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Review Article:

Breeding Methodology in Rice (*Oryza sativa* L.) — A Review*

by

J. CHANDRA MOHAN [1] and B. W. X. PONNAIYA [2]

Synopsis: The various methods of breeding employed for the improvement of rice crop have been discussed in detail. The conventional methods like introduction, mass selection, pure line selection and hybridisation and selection have been largely responsible for the evolution of many useful rice strains. The latest techniques like ploidy breeding and mutation breeding have also been adopted in this crop and their scope has been indicated.

Resume of History of Rice Breeding: Rice Breeding as an art was practised probably from ancient times. Huc (1938) quoted from the Memoirs of the Chinese Emperor K'ang-Hsi, (1662—1723) reports how "a chance stalk of rice in a field, more outstanding than others, was spotted out by the emperor and how the seeds were collected and raised to produce an improved variety". However, organised scientific breeding in rice was initiated for the first time in 1893 in Japan with the opening of the Imperial Experimental Station at Tokyo (Ramiah and Vachani 1950) and after the dawn of this century systematic breeding was taken up in many of the rice growing countries.

McKerral (1913) reported about the progeny selection in Burma and Hanu (1914) about a method of selection in vogue in Java. Intervarietal selection and isolation of economic types by hybridisation in Java have been described by Viellard (1921) and Copeland (1924). Pureline selection for improvement of rice varieties was in vogue in Indo-China (Carle 1925), in Ceylon (Lord, 1929), in Malaya (Sands, 1924) and (Birkinshaw, 1940) and in New South Wales (Poggendorff, 1932). Chambliss and Jenkins (1923) reported about the first improved variety in U. S. A. developed by a private breeder S. L. Wright after 1910.

The Pioneers in rice breeding in India were Hector (1911) in Bengal and Parnell (1912) in Madras followed by Ramiah (1918). Graham (1911) in Central Provinces adopted the progeny selection which was later developed by Mahata and Dave (1931). In Bombay, pure-line and progeny selection were employed by Chibber (1919) followed by Bhide and Kadam (Ramiah,

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[1] Assistant Lecturer in Botany, [2] Professor of Plant Breeding & Genetics, A. C. & R. I., Coimbatore-3.

1953). Alam (1932) isolated superior types from natural population of rice in Bihar, while inter-varietal hybridisation and selection were adopted in Assam by Mitra (1933) followed by Sethi (1940). From this modest beginning, rice breeding gathered momentum during last two decades with newer techniques of intensive and specific nature to produce economic strains.

Objectives in Rice Breeding and procedures adopted: Much work on breeding methodology in rice has been reported by various workers (Ramiah 1937, 1953; Richharia 1945, Ghose *et al* 1956 and Poehlman 1959).

The different objectives in rice breeding may be classified under the following heads.

BREEDING FOR

- Quantity
  - Yield of grain and Straw
- Quality
  1. Fineness of grain
  2. Milling quality
  3. Cooking quality
- Resistance to pests & diseases
- Specific objectives
  1. Drought resistance
  2. Saline resistance
  3. Flood resistance
  4. Lodging resistance
  5. Seed Dormancy in short term rice
  6. Earliness
  7. Suitability for late planting
  8. High fertility response
  9. Plasticity
  10. Seed fertility
  11. Control of wild rice
  12. Tolerance to cold water
  13. Suitability for Mehanical harvest
  14. Combining special traits like white rice, dense panicle, round grain, etc.

(a) *Introduction and acclimatisation:* Although this is the easiest and most rapid method of crop improvement, success has not been much in the case of rice. Ramiah and Rao (1953) record that "none of the varieties of rice introduced into India from sub-tropical regions of Japan, Korea, Italy and America have been of use except as parents in crosses". Liotard (1880) has described how the very first introduction viz., "Carolina Rice" from U. S. A. into India in 1868 by the Government of India was a failure despite its organised and systematic trial in all the provinces. Among the exotic rice varieties introduced into India certain Chinese varieties are the most successful, being adaptable to conditions existing in India (Ramiah 1953). Good performance of these Chinese rice varieties has been reported by Chatterjee (1952) in Uttar Pradesh, West Bengal and Orissa, Rania (1953) and Negi (1955) in Kashmir valley, Negi and Saini (1957) in the Kulu valley in the Punjab and Rajagopalan and Samad (1960) in Madras.

In India, introduction of varieties from one State into the other has been successful in many cases. Some of the successful introductions into Madras State are given below:

From	Variety	Special attributes
Bengal	Patnai	Yield
Uttar Pradesh	Basmati	Table rice, scented
Orissa	S. R. 26 - B	Saline resistance
Punjab	Sugadas	Aroma and flavour

Mem. Dept. Agric., Madras, 1954.

Collection of varieties from the different rice growing regions and maintenance of the "germ plasm" for direct introduction as well as for transference of genes possessing desirable traits have been in progress as part of the rice improvement programme in many countries. At Coimbatore, the world collection of rice varieties has exceeded 2,500 types (unpublished Agricultural Station Reports, 1960). The Central Rice Research Institute at Cuttack is one of the centres recognised by the F. A. O. for the collection and maintenance of World Rice genetic stock (Ghose *et al* 1956).

(b) *Mass selection:* Mass selection consisting of selecting phenotypically resembling desirable individual plants and breeding them *en masse* irrespective of their genotypic values, is now almost obsolete. This method was in vogue in Phillippines, Italy, Spain and India (Ramiah 1953). In earlier years, this method was adopted in Madras at various Rice Research centres like Aduthurai, Maruteru, Pattambi and Berhampur (Ramiah 1937). A variety developed by this method will be pure only for physical features which are easily seen and differ in quantitative or yield attributes (Poehlman 1959). The improvement effected by this method is rather temporary and this procedure has to be repeated. Some of the examples of mass selected rice strains are PTB. 28, PTB. 29, PTB. 30 *(Annual Station Report, Madras,* 1950—'51).

(c) *Pure - line selection:* Johannson's pure - line concept has been utilised in this crop with the single plant as the basis for selection. Alam (1932) is of the opinion that "in this crop the variations are so profuse and distinct that practically all the requirements of the farmer could be met simply through the isolation of pure strains". Butany (1957) has recorded that the natural crossing in the cultivated rices in India varies from 0·1 per cent to 4·0 per cent and due to the self - fertilising nature of the crop, in - breeding and maintenance of pure lines are easily achieved. Majority of the improved varieties of rice evolved the world over are by this method (Ramiah 1957). Ghose (1956) reports that 394 out of 446 strains evolved in India have been developed by pure - line selection.

(d) *Hybridisation and selection:* Direct improvement in yield in most cases was not achieved in rice by hybridisation. But where physiological characteristics such as disease resistance, resistance to lodging, drought and salinity and to overcome sterility were sought to be incorporated in otherwise desirable strains, success has been phenomenal (Ramiah 1953). Ekbote (1930) and Krishnaswamy and Chandrasekaran *t l* (1960) are of the opinon that artificial hybridisation in rice was probably known in ancient China.

(i) *Intervarietal hybridisation:* The easy crossability and the high fertility of the intervarietal hybrids in rice have afforded much scope for exploiting fully this procedure for combining desirable traits available in certain varieties. Ghose (1956) has listed 52 strains evolved by this method in India alone. Four blast-resistant strains, Taichung 171 in Taiwan and Co. 25, Co. 26 and ADT. 25 in India have been isolated with ten more cultures ready for release (Parthasarathy and Padmanabhan 1958). Hybridisation projects are in progress in various centres in India using Co. 4 as the blast-resistant gene donor (Parthasarathy 1956), Ramachandra Rao and Hanumantha Rao (1956) and Samad (1958). Breeding for drought resistance, saline resistance and flood resistance in India has been reported by Ramiah (1953), Samad (1954), Samad *et al* (1960) and Venkatanadhachari (1958). Hybridisation and selection for non-shedding character (Daiya 1958) and for seed dormancy in short term rices (Samad 1960) are also in progress. Strains Co. 14 for non-lodging, ADT. 20 for round grain with short duration and ADT. 8 for earliness suitable for winter season are some of the outstanding varieties evolved in Madras (Parthasarathy 1954). TKM. 6 is another outstanding strain from Madras which combines fineness of grain and short duration. In addition, the seeds have dormant nature and unlike its parent GEB. 24, this strain is non-sensitive to photoperiod (Bhavanishankar Rao 1956).

Work on breeding varieties resistant to insect pests like stem borer in Egypt (Koshairy *et al* 1957 and rice bug in India (Sethi 1936) as well as for resistance to diseases like Hoja Blanca (Atkins and Judson 1958) and straight head in U. S. A. (Beachell and Crane 1957) has been reported. Puran Singh Sangwan (1956) has recorded the progress of breeding for resistance to drought, salinity, etc., in Egypt.

(ii) *Interracial hybridization:* Among the cultivated species of rice, three geographical races, viz., *O. sativa* var. *indica*, *O. sativa* var. *japonica* (Kato 1930) and *O. sativa* var. *javanica* (Terao and Mizishima 1939) have been recognized. These races are distinguished by their differences in morphological and physiological traits as well as by their photoperiod and fertilizer responses. *Indica - japonica* hybridisation to combine the high fertilizer response, non - lodging and non - shattering grain characters of the *japonicas* with hardiness and tropical adaptability of the *indicas* has been in progress in India. Richharia and Misro (1959) and Parthasarathy (1960) have summarised the projects sponsored by the F. A. O. in 1950 and the I. C. A. R. in 1951, wherein different *indicas* from various Asian countries were crossed with few *japonicas* suggested by Dr. Morinaga. The results have indicated the prospects of isolating homozygous promising types from hybrids by F_7 generation despite the high percentage of sterility usually met with in F_2 and subsequent earlier generations.

(iii) *Interspecific hybridization:* Pal and Ramanujam (1944) have rightly pointed out that while agronomically useful genes like yield and quality are found in cultivated plants, those constituting hardiness and resistance have to be sought in the wild species through interspecific crosses. Ramiah (1953) Ghose *et al* (1956) and Morinaga (1959) have furnished the list of interspecific hybrids effected in rice. In most cases, the F_1s were highly sterile. Morinaga and Fukushima (1956) reported that back cross method to bring about fertility and doubling their chromosome numbers by colchicine have not been successful. However, Srinivasan *et al* (1941) have reported the isolation of promising cultures with drought resistance from a cross of GEB. 24 *(Oryza sativa* L.) and *Oryza longistaminata (Oryza perennis)* in India.

Selection Procedures in Hybridisation: (i) *Pedigree method or Line method:* In this method "plants with the desired combinations of characters are selected in the F_2 generation and the progenies of each selected plant is re-selected in succeeding generations until genetic purity is reached" (Poelhman 1959). In the F_2 generation, the segregating population is grown in rows to facilitate detailed examination and selection. But in subsequent generations, small plots of 4' x 5' are adopted for each progeny. Recently the replicated progeny row technique evolved by Hutchinson and Panse *(1937)* in cotton is being adopted in rice at Coimbatore *(unpublished Agricultural Station Report, 1959 Madras)*. Trials conducted by *Abraham et al (1956)* at Cuttack indicated the usefulness of this method in rice. Selection based on progeny mean has been found to be more reliable than selection based on single plant yields, as in the opinion of Panse (1942) the single plant yields are subject to a greater influence of environment than the means of a progeny.

(ii) *Bulk population method:* In this breeding procedure selection is delayed until the F_6 or F_7 after hybridisation by which time segregation would virtually have ceased. This method which was first tried in barley at Svalof in Sweden has been adopted in rice and is known as 'Svalof method' (Ramiah 1937).

(iii) *Multiple cross method:* This is a complex system involving hybridization between eight or more varieties with the objective of combining useful traits existing in the different parents. Multiple crosses are produced by hybridizing pairs of parents at first and then crossing pairs of F_1s until all parental combinations enter a common progeny. This method was adopted in rice in Madras with a view to isolate a cosmopolitan strain suitable for *Kuruvai*, *Kar* and *Samba* seasons and with this objective a project involving crosses between the different varieties suitable for each of the above seasons was initiated (Srinivasan 1942). F_1s of the primary crosses of the same group were again crossed, but it was found that none of the isolates from these crosses gave better performance than the parental strains themselves. Based on the above results, Narasinga Rao (1951) concluded that this method had certain limitations in rice improvement programme.

(iv) *Back cross method:* Harlan and Pope in 1922 pointed out the usefulness of the back cross method in plant breeding as a form of recurrent hybridisation by which a superior specific character like disease resistance is added on to an otherwise desirable variety (Hayes *et al* 1955). This method has not been exploited to any considerable measure in rice breeding. Failure of this method to bring about fertility in interspecific hybrids has been reported by Morinaga and Fukushima (1956).

The partial success achieved by the work of Shigemura in 1943 in introducing blast resistance from *indicas to japonicas* by back crossing has been reported by Morinaga (1954). Briggs and Allard (1953) have isolated a new variety 'calrose' by introducing the medium grain size character of 'calady' into an otherwise desirable strain 'Caloro' by repeated back crossing. This appears to be the only instance of utilising the back cross method in rice improvement work. Sampath and Mohanty (1954) and Venkataswamy (1957) suggested that this method might be more helpful in distant crosses than in straight hybridisation. Gopalakrishnan (1960) is of the opinion that this method can be employed in rice especially for the transfer of wild genes to cultivated varieties.

Hence the back cross method of breeding which has resulted in the isolation of useful varieties in other small grains, viz., mildew and scald resistant 'Atlas' variety of Barley (Schaller 1951) and leaf rust and stem rust resistant *T. vulgare* (Shands 1941) and Allard (1949) may be utilised in the rice improvement programme also.

(e) *Ploidy breeding:* Ploidy breeding in rice has been attempted mainly to produce gigas characters and to overcome sterility in interracial and interspecific crosses.

Haploids as Blakeslee (1939) has pointed out have potential value in plant breeding as a means of getting a desired combination in a homozygous condition. Morinaga and Fukushima *et al* (1932), Ramiah *et al* (1932) Sethi (1937) have reported the occurrence of haploids in hybrid population which were completely sterile. Production of haploids by induced parthenogenesis has not been successful.

Although triploids have been found in intervarietal and interspecific crosses as reported by Nakamori (1932), Ramiah *et al.* (1933), Nandi (1938), Ramanujam (1937) as well as spontaneous and X-ray mutant triploids recorded by Ichijima (1934) and Morinaga (1935), these have not been found useful economically.

Auto-tetraploids occurring spontaneously as well as induced by colchicine have been found to exhibit gigas characteristics in grain size, ear length etc. (Nakamori 1933), Morinaga and Fukushima (1936) and Nandi (1937). The high percentage of spikelet sterility found in them, however, make their cultivation unremunerative (Misro 1960). In addition, the artificially induced auto-tetraploids in varieties like G. E. B. 24, S. R. 26-B Indrasail and Seta, invariably exhibited awning which was absent in the diploids (Misro and Muralidharan *et al* 1960).

(f) *Mutation breeding:* Numerous instances of the occurrence of both spontaneous as well as induced mutations affecting almost every part of the rice plant and many of its physiological characters have been reported by various workers in India, Japan and other countries. Ramiah (1953) has compiled an exhaustive list of these mutations. X-ray and chemicals like Colchicine were the mutagens employed in the earlier years and almost all the induced mutations were recessive, uneconomical and of genetical interest only.

Soon after the pioneering work of Stadler (1928) in Barley with X-rays was reported, induction of mutation in rice by X-ray treatment was attempted in 1933 for the first time in India at Coimbatore by Ramiah and Parthasarathy (1938). Recent attempts reported by Chang and Hsieh (1957), Beachell (1957) and Oka *et al* (1958) where X-ray has been employed gave mutations showing variation in height, shattering of grain, chlorophyll deficiency etc., which were of no economic value. Irradiation of seed by thermal neutrons, Beeta rays from radio-active phosphorus and gama rays has been reported by Jodan (1958), Chalam *et al* (1959) and Yamaguchi and Ando (1959). These treatments have also resulted in inducing variation in duration and height.

Chemical mutagens like acenaphthene, benzene vapour and ceresan have been employed for artificial induction of mutations in rice by Narasinga Rao (1953) and variations in number of tillers, grain size, yield and duration have been reported.

Among the few artificially induced economic mutants, the dwarf mutant in the strain GEB.24 obtained by X-ray treatment (Ramiah and Parthasarathy 1938) which has profuse tillering and non-lodging habit is worthy of mention. Sukanya Bai *et al* (1957) reported isolation of economic mutants in acenaphthene treated GEB.24 and ceresan treated Co. 13.

Certain spontaneous mutations that were recorded in rice have been found useful economically. The first improved strain of Madras viz., GEB.24 is reported to be a probable mutant isolated from a variety Konamani of Godavari District by Parnel in 1916. Examples of similar mutants are ADT. 15 from Kuruvai, AKP.13 from Maharaja bhogam and MTU.20 from Basangi (*Mem. Dept. Agric.*, Madras, 1954)

It is seen from the above reports that mutation breeding in rice appears to have much scope in the improvement of rice crop and an intensive work in this line is warranted.

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REFERENCES

Abraham, T. P., R. K. Misra and R. L. M. Ghose	1956	*Indian J. Genet. Pl. Breed.*, **16**: 47—51.
Alam, M.	1932	*Agric. Livestook in India*, **1**: 497—511.
Allard, R. W.	1949	*J. Agric. Res.*, **78**: 33—64 (Quoted by Elliott. 1958).
Atkins John, G. & U. Judson	1958	*Int. Rice Comm. News Letter*, **7** *(3)*: 72.
Beachell, H. M.	1957	*Ibid.*, **6** *(1)*: 37—8.
——— & L. E. Crane	1957	*Ibid.*, **6** (2): 27—30.
Bhavanishankar Rao, M.	1956	*Rice News Teller*, **4** *(1)*: 33—4.
Birkinshaw, F.	1940	*Malayan Agric. J.*, **28**: 507—16.
Blakeslee, A. F.	1939	*Amer. J. Bot.*, **25**: 738—43, (Quoted by Ramiah, 1953).
Briggs & Allard,	1953	*Agron. J.*, **45**: 109—10.
Carle, E.	1925	*Int. Rev. Sci. Proc. of Agric.*, **11**: 716—17.
Chalam, G. V., H. K. Mohanty and B. Mallick,	1959	*Sci. & Cult.*, **23**, *(3)*: 202—03.
Chambliss, C. E. & J. M. Jenkins.	1923	*Some New Varieties of Rice.* U. S. Dept. of Agric., Deptal. Bull. No. 1127.
Chang, T. D. & S. C. Hsieh	1957	*Pl. Breed. Abst.*, **2715**, July 1960.
Chatterjee, U. N.	1952	*Indian Fmg.*, **11**, *(7)*: 32—5.
Copeland, E. B.	1924	*Rice.* MacMillan & Co., London, 425 pp.
Daiya, L. R.	1958	*Rice News Teller*, **6**. *(3)*: 13—5.
Ekbote, R. B.	1930	*Agric. J. India*, **25**: 396—407.
Ghose, R. L. M.	1956	*Int. Rice. Comm. News Letter.* **6** (3): 38.
———, M. B. Ghatge & V. Subramanyam	1956	*Rice in India*, I. C. A. R., New Delhi, 507 pp.
Gopalakrishnan, R.	1960	*Agric. Coll. J. Vellayanai*, 1959—'60, p. 44—50.
Graham, R. J. D.	1911	Proc. of the Board of Agriculture in 1911. Head—Rice (Quoted by Ramiah 1953.)

Hann, H. D. 1914 *Trop. Agriculturist*, **46** : 26—35.

Hayes, Immer & Smith, 1955 *Methods of Plant Breeding*. McGraw Hill Book Co., 551 pp.

Huc, E. R. 1938 Memmoires of Chinese Emperor K'ang Hsi (1662-1723) (Quoted by Walter in his book 'Genetics').

Ichijima, K. 1934 *Jap. J. Bot.*, **8** : 144 (Quoted by Ramiah, 1953).

Jodan, N. E. 1958 *Rice J.*, **61** (7): 20—1.

Jones, J. W. 1928 *J. Agric. Res.*, **36** : 581—601.

——— 1936 *Improvement in Rice*, Year book of Agri., U. S. D. A., pp. 415—54.

Kato, S. 1930 *J. Dep. Agric., Kyasbu*, **2** : 241—76. (Quoted by Sampath 1959).

Koshiry, M. A., C. L. Pan & Gad. El-Hak. 1957 *Int. Rice. Comm. News Letter*, **4**, *(1)*: 27—31.

Krishnaswamy, N. & S. N. Chandrasekaran 1960 *Cytogenetics and Plant Breeding*, P. Varadachari & Co., Madras, 653 pp.

Liotard, L. 1880 *Introduction of Carolina Rice into India.*, Memorandum—Calcutta Press, 48 pp.

Lord, L. 1923 *Trop. Agriculturist*, **73** : 32—5.

Mahata, D. N. & B. B. Dave. 1931 *Indian J. Agric. Sci.*, **1** : 351—70.

McKerral 1913 *Agric. J. India*, **8** : 317—30.

Misro, B. 1960 *Rice News Letter*, **8** *(3)*: 2—3.

——— & V. K. Muralidharan. 1960 *Ibid.*, **8** *(2)*: 16—19.

Mitra, S. K. 1933 Rice Breeding in Assam., *Proc. Worlds Grain Exhi. & Conf., Regina*, **2**: 131—3. (Quoted by Ramiah 1953).

Morinaga, T. 1935 *Jap. J. Bot.*, **7** : 207—25. (Quoted by Ramiah 1953).

——— 1954 Inter-cross breeding of phylogenetically distinct groups of rice. *Rep. 5th mtg. Int. Rice. Comm. Working Party in Rice breeding, Oct., 1954.*

Morinaga, T. & E. Fukushima 1932 *Proc. Imp. Acad.*, **7** : 383—4. (Quoted by Ramiah 1953).

——— 1936 *Jap. J. Bot.*, **9** : 71—94. (Quoted by Ramiah, 1953).

——— 1956 *Cytologia.*, **21** : 165—78.

Nakamori 1933 *Jap. J. Bot., Abrets.* No. **282**. (Quoted by Ramiah 1953).

Nandi, H. K. 1937 *Cytologia (Tokyo)*, **8** : 277-305 (Quoted by Ramiah, 1953).

——— 1938 Interspecific hybridisation in *Oryza. Bose Res. Instt., Calcutta*, 99—221 (Quoted by Ramiah, 1953).

Narasinga Rao, M. B. V. 1951 *Madras agric. Stat. Rep., 1959—'52*, p, 72—5.

——— 1953 *Proc. 2nd Sci. Workers' Conf.*, 1952, 95—101.

Negi, L. S. 1955 *Rice News Teller*, **3** *(2)*: 17—21.

——— & S. S. Safni 1957 *Ibid.*, **5** *(1)*: 5—9.

Oka, H., J. Hayashi & I. Shiojeri 1958 *J. Heredity*. **49** : 11—4.

Pal, B. P. & Ramanujam, S. 1944 *Indian J. Genet. Pl. Breed.*, **4** *(1)*: 78—89.

Panse, V. G. 1942 *Ibid.*, **2** *(2)*: 23—9.

Parthasarathy, N. 1954 *Rice News Teller*, **2** *(1)*: 34—45.

——— 1956 *Int. Rice Year Book*, 58—60.

——— 1960 *Int. Rice Comm. News Teller*, **10** *(4)*: 23—8.

——— & Padmanabhan, S. Y. 1958 *Rice News Teller*, **6** *(4)*: 10—17.

Poehlman, J. M. 1959 *Breeding Field Crops—Breeding Rice*, Holt—Dryden Book, New York, 427 pp.

Poggendorff, W.	1932	*Agric. Gaz. N. S. Wales*, **44**: 283—8. (Quoted by Ramiah 1953)
Puran Singh Sangwan	1958	*Rice News Teller*, **5** *(4)*: 9—11.
Rajagopalan, K. & Abdul Samad, A.	1960	*Ibid.*: **8** *(4)*: 9—19.
Ramachandra Rao, S. & Hanumantha Rao	1956	*Andhra agric. J.*, **3** *(4)*: 234—38.
Ramanujam, S.	1937	Cytological studies in *Oryza*—an autototraploid in rice. *J. Genetics.*
Ramiah, K.	1937	*Rice in Madras—a popular hand book*, Supdt., Govt. Press, Madras, 245 pp.
———	1953	*Rice Breeding and Genetics.* Sci. Monograph, I. C. A. R., 360 pp.
——— & Moti V. Vachani	1950	*Madras agric. J.*, **37** *(9)*: 4—7.
Ramiah, K. & N. Parthasarathy	1938	*Proc. 25th Indian Sci. Congr., Abst.*, 12.
Ramiah, K., N. Parthasarathy, & S. Ramanujam	1932	*Curr. Sci.*, **1**: 277—78.
———	1933	*Ibid.*, **2**: 170—72.
Ramiah, K, & M. B. V. Narasinga Rao	1953	*Rice Breeding & Genetics.* Part **2**, p. 36—37.
Rania, J. L.	1953	Rice *News Teller*, **1** *(3)*: 12—4.
Richharia, R. H.	1945	*Plant Breeding and Genetics in India*, Sci. Book Co. Patna, 402 pp.
——— & B. Misro	1959	*J. Biol. Sci.* **2** *(2)*: 35—47.
Samad, A. Abdul	1954	*Rice News Teller*, **2** *(2)*: 17.
———	1958	*Ibid.*, **6** *(2)*: 20—1.
———	1960	*Ibid.*, **8** *(3)*: 24—5.
———, A. Shanmugasundhram & K. Rajagopalan	1960	*Ibid.*, **8** *(3)*: 8.
Sampath and Mohanty	1954	*Curr. Sci.*, *23*: 182—3.
Sands, W.	1929	*Proc. Imp. Bot. Conf.*. **93** (Quoted by Ramiah 1953)
Schaller, C. W.	1951	*Agron. J.*, **43**: 183—8.
Sethi, R, L.	1940	*Ann. Repts., Rice Res. Stn., Nigeria, U. P.*, 1939—40 (Quoted by Ramiah 1953).
Srinivasan, C. R.	1942	*Madras agric. St. Rept*, 1941—42.
———, N. parthasarathy & K. Ramaswamy	1941	*Proc. 28th Indian Sci. Congr., Abst.*, **37** *(agric.)*
Stadler, L. J.	1928	*Sci.*, **68**: 186—7. (Quoted by Elliott, 1958).
Sukanya Bai, M. V., K. Rajagopalan & A. Abdul Samad	1957	*Madras agric. J.*, **44**: 664.
Torao, H. & V. Mizushiwa	1939	*Jap. J. Bot.*, **10**: 213—58 (Quoted by Ghose *et al*, 1956).
Venkatanadhachari, G.	1959	*Andhra agric. J.*, **6**: 174—80.
Venkataswamy	1957	*Genetical and cytological studies of sterility in interracial hybrids of rice (Oryza sativa L.)* I. A. R. I., Unpublished thesis (Quoted by Gopalakrishnan 1960).
Viollard	1924	*Trop. Agriculturist*, **57**: 232.
Yamaguchi, H. & A. Ando	1959	*Jap. J. Breed.*, **9**: 169—71.