III. Above Elevation of about 4000 feet above M. S. L:

1. Michelia nilagirica
2. Hydnocarpus wightiana and
   ,, alpina
3. Gordonia obtusa
4. Ilex wightiana
5. Elaeocarpus oblongus and
   ,, Munroii
6. Turpinia pomifera and
   ,, nepalensis
7. Meliosma arnothiana
8. ,, wightii
9. Photinia notoniana and lindleyana
10. Eugenia arnothiana and montana
11. Heptaplenrum spp.
12. Vilburnum erubes and
    ,, hebanthum
13. Vaccinium leschenaulti and
    ,, neigherrense
14. Sideroxylon tomentosum
15. Cinnamomum zeylanicum
16. Litsea wightiana
17. Neolitsea zeylanica
18. Glochidion neilgherrense
19. Rhododendron arboreum
20. Ligustrum perrotteii
21. Rapania wightiana
22. Celtis tetranda
23. Daphyniphyllum glaucescens
24. Microtropis spp.
25. Symplocos foliosa and spicata
26. Ternstroemia japonica
27. Eurya japonica
28. Evodia roxburghiana
29. Euonymus cremulabus

Under growth consists of:

1. Berberis tinctoria
2. Hypericum mysorense
3. Dodonea viscosa
4. Rhodomyrtus tomentosa
5. Osbeckia wightiana
6. Gaultheria fragrantissima
7. Eupatorium glandulosum
8. Mahonia leschenaultii
9. Strobilanthes spp.

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Studies on Drought Resistance in Rice*

by

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Discussion: The drought resistance of progensies of crosses between the cultivated rice and wild rice was tested in their F3 and F4 generations in the field under restricted water supply. These tests revealed that the cultivated low-land rices are unable to withstand drought whereas the hybrids between the cultivated and wild forms showed greater ability to resist drought. The progenies of crosses studied in the two generations were found segregating for drought resistance and drought susceptibility. This is in confirmation with what Ostermayer (1934) found in oats. Very little work on breeding for drought resistance in rice has been done except for the mention made by Srinivasan (1941), who obtained a few drought resistant cultures from an inter-specific cross, *Oryza sativa* x *Oryza longistaminata (perennis)*.

* Continued from May 1957 Issue.

A study of the morphological characters showed that the progenies resembling the wild parents were able to resist drought better than those resembling the cultivated parents. These resistant progenies exhibited an open type of tillering, broad and flowing leaf lamina and lighter shade of green in the colour of the foliage. The leaf was coarse and rough with bristles. These characters are typical of the wild rice varieties used in hybridisation and it is definite that the progenies resembling the wild rice are drought resistant as a result of inheritance.

The wild rices were, however, found to have delayed germination and slow growth in the early stages but were found to tide over successfully the drought occurring in later stages. On the other hand the cultivated rices showed quick germination and steady growth in the early stages though they were unable to withstand late drought and failed to produce any ears. Hence the progenies which have synthesised the characters of both the parents should be able to withstand both the early drought as well as late drought and this has been confirmed in the trials conducted when many progenies did successfully resist the severe drought in their F3 and F4 generations.

It has been possible to obtain drought resistant progenies possessing the good qualities of the cultivated rice. High yield and good quality grain are the ultimate aim of the rice grower. The wild rices have coarse grain and awns, are highly shedding and are poor yielders, but they possess the quality of resistance to drought. This good quality of the wild parent has been combined with the desirable qualities of cultivated rices.

Duration is one of the important characters in the rice crop, though it can be altered slightly by different cultural practices. This has been observed during the study and it has been found that withholding water and drying the plots enhanced the 'flowering duration' as well as the 'period of flowering' slightly. 'Flowering duration' was found to increase by about seven to ten days in the drought bound conditions and the period or range of flowering increased from seven to eleven days in the semi-wet condition and much protracted in the purely open and dry field. Though early maturing types are only 'drought escaping' they are to be preferred for cultivation under dry conditions. It may not be possible to grow a long duration variety either under purely rainfed condition or under limited water supply owing to the long period it will take to mature. The aim must be to select progenies, resistant to drought as well as shorter in

duration. Studies were made with progenies obtained from crosses of parents belonging to the short duration as well as the mid duration group and it has been clearly demonstrated that the short duration hybrid progenies were the successful ones under the extremely droughty condition in a purely open and dry field. Some of the mid duration progenies failed to put forth ears under this condition though a few progenies earlier than both the parents were obtained. However, these progenies did well under conditions of restricted irrigations. Droughty conditions prevailing at the time of ear emergence in the rice crop are disastrous as they cause bad setting resulting in poor yield. A good yield in rice is possible only with adequate water supply.

The dry rices are comparatively poor yielders with an average of 1000 to 1500 lb. of grain per acre whereas rices grown in swamps yield up to 5000 lb. per acre. Attempts have however, been made in the present study to select progenies which yield high under the droughty conditions. High yielding progenies selected in the F3 generation were found to give significantly higher yield in their F4 generation also as shown in Table 2. Correlation of duration and yield has shown that longer duration groups, with 125 days 'flowering duration' give significantly higher yield than the early duration groups with only 110 days 'flowering duration'. Light green foliage, though found associated with drought resistance, could not be correlated with high yield.

Review of the work of various authors shows successful evolution of drought resistant strains of wheat, oats and many other crops by hybridisation and selection under definite droughty conditions. It is seen that there is a definite varietal resistance to drought in crops. Progenies of crosses between the resistant and susceptible types as well as between two drought resistant types also exhibit variation in drought resistance (Vassiljjev 1936, Isenbeck 1939, Aamodt and Johnston 1936 etc.). The present study has demonstrated that drought resistance in the progenies is a heritable character and it is possible to evolve high yielding drought resistant strains from the hybrid populations by repeated selection from families raised both under extremely drought conditions as well as restricted irrigated conditions. The capacity to resist conditions of drought has thus been found to be genotypic.

The importance of root system has been stressed by more than one worker in this field. Osternayer (1934) found in oats that the progenies of the resistant types had a well developed root system

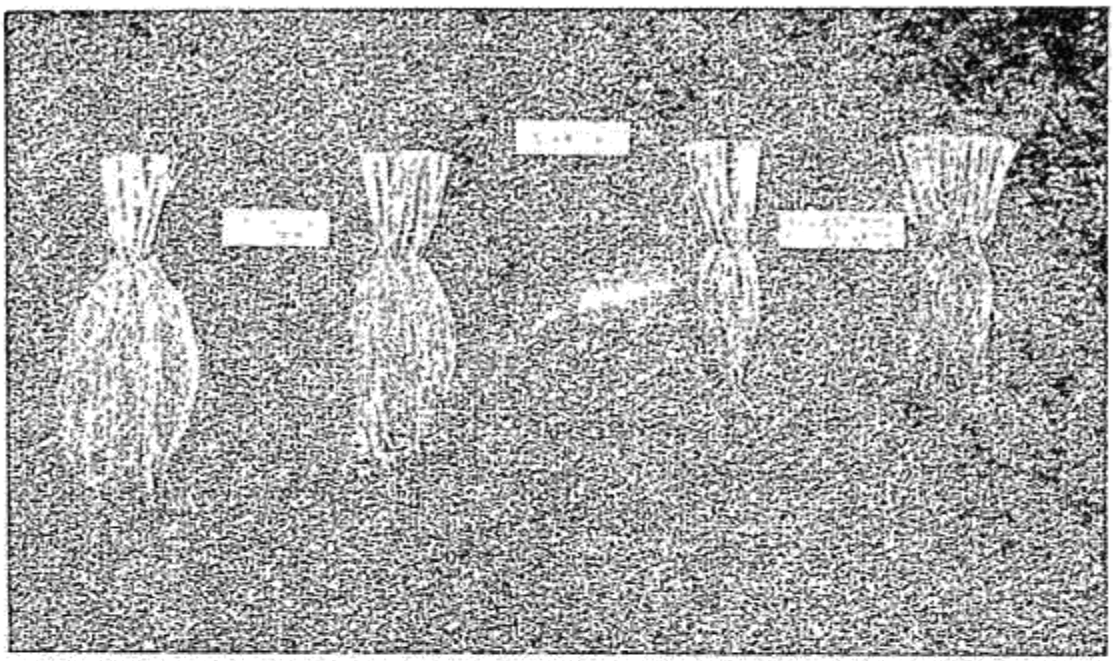

PLATE 1

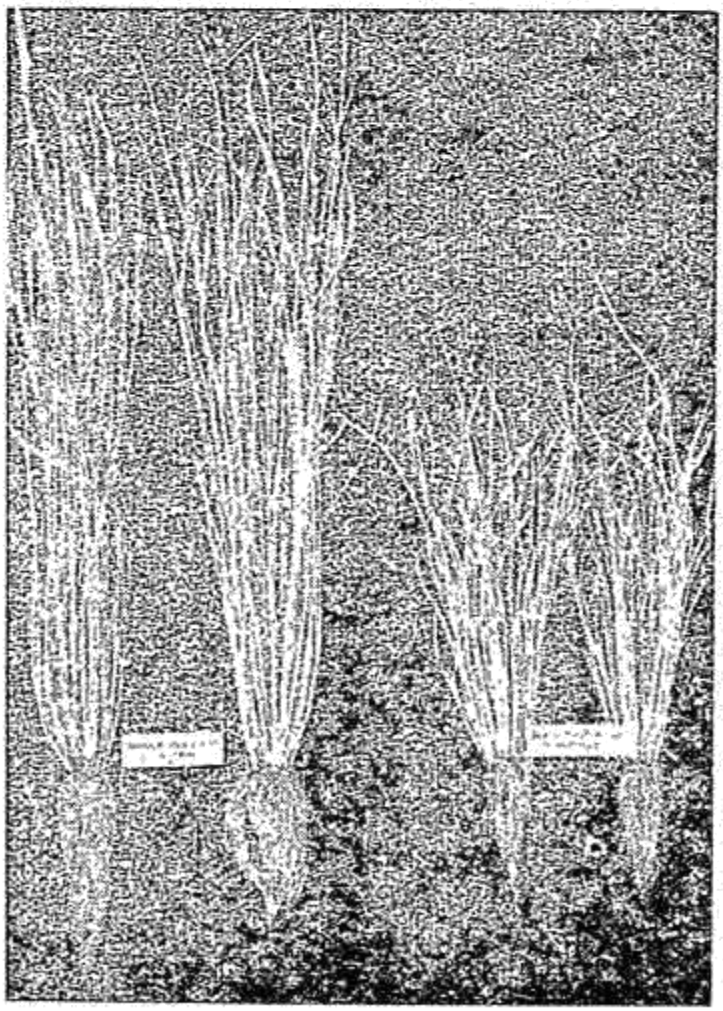

PLATE 2

as compared to their shoot. From his study of over twenty years in oats he has concluded that drought resistance behaves as a Mendelian character and it is associated with root system. Udoljskaja (1937) observed in the drought resistant *Triticum-Agropyron* hybrids, a much longer root system than the common wheat varieties. Similar observations have been recorded in the present study in the drought resistant F3 progenies of crosses between the cultivated and wild rice varieties (Plate 1). Root production was more in the resistant progenies and more of thick roots were noticed in them. The susceptible parents (Plate 2) as well as the susceptible progenies had poor shoot growth and the plants withered and died before they could throw out all the earheads. The production of tillers was good but many of them died and this should have happened since there were not enough of roots to support the tillers. The dry weight of roots of the resistant progenies was more than one and a half times that of susceptible plants. Thus it may be concluded that drought resistance is an inherited character and it is vitally associated with the root system in the rice plant.

Summary: Rice varieties belonging to the cultivated forms and the wild species of *Oryza* were taken for the study on drought resistance in rice. Among the cultivated forms five varieties grown under swamps which are high yielders but susceptible to drought were chosen. Nine wild rice varieties belonging to *Oryza sativa* forma *spontanea* were used as parents for hybridisation.

Crosses were effected between the cultivated and wild rices to synthesise the drought resistant habit of the wild species of *Oryza* with the high yielding, non-shedding nature and other good qualities of the cultivated rice. Nine successful hybrids were studied in their F1 and F2 generations for their morphological characters. The F3 and F4 generations were studied for their reaction to drought and segregation for tillering, height, awning and shedding of grains. Yields of the progenies were recorded in the F3 and F4 generations and a positive correlation between the two yields has been obtained.

The progenies were found segregating for drought resistant and drought susceptible plants and that drought resistance is an inherited character in rice has been established by the study. Attempts have been made to associate the morphological and physiological characters with drought resistance. Foliage colour was found associated with drought resistance. Light green plants were found to resist drought better than the dark green plants. Progenies

with spreading habit and open type of tillering, broad and flowing leaf lamina with coarse and rough bristles were able to survive drought better than those resembling the cultivated forms. Crosses of the short duration parents were more suitable for extremely droughty condition. The drought resistant progenies were found to possess a highly developed root system.

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TABLE 1

Root weight of drought resistant and drought susceptible F_3 progenies.

S. No.	Particulars	Mean dry weight of root in grams	Standard error	Standard error of the difference between means (Ed).	d/Ed.
1.	Drought resistant F_3 progenies	2·57	0·164	0·165	3·63*
2.	Drought susceptible F_3 progenies	1·48	0·018		

* = highly significant

TABLE 2

Correlation of yield between F_3 and F_4 generation of drought resistant cross between cultivated and wild rice, Co. 13 x T. 129.

F_4 yield as percentage on control	F_3 yield as percentage on control									
	80 to 89	90 to 99	100 to 109	110 to 119	120 to 129	130 to 139	140 to 149	150 to 159	160 to 169	Total
80— 89	3	1					1		1	6
90— 99	1	1								2
100—109	1	3		2						6
110—119										0
120—129			1							1
130—139										0
140—149	1									1
150—159		1			1	1				3
160—169		1	1	1		2				5
170—179				1				1		2
180—189					1	1				2
190—199					2					2
200—209		1		1		1				3
210—219			1	1	2		1			5
Total ..	6	8	3	6	6	5	2	1	1	38

$r = + 0·392 \pm 0·152$

TABLE 3

Frequencies of yield of progenies with light green and dark green foliage in F_3 generation of cross between cultivated and wild rice Co. 13 x T. 129.

Particulars	yield as percentage on control						
	90—99	100—109	110—119	120—129	130—139	140—149	150—159
Light green progenies	6	2	3	4	1	1	1
Dark green progenies	3	1	4	3	4	1	1

Particulars	Yield as percentage on control 160—169	Total	Mean	Standard error	Ed	d/Ed	
Light green progenies	..	18	113·9	4·26	6·17	1·25	Not significant
Dark green progenies	1	17	121·6	4·46			

TABLE 4

Frequencies of yield of progenies with light green and dark green foliage in F_4 generation of cross between cultivated and wild rice Co. 13 x T. 129.

Particulars	Yield as percentage on control							
	91–100	101–110	111–120	121–130	131–140	141–150	151–160	161–170
Light green progenies	4	3	7	11	5	10	6	5
Dark green progenies	8	6	10	10	17	13	7	12

	Yield as percentage on control							
	171–180	181–190	191–200	201–210	211–220	221–230	231–240	241–250
Light green progenies	4	4	1	3	1	3	3	3
Dark green progenies	10	9	8	10	8	6	5	4

	Yield as percetage on control					Total	Mean	Standard error	Ed	d/Ed
	251-260	261–270	271–280	281–290	291–300					
Light green progenies	..	2	1	2	1	79	165·1	5·76	7·05	1·59
Dark green progenies	6	7	3	2	2	163	176·3	4·07		Not significant

TABLE 5

Frequencies of yield progenies with 110 and 125 days flowering duration in F_4 generation of cross between cultivated and wild rice Co. 13 x T. 129.

Particulars	Yield as percentage on control							
	91–100	101–110	111–120	121–130	131–140	141–150	151–160	161–170
110 days	3	6	10	13	3	4	2	4
125 days	8	4	8	6	19	17	11	11

	Yield as percentage on control							
	171–180	181–190	191–200	201–210	211–220	221–230	231–240	241–250
110 days	1	2	1	..	..	3	2	..
125 days	12	11	8	12	8	5	7	5

	Yield as percentage on control					Total	Mean	Standard error
	251–260	261–270	271–280	281–290	291–300			
110 days	..	3	1	..	..	58	148·8	6·33
125 days	5	6	3	4	3	173	179·6	3·90

Ed.	d/Ed.	
7·43	4·15	Highly significant.

APPENDIX.

Description of rice varieties used in the study.

1. *G. E. B. 24.* '*Kichilisamba*'. Isolated from Konamani, probably a mutant. This is a very popular strain in Madras State on account of its high quality of table rice. It matures in about 150 days when sown in July-August but the duration will be extended or reduced according to the sowings being made earlier to or later than July-August. It gives an average yield of 3,600 lb. per acre and with intensive cultivation a maximum of 5,000 lb. per acre has been obtained.

Time of harvest: Fourth week of November
Grain size : L. 7·8 mm., B 2·4 mm., T. 1·8 mm.
Glume colour : Straw; Rice: white

2. *CO. 1.* '*Periakichili*' Isolated from GEB. 24 as a natural cross yielding 20 per cent over GEB. 24. Possesses the qualities of GEB. 24 but rice is coarser and duration is a week late. It is popular in Coimbatore and Tiruchirapalli districts.

Time of harvest: 1st week of December
Grain size : L. 8·5 mm., B. 2·6 mm., T. 1·9 mm.
Glume colour : Straw; Rice: white

3. *CO. 2.* '*Poombalai*' or '*Kartigaisamba*'. Isolated from Poombalai grown in Sivagiri Taluk of Ramanathapuram district. It adapts itself better than other varieties of late planted conditions in October-November. On an average it has recorded eight per cent over ryots' bulk. It has given a maximum yield of 4,000 lb. per acre.

Time of harvest: Second week of December
Grain size : L. 7·5 mm., B. 2·5 mm., T. 1·9 mm.
Glume colour : Straw; Rice: white

4. *CO. 5.* '*Chinnasamba*'. Isolated from Chinnasamba cultivated in Coimbatore. Yields 12 per cent over ryots' bulk. It responds to high manuring and yields about 3,500 lb. under average conditions. Rice is fine.

Time of harvest: Third week of December
Grain size : L. 7·9 mm., B. 2·6 mm., T. 1·9 mm.
Glume colour : Straw; Rice: white

5. *CO. 13.* '*Arupathamkodai*'. This strain was isolated from Arupathamkodai or vellaikodai from Madurai district. Yields 19 per cent over the local seed. It can be grown both in the first crop (June-September) and late navarai (February-May) season. It has given an yield upto 3,000 lb. of grain per acre with an average of 2,170 lb.

Duration : 110 days
Grain size : L. 7·8 mm., B. 3·1 mm., T. 2·0 mm.
Glume colour: Straw with purple tip; Rice: white

6. *T. 113.* Extracted wild rice. It is an awned variety with short tip to full awns and shedding.

Duration : 135 days.
Grain size : L. 8 5 mm., B. 2·4 mm., T. 1·8 mm.
Glume colour: Straw with light dirty furrows; Rice: white

7. *T. 128.* Extracted wild rice- Short awned and shedding.

Duration : 138 days
Grain size : L. 8·6 mm., B. 2·3 mm., T, 1·8 mm.
Glume colour : Dull straw ; Rice : red

8. *T. 129.* Extracted wild rice. Awns full and shedding.

Duration : 145 days
Grain size : L. 8·7 mm., B. 2·2 mm., T. 1·8 mm.
Glume colour : Light dirty furrows; Rice : red

9. *T. 162.* Extracted wild rice. Awned and shedding.

Duration : 145 days
Grain size : L. 6·9 mm., B. 2·5 mm., T. 1·9 mm.
Glume colour : Brown furrows; Rice : white

10. *T. 469.* 'Pasoher' wild rice. This is found in Madhya Pradesh. The grains are fully awned and badly shattering.

Duration : 128 days
Grain size : L. 8·5 mm., B. 2 9 mm., T. 2·0 mm.
Glume colour : Straw; Rice : red

11. *T. 740.* 'Kun-Kuan Mouning', a wild rice from China. It is an awned variety with short tip to medium awns and badly shedding of grain.

Duration : 125 days
Grain size : L. 8·0 mm., B. 3·0 mm., T. 2·1 mm.
Glume colour : Straw; Rice : white

12. *T. 1601.* 'Chulto Balunga Uriya', a wild rice from Berhampore, Orissa. It is a fully awned variety and a badly shedding type.

Duration : 145 days
Grain size : L. 7·9 mm., B. 2·1 mm., T. 1·8 mm.
Glume colour : Black; Rice : red

13. *T. 1602.* This is a wild rice from Berhampore called 'Berhampore wild 8'. This was collected from Para village. It is an awned variety with full awns. Grains are very easily shedding.

Duration : 145 days
Grain size : L. 8·1 mm., B. 2·1 mm., T. 1·8 mm.
Glume colour : Black; Rice : red.

14. *T, 1702.* 'Valnellu'. This is a wild rice collected from Kodaikanal in Madras State. It is a fully awned variety and grains are easily shedding.

Duration : 140 days
Grain size : L. 9·0 mm., B. 3·2 mm., T. 2·1 mm.
Glume colour : Dull straw; Rice : red.