦振興の兆しとなることを願った。（英文字で表現する必要がある場合には「Fukuakari」を用いる。）

Ⅹ 謝　　辞

本品種の育成にあたり、特性検定試験、系統適応性検定試験、奨励品種決定調査、栽培試験で関係各県、福島県内の現地試験の関係各位にご協力いただいた。また、育種を進める上で、中央農業総合研究センター（現　中央農業研究センター）企画調整部業務科職員が、圃場管理及び製粉・製めん作業に従事した。これらの方々に深甚の謝意を表する。

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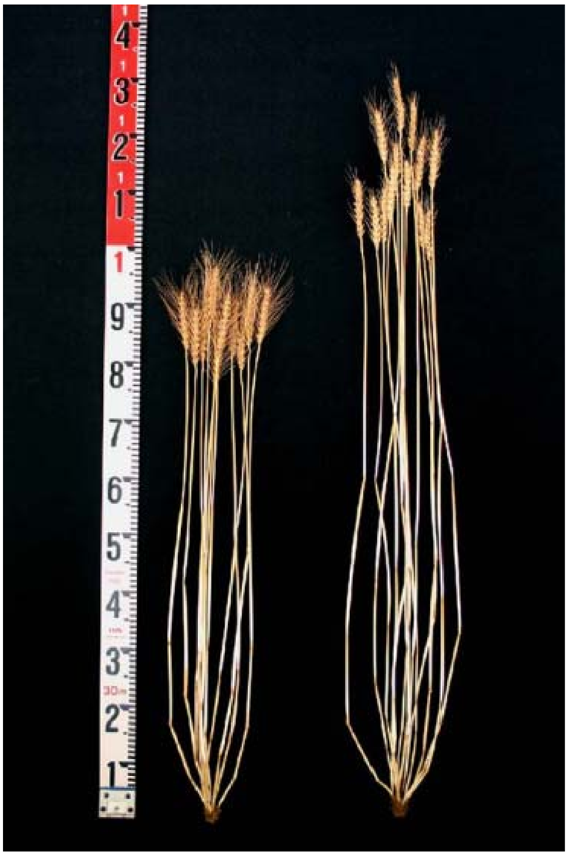

左：「ふくあかり」　右：「農林 61 号」
写真１　「ふくあかり」の株

左：「ふくあかり」　右：「農林 61 号」
写真２　「ふくあかり」の穂

左：「ふくあかり」　右：「農林 61 号」
写真３　「ふくあかり」の粒

付表１　育成従事者

播種年度	1997	1998	1999		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
世代	交配	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}
小田　俊介													―	―
乙部　千雅子	―	―	―	―	―	―	―	―			―	―	―	―
関　昌子									―	―	―	―	―	―
小島　久代													―	―
松中　仁						―	―	―	―	―	―	―	―	
藤田　雅也					―	―	―	―	―	―	―			
吉岡　藤治						―	―							
柳沢　貴司	―	―	―	―	―	―								
吉田　久	―	―	―	―										

Induced Mutations for Food and Energy Security: Challenge of Inducing Unique Mutants for New Cultivars and Molecular Research

Hitoshi NAKAGAWA [*1] and Hiroshi KATO

Abstract

Following the construction of the Gamma Field at the Institute of Radiation Breeding (IRB) in 1960, mutation breeding was accelerated in Japan. The facility is used to artificially induce mutations with a higher radiation dose (up to 2 Gy/day, that is *ca.* 300,000 times that of natural background) at a higher frequency than occurs in nature. Since the unit became operational, the number of mutant cultivars generated in Japan increased until 2000–2010 and has since decreased. There have been 295 direct-use mutant cultivars representing 70 species generated through irradiation utilizing gamma-rays, X-rays, ion beams and chemical mutagenesis and *in vitro* culture. Each cultivar has been registered and released in Japan, with approximately 79% of these induced by radiation. There have been 335 indirect-use mutant cultivars, including 298 rice, of which 150 cultivars (50.3%) were derived from the semi-dwarf mutant cv. "Reimei" or its offspring. The economic impact of these mutant cultivars, primarily of rice and soybean, is very large. Some useful mutations are discussed for rice, such as low digestible-protein content, low amylose content, giant embryo and non-shattering. Useful mutations in soybean such as radio-sensitivity, fatty acid composition, lipoxygenase lacking, glycinin rich and super-nodulation have been identified. A similar series of advantageous mutations have been found in Japanese pear and other crops through various screening methods. The achievements of biological researches such as characterization and determination of deletion size generated by gamma-rays, the effect of deletion size and the location are identified. Similarly, genetic studies generated through the use of gamma-ray induced mutations, such as phytochrome research, aluminum tolerance and epicuticular wax have also been conducted in Japan. A unique mutation induction technique for outcrossing Italian ryegrass is also explained. Mutation breeding is a very interesting and useful technology for isolating genes and for elucidating gene functions and metabolic pathways in various crops. Records show that mutation induction is a very useful conventional breeding tool for developing superior cultivars. The IRB is well equipped with appropriate facilities and equipment that will contribute to future mutation breeding developments and it will be a contributor in solving various genomic, proteomic and metabolic problems.

Keyword: genetic analysis, gamma-ray irradiation, Gamma Field, mutation breeding, mutant cultivar

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食料・エネルギー安全保障に貢献する誘発突然変異：品種育成や分子遺伝学的研究のための新たな突然変異体誘発への挑戦

中川　仁[*1]・加藤　浩

抄　　録

1960 年、放射線育種場にガンマーフィールドが建設されて以来、我が国では突然変異育種が加速された。ガンマーフィールドは人工的に突然変異の誘発率を高める施設であり、線源から最も近い地点では 1 日に 2 グレイ（Gy）（自然界の 30 万倍：1 日で 1,000 年分）照射できる。我が国の突然変異品種登録数は、2000-2010 年がピークとなり、現在は減少傾向にある。これまでの、ガンマ線、X 線、イオンビーム、化学誘発剤、培養変異を利用した突然変異直接利用品種数は 70 作物、295 にのぼり、その 79%が放射線による突然変異である。直接利用品種との交配による間接利用品種数は 335 であり、その大半はイネ（298 品種）であり、そのうちの 150 品種（50.3%）は「レイメイ」に由来する。突然変異品種の経済効果は、イネとダイズ品種の貢献が大きい。有用な突然変異としてイネの低易消化性タンパク質、低アミロース含量、巨大胚および難脱粒性、ダイズの放射線感受性、脂肪酸組成改変、リポキシゲナーゼ欠失、高グリシニンおよび根粒超着生などを記述した。また、生物学的研究の成功例として、ガンマ線が誘発する突然変異と欠失の大きさ、欠失の位置と大きさの差による突然変異形質の変化が解明された。実験材料としての成功例は、フィトクローム研究、アルミニウム耐性および無ワックス特性の解明である。また、放射線育種場で開発された他殖性のイタリアンライグラスの変異作出技術についても紹介した。突然変異育種は遺伝子単離や遺伝子機能や代謝経路の解明において魅力的かつ有用なテクノロジーである。突然変異品種数が示すように、突然変異誘発技術は優れた品種を育成するための簡易な従来育種ツールである。アジアでは韓国とマレーシアにガンマ線緩照射施設が建設され、突然変異育種が推進されている。放射線育種場はガンマーフィールドなどの有用な施設を有し、今後も突然変異育種の発展と生物学的問題解決に貢献していくことが期待される。

キーワード：遺伝解析、ガンマ線照射、ガンマーフィールド、
突然変異育種、突然変異品種

平成 28 年 11 月 17 日受付　平成 29 年 3 月 6 日受理

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Content

Ⅰ　Introduction

After the construction of the Gamma Field, considered the world's largest radiation field（100 m radius with an 88.8 TBq ^{60}Co source at the center; Fig. 1), at the Institute of Radiation Breeding（IRB）in Ohmiya-machi（now Hitachi-Ohmiya), Ibaraki, Japan in 1960, mutation breeding was accelerated through cooperative research with national and prefectural breeding laboratories, private companies and universities in Japan（Yamaguchi 2001).

Fig. 1. Gamma Field of IRB

In the New York Times (Broad 2007), Dr. P. J. L. Lagoda of the Joint FAO/IAEA was quoted to say, "Spontaneous mutations are the motor of evolution. We are mimicking nature in this. We're concentrating time and space for the breeder so he can do the job in his lifetime. We concentrate how often mutants appear – going through 10,000 to one million – to select just the right one".

The concept and objectives of the IRB's Gamma Field has the same goals for the plant breeder. The facility has an irradiation tower installed with an 88.8 TBq ^{60}Co at the center of a circular field with a radius of 100 m (Nakagawa 2010), and used to artificially induce mutations at a higher frequency than that occurs in nature. The radiation dose at the nearest point of the field (10 m from the center: *ca.* 2 Gy/day) is estimated to be about 300,000 times that of normal and natural background radiation when it is operated for 8 hours per day (Fig. 2). At the farthest point (100 m from the center: ca. 0.01 Gy/day), the radiation dosage is about 2,000 times the normal background radiation. This means that plants growing at the nearest point to the gamma-ray source are being treated to a 1,000 years of accumulated normal background rates of radiation per day. Although we do not know all the genes or mechanisms of mutations, radiation breeding has produced many useful mutant cultivars and contributed greatly to the farmers and industries of Japan and all over the world. In 1991, the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan launched the Rice Genome Research Program, with the aim of fully decoding the rice genome in three phases over a 21-year period. With the cooperation of 10 participating countries (Sasaki and Burr 1998), the genome sequencing of the 12 rice chromosomes was completed in 2005 (International Rice Genome Sequence Project 2005). Following this achievement, molecular genetic studies based on the results of the genome sequencing project became the most powerful tool for selecting mutants of certain characteristics in rice. This is anticipated to revolutionize mutation breeding success in rice, and be applicable to a number of other important crop species.

In this report, the mutant cultivars developed mainly by gamma-ray irradiation in Japan are discussed. In addition, their economic impacts in Japan, as well as molecular studies performed to contribute to food security and elucidate the mutation at the DNA level, are described.

Part of this report was presented in the 53rd Gamma Field Symposium held in Mito, Ibaraki, Japan in 2014.

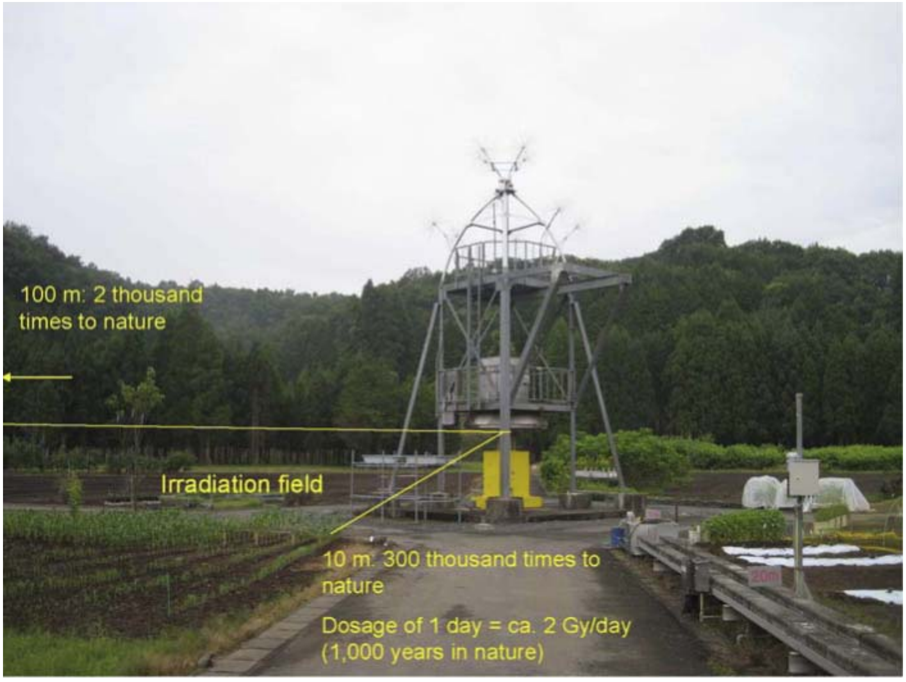


Fig. 2. Irradiation tower located in the center of the Gamma Field and its irradiation field.

Ⅱ Achievements from biological research on mutations induced by gamma-ray irradiation

1） Deletion size generated by gamma-ray irradiation

Naito *et al.*（2005）studied the deletion sizes of transmissible and non-transmissible mutations induced with gamma-ray and carbon ion beam irradiation by utilizing sophisticated pollen-irradiation methods in Arabidopsis. Many mutants induced with these ionizing irradiations possess extremely large deletions（more than 6 Mbp）and many also have small deletions（1 or 4 bp), which are normally transmissible. The larger 6-Mbp deletions were found to not be transmissible to the next generation.

In rice, the same trends were observed（Table 1). Morita *et al.*（2009）researched the frequency of transmission of different mutations possessing different deletion sizes obtained with gamma-ray irradiation. Among 24 gamma-ray induced mutants, three exhibited 1-bp substitution, 15 exhibited a small deletion, four exhibited large deletions and two exhibited inversions. Among 15 mutants with small deletions, six mutations including *cao*（*chlorophyllide-a oxygenase*), *cps*（*entcopalyl diphosphate synthase*), *ga3os*（*GA3-beta-hydroxylase*), *gid*（*GA-insensitive dwarf*), *gluA1*（*glutelin A1*）and *gluA2*（*glutelin A2*）exhibited 1-bp deletion; and nine mutations including *cao-g2* and *ga3ox-g2*, *kao-g1*, *kao-g2*, *pla1-g1* and *-g2*（*Plastochron1*), and *wx-g1, -g2, and -g3* exhibited deletion of 2–16 bp. In contrast, four mutations had large deletions including one *gid2-g1*, one *gluB4/5*（*glu1: Glutelin B4/5*), one *glb1*（*α-globulin*）and one *wx-g4* mutant with 42.2, 129.7, 62.8 and 9.4 kb, respectively. As a result, gamma-ray induced mutations transmittable to the next generation are primarily classified into four groups:（1）those with a base substitution;（2）those with small deletions（1−16 bp);

Table 1. I Gamma ray irradiation-induced deletions, base substitutions, and inversions and the size of mutation (Morita *et al.* 2009).

Mutation Type	Gene	Size (bp)
Small Deletion	*CAO* (*cao-g1*)	1
	CAO (*cao-g2*)	3
	CPS (*cps-g1*)	1
	GA3ox (*ga3ox-g1*)	1
	GA3ox (*ga3ox-g2*)	3
	GID1 (*gid1-g1*)	1
	GluA1 (*gluA1-g1*)	1
	GluA2 (*gluA2-g1*)	1
	KAO (*kao-g1*)	4
	KAO (*kao-g2*)	16
	PLA1 (*pla1-g1*)	5
	PLA2 (*pla2-g1*)	5
	Wx (*wx-g1*)	2
	Wx (*wx-g2*)	5
	Wx (*wx-g3*)	6
Large Deletion	*GID2* (*gid2-g1*)	42, 200
	Glb (*glb1*)	62, 800
	GluB4/B5 (*glu1*)	129, 700
	Wx (*wx-g4*)	9, 400
Base Substitution	*GluA2* (*gluA2-g2*)	1
	PLA1 (*pla1-g2*)	1
	Wx (*wx-g5*)	1
Inversion	*Wx*	1, 284, 800
	PLA2	3, 208, 500

CAO: chlorophyll b deficiency; *CPS*, *KAO* and *GA3ox*: gibberellin deficiency; *GID*: gibberellin insensitivity; *GluA* and *GluB*: glutelin deficiency; *Glb*: alpha-globulin deficiency; *PLA*: shortened plastochron; *Wx*: glutinous endosperm

(3) those with extremely large deletions; and (4) those with a large inversion of over 1 Mbp with small deletions. The mechanisms of generating extremely large deletions and inversions may be similar–the former mutation areas were missing and the latter mutation areas were reversely placed again. It is not known how difficult it may be to generate mutants with medium-sized deletions (1.0–5.0 kb) through gamma-ray irradiation, although some reports mentioned that neutrons with high linear energy transfer (LET) can induce deletions ranging between 300 bp–12 kb (Sun *et al.* 1992; Li *et al.* 2001; Nagano *et al.* 2008). However, it is interesting that inversions are not considered rare events following gamma-ray irradiation, as is the case for sorghum (Mizuno *et al.* 2013)–this is explained in the following section.

2) Different size and location of deletion generates different kinds of phenotypes

In the course of plant evolution, genes are often duplicated in tandem, resulting in functional redundancy. The analysis of function of these genes by developing double mutants may be difficult because they are located near each other and are tightly linked. Glutelin is a major digestible seed storage protein encoded by a multigene family. Mutants of tandem-duplicated glutelin genes were investigated for their genotypes and phenotypes. They represent a reversely repeated two-loci event (Fig. 3), with both regions coding for mRNA of glutelin production. Various mutants with low glutelin contents have been isolated using SDS-PAGE (polyacrylamide gel electrophoresis) (Iida *et al.* 1993, 1997). The mechanisms of low glutelin content in the mutants that have been studied suggest that the size and position of deletions generate different characteristics of mutations (Fig.

4). Some act as dominant or recessive genes, and these relationships between genotypes and phenotypes are provided as examples below.

Low glutelin content1（*Lgc-1*）is a dominant mutation that reduces glutelin content in rice grain. Kusaba *et al.*（2003）reported that in *Lgc-1* homozygotes contain a 3.5-kb deletion between two highly similar glutelin genes that forms a tail-to-tail inverted repeat, that could produce a double-stranded RNA molecule, a possible potent inducer of RNA silencing（Fig. 3). As a result of this inverted repeat, glutelin synthesis is suppressed and the glutelin content is lowered. This was the first report that showed the mechanism of a mutation was RNA interference（RNAi）in plants. The *Lgc-1* provides an interesting example of RNA silencing among genes that exhibit various levels of similarity to a gene-induced RNA silencing.

The “glu1” is a gamma-ray-induced rice mutant, which lacks an acidic subunit of glutelin. Morita *et al.*（2007）elucidated that the *glu1* gene of the “glu1” mutant harbors a 129.7-kb deletion involving two highly similar, tandem-repeated glutelin genes, *GluB5* and *GluB4*. The deletion eliminates the entire *GluB5* and *GluB4* genes except for half of the first exon of *GluB5*. As a result, the phenotype of the *glu1* gene completely lacks the acidic subunit of glutelin and acts as a recessive gene for low glutelin content in rice grains（Fig. 4).

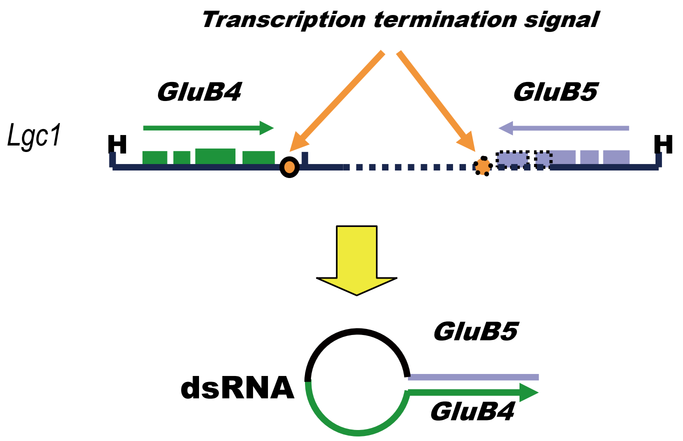
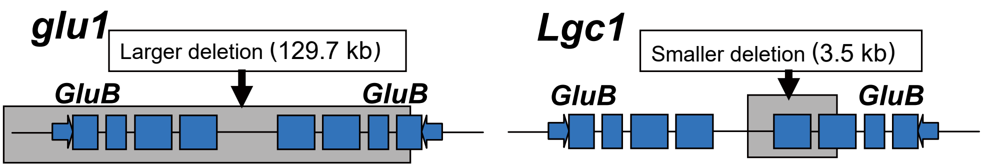


Fig. 3. Mechanism of low glutelin in LGC-1. A deletion containing the transcription termination signal between *GluB4* and *GluB5* causes generation of hairpin RNA with dsDNA region, which induces GluB mRNA degradation via RNA interference（based on Kusaba *et al.* 2003).（Courtesy of Prof. M. Kusaba, Hiroshima University）



	Phenotype	Dominant or Recessive	Mechanism
glu1[1]	Deletion of 1 acidic subunit of glutelin	Recessive	Knock-out of 2 genes
Lgc1[2]	Total glutelin contents lower	Dominant	Suppresses glutelin genes via RNAi

Fig. 4. Comparison of phenotype, mode of inheritance and mechanism of mutation character between *glu1* and *LGC1* mutation with different sizes and place of deletion in the same region of two loci, *GluB4* and *GluB5*; *glu1*[1]: Morita *et al.*（2007); *Lgc1*[2]: Kusaba *et al.*（2003).（Courtesy of Dr. R. Morita, RIKEN）

The above examples illustrate that the position and size of deletions at the same locus can dramatically alter the phenotype of mutant gene expression through the process of transcription and translation. The *glu1*, which has a large 129.7-kb deletion, acts as a recessive gene, while the *LGC1*, which has 3.5-kb deletion that probably includes a terminal signal of the transcript region, acts as a dominant gene.

Furthermore, the *GluB5* and the *GluB4* have the same amino acid sequence in their acidic subunit, suggesting that only the mutation involving both *GluB5* and *GluB4* generates the resultant phenotype. This is the reason for the lack of the glutelin acidic subunit deleted in the “glu1” mutant.

Sequenced plant genomes exhibit that more than 14% of their genes are highly similar, tandem-repeated genes (Arabidopsis Genome Initiative 2000; International Rice Genome Sequence Project 2005). This finding suggests that gamma-rays can be an effective mutagen to generate knockout mutants of both loci and to use for analysis of tandem repeat and functionally redundant genes.

Ⅲ Useful mutations from various screening methods

1) Low digestible-protein content

Although rice is not a high-protein grain crop, the protein content is *ca.* 7% when white rice is cooked. A mutant line with a low glutelin content was obtained from the ethyleneimine (EI) treatment of cv. “Nihon-masari”. The cv. “LGC-1” was developed from backcrossing this mutant with the original cv. “Nihon-masari” to eliminate undesirable characteristics, such as semi-sterility and semi-dwarfing (Iida *et al.* 1993). The seed protein of cv. “LGC-1” is mainly composed of a decreased amount of digestible glutelin induced by a dominant mutation that also increases the amount of indigestible prolamine. The characterization of this mutation and the mechanism were mentioned in the previous section. This construction of protein is disadvantageous for human digestion of rice grains, although the total amount of protein is similar to the original cultivar. As a result, cv. “LGC-1” is useful as a low-protein rice, and some clinical trials indicate that the cooked rice of this variety is a

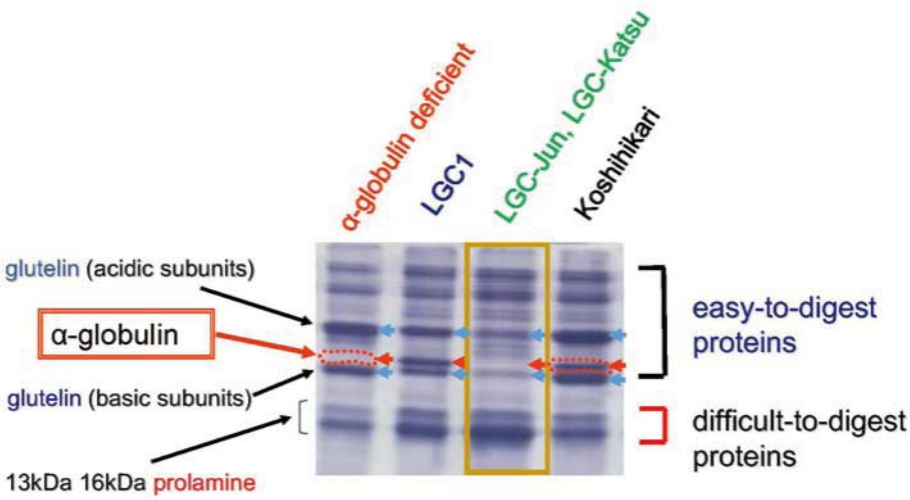


Fig. 5. Development of new cultivars, cv. “LGC-Jun” and cv. “LGC-Katsu” with lower easy-to-digest protein content by the hybridization of a low-glutelin mutant cv. “LGC1” and an α-globulin deficient mutant (named “89WPKG30-433”) of cv. “Koshihikari” (SDS-PAGE data) (based on Nishimura *et al.* 2005). (Courtesy of Prof. M. Nishimura, Niigata University)

useful and effective daily food for patients with kidney disease (Mochizuki and Hara 2000). The defect of cv. “LGC-1” is its eating quality and the presence of other loci that control the biosynthesis of digestible protein, such as globulin. Therefore, Nishimura *et al.* (2005) induced a mutant line “89WPKG30-433” that exhibited a deficiency in globulin through gamma-ray irradiation from the leading Japanese cv. “Koshihikari”, which is famous for a good eating quality. The “89WPKG30-433” was hybridized with cv. “LGC-1” and cvs. “LGC-Katsu” and “LGC-Jun” were selected from the hybrids (Fig. 5). The glutelin content of these two cultivars is as low as for cv. “LGC-1” and the globulin content is zero. The total digestible-protein content tested is about 30% of ordinary rice. As the eating quality is highly improved and digestible-protein content is lower than for cv. “LGC-1”, these two cultivars will greatly help in the dietary management of proteins in cases of chronic renal failure.

2) Glutinous rice (low amylose content)

Stickiness of cooked rice is one of the most important characteristics of rice cultivars, which are diverse and unique among peoples of the world. In general, people in Japan as well as Korea, northern Thailand, Myanmar and southern China prefer sticky rice. Amylose contents are closely related to this character and range from 0 (waxy: glutinous) to higher than 20, especially in indica-type rice. In Japan, glutinous rice has a special utilization for “okowa” and “mochi” production for festivals and celebrations, as well as non-glutinous popular cultivars used for daily cooking, which exhibit ca. 17% amylose content. This waxy locus (*Wx*) was mapped on chromosome 6 of rice (Iwata and Omura 1971) and knockout of *Wx* makes non-glutinous ordinary rice completely glutinous (*wx*). The waxy genes were identified to encode granule-bound starch synthesis, which is performed by a key enzyme in amylose synthesis of plants (Nelson and Pan 1995). In Japan, glutinous cv. “Miyuki-mochi” (Toda 1982) was induced from non-glutinous cv. “Toyonishiki”, glutinous cv. “Fujimi-mochi” from non-glutinous cv. “Aki-chikara”, and gulutinous cv. “Odoroki-mochi” (Imbe *et al.* 2004) from non-glutinous cv. “Takanari” through gamma-ray irradiation in the IRB Gamma Field.

There is another type of endosperm starch mutation termed “dull”, whose amylose content is not zero as found with the waxy (*wx*) mutation in rice. The dull mutation has *ca.* 10% amylose content, which is lower than the *ca.* 20% of non-waxy (*Wx*) rice, and exhibits partial stickiness when cooked. Genetic analysis of dull mutants induced by ^{32}P (beta-ray radiation) showed that the mutations were controlled by a single recessive gene which is non-allelic to the *wx* alleles (Okuno *et al.* 1983). One of the most popular dull cultivars is cv. “Milky Queen” induced by chemical mutagen (MNU: N-methyl-N-nitrosourea) treatment of the most popular cv. “Koshihikari” with amylose content of 9–12% (Ise *et al.* 2001). This dull phenotype is caused by *wx* locus mutation (*Wx-mq*) (Sato et al. 2002).

3) Giant embryo

The rice embryo contains a high level of proteins, fats, vitamins and some compounds good for human health. As the embryo grows, gamma-aminobutyric acid (GABA) accumulates following transformation from glutamic acid caused by soaking rice in water (Saikusa *et al.* 1994a, 1994b). Defatted rice embryos enriched with GABA are useful as a functional food for controlling blood pressure and sedative qualities related to sleeplessness and autonomic disorder (Okada *et al.* 2000). The GABA-accumulated brown rice is already on the market as a health food based on an ordinary rice variety. The giant embryo lines “EM40” and “GM15-34”, each possessing giant embryo by treating cv. “Kinmaze” with MNU (Satoh 1981), useful for this purpose are anticipated. The embryo volume of these lines is 3–4 times that of ordinary rice cultivars. The giant embryo trait of the “EM40” is known to be controlled by one recessive gene (*ge*) located on chromosome 7 (Satoh and Iwata

1990).

The utilization of the giant embryo mutants was previously limited to the development of rice bran oil. However, the nutritional value of cooked brown rice is beginning to attract the attention of consumers interested in healthy food. The first giant embryo mutant cv. “Haiminori” was developed by the hybridization between the “EM40” and cv. “Akenohoshi”, and selection from the hybrid population in 1990 (Nemoto *et al.* 2001). The embryo volume of cv. “Haiminori” is 3–4 times that of ordinary rice. After soaking in water for four hours, the amount of accumulated GABA in cv. “Haiminori” is about four times that of the traditional cv. “Nipponbare”. The cv. “Haiminori” is utilized in the commercial production of rice cakes. Common defects of giant embryo cultivars are lower germination and seedling establishment rates, sometimes only 40–50 % of that of cv. “Nipponbare”.

The GIANT EMBRYO (*GE*) gene has been identified as essential for controlling the size balance in rice, and the function of *GE*, which encodes CYP78A13, is predominantly expressed in the interfacing tissues of the both embryo and endosperm and controlling cell size in the embryo and cell death in the endosperm (Nagasawa *et al.* 2013). Development of giant embryo lines with good seedling establishment will be a continuing objective of the breeding.

4) Non-shattering

Much attention has been paid recently to indica-type high-yielding genetic resources for improving biomass productivity as forage rice. Seed shattering is one of the most important characteristics of indica-type rice that requires improvement. Mutation in the dominant *qSH1* gene in domesticated rice eliminates the abscission layer and results in non-shattering seeds (Konishi *et al.* 2006). Thus, knockout of this dominant gene generates a non-shattering rice. Kato *et al.* (2006) attempted to induce a mutation at this locus in cv. “Mohretsu”. The cv. “Mohretsu” is a mutant forage rice cultivar induced through NMU treatment and through gamma-ray irradiation of seeds in IRB, National Institute of Agrobiological Sciences (NIAS), which was eventually developed as the direct-use, non-shattering mutant cv. “Minami-yutaka” for use as rice silage. Sakai *et al.* (2013) attempted to induce mutation at the same locus in the high-yielding traditional cv. “Taporuri” introduced from Taiwan through gamma-ray irradiation of seeds in IRB, and successfully released the direct-use non-shattering mutant cv. “Ruri-aoba” as a rice silage crop. The loci or genes controlling non-shattering in these newly induced mutant cultivars have not been identified. However, through genetic analyses of rice cultivars and wild relatives, as well as chromosomal segment substitution lines and an induced shattering mutant line derived from gamma-ray irradiation (Zhou *et al.* 2012), several quantitative trait loci associated with seed shattering have been identified. These includes *SH4* which promotes hydrolyzing of an abscission zone cells during the abscission process (Li *et al.* 2006), *OsCPL1* (*Oryza sativa CTD phosphatase-like 1*) that enhances the development of the abscission layer during panicle development (Ji *et al.* 2010) and *SHAT1* (*Shattering Abortion1*), the AP2 domain-containing transcription factor gene responsible for abscission zone development (Zhou *et al.* 2012).

5) Radio-sensitivity

Takagi (1969) identified two major genes that control radio-sensitivity in some soybean cultivars. When the 50% reduction rate (RD_{50}) of root length was associated with exposure to acute irradiation of seeds or chronic irradiation of plants for the entire growth period, radio-sensitivity of soybean was identified. The cv. “Shinmejiro” is more than twice as high for radio-sensitivity as the resistant cv. “Tachisuzunari”. The differences in radio-sensitivity between the cultivars to chronic irradiation in the Gamma Field are controlled by a single recessive *rs1* gene. A second recessive gene, *rs2*, was discovered in cv. “Goishi-shirobana”, whose activity is only expressed following acute seed radiation.

6） Fatty acid composition

Soybean is the most widely used source of edible oil for human consumption. Every oil crop produces unique oil with a specific fatty acid composition. For example, linolenic acid content is high and generally 8.0% in soybean, and is not found in oils from maize, traditional sunflower and traditional safflower. There is an extremely high diversity of fatty acid compositions across the oil crops. The biosynthesis of fatty acids in oil crops is summarized in Fig. 6. The biosynthesis for fatty acid composition, common to all plant species, involves a carbon elongation process（palmitic acid（16:0）→ stearic acid（18:0））and unsaturated reaction process（stearic acid（18:0）→ oleic acid（18:1）→ linoleic acid（18:2）→ linolenic acid（18:3））. Another biosynthesis is a carbon elongation reaction unique to traditional rapeseed of oleic acid（18:1）→ eicosenoic acid（20:1）→ erucic acid（22:1）. The particular fatty acid contents of these cultivars or species result from differences in activity or reactivity of their enzymes and the number of genes encoding each enzyme involved in the various steps related to carbon elongation and unsaturated reaction of their fatty acids.

The incorporation of target genes, known to modify the fatty acid components of oil crops were initially identified in natural populations of specific species, and then incorporated by various breeding techniques. White *et al.*（1961）previously identified inter-varietal variation of fatty acid composition in 251 soybean cultivars and reported that contents of linoleic and linolenic acids were controlled by polygenes and exhibited heritability typically associated with quantitative traits because the investigated hybrid population exhibited continuous variation across their fatty acid compositions. However, Takagi *et al.*（1986）reported that the expression and levels of oleic and linolenic acids were controlled by two and one gene, respectively. Recent research suggests that the effects of each gene on fatty acid content are small and indicates quantitative trait expression and larger

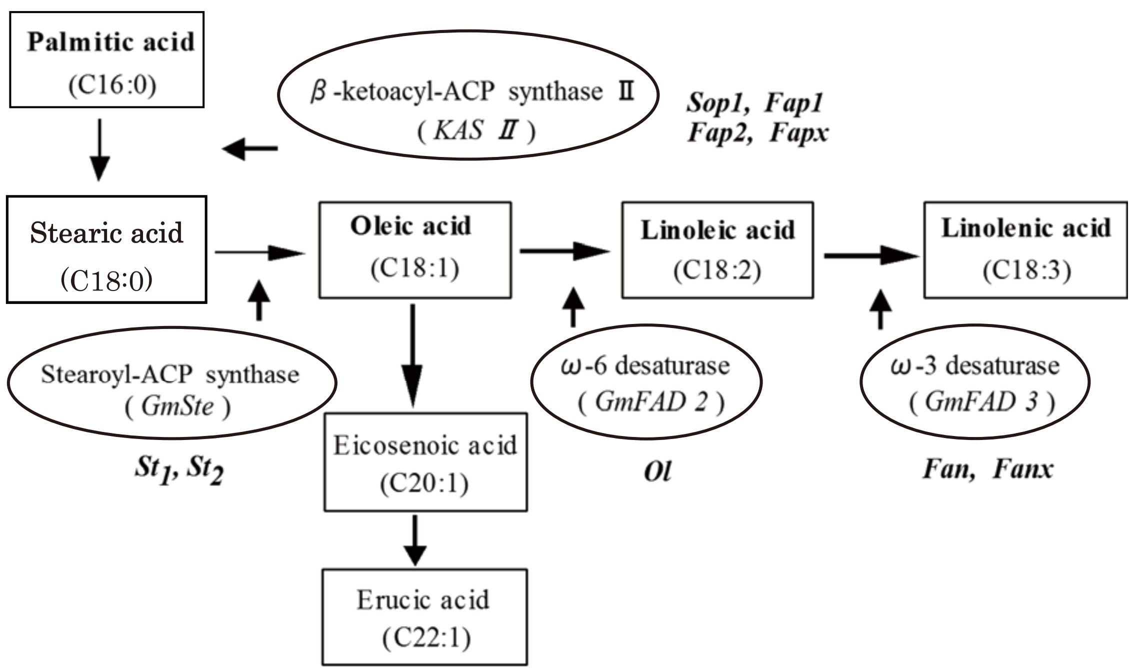


Fig. 6. Genes responsible for different fatty acid biosynthesis（based on Takagi and Anai 2006; Nakagawa *et al.,* 2011）.（Courtesy of Prof. Y. Takagi, Saga University）.

environmental effects.

Takagi and his colleagues identified 46 mutant lines from a 12,266 M_2 population generated by X-ray application to cv. “Bay”. Fatty acid compositional changes of the mutant lines are listed in Table 2. The mutant lines include “J3” with low palmitic acid content (6.1%) (Takagi *et al.* 1995), “J10” with high palmitic acid content (17.2%) (Takagi *et al.* 1995), “M25” with high stearic acid content (21.2%) (Rahman *et al.* 1995), “M23” with high oleic acid content (48.6%) (Rahman *et al.* 1994), “M5” with low linolenic-acid content (4.9%) (Takagi *et al.* 1990) and “B739” with high linolenic acid content (18.4%) (Takagi *et al.* 1989). In addition, lines with wider fatty acid composition variability were obtained from the hybridization between these mutants.

The 46 individual mutant populations generated from cv. “Bay” exhibit a wider range of fatty acid composition than the 99 landraces developed from naturally occurring variation (Table 3) (Takagi and Rahman 1995). This induction of fatty acid variability confirms that artificial mutation is useful for enhancing fatty acid diversity of soybean.

Table 2. Fatty acid composition (% of total oil) of different soybean mutants and their genotypes (Nakagawa *et al.* 2011).

Mutant Line	Fatty Acid Composition (%)					Genotype
	Palmitic Acid (16:0)	Stearic Acid (18:0)	Oleic Acid (18:1)	Linoleic Acid (18:2)	Linolenic Acid (18:3)	
J3	6.1	3.4	26.5	55.4	8.6	*sop1*
C1726	8.5	3.9	22.1	56.0	9.6	*fap1*
LPKKC-3	4.4	3.2	27.1	55.5	9.8	*sop1, fap1*
KK7	14.2	5.0	23.3	49.5	7.9	*fapx*
J10	17.2	5.0	19.7	48.4	9.7	*fap2*
HPKKJ10	21.6	5.7	18.0	45.6	9.0	*fapx, fap2*
KK-2	10.3	7.2	23.1	51.6	7.9	st_1
M25	9.5	21.2	15.6	44.0	9.8	st_2
M25KK2	9.4	31.4	12.4	38.4	8.4	st_1, st_2
M11	10.3	4.3	35.8	41.4	8.2	ol^a
M23	8.9	4.4	48.6	29.5	8.5	*ol*
M24	10.0	5.3	27.3	51.5	5.9	$fanx^a$
M5	9.8	4.9	25.5	55.3	4.9	*fan*
LOLL	10.3	4.5	27.7	54.7	2.9	*fan*, $fanx^a$
B739	7.9	4.3	14.3	55.1	18.4	lin^h
cv. Bay	10.6	4.2	25.2	51.7	8.3	

Table 3. Mean and range of fatty acid composition (% of total oil) in 46 different soybean mutants and 99 cultivars developed by using natural resources (Takagi and Rahman 1995).

	Fatty Acid Composition (%)				
	Palmitic Acid (16:0)	Stearic Acid (18:0)	Oleic Acid (18:1)	Linoleic Acid (18:2)	Linolenic Acid (18:3)
Mutants					
Mean	10.6	5.2	26.5	49.8	7.9
Range	6.3-16.7	2.9-16.1	17.5-48.2	32.2-60.5	4.6-12.6
Cultivars					
Mean	12.1	2.9	25.1	51.9	8.0
Range	10.0-15.5	1.6-4.1	14.2-44.3	36.6-61.1	5.2-12.6

As mentioned above, Takagi and his colleagues isolated a significant number of mutant lines exhibiting varying fatty acid composition through use of X-rays. Hybridization of these mutant lines, selection, characterization and experimentation can attain the pyramiding of mutant genes exhibiting complementary gene action in order to modify expression of various fatty acids. Following the hybridization and examination of the subsequent generations, the inheritance of genes conditioning low and high palmitic, high stearic, high oleic, and low and high linolenic acids were elucidated.

Figure 6 illustrates the fatty acid biosynthesis pathway of soybean seed oil. Palmitoyl-ACP（16:10）is synthesized from malonyl-ACP（4:0）through the condensation（fatty acid elongation）cycle. Three types of β-ketoacyl-synthases（βKASs）are involved in this condensation cycle. Palmitoyl-ACP is synthesized by βKASI and βKASIII, and then stearoyl-ACP（18:0）is synthesized by βKASII. Following this process, stearoyl-ACP is converted into oleoyl-ACP by stearoyl-ACP desaturase. Acyl-ACP thioesterase catalyzes the acyl-ACPs, and palmitic, stearic and oleic acids are produced with these reactions. Then oleic acid is converted to linolenic acid through linoleic acid by two distinct microsomal fatty acid desaturases, omega-6 and omega-3. These fatty acid biosynthesis enzymes are encoded by *GmβKASII*, *GmSte*, *GmFAD2* and the *GmFAD3* gene family, respectively. As discussed above, genetic analysis of fatty acid content in soybean mutants suggests that several genes are involved in each step of fatty acid synthesis pathway.

Byrum *et al.*（1997）reported that one of the low linolenic-acid mutants, “A5”, carries a deletion in gene *GmFAD3*. Takagi’s group also identified a large deletion in gene *GmFAD3* of “J18”（Yamashita *et al.* 1998）, *GmFAD2* of “M23”（Kinoshita *et al.* 1998）and *GmSte* of “KK2”（Rahman *et al.* 1998）with Southern-blot analysis and also confirmed that these deletions co-segregated with their fatty acid content phenotypes. However, the vast majority of fatty acid mutants of soybean have not been characterized in detail. A superior understanding of the relationships between the corresponding gene and the phenotype of individual mutants will be valuable for soybean oil breeding programs.

Takagi’s group determined the corresponding genes of three low linolenic-acid mutants（“M24”, “M5” and “J18”）and divided them into two groups: “M24” had a mutation on gene *GmFAD3-1a*, and “M24” and “J18” had a respective mutation on *GmFAD3-1b*（Anai *et al.* 2005）. The molecular status of these mutated genes were as follows: a 1-bp deletion in the open reading frame（ORF）of gene *GmFAD3-1a*, a 19-bp deletion in the ORF of *GmFAD3-1b* and a large deletion in the region containing *GmFAD3-1b*, respectively. The mutant of *GmFAD3-2a* has not yet been obtained from Takagi’s mutant collection, but this mutant represents an important target for decreasing linolenic acid content in soybean. Because gene *GmFAD3-2a* is expressed in developing seeds and its product exhibits the correct enzymatic activity in yeast cells（Anai *et al.* 2005）, it is anticipated that further study of the *GmFAD3-2a* mutant line may result in development of a near-zero linolenic acid soybean cultivar.

Allele-specific genotypic selection, through use of molecular markers related to these gene families, will be superior to phenotypic selection using gas-liquid chromatography. Multiple sources of alleles for each candidate gene isoform can provide further benefits in the breeding of germplasm with superior fatty acid composition and minimize fixation of alleles linked to target genes（Takagi *et al.* 1998; Anai *et al.* 2005; Takagi and Anai 2006; Nakagawa *et al.* 2011a）.

7） Lipoxygenase-lacking soybean

Lipoxygenase is an enzyme that generates a beany-flavor within soybean and its processed products. When soybean meal is mixed with water, lipoxygenases oxidize the abundant unsaturated fatty acids in the soybean seed and produce aldehydes such as n-hexanal（Fig. 7）. Heat treatment is generally used to reduce this

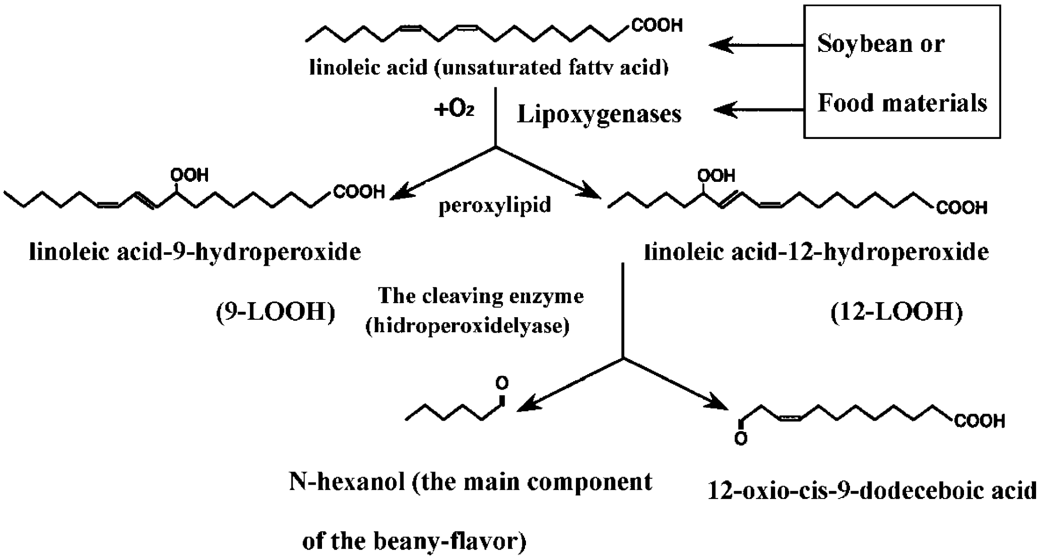


Fig. 7. The reaction pathway of the seed lipoxygenases (based on Arai *et al.* 1970). (Courtesy of Dr. M. Hajika, NARO)

flavor in soybean products; however, once produced, heat treatment will not completely eliminate this flavor and this results in soybean products with poor taste quality. Trials have been performed to determine a better method to remove these undesirable flavors from soybean products in the food processing industry.

Soybean seed has three lipoxygenases: L-1, L-2 and L-3 (Arai *et al.* 1970). In the 1980s, mutant cultivars lacking lipoxygenase were isolated from germplasm (Hildebrand and Hymowits 1981; Kitamura *et al.* 1983, 1985) and both L-1 and L-3 lacking and L-2 and L-3 lacking lines were bred by hybridizations between the two types. However, neither L-1 and L-3 lacking plants nor plants lacking L-1, L-2 and L-3 were obtained through breeding and hybridization. Therefore, mutation breeding was conducted to induce soybean mutants lacking L-1, L-2 and L-3 (Kitamura *et al.* 1985). Expecting not only the mutations but also chromosome crossing-over, 100−150 g of F_2 seeds derived from the cross between cv. “Kankei 2” (later named cv. “Kanto No. 102”, which lacks L-1 and L-3), and cv. “Kankei 1” (later registered as cv. “Yume-yutaka”, which lacks L-2 and L-3) were irradiated at the IRB in 1989.

The irradiated F_2 seeds (M_1) were planted to establish the M_1 population and obtain M_2 seeds. Harvested M_2 seeds were analyzed for protein composition using SDS-PAGE. The F_2 seeds derived from a cross between a line without *L-1* and *L-3* and a line without *L-2* and *L-3* were irradiated with gamma-rays. After surveying 1,813 M_3 seeds using SDS/PAGE, one mutant seed lacking *L-1, L-2*, and *L-3* was selected (Hajika *et al.* 1991; Nakagawa *et al.* 2011a). This lipoxygenase-lacking line was accelerated to obtain the M_6 generation in a field in summer and a greenhouse in winter. From the M_7 generation, field tests were conducted to evaluate yield and agronomic characteristics. In 1995, one selected line was released as cv. “Ichi-hime” (Hajika *et al.* 2002), and exhibits similar agronomic characteristics to cv. “Suzu-yutaka”, the recurrent parent of “Kankei 1” and “Kankei 2”. Several all-lipoxygenase-lacking soybean cultivars were developed by crossing between normal soybean cultivars and the all-lipoxygenase-lacking mutant lines. Several of these lines were sent to other countries and many all-lipoxygenases-lacking cultivars have since been developed.

8) Glycinin-rich soybean

The major components of soybean seed storage proteins are glycinin (11S globulin) and β-conglycinin

(7S globulin), which account for about 70% of all seed proteins. The amount of sulfur-containing amino acids (methionine and cysteine) in glycinin is 3–4 times that of β-conglycinin. Compared with β-conglycinin, glycinin exhibits better processing properties in texturized and filmed soy foods as well as in tofu gels. The β-conglycinin is composed of α-, α'- and β-subunits. The cv. "Keburi" characterized by the absence of the α'-subunit, and cv. "Mo-shi-dou Gong 503" with low levels of α- and β-subunits, were identified in Japanese soybean germplasm collections (Kitamura and Kaizuma 1981). Ogawa *et al.* (1989) developed some lines from these spontaneous soybean mutants and showed that it was possible to increase the amount of glycinin by decreasing the amount of β-conglycinin. The cv. "Kari-kei 434" was developed as one line characterized by the lack of the α'-subunit and a marked decrease of the level of α- and β-subunits of β-conglycinin. However, neither α-less nor β-less cultivars were identified in the germplasm collection. Therefore, knockout of the α-subunit gene was attempted by gamma-ray irradiation of seed of cv. "Kari-kei 434" at the IRB, and five mutated seeds, which exhibited loss of the α-subunit and α'-subunit, were identified using SDS-PAGE in the M_2 and M_3 populations. The deleted form of the α-subunit was controlled by a recessive gene and crossing studies showed that existence or nonexistence of the α-subunit was independent of the α'-subunit (Takahashi *et al.* 1996). In 2001, a new mutant cv. "Yumeminori" was developed from this mutation and released as a glycinin-rich and hypoallergenic soybean (Fig. 8; Takahashi *et al*, 2004; Nakagawa *et al.* 2011a). The cause for the hypoallergenic property in cv. "Yumeminori" is due to; (a) the α-subunit is a major allergen in soybean (Ogawa *et al.* 1991); and (b) GlymBd30K, which represents one major allergen, was effectively removed from soybean protein isolates using chemical and physical methods (Samoto *et al.* 1996). Almost all growth habits of cv. "Yumeminori" were similar to cv. "Tachinagaha" except for the slightly lower seed weight and ca. 4% higher protein content. However, the processing properties of tofu curd were poorer than those for normal soybeans presumably caused by the high reactivity of glycinin proteins in cv. "Yumeminori". To solve this problem, further studies are required. Recently, it was clearly shown that the deficiency of the α-subunit in a mutant line "α-null (1)" was caused by the termination codon resulting from inserting four bases into gene *CG-2* encoding the α-subunit (Ishikawa *et al.* 2006).

Today, these glycinin-rich soybeans are utilized for soymilk products with decreased allergic reaction.

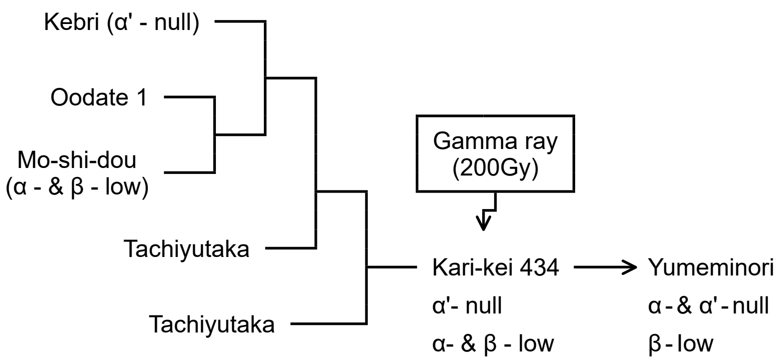


Fig. 8. Pedigree chart of glycinin rich mutant cv. "Yumeminori" (based on Takahashi *et al.* 2004).
(Courtesy of Dr. M. Hajika, NARO)

9) Super-nodulation

Super-nodulation is a character that generates a large number of root nodules in leguminous plants. Super-nodulating mutants of soybean may provide a new genetic resource for improving soybean productivity by higher nitrogen-fixation as well as for elucidating mechanism of rhizobium-plant interactions. A super-nodulating mutant "En6500" was isolated from a 2,800 M_2 population generated by treating cv. "Enrei" with 0.5% of ethyl methanesulfonate (EMS) (Akao and Kouchi 1992). The "En6500" had an increased number of nodules, inherited as a Mendelian recessive trait (Kokubun and Akao 1994); however, its growth and yield performance were inferior to that of cv. "Enrei". The cause of this reduced yield performance is presumably from the high consumption of carbohydrates by nodules and a decrease of total nitrogen assimilation through the reduction of nitrate absorption (Takahashi, *et al*, 1995). Due to the inferior performance of this new germplasm, a second attempt utilizing traditional backcross breeding to cv. "Enrei" was initiated and the super-nodulating cv. "Kanto 100" was successfully selected at the National Institute of Crop Science (NICS), National Agriculture and Food Research Organization (NARO). The cv. "Kanto 100" exhibits super-nodulation and the yield is similar to that of cv. "Enrei" (Takahashi *et al.* 2003). This super-nodulating mutation has potential impact on the development of high efficiency, nitrogen-fixing soybeans as well as for elucidation of rhizobium-plant interaction.

10) Japanese pear and apple resistant to Alternaria disease

A popular cultivar of Japanese pear (*Pyrus serotina* Rehd. var. *culta* Rehd.), cv. "Nijisseiki", was a leading cultivar that occupied 28% of the total cultivated area of Japanese pear in 1990 in Japan. However, the cultivar is highly susceptible to the black spot disease, *Alternaria alternata* (Fr.) Keissier (= *Alternaria kikuchiana* Tanaka), one of the most serious diseases of pear (Nishimura *et al.* 1978). Growers need to spray fungicides several times during the growing season to counter the disease. To induce mutations resistant to the disease, small plants of the cv. "Nijisseiki" were planted every 4 meters within 37-63 m from the ^{60}Co source in 1962 and chronic gamma-ray irradiation was applied (30×10^{-2} to 4×10^{-2} Gy/day) in the Gamma Field (Sanada *et al.* 1993). In 1981, nearly 20 years after the planting, a twig bearing green leaves exhibiting no symptom of the disease while all the other twigs were infected by the fungus and most leaves had many black spots. The resistant twig was found on a plant planted 53 m from the radiation source. As it was ascertained that there was no difference in other agronomic characteristics between the mutant and the original cultivar except for resistance to black spot disease, it was registered and released in 1991 with the name cv. "Gold Nijisseiki" (Sanada *et al.* 1993). It was registered under the same name in Australia in 2004 (Certificate Number 2533).

Dr. Sanada, one of the breeders of this cultivar mentioned, "The situation of mutation breeding on Japanese pear has been severely criticized because there have been no successful results". Although it took them nearly 20 years to identify a useful mutation and 30 years for its registration, the release of cv. "Gold Nijisseiki" became a monumental achievement for the IRB's Gamma Field.

At the same time, an easy and effective method for screening of resistance to the fungus was developed by treating leaf disks (punched out by 7 mm in diameter) of each branch by the toxin produced by the fungus in the culture (Sanada 1988). After that, Nakashima *et al.* (1982, 1985) isolated and identified the chemical structure of the toxin ("AK-toxin") produced by the fungus of black spot disease. As a consequence, the breeding group of the IRB entered into a cooperative research program with the chemistry group in Kyoto University and established the further use of this approach. When the punched leaf disks are placed on filter paper in a Petri dish soaked with AK-toxin obtained either from the extracts of the fungal body or artificial synthesis, and kept for 2 days at 25°C, leaves of susceptible cultivars such as cv. "Nijisseiki" turn black and leaves of resistant cultivars such as cv. "Chojyurou" stay green (Fig. 9). The intact leaves and old leaves of cv. "Gold Nijisseiki" are completely resistant, but interestingly the cut young leaves are partially susceptible, probably because only leaf surface tissues (the L1 layer) became resistant but inner tissues still keep susceptible genotype. As a result, leaves of cv. "Gold Nijisseiki" is really resistant to the disease in the field. Following its development, two new mutant cvs. "Osa-Gold (Masuda *et al.* 1997, 1998)" and "Kotobuki Shinsui (Kitagawa *et al.* 1999)" were

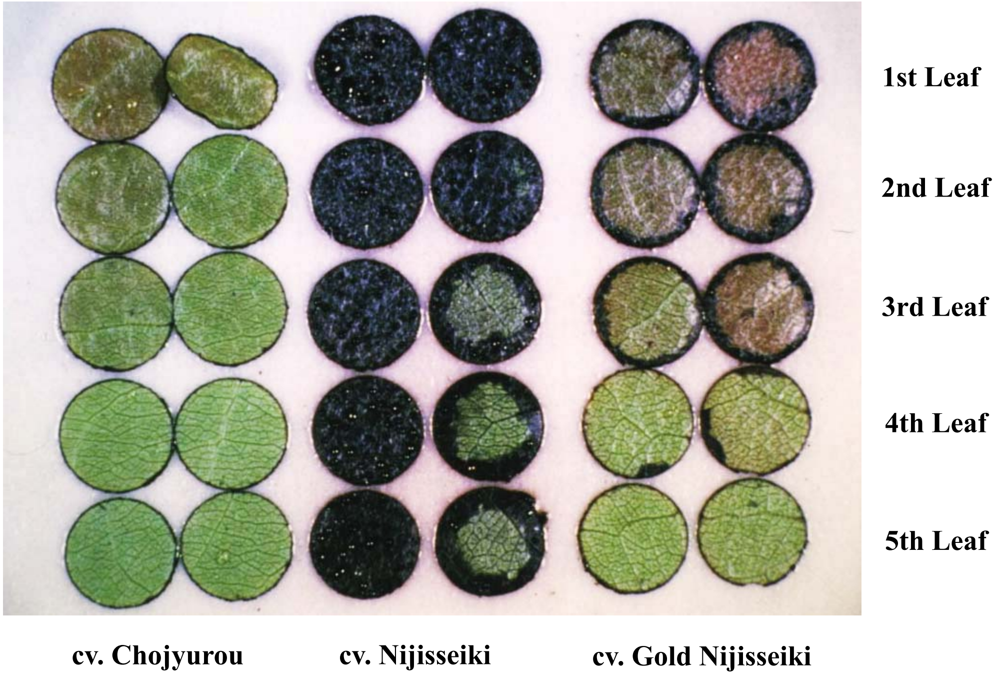


Fig. 9. Resistance bioassay for black spot disease using the AK-toxin obtained from the culture of the fungus (based on Nakagawa 2009). Upper to lower leaf disks (1–5) indicate 1 (young) to 5 (older) leaf; cv."Chojyurou": highly resistant; cv. "Nijisseiki": highly susceptible; cv. "Gold Nijisseiki": resistant

developed in a short period using this unique screening method. The economic effect of this research has been great.

Furthermore, the same bioassay method can also be utilized for the selection of plant resistant to Alternaria blotch disease using the AM-toxin (Ueno *et al.* 1977) produced by the fungus *Alternaria mali* that attacks apple. A new mutant apple cv. "Houiku Indo" was selected from gamma-ray irradiated micro-propagated shoots of susceptible cv. "Indo" (total dose: 80 Gy) and found to be resistant to this disease (Yoshioka *et al.* 2001).

This research suggests that breeding of fruit trees requires patience and that development of simple, efficient and precise screening methods is very important for mutation breeding.

11) Others

Many other interesting mutations have been identified using various screening methods in Japan. Additional information about unique mutations, screening methods, and released cultivars is given in the Appendices of this report. Gamma Field Symposia (a series of proceedings; http://www.nias.affrc.go.jp/eng/public/index2.html) and Radiation Breeding Technologies (*ibid.*) also provide a wide range of information.

Ⅳ Genetic studies of the useful mutations induced by acute or chronic gamma-ray irradiation

Spontaneous and induced-mutation resources have played important roles not only for mutation breeding but also in genetic studies and the elucidation of gene functions. Some examples are mentioned here.

1) Phytochrome

Takano *et al.* (2005) isolated *phytochrome B* (*phyB*) and *phy C* mutants from rice and produced all combinations of double mutants. Seedlings of *phy B* and *phyB phyC* mutants exhibited a partial loss of sensitivity to continuous red light but still showed significant de-etiolation responses. The response to red light was completely lost in *phyA phyB* double mutants. These results indicate that *phyA* and *phyB* act in a highly redundant manner to control de-etiolation under red light. They also found that mutations in either the *phyB* or *phyC* locus cause moderate early flowering under a long-day photoperiod, but monogenic *phyA* mutations had little effect on flowering time. However, the *phyA* mutation in combination with the *phyB* or *phyC* mutation caused dramatically early flowering. The *phyB* mutants were generated by chronic gamma-ray irradiation with dose rates of 3-6 Gy/day (Takano *et al.* 2005).

2) Aluminum tolerance

Ma *et al.* (2005) isolated a mutant with high sensitivity to aluminum (Al) concentration from cv. "Koshihikari", an Al-resistant japonica rice (Wu *et al.* 1997). The mutant was induced through chronic gamma-ray irradiation and exhibited the same phenotype as the wild-type; however, without Al tolerance. That is, M_1 plants were irradiated in the Gamma Field from 7 days before heading to 2 days after heading under 20 Gy/day for 8 days. The root elongation of the mutant was highly inhibited in the presence of 10 μM Al. The mutant also exhibited poorer root growth in acid soil. Genetic analysis showed that the high sensitivity to Al is controlled by a single recessive gene, mapped to the long arm of chromosome 6.

3) Wax-free mutation of sorghum

Sorghum (*Sorghum bicolor* (L.) Moench.) produces and deposits bloom or epicuticular wax on the surface of stems and leaves (Fig. 10 left). The deposition of this wax is a dominant trait (*Bm*) with variation under different environments (Jordan *et al.* 1983), and bloomless (*bm*) mutants have no bloom or wax on the surface of plant parts. This wax is thought to make an important contribution to tolerance to abiotic stresses such as drought through reduced cuticular transpiration (Blum 1975) and protection from ultraviolet (UV) light in the semiarid tropics (Jordan *et al.* 1983). Reducing cuticular wax and cuticle deposition is also known to increases susceptibility to the fungal disease northern corn leaf blight caused by *Exserohilum turcicum* (Jenks *et al.* 1994). However, *bm* sorghum tends to increase resistance to biotic stresses such as resistance to greenbug attacks (Peiretti *et al.* 1980; Nakagawa *et al.* 2011b), which is achieved through nonpreference (Weibel and Starks 1986), and sheath blight (Kasuga *et al.* 2001).

In Japan, sweet sorghum has recently become a candidate crop for bioethanol production by utilizing the sugars produced and stored in stems and lignocellulose of stems and leaves through fermentation (Nakagawa *et al.* 2013). The development of sorghum cultivars resistant to biotic-stresses will have advantages for low-input without pesticides and fungicide and sustainable biofuel production. In 2006, groups of 1,000 seeds of sweet sorghum cv. "Italian" were irradiated with different doses of gamma-rays (0, 100, 200, 400, 500, 800, and 1,000 Gy for 20 hours) in the Gamma Room at the IRB, NIAS. After germination tests of the M_1 seeds, the seedlings were transplanted in the field and self-pollinated M_2 seeds were obtained by bagging of M_1 inflorescences before heading. In 2008, six seeds from each M_2 line were planted in the field plots for the evaluation. Two *bm* mutant plants without visible epicuticular wax (bloom) on the stems (Fig. 10) were identified from the M_2 population irradiated with 400 Gy of gamma-rays. The two self-pollinated lines were planted in the field and identified as pure lines with no variations. At the same time, these two lines were hybridized with the original cv. "Italian" plants, and the F_1 seeds and self-pollinated F_2 seeds were obtained. In 2010, 96 F_2 seeds from each hybridization were planted in the field for genetic and molecular analyses. The F_2 population segregated for individuals with

Fig. 10. Wild type (left) and *bm* mutant (right) of sorghum cv. “Italian”.

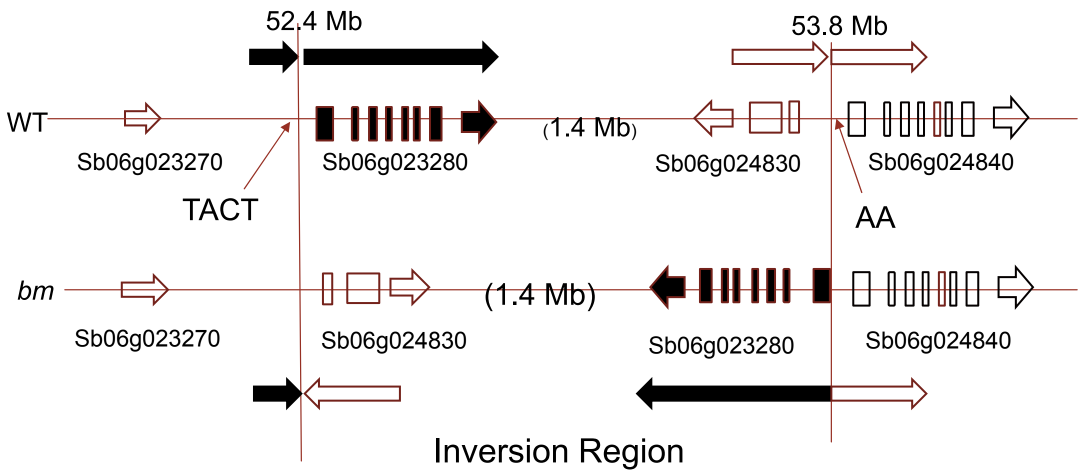


Fig. 11. Genomic inversion in the *bm* mutant. An inversion of *ca.* 1.4 Mbp occurred on the chromosome 6 (based on Mizuno *et al.* 2013). Arrows indicate cloned sequence from the wild-type (WT) and the *bm* mutant genome. At the junction, four bases (TACT) or two bases (AA) were deleted in the *bm* mutant genome. Because of this inversion, the upstream region of the Sb06g023280/WBC11 gene (black arrow) was exchanged with the downstream sequence. (Courtesy of Dr. H. Mizuno, NARO)

and without epicuticular wax at a frequency of 74:22 (χ^2 = 0.1277; P = 0.7209 for a 3:1 segregation ratio, Chi square test) suggesting that the *bm* phenotype was controlled by a single recessive nuclear gene (Nakagawa *et al.* 2011c; Mizuno *et al.* 2013). The leaf-sheath of F_2 plants with the wild-type phenotype and those with the *bm* phenotype were subjected to RNA-seq analysis. In addition, the sorghum *bm* mutant and wild-type plants were examined using scanning electron microscopy, which showed that the wax was not located on the leaf surface of plants but deposited inside of the cells (Mizuno *et al.* 2013).

Total RNA of both wild-type and *bm* mutant were extracted from leaves, and converted to cDNA for massive parallel sequencing in an Illumina Genome Analyzer and differentially expressed genes were identified (Mizuno *et al.* 2013). Of the 31 downregulated genes, one gene was similar to the ABC transporter responsible for wax secretion in Arabidopsis (Bird *et al.* 2007; Panikashvili *et al.* 2007; Ukitsu *et al.* 2007). The induced *bm* mutant was identified to carry a 1.4-Mb genomic inversion proximal to the promoter region of Sb06g023280, which is the candidate gene of the *bm* mutant, with small deletions at both ends (Fig. 11). Using genome PCR, six *bm* mutant-phenotype progeny of the F_2 population were found to carry the same inversion. The analysis proved that the inversion involving the Sb06g023280 gene inhibited wax secretion in the bloomless sorghum, although the epicuticular wax was synthesized inside the cells.

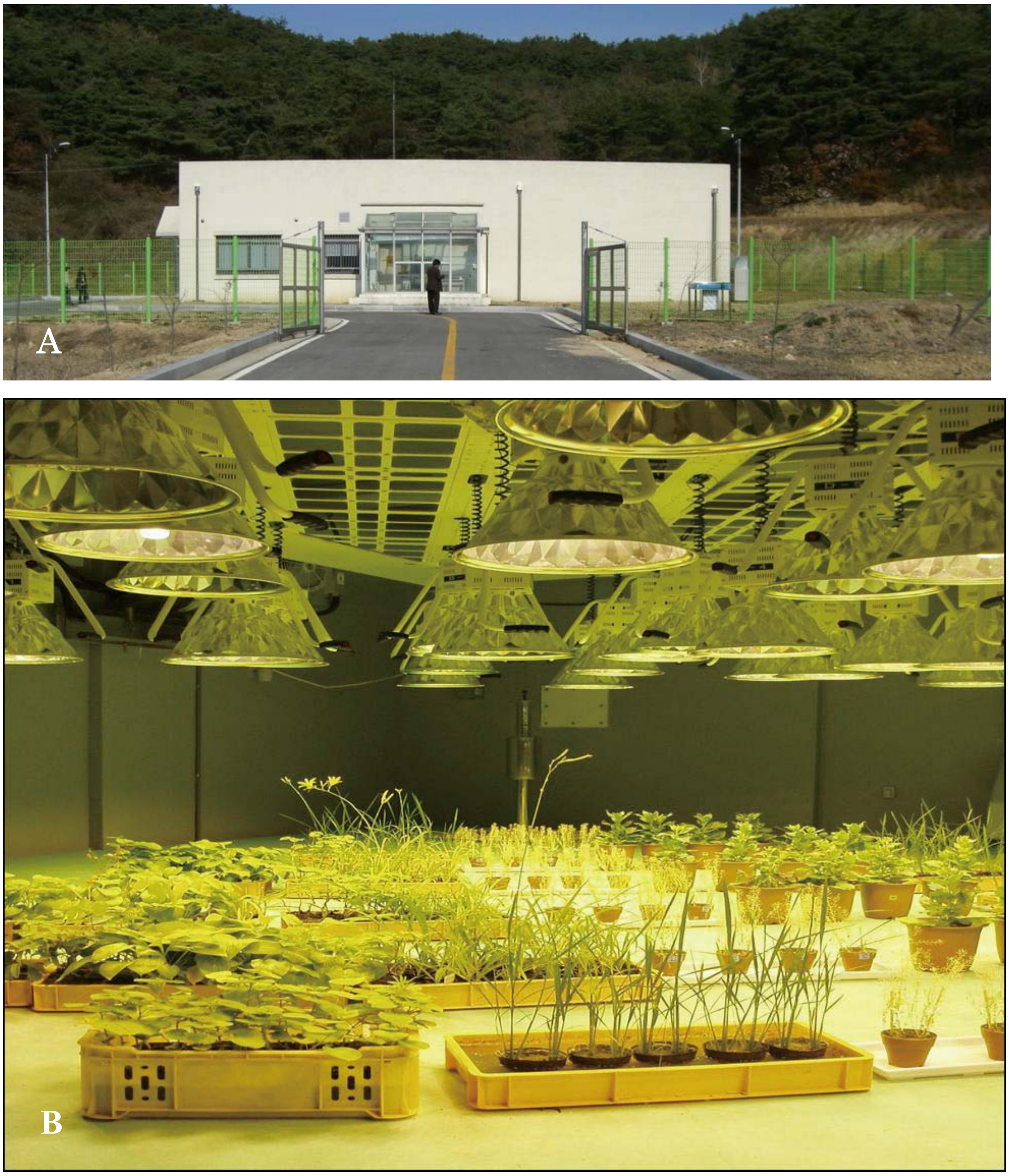


Fig. 12. Gamma Phytotron located at Korean Atomic Energy Research Institute (KAERI) in Jeoungup, Jeon buk Province, Republic of Korea. (Courtesy of Dr. Si-Yong Kang, KAERI), A: A building of the Gamma Phytotron; B: Inside the Gamma Phytotron

4） Chronic gamma-ray irradiation facilities in Asia

Two facilities for chronic gamma-ray irradiation were recently established in Asia. The Gamma Phytotron（Fig. 12）was established at the Advanced Radiation Technology Institute, Korea Atomic Energy Research Institute in Jeongeup, Jeollabuk-do, Rep. of Korea in 2005. The irradiation source is ^{60}Co with the radioactivity strength of about 400 curies（Kang et al. 2010）. The Gamma Greenhouse（Fig. 13）was established at the Malaysian Nuclear Agency, Ministry of Science, Technology and Innovation in Bangi, Selangor, Malaysia

Fig. 13. Gamma Greenhouse located at Malaysia Nuclear Agency, Ministry of Science, Technology and Innovation, Bangi, Kajang, Selangor, Malaysia.（Courtesy of Dr. Rusli bin Ibrahim, Malaysian Nuclear Agency）. A: A building of the Gamma Greenhouse; B: Inside the Gamma Greenhouse

in 2008. The Gamma Greenhouse is a circular greenhouse with a radius of 15 m, installed with ^{137}Cs with the radioactivity strength of about 800 curies at the center (Ibrahim 2010). As with the Gamma Field, both facilities are focused on the induction of mutation by chronic gamma-ray irradiation in growing plants of important crop species. As described above, chronic irradiation is a useful tool for the generation of mutant genome resources that have application for molecular analysis as well as conventional breeding.

Ⅴ Mutation breeding of outcrossing crops

Mutation breeding has been primarily performed in seed propagated, self-pollinated species. Although several methods have been widely used for screening of mutants in self-pollinated species by the single-seed descent approach (Stadler 1930; Nybom 1954) and by one-plant-one-grain method (Yoshida 1962), these methods have not been applied to cross-pollinated species. Ukai (1990) developed a new and efficient method - the "crossing-within-spike-progenies method"- for obtaining mutants of cross-pollinated species in a temperate forage grass, Italian ryegrass (*Lolium multiflorum* Lam.). This method composes (1) taking seeds separately from each spike from a population of plants following gamma-ray irradiation, (2) sowing the seeds in a hill plot as a spike-progeny, (3) isolating each hill from others at the time of flowering and allowing the open-pollination of plants within hills and (4) taking seeds from each of the hills and sowing the seeds in hill progenies for the screening of mutants. This procedure is repeated each year. Using 300 Gy of gamma-ray irradiation for the seed, the frequency of chlorophyll mutations was approximately 70.6% per hill progeny and 1.87% per plant; in comparison, open-pollinated populations exhibited only 10% per progeny and 0.12% per plant. This method has application in other wind- or insect-pollinated outcrossing crop species.

Ⅵ Mutation breeding and cultivars released in Japan

In a 2015 search regarding the number of induced-mutation cultivars in the IAEA database (http://mvgs.iaea.org/AboutMutantVarities.aspx), China had the most described induced-mutation cultivars with 810, Japan was second with 481 and India was third with 330 (including those with doubled chromosome numbers through colchicine treatment). The total number of mutant cultivars, including direct-use mutant cultivars and indirect-use cultivars exceed these totals because all mutant cultivars have not yet been listed by breeders. A selection of mutant cultivars developed in Japan, including their economic impact of these cultivars, and their characteristics are reviewed here.

1) The number of cultivars developed by mutation breeding

The numbers of direct-use and indirect-use (hybrid) mutant cultivars registered in Japan in each 5-year period from 1960 to 2015 are shown in Fig. 14. The number of registered direct-use cultivars rapidly increased until 2000 when 65 cultivars were registered in five years (13 cultivars per year). This number has since fallen, with 49 cultivars registered during 2001-2005, 54 cultivars during 2006-2010 (*ca.* 10 cultivars per year) and 27 cultivars during 2011-2015. The number of indirect-use cultivars primarily generated in rice steadily increased with 79 during 2001-2005 and 80 during 2006-2010 but decreased to 58 during 2011-2015. This reduction can

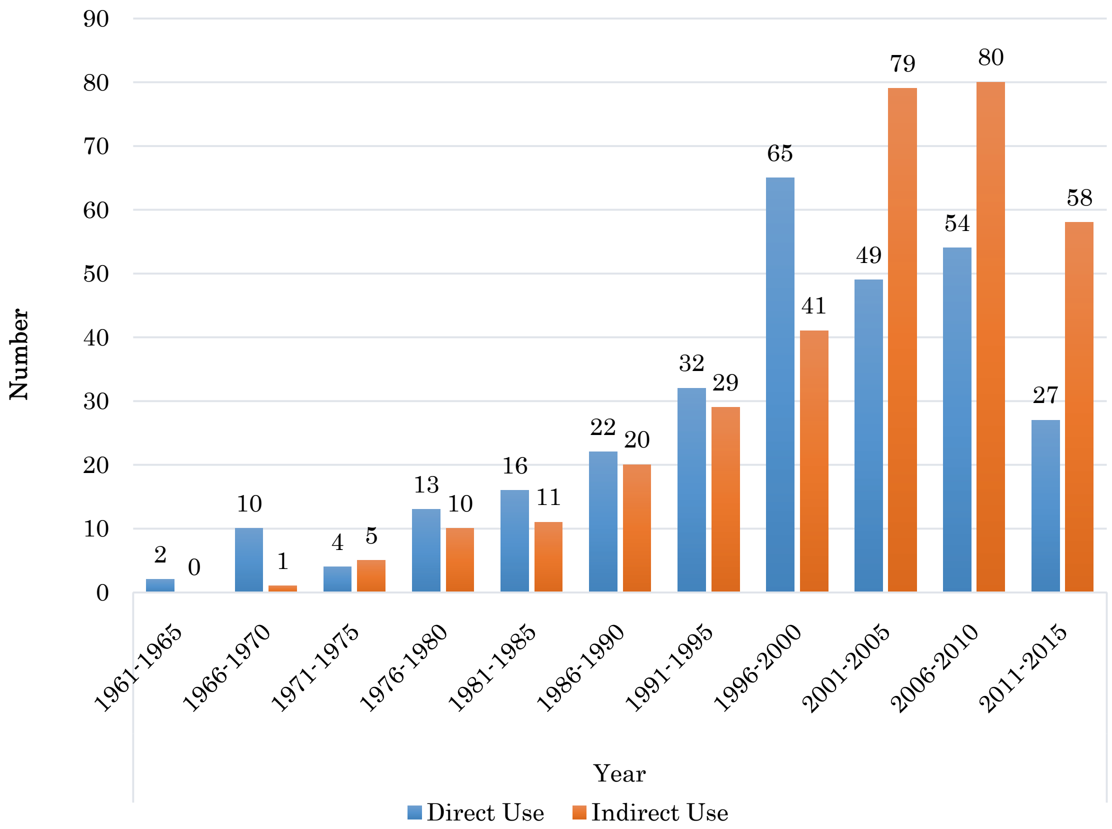


Fig. 14. Number of cultivars developed by mutation breeding in each five years from 1961–2015. The total number of direct use cultivars is 295 and that of indirect use cultivars is 334.

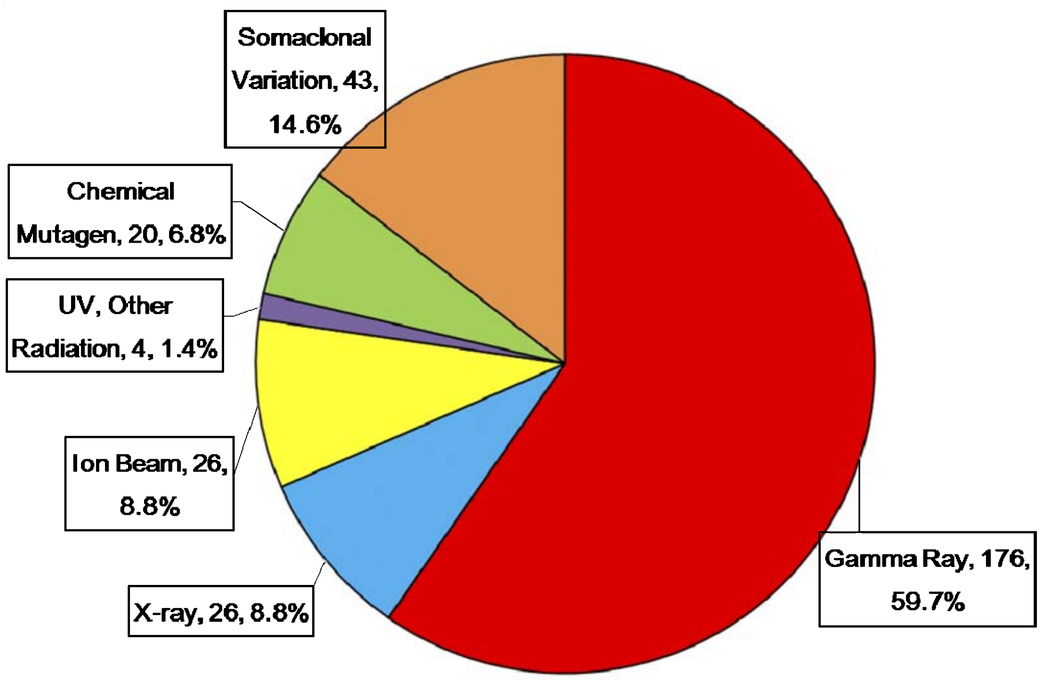


Fig. 15. Numbers and percentages of total 295 cultivars developed by mutation breeding using various methods in Japan (2016). Chemical mutagen does not include colchicine.

be turned around if agronomically useful, direct-use mutant cultivars, such as cv. "Reimei", possessing the *sd1* dwarf gene for rice are induced and utilized by rice breeders. It is presumed that such breeders will gravitate toward this and other cultivars carrying advantageous unique genes.

There have been 295 direct-use mutant cultivars comprising 70 species generated through irradiation utilizing gamma-rays, X-rays and ion beams, chemical mutagenesis and in *vitro* culture (somaclonal variation), registered and released in Japan (Fig. 15). Approximately 79% of these were induced by radiation, including gamma-rays (59.3%), ion beams (9.2%), X-rays (8.8%) and other radiation sources such as UV radiation or those providing no information of radiation source (1.4%). Those induced by somaclonal variation and chemical mutagens (not including those with doubled chromosome numbers through colchicine treatment), are 14.6 and 6.8%, respectively. Recently, the development of mutant cultivars of flower and food crops, generated by ion beam irradiation has been a growing area of mutation induction in Japan.

Table 4 shows the number of registered direct-use mutant cultivars of some crops developed by radiation, gamma-rays, and those irradiated at the IRB, NIAS. These include 43 mutant cultivars of rice (*Oryza sativa* L.), 17 of soybean (*Glycine max* (L.) Merrill), four of wheat (*Triticum aestivum* L.), four of barley (*Hordeum vulgare* L.), five of barnyard millet (*Echinochloa esculenta* (A. Braun) H. Scholz: glutinous mutants for

Table 4. Number of registered direct-use mutant cultivars developed by radiation, gamma rays, and those irradiated in the Institute of Radiation Breeding (IRB), NIAS (2016).

	Cultivar[1]	Radiation	Gamma rays	IRB[2]
70 Crops	295	228	176	127
Rice	43	21	20	19
Wheat	4	2	2	0
Barley	4	4	3	0
Soybean	17	16	15	9
Adzuki bean	1	1	1	1
Broad bean	1	1	1	0
Barnyard millet	5	5	4	4
Job's tear	2	2	2	2
Buckwheat	3	3	3	3
Tartary buckwheat	3	2	1	1
Taro	3	1	0	0
Potato	2	0	0	0
Sweet potato	1	1	0	0
Sugarcane	1	1	1	1
Burdock	5	5	5	4
Apple	2	2	2	2
Japanese pear	3	3	3	3
Peach	2	2	2	2
Loquat	1	1	1	1
Enoki mushroom	2	2	2	2
Chrysanthemum	60	55	40	38
Rose	10	7	7	6
Carnation	15	11	3	2
Sea pink (*Limonium*)	6	6	6	0
Cytisus	8	8	8	8
Statice	6	6	6	0
Begonia	6	6	6	0
Lily	4	4	4	0
Clematis	2	2	2	2
Petunia	5	5	0	0
Margaret	4	4	0	0
Others	64	39	26	17

1: Total number of mutant cultivars developed by radiation (gamma-ray, X-ray, ultraviolet, ion beams and unwritten radiation), chemicals (excluding colchicine treatment), somaclonal variation: 2: Number of mutant cultivars irradiated in the Institute of Radiation Breeding (IRB).

health food use), 60 of chrysanthemum (*Chrysanthemum*) and 10 of rose (*Rosa*). Among them, 126 cultivars (ca. 72.1% of gamma-ray induced cultivars) have been generated through gamma-ray irradiation in the Gamma Field, the Gamma Room and the Gamma Greenhouse of the IRB. This high percentage of gamma-ray-irradiated mutants indicates that mutation breeding via gamma-ray irradiation is an effective and highly successful approach for generation of commercial cultivars. Detailed data of developed cultivars are listed in Appendix 1, that includes cultivars induced through colchicine treatment.

The first mutant rice cultivar developed using gamma-ray irradiation was cv. “Reimei”, which means “dawn” in Japanese. Its development illustrated the potential of gamma-rays for breeding improvements in Japan. The cv. “Reimei”, registered in 1966 (Futsuhara 1968), was a successful case of an irradiation-induced semi-dwarf mutant. This cultivar exhibits a mutation of the *SD1* locus (Ashikari *et al.* 2002), which is same as the mutation of a miracle rice, cv. “IR8”, through cv. “Dee-geo-woo-gen” and later contributed to the “Green Revolution” of rice, and shows a culm 15 cm shorter than the original cv. “Fujiminori”. The semi-dwarf character is associated with the high-yielding ability and recorded the highest yield in Japan in 1967 (Futsuhara 1968)

In Japan, the total number of indirect-use mutant cultivars is 335, which includes 298 rice, 15 soybean, eight barley, six wheat, three tomato, one eggplant, one Japanese lawngrass (*Zoysia japonica* Steud), two mat rush (*Juncus effusus* L. var. *decipens* Buchen.) and one Job’s tear (*Coix lacryma-jobi* L. var. *ma-yuen* Stapf) in 2016 (Table 5). Detailed data of developed cultivars are listed in Appendix 2. Interestingly, among the 298 indirect-use mutant rice cultivars in 2016, 150 cultivars (50.3%) exhibited lodging resistance characteristics in the semi-dwarf cultivars derived from cv. “Reimei” or its offspring. This demonstrates that agronomically useful mutations can be efficiently and intensely utilized as parental lines to develop new cultivars with the same characteristic, and over the years the mutant gene multiplies itself in the farmers’ fields.

Table 5. Number of indirect-use mutant cultivars in Japan (2016).

Rice	Wheat	Barley	Soybean	Tomato	Others	Total
298	6	8	15	3	5	335

2) The economic impact of mutant cultivars in Japan

The increase of mutant rice cultivars derived from mutants generated by gamma-rays and sown in farmers’ fields in Japan since 1960 is shown in Fig. 16. The cv. “Reimei” was first cultivated on 61,598 ha in 1968 (http://ineweb.narcc.affrc.go.jp/). The number of mutant cultivars has been increasing and 99 mutant cultivars (two direct-use and 97 indirect-use cultivars) were in cultivation in 2005 (Nakagawa 2008).

The total cultivated area of mutant cultivars mostly derived from gamma-ray irradiation during 1961-2005 is shown in Fig. 17. This number increased after cv. “Reimei” was released for cultivation in 1968. The peak use of induced-mutation cultivars was 250,000 ha in 1986 and slightly exceeded 200,000 ha during 1994-2005. In 2005, the total cultivated area of mutant cultivars was 210,692 ha, which was 12.4% of the 1,702,000 ha cultivated for paddy rice in Japan (Nakagawa 2008).

The total crude income of farmers selling the brown rice of mutant cultivars has also increased with the expanding cultivation area. The amount of total income was estimated to be approximately 250 billion Yen (2.34 billion USD) in 2005 (Fig. 18) (Nakagawa 2008).

The following 17 cultivars were derived from mutant cultivars induced through gamma-ray irradiation (Appendix 2) and were cultivated on more than 5,000 ha during 2001-2005: cv. “Kinuhikari” (263,223 ha), cv. “Haenuki” (219,734 ha), cv. “Tsugaru-roman” (106,423 ha), cv. “Yume-akari” (66,491 ha), cv. “Yume-

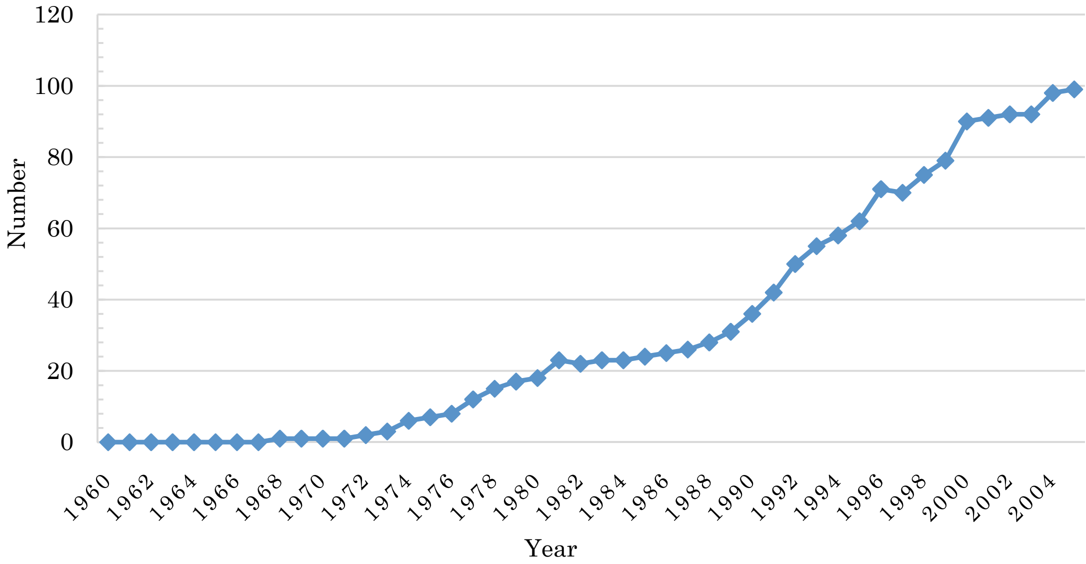


Fig. 16. Total number of mutant rice cultivars derived from mutants mostly generated by gamma-rays, cultivated in farmers' fields during 1960–2005 in Japan (Nakagawa 2008, 2009).

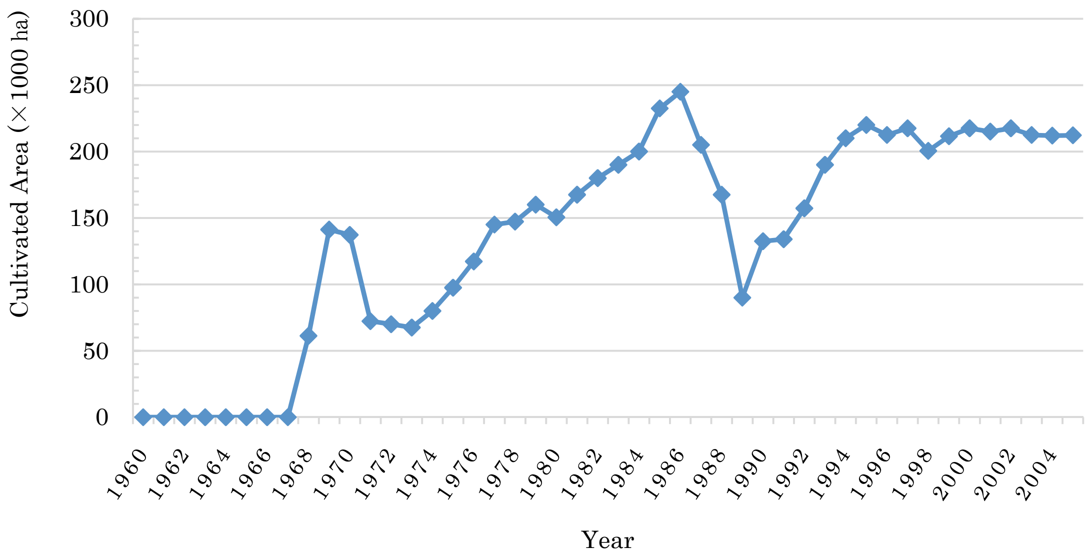


Fig. 17. Total cultivated areas of mutant rice cultivars derived from mutants mostly generated by gamma-rays, cultivated in farmers' fields during 1960–2005 in Japan (Nakagawa 2008, 2009).

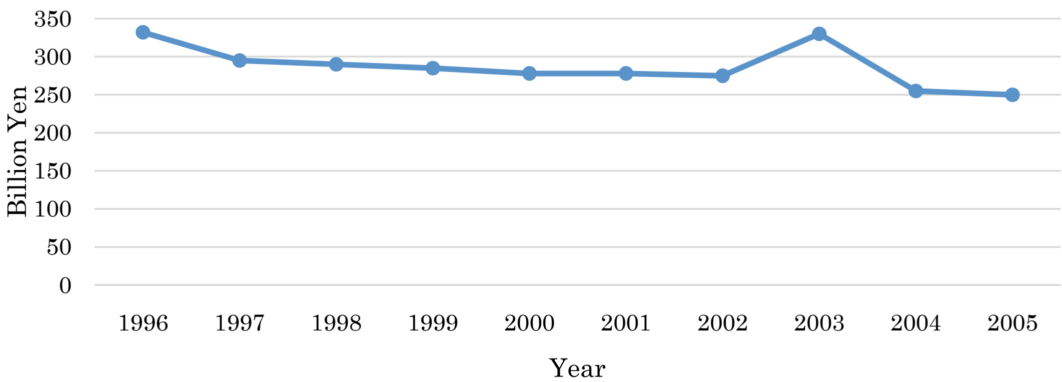


Fig. 18. Total estimated crude income of farmers obtained from cultivation of mutant rice cultivars mostly induced by gamma-rays in Japan during 1996–2005 (Nakagawa 2008, 2009).

tsukushi” (58, 893 ha), cv. “Aichi-no-kaori” (53,697 ha), cv. “Asahi-no-yume” (51,049 ha), cv. “Mutsuhomare” (46,959 ha), cv. “Dontokoi” (17,008 ha), cv. “Yume-shizuku” (14,076 ha), cv. “Mine-asahi” (10,698 ha), cv. “Yume-hitachi” (10,440 ha), cv. “Yume-minori” (9,957 ha), cv. Aki-geshiki” (7,510 ha), cv. “Aki-roman (7,450 ha)”, “Miyama-nishiki (7,242 ha)”, and “Tsukushi-roman (5,533 ha)”. The following five mutant cultivars have been cultivated on more than 100,000 ha of farmers’ fields: cv. “Akihikari” (1,410,810 ha), cv. “Reimei” (886,188 ha), cv. “Kinuhikari” (263,223 ha), cv. “Haenuki” (219,734 ha) and cv. “Tsugaru-roman” (106,423 ha). Among them, only cv. “Reimei” is a direct-use mutation cultivar and the others are indirect-use cultivars (Nakagawa 2008; Appendix 1, 2).

The latest data of the top three paddy rice cultivars in 47 prefectures of Japan in 2013 shows that 14 indirect-use mutation cultivars are listed in 180,233 ha of paddy field (11.03% of total paddy field) (Table 6). Among them, cv. “Kinuhikari”, which is descended from a gamma-ray induced semi-dwarf and lodging-tolerant mutant line, cv. “Hokuriku 100 Gou” (Samoto and Kanai 1975), from the most popular tall cv. “Koshihikari” and semi-dwarf “IR8” (Koga *et al* 1989), is the most popular mutation variety with a good taste and shorter stems and covered 48,187 ha in 11 prefectures in 2013. The cv. “Haenuki” descended from cv. “Reimei”, covered 63% of Yamagata Prefecture’s paddy fields (43,848 ha). Interestingly, cvs. “Yume-hitachi”, “Kinumusume”, “Ikuhikari”, “Yume-tsukushi”, “Genki-tsukushi”, “Yume-shizuku”, “Saga-biyori” and “Nikomaru” are descended from cv. “Kinuhikari”. Therefore, the total cultivated area of cv. “Kinuhikari” and its descendants was 95,103 ha or 5.8% of all the paddy field in Japan. The real cultivated areas of mutant cultivars exceed these values because the data include only the top three cultivars of prefectures and do not include all cultivars. This means the economic impacts of mutant cultivars of rice are huge and the roles of cvs. “Reimei”, “Kinuhikari” and “Mineasahi” are very important in Japan.

There have been 16 direct-use mutant cultivars of soybean registered in Japan (Table 4) since cvs. “Raiden” and “Raikou” were developed by gamma-ray irradiation in 1960. The improved characteristics were early- and late-maturity, yellow hilum, seed-coat color, short-stems, numbers of pods/stem, lipoxygenase-free and low allergens (Nakagawa *et al.* 2011a). Among them, cv. “Mura-yutaka” with yellow hilum color mutation is

Table 6. Mutant rice cultivars listed in the top 3 in 47 prefectures in 2013.

Variety	Cultivated Area (ha)	No. of Pref.	Origin of Mutant Cultivar
Kinuhikari	48,187	11	Hokuriku No. 100
Haenuki	43,848	1	Reimei
Koshi-ibuki	20,400	1	Reimei
Asahi-no-yume	17,598	3	Mineasahi
Yume-tsukushi	16,120	1	Kinuhikari
Yume-shizuku	8,463	1	Kinuhikari
Kinumusume	6,192	1	Kinuhikari
Sagabiyori	6,006	1	Mineasahi; Kinuhikari
Genki-tsukushi	3,627	1	Kinuhikari
Nikomaru	3,266	1	Kinuhikari
Aki-roman	2,358	1	Mineasahi
Yume-hitachi	2,331	1	Kinuhikari
Mie-no-yume	927	1	Mineasahi
Ikuhikari	911	1	Kinuhikari
Total	180,233	23	
Total paddy field in Japan	1,632,000		
%	11.03		

preferred in Japan and was induced by X-rays at Saga University (Nakamura *et al.* 1991; Appendix 1). There are 15 indirect-use mutant soybean cultivars (Table 5), of which four, including cv. "Ryuhou" are descended from a mutant cv. "Raiden" with induced early-maturity characteristics (Appendix 2). Table 7 shows the cultivated areas and estimated farmers' income for soybean mutant cultivars in 1997, 2001, 2005, 2006, 2011 and 2014 in Japan. Among the direct-use mutant cultivars, the cultivated area of cvs. "Mura-yutaka" was 1,173 ha (1,403 ha in 2011), "Kosuzu" 134 ha (194 ha in 2011) and "Akita-midori" 40 ha (0 ha in 2011) in 2014. Among the indirect-use mutant cultivars, the cultivated area of cv. "Ryuhou", a descendant of the gamma-ray induced mutant cv. "Raiden", was the third of all soybean cultivars planted in Japan with 10,548 ha in 2011 and fourth with 9,600 ha in 2014; cv. "Nanbu-shirome", which was selected from hybridization between cvs. "Raiden" and "Kitami-nagaha", had 1,472 ha (2,132 ha in 2011); and cv. "Suzu-sayaka" descended from a lipoxygenese-free mutant, and cv. "Suzu-kaori", which was selected from hybridization between cv. "Kosuzu", a gamma-ray induced direct-use mutant cultivar from cv. "Natto Kotsubu", and "Karikou 778F5", a descendant of cv. "Kosuzu" (Appendix 1, 2), had 61 ha (65 ha in 2011) and 70 ha (56 ha in 2011), in 2014, respectively. The cv. "Kyo-shirotanba", selected from hybridization between gamma-ray induced direct-use mutant cv. "Murasaki-zukin" and local cv. "Tamadaikoku" (Appendix 1, 2), was cultivated in 4 ha of Kyoto Prefecture. Thus, the economic impact of mutant cultivars of soybean is huge in Japan. The total cultivated area of mutant cultivars in farmers' fields was 14,399 ha (10.5% of total cultivated area of 136,700 ha of soybean in Japan) in 2011 and 12,614 ha (9.5% of total area of 131,900 ha in 2014), and total farmers' crude income was estimated as 11.6 billion Yen (*ca.* 116 million USD) in 2011.

Table 7. Cultivated areas (ha) of soybean mutant cultivars and income of farmers from the production in 1997, 2001, 2005, 2006, 2011 and 2014 in Japan.

Cultivar Name	1997	2001	2005	2006	2011	2014
Raiden[1]	80	8				
Wase-suzunari[1]	120					
Mura-yutaka[1]	3507	5910	2466	2265	1403	1173
Kosuzu[1]	498	863	576	512	194	134
Ichi-hime[1]		35	130			
Akita-midori[1]		8	87	95		40
Nanbu-shirome[2]	1246	1550	1534	1365	2132	1472
Tomo-yutaka[2]	2					
Suzu-no-ne[2]	10	50				
Eru-star[2]			447	43		
Suzu-sayaka[2]			10	234	65	61
Suzu-kaori[2]				25	56	70
Ryuhou[2]	1150	7050	8033	7955	10548	9600
Tsuya-homare[2]					1	
Kinu-sayaka[2]						61
Kyo-shirotanba[2]						4
Total	6,613	15,474	13,283	12,494	14,399	12,614
Total cultivated areas of soybean in Japan	83,200	143,900	134,000	142,100	136,700	131,900
%	7.95	10.75	9.91	8.79	10.53	9.56
Income of farmers (Million USD)	ca. 20	ca. 59	ca. 52	-	22.6 (115.7 with subsidy)	

[1] Direct-use mutant cultivar
[2] Indirect-use mutant cultivar

Ⅶ　Conclusions

A. M. van Harten（1998）describes in the Preface of "Mutation Breeding – Theory and Practical Application":

"An explanation for the decreasing interest in mutation breeding, at least in most "developed" countries, may be that during the past two decades attention has become more and more directed towards studying the possibilities offered to plant breeding by various new molecular technologies…As a result of these developments mutation breeding seems to have lost part of its previous attraction for young researchers. It is even not inconceivable that mutation breeding, as a discrete branch of plant breeding, may sink into oblivion and that, as a consequence, much valuable knowledge on this topic built up throughout the years, will be lost."

The record has also shown that mutation induction is a very useful conventional breeding tool for developing superior cultivars. Today, site-directed mutagenesis in *vivo* or *in vitro* cell can be envisioned and many researchers are conducting programs in this direction.

New fields of science and technologies were developed on the basis of achievements through the application of traditional or classic methods. It is highly desirable that the IRB continues its work while incorporating new discoveries and technologies. The IRB is well equipped with appropriate facilities and accumulated know-hows that will contribute to the future mutation breeding developments and it will remain a viable cooperator in solving the problems and opportunities of world food security and production.

The list of direct-use mutant cultivars（Appendix 1）includes information of crop species, cultivar names, year of registration in Japan and the registration number, breeding methods, the institutes of treatment and development, improved characteristics, ID numbers listed in IAEA database and references. The list of indirect-use（hybrid）mutant cultivars（Appendix 2）includes the crop species, cultivar name, parental lines（descendants of mutant cultivars are written in red font with the lineage), year of registration in Japan and the registration number, the institute of development, improved characteristics of original mutant cultivars, ID numbers listed in IAEA database, and references. These lists include only mutant cultivars identified from the references and a database of the Plant Variety Protection office at MAFF, Japan（http://www.hinsyu.maff.go.jp/en/en_top.html). Therefore, if the cultivar breeder did not mention that it was a mutation cultivar induced through a certain method, we cannot identify it. We did not include cultivars from spontaneous mutations, which are mentioned just as a mutant plant or twig found in the original cultivar, in the lists. We anticipate that these lists will demonstrate the importance of mutation breeding in Japan.

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Appendix 1. Direct-use mutant cultivars

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
Rice		*Oryza sativa* L.										
1	Reimei	Fuji-minori	1959	Gamma ray 20kR	National Institute of Agricultural Sciences (Hiratsuka)	1966		-	Aomori PAES	Shorter stem; lodging resistance; high-yielding	1138	Futsuhara (1968)[5)]
2	Miyama-nishiki	Takane-nishiki	1972	Gamma ray 30kR	IRB	1978		-	Nagano PAES	High ratio of white core; very suitable for sake brewery	1129	
3	Miyuki-mochi	Toyo-nishiki	1973	Gamma ray 20kR	IRB	1979		-	Nagano PAES	Became glutinous	1131	
4	Shinano-sakigake	Toyo-nishiki	1973	Gamma ray 20kR	IRB	1982	1983	335	Nagano PAES	Big grain; very high-yielding; rice for forage	1141	
5	Shirakaba-nishiki	Reimei	1973	Gamma ray 20kR	IRB	1982	1983	336	Nagano PAES	Big grain; white core; brewery use	1142	
6	Iwate 21	Sasa-nishiki	1979	Gamma ray 20kR	IRB	1986		-	Iwate PAES	Shorter stem; earlier maturity; good taste	1156	Ishikawa *et al*. (1988)[18)]
7	Iwate 26	Koshihikari	1979	Gamma ray	IRB	1989		-	Iwate PAES	Extremely early maturing; shorter stem; good taste	2445	
8	Hatsu-akane	Sasa-nishiki	1984	Protoplast culture	Mitsui Chemical Ltd.	1988	1990	2508	Mitsui Chemical, Inc.	Shorter stem	2446	
9	Hatsu-yume	Koshi-hikari	1985	Protoplast culture	Plantech Research Institute	1988	1990	2509	Plantech Research Institute	Shorter stem	2447	Ito (1991)[19)]
10	Suzu-takara	Akenohoshi	1984	EMS treatment	Sumitomo Chemical Company	1988	1990	2510	Sumitomo Chemical Co.	Shorter stem; earlier maturity	1165	
11	Sumi-takara	Kogane-bare	1986	Anther culture	Sumitomo Chemical Company	1987	1991	2627	Sumitomo Chemical Co.	No hairs on the leaf blade; smaller seed	2448	
12	Yume-kahori	Tsukino-hikari	1986	Protoplast culture	Plantech Research Institute	1990	1993	3573	Plantech Research Institute	Short stem; lower 1000-kernel weight	2449	Ito (1991)[19)]
13	Fujimi-mochi	Aki-chikara	1988	Gamma ray	IRB	1991	1994	4052	ZEN-NOH	Became glutinous; white seed color	2450	
14	Rinx-Kobayashi	Rinx89	1989	NMU	Plant Laboratory, Kirin Brewery Co., Ltd.	1991	1994	4170	Plant Laboratory, Kirin Brewery Co., Ltd.	Seed-shattering resistance (no seed shattering)	2451	
15	Hareyaka	Sasa-nishiki	1989	Protoplast culture	Plantech Research Institute	1993	1995	4413	Plantech Research Institute	High lodging tolerance	2452	
16	Yume-gokochi	Koshihikari	1986	Protoplast culture	Plantech Research Institute	1992	1995	4709	Plantech Research Institute	Lower amylose	2454	
17	Syonan 3 Gou	Aki-chikara	1988	Radiation		1994	1996	5125	ZEN-NOH	Long and thin grain; high ratio of white core	2453	
18	Meguriai	Norin No. 22	1980	EMS	Hiroshima PARC	1994	1996	5187	Hiroshima PARC	Short stem; for brewery	2355	Maeshige *et al*. (1995)[27)]
19	Akane-fuji	Norin No. 8	1974	EMS	IRB	1994	1997	5307	IRB and Institute of Processing Rice Breeding	Low amylose	2456	

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
20	Oita 3 Gou	Norin No. 22	1988	Anther culture	Oita PARC	1993	1997	5308	Oita PARC	10% shorter stem; slightly small grain	2457	
21	Milky Queen	Koshihikari	1985	NMU	NARC	1995	1998	6385	NARC	Lower amylose content	2458	Ise *et al*. (2001)[16)]
22	Odoroki-mochi	Kanto No. 146	1988	Gamma ray 30kR	IRB	1996	1998	6386	NARC	Became glutinous	2459	Imbe *et al*. (2004)[14)]
23	Yume-ekubo	Sasa-nishiki	1988	Protoplast culture	Plantech Research Institute	1996	2000	8546	Plantech Research Institute	Short stem; late maturing	2460	
24	Sakata-mezuru	Mezuru	1988	Gamma ray	IRB	1996	2001	8628	Sakata City	Short stem	2461	
25	Iwata 15 Gou	Kinuhikari	1989	Seed callus	Japan Tobacco Inc.	1996	2001	8632	Japan Tobacco Inc.	Low amylose	2462	
26	Hana-kahori	Yamada-nishiki	1988	Radiation		1986	2002	9784	NARO	Short stem	2463	
27	LGC-1	Nihonmasari	1988	EI	IRB	2001	2002	10469	IRB	Low glutelin contents in grain	2464	Iida *et al*. (1993)[11)]
28	Moh-retsu	Rinx89	1989	EMS	Plant Laboratory, Kirin Brewery Co., Ltd.	1988	2003	10961	Plant Laboratory, Kirin Brewery Co., Ltd.	Long stem; tough stem; shattering resistance	2465	
29	Flower Hope	Koshihikari	1985	Gamma ray	IRB	1995	2003	11356	IRB	Low content of globulin in the grain	2466	
30	Kazoku Danran	Nihon-masari	1988	EI	IRB	2000	2004	12176	IRB and Institute of Allergen Free Technology	Low allergen	2467	
31	Minami-yutaka	Moh-retsu	2001	Gamma ray 200Gy	IRB	2004	2007	15001	Miyazaki PAES	Seed-shattering resistance	2886	Kato *et al*. (2006)[22)]
32	Homare-fuji	Yamada-nishiki		Gamma ray	IRB		2010	18111	Shizuoka PAES	Semi-dwarf		Shizuoka Prefecture (2010)[49)]
33	Shizuku-hime	Matsuyama-mitsui		Callus from mature grain	Ehime PAES		2010	19046	Ehime PAES	White center of grain appearing 11-20%		Kanetou *et al*. (2010)[21)]
34	Kumika 1 gou	Taichu 65 gou		Anther culture			2010	19048	Kumiai Kagaku and Tohoku Univ.	Herbicide tolerance		
35	Yuki-hime-habutae-mochi	Shiga-habutae-mochi		Anther culture of regenerated plant from callus	Shiga PARC		2010	19052	Shiga PARC	Long stem		http://www.pref.shiga.lg.jp/g/nogyo/saibai/files/yukihime.pdf (in Japanese)
36	Yuki-no-megumi	Yukihikari		Gamma ray	IRB		2010	19410	NARO (Institute of Crop Science)	Large embryo		https://www.naro.affrc.go.jp/patent/breed/0100/0107/001690.html (in Japanese)
37	Hatsu-yamabuki	Kinuhikari		Gamma ray	IRB		2012	22049	NARO and JIRCAS	Yellow endosperm color; semi transparent		Kaji *et al*. (2010)[20)]
38	Ruri-aoba	Taporuri		Gamma ray	IRB		2012	21771	NARO	Non or low seed-shattering		Sakai *et al*.(2013)[43)]
39	Hoshinoko	Hoshi-no-yume		Gamma ray	IRB		2012	21384	NARO	White colored brown-rice		https://www.naro.affrc.go.jp/project/results/laboratory/harc/2008/cryo08-03.html
40	Kikusui-HD1 gou	Kikusui		Gamma ray	IRB		2012	22079	Keiichi OKAZAKI (Kikusui Shuzou)	Later maturing		
41	EM10	Kinmaze		NMU	Kyushu University		2014	22986	Kyushu University	Smaller grain; white colored brown-rice		Nishi *et al*. (2001)[37)]
42	Amiro-mochi	Kinmaze		NMU	Kyushu University		2014	22987	Kyushu University	Smaller grain; white colored brown-rice		

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
43	Koshihikari Kan 1 gou	Koshihikari		Carbon ion beam	Japan Atomic Energy Agency		2015	24338	NIAES and NARO (Institute of Crop Science)	Accumulation of cadmium (Cd) in the grain is less than that of Koshihikari.		
Wheat		*Triticum aestivum* L.										
1	Zenkouzi-komugi	Iga-Chikugo-Oregon	1958	Gamma ray 30kR	National Institute of Agricultural Sciences (Hiratsuka)	1969	-	-	Nagano PAES	Shorter stem (15−20cm lower than the origin); lodging tolerance	1144	
2	Shirowase-komugi	Shirogane-komugi	1966	Gamma ray 25kR	Kyushu University	1977	-	-	Kyushu NAES	Erect plant-type; large inflorescence; slightly heavier head type	1143	Nonaka *et al*. (1979)[38]
3	Wheat Noh PL 7	Kanto No. 107	1988	EMS	IRB	1994	1999	7169	NARC	Lower amylose content; lower 1,000 kernel weight	2469	Yamaguchi *et al*. (1998)[56]
4	Wheat Noh PL 8	Tani-kei A6099	1991	Sodium azide (NaN_3)	IRB	2000	2003	11365	NARC	Low amylose content	2470	Kiribuchi-Otobe *et al*. (2001)[24]
Barley		*Hordeum vulgare* L.										
1	Haya-shinriki	Aka-shinriki	1957	Gamma ray 40kR	National Institute of Genetics	1961	-	-	National Institute of Genetics	Extremely early maturing; good quality	1118	
2	Gamma 4	Kirin cyoku 1 gou	1958	Gamma ray 15kR	Kanagawa Prefectural Industrial Experiment Station	1962	-	-	Barley Research Center, Kirin Brewery Co., Ltd.	Short stem（15cm shorter); slightly early maturing（1-2 day earlier）	1116	
3	Amagi Nijo 1 gou	Fuji Nijo	1965	X-ray 20kR	Tokyo University (Faculty of Agriculture)	1971	-	-	Barley Research Center, Kirin Brewery Co., Ltd.	Early maturing（7 days earlier）; short stem（14cm shorter）	1114	
4	Fuji Nijo II	Fuji Nijo	1967	BUdR(1mM)＋gamma ray 1kR	Tokyo University (Faculty of Agriculture)	1974			Barley Research Center, Kirin Brewery Co., Ltd.	Tough stem	1115	
Barnyard millet		*Echinochloa esculenta* (A. Braun) H. Scholz										
1	Chojurou-mochi	Nogebie		Gamma ray	IRB		2012	21495	Iwate University	Became glutinous		Hoshino *et al*. (2010)[10]
2	Nebarikko 1 gou	Mojappe		Gamma ray	IRB		2012	21577	Iwate Prefecture	Medium stem length; fewer awns; earlier maturity		Nakajo *et al*. (2013)[35]
3	Nebarikko 2 gou	Mojappe		Heavy ion beam	Riken		2012	21578	Iwate Prefecture	Shorter stem length; very few awns		Nakajo *et al*. (2013)[35]
4	Nebarikko 3 gou	Mojappe		Gamma ray	IRB		2012	21579	Iwate Prefecture	Shorter stem length		Nakajo *et al*. (2013)[35]
5	Yume-sakiyo	Nogebie		Gamma ray	IRB		2013	22559	Iwate University	Short stem; earlier maturity		
Job's tear		*Coix ma-yuen* Roman.										
1	Hato-musume	Okayama Zairai	1980	Gamma ray 20kR	IRB	1992	1993	3634	Tohoku NAES	Early maturing; short stem	159	Okuyama *et al*. (1995)[40]

No.	Cultivar Name	Original Variety	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
2	Hato-hikari	Okayama Zairai	1980	Gamma ray 200Gy	IRB	1995	1996	5069	Tohoku NAES	Early maturing; short stem	2471	Ishida *et al*. (1995)[17)]
Buckwheat		*Fagopyrum esculentum* Moench										
1	Dewa-kaori	Mogami Wase	1988	Colchicine	Yamagata PAES	1995	1996	5069	Yamagata PAES	Larger grain	2472	
2	Hokkai 3 Gou	Botan-soba	1979	Colchicine	NARC for Hokkaido Region	2001	2005	12967	NARO	Tetraploid; large seed	2473	
3	Gamma-no-irodori	Botan-soba		Gamma ray	IRB		2005	22872	IRB, NIAS	Higher rutin content in the seed, smaller seed		
4	Cobalt-no-chikara	Botan-soba		Gamma ray	IRB		2013	22873	IRB, NIAS	Smaller seed		
5	Ruchiking	Botan-soba		Gamma ray (repeated irradiation for the generations)	IRB		2013	22874	IRB, NIAS	Very high rutin content in the seed; smaller seed		
Tartary buckwheat		*Fagopyrum tataricum* (L.) Gaertn.										
1	Daizen	No name		Colchicine	Tokita Seed Company		2010	19044				
2	Hokkai T9 gou	Dattan		Colchicine	NARO		2010	19466	NARO			Suzuki *et al*. (2008)[51)]
3	Hokkai T10 gou	Hokkai T8 gou		Ethyl methane sulfonate (EMS)	NARO		2010	19526	NARO	Pale red flower color; less maturing seed		Suzuki *et al*. (2008)[51)]
4	Shinano Kurotsubu	Bhate Parpar		Colchicine	Shinshu University		2010	19527	Shinshu University			
5	Daruma Dattan	Hokkai T8		Gamma ray	IRB		2013	22633	NIAS (IRB)	Semi-dwarf		
6	Ion-no-kousai	Routundatum		Helium ion beam	JAEA, Takasaki		2013	22634	NIAS (IRB) and JAEA	Shorter stem; light leaf		
Amaranthus		*Amaranthus* L.										
1	New Aztec	Mexico-kei	1989	Gamma ray 50kR	IRB	2001	2006	14399	NARO (National Institute of Crop Science)	Early maturing; short stem	2474	Katsuta *et al*. (2001)[23)]
Rapeseed		*Brassica napus* L.										
1	Haya-natane	Michinoku-natane	1955	Colchicine 0.03× 24h	Fukuoka PAES	1961			Fukuoka PAES	Maturing 3 days earlier than the original variety (earliest of all varieties)	1720	
2	Hanakkori	Wase-kei Saishin×Jyo-	1990	Colchicine treatment	Yamaguchi PAES	1995	1999	7324	Yamaguchi PAES	Morphology	2475	
Soybean		*Glycine max* (L.) Merr.										
1	Raiden	Nemashirazu	1960	Gamma ray 10kR	National Institute of Agricultural Sciences (Hiratsuka)	1966			Tohoku NAES	Earlier maturity (25 days); shorter stem lodging resistance	1594	Laboratory of Soybean Breeding (1970)[26)]

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2	Raiko	Nemashirazu	1960	Gamma ray 10kR	National Institute of Agricultural Sciences (Hiratsuka)	1969			Tohoku NAES	Earlier maturity (15 days); shorter stem lodging resistance	1595	Laboratory of Soybean Breeding (1970)[26)]
3	Wase-suzunari	Oku-shirome	1975	Gamma ray 10kR	IRB	1983	1984	610	Tohoku NAES	Earlier maturity (extremely early)	1597	Hashimoto *et al.* (1985)[8)]
4	Mura-yutaka	Fuku-yutaka	1984	X-ray 24kR	Saga Univ. Facul. Agric.	1988	1990	2156	Saga PAES	From brown hilum to white hilum	2476	Nakamura *et al* . (1991)[36)]
5	Kosuzu	Natto-Kotsubu	1979	Gamma ray 10kR	IRB	1987	1990	2397	Tohoku NAES	Earlier maturity (medium); lodging resistance	1596	Hashimoto *et al* . (1988)[7)]
6	Ryokusui	Fukura	1984	Gamma ray 20kR	IRB	1988	1980	2516	Iwate PAES	Later maturity; brown seed color	1598	
7	Saotome	Aji-ichiban	1986	Gamma ray 15kR	Tokyo Metropolitan Isotope General Research Institute	1991	1994	4055	Mitsui Chemical Ltd.	Yellow seed color; higher pod density	2477	
8	Kokoro-zukushi	Aji-ichiban	1986	Gamma ray 15kR	Tokyo Metropolitan Isotope General Research Institute	1991	1994	4115	Mitsui Chemical Ltd.	Earlier maturity; higher pod density	2478	
9	Murasaki-zukin	Kyoto No. 1 (Shin-Tanba)	1975	Gamma ray 10Gy	Kyoto Univ. Facul. Agric.	1992	1995	4715	Kyoto PARI	Later maturity; for green soybean-use	2479	
10	Ichi-hime	（Kanto No. 2/Kanto No. 1）F2	1989	Gamma ray 15kR	IRB	1996	1997	5369	Kyushu NAES	All lipoxygenase knock-out	2480	Hajika *et al* . (2002)[6)]
11	Taki-hime	Komaki Dadacha	1988	Gamma ray 8kR	IRB	1996	2000	8365	Yanagawa Saisyu Kenkyukai	Shorter stem; high pod density; earlier maturity	2481	
12	Aomori-toyomaru	Kemame（Aomori Local var.）	1989	Gamma ray	IRB	1995	2001	8642	Aomori Prefectural Agriculture and Forestry Research Center	Earlier maturity; shorter stem; ecological mutation（summer-type）	2482	
13	Aomori-fukumaru	Kemame（Aomori Local var.）	1989	Gamma ray	IRB	1995	2001	8643	Aomori Prefectural Agriculture and Forestry Research Center	Earlier maturity; shorter stem; ecological mutation（summer-type）	2483	
14	Akita-midori	Aome-daizu	1990	Gamma ray 10kR	IRB	1998	2002	9650	Akita PAES	Earlier maturity	2484	Sasaki *et al* . (2000)[46)]
15	Yume-minori	Kari-kei No.434	1991	Gamma ray	IRB	2001	2004	12280	Tohoku NAES	Low-allergic	2485	Takahashi *et al* . (2004)[52)]
16	Sayane	Saya-musume	1995	Gamma ray	IRB	2002	2006	13749	Snow Brand Ltd.	Earlier maturity; shorter main stem length	2487	
17	Akita-honoka	Hiden		Somaclonal variation from somatic embryo	Akita PAES		2015	24350	Akita PAES	Earlier maturity; larger bean size		Sato *et al.* (2015)[47)]

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Adzuki bean		*Vigna angularis* (Willd.) Ohwi & H. Ohashi										
1	Beni-nambu	Monbetsu No.26	1968	Gamma ray 10kR	IRB	1978			Iwate PAES	Earlier maturity (10 days)	406	Satoh *et al*. (1982)[48)]
Broad bean		*Vicia faba* L.										
1	Rin-rei	Niigata Zairai one-bean type	1982-8	Gamma ray irradiation (recurrent irradiation)	Tokyo Metropolitan Isotope General Research Institute	1988	1991	2695	Hokuetsu Nouji Co.	Dwarf	2490	
Sweet potato		*Ipomoea batatas* (L.) Lam.										
1	Sweet Garden	CN1367-2	1990	Gmma-ray irradiation to tissue culture	Kagoshima Biotechnology Institute	1993	1998	6390	Miwa Green Co.	Leaf-shape	2491	
Potato		*Solanum tuberosum* L.										
1	White Baron	Danshaku	1989	Protoplast culture	Hokuren	1985	1997	5965	Hokuren	Less browning after cutting	2492	
2	Jagakids Purple	Neo Delicious	1986	Protoplast culture	Plant Laboratory, Kirin Brewery Co., Ltd.	1990	1994	4054	Plant Laboratory, Kirin Brewery Co., Ltd.		2493	
Sugarcane		*Saccharum officinarum* L.										
1	Nan-ei	Ni1	1976	Gamma ray to the plant	IRB	1985	1986	1024	Kagoshima University; Faculty of Agriculture	Larger plant size; High-yielding	375	
Chinese matgrass		*Cyperus malaccensis* Lam. ssp. *monophyllus* (Vahl) T. Koyama										
1	Toyo-midori	Ohoi 2 Gou	1969	Gamma ray to plant 115kR	IRB	1979			Ooita Prefectural Igyou Shidousyo	Thicker stem; lodging tolerance; resistance to fungal disease	373	
Rush		*Juncus effusus* L. var. *decipiens* Buchenau										
1	Seto-nami	Asa-nagi	1963	Gamma ray to plant 68kR	IRB	1982	1983	397	Hiroshima PAES, Rush Breeding Station	More longer stems; High yielding; good quality; beautiful straws	345	Sadahira *et al*. (1982)[41)]
2	Fuku-nami	Asa-nagi	1965	Gamma ray to plant 96kR	IRB	1984	1986	941	Hiroshima PAES, Rush Breeding Station	Early-harvest and high yielding; less browning of leaf tops; stronger straw	346	Sadahira *et al*. (1984)[42)]
3	Chikugo-midori	Iso-nami	1989	Meristem culture	Fukuoka ARC	1997	2001	9033	Fukuoka ARC	More long stem number; higher weight of total long stems	2494	Nakahara *et al*. (1998)[34)]
Lettuce		*Lactuca sativa* L.										
1	Evergreen	Waya-head	1959	^{32}P100μCi and gamma ray 42kR	Hyogo PAES	1966			Hyogo PAES	Later volting under high summer temperature	2219	

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2	Giant Green	Waya-head	1959	^{32}P	Hyogo PAES	1966			Hyogo PAES	More heat tolerance	2220	
3	Satilo	Empire	1990	EMS	Sumitomo Chemical company	1992	1995	4778	Sumitomo Chemical Co.	Shrunken leaf; wave in leaf edge	2495	
Japanese parsley		*Oenanthe javanica* (Blume) DC.										
1	Miyagi VWD 1 Gou	Shimane-midori	1994	Protoplast culture	Miyagi Prefectural Agriculture and Horticulture Research Center	1996	2002	10071	Miyagi Prefectural Agriculture and Horticulture Research Center	Resistant to leaf disease	3163	
Butterbur		*Petasites japonicus* (Siebold & Zucc.) Maxim.										
1	Okayama Nohshi B1 Gou	Aichi-wase	1985	Callus (meristem)	Okayama PAES	1992	1996	5017	Okayama PAES	Less anthocyanin in leaf stem	3164	Hikawa *et al*. (1998)[9)]
Tomato		*Solanum lycopersicum* L.										
1	Kyoryoku-reikou	Syugyoku	1967	Gamma ray irradiation to pollen 2340R	IRB	1974			Musashi Breeding Station Co.	Resistant to TMV and wilt disease	2221	
Strawberry		*Fragaria* L.										
1	Shin-Nyohou	Nyohou	1963	Callus formation	Tochigi PAES, Tochigi Branch	1989	1989	2048	Tochigi PAES, Tochigi Branch	Earlier harvest type; high yielding	3213	
2	Akita Berry	Morioka 16 Gou	1967	Meristem culture	Akita Prefectural College of Agriculture	1990	1992	3224	Akita Prefectural College of Agriculture	Resistant to black leaf spot disease (*Alternaria alternata*)	3214	
3	Anther	Nyohou	1986	Anther culture	Ibaraki PAES	1991	1994	4176	Ibaraki PAES	Early maturing	3215	Ezura *et al*. (1998)[2)]
4	Himatsuri	Toyonoka	1988	Meristem culture	Kyushu Tokai University	1992	1995	4593	Kyushu Tokai University	Bright red fruit skin; light red flesh color	3216	Fukuoka *et al*. (1996)[3)]
5	Smile Heart	Ai-berry	1993	Tissue culture	Shikoku Research Institute Inc.	1994	1998	6563	Shikoku Research Institute Inc.	Resistant to phytophthora rot (*Phytophthora nicotinae*)	3217	
Burdock		*Arctium lappa* L.										
1	Cobalt Wase	Yanagawa-risou	1969	Gamma ray 10kR	IRB	1978	1981	73	Yanaken Co.	Earlier root growth; earlier maturing (growing days: 120 days)	2218	
2	Cobalt Goku-wase	Yanagawa-nakate	1969	Gamma ray 10kR	IRB	1978	1981	74	Yanaken Co.	Shorter root; extremely early maturing (growing days 100 days)	2216	
3	Cobalt Okute	Yanagawa-nakate	1969	Gamma ray 10kR	IRB	1978	1981	75	Yanaken Co.	Less pithy tissue; higher storability; late maturing	2217	
4	Tsune-yutaka	Yanagawa-risou	1969	Gamma ray 10kR	IRB	1984	1986	1233	Yanaken Co.	Thicker root; thick at upper root	2225	

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5	Tegaru	Cobalt Goku-wase	1982	Gamma ray 10kR	Tokyo Metropolitan Isotope General Research Institute	1991	1995	4422	Yanaken Co.	Shorter root; thick at upper root	2496	
Taro		*Colocasia esculenta* Schott										
1	Fukugashira	Yatsugashira	1984	MNU	Saga University, Faculty of Agriculture	1989	1992	3172	Saga PAES	Round mother corm; higher cooking and processing suitability	2497	
2	Chiba-maru	Dotare	1995	Soft X-ray	Chiba PAES	2004	2007	15137	Chiba PAES	Tuber shape	2901	Suzuki *et al* . (2006)[50)]
3	Ehime-Noushi V2 gou	Onna-wase	1994	Callus from meristem part	Ehime PAES	2000	2008	16024	Ehime PAES	Number and size of grand-son tuber is larger		Nakagawa *et al.* (2015)[33)]
Wasabi (Japanese horseradish)			*Wasabia japonica* (Miq.) Matsum.									
1	Green Magic	Matsuma	1991	Meristem culture	Miyoshi Co.	1993	1997	5312	Miyoshi Co.	Longer stem; less anthocyanin at leaf stem; light color at root stem; stronger bitterness		
2	Amagi-nishiki	Matsuma	1988	Tissue culture	Miyoshi Co.	1991	1998	6030	Miyoshi Co.	Less pithy tissue	3219	
Scarlet runner bean		*Phaseolus coccineus* L.										
1	Shiro-hanakko	Oo-shirohana	1991	Gamma ray		2002	2002	14409	Hokkaido Prefectural Central Agriculture Experiment Station	Higher pod width		Minami, M. and H. Sato (2009)[29)]
Limonium		*Limonium* Mill.										
1	Tall Pink Emirre	Tall Emirre	1962	Gamma ray	Tokyo Metropolitan Isotope General Research Institute	1993	1998	6100	Miyoshi Co.	Petal color: pale pink	3181	
2	Neo Misty Blue	Misty Blue	1990	Gamma ray	Tokyo Metropolitan Isotope General Research Institute	1994	1998	6101	Miyoshi Co.	Less number of floral stalks	3182	
3	Daifura Lavender	Daifura Pink	1992	Gamma ray irradiation to tissue culture	Tokyo Metropolitan Isotope General Research Institute	1995	1999	7104	Daiichi Seed Co., Ltd.	Sepal color: bright reddish purple	3183	
4	Daifura Pink Super	Daifura Pink	1992	Gamma ray irradiation to tissue culture	Tokyo Metropolitan Isotope General Research Institute	1995	2000	7938	Daiichi Seed Co., Ltd.	Sepal color: bright purple; less number of floral stalks	3184	
5	Dai-lady Rose	Super Lady	1991	Gamma ray irradiation to tissue culture	Tokyo Metropolitan Isotope General Research Institute	1996	2000	8490	Daiichi Seed Co., Ltd.	Petal color: vivid yellowish green	3185	
6	Dai-lady White	Super Lady	1991	Gamma ray irradiation to tissue culture	Tokyo Metropolitan Isotope General Research Institute	1996	2001	8971	Daiichi Seed Co., Ltd.	Sepal color: pinkish white	3186	

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Showy baby's breath		*Gypsophyla elegans* M. Bieb.										
1	Kishu Kasumi 1 Gou	Perfecta	1989	Meristem culture	Wakayama Research Center of Agriculture, Forestry and Fisheries	1994	2000	7762	Wakayama Research Center of Agriculture, Forestry and Fisheries	More wax on the leaf surface; top of the petal, V-shape	3220	Miyamoto *et al*. (2003)[30)]
2	Buranka	Diamond	1993	Gamma ray	Tokyo Metropolitan Isotope General Research Institute	1997	2002	9667	Miyoshi Co.	Sepal shape	3165	
3	Ayami	Bristle Fairy	1993	Colchicine	Sumitomo Chemical company	1993	1999	7094	Sumitomo Chemical Company	Shorter internode length; more petal number	3166	
Gymnaster		*Aster savatieri* Makino										
1	Seto-no-otome	Hama-otome	1991	Gamma ray irradiation to meristem culture	IRB	1994	1998	6896	Minoru Industrial Co., Ltd.	More ligulose flowers; deep flower color	3167	
2	Minoru-otome	Hama-otome	1990	Gamma ray	IRB	1995	2000	7831	Minoru Industrial Co., Ltd.	Flower shape; flower color: bright reddish purple	3168	
Prairie gentian		*Eustoma grandiflorum* (Raf.) Shinners										
1	Purple Robin	Pastel Murasaki	1992	Gamma ray	IRB	1995	1999	7266	IRB and Naganoken Nourin	Small-flowered; spray type	2004	
2	Red Robin	Morugen Rhoto	1992	Gamma ray	IRB	1995	1999	7267	IRB and Naganoken Nourin	Small-flowered; spray type	2006	
3	Tokyo E1 gou	Crystal Yellow		Gamma ray	Tokyo Metropolitan Agriculture and Forestry Research Center	2011	2015	24321	Tokyo Metropolitan Agriculture and Forestry Research Center			Miyashita *et al*. (2014)[31)]
4	Izu-Ohshima E3 gou	Tenryu Otome		Gamma ray	Tokyo Metropolitan Agriculture and Forestry Research Center	2005	2009	18330	Tokyo Metropolitan Agriculture and Forestry Research Center			Miyashita *et al*. (2014)[31)]
Carnation		*Dianthus caryophyllus* L.										
1	Scarlet Bell	Angel	1977	Gamma ray 31kR	Tokyo Metropolitan Isotope General Research Institute	1980	1983	379	Miyoshi Co.	Flower color: from deep pink to red	53	
2	Mrs. Elegant	SP	1996	Tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	1997	2001	9247	Plant Laboratory, Kirin Brewery Co., Ltd.	Small flowered; smaller number of flowers per flower stalk	2498	
3	Boh-red	Nora	1995	Meristem culture	Akita Prefectural Agriculture, Forestry and Fisheries	1998	2002	10550	Akita Prefectural Agriculture, Forestry and Fisheries	Flower color: vivid red	2499	

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4	Kirikami Red (Mrs. Red)	Mrs. Elegant	1997	Tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	1999	2002	10926	Plant Laboratory, Kirin Brewery Co., Ltd.	Surface of flower: deep orange red	2500	
5	Garden Spice carnation Salmon (Kirinade Salmon)	Garden Spice carnation Cool Pink	1998	X-ray to tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	1999	2004	12103	Plant Laboratory, Kirin Brewery Co., Ltd.	Flower surface: vivid pink	3169	
6	Garden Spice carnation Pink (Kirinade Cool Pink)	Garden Spice carnation Cool Pink	1998	X-ray to tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	1999	2004	12103	Plant Laboratory, Kirin Brewery Co., Ltd.	Flower color: pale pink	2502	
7	Your Red	Nora	1995	Meristem culture	Akita Prefectural Agriculture, Forestry and Fisheries	2000	2005	13051	Akita Prefectural Agriculture, Forestry and Fisheries	Flower color: vivid red; suspended flower; large flower	2503	Arai (2001)[1)]
8	Garden Spice carnation Marble (Kirinade Marble)	Garden Spice carnation pearl White	1995	X-ray to tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	2000	2005	13052	Plant Laboratory, Kirin Brewery Co., Ltd.	Flower color: pinkish white with vivid purple red stripe	2504	
9	Misty Pink Vital Ion	Vital	2000	C ion beam on regenerating callus	JAEA, Takasaki	2002	2005	13585	Plant Laboratory, Kirin Brewery Co., Ltd.	Flower color; petal shape	2505	
10	Dark Pink Vital Ion	Vital	2000	C ion beam on regenerating callus	JAEA, Takasaki	2002	2005	13586	Plant Laboratory, Kirin Brewery Co., Ltd.	Flower color; petal shape	2506	
11	Red Vital Ion	Vital	2000	C ion beam on regenerating callus	JAEA, Takasaki	2002	2005	13587	Plant Laboratory, Kirin Brewery Co., Ltd.	Flower color: bright red	2507	
12	Red Vital	Vital	2001	C ion beam on the leaf	JAEA, Takasaki	2004	2008	16064	Barbre & Branc S. A	Double flower with bright red color		
13	Beam Cherry	Vital		C ion beam on the leaf	JAEA, Takasaki		2009	17297	Barbre & Branc S. A	Flower color		Okamura *et al*. (2006)[39)]
14	Loro Red	Loro		Gamma ray	IRB	2007	2010	19121	Miyazaki Prefecture	Early flowering; flower color		http://www.pref.miyazaki.lg.jp/contents/org/nosei/mae-station/topics/21.html
15	Loro Pink	Loro		Gamma ray	IRB	2007	2010	19122	Miyazaki Prefecture			http://www.pref.miyazaki.lg.jp/contents/org/nosei/mae-station/topics/21.html
Clematis		*Clematis* L.										
1	Pastorale	Hakuba	1986	Gamma ray 2kR	IRB	1989	1992	3130	Mr. Fukutarou MIYATA	Flower color; flower shape	3170	
2	Nachtmusik	Hakuba	1986	Gamma ray 2kR	IRB	1989	1992	3131	Mr. Fukutarou MIYATA	Flower color; flower shape (double flowered)	3171	

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Chrysanthemum		*Chrysanthemum* x *morifolium* Ramat.										
1	Ki-uzushio	Uzushio	1962	Gamma ray 2.5kR	IRB	1983	1986	1044	Seikoen Ltd.	Flower color: from white to yellow	1987	
2	Baiogiku Rainbow White	Seikou-no-kurenai	1983	Gamma ray	IRB	1985			Seikoen Ltd.	Flower color: from red to white	1991	
3	Baiogiku Rainbow Yellow	Seikou-no-kurenai	1983	Gamma ray	IRB	1985			Seikoen Ltd.	Flower color: from red to yellow	1993	
4	Baiogiku Rainbow Peach	Seikou-no-kurenai	1983	Gamma ray	IRB	1985			Seikoen Ltd.	Flower color: from red to rose color	1988	
5	Baiogiku Rainbow Pink	Seikou-no-kurenai	1983	Gamma ray	IRB	1985			Seikoen Ltd.	Flower color: from red to pink	1990	
6	Baiogiku Rainbow Orange	Seikou-no-kurenai	1983	Gamma ray	IRB	1985			Seikoen Ltd.	Flower color: from red to reddish yellow	1989	
7	Pink Orizuru	Orizuru	1986	Gamma ray	IRB	1988	1990	2537	Seikoen Ltd.	Flower color: from white to pink	1997	
8	Hae-no-hatsu-yuki	Taihei	1987	Gamma ray to tissue culture	IRB	1990	1995	4305	IRB and Okinawa PAES	Flower color: yellowish white	2508	
9	Hae-no-kirameki	Taihei	1987	Gamma ray to tissue culture	IRB	1990	1995	4306	IRB and Okinawa PAES	Flower color: yellowish orange	2512	
10	Hae-no-kurenai	Taihei	1987	Gamma ray to tissue culture	IRB	1990	1995	4307	IRB and Okinawa PAES	Flower color: purple pink	2509	
11	Hae-no-miyarabi	Taihei	1987	Gamma ray to tissue culture	IRB	1990	1995	4308	IRB and Okinawa PAES	Flower color: pale yellowish pink	2513	
12	Hae-no-yuugure	Taihei	1987	Gamma ray to tissue culture	IRB	1990	1995	4309	IRB and Okinawa PAES	Flower color: pink	2514	
13	Hae-no-kagayaki	Taihei	1987	Gamma ray to tissue culture	IRB	1990	1995	4310	IRB and Okinawa PAES	Flower color: bright yellow	2515	
14	Iero Sei Roza (Reagan Yellow)	Sei Roza	1989	Gamma ray 2kR	IRB	1992	1997	5398	Seikoen Ltd.	Flower color: bright greenish yellow	2516	
15	Orenji Sei Roza (Reagan Orange)	Sei Roza	1989	Gamma ray 2kR	IRB	1992	1997	5399	Seikoen Ltd.	Flower color: orange	2517	
16	Dipu Sei Roza (Reagan Royal)	Sei Roza	1989	Gamma ray 2kR	IRB	1992	1997	5400	Seikoen Ltd.	Flower color: deep purplish pink	2718	
17	Paru Sei Roza (Reagan Pearl)	Sei Roza	1989	Gamma ray 2kR	IRB	1992	1997	5401	Seikoen Ltd.	Flower color: vivid purplish pink	2519	
18	Howaito Sei Roza (Reagan White)	Sei Roza	1989	Gamma ray 2kR	IRB	1992	1997	5402	Seikoen Ltd.	Flower color: yellowish white	2520	
19	Yellow Prism	Goldstock Bar	1991	Gamma ray to tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	1997	1997	5874	Plant Laboratory, Kirin Brewery Co., Ltd.	Erect flower petal; petal color: bright yellow	2521	

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20	Pearl Prism	Goldstock	1992	Tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	1993	1997	5875	Plant Laboratory, Kirin Brewery Co., Ltd.	Erect flower petal; more transparent petal	2522	
21	Amazon	Bred line	1992	Gamma ray to tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	1998	1998	6167	Plant Laboratory, Kirin Brewery Co., Ltd.	Petal color: deep orange red	2523	
22	Joy Light	Bred line	1992	Gamma ray	IRB	1998	1998	6218	ZEN-NOH		2524	
23	Joy Coral	Bred line	1992	Gamma ray	IRB	1998	1998	6219	ZEN-NOH		2525	
24	Joy Royal	Bred line	1993	Gamma ray	IRB	1998	1998	6220	ZEN-NOH		2526	
25	Joy Apricot	Bred line	1993	Gamma ray	IRB	1998	1998	6221	ZEN-NOH		2527	
26	Royal Wedding Seruengi	Goldstock Rose	1992	Tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	1998	1998	6638	Plant Laboratory, Kirin Brewery Co., Ltd.	Flower color: deep purple pink	2528	
27	Joy Light Yellow	Joy Light Salmon	1994	Gamma ray	IRB	1994	1999	7096	ZEN-NOH	Flower color: pale yellow	2529	
28	White Lineker OW-1	Goldstock Lineker	1995	X ray to tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	2000	1998	8318	Plant Laboratory, Kirin Brewery Co., Ltd.	Flower color: white	2530	
29	Jey Prelude Apricot	Joy prelude Pink	1995	Gamma ray	IRB	1996	2000	8477	ZEN-NOH		2531	
30	Joy Prelude Coral	Joy prelude Pink	1995	Gamma ray	IRB	1996	2000	8479	ZEN-NOH		2532	
31	Etenraku	Kotobuki	1992	Tissue culture	Yamagata Prefectural Horticulture Experiment Station	1997	2001	8867	Yamagata Prefectural Horticulture Experiment Station	Shorter stem	2533	
32	Pretty Wedding	Royal Wedding	1996	X ray to tissue culture	Plant Laboratory, Kirin Brewery Co., Ltd.	2001	2001	8878	Plant Laboratory, Kirin Brewery Co., Ltd.	Flower color (bi-color; outside: pink; inside: white)	2534	
33	Remukoiero (Remco Yellow)	Remco	1995	Radiation	Kinki University	1998	2001	9570	Seikoen ltd.		2535	
34	Ray Sunrise	Erias	1991	Soft X ray	Shizuoka PAES	1997	2002	10538	Shizuoka PAES	Petal color (abaxial: orange; adaxial: yellow)	2536	Yamada *et al*. (1999)[54)]
35	Dreaming	Dream Nurse	1993	Soft X ray 200Gy	Shizuoka PAES	2000	2004	12420	Shizuoka PAES	Flower color: from white to yellow	2537	Yamada *et al.* (2002)[55)]
36	Princess Kagawa	Pink Seiko	1997	Tissue culture + X ray	Kagawa PAES	2001	2004	12415	Kagawa PAES	Stem color and petal color: reddish purple	2538	Furuichi *et al*. (2003)[4)]
37	Emi-akari	Sei-un	1997	Soft X ray irradiation to meristem culture	Aomori Prefectural Agriculture and Forestry Research Center	2003	2006	14099	Aomori Prefectural Agriculture and Forestry Research Center	Ligulate petal color: pale greenish yellow		

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38	Arajin (Araddin)	Jimba	2001	Ion beam irradiation to leaf	JAEA, Takasaki	2003	2006	14118	Kagoshima PAES	Reduction of axillary bud number (Farmers do not need to cut many axillary bud to produce one large flower)	2540	Imakiire *et al*. (2006)[13)]
39	Imajin (Imagine)	Jimba		Ion beam irradiation to leaf	JAEA, Takasaki	2003	2006	14119	Kagoshima PAES	Reduction of axillary bud number (Farmers do not need to cut many axillary bud to produce one large flower)	2541	Imakiire *et al*. (2005)[13)]
40	Hae-no-eikou	Taihei		Tissue culture of flower petals from plants irradiated in the Gamma Field were regenerated	IRB	2002	2006	14563	IRB	Petal color	3409	
41	Hae-no-myojyo	Taihei		Tissue culture of flower petals from plants irradiated in the Gamma Field were regenerated	IRB	2002	2006	14564	IRB	Petal color	3416	
42	Hae-no-yumeguruma	Taihei		Tissue culture of flower buds from plants irradiated in the Gamma Field were regenerated	IRB	2002	2006	14565	IRB	Petal shape and color	3417	
43	Hae-no-awabeni	Taihei		Callus generated from leaves was irradiated with gamma ray	IRB	2002	2006	14566	IRB	Petal color	3418	
44	Ion-no-koumyo	Taihei		Callus generated from petals was irradiated with a carbon ion beam	JAEA, Takasaki	2002	2006	14567	IRB and JAEA, Takasaki	Petal color	3395	
45	Ion-no-seikou	Taihei		Callus generated from petals was irradiated with a carbon ion beam	JAEA, Takasaki	2002	2006	14568	IRB and JAEA, Takasaki	Petal color	3396	
46	Ion-no-hatsune	Taihei		Callus generated from petals was irradiated with a carbon ion beam	JAEA, Takasaki	2002	2006	14569	IRB and JAEA, Takasaki	Petal color	3398	

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47	Ion-no-kouki	Taihei		Callus generated from petals was irradiated with a carbon ion beam	JAEA, Takasaki	2002	2006	14570	IRB and JAEA, Takasaki	Petal color	3399	
48	Ion-no-mahou	Taihei		Callus generated from petals was irradiated with a neon ion beam	JAEA, Takasaki	2002	2006	14571	IRB and JAEA, Takasaki	Petal color	3400	
49	Sei-faust-cream	Sei-faust		Gamma ray	IRB	2007	2010	19333	Seikoen Ltd.	Petal color: 155A		
50	Sei-piaje-white	Piaje		Gamma ray	IRB	2007	2010	19185	Seikoen Ltd.	Petal shape		
51	Sei-piaje-pink	Piaje		Gamma ray	IRB	2007	2010	19186	Seikoen Ltd.	Petal color: 187C		
52	Sei-piaje-yellow	Piaje		Gamma ray	IRB	2007	2010	19187	Seikoen Ltd.	Petal color: 9A		
53	Sei-rocket-yellow	A developed line		Gamma ray	IRB	2007	2010	19335	Seikoen Ltd.	Flower disc color: 144B		
54	Sei-patrick-yellow	Sei-patrick		Gamma ray	IRB	2007	2010	19336	Seikoen Ltd.	Flower color (182A); shape (flower disc is smaller)		
55	Sei-patrick-sermon	Sei-patrick		Gamma ray	IRB	2007	2010	19337	Seikoen Ltd.	Flower color: 49D		
56	Sei-roys-yellow	Sei-bingo		Gamma ray	IRB	2007	2010	19003	Seikoen Ltd.	Flower color: 4A		
57	Arajin 2 (Aladdin 2)	Arajin		Ion beam	JAEA, Takasaki	2007	2010	19096	Kagoshima PAES	Fewer flower buds		Ueno *et al*. (2013)[53)]
58	Lemon smile	Egao		Soft X-ray	Aomori Prefectural Agriculture and Forestry Research Center	2011	2013	22281	Aomori Prefectural Agriculture and Forestry Research Center and Seikoen Ltd.	Flower color (cream)		
59	Akebono-no-mai	Taihou-senryu		Soft X-ray irradiation to shoot-apex culture	Aomori Prefectural Agriculture and Forestry Research Center	2014	2016	24889	Aomori Prefectural Agriculture and Forestry Research Center and Seikoen Ltd.			
60	Akane-no-mai	Taihou-senryu		Soft X-ray irradiation to shoot-apex culture	Aomori Prefectural Agriculture and Forestry Research Center	2014	2016	24890	Aomori Prefectural Agriculture and Forestry Research Center and Seikoen Ltd.			
Lily		*Lilium* L.										
1	Rosetone	Rohto-horun	1987	Gamma ray	Tokyo Metropolitan Isotope General Research Institute	1992	1998	6608	Hanano-Yamato Co.	Leaf shape: ellipse	3172	

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2	Light Memory	Rohto-horun	1987	Gamma ray	Tokyo Metropolitan Isotope General Research Institute	1992	1998	6609	Hanano-Yamato Co.	Petal color: pale pink; deep purple stripe in the center rib of petal	3173	
3	Ivory Memory	Rohto-horun	1988	Gamma ray to tissue culture	Tokyo Metropolitan Isotope General Research Institute	1993	1998	6610	Hanano-Yamato Co.	Petal color: pale orange yellow	3174	
4	Coral Bouquet	Rohto-horun	1987	Gamma ray	Tokyo Metropolitan Isotope General Research Institute	1993	1999	7544	Hanano-Yamato Co.	No pollen production; smaller stem, umbel	3175	
Cymbidium		*Cymbidium* Sw.										
1	Cocktail Dress	Inasa	1987	Tissue culture (mericlone)	Purchase	1992	1997	5707	Mr. Makoto MATSUO	Color and shape of petal	3221	
Kalanchoe		*Kalanchoe* Adans.										
1	Harvest Moon	*K. miniata/K. polyphyloukaricus*	1985	Gamma ray	IRB	1992	1996	5148	Mr. Isao KOBAYASHI	Flower shape	2542	
Caladium		*Caladium* Vent.										
1	Soyogi	Candydam	1991	X ray	Kagoshima PAES	1993	2000	8250	Kagoshima PAES		3176	
Petunia		*Petunia* Juss.										
1	Kirimaji Cherry Red (Cherry Red Wave)	Kirimaji (Purple Wave)	1998	X-ray to protoplast culture	Plant Laboratory, Kirin Brewery Co., Ltd.	2000	2004	12082	Plant Laboratory, Kirin Brewery Co., Ltd.	Monotone flower color: vivid red	3177	
2	Sun-lobein	Revolution brilliant pink		Heavy ion beam irradiation to callus developed from axillary buds	Riken	2001	2006	13913	Suntory Flowers ltd and Keisei Rose Co.	Flower color: JHS color chart 9507		
3	Seto-fuku-white-bariegata	A developed line		Ion beam	The Wakasawan Energy Research Center	2007	2009	17653	Hakusan International Co. and The Wakasawan Energy Research Center	Flower color and plant type		
4	Hamapetu 3 gou	Calen Beach		X-ray	Shizuoka PAES	2007	2010	18926	The Yokohama nursery Co.	Flower color: 76C		
5	Sunsurfsirou	An original line		Radiation		2007	2014	23217	Suntory Flowers Ltd.			
Begonia		*Begonia* L.										
1	Ryoku-ha	Winter Queen	1966	Gamma ray 10kR	Tokyo Metropolitan Isotope General Research Institute	1976	-	-	Tokyo Metropolitan Industrial Technology Research Institute	Leaf color; variation in leaf spot; higher ozone/oxidant sensitivity	1985	

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2	Ginsei	Winter Queen	1966	Gamma ray 10kR	Tokyo Metropolitan Isotope General Research Institute	1976	-	-	Tokyo Metropolitan Industrial Technology Research Institute	Leaf color; variation in leaf spot	1981	
3	Orange Iron	Iron Cross	1971	Gamma ray 0.5kR	Tokyo Metropolitan Isotope General Research Institute	1976	-	-	Tokyo Metropolitan Industrial Technology Research Institute	Leaf color; leaf shape; brown purple iron-cruciate leaf spot	1984	
4	Mini-mini Iron	Iron Cross	1971	Gamma ray 1kR	Tokyo Metropolitan Isotope General Research Institute	1976	-	-	Tokyo Metropolitan Industrial Technology Research Institute	Dwarf; leaf spot; leaf shape	1983	
5	Big Cross	Iron Cross	1971	Gamma ray 3kR	Tokyo Metropolitan Isotope General Research Institute	1976	-	-	Tokyo Metropolitan Industrial Technology Research Institute	Leaf color; variation in leaf spot; larger iron-cruciate spot	1980	
6	Kaede Ion	Iron Cross	1972	Gamma ray 10kR	Tokyo Metropolitan Isotope General Research Institute	1976	-	-	Tokyo Metropolitan Industrial Technology Research Institute	Leaf shape; variation in leaf spot; reddish brown maple leaf shaped spot	1982	
Regal pelargonium		*Pelargonium* L'Her. ex Ait.										
1	Capri Ice	Strawberry Thunder	1976	Petal culture	Ehime University	1985	1988	1096	Daiichi Seed Co., Ltd.		3222	
2	Capri Lullaby	Strawberry Thunder	1976	Anther culture	Ehime University	1985	1986	1098	Daiichi Seed Co., Ltd.		3223	
Sonerila picta		*Sonerila* Roxb.										
1	Splash	Sonerila picta korth	1995	Chemical	Kansai TEC Co.	1997	2003	11451	Kansai TEC Co.	More spot on leaves	3178	
Glossy abelia		*Abelia* R. Br.										
1	Meihan Hane-tsukubane-utsugi	Hana-tsukubane-utsugi	1972	Gamma ray 3kR	Tokyo Metropolitan Isotope General Research Institute	1976	-	-	Tokyo Metropolitan Industrial Technology Research Institute	Leaf spot; slightly dwarf	1978	
Japanese azalea		*Rhododendron indicum* (L.) Sweet										
1	Cobalt	Takasago	1964	Gamma ray 5kR	National Institute of Agricultural Sciences (Hiratsuka)	1972	-	-	Tochigi PAES	More branching; dwarf (useful for bonsai)	1986	
Rose		*Rosa* L.										
1	Bridal Sonia	Sonia	1979	Gamma ray to plant 15kR	IRB	1982	1985	801	Kanagawa Prefectural Horticulture Experiment Station	Flower color: from salmon to pale pink	1994	
2	San Jol	Santa Monica	1985	Gamma ray	IRB	1987	1990	2264	Mr. Yuitsu MIZUTANI	Flower color: vivid purple pink	2543	

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
3	Ohmiya-bito	Queen Elizabeth	1964	Gamma ray	IRB	1976	1990	2384	Keisei Rose Nurseries, Inc.	Flower color: from pink to pinkish white	1996	
4	Miss Ohmiya	Queen Elizabeth	1964	Gamma ray	IRB	1976	1990	2385	Keisei Rose Nurseries, Inc.	Flower color: from pink to vivid pink	1995	
5	Banbina	Green Eyes	1987	Chemical	KYOWA	1989	1995	4274	KYOWA	Flower color: pale pink	2544	
6	Ichi-anda	Asami Red	1983	Chemical	Mishima-shi	1996	2000	8349	Mr. Keiichi ICHIKAWA	Small leaf; thread type	2545	
7	Ichi-runa	Aarus Mail Goal	1994	Chemical	Mishima-shi	1996	2000	8350	Mr. Keiichi ICHIKAWA	Flower color and shape	2546	
8	Ichi-jiru	Ichity	1994	Gamma ray	Tokyo Metropolitan Isotope General Research Institute	1997	2001	8704	Mr. Keiichi ICHIKAWA	Flower color and shape	2547	
9	Hitachi Smile	Samantha	1990	Gamma ray	IRB	2002	2007	15714	IRB and Okinawa Prefecture	Flower color and shape		
10	Hitachi Poeny	Samantha	1990	Gamma ray	IRB	2002	2007	15715	IRB and Okinawa Prefecture	Flower color and shape		
Oncidium		*Oncidium* Group										
1	Gold One	Gower Ramsey	1986	Mericlone culture	Mr. Masayoshi SHIMOKAWA	1992	1995	4463	Mr. Masayoshi SHIMOKAWA	Flower color		
2	Sherley Baby White Flush Rika	Sherley Baby Sweet Fragrance	1988	Mericlone culture	Mr. Saneharu MATSUMOTO	1990	1997	5601	Mr. Saneharu MATSUMOTO	Flower color		
Salvia		*Salvia splendens* Ker Gawl.										
1	Magunasu Cherry	Cherry Sage	2001	Colchicine	Toyota Motor Cooperation	2003	2006	14059	Toyota Motor Cooperation	Larger petal		
2	TL585	Lady In red		Ion beam irradiation to seed	JAEA, Takasaki	2012	2015	24473	Takii & Co, Ltd.	Shorter stem		
Delphinium (larkspur)			*Delphinium* L.									
1	Star Dust	Bluecloud	1996	Colchicine	Toyama City Agriculture Center	1996	2001	8746	Toyama City Agriculture Center	Larger petal; leaf shape		
2	Sunny Sky	Plage Sky Blue	1988	Tissue culture	Kaneko Seeds	2000	2005	12735	Kaneko Seeds	Shorter plant; shorter inflorescence		
Torenia (wishbone flower)			*Torenia* L.									
1	San-reniramu	San-renimu	1998	Colchicine chromosome doubling	Suntory Flowers Ltd.	1999	2004	12092	Suntory Flowers Ltd.	Plant type: stoloniferous; flower color	3187	
2	San-renirahopasu	San-renihopasu	1998	Colchicine chromosome doubling	Suntory Flowers Ltd.	1999	2004	12093	Suntory Flowers Ltd.	Flower color of labium: uniformly colored	3188	

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
3	San-reniraba	San-renireba	1999	Colchicine chromosome doubling	Suntory Flowers Ltd.	2000	2005	12993	Suntory Flowers Ltd.	Flower color of labium: uniformly colored	3189	
4	Sunreniripin	A developed line		Ion beam	Riken (Wako)	2007	2010	19301	Suntory Flowers Ltd.	Petal color: 72B		
5	Sunreniripihokai	Sunrenipiho		Colchicine	Suntory Flowers Ltd.	2003	2013	22609	Suntory Flowers Ltd.	Earlier flowering		
6	Sunrekodou	A developed line		Heavy ion beam	Riken (Wako)	2011	2013	22611	Suntory Flowers Ltd.	Petal color: 8B		
Margaret		Argyranthemum *frutescens* (L.) Sch. Bip.										
1	Star Light Ripple	Zairai-shiro	1998	Soft X-ray to immature ovary culture	Shizuoka PAES	2002	2005	12779	Shizuoka PAES	Shorter plant type; larger stock		
2	Angel Maisu	not written	2002	Soft X ray to cuttings	Shizuoka PAES	2003	2006	14146	Shizuoka PAES	Flower color		
3	Southern Venus White	An original line	2002	Soft X ray to plants	Shizuoka PAES	2005	2007	14971	Shizuoka PAES			
4	Canary Queen	Peach Queen	2003	Soft X ray to plants	Shizuoka PAES	2005	2007	14992	Shizuoka PAES	Ligulate flower color change		http://www.geocities.jp/yunakisaragi/x-ma-garetto-kanariakuiin.html (in Japanese)
Lavender		*Lavandula angustifolia* Mill.										
1	Cosmic Blue	Yuulong	1998	Tissue culture of leaf	Kyoto Prefectural University	2001	2006	14044	SAKATA SEED CORPORATION	Plant type: spreading; color of calyx: deep purple; more flowers in the inflorescence		
Cytisus (Scotch broom)			*Cytisus scoparius* (L.) Link									
1	Mei Shower	Crimson King	1990	Gamma ray to tissue culture	IRB	1993	1998	7027	IRB and Meiji Seika Kaisha, Ltd.	Extremely short plant; flower color: vivid yellow	3190	
2	Mei Wako	Crimson King	1990	Gamma ray to embryo culture	IRB	1993	1998	7028	IRB and Meiji Seika Kaisha, Ltd.	Extremely short plant; flower color: ground color: pale yellow; brown, deep purple pink	3191	
3	Mei Rose	Crimson King	1990	Gamma ray to embryo culture	IRB	1993	1998	7029	IRB and Meiji Seika Kaisha, Ltd.	Medium plant height; flower color: ground color: pale greenish yellow, brown purple pink	3192	
4	Mei Eve	Crimson King	1990	Gamma ray to embryo culture	IRB	1994	1998	7030	IRB and Meiji Seika Kaisha, Ltd.	Extremely short plant; flower color: ground color: pinkish white, brown reddish purple	3193	

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
5	Mei Hiro	Crimson King	1990	Gamma ray to embryo culture	IRB	1993	2002	10948	IRB and Meiji Seika Kaisha, Ltd.	Outer standard ground color: rainbow; outer wing color: deep reddish brown	3194	
6	Mei Samson	Park Woody	1990	Gamma ray	IRB	1993	2002	10949	IRB and Meiji Seika Kaisha, Ltd.	Outer wing color: several colors; small wing	3195	
7	Mei Fanny	Crimson King	1990	Gamma ray to embryo culture	IRB	1997	2002	10950	IRB and Meiji Seika Kaisha, Ltd.	Outer standard and wing ground color: deep red	3196	
8	Mei Lord	Crimson King	1990	Gamma ray to embryo culture	IRB	1997	2002	10951	IRB and Meiji Seika Kaisha, Ltd.	Outer keel color: brown; wide keel	3197	
Abelmoschus		*Abelmoschus manihot* Medik										
1	Hiroshima Local No. 1	Hiroshima Zairai	1956	Gamma ray 0.5kR	Kyoto University	1967	―	―	Kagawa University	Higher resistance to phytophthora rot	341	
2	Hiroshima Local No. 3	Hiroshima Zairai	1956	Gamma ray 0.5kR	Kyoto University	1967	―	―	Kagawa University	Higher resistance to phytophthora rot	342	
3	Hiroshima Local No. 5	Hiroshima Zairai	1956	Gamma ray 0.5kR	Kyoto University	1967	―	―	Kagawa University	Higher resistance to phytophthora rot	343	
4	Hiroshima Local No. 8	Hiroshima Zairai	1956	Gamma ray 0.5kR	Kyoto University	1967	―	―	Kagawa University	Higher resistance to phytophthora rot	344	
Hibiscus (common rose mallow)			*Hibiscus moscheutos* L.									
1	Shirasagi-no-yume	Sakai-no-hana	1981	Gamma ray 30kR	Osaka Prefectural Radiation Research Center (now Osaka Prefectural University)	1987	1987	1311	Osaka Prefectural Radiation Research Center (now Osaka Prefectural University)	Flower color: pinkish white-vivid purple pink with purple red stripe	1979	
Gentiana		*Gentiana* L.										
1	Miyama Love	Sasa-rindou		Colchicine treatment	Sky Blue Seto Co.	2001	2005	13126	Sky Blue Seto Co.	Late maturing		
2	Shinano Love	Ezo-rindou		Colchicine treatment and hybridization between chromosome-doubled plants	Sky Blue Seto Co.	2001	2005	13128	Sky Blue Seto Co.	Chromosome doubling (tetraploid)		
Verbena		*Verbena* L.										
1	San-mariko-rabi	San-mariribi	1998	Ion beam	Riken (Wako)	2001	2005	12999	Suntory Flowers Ltd.	Flower color: vivid purple; eye-shaped spot on the petal		
2	San-mari-sakura	San-marisa		Radiation	No description	2003	2011	20462	Suntory Flowers Ltd.	Plant type		

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
3	San-mari-peach	A developed line		Heavy nitrogen ion beam irradiation to flower buds	Riken (Wako)	2006	2008	16854	Suntory Flowers Ltd.	Flower color and shape		
Osteospermum		*Osteospermum* L.										
1	Viento Flamingo	Mother Symphony		Ion beam	JAEA, Takasaki	2007	2009	18549	JAEA and Hanasekiguchi Co.	Petal color: 29D		Iizuka *et al* . (2011)[12)]
2	Viento Labios	Viento Flamingo		Radiation	JAEA, Takasaki	2011	2016	24758	JAEA and Hanasekiguchi Co.			
Bidens		*Bidens* L.										
1	San-bideki	Bidens triplinervia	1997	Colchicine	Suntory Flowers Ltd.	2001	2004	12262	Suntory Flowers Ltd.	Ever-flowering		
Gardenia		*Gardenia jasminoides* J. Ellis										
1	Vald	A domestic line		Colchicine treatment to seeds	Toyota Motor Corporation		2005	13621	Toyota Motor Corporation	Leaf shape		
Asian melastoma		*Melastoma* L.										
1	Pink Pearl	Belgra	1996	Gamma ray irradiation to callus	GIFUSEED Co. Ltd.		2005	13519	GIFUSEED Co. Ltd.	Pattern of leaf surface		
Morning glory		*Ipomoea indica* (Burm.) Merr.										
1	IRBIi Light Blue	Capetown Blue		Chronic gamma ray irradiation in the Gamma Field	IRB, NIAS	2012	2015	24599	IRB, NIAS, Fukukaen Nursery & Bulb Co., Ltd.	Flower color: 98B		
Italian ryegrass		*Lolium multiflorum* Lam. ssp. *italicum* (A. Br.) Volkart										
1	Miyuki-aoba	Taka-kei No. 4		Maternal selection after colchicine treatment	Hokuriku NAES	1983	1984	649	Hokuriku NAES	Larger leaf	2548	
Japanese lawngrass		*Zoysia* Willd.										
1	Winter Carpet	Tsukuba-kei	1990	Gamma ray	IRB	1992	1995	4299	IRB and Sumitomo Metal Industries, ltd.	Earlier green color of leaf	3201	
2	Winter Field	Tsukuba-kei (*Z. Matrella; manilagrass*)	1990	Chronic gamma ray irradiation (Gamma field)	IRB	1994	1996	5254	IRB and Sumitomo Metal Industries, ltd.	Better stolon vigor; narrower and shorter leaf	3202	

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
3	Kopurosu	Tottori-kourai	1995	X ray to meristem culture	Yamaguchi PAES	1998	2002	10638	Kaisui Chemical Industry Co.	Better spring vigor; earlier green color of leaf; no browning in winter	3203	
4	Tee Emu 9	*Z. matrella* ecotype	2000	Soft X-ray irradiation to the seeds	Toyota Motor Corporation	2003	2006	14320	Toyota Motor Corporation	More flower heads; earlier browning in autumn		
5	Shiba Noh Pl 1	Ecotype		Tissue culture of seeds and regeneration from callus	NARO, National Institute of Livestock and Grassland Science	2007	2009	18204	NARO	Thicker turf development		
Creeping bentgrass		*Agrostis stolonifera* L.										
1	Springs	Penncross	1970	Gamma ray	Kyushu University	1982	1983	469	Nihon Ryokuei Co.	Resistance to summer heat	293	
2	Chiba Green B-2	Penncross	1991	Soft X ray to seedling	Chiba PAES	1996	1997	5439	Chiba PAES	Resistant to brown patch disease	2549	
3	My Comfort	Penncross	1992	Tissue culture	Chiba PAES	1996	2001	9043	Maekawa MFG Co.	Taller plant	2550	
Guineagrass		*Panicum maximum* Jacq.										
1	guineagrass Noh PL 1 (Nekken No. 1)	GR297		Colchicine	Coastal Plain Experiment Station, Tifton, USDA, GA, USA	1990	1993	3708	Tropical Agriculture Research Center (Now JIRCAS)	Chromosome doubling; shorter plant		Nakagawa *et al*. (1992)[32)]
Red clover		*Trifolium pratense* L.										
1	Taisetsu	Sapporo		Colchicine	Hokkaido NAES		1991	2934	Hokkaido NAES	Chromosome doubling; larger leaf	3205	
Apple		*Malus pumila* Mills.										
1	Mori-hou-fu 3A	Fuji	1963	Gamma ray 3kR to scion	IRB	1963			IRB	Resistance to disease	2551	
2	Houiku Indo	Indo	1992	Gamma ray irradiation to meristem culture	IRB	2003	2007	15022	IRB	Resistant to Alternaria disease		
Japanese pear		*Pyrus pyrifolia* (Burm. f.) Nakai var. *culta* (Mak.) Nakai										
1	Gold Nijisseiki	Nijisseiki	1962～8	Chronic irradiation (53m from center of source in Gamma Field)	IRB	1990	1991	2932	IRB	Resistance to black spot disease	278	Sanada *et al*. (1993)[45)]
2	Kotobuki Sinsui	Sinsui	1989	Gamma ray 80Gy to scion	IRB	1996	1997	5436	IRB and Tottori Prefectural Horticulture Experiment Station	Resistance to black spot disease	279	Kitagawa, K. *et al*. (1999)[25)]

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
3	Osa Gold	Osa-nijisseiki	1986～9	Chronic irradiation (40m from center of source in Gamma Field)	IRB	1995	1997	5620	IRB and Tottori Prefectural Horticulture Experiment Station	Resistance to black spot disease	2552	Masuda *et al*. (1998)[28]
Peach		*Prunus persica* (L.) Batsch										
1	Fuku-ekubo	Akatsuki	1987	Gamma ray 3kR	IRB	1994	1996	5076	Fukushima Prefectural Fruit Tree Experiment Station	Early maturing	2553	Sakuma *et al*. (1999)[44]
2	Shimizu Hakutou RS	Shimizu Hakutou	1996	Gamma ray irradiation to nursery stock	IRB	2001	2004	12302	Okayama PAES	Resistant to black spot disease	2554	Inoue *et al*. (2006)[15]
Loquat		*Eriobotrya japonica* (Thunb.) Lindl.										
1	Shiro-Mogi	Mogi		Gamma ray	IRB	1981	1982	300	Nagasaki Prefectural Fruit Tree Experiment Station		240	
Cherry		*Prunus avium* (L.) L.										
1	Super 6	Koruto	1985	Colchicine treatment to meristem culture	Tenkoen Co.	1988	1997	5374	Tenkoen Co.	Thicker branch; flower petal: round; larger leaf		
2	Roman Nishiki	Masamitsu-nishiki	1987	Colchicine treatment to buds	Mr. Masamitsu SATO	1998	2005	9929	Mr. Masamitsu SATO	Larger leaf; stickiness between seed and skin: medium sticky		
Cherry flower		*Prunus* L.										
1	Nishina-Zaou	Gioiko		Carbon ion beam	Riken (Wako)	2007	2009	17785	Riken and Shigehisa ISHII	Leaf shape and flower structure	3355	
2	Nishina-otome	Keiou Zakura		Heavy ion beam	Riken (Wako)	2009	2011	21281	Riken	Perpetual flowering		
Mulberry		*Morus* L.										
1	Lala Berry	Kataneo	1994	Colchicine treatment to axillary buds	NIAS	2000	2003	11242	NIAS	Thicker and larger leaf		
2	Pop Berry	Daitou-guwa	1994	Colchicine treatment to axillary buds	NIAS	2001	2004	12194	NIAS	Periclinal chimera; heavier fruit		
Tea		*Camellia sinensis* (L.) Kuntze										
1	Tea Noh Pl 2	Yabukita	1970-1971	Chronic irradiation in gamma field	IRB	1988	1998	6449	IRB	From self-incompatible to self-compatible; deeper leaf color		

No.	Cultivar Name	Original Cv. or Line	Treat. Year	Treatment	Treated Institution	Dev. year	Reg. Year	Reg. No.[a]	Institution of Development	Improved Characteristics	IAEA ID[b]	Reference
Cape jasmine		*Gardenia jasminoides* J. Ellis										
1	Vald	Zairai-shu	1994	Colchicine treatment to seeds	Toyota Motor Cooperation	2002	2005	13621	Toyota Motor Cooperation	Leaf shape: reverse egg-shape		
Pineapple		*A. ananasoides* (Baker) Smith										
1	Natsu-hime	*A.ananasoides* (Baker) Smith		Chronic gamma ray irradiation (Gamma Greenhouse)	IRB	2004	2005	17459	Okinawa PAES and IRB	Leaf color	3209	
Velvet shank mushroom			*Flammulina velutipes* (Fr.) Sing.									
1	Shinano-no-hana	K1	1992	Gamma ray to tissue culture	IRB	1994	1998	6559	IRB and Nagano Prefectural Agricultural Engineering Experiment Station	Albino	3227	
2	Pakinko-ajihime	wild type	1997	Gamma ray	IRB	1998	2002	10048	Bio-oriented Technology Research Advancement Institution and Nagano Prefectural Agricultural Engineering Experiment Station	Color of surface of fungus: brown	3228	
Shiitake mushroom		*Lentinus edodes* (Berk.) Sing.										
1	Susono 360-gou	Nichinou 270-gou	1979	Ultraviolet light	Nihon Norin Shukin Co.	1991	1998	6383	Nihon Norin Shukin Co.	Shape of surface of fungus: un even	3229	
Oyster mushroom		*Pleurotus ostreatus* Quel										
1	Shinrinsouken PO 1 gou	Reserved line	1983	Nitrosoguanidine treatment	Forestry and Forest Product Research Institute	1990	1993	3451	Forestry and Forest Product Research Institute	Shorter maturity period, mushroom shape		
Chinese tallow		*Sapium sebiferum* (L.) Roxb.										
1	Green honet	unknown	1997	Gamma ray 50Gy	IRB	1998	2003	11568	Gyoutoku Ryokuka Noujyou	Round spot on the leaf	3210	
Mint		*Mentha* L.										
1	Rose mint		1977	Gamma ray to cell culture						Amount of substance of flavor (20 times stronger)		

Note:

[a]Reg. No. is the registration number of The Plant Variety Protection System in Japan

[b]IAEA ID is the variety ID number of the Joint FAO/IAEA Mutant Variety Database (https://mvd.iaea.org/#!Home)

Abbreviations:

ARC: Agricultural Research center
ARI: Agricultural Research Institute
IRB: Institute of Radiation Breeding
JAEA: Japan Atomic Energy Agency
JIRCAS: Japan International Research Center for Agricultural Sciences
NAES: National Agricultural Experiment Station
NARC: National Agriculture Research Center
NARO: National Agriculture and Food Research Organization
NIAES: National Institute of Agro-environmental Sciences
NIAS: National Institute of Agrobiological Sciences
PAES: Prefectural Agriculture Experiment Station
PARC: Prefectural Agriculture Research Center

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Appendix 2. Indirect-use mutant cultivars

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
Rice		*Oryza sativa* L.									
1	Hyokei-sake 18	Yamada-nishiki	I-M106*	*Gamma ray irradiation to cv. Norin No. 8	Hyogo PAES	1972			Short and tough culm; good quality; very large seed	1125	
2	Mutsuhonami	Etsu-nan No. 39	Fu-kei No. 70 (Reimei)*	*cf. cv. Reimei (Appendix 1)	Aomori PAES, Fujisaka Branch	1973			Short and tough culm; high-yielding	1133	
3	Kagahikari	R6-1*	Fu-kei No. 72	*Gamma ray to cv. Koshihikari	Ishikawa PAES	1973			Early maturity	1126	
4	Hanahikari	stripe36/Bi-kei No. 53/Bi-kei No. 53.	Fu-kei No. 70 (Reimei)*	*cf. cv. Reimei (Appendix 1)	Yamagata PAES	1975			Short and tough culm; early maturity	1122	Kamei *et al*. (1980)[58)]
5	Houhai	Ao-kei No. 62 (Kojyou-nishiki)	Reimei*	*cf. cv. Reimei (Appendix 1)	Aomori PAES	1975			Short and tough culm; cold tolerance	1124	
6	Akihikari	Ouu No. 269 (Toyonishiki)	Reimei*	*cf. cv. Reimei (Appendix 1)	Aomori PAES, Fujisaka Branch	1976			Short and tough culm; very high-yielding	1120	Kushibuchi *et al*. (1977)[85)]
7	Hayahikari	Fu-kei No. 70 (Reimei)*	Ouu No. 269 (Toyonishiki)	*cf. cv. Reimei (Appendix 1)	Tohoku NAES	1976			Semi-dwarf; lodging resistance	1123	Hirano *et al*. (1977)[26)]
8	Nadahikari	5810-19/Hyou-kei Sake No. 18*	Tou-Kin-kei No. 1011	*cf. cv. "Hyo-kei-sake No. 18	Hyogo PAES	1977			Short culm; big seed	1136	
9	Fujihikari	R151*	Fu-kei No. 71**/No. 67/Koshihikari B1F1	*Gamma ray to cv. Koshihikari; **Gamma ray to cv. Fujiminori	Chugoku NAES				Extremely early-maturing; short culm	1121	Fujii *et al.* (1981)[11)]
10	Sachiminori	Manryou/R4B*	Yamase-nishiki	*Gamma ray to "Pi No.4"	Hokuriku NAES	1978			Slightly tough stem; resistant to rice blast (Pi-ta^2)	1140	Samoto *et al*. (1979)[141)]
11	Katsura-wase	Fu-kei No. 67×Fu-kei No. 71*	Koshihikari	*Gamma ray to the seed of cv. Fujiminori	Kagoshima PAES	1978			Early maturing; short and tough culm	1127	
12	Miyanishiki	Kanto No. 79*	Todoroki-wase	*Gamma ray (20kR) to the seed of cv. Koshihikari	Miyazaki PAES	1978			Good quality; good taste	1130	Uchiyamada *et al*. (1979)[185)]
13	Niigata-wase	Fu-kei No. 91*	Chou 60	*A descendant (the 1st generation) of cv. Reimei	Niigata PAES	1979			Short and tough culm	1137	Ichikawa *et al*. (1981)[38)]
14	Mine-asahi	Kanto No. 79*	Kihou	*Gamma ray (20kR) to the seed of cv. Koshihikari	Aichi PAES	1980	1981	100	Good taste; short culm	1128	Morimoto *et al*. (1980)[108)]
15	Musashi-kogane	Tama-kei No. 56*	Aichi No. 21	*cv. Reimei/cv. Nipponbare	Saitama PAES	1981	1982	239	Short culm; lodging resistance	1132	Shiobara *et al*. (1982)[154)]
16	Mutsu-komachi	Mutsu-nishiki	Fu-kei No. 104 (Akihikari)*	*cf. cv. Akihikari (the 1st generation of cv. Reimei)	Aomori PAES	1981	1982	241	Short culm; lodging resistance	1135	Ono *et al*. (1982)[133)]
17	Mutsu-kaori	Mutsu-nishiki	Fu-kei No. 104 (Akihikari)*	*cf. cv. Akihikari (the 1st generation of cv. Reimei)	Aomori PAES	1981	1982	242	Short culm; lodging resistance	1134	Ono *et al*. (1982)[134)]
18	Rokko-nishiki	5810-19/Hyou-kei Sake No. 18*	Tou-Kin-kei No. 1011	*cf. cv. "Hyo-kei sake No. 18"	Hyogo PAES	1981	1983	326	Large seed	1139	
19	Miyakaori	Iwaga	Ouu No. 282*	*Named as cv. Hayahikari (the 1st generation of cv. Reimei)	Miyagi PAES Furukawa Branch	1983	1984	588	Semi-dwarf	2986	Oikawa *et al*. (1991)[130)]
20	Natsuhikari	Ka-kei No. 639*	Sei-nan No. 45	* Named as "Katsura-wase" (the 3rd generation of a gamma ray induced strain "Fu-kei 71")	Kagoshima PAES	1983	1984	598	Tough stems; lodging resistance	2987	Iwashita *et al*. (1984)[49)]
21	Megumi-mochi	Aichi-mochi No. 27	Fu-kei No. 102*	*cv. Reimei/cv. Fujiminori/cv. Somewake	Aichi ARC	1983	1985	623	Short and tough culm; high-yielding	1145	Koumura *et al*. (1983)[83)]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
22	Hatsukogane	Fu-kei No. 102*	Matsumae	*cv. Reimei/cv. Fujiminori/cv. Somewake	Aomori PAES, Fujisaka Branch	1984	1985	889	Short and tough stem	1146	Shimura *et al.* (1986)[153)]
23	Okuhomare	Hyo-kei-sake No. 18*	Reimei**	*cf. cv. "Hyo-kei-sake No. 18"; **cf. cv. Reimei (Appendix 1)	Hyogo PAES	1984			Semi-dwarf	2988	
24	Ibuki-wase	Mine-asahi*	Hourei	*cf. cv. "Mine-asahi" (the 1st generation of gamma ray induced mutant line "Kanto No. 79" from cv. Koshihikari)	Aichi ARC	1985	1986	1204	Cold tolerance	1148	Akama *et al*. (1985)[2)]
25	Mutsu-homare	Todoroki-wase/Akihikari*	Fuji 329	*cf. cv. Akihikari (the 1st generation of cv. Reimei)	Aomori PAES	1985	1986	1206	Short culm; good taste	1149	Yamazaki *et al*. (1987)[210)]
26	Hanafubuki	Ao-kei No. 79 (Oku-homare)*	Fu-kei No. 103**	*cf. cv. Okuhomare,**A descendant (the 1st generation) of cv. Reimei	Aomori PAES	1985	1988	1494	Semi-dwarf	2989	Tanabu *et al*. (1987)[172)]
27	Tamaminori	Tama-kei No. 56*	Aichi No. 21	*cv. Reimei/cv. Nipponbare	Saitama PAES	1986	1986	1196	Tough culm; semi-dwarf	2990	Niwayama *et al*. (1987)[125)]
28	Hyogo-Kitanishiki	Nadahikari*	Gohyaku-mangoku	*cf. cv. Nadahikari	Hyogo PAES	1986	1987	1374		2991	
29	Akichikara	Hokuriku No. 101*	Akihikari**	*A descendant of cv. Reimei; **A descendant (the 1st generation) of cv. Reimei	Hokuriku NAES	1986	1987	179	Short and tough culm; high-yielding	1147	Koga *et al*. (1987)[78)]
30	Manyo-mochi	77-5133*	To-kou No. 76	*A glutinous mutant of cv. Koshihikari	Toyama PAES	1987	1988	1738	Glutinous	2992	Yamamoto *et al*. (1989)[208)]
31	Seihou No. 1	Akihikari*	Nishihomare	*cf. cv. Akihikari (the 1st generation of cv. Reimei)	Mr. Seiichi HIROKI	1987	1988	1799		2993	
32	Aichi-no-kaori	Hatsushimo	Mine-asahi*	*A descendant of Gamma ray (20kR) induced mutant line "Kanto 79" from cv. Koshihikari	Aichi ARC	1987	1988	1802	Good taste; big seed	1151	Koomura *et al*. (1989)[82)]
33	Michinoku-wase	Bi-kei No. 113*	Bi-kei No. 110**	*, **A descendant of cv. Reimei	Yamagata PAES	1988			Semi-dwarf	2994	Sato *et al*. (1988)[149)]
34	Kinuhikari	Shu2800/Hokuriku No. 100*	Nago-yutaka	*Gamma ray to cv. Koshihikari	Hokuriku NAES	1988	1989	2037	Short culm; good taste; lodging resistance	1160	Koga *et al*. (1989)[77)]
35	Tsugaru-otome	Ouu 305	Mutsu-kaori*	*cf. cv. Mutsukaori: a descendant (the 2nd generation) of cv. Reimei through cv. Akihikari	Aomori PAES	1988	1990	2389	Good taste; cold tolerance; short culm	1153	Takadate *et al.* (1990)[161)]
36	Heisei-mochi	Musashi-kogane*	Musashi-mochi	*cf. cv. "Musashi-kogane": a descendant (the 2nd generation) of cv. Reimei	Saitama PAES	1988	1990	2394	Lodging resistance; resistant to stripe virus	1157	Niwayama *et al*. (1991)[127)]
37	Nijihikari	Tori-kei No. 4*	Satominori	*Gamma ray to cv. "Norin No. 8"	Tottori PAES	1988	1991	2867	Short culm; lodging resistance	1163	
38	Oochikara	BG1*	Shu3116**	*A descendant (the 1st generation) of mutant cv. Taihou; **A descendant (the 3rd generation) of "R4-B" through cv. Sachiminori	Hokuriku NAES	1989	1990	2271	Large seed; tough stem and lodging resistance	2295	Kobayashi *et al*. (1990)[71)]
39	Koihime	Koshihikari/Reimei*	Akihikari*	*cf. cv. Reimei (Appendix 1); **cf. cv. Akihikari (the 1st generation of cv. Reimei)	Aomori PAES, Fujisaka Branch	1989	1990	2329	High-yielding; cold tolerance	1161	Shimura *et al*. (1990)[152)]
40	Hirohikari	Fu-kei No. 130*	Akihikari**	*cv. Koshihikari/cv. Reimei//"Fu-kei No. 104"; **cf. cv. Akihikari	Hiroshima PAES	1989	1990	2392	Tough culm; high-yielding; good taste	1152	Maeda *et al.* (1990)[89)]
41	Hirohonami	Fu-kei No. 130*	Yoneshiro	*cv. Koshihikari/cv. Reimei//"Fu-kei No. 104"	Hiroshima PAES	1989	1990	2393	Tough culm	2996	Maeda *et al*. (1990)[89)]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
42	Yumeminori	Etsunan No. 119	Musashi-kogane*	*cf. cv. "Musashi-kogane": a descendant (the 2nd generation) of cv. Reimei	Saitama PAES	1989	1992	3222	Lodging resistance	1166	Niwayama *et al.* (1994)[126)]
43	Koshi-no-hana	Shounai No. 32	To-kei 196*	*Gamma ray to cv. Koshihikari	Toyama PAES	1980	1991	2869	Low amylose; panicle weight type	2997	
44	Kitaou	Fu-kei No. 108	Fu-kei No. 113*	*A descendant (the 2nd generation) of cv. Reimei	Aomori PAES, Fujisaka Branch	1990	1991	2871	Short culm	2998	Kobayashi *et al*. (1993)[72)]
45	Kaguya-mochi	Chubo37*	Fu-kei No. 126 (Kochiminori)	*A descendant (the 2nd generation) of cv. Reimei	Aomori PAES, Fujisaka Branch	1990	1991	2872	Semi-dwarf; middle to short culm	2999	Horisue *et al.* (1992)[31)]
46	Hagi-no-kaori	Tohoku No. 125	Furu2986 (cv. Miyakaori)*/Tohoku No. 125	*A descendant (the 2nd generation) of cv. Reimei	Miyagi PAES Furukawa Branch	1991	1992	3044	Semi-dwarf	3000	Sasaki *et al*. (1994)[143)]
47	Aya	Douhoku No. 43 (Naga-kei 84271)*	Kita-ake	*NM391 (a gamma ray induced mutant from cv. "Nihon-masari")/cv. Ishikari	Hokkaido AES Kamikawa Station	1991	1992	3283	Good taste	1169	Tanno *et al*. (1997)[173)]
48	Yama-uta	Bi-kei No. 108*/ Akihikari**	Fu-kei No. 127***	*, **, ***A descendant of cv. Reimei	Aomori PAES, Fujisaka Branch	1991	1992	3284	Semi-dwarf	3001	Kobayashi *et al*. (1993)[70)]
49	Yukimi-mochi	Fuji-mochi712*	Fu-kei-mochi No. 119**	*, **A descendant of cv. Reimei	Aomori PAES, Fujisaka Branch	1991	1992	3285	Semi-dwarf	3003	Horisue *et al*. (1993)[30)]
50	Aneko-mochi	Fu-kei-mochi No. 133*	Fu-kei-mochi No. 119**	*, **A descendant (the 2nd generation) of cv. Reimei	Aomori PAES, Fujisaka Branch	1991	1992	3286	Semi-dwarf	3004	Horisue *et al.* (1993)[32)]
51	Yuki-gesyou	Oou No. 301	Bi-kei No. 94*	*"Bi-kei 67"/cv. Reimei//cv. Sasanishiki	Yamagata PAES	1991	1993	3344	Semi-dwarf	3005	
52	Doman-naka	Chubu No. 42*	Shounai No. 29**	*Named as cv. "Ibuki-wase" (the 1st generation of cv. Mine-asahi), **A descendant of cv. Reimei	Yamagata PAES	1991	1993	3345	Short stem	1168	
53	Hae-nuki	Shounai No. 29*	Akita No. 31	*A descendant (the 3rd generation) of cv. Reimei	Yamagata PAES	1991	1993	3346	Semi-dwarf	3006	Kyoya *et al*. (2002)[86)]
54	Hatsu-nanori	Natsuhikari	Niigata-wase*	*A descendant (the 2nd generation) of cv. Reimei; cf. cv. "Niigata-wase"	Kochi PARC	1991	1994	4051	Semi-dwarf	3007	Nakamura *et al.* (1993)[118)]
55	Hashiri-aji	Niigata-wase*	Shounai No. 32	*A descendant (the 2nd generation) of cv. Reimei; cf. cv. "Niigata-wase"	Niigata PAES	1991	1997	5784	Semi-dwarf	3008	Hoshi *et al*. (1998)[36)]
56	Ougi-wase	Inaba-wase	Yo128 (Kagahikari)*	*cf. cv. Kagahikari: a descendant (the 1st generation) of a gamma ray induced mutant of cv. Koshihikari	Ishikawa PAES	1991			Large grain; a good grain quality	3009	Matsumoto *et al*. (1993)[94)]
57	Gin-no-sei	Aikawa No. 1*	Aki-kei 53	*A mutant of cv. Akiyutaka	Akita PAES	1993	1993	3343		1167	Takahashi *et al*. (1999)[163)]
58	Kinu-no-hada	Chubu-mochi No. 37	Akihikari*	*cf. cv. Akihikari: a descendant (the 1st generation) of cv. Reimei	Akita PAES	1993	1993	3574	Tough stem; high-yielding	3010	Kato *et al*. (1995)[68)]
59	Tatsuko-mochi	Chubu-mochi No. 37	Akihikari*	*cf. cv. Akihikari: a descendant (the 1st generation) of cv. Reimei	Akita PAES	1993	1993	3575	Tough stem; high-yielding	3011	Kato *et al*. (1995)[68)]
60	Ippon-jime	Gohyaku-mangoku	Houhai*	*cf. cv. Houhai: a descendant (the 1st generation) of cv. Reimei	Niigata PAES	1993	1994	4172	Semi-dwarf	3012	Sasaki *et al*. (1994)[144)]
61	Natsu-no-tayori	Fu-kei No. 125*	Ouu No. 309	*cv. Sasaminori/cv. Reimei	Kagoshima PAES	1993	1995	4349	Semi-dwarf	3013	Yatou *et al*. (1994)[212)]
62	Yume-tsukushi	Kinuhikari*	Koshihikari	*cf. cv. Kinuhikari	Fukuoka PAES	1993	1995	4414	Good taste; lodging resistance	3014	Imabayashi *et al*. (1995)[42)]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
63	Inahikari	Chubu No. 35	Mine-asahi*	*A descendant (the 1st generation) of Gamma ray (20kR) induced mutant line "Kanto 79" from cv. Koshihikari	Aichi ARC	1993	1995	4415	Short culm; good taste	3015	Inoue *et al.* (1993)[43)]
64	Matsuri-bare	Tsuki-no-hikari	Mine-asahi*	*A descendant of Gamma ray (20kR) induced mutant line "Kanto 79" from cv. Koshihikari	Aichi ARC	1993	1995	4416	Tough culm	3016	Syumura *et al*. (1994)[159)]
65	Maihime	Ao-kei No. 69	Fu-kei No. 130*	*cv. Koshihikari/cv. Reimei//"Fu-kei No. 104"	Aomori PAES, Fujisaka Branch	1993	1995	4471	Tough culm	3017	Horisue *et al*. (1994)[34)]
66	Fukuhibiki	Kochihibiki	Ouu 316 gou*	* A descendant (the 3rd generation) of cv. Reimei	Tohoku NAES	1993	1995	4710	Semi-dwarf	3018	Higashi *et al*. (1994)[21)]
67	Mitsu-tarou	Shinano-sakigake*	Akita-komachi	*cf. cv. "Shinano-sakigake" (a gamma ray induced mutant cultivar from cv. Toyonishiki)	Mitsui Chemicals, Inc.	1993	1996	5007		3019	
68	Owara-bijin	Shounai No. 32 (Hana-no-mai)	To-kei 196*	*A mutant strain induced through gamma ray irradiation to cv. Koshihikari	Toyama PAES	1994	1995	4409	Early-maturing; short culm	3020	Kaneda *et al.* (1996)[60)]
69	Dewahikari	Shounai No. 32 (Hana-no-mai)	Ouu No. 302*	*A descendant (the 2nd generation) of cv. Reimei	Akita PAES	1994	1996	5065	Semi-dwarf	3021	
70	Aki-roman	Mine-asahi*	Nakate-shinsenbon	*A descendant (the 1st generation) of Gamma ray (20kR) induced mutant line "Kanto 79" from cv. Koshihikari	Hiroshima PAES	1994	1996	5185	Good taste	3022	Tsuchiya *et al.* (1995)[183)]
71	Hoso-omote	Shin-hou No. 38 (Shinano-sakigake)*	Miyan No. 23	*cf. cv. "Shinano-sakigake" (a gamma ray induced mutant cultivar from cv. Toyonishiki)	Nagano PAES	1994	1996	5247		3023	
72	Nebari-gachi 94	Akinishiki	Tan-kei 1915*	*Named as "Noh PL No. 13" (a hybrid between two MNU induced mutants)	Plant Laboratory, Kirin Brewery Co., Ltd.	1994	1997	5844	Low amylose	3024	
73	Sai-no-yume	Kanto PL3	Tama-kei No. 74*	*cf. cv. "Yume-minori": a descendant (the 3rd generation) of cv. Reimei	Saitama PAES	1994	1998	6445	Semi-dwarf	3025	Tokura *et al*. (1999)[177)]
74	Dewa-sansan	Miyama-nishiki*	Ao-kei Sake No. 97 (Hanafubuki)**	*cf. cv. "Miyama-nishiki" (a gamma ray induced mutant cultivar from cv. "Takane-nishiki"; **cf. cv. Hanafubuki: a descendant (the 2nd generation) of cv. Reimei)	Yamagata PAES	1995	1997	5545	High % of white core rice; suitable for sake-brewery; semi-dwarf	3026	
75	Otome-gokoro	Akita-komachi	Akihikari*	*cf. cv. Akihikari: a descendant (the 1st generation) of cv. Reimei	Okayama PAES	1995	1997	5546	Semi-dwarf	3027	Nihara *et al.* (1996)[122)]
76	Yume-kogane	Yuki-hikari	Hatsu-kogane*	*cf. cv. Hatsukogane: a descendant (the 2nd generation) of cv. Reimei	Aomori PAES, Fujisaka Branch	1995	1997	5785	Semi-dwarf	3028	Uehara *et al*. (1997)[186)]
77	Hama-yutaka	Fu-kei No. 115×Ouu No. 321*	Fu-kei No. 140 (Kita-ou)**	*A descendant (the 3rd generation) of cv. Reimei; **cf. cv. Kitaou: a descendant (the 3rd generation) of cv.	Aomori PAES, Fujisaka Branch	1985	1997	5786	Semi-dwarf	3029	Uehara *et al.* (1997)[187)]
78	Dontokoi	Kinuhikari*	Hokuriku No. 120	*cf. cv. Kinuhikari	Hokuriku NAES	1995	1997	5845	Good taste; lodging resistance	3030	Uehara *et al*. (1995)[193)]
79	Soft 158	Hokuriku No. 127 (Kinuhikari)*	Ken-kei 2078**	*cf. cv. Kinuhikari; **A mutant from EMS treatment to cv. Sasanishiki	Hokuriku NAES	1995	1997	5846	Good taste; lodging resistance	3031	Uehara *et al*. (1995)[188)]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
80	Rinx-wase	KRN3501 (Rinx-Kobayashi)*	KRN3502	*cf. cv. "Rinx-Kobayashi" (Appendix 1)	Plant Laboratory, Kirin Brewery Co., Ltd.	1995	1998	6265	Seed-shattering resistance	3032	
81	Hoho-emi	Aichi No. 52	Mine-asahi*	*A descendant (the 1st generation) of gamma ray (20kR) induced mutant line "Kanto 79" from cv. Koshihikari	Miyazaki PAES	1995	1998	6388	Good taste; tough culm	3033	Takita *et al*. (1997)[168)]
82	Shimasayaka	Tsuki-no-hikari	Kinuhikari*	*cf. cv. Kinuhikari	Plant Laboratory, Kirin Brewery Co., Ltd.	1995	1998	6444	Good taste; lodging resistance	3034	
83	Tsukushi-wase	Norin No. 22	Kinuhikari*	*cf. cv. Kinuhikari	Fukuoka PAES	1995	1999	7321	Good taste; lodging resistance	3035	Hamachi *et al*. (1998)[18)]
84	Tsugaru-roman	Fu-kei No. 141*	Akita-komachi	*A descendant (the 2nd generation) of cv. Reimei	Aomori PAES	1995	2000	8280	Semi-dwarf	3036	Takadate *et al.* (1997)[160)]
85	Ishikawa Sake No. 30	Gohyaku-mangoku	Hanafubuki*	*cf. cv. Hanafubuki: a descendant (the 2nd generation) of cv. Reimei	Ishikawa PAES	1996	1996	5188	Semi-dwarf	3037	
86	Asamurasaki	Tou-mochi 396	Ouu 331 gou (later named as "cv.	*A descendant (the 4th generation) of cv. Reimei	Tohoku NAES	1996	1998	6504	Semi-dwarf	3038	Higashi *et al*. (1997)[24)]
87	Sakitamahime	Kinuhikari*	Yumeminori**	*cf. cv. Kinuhikari; ** A descendant (the 3rd generation) of cv. Reimei through cv. "Musashi-kogane"	Saitama PAES	1996	2000	7644	Good taste; lodging resistance	3039	Tokura *et al.* (2000)[176)]
88	Aki-no-sei	Toyo-nishiki	Miyama-nishiki*	*cf. cv. "Miyama-nishiki" (a gamma ray induced mutant cultivar from cv. "Takane-nishiki")	Akita PAES	1996	2000	7755	High % of white core rice; suitable for sake-brewery	3040	Masaki *et al*. (1999)[93)]
89	Okini-iri	Chubu No. 47	Ouu No. 313*	*A descendant (the 3rd generation) of cv. Reimei	Tohoku NAES	1996	2000	7812	Semi-dwarf	3041	Higashi *et al.* (1997)[23)]
90	Ideyu-mochi	Fuji-mochi773*	Wasetora-mochi	*A descendant (the 2nd generation) of cv. Reimei	Aomori PAES, Fujisaka Branch	1996	2000	7813	Semi-dwarf	3042	Horisue *et al*. (1997)[33)]
91	Yume-musubi	Tohoku No. 137	Hokuriku No. 122 (Kinuhikari)*	*cf. cv. Kinuhikari	Miyagi PAES Furukawa Branch	1996	2000	7814	Good taste; tough culm	3043	Matsunaga *et al*. (2002)[97)]
92	Asahi-no-yume	Aichi No. 70 (Aichi-no-kaori)*	Aichi No. 56/Aichi No. 65**	*, **: A descendant (the 2nd generation) of a gamma ray induced mutant line "Kanto 79 gou" through "Mine-asahi"	Aichi ARC	1996	2000	7888	Good taste; tough culm	3044	Izawa *et al*. (2001)[50)]
93	Yume-izumi	Yumehikari	Kinuhikari*	*cf. cv. Kinuhikari	Kumamoto PARC	1996	2000	8124	Good taste; lodging resistance	3045	Izumi *et al*. (1998)[54)]
94	Yume-hitachi	Chiyo-nishiki	Hokuriku No. 122 (Kinuhikari)*	*cf. cv. Kinuhikari	Ibaraki PAES	1996	2000	8213	Good taste; lodging resistance	3046	Suga *et al.* (2000)[155)]
95	Rinx-nakate	Rinx Kobayashi*	KRN3505	*cf. cv. "Rinx-Kobayashi" (Appendix 1)	Plant Laboratory, Kirin Brewery Co., Ltd.	1996	2000	8359	Non seed shattering	3047	
96	Iwata No. 12	Asominori	Aichi-no-kaori*	*cf. cv. "Aichi-no-kaori"	Japan Tobacco, Inc.	1996	2001	8631	Semi-dwarf	3048	
97	Hoshi-akari	Hatsuboshi	Miyama-nishiki*	*cf. cv. "Miyama-nishiki" (a gamma ray induced mutant cultivar from cv. "Takane-nishiki") (Appendix 1)	Kako-mai Breeding Institute, Inc. and Tohoku Electric Power Co., Inc.	1996	2001	9116	High % of white core rice; suitable for sake-brewery	3049	

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98	Hayatsukushi	Hatsuboshi	Seinan No. 89*	*Named as cv. "Natsu-no-tayori": a descendant (the 2nd generation) of cv. Reimei	Fukuoka ARC	1997	2000	8360	Semi dwarf	3050	Hamachi *et al.* (1998)[17)]
99	Aki-geshiki	Kyu-kei 919*	Hinohikari	*A descendant of cv. "Mine-asahi"	Miyazaki PAES	1997	2000	8544	Good taste; tough culm	3051	The Miyazaki Breeding Group of Rice (2005)[174)]
100	Oyama-nishiki	Hida-homare	Akita Sake No. 33*	*A descendant of cv. "Miyama-nishiki" (Appendix 1)	Toyama PAES	1997	2001	9029	High % of white core rice; suitable for sake-brewery	3052	Kaneda *et al.* (1999)[59)]
101	Hatajirushi	Tohoku No. 141	Tohoku No. 142* (Ibukiwase/Tohoku No. 125)	*cv. Ibukiwase: a descendant (the 2nd generation) of "Kanto 79 gou" through cv. "Mine-asahi"	Miyagi PAES Furukawa Branch	1997	2001	8832	High % of white core rice; suitable for sake-brewery	3053	Matsunaga *et al.* (2002)[98)]
102	Banbanzai	Chiyo-nishiki	Tama-kei No. 74 (cv. Yume-minori)*	*cf. cv. "Yume-minori": a descendant (the 3rd generation) of cv. Reimei through cv. "Musashi-kogane"	Saitama PAES	1997	2001	9304	Semi-dwarf	3054	Tokura *et al* . (2002)[175)]
103	Snow Pearl	74wx2N1*	Reimei**	*A mutant of "Norin No. 8"; **cf. cv. Reimei (Appendix 1)	Tohoku NAES	1998	1999	7062	Low amylose; semi-dwarf	3055	Higashi *et al* . (1998)[22)]
104	Koimomiji (Hiroshima No. 21)	Sachi-izumi	Fu-kei No. 141*	*A descendant (the 2nd generation) of cv. Reimei	Hiroshima PARC	1998	2001	9301	Semi-dwarf	3056	Maeda *et al.* (2000)[90)]
105	Daichi-no-kaze	A-kei 558 (Matsuribare)*	Aichi No. 78/4/Tsuki-no-hikari/3/Aichi No. 77//Iku D759/A-kei	*cf. cv. Matsuribare: a descendant (the 2nd generation) of a gamma ray induced mutant line "Kanto 79 gou" through cv. "Mine-asahi"	Aichi ARC	1998	2002	8640	Good taste; tough culm	3057	Izawa *et al* . (2001)[52)]
106	Koshihikari Toyama BL No. 1	Koshihikari	Koshihikari/BC-ta2*	*Kinuhikari2/"Tohoku IL No. 7"	Toyama ARC	1998	2002	9641	Good taste; lodging resistance	3058	Kojima *et al* . (2003)[79)]
107	Hanabusa	Douhoku No. 53*	Kita-ake	*A sister line of cv. Aya; a descendant (the 2nd generation) of a gamma ray induced mutant line "NM391"	Hokkaido NAES	1998	2002	9785	Low amylose	3059	Araki *et al.* (2002)[8)]
108	Sawa-pikari	Tan-kei 2018*	Asa-no-hikari	*A mutant line through MNU treatment to cv. Kochihibiki	Gunma PAES	1998	2002	9786	Low amylose	3060	Narizuka *et al* . (1998)[120)]
109	Awaminori	Hokkai No. 132	Hokuriku No. 122 (Kinuhikari)*	*cf. cv. Kinuhikari	Hokuriku NAES	1998	2002	9788	Good taste; lodging resistance	3061	Uehara *et al.* (1998)[192)]
110	Haiminori	EM40*	Ake-no-hoshi	*A mutant from MNU treatment to cv. Kinmaze	Chugoku NAES	1999	2000	8008	Giant embryo	3062	Nemoto *et al* . (2001)[121)]
111	Yume-ohmi	Etsunan No. 135*	Shi-kei No. 51	*A descendant (the 3rd generation) of cv. Reimei through cv. Akihikari.	Shiga PAES	1999	2001	8944	Semi-dwarf	3063	Noda *et al* . (1999)[128)]
112	Mie-no-emi	Yamagata No. 41*	Hitomebore	*"Shounai No. 32"/cv. "Mine-asahi" (a descendant (the 1st generation) of Gamma ray (20kR) induced mutant line "Kanto 79" from cv. Koshihikari)	Mie PARC	1999	2002	9911	Good taste; tough culm	3064	Yamakawa *et al* . (2000)[207)]
113	Yume-akari	Akita-komachi	Ao-kei No. 110*	*A descendant (the 4th generation) of cv. Reimei through cv. Mutsukaori	Aomori PAES	1999	2002	9912	Semi-dwarf	3065	Mikami *et al.* (2000)[100)]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
114	Gin-ginga	Yamagata Sake No. 49*	Akita Sake No. 49**	*Named as cv. "Dewa-sansan" (a descendant (the 3rd generation) of cv. Reimei); **a descendant (the 3rd generation) of cv. Reimei through cv. Akihikari	Iwate PAES, Kennan Station	1999	2002	1047	Semi-dwarf	3066	Odanaka *et al*. (2000)[129]
115	Yume-no-kaori	Hattan-nishiki No. 1	Yamagata Sake No. 49*	*Named as cv. "Dewa-sansan" (a descendant (the 3rd generation) of cv. Reimei)	Fukushima PAES	1999	2003	1096	Semi-dwarf	3067	Sato *et al*. (2003)[148]
116	Aichi-no-kaori SBL	Aichi-no-kaori*	F3 (Aichi-no-kaori*/2//Aichi No. 78/Aichi-no-kaori*)	*cf. cv. "Aichi-no-kaori"	Aichi ARC	1999	2003	10968	Good taste; big seed	3068	Izawa *et al*. (2001)[51]
117	Oku-no-murasaki	Tohoku Mochi 149 gou	Ouu 331 gou (later named as cv. Fukuhibiki")*	*A descendant (the 4th generation) of cv. Reimei	NARO NARC Tohoku Region	1999	2003	11088	Semi-dwarf	3069	Yokogami *et al*. (2000)[213]
118	Oshimako 180	Douhoku No. 43 (NM391*/Ishikari)	Fu-kei No. 144**	*Gamma ray to cv. "Nihon-masari"; **A descendant (the 3rd generation) of cv. Reimei	Aomori PAES	1999	2003	11230	Semi-dwarf	3070	
119	Koshi-ibuki	Tohoku No. 143 (Hitomebore)	Yamagata No. 35*	*Named as cv. "Doman-naka" (a descendant (the 3rd generation) of a gamma ray induced mutant line "Kanto 79 gou" through cv. "Mine-asahi" from cv. Koshihikari)	Niigata PAES	1999	2003		Good taste; tough culm	3071	Hoshi *et al*. (2002)[37]
120	Yawarakomachi	Nishihomare+B140	Tan-kei 2021*	*A mutant line through NMU treatment to cv. Kinmaze	Kyushu NAES	1995	1999	7084	Low amylose content	3072	Okamoto *et al*. (2001)[131]
121	Kan-no-mai	Gohyaku-mangoku	Miyama-nishiki*	*cf. cv. "Miyama-nishiki" (Appendix 1)	Shimane PAES	1995	2000	7890	High % of white core rice; suitable for sake-brewery	3073	Yamamoto *et al*. (1999)[209]
122	Hanakirari	PR3*	Koshihikari	*A mutant from protoplast culture of cv. Nipponbare	Plantec Research Institute	2000	2000	8545	Early-maturing	3074	
123	Chiho-no-kaori	Tohoku No. 144 (Hagi-no-kaori)*	Nankai No. 122	*cf. cv. "Hagi-no-kaori" (a descendant (the 4th generation) of cv. Reimei.)	Miyazaki PAES	2000	2002	1087	Semi-dwarf	3075	Takita *et al.* (2000)[169]
124	Gin-otome	Akita Sake No. 44*	Tohoku No. 141	*Gamma ray to F6 ("Hyo-kei-sake No. 16"/cv. Yoneshiro)	Iwate PAES	2000	2003	1096	Short culm	3076	Sugawara *et a* l. (2012)[156]
125	Yume-ippai	Yume-gokochi*	Yume-kahori**	*cf. cv. "Yume-gokochi"; **cf. cv. "Yume-kahori"	Mitsui Chemicals, Inc.	2000	2003	10965	Short culm	3077	
126	Yume-sayaka	Yamagata No. 40*	Oou No. 341	*A descendant (the 3rd generation) of cv. Reimei	Yamagata PAES	2000	2003	10966	Semi-dwarf	3078	Sato *et al*. (2000)[145]
127	Itadaki	Shu4885 (Dontokoi)*	Shu4695	*cf. cv. Dontokoi: a descendant (the 2nd generation) of cv. Kinuhikari	NARO (NARC, Hokuriku Center)	2000	2003	11087	Good taste; lodging resistance	3079	Uehara *et al*. (2000)[195]
128	Mine-hibiki	Sachi-izumi	Mine-asahi*	*cf. cv. "Mine-asahi": A descendant (the 1st generation) of gamma ray induced mutant line "Kanto No. 79" from cv. Koshihikari	Aichi ARC	2000	2003	11089	Good taste; tough culm	3080	Kudo *et al*. (2000)[84]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
129	Chiyo-no-mochi	Ouu-mochi No. 317*× Fu-kei No. 141**	Fu-kei No. 143***	*,**A descendant (the 3rd generation) of cv. Reimei; ***Named as cv. "Yama-uta" (a descendant (the 4th generation) of cv. Reimei)	Aomori PAES, Fujisaka Branch	2000	2003	11091	Semi-dwarf	3081	Uehara *et al.* (2001)[196)]
130	Milky Princess	Kanto No. 163	Kou272 (Milky Queen)*	*cf. cv. "Milky Queen" (Appendix 1)	NARO (National Institute of Crop Science)	2000	2003	11234	Low amylose content	3082	Sato *et al.* (2008)[146)]
131	Koshi-no-shizuku	Hyogo-kita-nishiki*	Miyama-nishiki**	*cf. cv. "Hyo-kei-sake No. 18"; **cf. cv. "Miyama-nishiki" (Appendix 1)	JA, Teraru-Echizen	2000	2003	11361		3083	
132	Yume-shizuku	Kinuhikari*	Tohoku No. 143 (Hitomebore)	*cf. cv. Kinuhikari	Saga PARC	2000	2003	11358	Good taste; lodging resistance	3084	Hirota *et al.* (2001)[28)]
133	Fusa-no-mai	Sirotae-nishiki	Chubu No. 72*	*A descendant of cv. Reimei (the 3rd generation) and cv. "Mine-asahi" (the 2nd generation)	Chiba PARC	2000		11583	Good taste; tough culm	3085	Wada *et al* . (2002)[197)]
134	Fukumirai	Chubu No. 82*	Chiyo-nishiki	*"Chubu No. 44"/cv. Mine-asahi; cf. cv. "Mine-asahi"	Fukushima PAES	2000	2004	11842	Good taste; tough culm	3086	Sato *et al.* (2006)[147)]
135	Ten-no-midori	PR3*	Koshihikari	*A mutant from protoplast culture of cv. Nipponbare	Mitsubishi Chemical Co.	1996	2001	8833	Early-maturing	3087	
136	Shun-you	LGC-1*	Hokuriku No. 153**	*cf. cv. LGC1 (Appendix 1); **cv. Oochikara (the 2nd generation) of cv. Taihou x cv. Kochihibiki	NARO (NARC, Hokuriku Center)	2001	2004	12181	Low glutelin content in the grain	3088	Uehara *et al* . (2002)[194)]
137	Silky Pearl	Tan-kei2019 (Noh PL No. 14)*	Fu-kei No. 143 (cv. Yamauta)**	*A mutant from NMU treatment to cv. Kochihibiki; **cf. cv. Yamauta (the 3rd generation of cv. Reimei)	NARO(NARC for Tohoku Region)	2001	2004	12274	Semi-dwarf	3089	Takita *et al.* (2002)[167)]
138	Asa-tsuyu	Hokuriku No. 127 (Kinuhikari)*	Douhoku No. 43 (NM391**/Ishikari)	*A descendant (the 2nd generation) of cv. Reimei; **Gamma ray irradiation to cv. Nihonmasari	NARO (NARC, Hokuriku Center)	2001	2004	12180	Semi-dwarf; low amylose content	3090	Uehara *et al* . (2002)[191)]
139	Takitate	Ouu No. 343*	Tohoku No. 153	*74wx2N1/Reimei	Miyagi PAES Furukawa Branch	2001	2004	12055	Semi-dwarf	3091	Nagano *et al.* (2005)[111)]
140	Yume-no-hana	Yume-gokochi*	Yume-kahori**	*cf. cv. "Yume-gokochi"; **cf. cv. "Yume-kahori"	Plantec Research Institute	2001	2004	12045	Low amylose contents; short stem	3092	
141	Kahoruko	Kanto No. 154 (Sally Queen)	Akihikari*	*cf. cv. Akihikari (a descendant (the 1st generation) of cv. Reimei)	Niigata ARI	2001	2004	11843	Semi-dwarf	3093	
142	Akigumo	Niigata-wase*	Tan-kei 2019**	*cf. cv. "Niigata-wase"; **Named as "Noh PL No. 14"	Niigata ARI	2001	2004	11844	Low amylose content	3094	
143	Natsugumo	Yuki-no-sei	Aya*	*cf. cv. Aya	Niigata ARI	2001	2004	11845		3095	
144	Shihou	Wataboushi	Asamurasaki*	*A descendant of cv. Reimei (the 5th generation)	Niigata ARI	2001	2004	11846	Semi-dwarf	3038	
145	Benika	Niigata-mochi No. 31/Shinonoi	Niigata-mochi No. 31/Tohoku No. 144 (Hagi-no-kaori)*	*cf. cv. "Hagi-no-kahori" (a descendant (the 4th generation) of cv. Reimei)	Niigata ARI	2001	2004	11847	Semi-dwarf	3097	
146	Benisarasa	Niigata-mochi No. 31/Shinonoi	Niigata-mochi No. 31/Tohoku No. 144 (Hagi-no-kaori)*	*cf. cv. "Hagi-no-kahori" (a descendant (the 4th generation) of cv. Reimei)	Niigata ARI	2001	2004	11848	Semi-dwarf	3098	

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
147	Natsushizuka	Kanto No. 136/Koshihikari	Natsuhikari*	*cf. cv. Natsuhikari: a descendant (the 4th generation) of a gamma ray induced mutant line "Fu-kei 71 gou"	Shizuoka PAES	2001	2005	12562	Semi-dwarf	3099	Miyata *et al.* (2001)[106)]
148	Toji-no-hana (Hyo-kei-sake No. 65)	Hyogo-kitanishiki*	Hidahomare	*cf. cv. "Hyogo-kita-nishiki": a descendant (the 4th generation) of cv. Reimei	Hyogo PAFFRC	2001	2004	12178	Semi-dwarf	3100	
149	Toji-no-yume (Hyo-kei-sake No. 66)	Hyogo-kitanishiki*	Gin-no-sei**	*cf. cv. "Hyogo-kita-nishiki": a descendant (the 4th generation) of cv. Reimei; **cf. cv. "Gin-no-sei"	Hyogo PARC	2001	2004	12179	Semi-dwarf	3101	
150	Nebarigoshi	21-3-6*	Kinuhikari**	*A mutant of cv. "Todoroki-wase"; **cf. cv. Kinuhikari	Nagano PAES	1997	2002	9644	Good taste; lodging resistance	3102	
151	Koshihikari Niigata BL No. 4	Koshihikari/Niigata-wase*	Koshihikari	*A descendant (the 2nd generation) of cv. Reimei	Niigata ARI	1998	2002	1023	Semi-dwarf	3103	Ishizaki, K. (2007)[46)]
152	Misato-nishiki	Yamada-nishiki	Miyama-nishiki*	*cf. cv. "Miyama-nishiki" (Appendix	Akita PAES	1998	2002	1023		3104	Masaki *et al.* (2004)[92)]
153	Koimusubi	Chubu No. 73*	Tohoku No. 143 (Hitomebore)	*Chubu No. 44/Mine-asahi; cf. cv. "Mine-asahi"	Miyagi PAES Furukawa Branch	1998	2002	1036		3105	Nagano *et al*. (2005)[110)]
154	Hoshi-aoba	Tashu-kei174（Chugoku No. 113）	Hokuriku No. 130 (Oochikara)*	*cf. cv. Oochikara	NARO (NARC for Chugoku and Shikoku Region)	2000	2003	11360		3106	Maeda *et al*. (2003)[88)]
155	LGC Soft	NM391*	LGC-1**	*A mutant line induced through gamma ray irradiation to cv. Nihonmasari; **cf. cv. "LGC-1": a mutant cultivar induced through EI treatment to cv. Nihonmasari (Appendix 1)	NARO（NARC for Chugoku and Shikoku Region） and NIAS(IRB)	2002	2005	12564	Low amylose♀; low glutelin♂	3107	Iida *et al*. (2004)[41)]
156	Mebae-mochi	EM40*	Chubu-mochi No. 57	*A mutant from NMU treatment to cv. Kinmaze	NARO (NARC, Hokuriku Center)	2002	2005	13188	Giant embryo	3108	Uehara *et al.* (2003)[189)]
157	Kusa-yutaka	Chugoku No. 105	Hokuriku No. 130 (Oochikara)*	*cf. cv. Oochikara	NARO (NARC, Hokuriku Center)	2002	2005	13189		3109	Uehara *et al*. (2003)[190)]
158	Benigoromo	Fukuhibiki*//A5	Ouu 331 gou (later named as cv. Fukuhibiki)**	*, **A descendant of cv. Reimei (the 4th generation)	NARO (NARC, Tohoku Region)	2002	2005	13186	Semi-dwarf	3110	Yamaguchi *et al.* (2005)[204)]
159	Akisayaka	Saikai No. 195	Hokuriku No. 148 (Dontokoi)*	*cf. cv. Dontokoi: a descendant (the 4th generation) of a gamma ray induced mutant line "Hokuriku 100 gou" through cv. Kinuhikari	NARO（NARC for Kyushu and Okinawa Region）	2002	2005	13187	Good taste; lodging resistance	3111	Okamoto *et al*. (2008)[132)]
160	Mie-no-yume	Aichi No. 92 (Matsuribare)*	Etsunan No. 148	*cf. cv. Matsuribare	Mie PARC	2002	2004	12056		3112	Yamakawa *et al*. (2002)[206)]
161	Tsukushi-roman	Chikushi No. 6 (Yume-tsukushi)*	Chubu No. 88 (Mochi-kei 347/Mine-asahi**)	*cf. cv. "Yume-tsukushi"; **cf. cv. "Mine-asahi"	Fukuoka ARC	2002	2005	12959		3113	Hamachi *et al.* (2003)[19)]
162	Tabegokochi	Dontokoi*	Koshihikari	*cf. cv. Dontokoi	Monsanto Japan Limited	2002	2005	12827	Good taste; lodging resistance	3114	
163	Tone-no-megumi	Dontokoi*	Koshihikari	*cf. cv. Dontokoi	Monsanto Japan Limited	2002	2005	12828	Good taste; lodging resistance	3115	

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
164	Hanaemaki	Douhoku No. 53*/Noh PL No. 11	Kuu-iku No. 139 (Yukimaru)	*A mutant of "Nihon-masari" (NM391)	NARO (NARC for Hokkaido Region)	2003	2006	14032	Low amylose content	3116	
165	Oborozuki	Kuu-iku No. 150 (Akiho)	Hokkai No. 287*	**in vitro* variation of cv. "Kirara 397"	NARO (NARC for Hokkaido Region)	2003	2006	14033		3117	Ando *et al*. (2006)[4)]
166	Churahikari	Tohoku No. 143 (Hitomebore)	Ouu No. 338*	*A descendant (the 2nd generation) of cv. "Mine-asahi"	NARO (NARC for Tohoku Region)	2003	2006	14034		3118	Yamaguchi *et al*. (2005)[203)]
167	Sakihikari	Hinohikari	Kinuhikari*	*cf. cv. Kinuhikari	Fukui PAES	2003	2006	13875	Good taste; lodging resistance	3119	Horiuchi *et al.* (2004)[35)]
168	LGC-Katsu	LGC-1*	89WPKG30-433**	*cf. cv. "LGC-1" (Appendix 1); **A mutant with 26Da globulin deletion induced by gamma ray irradiation to WPK	NARO (National Institute of Crop Science) and NIAS (IRB)	2004	2006	13871	Easy-to-digest protein 50 % decrease	3120	Nishimura *et al.* (2005)[124)]
169	LGC-Jun	LGC-1*	89WPKG30-433**	*cf. cv. "LGC-1" (Appendix 1); **A mutant with 26Da globulin deletion induced by gamma ray irradiation to WPK	NARO (National Institute of Crop Science) and NIAS (IRB)	2004	2006	13872	Easy-to-digest protein 50 % decrease	3121	Nishimura *et al*. (2005)[124)]
170	Hana-omoi	Yamada-nishiki	Hanafubuki*	*A descendant (the 2nd generation) of cv. Reimei	Aomori PAES	2002	2006	13863	Semi-dwarf	3122	Mikami *et al*. (2003)[102)]
171	Sai-no-kagayaki	Aichi No. 92 (Matsuribare)*	Tama-kei No. 88 (Sai-no-yume)**	*cf. cv. Matsuribare; **cf. cv. "Sai-no-yume"	Saitama PAFRI	2002	2005	12699		3123	Arakawa *et al.* (2003)[7)]
172	Sai-no-kirabiyaka	Aichi No. 92 (Matsuribare)*	Tama-kei No. 88 (Sai-no-yume)**	*cf. cv. Matsuribare; **cf. cv. "Sai-no-yume"	Saitama PAES	2002	2005	12700		3124	Arakawa *et al*. (2003)[7)]
173	Fuku-izumi	Saikai No. 199	Dontokoi*	*cf. cv. Dontokoi	NARO (NARC for Kyushu and Okinawa Region)	2004	2007	14889	Good taste; lodging resistance	3125	Kaji *et al*. (2006)[56)]
174	Ikuhikari	Etsunan No. 148	Hokuriku No. 148 (Dontokoi)*	*cf. cv. Dontokoi	Fukui PAES	2004	2007	14999	Good taste; lodging resistance	3126	Tomita *et al.* (2005)[182)]
175	Miya-yutaka	Nankai No. 133	Saikai No. 215 (Yawarakomachi)*	*cf. cv. Yawarakomachi	Miyazaki ARI	2004	2007	15000	Low amylose content	3127	Kato *et al*. (2006)[64)]
176	Aki-neiro	Koganebare	Milky Queen (Kanto No. 168)*	*A mutant cultivar with low amylose content induced by a chemical mutagen (NMU) + anther culture; cf. cv. "Milky Queen" (Appendix 1)	Kumamoto PARC	2001	2005	12566	Low amylose content	3128	Mitsukawa *et al*. (2002)[103)]
177	Seiki-wan	Koshihikari	Haenuki*	*A descendant (the 4th generation) of cv. Reimei	Mr. Masaki OIKAWA	1998	2003	11232	Semi-dwarf		
178	Komurasaki	Tohoku-mochi 149 gou	Tatsuko-mochi*	*A descendant (the 2nd generation) of cv. Reimei through cv. Akihikari	Akita PAES	2000	2004	11841	Semi-dwarf		Matsumoto *et al*. (2006)[96)]
179	Hikari-shinseiki	Kanto 79 gou*	Jikkoku	*A mutant line induced through gamma ray irradiation to the seed of cv. Koshihikari	Tottori University	1999	2004	12273	Semi-dwarf		Tomita (2006)[178)]
180	Kaze-naruko	Tsuyuhakaze	Ippon-jime*	*A descendant (the 2nd generation) of cv. Reimei through cv. Houhai	Kochi PARC	2001	2005	12563	Semi-dwarf		Mizobuchi *et al.* (2003)[107)]
181	Chigo-no-hoho	Wataboushi	Hagi-no-kaori*	*A descendant (the 3rd generation) of cv. Reimei through cv. Houhai	Niigata PAES	2001	2005	12702	Semi-dwarf		Kobayashi (2008)[73)]

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182	Ekkakou	Todoroki-wase	Hagi-no-kaori*	*A descendant (the 3rd generation) of cv. Reimei through cv. Houhai	Niigata PAES	2001	2005	12703	Semi-dwarf		Kobayashi (2008)[73]
183	Koshiguruma	Hokkai 269 gou*	Niigata wase**	*A descendant of a mutant line "Tankei 2006", whose embryo is very large, that is induced through gamma ray irradiation to cv. Kinmaze; **A descendant (the 2nd generation) of cv. Reimei	Niigata PAES	2001	2005	12704	Large embryo		
184	Akita 63 gou	Oochikara*	Akita 39 gou	*A hybrid variety between 2 mutant lines, cf. cv. Oochikara	Akita PAES	2001	2005	12826			Kodama *et al*. (2014)[75]
185	Fukkura-momoko	Kinuhikari*	Koshihikari	*A mutant cultivar induced through gamma ray irradiation to cv. Koshihikari	Okayama PAES	2002	2005	13297	Good taste; lodging resistance		Hihara *et al.* (2004)[25]
186	Kinpika	An original line	Haenuki*	*A descendant (the 4th generation) of cv. Reimei	Ibigawa Kougyo Co. Ltd.	2002	2006	13636	Semi-dwarf		
187	Hana-hyogo	Hatsugozen	Kinuhikari*	*cf. cv. Kinuhikari	Hyogo PARC	2002	2006	13742	Good taste; lodging resistance		
188	Fuyu-geshiki	Yamagata 40 gou*	Ao-kei 113 gou**	*A descendant (the 3rd generation) of cv. Reimei through cv. Akihikari; **A descendant (the 3rd generation) of cv. Reimei	Aomori PAES	2002	2006	13867	Semi-dwarf		Mikami *et al.* (2004)[99]
189	Koma-no-mai	Yamagata 40 gou*	Fu-kei 164 gou**	*A descendant (the 3rd generation) of cv. Reimei through cv. Akihikari; **A descendant (the 3rd generation) of cv. Reimei through cv. Akihikari	Aomori PAEX	2003	2006	13874	Semi-dwarf		Sunohara *et al*. (2004)[158]
190	Yume-mirai	Yume-gokochi*	Yume-kahori**	*A mutant cultivar induced through a protoplast somaclonal variation from cv. Koshihikari; **A mutant cultivar induced through a protoplast somaclonal variation from cv. "Tsuki-no-hikari"	Plantec Research Institute Ltd.	2003	2006	14036	Low amylose content		
191	Tenshi-no-uta	Saikai 201 gou*	Kanto 165 gou**	*A descendant of cv. "Mine-asahi"; **A descendant of cv. Kinuhikari	Saga PARC	2001	2006	14296	Good taste; lodging resistance		
192	Yume-ikkon	Hokuriku 160 gou*	Yume-tsukushi**	*A descendant (the 3rd generation) of cv. Reimei through cv. "Niigata-wase"; **A descendant (the 2nd generation) of cv. Kinuhikari	Fukuoka PAES	2002	2006	14525	Semi-dwarf; good taste; lodging resistance		Hamachi *et al.* (2004)[20]
193	Nasuhikari	Koshihikari	Aichi 87 gou*	* A descendant of cv. "Mine-asahi"	Tochigi PAES	2004	2007	14775			Izawa *et al.* (2005)[53]
194	Hyogo-yume-otome	Kinuhikari*	Aoi-no-kaze	*cf. cv. Kinuhikari	Hyogo PARC	2003	2007	14776	Good taste; lodging resistance		
195	Chiba 28 gou	Chubu 64 gou*	Fusa-otome	*A descendant of cv. "Mine-asahi"	Chiba PARC	2003	2007	14882			Nishikawa *et al.* (2006)[123]
196	Koi-honoka	An original line	Yamauta*	*A descendant (the 3rd generation) of cv. Reimei through cv. Akihikari	Aomori PAES	2004	2007	14884	Semi-dwarf		Mikami *et al.* (2007)[101]
197	Yuki-no-hana	Oshimako180*	Kakehashi	*A hybrid between cv. Reimei and a mutant line of "Nihon-masari"	Aomori PAES	2003	2007	14886	Semi-dwarf		Sunohara *et al*. (2007)[157]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
198	Yume-aoba	An indica-japonica hybrid line	Fukuhibiki*	*A descendant (the 4th generation) of cv. Reimei	NARO Hokuriku ARC	2004	2007	14887	Semi-dwarf		Miura *et al.* (2006)[105]
199	Nishi-aoba	Oochikara*	Hitohana	*cf. cv. Oochikara	NARO Kyushu Okinawa ARC	2004	2007	14888	Semi-dwarf	3325	Tamura *et al*. (2007)[171]
200	Dewa-no-sato	Gin-fubuki	Dewa-sansan*	*cf. "Dewa-sansan": a descendant of cv. Reimei (the 3rd generation) through cv. Hanafubuki and cv. "Miyama-nishiki" (the 2nd generation)	Yamagata PAES	2004	2007	15119	Semi-dwarf	3361	Yuki *et al*. (2006)[215]
201	Sato-no-yuki	Shou 1658*	Yamagata 63 gou**	*A descendant of a somaclonal variation from the anther culture of cv. "Akita-komachi"; **A descendant of cv. Kinuhikari	Yamagata PAES	2004	2007	15534	Good taste; lodging resistance		
202	Lake 65	Hinohikari	Kinuhikari*	*cf. cv. Kinuhikari	Shiga PAES	2004	2008	16011	Good taste; lodging resistance		Nakagawa *et al.* (2005)[115]
203	Yukinko-mai	Doman-naka*	Yukinosei	*A descendant (the 2nd generation) of cv. "Mine-asahi"; a descendant (the 3rd generation) of cv. Reimei	Niigata PAES	2004	2008	16012	Semi-dwarf		Ishizaki *et al.* (2008)[47]
204	Fuku-okoshi	Hoso-omote*	Fukuhibiki**	*A descendant of cv. "Shinano-sakigake", a mutant through gamma ray irradiation to cv. Toyonishiki; **A descendant (the 4th generation) of cv. Reimei	Nagano PAES	2004	2008	16288	Semi-dwarf		
205	Yume-kanae	LGC1*	Hitomebore	*cf. cv. LGC1 (Appendix 1)	Chiba PARC	2004	2008	16289	Low glutelin content in the grain		
206	Awayuki-komachi	Ouu 343 gou*	Dewahikari**	*A descendant (the 1st generation) of cv. Reimei; **A descendant (the 3rd generation) of cv. Reimei	Akita PAES	2002	2008	16290	Semi-dwarf		Kodama *et al*. (2010)[76]
207	Himuka-mochi	Mine-no-yuki-mochi*	Miyazaki-mochi	*A descendant of cv. Reimei through cv. Hayahikari	Miyazaki PAES	2005	2008	16466	Semi-dwarf		
208	Donpishyari	Gan-nan 7 gou	Fu-kei 179 gou*	*A descendant (the 4th generation) of cv. Reimei through cv. Hatsukogane	Iwate PAES	2005	2008	16604	Semi-dwarf		Tamura *et al.* (2007)[170]
209	Akimasari	Manpuku-mochi	Akisayaka*	*A descendant (the 2nd generation) of cv. Kinuhikari through cv. Dontokoi	NARO Kyushu Okinawa ARC	2006	2008	16606	Good taste; lodging resistance		Sakai *et al*. (2006)[138]
210	Ayu-no-hikari	EM5*	Fukuhibiki**	*A mutant induced through NMU treatment to cv. Kinmaze; **A descendant (the 4th generation) of cv. Reimei	NARO Hokuriku ARC	2005	2008	16607	Semi-dwarf		Miura *et al*. (2007)[104]
211	Kinumusume	Kinuhikari*	Matsuribare**	*cf. cv. Kinuhikari; **A descendant of cv. "Mine-asahi"	NARO Kyushu Okinawa ARC	2005	2008	16609	Good taste; lodging resistance		Kaji *et al.* (2009)[57]
212	Beko-aoba	Oochikara*	Saikai 203 gou	*cf. cv. Oochikara	NARO Tohoku ARC	2005	2008	16610		3320	Nakagomi *et al.* (2006)[116]
213	Nikomaru	Kinumusume*	Hokuriku 174 gou**	*A descendant of cv. Kinuhikari; **A descendant of cv. Kinuhikari through cv. Dontokoi	NARO Kyushu Okinawa ARC	2005	2008	16611			Sakai *et al*. (2010)[140]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
214	Hikarikko	Koshihikari	Reimei*	*cf. cv. Reimei (Appendix 1); A mutant cultivar induced through a gamma ray irradiation to cv. Fujiminori	Mr. Masayuki MURAI		2009	18110	Semi-dwarf		
215	Nangoku-sodachi	Kouiku 30 gou*	Kou-kei 265**	*A descendant of cv. Reimei through cv. Hayahikari; **A descendant of cv. "Katsura-wase", cf. cv. "Katura-wase"	Kochi PARC		2009	18117	Semi-dwarf		Takata *et al*. (2005)[166)]
216	Satsuma-yuki-mochi	Mine-no-yuki-mochi*	KG Mochi 102	*A descendant (the 3rd generation) of cv. Reimei through cv. Hayahikari (the 1st generation)	Kagoshima Prefectural Institute for Agricultural Development		2009	18117	Semi-dwarf		Wakamatsu *et al*. (2007)[200)]
217	Mine-no-yuki-mochi	Ouu 302 gou*	Himeno-mochi	*A descendant (the 2nd generation) of cv. Reimei	Hokuriku NAES	1991	1995	4231	Semi-dwarf		Shimizu *et al*. (1993)[151)]
218	Massigura	Ouu 341 gou	Yamagata 40 gou*	*A descendant (the 4th generation)of cv. Reimei through cv. Akihikari	Aomori Prefectural Industrial Technology Research Center		2009	18348	Semi-dwarf		
219	New Hikari	Etsunan 148 gou	Milky Queen (Kanto No. 168)*	*cf. cv. "Milky Queen" (Appendix 1)	Fukui PAES		2009	18349	Low amylose content		Tomita *et al.* (2007)[181)]
220	Hoshimaru	Kami-iku 428 gou	Kuiku 159 gou*	*A descendant (the 4th generation) of cv. Hayamasari through cv. Ishikari	Hokkaido Prefectural Kamikawa Agricultural Experiment Station		2009	18350			
221	Moe-minori	Nankai 128 gou	Haenuki*	*A descendant (the 4th generation) of cv. Reimei through "Shonai 29 gou"	NARO Tohoku ARC		2009	18351	Semi-dwarf		Kataoka *et al*. (2007)[62)]
222	Tachi-aoba	Ha-kei 906*	An original line**	*A descendant (the 3rd generation) of cv. "Mine-asahi" through cv. Matsuribare; **A descendant (the 3rd generation) of cv. Kinuhikari	NARO Kyushu Okinawa ARC		2009	18352			Sakai *et al*. (2009)[139)]
223	Yuyake-mochi	Tatsuko-mochi*	Benigoromo**	*A descendant (the 2nd generation) of cv. Reimei through cv. Akihikari; **A descendant of cv. Reimei through cv. Fukuhibiki (the 4th generation)	NARO Tohoku ARC		2009	18353	Semi-dwarf	3356	Kataoka *et al*. (2007)[61)]
224	Kareimai	Miyan 23 gou	Akihikari*	*A descendant (the 1st generation) of cv. Reimei	NARO Hokuriku ARC		2009	18473	Semi-dwarf		Shigemune *et al*. (2011)[150)]
225	Koyuki-mochi	Wataboushi	Yamagata mochi 55 gou*	*A descendant (the 4th generation) of cv. Reimei through cv. "Kaguya--mochi"	Yamagata PAES		2009	18546	Semi-dwarf		Chuba *et al*. (2007)[9)]
226	Sue-akari	Aoi-no-kaze	Milky Queen (Kanto No. 168)*	*cf. cv. "Milky Queen" (Appendix 1)	Mr. Jiro OZEKI		2008	16008	Low amylose content		
227	Ayanatsuki	Aya*	An original line	*cf. "Aya" (NM391/Ishikari); (the 2nd generation of a gamma ray induced endosperm mutant "NM391"	Kagoshima PAES		2008	16010	Low amylose content		Wakamatsu *et al*. (2005)[199)]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
228	Mizuhonoka	LGC1*	Hyogo-kitanishiki**	*cf. cv. "LGC 1" (Appendix 1); **A descendant (the 4th generation) of cv. Reimei through cv. Nadahikari	NARO Kinki Chugoku Shikoku ARC		2010	19409	Low glutelin content in the grain; semi-dwarf		Iida *et al*. (2009)[40)]
229	Manpuku-mochi	Etsunan 144 gou	Fukuhibiki*	*A descendant (the 4th generation) of cv. Reimei	Fukui PAES		2010	19053	Semi-dwarf		Tomita *et al.* (2008)[179)]
230	Yukimusubi	Hatajirushi*	Higashi 810**	*A descendant (the 3rd generation)of cv. "Mine-asahi"; **A descendant (the 2nd generation) of cv. Reimei	Miyagi Prefectural Furukawa Agricultural Experiment Station		2010	19502	Tolerance to cold; semi-dwarf		Nagano *et al*. (2008)[109)]
231	Koujyu-muryou	Yume-gokochi*	Yume-kahori**	*cf. cv. "Yume-gokochi" (Appendix 1); **cf. cv. "Yume-kahori" (Appendix 1)	Katayama Kometen Co.		2010	18775			
232	Seto-no-niji	Hinohikari	Matsuribare*	*A descendant (the 1st generation) of cv. "Mine-asahi"	Yamaguchi Technology Center for Agriculture and Forestry		2010	19691			Hajima *et al*. (2010)[16)]
233	Aki-matsuri	Yamahikari	Matsuribare*	*A descendant (the 1st generation) of cv. "Mine-asahi"	Yamaguchi Technology Center for Agriculture and Forestry		2010	19692			Hajima *et al*. (2012)[15)]
234	Yume-sorara	Koshihikari	Akihikari*	*A descendant (the 1st generation) of cv. Reimei	Tottori PAES		2010	18780	Semi-dwarf		
235	Tenryu-otome	Inahikari*	Matsuribare**	*, **A descendant (the 1st generation) of cv. "Mine-asahi"	Nagano PAES		2010	19267			
236	Takane-murasaki	Kaguya-mochi*	Tohoku mochi 149 gou	*A descendant (the 4th generation) of cv. Reimei	Nagano PAES		2010	19045	Semi-dwarf		
237	Kinuhikari-Saitama SBL	Kinuhikari*	Sai-no-kagayaki**	*cf. cv. Kinuhikari; ** A descendant of cv. "Mine-asahi"	Saitama PAES		2010	19049	Good taste; lodging resistance		Arakawa *et al*. (2008)[6)]
238	Mine-no-murasaki	An original line	Asamurasaki*	*A descendant (the 5th generation) of cv. Reimei through cv. Fukuhibiki	Aichi PAES		3010	19055	Semi-dwarf		Saka *et al*. (2007)[137)]
239	Beko-gonomi	An original line*	Fukuhibiki**	*A descendant (the 4th generation) of cv. Reimei; **A descendant (the 4th generation) of cv. Reimei	NARO NARC Tohoku Reg.		2010	19355	Semi-dwarf		Nakagomi *et al.* (2008)[117)]
240	Yume-matsuri	Asahi-no-yume*	Daichi-no-kaze**	*, **A descendant of cv. "Mine-asahi"	Aichi PAES		2010	19357			Kato *et al*. (2008)[65)]
241	Ishikawa Sake 52 gou	An original line	Ippon-jime*	*A descendant (the 2nd generation) of cv. Reimei through cv. Houhai	Ishikawa PAES		2010	19695	Semi-dwarf		
242	Tomi-no-kaori	Yamadanishiki	Oyamanishiki*	*A descendant (the 2nd generation) of cv. "Miyama-nishiki", that was induced through gamma ray irradiation to cv. Takanenishiki (Appendix 1)	Toyama PAES		2010	19696			Ebitani *et al.* (2009)[10)]
243	Mini-hikari	Hikari-shinseiki*	An original line	*A descendant (the 3rd generation) of "Kanto 79 gou", that was induced through gamma ray irradiation (200 Gy) to the seed of cv. Koshihikari	Mr. Motonori TOMITA		2010	19985			

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
244	Sai-no-minori	Yumematsuri (Aichi 108 gou)*	Sai-no-kagayaki**	*A descendant of (G4 and G5, respectively) a gamma ray induced line "Kanto 79 gou" through cv. "Mine-asahi" and cv. Matsuribare; **A descendant (the 3rd generation) of "Kanto 79 gou" through cv. Matsuribare , a descendant (the 4th generation) of cv. Reimei	Saitama Pref. Agr. Forest. Res. Ctr.		2010	20027	Semi-dwarf		Ooka *et al* . (2009)[136)]
245	Koshi-no-kaori	Kinuhikari*	An indica-japonica hybrid back-crossed to Kinuhikari**	*, **cf. cv. Kinuhikari	NARO		2011	20349	Good taste; lodging resistance		Sasahara *et al* . (2013)[142)]
246	Shikibu-mochi	Asamurasaki (Ouu mochi 349 gou)*	Fu-kei mochi 170 gou	*A descendant (the 4th generation) of cv. Reimei through cv. Fukuhibiki	Aomori Prefectural Industrial Technology Research Center		2010	20030	Semi-dwarf		
247	Murasaki-no-kimi	Asamurasaki (Ouu mochi 349 gou)*	Fu-kei 176 gou	*A descendant (the 4th generation) of cv. Reimei through cv. Fukuhibiki	Aomori Prefectural Industrial Technology Research Center		2010	20031	Semi-dwarf		
248	Ake-no-murasaki	Asamurasaki (Ouu mochi 349 gou)*	Silky Pearl (Ouu 354 gou)**	*A descendant (the 4th generation) of cv. Reimei through cv. Fukuhibiki; **cf. cv. "Silky Pearl"	Iwate ARC		2011	20710	Semi-dwarf		Takakusagi *et al.* (2008)[162)]
249	Gin-sayaka	Syun-yo (Hokuriku 183 gou)*	Gin-ginga (Iwate minami sake 13 gou)**	*A descendant (the 1st generation) of cv. "LGC1" (Appendix 1); **A descendant of cv. Reimei (Appendix 1) and cv. "Miyama-nishiki"	Iwate ARC		2011	20711	Semi-dwarf		
250	Aki-sakari	Awaminori (Hokuriku 159 gou)*	Etsunan 173 gou**	*A descendant (the 1st generation) of cv. Kinuhikari; **A descendant (the 1st generation) of both cv. Kinuhikari and a descendant (the 3rd generation) of cv. Reimei	Fukui PAES		2011	20431	Semi-dwarf		Tomita *et al* . (2009)[180)]
251	Kita-aoba	Yume-aoba (Hokuriku 187 gou)*	cv. "Hatsushizuku" and cv. "Nanatsuboshi"	*A descendant (the 4th generation) of cv. Reimei through cv. Fukuhibiki	NARO		2011	20615	Semi-dwarf		
252	Ushi-yutaka	Yume-akari (Ao-kei 125 gou)*	Kanto PL 12 (Tsu-kei 995 gou)**	*A descendant of cv. Reimei; **A descendant of cv. Reimei through cv. "Musashi-kogane"	Aomori Prefectural Industrial Technology Research Center		2011	20530	Semi-dwarf		Maeda *et al* . (2008)[87)]
253	Murasaki-koboshi	Kanto 195 gou	Asamurasaki*	*A descendant (the 4th generation) of cv. Reimei through cv. Fukuhibiki	NARO NARC Tohoku Reg.		2011	20714	Semi-dwarf		Kataoka *et al* . (2010)[63)]
254	Nebari-yuki	Takitate (Tohoku 172 gou)*	Ao-kei 134 gou**	*A descendant (the 2nd generation) of cv. Reimei through "Ouu 343 gou"; **A descendant (the 3rd generation) of cv. Reimei through cv. Akihikari	Aomori Prefectural Industrial Technology Research Center		2011	20533	Semi-dwarf		Kon *et al* . (2008)[80)]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
255	Saga-biyori	Tenshi-no-uta*	Aichi-no-kaori SBL**	*A descendant of both cv. "Mine-asahi" (the 3rd generation) and cv. Kinuhikari (the 2nd generation); **A descendant (the 3rd generation) of cv. "Mine-asahi"	Saga PARC		2011	20775			Hirota *et al*. (2012)[29)]
256	Genki-tsukushi	Tsukushi-roman (Chikushi 46 gou)*	Tsukushi wase**	*A descendant (the 2nd generation) of cv. Kinuhikari; **A descendant (the 2nd generation) of cv. Kinuhikari	Fukuoka PAES		2011	20744	Good taste; lodging resistance		Wada *et al.* (2010)[198)]
257	Tsubu-yutaka	An original line	Fukuhibiki*	*A descendant (the 4th generation) of cv. Reimei	Iwate ARC		2011	20716	Semi-dwarf		Abe *et al.* (2009)[1)]
258	Akidawara	Mirenishiki (Kanto 188 gou)	Ikuhikari (Etsunan 176 gou)*	*A descendant (the 2nd generation) of cv. Kinuhikari through cv. Dontokoi	NARO National Institute of Crop Science		2011	20717	Good taste; lodging resistance		Ando *et al.* (2011)[5)]
259	Milky Star	Tohoku 168 gou*	Milky Princess (Tohoku 194 gou)**	*A descendant (the 4th generation) of cv. Reimei through cv. Akihikari; **A descendant (the 1st generation) of cv. "Milky Queen" (Appendix 1)	NARO National Institute of Crop Science		2011	20718	Low amylose content		Ishii *et al.* (2012)[44)]
260	Milky Summer	Wa-kei 243	Milky Queen (Kanto No. 168)*	*cf. cv. "Milky Queen" (Appendix 1)	NARO National Institute of Crop Science		2011	20745	Low amylose content		
261	Kinefuri-mochi	Mine-no-yuki-mochi*	Kokonoe-mochi	*A descendant (the 3rd generation) of cv. Reimei through cv. Hayahikari	Gifu PAES		2011	20945	Semi-dwarf		Hirose *et al.* (2010)[27)]
262	Mina-yutaka	Fuyu-geshiki*	Fu-kei 186 gou**	*A descendant (the 4th generation) of cv. Reimei through cv Akihikari; **A descendant (the 3rd generation) of cv. Reimei through cv. Akihikari	Aomori Prefectural Industrial Technology Research Center		2011	20913	Semi-dwarf		Ono *et al*. (2009)[135)]
263	Maki-mizuho	Hoshi-aoba*	Kusa-yutaka**	*A descendant (the 1st generation) of cv. Oochikara; ** A descendant of cv. Oochikara	NARO Kyushu Okinawa ARC and JIRCAS		2011	21175	Semi-dwarf		
264	Mogu-mogu-aoba	Hoshi-aoba*	Mizuho-chikara**	*A descendant (the 1st generation) of cv. Oochikara; **A descendant (the 3rd generation) of cv. Reimei through cv. Akihikari	NARO Kyushu Okinawa ARC and JIRCAS		2011	20915	Semi-dwarf		
265	Hime-gonomi	Milky Queen*	Chugoku 169 gou	*cf. cv. "Milky Queen" (an NMU induced mutant cultivar) (Appendix 1)	NARO NARC for Western Region and JIRCAS		2012	21717	Low amylose content		Iida *et al*. (2011)[39)]
266	Yamadawara	Izumi 348*	Kanto 192 gou**	*A descendant (the 5th generation) of cv. Reimei through cv. Akihikari; **A descendant (the 3rd generation) of cv. Kinuhikari through cv. Dontokoi	NARO National Institute of Crop Science and JIRCAS		2014	23197	Semi-dwarf		
267	Kita-aoba	Yume-aoba (Hokuriku 187 gou)*	Nanatsuboshi (Kuiku 163 gou)	*A descendant (the 5th generation) of cv. Reimei through cv. Fukuhibiki	NARO Hokuriku ARC		2011	20615	Semi-dwarf		
268	Tsukuba SD2 gou	An original line	Milky Queen*	*cf. cv. "Milky Queen": an NMU induced mutant cultivar (Appendix 1)	Plant Genome Center Co. Ltd.		2012	21431	Low amylose content		
269	Torihime	Kan-no-mai*	Gyokuei	*A descendant (the 1st generation) of cv. "Miyama-nishiki"	Tottori PAES		2012	21383			

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
270	Yuki-asobi	An original line	Yume-akari*	*A descendant (the 5th generation) of cv. Reimei	Aomori Prefectural Industrial Technology Research Center		2012	21433	Semi-dwarf		Kobayashi *et al*. (2010)[74)]
271	Natsu-aoba	Yume-aoba (Hokuriku 187 gou)*	Akichikara**	*A descendant (the 5th generation) of cv. Reimei through cv. Fukuhibiki; **A descendant (the 2nd generation) of cv. Reimei	NARO Hokuriku ARC		2012	21434	Semi-dwarf		Nagaoka *et al*. (2013)[112)]
272	Jyugemu	Yume-ikkon*	Yamadanishiki	*A descendant of both cv. Reimei and cv. Kinuhikari	Mr. Norimitsu KAWAMURA		2012	22025	Semi-dwarf		
273	Niigata-Jiro	Akihikari*	Niigata 11 gou	*A descendant (the 1st generation) of cv. Reimei	Niigata PAES		2013	22426	Semi-dwarf		Ishizaki *et al*. (2014)[48)]
274	Kin-no-megumi	Okini-iri*	Asominori	*A descendant (the 4th generation) of cv. Reimei	NARO, Toyo Rice Co. Ltd.		2013	22530	Semi-dwarf		Kaji *et al.* (2013)[55)]
275	Harumi	Koshihikari	Kinuhikari*	*cf. cv. Kinuhikari	Japan Agricultural Co-operatives (JA)		2014	22985	Good taste; lodging resistance		
276	Rakufumai	Dontokoi*	Gohyaku-mangoku	*A descendant (the 1st generation) of cv. Kinuhikari	NARO ARC		2014	23198	Good taste; lodging resistance		
277	Tachi-ayaka	Hoshi-aoba*	An original line	*A descendant (the 2nd generation) of "BG1" through cv. Oochikara	NARO Kinki Chugoku Shikoku ARC		2014	23275	Semi-dwarf		
278	Haigokoro	Milky Princess*	An original line	*A descendant (the 1st generation) of cv. "Milky Queen"	NARO Kinki Chugoku Shikoku ARC		2014	23276	Low amylose content		Ishii *et al*. (2013)[45)]
279	Sato-no-shirayuki	Hokuriku mochi 175 gou*	Aneko-mochi**	*,**A descendant (the 3rd generation) of cv. Reimei	NARO ARC		2014	23429	Semi-dwarf		
280	Yume-no-mai	Koimusubi (Tohoku 160 gou)*	Syu 6084**	*A descendant (the 3rd generation) of "Kanto 79 gou" through cv. "Mine-asahi"; ** A descendant (the 2nd generation) of cv. Kinuhikari	NARO Agricultural Research Center		2014	23320	Good taste; lodging resistance		
281	Tochigi-no-hoshi	Tochigi 11 gou	Nasuhikari (Tochigi 7 gou)*	*A descendant of both "Kanto 79 gou" through cv. "Mine-asahi" (the 5th generation) and cv. Reimei (the 4th generation)	Tochigi PAES		2015	24269	Semi-dwarf		Yamazaki *et al.* (2012)[211)]
282	Kazusa 1 gou	Koshihikari Kazusa 9 gou	Milky Queen (Kanto No. 168)*	*cf. cv. "Milky Queen" (Appendix 1)	Honda Motor Co., Ltd.		2015	24336	Low amylose content		
283	Koshi-izumi	Hikari-shinseiki*	Yutaka-Koshihikari	*A descendant (the 5th generation) of "Kanto 59 gou"	Tottori University and Shizuoka University		2015	23807			
284	Pikamaru	Kanto 221 gou*	Nikomaru (Saikai 250 gou)**	*A descendant of cv. "Milky Queen" through cv. "Milky Princess"; **A descendant of cv. Kinuhikari	NARO Kyushu Okinawa ARC		2015	24270	Low amylose content; good taste; lodging resistance		

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
285	Konadamon	Hinohikari	Houiku 5 gou*	*A hybrid between an EI induced mutant cv. "LGC1" and a gamma ray induced mutant line "89WPKG30-433)	NARO Kyushu Okinawa ARC		2015	24337	Low digestible protein content (low glutelin content; low globulin content) and high non-digestible protein (prolamine) content		
286	Seto-no-kagayaki	Kinumusume (Saikai 232 gou)*	Yumematsuri (Aichi 108 gou)**	*cf. cv. Kinumusume; **cf. cv. Yumematsuri	NARO Kinki Chugoku Shikoku ARC		2015	24361	Good taste with lodging resistance		
287	Emi-no-aki	Mine-haruka (Chubu 111 gou)*	Moeminori (Ouu 382 gou)**	*A descendant of "Kanto 79 gou" through cv. Mineasahi; **A descendant (the 5th generation) of cv. Reimei	NARO Tohoku ARC		2015	24271	Semi-dwarf		
288	Yume-fuwari	Takitate (Tohoku 172 gou)*	LGC-Katsu**	*A descendant (the 2nd generation) of cv. Reimei; **A descendant (the 1st generation) of cv. "LGC1"	NARO Tohoku ARC and JIRCAS		2015	24272	Semi-dwarf		
289	Tachi-hayate	An original line*	Hoshi-aoba (Chugoku 146 gou)**	*A descendant (the 1st generation) of cv. "Odoroki-mochi" (Appendix 1); **A descendant (the 3rd generation) of Taihou through cv. Oochikara	NARO National Institute of Crop Science		2015	24364			
290	Yamagata mochi 110 gou	Tatsuko-mochi (Akita mochi 45 gou)*	Oochikara**	*A descendant (the 2nd generation) of cv. Reimei through cv. Akihikari; **A descendant (the 2nd generation) of cv. Taihou	Yamagata PAES		2015	24457	Semi-dwarf		
291	Kiraho	Milky Princess*	Iwate 61 gou	*A descendant (the 1st generation) of cv. "Milky Queen" (Appendix 1)	Iwate ARC		2015	24582	Low amylose content		
292	Kin-no-ibuki	Takitate (Tohoku 172 gou)*	Mebae-mochi**	*A descendant (the 3rd generation) of cv. Reimei; **A descendant (the 2nd generation) of a NMU induced mutant line from cv. Kinmaze	Miyagi Prefectural Furukawa Agricultural Experiment Station		2015	24378	Semi-dwarf		
293	Yamagata 95 gou	Yamagata 59 gou*	Chura-hikari (Ouu 366 gou)**	*A descendant of cv. Reimei; **A descendant (the 4th generation) of "Kanto 79 gou" through cv. "Mine-asahi"	Yamagata PAES		2015	24454	Semi-dwarf		
294	Iwai-dawara	Ouu shi 394 gou	Beko-gonomi (Ouu shi 395 gou)*	*A hybrid between 2 descendants (both the 5th generation) of cv. Reimei	NARO National ARC for Tohoku Region		2015	24363	Semi-dwarf		
295	Hana-sayaka	Kuro 1900*	Gin-ginga (Gannan sake 13 gou)**	*A descendant of cv. Reimei; **A descendant of both cv. Reimei and cv. "Miyama-nishiki"	Aomori Prefectural Industrial Technology Research Center		2015	24456	Semi-dwarf		
296	Mine-no-hoshi	Akita-komachi*4/Mine-asahiRF*	Akita-komachi*4/(Chubu 111	*,**cf. cv. "Mine-asahi"	Aichi PAES		2015	24365			
297	Ginsan	Iwate 75 gou	Akita 63 gou*	*A descendant (the 3rd generation) of cv. Taihou through cv. Oochikara	Akita PAES		2015	28538			

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
298	Mineharuka	Chubu 100 gou*	cv. "Chiyo-nishiki" X "Kumo14252"	*A descendant (the 1st generation) of cv. "Aichi-no-kaori"	Aichi PAES		2010	19054			
Wheat		*Triticum aestivum* L.									
1	Akebono-mochi	Kinu-iroha	Tani-kei A6099*	*A mutant from EMS treatment to "Kanto No. 107"	NARC	2000	2000	8363	Extremely low amylose content	3129	Yamaguchi *et al*. (2003)[215]
2	Ibuki-mochi	Kinu-iroha	Tani-kei A6099*	*A mutant from EMS treatment to "Kanto No. 107"	NARC	2000	2000	8364	Extremely low amylose content	3130	Yamaguchi *et al*. (2003)[202]
3	Tama-izumi	Kan-kei w364	Kan-kei w361*	*A descendant (the 2nd generation) of gamma ray induced mutant cv. "Shiro-wase-komugi"	NARO (National Institute of Crop Science)	2002	2005	12962		3131	Fujita *et al*. (2004)[13]
4	Urara-mochi	Bandou-wase	Akebono-mochi *	*A descendant (the 1st generation) of EMS induced mutant line "Tani-kei A6099" from "Kanto 107 gou"	NARO (National Institute of Crop Science)		2009	18434			Fujita *et al.* (2007)[12]
5	Yume-shiho	Tamaizumi (Kanto w421)*	An original line	*A descendant (the 3rd generation) of gamma ray induced mutant cv. "Shiro-wase-komugi"	NARO (National Institute of Crop Science)		2010	19418			Kiribuchi-Otobe *et al*. (2009)[69]
6	Yume-akari	Haru-ibuki	Tamaizumi*	*A descendant (the 3rd generation) of gamma ray induced mutant cv. "Shiro-wase-komugi"	Aichi PAES		2014	23409			
Barley		*Hordeum vulgare* L.									
1	Nirasaki Nijo 8	Gamma No. 4*	34r127	*Gamma ray irradiation to "Kirin-cyoku No. 1"	Barley Research Center, Kirin Brewery Co., Ltd.	1967				1119	
2	Kawamizuki	U-kei H-83*	U-kei H-79**	*Gamma ray irradiation to cv. "Kanto-nakate-gold"; **Gamma ray irradiation to "Asahi No. 5"	Kyushu NAES	1979			Early maturing; short and tough culm; constantly high-yielding	1118	Tsuru *et al*. (1981)[184]
3	Tone-nijo	M4-66*	Nitta-kei 1	*Gamma ray irradiation to "Nitta-nijo No. 1"	Sapporo Breweries, Ltd.	1989	1989	1972		1164	
4	Masakado-mugi	Ea52*	Kanto-kawa No. 53	*Gamma ray irradiation to the plant of "Takebayashi-Ibaraki No. 1"	NARC	1989	1991	2688	Early maturing; resistant to stripe virus disease	1154	Makino *et al.* (1992)[91]
5	Komaki-nijo	(Nitta-kei 1×Tochi-kei 85)F2	M4-66*	*Gamma ray irradiation to "Nitta-nijo No. 1"	Sapporo Breweries, Ltd.	1996	1996	5066		3132	
6	Sayakaze	Kanto-kawa No. 70*	Kanto-kawa No. 68 (Suzukaze)	*"Ea52"×"Kanto-kawa No. 60"; "Ea52": Gamma ray irradiation to the plant of "Takebayashi-Ibaraki No. 1"	NARO (National Institute of Crop Science)		2003	14301	Stripe virus disease resistance	3133	Yoshioka *et al*. (2005)[214]
7	Sakitama nijo	Tone nijo (Nitta-kei 25)*	Yasu-kei 58	*A descendant (the 2nd generation) of gamma ray induced "M4-66" through cv. "Tone nijo"	Sapporo Breweries, Ltd.		2003	11235			
8	Kashima-goal	Sayakaze (Kanto kawa 78 gou)*	Kanto hadaka 78 gou	*A descendant (the 2nd generation) of Gamma ray induced disease resistant mutant "Ea52"	NARO Kinki Chugoku Shikoku NARC		2012	21880	Stripe virus disease resistance		

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
Soybean		*Glycine max* (L.) Merr.									
1	Nanbu-shirome	10kR-3-7 (Raiden)*	Kitami-nagaha	*cf. cv. Raiden (Appendix 1)	Tohoku NAES	1977			Medium-maturing	1593	Matsumoto *et al*. (1979)[95)]
2	Tomo-yutaka	Tohoku No. 52*	Kari-kei No. 102	*Raiden/"Toiku No. 109"	Tohoku NAES	1990	1991	2878		3134	Watanabe *et al*. (1990)[201)]
3	Ryuhou	Suzu-yutaka	Kari-kou 343*	*A descendant (the 2nd generation) of cv. Raiden	Tohoku NAES	1995	1997	5859		3135	Nakamura *et al.* (1996)[113)]
4	Suzu-no-ne	Kari-kei No. 244*	Kari-kei No. 221**	*A descendant (the 2nd generation) of cv. Raiden; **Named as cv. Kosuzu: cf. cv. Kosuzu (Appendix 1)	Tohoku NAES	1995	1998	6206		3136	Nakamura *et al*. (1996)[114)]
5	Eru-star (L-star)	Fuku-yutaka/Kyu-kou 506*	Mura-yutaka**	*Named as cv. Ichihime: cf. cv. Ichihime (Appendix 1); **cf. cv. "Mura-yutaka" (Appendix 1)	Kyushu NAES	2000	2001	8646		3137	Takahashi *et al.* (2003)[165)]
6	Suzu-sayaka	Suzu-yutaka	Kyu-kou 365F2(γ)-M4*	*A mutant line induced through Gamma ray irradiation to a hybrid between "Kanto 102 gou" and "Kan-kei 1 gou (later named as cv. Yumeyutaka)"	NARO (NARC for Tohoku Region)	2003	2006	14042	Complete absence of lipoxygenases	3138	Yumoto *et al.* (2006)[217)]
7	Suzu-kaori	Kari-kou 778F5*	Kosuzu**	*A progeny of cv. Kosuzu and "Kitsurin No. 13"; **cf. cv. Kosuzu	NARO (NARC for Tohoku Region)	1995	2007	15131		3139	Kono *et al.* (2006)[81)]
8	Kanto 100 gou	Enrei	En6500*	*A mutant line induced through EMS treatment to cv. Enrei	NARO (NARC)	2002	2005	13531	Supernodulating character	3412	Akao & Kouchi (1992)[3)]; Takahashi *et al*. (2003)[164)]
9	Olerich50	M23*	LOLL**	*A high oleic acid mutant line induced through X-ray irradiation to cv. Bay;**A hybrid of M5 x M24, both of which are low linoleic acid content mutant through X-ray irradiation to cv. Bay	Saga University	1996	2008	16459			
10	Kinu-sayaka	Karikei 508 gou*	Developed line	*A lipoxygenase free mutant induced through a gamma ray irradiation	NARO (NARC for Tohoku Region)	1995	2008	16460	All lipoxygenase free		Kato *et al*. (2007)[67)]
11	Kyo-shirotanba	Murasaki-zukin*	Tama-daikoku	*Gamma ray irradiated mutant cultivar: cf. cv. "Murasaki-zukin"	Kyoto Prefecture		2013	22491			
12	Satohonoka	Kanto 100 Gou*	Nanbu-shirome**	*EMS treated mutant: cf. "Kanto 100 gou"; **derived from cv. Raiden (Appendix 1)	Iwate University and Akita Prefectural University		2014	23737			
13	Takamaru	Fukuibuki	Kanto 100 gou*	*EMS treated super-nodulating mutant: cf. "Kanto 100 gou"	Iwate University and Akita Prefectural University		2014	23738	Supernodulating character		
14	Murasaki-zukin 3 gou	Murasaki-zukin 2 gou	Murasaki-zukin*	*Gamma ray induced mutant cultivar	Kyoto Prefecture		2015	23850			
15	Kogane-sayaka	Eru-star*	Sachi-yutaka	*cf. cv. Eru-star	NARO (National Institute of Crop Science)		2016	24955			
Rush		*Juncus effusus* L. var. *decipiens* Buchenau									
1	Hinomidori	Shimomasuda-zairai	Seto-nami*	*cf. cv. "Seto-nami" (Appendix 1)	Kumamoto PARC	1998	2001	9034	Long and many stems	3141	Nakazawa *et al.* (1999)[119)]

No.	Cultivar Name	Maternal Line	Paternal Line	Origin of Parental Line	Institution of Development	Dev. Year	Reg. Year	Reg. No.[a]	Mutant Characteristics Transferred	IAEA ID[b]	Reference
2	Suzukaze	Hinomidori*	An original line	*cf. cv. Hinomidori	Kumamoto PARC		2015	23967			Fushimizu *et al.* (2015)[14)]
Tomato		*Solanum lycopersicum* L.									
1	Kyoryoku-oogata-reikou	IRB301-31*×Sekai-ichi	(Anahu×Ichihara)×Sekai-ichi	*Gamma ray irradiation to a wild relative species	Musashi Breeding Station Co.	1984			Resistance to both TMV and crown and root rot	2222	
2	Kagyoku	Noh PL No. 4*	Noh PL No. 3	*Gamma ray irradiation to a wild relative species	National Institute of Vegetables	1984	1986	964	Resistance to crown and root rot	2223	Yamakawa *et al.* (1987)[205)]
3	Ryugyoku	Noh PL No. 5*	Noh PL No. 4**	*, **Gamma ray irradiation to a wild relative species	National Institute of Vegetables	1984	1986	965	Resistance to fusarium crown and root rot	2224	Yamakawa *et al* . (1987)[205)]
Egg plant		*Solanum melongena* L.									
1	Daijiro	Mutant of Daitaro*	Hiranasu	*Selected from anther culture	Kochi PARC	2000	2004	1185	Fruit shape; green skin color	3142	
Snapdragon		*Antirrhinum* L.									
1	Fuji Sweet Pink 1	A mutant of cv. Touen*	cv. Yukihime	*Colchicine treatment	Nihon Nohyaku Co., Ltd.	1993	1998	6398	Doubled chromosome number	3143	
Job's tear		*Coix ma-yuen* Roman.									
1	Hato-yutaka	Tohoku No. 1*	Oou No. 4**	*A progeny of a gamma-ray induced mutant line "TS-kei" from a foreign cultivar; **Gamma ray irradiation to "Okayama-zairai"	NARO（NARC for Tohoku Region）		2004			3144	Kato *et al.* (2007)[66)]
Japanese lawn grass		*Zoysia japonica* Steud.									
1	FLATZ	An original line	COPROS*	*A descendant (the 1st generation) of a somaclonal mutant through x-ray irradiation to a meristem callus	Kaisui Chemical Industry Co. Ltd.		2006	13648			

Note: Paternal and maternal line written in red are mutant lines or cultivars

[a]Reg. No. is the registration number of The Plant Variety Protection System in Japan

[b]IAEA ID is the variety ID number of the Joint FAO/IAEA Mutant Variety Database (https://mvd.iaea.org/#!Home)

Abbreviations:
ARC: Agricultural Research Center
ARI: Agricultural Research Institute
JIRCAS: Japan International Research Center for Agricultural Sciences
NAES: National Agricultural Experiment Station
NARC: National Agriculture Research Center
NARO: National Agriculture and Food Research Organization
PAES: Prefectural Agriculture Experiment Station
PARC: Prefectural Agriculture Research Center

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高リグナン含有ゴマ品種「にしきまる」の育成

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抄　録

「にしきまる」は、高リグナンゴマのバリエーションの充実を目的に、茨城県の在来種の金ゴマ「真瀬金」を母に、セサミンとセサモリン含量が高く粒色が褐色の「関東 12 号(ごまぞう)」を父とした交配組み合わせから育成された品種であり、以下の特徴を有する。

1．成熟期は金ゴマの在来種「真瀬金」と同程度で、高リグナン品種「ごまぞう」より約 2 週間程度早い。
2．草丈は「ごまぞう」と「真瀬金」より低く、分枝数は「真瀬金」より多く、「ごまぞう」と同程度である。
3．子実収量は「ごまぞう」より少ないが、「真瀬金」と同程度かやや多く、「まるえもん」と「まるひめ」よりも多い。
4．セサミンとセサモリン含量は「真瀬金」より高く、「まるひめ」と同程度である。
5．種皮色は「真瀬金」よりやや赤みのある黄褐色である。
6．関東以西の栽培に適する。

本品種は 2016 年から三重県と鹿児島県などの産地で栽培が始まっており、今後は金ゴマの特性を生かした機能性の高い商品の開発などによって国産ゴマの生産振興に役立つことが期待できる。

キーワード：金ゴマ、品種、リグナン、セサミン、セサモリン

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Breeding of the High-lignan Sesame Variety "Nishikimaru"

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Abstract

A new high-lignan sesame variety "Nishikimaru" was developed at the NARO Institute of Crop Science in 2015. "Nishikimaru" was selected from the progeny of a cross between "Masekin" and "Kanto12（Gomazou）" to improve high-lignan sesame. "Nishikimaru" has an earlier harvesting date than "Gomazou". The plant height of "Nishikimaru" is shorter than that of "Masekin" and "Gomazou", and it has more branches than "Masekin". The yield ability of "Nishikimaru" is similar to or higher than that of "Masekin" and lower than that of "Gomazou". "Nishikimaru" has a gold seed coat color, and contains higher levels of sesamin and sesamolin than "Masekin". "Nishikimaru" is adapted to the flatland from the Kanto region to the west of Japan.

Key Words : gold sesame, variety, lignan, sesamin, sesamolin

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Ⅰ　緒　　言

日本のゴマは戦後、水田畑作における換金作物として各地で栽培されていた。しかし、その後の経済成長下における農家人口減少に伴い、経営形態が多様化するなかで、ゴマ栽培は省力化への対応の遅れやその低収益性から敬遠され、近年では作付け面積は数百haまで減少し、ゴマの自給率は0.1%程度と推測されている（農林水産省 2007)。一方、消費者からは日本食への回帰や、セサミンやセサモリンに代表されるゴマリグナン類の健康機能性が注目され、日本におけるゴマの総需要量は年々増加し、およそ16万トンとなっている。この中、欧米や中国における需要の増大からゴマの需給は逼迫しており、中南米やアフリカ諸国から日本への輸入価格はトン当たり20万円を超え高騰している（農林水産 2016)。このため、実需者、消費者にとっても国産ゴマが魅力的な商品となり、各地のゴマ加工メーカーによる国産ゴマ商品は例年品薄の状態になっている。また、近年、各地で産地形成が進みゴマ単品でも6次産業化を推進している産地も見られる（大潟　2011)。

これまで、農業・食品産業技術総合研究機構次世代作物開発研究センター（旧作物研究所。以下、次世代作物開発研究センター）はゴマの高付加価値化を目指し、2002年に従来のゴマ商品にはない特徴としてセサミンとセサモリンを多く含んでいる新品種「ごまぞう」（安本ら　2003）を開発し、これは国産ゴマ復活に大きく貢献できる品種として期待された。「ごまぞう」は機能性に優れた国産ゴマとして消費者に受け入れられ、需要が伸びつつあるが、成熟期が遅いことや萎ちょう病に弱いことなどから、生産者からは成熟期が早く、病気に強い栽培特性の優れた品種が求められている。

食用ゴマには白ゴマ、黒ゴマの他、金ゴマ（種皮色が黄褐色のゴマ）が主として用いられ、それぞれの特色を生かしたゴマ商品が売り出されているが、中でも金ゴマは香りが高く味にコクがあることから人気がある。このため、次世代作物開発研究センターでは、セサミン、セサモリン含量の高い金ゴマ品種の育成を進め、「にしきまる」を育成した。「にしきまる」はセサミンとセサモリンを多く含む金ゴマであるので、商品化しやすい。また、「ごまぞう」よりも熟期が早く、萎ちょう病にも強い。次世代作物開発研究センターで育成されたセサミン含量の高い黒ゴマ品種の「まるえもん」やセサミンとセサモリン含量が高い白ゴマ品種の「まるひめ」（大潟ら　2013）より収量が多い。これらのことから「にしきまる」は国産ゴマの生産振興や産地形成に大きく貢献できると考えられる。本報告では「にしきまる」の育成経過及び特性について報告する。

本品種の育成にあたって、地域適応性試験を実施していただいた岩手大学、鳥取大学、九州沖縄農業研究センター、そして現地試験を実施していただいた長野県駒ケ根市、兵庫県西脇市、鹿児島県南さつま市金峰町の関係者の方々に多大なご協力をいただいた。また、加工試験や食味試験にご協力いただいた九鬼産業（株）、カタギ食品（株）の方々に厚く感謝する。なお、本品種の育成にあたって、選抜および生産力検定試験などの圃場試験は、中央農業総合研究センター業務3科および業務2科の支援により遂行したものである。ここに、深甚の謝意を表する。

Ⅱ　来歴及び育成経過

「にしきまる」は、高リグナン含量品種「ごまぞう」の特性である粒色が褐色な点、既存品種よりも晩生な点等を改良することを目的に、次世代作物開発研究センターにおいて、茨城県の在来品種の

金ゴマ「真瀬金」を母本、「関東12号（ごまぞう）」を父本として、2001年に交配した後代から育成した品種である（図1、表1）。

2002年には作物研究所において成熟期の早さについて集団選抜を行い、2003年には粒色が黄褐色の系統の選抜を行った。以後、系統育種法によりリグナン含量、農業特性を中心に選抜・固定を行った。2010年と2011年に生産力予備検定を行い、2012年からは「関東17号」の地方系統番号を付して生産力検定試験を行うとともに地域適応性試験に供試した。これらの試験から成績が優秀であると判断し、2015年6月に品種登録出願を行った。2014年における世代は F_{15} である。

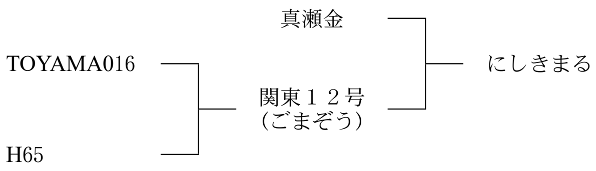

図１　「にしきまる」の系譜

表１　「にしきまる」の選抜経過

	年次世代	2001		2002	2003	2004	2005	2006	2007	2008
		F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
栽植	系統群数	2	2	2	1	2	2	1	1	1
	系統数	2	2	2	1	32	24	18	12	8
	個体数	5		364	360					
選抜	系統群数		世促	2	2	2	2	1	1	1
	系統数			2	2	20	16	14	10	8
	個体数			36	32	24	18	12	8	8

	年次世代	2009	2010	2011	2012	2013	2014
		F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
栽植	系統群数	1	1	1	1	1	1
	系統数	5	5	5	1	1	1
	個体数						
選抜	系統群数	1	1	1			
	系統数	4	4	4			
	個体数	5	5	5			

Ⅲ　特性概要

育成地において、表2と図2に示した耕種概要により、表3の調査方法に基づき生産力検定試験と特性検定試験を行った。種苗特性審査基準に従い、茨城県の在来品種「真瀬金」を標準品種、「ごまぞう」を対照品種とした調査結果に基づいて分類した「にしきまる」の特性を表4に示した。

「にしきまる」の伸育性は“無限型”、草丈は“中”で標準・対照品種と同程度かやや低い。茎の形状では分枝が「ごまぞう」と同じ“下位分枝型”で「真瀬金」の“無分枝型”と異なる。茎の毛が“やや疎”、第1果までの節数が「ごまぞう」と同じ“中”である。葉の形状では、葉身長、葉幅はそれぞれ“やや長”と“中”で「真瀬金」と同じで、葉身の緑色は“中”で対照・標準品種と

同じである。

花の形状は葉脈当たりの花数が「真瀬金」と同じ“2花以上（3花型）”で蜜腺はない。果実の形状は、対照・標準品種と同じで、“4房室型”である。

種皮の色は“黄褐”でセサミン含有量は「真瀬金」より多く、「ごまぞう」よりやや少ない“やや多”である。早晩性では、「ごまぞう」より早生、「真瀬金」と同等で、開花初めは“早”で、成熟期は“中”である（表4、写真1、写真2、写真3）。

表2　育成地耕種概要（つくば市観音台地区試験圃場）

試験年度	播種期（月．日）	畦間（cm）	株間（cm）	施肥量（kg/10a） N	P_2O_5	K_2O	面積（m^2/区）	反復数	マルチ
2012	6.5	80	15	4.8	7.2	4.8	12.8	3	黒色ビニル
2013	6.4	80	15	4.8	7.2	4.8	12.8	3	黒色ビニル
2014	6.3	80	15	4.8	7.2	4.8	12.8	3	黒色ビニル

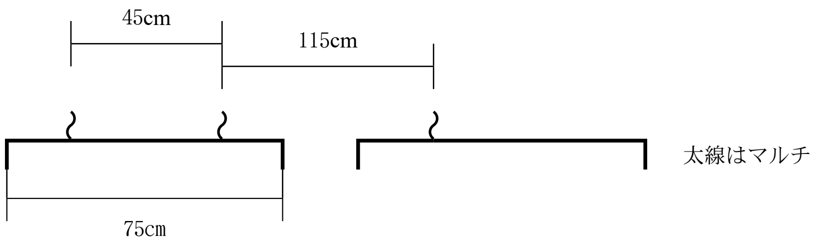

図2　マルチ栽培法概略図

表3　調査方法

項　目	調　査　方　法
開花期	開花した個体数が５０％に達した日
成熟期	蒴が裂開した個体数が５０％に達した日
草丈	成熟期における地際から茎頂までの高さ（１０－１２個体／区調査）
最下着朔高	成熟期における最も下部にある蒴までの高さ（１２個体／区）
分枝数	成熟期における主茎に着生した茎の本数（１０－１２個体／区）
主茎蒴数	成熟期における主茎に着生した朔の個数（１０－１２個体／区）
朔長	成熟期における蒴の基部から先端までの長さ（２個／個体×１０－１２個体／区）
子実収量	成熟期以降に刈り取り、乾燥、脱穀後、唐箕をかけた子実の重さ
千粒重	子実千粒の重さ（４抽出／区）
容積重	子実１００mlの重さ（４抽出／区）
ｾｻﾐﾝ含量	子実２０粒を磨砕し８０％エタノールで抽出したのちHPLCで計測（２抽出／区）。子実重当たりの含量
ｾｻﾓﾘﾝ含量	子実２０粒を磨砕し８０％エタノールで抽出したのちHPLCで計測（２抽出／区）。子実重当たりの含量
倒伏程度	成熟期における倒伏の発生程度について指数：０（無）から４（甚）で観測調査（試験区単位）
病害発生程度	成熟期における各病害の発生程度について指数：０（無）から４（甚）で観測調査（試験区単位）

表4　種苗特性分類

品種名	草姿		茎の形状				葉の形状					
	伸育性	草丈	分枝位置	茎毛密度	第1果まで節数	帯化有無	葉身長	葉幅	葉身長と葉幅比	複葉着生	葉身緑色	葉柄長
にしきまる	無限	中	下	やや疎	中	無	やや長	中	やや小	少	中	中
真瀬金（標準）	無限	中	無	中	少	無	やや長	中	小	少	中	長
ごまぞう（対照）	無限	中	下	中	中	無	やや長	やや狭	中	少	中	中

品種名	葉柄アントシアニン蓄積	花の形状					果実の形状				
		葉腋花数	蜜腺	花筒部ピンク濃さ	下唇先端ピンク濃さ	花筒部毛密度	蒴果房室数	蒴果長	蒴果幅	蒴果毛	蒴果の裂開
にしきまる	有	3花	無	中	中	中	4	中	中	中	有
真瀬金（標準）	有	3花	無	中	中	中	4	中	中	中	有
ごまぞう（対照）	有	1花	有	中	濃	中	4	中	中	中	有

品種名	種皮色	セサミン含有量	早晩性	
			開花始	成熟期
にしきまる	黄褐	やや多	早	中
真瀬金（標準）	黄褐	少	早	中
ごまぞう（対照）	褐	多	やや早	やや晩

平成17（2005）年3月作成の審査基準に基づく

写真1「にしきまる」（左）と「真瀬金」（右）の立毛草姿
（2014年9月3日撮影、つくば市観音台圃場）

写真２「にしきまる」（左）と「ごまぞう」（中）と「真瀬金」（右）の個体全図
（２０１４年９月２日撮影、つくば市観音台圃場）

写真３　「まるえもん」（左上）、「ごまぞう」（右上）
「まるひめ」（左下）、「にしきまる」（中下）、「真瀬金」（右下）の子実外観

Ⅳ　試験成績

１．育成地における試験成績

2012 − 2014 年の 3 年間実施した生産力検定試験の結果を表 5 から表 8 に示した。「にしきまる」の成熟期は「真瀬金」と同程度で、「ごまぞう」より 2 週間程度早かった。草丈は「真瀬金」より 12cm、「ごまぞう」より 13cm 低く、最下着蒴高は「真瀬金」より 18cm 高く、「ごまぞう」より 6cm 低かった。分枝数は「真瀬金」より多く、「ごまぞう」と同程度であった（表 5）。主茎蒴数は「ごまぞう」より多く、「真瀬金」より少なかった。子実収量は「真瀬金」と同程度かやや多いが、「ごまぞう」より少なかった。千粒重は「真瀬金」よりやや小さく、「ごまぞう」と同程度であった（表 6）。種皮色は「真瀬金」と同じ黄褐色であるが、やや赤みのある黄褐色であった（写真 3）。セサミン含量は「真瀬金」より多いが、「ごまぞう」よりやや少なかった。セサモリン含量は「真瀬金」より多く、「ごまぞう」と同程度であった（表 7）。

表５　育成地における生産力検定試験（生育特性）

品種・系統名	試験年度	開花期（月.日）	成熟期（月.日）	草丈（cm）	最下着蒴高（cm）	分枝数（本）
にしきまる	2012	7.28	9. 9	127	47	3.7
	2013	7.25	9. 5	149	50	3.1
	2014	7.21	9. 4	161	67	2.6
	平均	7.25	9. 6	146(92)	55(149)	3.1(310)
真瀬金	2012	7.24	9.11	128	31	0.9
	2013	7.24	9.10	171	35	1.0
	2014	7.21	9. 5	174	45	1.0
	平均	7.23	9. 9	158(100)	37(100)	1.0(100)
ごまぞう	2012	7.27	9.25	125	45	3.3
	2013	7.27	9.22	168	63	3.1
	2014	7.25	9.18	184	76	2.7
	平均	7.26	9.22	159(101)	61(165)	3.0(300)
まるえもん	2012	7.23	9. 4	103	32	4.0
	2013	7.22	9. 5	126	33	3.9
	2014	7.20	9. 3	133	38	3.7
	平均	7.22	9. 4	121	34	3.9
まるひめ	2012	7.19	8.28	120	34	4.3
	2013	7.20	8.28	123	40	4.9
	2014	7.18	8.27	143	46	5.2
	平均	7.19	8.28	129	40	4.6
岩手黒	2012	7.23	9.18	125	48	3.9
	2013	7.22	9.23	157	52	3.8
	2014	7.20	9.20	172	64	3.6
	平均	7.22	9.20	151	55	3.8
関東１号	2013	7.24	9. 1	143	60	4.7
	2014	7.22	9. 4	150	76	4.3
	平均	7.23	9. 3	147	68	4.5

括弧の数値は「真瀬金」を標準とした時の標準比。

表６　育成地における生産力検定試験（生産性・生産物特性）

品種・系統名	試験年度	主茎径 (mm)	主茎蒴数 (個)	子実収量 (kg/10a)	千粒重 (g)	容積重 (g/100ml)
にしきまる	2012	11.2	82	177	2.4	−
	2013	13.8	95	154	2.4	64.8
	2014	14.3	106	156	2.4	66.3
	平均	13.1(96)	94(83)	162(105)	2.4(96)	65.6
真瀬金	2012	11.8	90	165	2.5	−
	2013	14.0	124	173	2.5	65.4
	2014	15.0	125	127	2.4	66.4
	平均	13.6(100)	113(100)	155(100)	2.5(100)	65.9
ごまぞう	2012	11.2	39	203	2.4	−
	2013	13.7	61	161	2.4	65.1
	2014	14.8	70	170	2.4	65.7
	平均	13.2(97)	57(50)	178(115)	2.4(96)	65.4
まるえもん	2012	10.5	40	127	2.3	−
	2013	12.0	47	137	2.5	63.4
	2014	12.9	56	109	2.5	65.3
	平均	11.8	48	124	2.4	64.4
まるひめ	2012	9.5	39	131	2.1	−
	2013	10.2	33	94	2.1	62.9
	2014	14.5	42	140	2.2	64.2
	平均	11.4	38	122	2.1	63.6
岩手黒	2012	10.1	37	130	2.8	−
	2013	11.8	44	137	2.9	61.0
	2014	14.2	49	138	2.9	63.8
	平均	12.0	43	135	2.9	62.4
関東１号	2013	12.7	43	166	2.6	64.9
	2014	15.1	39	152	2.6	65.5
	平均	13.9	41	159	2.6	65.2

括弧の数値は「真瀬金」を標準としたときの標準比。

表７　育成地における生産力検定試験（生産性・生産物特性）

品種・系統名	試験年度	粒色	セサミン含量 (mg/g)	セサモリン含量 (mg/g)
にしきまる	2012	黄褐	6.0	3.1
	2013	黄褐	6.5	3.7
	2014	黄褐	7.0	3.8
	平均	黄褐	6.5(186)	3.5(152)
真瀬金	2012	黄褐	2.9	2.0
	2013	黄褐	3.4	2.2
	2014	黄褐	4.3	2.6
	平均	黄褐	3.5(100)	2.3(100)
ごまぞう	2012	褐	7.5	3.4
	2013	褐	7.4	3.6
	2014	褐	7.7	3.8
	平均	褐	7.5(214)	3.6(157)
まるえもん	2012	黒	9.8	0
	2013	黒	9.1	0
	2014	黒	10.5	0.4
	平均	黒	9.8	0.1
まるひめ	2012	白	6.4	3.7
	2013	白	5.5	3.4
	2014	白	6.3	3.6
	平均	白	6.1	3.6
岩手黒	2012	黒	0.5	0.8
	2013	黒	0.5	0.7
	2014	黒	0.9	0.9
	平均	黒	0.6	0.8
関東１号	2013	白	3.1	2.0
	2014	白	3.4	2.2
	平均	白	3.3	2.1

括弧の数値は「真瀬金」を標準としたときの標準比。

倒伏の発生は「真瀬金」よりやや多く、「ごまぞう」と同程度であった。萎ちょう病の発生は「真瀬金」と同程度で、「ごまぞう」より少なかった（表8）。

2013～2014年の2年間、栽培特性を明らかにするために標肥標植、標肥密植、多肥標植、多肥密植の4種類の試験を行った。生育調査及び収穫物調査の結果を表9、表10に示す。「にしきまる」は施肥量や栽植密度を変えても成熟期や草丈、最下着蒴高はあまり変わらなかったが、密植栽培では分枝数が少なくなった（表9）。子実収量と千粒重は栽植密度や施肥量を変えても変わらない

表8　育成地における生産力検定試験（倒伏および病害発生程度）

品種名	試験年度	倒伏（指数）	萎ちょう病（指数）
にしきまる	2012	1.0	0.2
	2013	2.5	0.5
	2014	0.3	0.3
	平均	1.3	0.3
真瀬金	2012	0.8	0.2
	2013	1.5	0.5
	2014	0.4	0.3
	平均	0.9	0.3
ごまぞう	2012	2.2	2.5
	2013	2.0	2.5
	2014	0.6	1.6
	平均	1.6	2.2

表9　育成地における栽培特性試験（施肥・栽植密度）における生育特性

栽培条件	品種名	試験年度	開花期（月.日）	成熟期（月.日）	草丈（cm）	最下着蒴高（cm）	分枝数（本）
標肥標植	にしきまる	2013	8.21	10. 2	137	51	2.6
		2014	7.22	9. 4	164	70	2.9
		平均	8. 6	9.18	150	61	2.8
	真瀬金	2013	8.19	10. 2	146	31	1.4
		2014	7.21	9. 6	173	49	2.0
		平均	8. 5	9.19	160	40	1.7
	ごまぞう	2013	8.21	10.14	146	57	3.2
		2014	7.26	9.18	171	80	2.7
		平均	8. 8	10. 1	158	69	3.0
標肥密植	にしきまる	2013	8.21	10. 3	134	55	2.1
		2014	7.22	9. 3	162	80	1.8
		平均	8. 6	9.18	148	68	1.9
	真瀬金	2013	8.18	10. 1	149	36	1.0
		2014	7.21	9. 7	166	64	0.4
		平均	8. 4	9.19	157	50	0.7
	ごまぞう	2013	8.22	10.15	146	62	1.8
		2014	7.26	9.14	167	77	1.9
		平均	8. 9	9.30	157	69	1.9
多肥標植	にしきまる	2013	8.24	10. 3	135	51	2.6
		2014	7.21	9. 3	165	67	2.7
		平均	8. 7	9.18	150	59	2.7
	真瀬金	2013	8.20	10. 2	146	36	1.0
		2014	7.21	9. 6	171	50	0.9
		平均	8. 5	9.19	159	43	1.0
	ごまぞう	2013	8.23	10.13	150	59	2.5
		2014	7.27	9.23	180	82	2.2
		平均	8.10	10. 3	165	70	2.4
多肥密植	にしきまる	2013	8.23	10. 2	131	54	2.5
		2014	7.22	9. 4	168	79	1.7
		平均	8. 7	9.18	149	66	2.1
	真瀬金	2013	8.20	9.30	152	35	0.7
		2014	7.21	9. 6	179	67	0.6
		平均	8. 5	9.18	165	51	0.7
	ごまぞう	2013	8.25	10.15	144	64	1.3
		2014	7.26	9.18	177	93	1.8
		平均	8.10	10. 2	160	79	1.6

多肥区では基肥が標肥区の1.5倍。密植区では標植区が1本立てであるのに対して2本立てである。

が、セサミン含量とセサモリン含量は密植区でやや低くなった（表 10）。また、播種期試験（標播と晩播）を行い、結果を表 11 と表 12 に示した。「にしきまる」は晩播すると収量がかなり低くなり、セサミン、セサモリン含量が低くなり（表 11）、オレイン酸含量が低くなった（表 12）。晩播では標播より種皮色が濃くなる傾向があった（写真 4）。

固定度調査の結果より、開花期、成熟期、草丈、最下着蒴高、主茎蒴数、分枝数、千粒重、セサミン含量、セサモリン含量の平均値および変異係数より、「にしきまる」は実用的に十分固定していると推定できた（表 13）。

表 10　育成地における生産力検定試験（倒伏および病害発生程度）

栽培条件	品種名	試験年度	収量 (kg/10a)	千粒重 (g)	ｾｻﾐﾝ含量 (mg/g)	ｾｻﾓﾘﾝ含量 (mg/g)	倒伏程度	萎ちょう病発病指数
標肥標植	にしきまる	2013	106	2.3	6.2	4.2	2.5	0.5
		2014	159	2.4	7.4	4.1	0.5	0.0
		平均	132	2.3	6.8	4.2	1.5	0.3
	真瀬金	2013	125	2.4	3.7	2.6	1.5	0.5
		2014	158	2.4	3.6	2.5	0.5	0.5
		平均	141	2.4	3.7	2.5	1.0	0.5
	ごまぞう	2013	82	2.4	7.7	4.2	2.0	2.5
		2014	115	2.2	8.8	3.9	0.5	2.0
		平均	99	2.3	8.3	4.1	1.3	2.3
標肥密植	にしきまる	2013	109	2.3	6.4	4.1	2.0	0.0
		2014	153	2.4	6.9	3.9	0.5	0.5
		平均	131	2.3	6.6	4.0	1.3	0.3
	真瀬金	2013	141	2.3	3.7	2.5	2.0	0.0
		2014	174	2.4	3.9	2.1	0.5	0.5
		平均	158	2.4	3.8	2.3	1.3	0.3
	ごまぞう	2013	110	2.5	7.5	4.3	3.0	1.5
		2014	95	2.2	8.6	3.8	0.0	2.5
		平均	103	2.3	8.1	4.0	1.5	2.0
多肥標植	にしきまる	2013	100	2.2	6.2	4.2	2.0	0.0
		2014	169	2.4	7.2	4.1	0.0	0.5
		平均	134	2.3	6.7	4.1	1.0	0.3
	真瀬金	2013	131	2.4	3.8	2.6	2.0	0.5
		2014	156	2.5	3.7	2.4	0.0	0.0
		平均	143	2.4	3.7	2.5	1.0	0.3
	ごまぞう	2013	67	2.4	7.4	4.1	3.0	3.5
		2014	142	2.3	8.7	4.2	0.5	1.0
		平均	104	2.4	8.1	4.1	1.8	2.3
多肥密植	にしきまる	2013	96	2.3	6.0	4.0	2.0	0.0
		2014	176	2.4	7.2	4.0	0.0	0.0
		平均	136	2.4	6.6	4.0	1.0	0.0
	真瀬金	2013	137	2.4	3.8	2.6	1.5	0.5
		2014	183	2.5	3.9	2.5	0.5	0.0
		平均	160	2.4	3.9	2.5	1.0	0.3
	ごまぞう	2013	71	2.5	7.8	4.2	3.0	1.5
		2014	105	2.2	8.9	3.8	1.5	1.0
		平均	88	2.3	8.4	4.0	2.3	1.3

多肥区では基肥が標肥区の1.5倍。密植区では標植区が1本立てであるのに対して2本立てである。

表 11　育成地における栽培特性試験（播種期）の特性

品種名	試験年度	播種期（月.日）	成熟期（月.日）	子実重(kg/10a)	セサミン含量(mg/g)	セサモリン含量(mg/g)
にしきまる	2013	6. 3	9.18	159	6.6	4.2
	2014	6. 4	9. 6	173	6.8	5.0
	平均		9.12	166	6.7	4.6
ごまぞう	2013	6. 3	10. 5	124	7.9	4.0
	2014	6. 4	9.22	132	8.7	4.3
	平均		9.29	128	8.3	4.2
にしきまる	2013	6.28	10. 3	83	6.2	4.0
	2014	7. 3	10. 1	52	6.3	4.7
	平均		10. 2	68	6.3	4.4
ごまぞう	2013	6.28	10.16	87	7.4	4.2
	2014	7. 3	10. 8	59	7.4	4.7
	平均		10.12	73	7.4	4.5

表 12　育成地における栽培特性試験（播種期）の品質特性

品種名	試験年度	播種期（月.日）	総脂肪酸含量(g/100g seed)	脂肪酸組成(%)			
				パルミチン酸	ステアリン酸	オレイン酸	リノール酸
にしきまる	2014	6. 4	52.0	6.8	4.2	36.8	40.3
ごまぞう	2014	6. 4	53.3	7.7	4.6	32.7	47.3
にしきまる	2014	7. 3	53.6	6.6	3.8	36.1	41.6
ごまぞう	2014	7. 3	48.7	6.8	4.4	31.3	45.0

写真４　播種期を異にする「にしきまる」の種皮色
播種期は、2013 年 6 月 3 日（左上）、2013 年 6 月 28 日（左下）、
2014 年 6 月 4 日（右上）、2014 年 7 月 3 日（右下）
いずれも作物研究所谷和原試験圃場産

表 13 「にしきまる」の各種形質に関する平均値と変異係数（2014）

品種名	個体数	開花期	成熟期	草丈 cm 平均	草丈 cm 変異係数	最下着蒴高 cm 平均	最下着蒴高 cm 変異係数	分枝数 本 平均	分枝数 本 変異係数	主茎蒴数 個 平均	主茎蒴数 個 変異係数
にしきまる-1	15	7.21	9. 4	155	5.4	70	9.1	2.9	35.2	79	22.3
-2	15	7.21	9. 3	148	3.9	61	10.5	2.5	46.4	92	15.8
-3	15	7.21	9. 3	146	6.0	64	9.2	2.2	33.1	88	25.6
-4	15	7.21	9. 4	155	4.9	72	5.6	3.1	32.6	83	16.8
⑤	15	7.21	9. 4	152	6.0	71	9.1	3.4	30.5	87	14.2
品種間平均				151	2.6	68	7.1	2.8	17.1	86	6.0
ごまぞう①	15	7.26	9.19	169	7.3	73	6.7	3.0	43.6	63	15.1
-2	15	7.25	9.20	177	5.3	71	9.6	2.6	40.6	70	18.1
-3	15	7.25	9.20	176	8.5	68	5.6	3.3	27.0	72	14.2
-4	15	7.25	9.21	182	5.8	70	6.3	2.9	43.9	75	15.1
-5	15	7.26	9.21	179	5.4	69	11.3	3.5	35.3	72	10.0
品種間平均				176	2.7	70	2.6	3.1	12.1	71	6.7

品種名	千粒重 g 平均	千粒重 g 変異係数	ｾｻﾐﾝ含量 mg/g 平均	ｾｻﾐﾝ含量 mg/g 変異係数	ｾｻﾓﾘﾝ含量 mg/g 平均	ｾｻﾓﾘﾝ含量 mg/g 変異係数
にしきまる⑤	2.6	4.0	6.2	3.2	4.0	3.2
ごまぞう①	2.3	5.6	8.0	7.7	4.0	13.7

〇印が選抜系統。

2．配布先における「にしきまる」の試験成績

栽培地による「にしきまる」の生育特性の違いを明らかにするため、2012 年度から 2014 年度に全国 6 ヵ所で地域適応性試験を実施した。対照品種として「真瀬金」、比較品種として「ごまぞう」を供試し、慣行法による栽培を行って生育特性を比較した。配布先における耕種概要を表 14 に示す。また、生育特性の試験結果を表 15、生産性および品質特性を表 16 に示す。

開花期と成熟期は地域間で異なっているが概ね「真瀬金」と同程度で「ごまぞう」より早かった。分枝数はどの地域においても「真瀬金」より多く、「ごまぞう」と同じ下位分枝型の草型であった。草丈は「真瀬金」と「ごまぞう」より低かったが、最下着蒴高は地域によって異なるが概ね「真瀬金」より高く、「ごまぞう」と同程度であった（表 15）。

子実収量は地域間での変動が大きく、長野県駒ヶ根市と兵庫県西脇市、鳥取大学、九州沖縄農業研究センターでは「真瀬金」と同等かやや多収だったが、岩手大学と鹿児島県南さつま市金峰町では「真瀬金」より低収であった。種皮色はどの地域においても「真瀬金」と同じく黄褐色で「ごまぞう」は褐色であった。千粒重は地域間と年次間で差があり、作柄によって影響を受けていると推察された。

セサミン含量は「にしきまる」が 4.4–7.6mg/g であるのに対して「真瀬金」は 2.3–4.3mg/g、「ごまぞう」が 6.1–10.1mg/g で、地域によって差はあるが、どの地域においても「真瀬金」より多く、「ごまぞう」より少なかった。セサモリン含量は「にしきまる」

表 14　配布先における生産力検定試験耕種概要

試験場所	試験年度	播種期（月.日）	畦間（cm）	株間（cm）	施肥量（kg/10a） N	P_2O_5	K_2O	区面積（m^2）	反復数	マルチ処理
岩手大(滝沢)	2012	6. 5	100	40	7.0	9.2	6.5	7.5	2	黒
岩手大(滝沢)	2013	6. 5	45	30	7.0	9.1	6.5	2.7	2	黒
岩手大(滝沢)	2014	5.28	70	30	7.0	9.1	6.5	7.0	2	黒
長野県駒ヶ根市	2012	6.26	45	27	3.0	3.0	2.4	7.3	1	黒
長野県駒ヶ根市	2013	6.12	45	27	3.0	3.0	2.4	7.3	1	黒
長野県駒ヶ根市	2014	6.10	45	27	3.0	3.0	2.4	7.3	1	黒
兵庫県西脇市	2012	5.22	70	30	0.3	0.3	0.2	4.2	1	黒
兵庫県西脇市	2013	5.20	70	30	0.3	0.3	0.2	4.2	1	黒
鳥取大学	2012	6.29	70	15	7.0	10.5	7.0	6.9	3	無
鳥取大学	2013	6.28	70	15	7.0	10.5	7.0	6.9	3	無
鳥取大学	2014	6.23	70	15	7.0	10.5	7.0	6.9	3	無
九沖農研	2012	6.22	70	25	16.0	14.0	14.0	8.4	3	無
九沖農研	2013	6.12	70	25	20.0	15.0	15.0	8.4	3	無
九沖農研	2014	6.12	70	25	18.7	14.0	14.0	8.4	3	無
鹿児島県南さつま市金峰町	2012	5.29	70	15		牛糞堆肥1t		1a	2	無
鹿児島県南さつま市金峰町	2014	5.24	70	15		牛糞堆肥1t		8.4	3	無
〃　（水田）	2014	5.24	70	15		牛糞堆肥1t		5.7	3	黒

注）長野県駒ケ根市の試験実施機関は長野県上伊那農業改良普及センター駒ヶ根支所と駒ヶ根市営農センターが実施した。
兵庫県西脇市の試験実施機関は北播磨県民局加西農業改良普及センターと日本のへそゴマ研究会が実施した。
鹿児島県南さつま市金峰町の試験実施機関は鹿児島県南薩地域振興局農林水産部農政普及課と金峰ごま生産組合が実施した。

が 3.2–5.6mg/g であるのに対し、「真瀬金」が 1.7–3.6mg/g、「ごまぞう」が 3.1–5.9mg/g で、どの地域においても「真瀬金」より多く、「ごまぞう」やや少なかった。この結果より、「にしきまる」の高リグナン系統としての特性は安定していることが明らかとなった（表 16）。

「にしきまる」は岩手大学（岩手県滝沢市）の試験において、収量が上がらなかったため、寒冷地での栽培には適していないと考えられた。また、九州地方においては地域適応性試験を行った 3 年間のうち 2013 年と 2014 年は台風などの害を受け大幅に子実収量が下がった。本来、九州地方はゴマの栽培適地であり、「にしきまる」についても九州地方の栽培に適していると考えられるが、台風などの害を受けることによって減収することがあることに留意する必要があると考えられた。

３．実需者による品質評価

国内ゴマメーカー 2 社による「にしきまる」の加工試験と官能試験の結果を表 17 と表 18 に示す。

A 社の試験では「にしきまる」は搾油用原料としては、油分含量が 50%以上、酸価も低い値であり、ゴマ油用の原料として利用可能である。ゴマ油としての香味はゴマ油特有の焙煎臭を有し、ゴマ油原料として問題ない香味であると評価された。いりゴマとしては、いりゴマの焦げ香ばしさ、香味が濃く感じられ、原料由来の香味（土、ほこり臭味）が有り、苦みがあると評価された。

B 社の試験では「にしきまる」は、酸価や過酸化物価などに問題はなく、香味に異味異臭はなく、いりゴマ、搾油どちらもおいしく食用として問題はないと評価された。また、セサミン量に関しては、「ごまぞう」よりも低い分析値となったものの、通常のゴマと比較してセサミン量の多いゴマであると言える、と評価された。

表 15 「にしきまる」の配布先における生育特性

試験場所	試験年度	品種名	開花期（月.日）	成熟期（月.日）	草丈（cm）	最下着蒴高（cm）	分枝数（本）	主茎蒴数（個）
岩手大学農学部附属寒冷フィールドサイエンス教育研究センター滝沢農場	2012	にしきまる	―	9.24	139	―	5.9	―
		真瀬金	―	9.24	143	―	2.7	―
		ごまぞう	―	10.12	145	―	6.5	―
	2013	にしきまる	7.25	9.26	103	52	3.3	32
		真瀬金	7.31	9.26	106	79	0	35
		ごまぞう	7.28	9.26	93	72	2.3	34
	2014	にしきまる	7.27	9.30	104	―	5.1	―
		真瀬金	8. 1	9.30	119	―	2.2	―
		ごまぞう	8. 3	10.10	116	―	5.3	―
長野県駒ケ根市（現地試験）	2012	にしきまる	―	9.18	118	59	1.4	46*
		真瀬金	―	9.18	124	42	0.4	69*
		ごまぞう	―	10.10	137	69	2.6	71*
	2013	にしきまる	―	9. 9	131	72	1.9	71*
		真瀬金	―	9. 9	139	51	0.3	63*
		ごまぞう	―	9.18	134	73	1.7	55*
	2014	にしきまる	―	9. 9	117	65	2.4	81*
		真瀬金	―	9. 9	110	51	0.0	53*
		ごまぞう	―	9.18	132	67	2.8	94*
兵庫県西脇市（現地試験）	2012	にしきまる	7. 8	8.17	129	48	4.8	269*
		真瀬金	7. 3	8.20	151	30	0.1	195*
		ごまぞう	9. 9	8.19	137	44	8.8	290*
	2013	にしきまる	7. 8	8.17	129	65	3.6	78*
		真瀬金	7. 3	8.18	128	38	0.7	93*
		ごまぞう	7. 9	8.22	137	66	2.9	50*
鳥取大学（鳥取市）	2012	にしきまる	―	―	98	56	―	―
		真瀬金	―	―	90	54	―	―
		ごまぞう	―	―	109	63	―	―
	2013	にしきまる	8. 4	9.22	140	79	3.7	―
		真瀬金	8. 7	9.17	163	107	0.3	―
		ごまぞう	8. 8	9.24	156	91	5.3	―
	2014	にしきまる	8. 5	9.16	121	62	1.5	―
		真瀬金	8. 7	9.16	123	52	0.0	―
		ごまぞう	8. 9	9.22	120	62	1.8	―
九州沖縄農業研究センター（熊本県合志市）	2012	にしきまる	8.14	9.24	107	―	4.4	171*
		真瀬金	8.13	9.30	116	―	0.5	133*
		ごまぞう	8.18	10. 3	127	―	4.7	179*
	2013	にしきまる	―	9.14	104	―	4.8	201*
		真瀬金	―	9.18	100	―	0.5	106*
		ごまぞう	―	9.18	112	―	6.1	177*
	2014	にしきまる	―	9.12	116	―	2.7	187*
		真瀬金	―	9.17	144	―	0.2	161*
		ごまぞう	―	9.26	142	―	4.0	219*
鹿児島県南さつま市金峰町（現地・畑）	2012	にしきまる	8. 3	9. 6	131	―	3.0	―
		真瀬金	7.28	9. 3	149	―	0.8	―
		ごまぞう	8. 5	9. 7	121	―	2.0	―
	2014	にしきまる	6.29	8.18	90	35	1.3	42
		真瀬金	6.29	8.18	99	29	0.0	46
		ごまぞう	6.29	8.31	97	44	1.1	42
鹿児島県南さつま市金峰町（現地水田）	2014	にしきまる	7.10	8.20	77	43	1.8	35
		真瀬金	7.10	8.20	92	31	0.2	42
		ごまぞう	7.10	8.26	85	39	1.3	29

*主茎蒴数ではなく1個体あたり蒴数

表 16 「にしきまる」の配布先における生産性および品質特性

試験場所	試験年度	品種名	子実収量 (kg/10a)	千粒重 (g)	種皮色	ｾｻﾐﾝ含量 (mg/g)	ｾｻﾓﾘﾝ含量 (mg/g)
岩手大学農学部附属寒冷フィールドサイエンス教育研究センター滝沢農場	2012	にしきまる	94	2.6	黄褐	7.0	4.6
		真瀬金	90	2.6	黄褐	2.8	1.7
		ごまぞう	97	2.5	褐	8.4	5.5
	2013	にしきまる	9	2.0	黄褐	4.4	5.6
		真瀬金	57	2.1	黄褐	2.7	3.6
		ごまぞう	43	1.7	褐	6.1	5.9
	2014	にしきまる	18	2.0	黄褐	5.6	5.4
		真瀬金	31	2.4	黄褐	3.4	2.8
		ごまぞう	34	2.2	褐	5.8	4.5
長野県駒ケ根市（現地試験）	2012	にしきまる	188	2.5	黄褐	6.3	4.5
		真瀬金	215	2.5	黄褐	3.5	3.0
		ごまぞう	266	2.5	褐	7.0	5.3
	2013	にしきまる	174	－	－	－	－
		真瀬金	160	－	－	－	－
		ごまぞう	145	－	－	－	－
	2014	にしきまる	68	2.4	黄褐	7.1	4.8
		真瀬金	46	2.3	黄褐	4.3	2.9
		ごまぞう	45	2.2	褐	8.4	4.7
兵庫県西脇市（現地試験）	2012	にしきまる	114	2.7	黄褐	5.7	3.4
		真瀬金	90	2.7	黄褐	2.9	2.0
		ごまぞう	79	2.5	褐	7.7	3.2
	2013	にしきまる	80	2.6	黄褐	4.7	4.6
		真瀬金	68	2.5	黄褐	2.3	2.6
		ごまぞう	65	2.6	褐	6.5	4.9
鳥取大学（鳥取市）	2012	にしきまる	73	2.6	黄褐	5.6	3.8
		真瀬金	72	2.4	黄褐	3.2	2.3
		ごまぞう	121	2.5	褐	10.1	4.7
	2013	にしきまる	28	1.9	－	－	－
		真瀬金	37	2.3	－	－	－
		ごまぞう	67	2.1	－	－	－
	2014	にしきまる	78	2.2	－	－	－
		真瀬金	59	2.3	－	－	－
		ごまぞう	58	2.0	－	－	－
九州沖縄農業研究センター（熊本県合志市）	2012	にしきまる	103	2.4	黄褐	6.6	3.6
		真瀬金	111	2.7	黄褐	3.5	2.1
		ごまぞう	127	2.6	褐	8.2	3.6
	2013	にしきまる	79	2.2	黄褐	5.9	4.9
		真瀬金	60	2.3	黄褐	3.7	3.2
		ごまぞう	78	2.1	褐	6.9	5.1
	2014	にしきまる	92	2.4	黄褐	7.6	4.2
		真瀬金	89	2.5	黄褐	4.1	2.6
		ごまぞう	107	2.5	褐	8.0	3.8
鹿児島県南さつま市金峰町（現地・畑）	2012	にしきまる	51	2.3	黄褐	5.5	3.2
		真瀬金	51	2.5	黄褐	3.2	2.1
		ごまぞう	64	2.1	褐	7.4	3.1
	2014	にしきまる	22	2.4	黄褐	6.9	3.7
		真瀬金	32	2.5	黄褐	3.7	2.4
		ごまぞう	29	2.2	褐	9.2	4.2
鹿児島県南さつま市金峰町（現地水田）	2014	にしきまる	14	2.3	黄褐	5.2	3.2
		真瀬金	18	2.3	黄褐	2.6	2.1
		ごまぞう	26	2.4	褐	8.7	3.4

表 17　Ａ社における「にしきまる」の品質評価結果

項　　目	にしきまる		ごまぞう	
	6月3日播き	6月28日播き	6月3日播き	6月28日播き
油　分(%)	52.4	53.2	52.0	55.3
粗ﾀﾝﾊﾟｸ質(%)	21.7	20.4	19.2	19.3
酸　価	0.5	0.5	0.5	0.5
粒度分布				
10mesh on	1.0	0.6	0.6	1.6
10~12mesh	59.3	54.8	71.1	72.5
12~14mesh	38.7	43.6	27.7	25.3
14~16mesh	0.8	1.0	0.6	0.4
16mesh pass	0.2	0.0	0.0	0.2
脂肪酸組成(%)				
C16	7.8	7.7	8.1	7.8
C16-1	0.1	0.1	0.1	0.1
C18	4.6	4.6	4.8	4.8
C18-1	43.4	40.7	37.4	36.5
C18-2	43.0	45.6	48.4	49.5
C18-3	0.3	0.4	0.3	0.3
C20	0.5	0.5	0.6	0.6
C20-1	0.2	0.2	0.2	0.2
C22	0.1	0.1	0.1	0.1
C24	不検出	0.1	不検出	0.1
セサミン(mg/g)	7.9	8.1	9.0	8.8
セサモリン(mg/g)	4.1	4.4	3.9	4.1

サンプルは2013年つくば市谷和原圃場産を使用。

概評
搾油用原料として：ごま油としての香味、油分含量が重視され、JAS 規格で定められた酸価(4.0以下)をクリアする必要がある。「にしきまる」と「ごまぞう」は油分含量が50%以上、酸価も低い値であり、ごま油用の原料として利用可能である。
ごま油としての香味：ごま油特有の焙煎臭を有し、ごま油原料として問題ない香味である。
いりごまとしての香味：焦げ香ばしさ、ごま香味が濃く感じられる。原料由来の香味（土、ほこり臭味）が有る。苦みあり。

表 18　Ｂ社における「にしきまる」の品質評価結果

評価項目	にしきまる	ごまぞう	方法
いりごまの香味	5点	5点	官能評価
搾油の香味	5点	5点	官能評価
酸価	0.45	0.47	滴定法
過酸化物質(meq/kg)	検出せず	検出せず	滴定法
水分(%)	4.97	4.81	加熱乾燥法
含油分(%)	44.7	46.1	ソックスレー法
セサミン(mg/100g)	719.7	843.6	HPLC 法

サンプルは2014年つくば市谷和原圃場産を使用。評価に用いたいりごまは、ごまを水洗の後、フライパンで品温130℃まで炒って得た。搾油はごまを品温180℃までフライパンで炒った後、ジャッキにて圧搾して得た。官能評価は B 社の部内官能評価員5名による評価結果である。
評点基準　1点：まったく食べられない。2点：商品価値ない。3点：商品価値ある。
　　　　　4点：食べられる。5点：おいしく食べられる。

概評
にしきまるは、酸価や過酸化物価など分析値に問題はなかった。香味に異味異臭はなく、いりごま、搾油どちらもおいしく食用として問題はなかった。また、セサミン量に関しては、ごまぞうよりも低い分析値となったものの、通常のごまと比較してセサミン量の多いごまであると言える。

Ⅴ　適応地帯と栽培上の注意

育成地及び配布先の成績から、「にしきまる」の栽培適地は関東以西の平坦地であると考えられる。

通常のゴマと同様に、連作による減収を避けるため、輪作に努める。

Ⅵ　命名の由来

「にしきまる」のやや赤みがかった金色の粒色を表すとともに、錦を飾ってほしいという願いを込め命名した。

Ⅶ　育成従事者

「にしきまる」の育成に従事した研究員の担当した世代を表 19 に示す。

表 19　育成従事者と試験期間

氏　　名	2001		′02	′03	′04	′05	′06	′07	′08	′09	′10	′11	′12	′13	′14	2014 年度所属機関
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	
加藤晶子														—	—	作物研
大潟直樹									—	—	—	—	—	—	—	作物研
勝田真澄	—	—	—	—	—	—	—	—	—							北農研
山田哲也						—	—									作物研
安本知子	—	—	—	—	—	—	—									中央研
杉浦　誠	—	—	—	—												近農研

Ⅷ　考　　察

次世代作物開発研究センターではこれまでにセサミンとセサモリン含量の高い褐色のゴマ「ごまぞう」、黒ゴマ「まるえもん」、白ゴマ「まるひめ」を育成した。この 3 品種に金ゴマ「にしきまる」が加わり、高リグナンゴマのカラーバリエーションが揃ったことから、それぞれの種皮色や食味の特色を生かした加工品の開発が行われることを期待している。これまでに育成した品種の中でも「ごまぞう」は消費者の国産志向に加えてゴマの健康機能性が注目されていることから、需要が伸びている。今回育成した「にしきまる」についても 6 次産業化を行っている生産者や国産ゴマを取り扱う実需者から注目されており、2016 年から三重県や鹿児島県などで栽培が始まっている。三重県では県産ゴマ増産プロジェクトを行っており、その中で「にしきまる」が増産の対象となっているため、さらに栽培面積が拡

大すると考えられる。今後は品種名を表記したゴマ加工品の開発・販売を目標として、普及を進めて栽培面積を増やすとともに単収を上げるための栽培技術を明らかにすることが必要である。「にしきまる」は在来種の金ゴマ「真瀬金」より草丈が低く収量性も同程度かやや優れており、「ごまぞう」より草丈が低く、病気に強く、早く収穫できるため栽培しやすい品種である。これらの特性を生かした栽培技術を確立することによって、生産量が増加し商品開発も進むと考えられ、国産ゴマの生産振興に大きく貢献できると期待できる。

ゴマの機能性成分については、ゴマリグナンの一種であるセサミンは機能性に関する研究が進んでおり、サプリメントなども販売されているため知名度が高い。セサモリンはセサミンの化学構造の一方にアセタール酸素架橋をもつ構造をしており、ゴマ油精製工程で抗酸化性リグナンであるセサモールに変換されることが明らかになっている。主なゴマリグナンにはセサミンとセサモリンのほかにもセサミノールがあり、セサミンやセサモリンとは異なる機能性が明らかになりつつあり、注目されている（並木ら 2015）。セサミノールはゴマ種子中に配糖体の形で含まれており、腸内細菌によって加水分解されて腸管から吸収され、生体膜などの酸化的障害を防御すると考えられている（Kang *et al*. 1999）。セサミノール配糖体の含量は品種間差が大きいことが明らかになっており（加藤ら 2015）、このことはセサミノール配糖体を多く含む個体や系統を選抜できる可能性が高いことを示唆している。これまで当研究センターで育種した品種は十分高いセサミン・セサモリン含量を有しているため、「ごまぞう」以上に高含量の品種の育成は難しいと考えられる。筆者らの予備的な分析の結果、「にしきまる」のセサミノール配糖体の含量は高含有の遺伝資源と比較するとやや低かった。今後はさらなる高付加価値化を目指すため、「にしきまる」のセサミノール配糖体含量を高めるなど、新たな育種に取り組む必要があるだろう。

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次世代作物開発研究センターの許可を得て下さい。

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