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Studies on Drought Resistance in Rice*

by
Sri K. RAJAGOPALAN, B. Sc., (Ag.,) M. Sc.,
(Agricultural College and Research Institute, Coimbatore)

Introduction: According to Maximov (1929) "drought resistance means the capacity of plants to endure drought and to recover readily after permanent wilting, with the minimum of damage to the plant itself and to the yield produced." He suggests that the most important step must be to select from plants capable of growing in drier regions, those which can readily endure and do not merely escape or evade severe drought. In his opinion it should be possible. when we have decided which plants are truly drought resistant, to attack with success the problem of determining the peculiarities of organisation that actually confer on plants the faculty of enduring drought.

Drought itself is by no means a simple phenomenon. Categorically it is of two types; soil drought and atmospheric drought, of which the former is often more important than the latter. Hot and dry winds cause atmospheric drought and consequent wilting or desiccation of the plant, though the soil in which it grows might have enough moisture. Soil drought, on the other hand, causes the plant to wilt by not providing it with adequate water or providing it only in insufficient quantities so that the plant is not able to replenish the water lost by transpiration. Soil drought causes a permanent wilting of the plant, whereas wilting due to atmospheric drought is mostly temporary. Both soil and atmospheric drought therefore cause havoc to plant growth and adversely affect crop production in the semi-arid regions of the world.

In Madras State, rice on 75 percent of the area, is raised under wet conditions. The remaining 25 percent of the area is sown with rice varieties which are entirely rainfed. Some of them are dryland types grown under open conditions while some others are treated as wet rice, if conditions are favourable; but all of them have to withstand drought for considerable periods. In marked contrast, the wet rices grown in the majority of the rice growing areas, require a plentiful supply of water. Apart from this, there are about 25 species of *Oryza* known to occur in the wild state, of which *Oryza sativa* forma *spontanea* reckoned as the immediate progenitor of most of the cultivated rices in India, has a close resemblance to cultivated

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forms in several characteristics, with an affinity for easy crossing with them. It occurs all over India, and differs from the cultivated forms in respect of the ease with which the grains shatter from the panicle, helping in its dispersal. These wet, dry and wild rices greatly vary in their water requirements and consequently resistance to drought. It may therefore be assumed that drought resistance should be a specific character and one which requires very close study.

The present studies are directed towards the characteristics which are associated with drought resistance so that these may enable the breeder to use them in his attempts to evaluate drought resistance in his work of evolution of drought resistant forms. It relates to the study of hybrids between high yielding cultivated low-land rices and drought resistant wild rices and their behaviour towards drought.

Materials and Methods : A collection of 2,300 varieties of rice belonging to the cultivated forms of indigenous and exotic types as well as the wild species of *Oryza* is being maintained at the Paddy Breeding Station, Coimbatore as a live herbarium. The wild varieties chosen for the study belong to the species of *Oryza sativa* forma *spontanea* and are characterised by free awning and severe shedding of grain. These wild rices both exotic and indigenous are not therefore cultivated and they are very poor yielders besides possessing poor quality of grain. Some of them are extracted or synthetic types obtained from pure breeding hybrid materials studied. The wild rices are maintained in pure condition for their genetic characters as valuable material for study and use as parents in hybridization to combine their desirable qualities such as disease resistance, drought resistance, etc., with the cultivated types.

Among the wet varieties chosen for the study, GEB. 24 is an improved strain very popular throughout the State for its good quality as table rice, comparatively high proportion of rice to paddy by weight and its capacity for high yield under early planted conditions. The other strains evolved from the Paddy Breeding Station, Coimbatore, namely, Co. 1, Co. 2, Co. 5 and Co. 13 are equally popular in different parts of the State and also high yielding. The strain Co. 13 is a short duration variety which comes up for harvest in 110 days and is cosmopolitan in nature as it can be fitted into any season, either in the first crop season from June to September, or later in the 'Navarai' season from February to May or the intermediate season as well.

Hybridisation was started in the year 1947 with the object of combining drought resistant habit of the wild species of *Oryza* with the high yielding non-shedding and other good qualities of the cultivated *Oryza sativa*. Nine sets of successful crosses namely, Co. 13 x T. 129 and Co. 13 x T. 469 (short duration crosses maturing in 125 days) and GEB. 24 x T. 1601, Co. 1 x T. 1702, Co. 2 x T. 1602, Co. 2 x T. 162, Co. 2 x T. 740, Co. 5 x T. 113 and Co. 5 x T. 128, (medium duration crosses maturing in 150 days) were effected during the year. (The description of the parents is given in Appendix).

The hybrids were grown during 1948—'49 under irrigated condition. The F1 and F2 generations were studied for their morphological characters. Single plants with ability to withstand drought and in addition possessing desirable characters such as good tillering, non-shattering, awnlessness and early maturity were selected.

The F3 and F4 generations of the crosses were studied for their reaction to drought by growing the progenies under controlled conditions of irrigation where the plants were subjected to artificial drought in the field. In one set of experiment the progenies were grown in a wet field where the plants were subjected to artificial drought by withholding irrigation at intervals till the crop flowered, after which the fields were always kept wet for the proper maturity of grains.

In another set of experiment the progenies were grown under purely dry conditions in an open dry field. The seeds were sown dry and the crop matured with the help of rains received during the season in addition to few irrigations.

The ultimate object of the studies was to synthesise ideal new types appropriate for every environment by accumulating in them valuable ancillary characters conducive to resistance to drought.

Review of Literature: Ashton (1948) who has adequately reviewed the work on 'Breeding for drought resistance in crops' observes that "comparatively little specific breeding for drought resistance bas been carried out on account of the complex nature of reaction to drought." Aamodt and Jonston (1936) observe that in Russia the nature of drought resistance and its application to breeding problems are being studied intensively and several new drought resistant wheat varieties superior to the old Russian ones both in yield and quality have been developed by plant breeders of

that country. Investigations were started in America in 1928 and much work on breeding for drought resistance has been reported in wheat from that country.

Stefanovskii and Petropavlovskii (1934), studied thoroughly the reaction of a large number of varieties, including 400 varieties of the world collection of wheats and arranged them according to their reaction to drought. Fleischmann (1934) in discussing the problem of developing drought resistant wheats in Hungary suggested hybridisation between Hungarian wheats and introduced wheats such as Marquis, as possible methods of breeding drought resistant varieties needed for local conditions. Udoljskaja (1936) distinguishes two distinct biological types of spring wheats on the basis of physiological behaviour and morphological characters and presents notes on a number of wheat varieties which are of interest in breeding work in the evolution of drought resistant forms.

Stefanovskii (1937 b) considers that the Afghanistan soft early maturing wheats of the desert and semi-desert types are considered to be of particular interest to the breeder in view of their general drought resistance. Udoljskaja (1937) found that the F1 hybrids of *Triticum - Agropyron* which resembled *Agropyron* were highly drought resistant. The F2 hybrids obtained by backcrossing the F1 to wheat varied in reaction to drought and some promising progenies were selected. Many lines that appeared uniform segregated with regard to drought resistance, when subjected to rigorous conditions of drought. Testing under these conditions is therefore suggested as the best means of selecting the most drought resisting forms. Isenbeck (1939) was of opinion that breeding for drought resistance is greatly hampered by the absence of any definite method by which it can be determined and carried out in the laboratory and hence only a general estimate of drought resistance of plants under field conditions becomes possible. Stefanovskii and Veceslova (1939 a) found that promising hybrids could be obtained only from crosses between parents both of which were drought resistant. They claim that the proportion of resistant plants were higher in families raised under arid conditions than otherwise owing to natural selection operating in the early stages.

Krasovskaja (1940) states that drought resistance and yield under drought conditions were higher in individuals derived from parents which had been grown in an arid environment. Saks (1941) stresses that in breeding drought resistant varieties it is important

to select forms that yield well both in bad years as well as in good years. Pal (1944) in discussing the wheat breeding work of the Indian Agricultural Research Institute points out the possibility of effecting wide crosses between wheat species and of cereals and grasses of the genera allied to *Triticum* which are reputed to possess characters such as disease resistance and drought resistance. Chinoy (1947 a, b) studied about 260 selected varieties of exotic and Indian wheats grown under dry and irrigated conditions. On the basis of such a study a classification of wheat varieties for their reaction to drought resistance has been made.

Various investigations on breeding for drought resistance in maize, (Jenkins, 1932, Heyne and Brunson, 1940), oats (Ersov, 1935), barley (Harrington, 1935), *Paspalum*, grasses and other crops such as potato, *Luffa*, *Citrullus*, tomato, beans and forest trees, have been reported. (Ashton, 1948).

There has not been much of breeding work with regard to rice in the matter of drought resistance in India. "Crossing between wild and cultivated types has been done at Coimbatore and it appeared possible to evolve types having the drought resistant character of the wild rice, without any of its undesirable characteristics." (Ramiah 1937). Srinivasan et al (1941) have recorded that some drought resistant cultures were obtained from the progenies of an inter-specific cross, *Oryza sativa* X *Oryzo longistaminata (Perennis)*. It was found in Madhya Pradesh that the trouble due to the wild rice *Oryza Sativa* L. Var. *fatua* (Spontanea) in rice fields was serious in years of drought than in normal conditions when it tillers more rapidly and profusely than the cultivated rice, showing that it can thrive better under unfavourable moisture conditions, At the Rice Research Station, Berhampore, from a cross made between the cultivated rice and the wild species *Oryza perennis*, progenies partially resistant to drought were obtained. Hybridisation was started in 1940 in Kashmir between low yielding, awned, hardy varieties of rice grown in higher altitudes and high yielding types of Kashmir valley proper. (Ramiah and Narasinga Rao, 1953).

In the fields of drought resistance, high yielding strains of dry varieties have been evolved by mass selection as well as pure line selection. Hybridisation has not produced so far a suitable strain to meet such conditions.

Observations: The progenies of nine sets of crosses between cultivated and wild rices were studied for their morphological and

physiological characters and compared with their parents from 1948 onwards. Dominant characters such as purple pigmentation, awning, red rice, bold grain and shattering of grains were exhibited in the F1 generation. In this connection it may be pointed out that the cultivated rice varieties were used as male parents and the wild *Oryza sativa* forma *spontanea* forms were used as female parents, since the wild parent shatters its grain even ten days after seed setting. Out of the nine successful hybrids, two belong to the short duration group and seven to the medium duration group. The 54 F1 plants grown in 1949 were again studied in all stages of their growth for characters such as anthocyanin pigmentation in the leaf sheath, internode, junctura, auricle, ligule, pulvinus, septum, leaf axil, stigma, glume, lemma-palea, apiculus and leaf blade; sterility, duration, height, tillering, lodging of straw, shattering of grain and other panicle characters.

F3 progenies numbering 485 were subjected to rigorous drought test during the 1950—'51 season under purely dry conditions and under semi-wet condition. Parents of both the cultivated and wild varieties were sown after every 15 progenies. Sowing was done in July and it was found that the germination started in most of the progenies on the fifth day and continued upto the seventh day. The cultivated parents were quick in germination and they started their germination on the third day whereas the wild parents and some of the progenies showed delayed germination. This is an indication that the wild varieties and their progenies are slow in germination. The crop had an uniform stand and the seedlings were coming up well till the first week of September. The seedlings were thinned uniformly to one seedling per hole. The South-west monsoon showers received during the period were adequate and optimum. Some of the progenies were found to thrive very well with proper tillering and vigorous growth.

During the month of September when the South-west monsoon waned, the crop was affected by drought as the North-east monsoon was below normal and it was noted that some of the progenies were able to withstand the drought quite well while a few of them succumbed to drought altogether. It was also found that in the same progeny some plants were more susceptible to drought than the others. The drought susceptible progenies started yellowing, showed symptoms of wilting and finally dried up. The first symptom of wilting was noted on the 55th day after sowing. The plots were not irrigated immediately after the symptoms were

noticed. The next irrigation was given a month after the plants started symptoms of wilting. By this time some of the susceptible progenies had wilted permanently and never survived.

Association of drought resistance with other characters: The progenies as may be expected were segregating for many morphological characters as well as physiological characters. The study of the morphilogical characters revealed that anthocyanin pigmentation was not associated with the drought resistance of the plants since it was noticed that plants with different intensities of pigmentation had succumbed to drought. It may be mentioned, however, that the intensity of the purple pigmentation became more pronounced as the drought advanced.

Segregation for compact tillering resembling the cultivated parents and spreading habit resembling the wild parent were noticed. (Ramiah, 1930). Progenies wlth spreading habit were able to withstand drought better than the compact type. There was a great deal of variation in the thickness of culm and progenies possessing thicker or stouter culms were in general able to survive the drought better than those with thin culms. Other characters of the stem, viz., brittleness, pulvinus colour, node colour and pigmentation in the septum were not associated with drought resistance.

The leaf consisting of the leaf sheath, junction, ligule, auricle and the leaf blade were taken into consideration. It was noticed that few of the progenies possessed well developed auricle resembling that of the wild parent. No purple pigmentation was noticed in the leaf blade. But some differences in the intensity of the green colour in the foliage were observed and there appeared two definite shades of green, viz., light green and dark green. Progenies were segregating for these foliage colours and it was observed that plants with light green foliage were more drought resistant than dark green plants.

Size of the leaf blade was studied and both the narrow and the broad leaf blades were observed in the segregating progenies. The wild parents are characterised by a broad leaf blade. Progenies with broad leaf blades gave higher percentage of survival in the drought test than that with narrow leaf blades. Hairiness of the leaf was found in many of the resistant F3 progenies which possessed coarse hairs, and rough feel characteristic of the wild parents.

Another character of the leaf that was observed was its long, flowing habit as distinguished from the normal erect habit of the leaf blade. Most of the wild species of *Oryza* have the flowing habit of

the lamina and this character was inherited by the progenies. It may be said that the narrower the leaf blade, the less is the transpiring surface. But quite contrary to this fact the wild parents possess a broad leaf with flowing habit and progenies resembling this type were more drought resistant. It was observed in another study (vide physiological studies) that size of the leaf blade, both length and width, was not correlated with the drought resistant habit of the plant.

After the crop had flowered the characters of the panicle and the grain were observed. Genetic variations in the size and density of the panicle, colour of the glume, lemma and palea, colour of the apiculus, fertility of the spikelet, ripening colour of the lemma and palea, colour of the apiculus, fertility of the spikelet, ripening colour of the lemma and palea, awns and rice colour were all studied.

The wild rices are characterised by very low density of grain setting in the panicle and the ears are very open with sparsely arranged spikelets, in marked contrast with the cultivated rices. Both the lax, open type of panicle and the dense and close type of panicle were noticed. (Mitra and Ganguli 1935).

Lax type of panicle was always associated with other wild characters and it was found that some plants with lax panicle were able to withstand drought. While selecting plants, both the types with the lax panicle and the dense panicle were selected. Panicles of varying lengths were observed and care was also taken to select plants with longer panicles. Straw, brown and purple colours in the glumes were noticed with similar variations in ripening colour of grain. Since the ultimate aim was to carry forward plants which were able to withstand the drought test these characters did not weigh much in selection. Awn, however, which has an important physiological function as demonstrated by Hayes and Wilcox (1922) in barley, was studied with greater care as it has been found to be the most subject to change than other structure from environmental influences (Anandan 1933, Sethi *et al* 1937 b). Droughty conditions restrict awn development while shade induces greater awn development. Mendiola (1926) records that increased water supplies augmented awn growth in rice. Awn in rice, it is believed, has an intimate association with the general hardiness of the variety.

All the wild rices have fully developed awns. Both awnless and awned types were met with in the progenies and it was observed that the awned plants were more in number. Segregation for tip,

awned and long awned plants were observed in the hybrid population Though awning is not a desirable economic character, recognising its importance in drought resistance studies, plants with awns were not drastically rejected. Many promising plants with awns were found to come up well in an adverse condition and all of them were therefore selected for further tests.

The size and shape of the grain varied in the different cultivated and wild parents used for hybridisation in the study. Though genetic factors control the size of grain, environmental conditions also affect it. It was observed that in general, there was a reduction in size of grain in progenies grown under open dry conditions. The wild parents have coarse grains and the cultivated parents have medium and fine grains. Segregation for these characters were noticed in the F3 generation, but plants irrespective of the grain size were selected though fine and medium types were given preference. Segregation for rice colour, red and white, were observed and the majority of the progenies were red riced since red colour in rice is dominant over white (Parnell et al 1922). All the wild progenies except T. 113, T. 162 and T. 740 used for hybridisation in the study are red riced and the cultivated parents white riced. Here again progenies with red and white rice colour were selected. In all the several characters studied, those factors associated with drought resistance alone were given importance.

The drought resistant progenies selected were studied with special reference to their duration, tillering and root development.

It is very rarely that a variety is found to have a constant duration under different conditions of culture. As Copeland (1924) put it "duration although constant under fixed conditions, it is rarely a simple character". External conditions have a very marked effect upon this complex character of duration. The study of the F3 progenies under dry environment and under controlled irrigated conditions shows that withholding water and drying the plots slightly enhances the "flowering duration," as well as the "period of flowering". Taking the parents alone into consideration it was found that the short duration parent Co. 13 with a 'flowering duration' of 80 days completed flowering after 96 days in the semi-wet condition and after 104 days in the purely open dry condition. Similarly GEB. 24, a medium duration variety of 98 days flowering duration when sown in August 1st (Ramiah 1933 a) flowered in the semi-wet condition after 104 days but it failed to flower in the dry condition

as the plants did not survive the drought in the later stages of growth. Co. 1 with a 'flowering duration' of 110 days, flowered after 118 days in the semi-wet condition and 134 days in the dry condition. Co. 2 and Co. 5 with flowering duration of 127 and 134 days respectively flowered a week days later under the semi-wet condition but failed to flower under the dry condition. The "period of flowering" was also found influenced by the dry and semi-wet environment. The normal 'period of flowering' of a variety, that is the interval between the beginning and the ending of the flowering phase, is seven days. But it was observed that this period was extended upto 11 days in the semi-wet condition and very much protracted in the dry condition since the emergence of the ears in an individual plant itself was very slow. This kind of protracted flowering resulted in the uneven ripening of the ears. Hence under dry conditions individual yield of the progenies could not be recorded and only single plants were selected. In the semi-wet condition, from the time the progenies had started flowering, the plots were kept wet and never allowed to dry and hence ripening was uniform.

The F3 progenies were segregating for duration and it was found that the majority of the progenies were late. Duration was one of the main considerations in slection and it was seen that many plants earlier than the cultivated parents with good drought resistant quality were selected. From the performance of the hybrid progenies grown under purely open dry condition it was observed that cross Co. 13 x T. 469 was the earliest to flower with a 'flowering duration' ranging from 104 to 123 days and the most suitable for growing as dry paddy, though late duration cross progenies of Co. 1 x T. 1702 and Co. 2 x T. 1602 showed better resistance to drought in the early stages of growth.

The performance of the 284 F3 progenies grown in the puddle was watched for their drought resistance. The drought treatment here was not so severe as in the first instance. After transplanting, the plots were under restricted irrigation till the time of flowering. After blooming, there was a continuous supply of water. The observations recorded were but similar to what had already been described. There was no actual wilting of the progenies as noted under the purely dry condition but they showed differential behaviour towards the drought treatment, many of them having successfully withstood the test. Co. 13 x T. 129, the earliest among the hybrids studied, was the most promising. Among the medium duration hybrids. Co. 2 x T. 1602 was highly shedding since the wild parent is

of that character. Out of the 157 progenies studied, 120 were found shedding and hence no selection was made from the shedding types as they may not be useful in the later generations. Co. 2 x T. 162 and Co. 2 x T. 740 were quite promising crosses. A total of 2356 single plants were selected after going through all the F3 progenies. Weight of grain in all the progenies was recorded and selections which yielded above the mean for each progeny were carried forward. 1172 F3 selections on the aggregate were made available for further study.

The F4 generation of the short duration cross Co. 13 X T. 129 was subjected to drought for the second time during January to April in 1951. A total of 367 F4 progenies was transplanted and treated as a semi-wet crop with intermittent irrigation. Irrigation was cut off on the 17th day after transplanting, when the seedlings had established. It was observed that on the 12th day after stopping irrigation, some of the progenies started wilting with rolled leaves. The plots developed cracks on the 4th day and by the 12th day the soil cracks became wider. At this stage irrigation was given, though thereafter it was impossible to maintain the wet puddle condition in the plot. Fortnightly irrigation was never stopped. Observations as in the previous study were again recorded and it was quite obvious that drought resistance is an inherited character. Some of the progenies wilted in the drought test and some successfully withstood it.

The F3 progenies subjected to drought under dry and open condition were examined for their root development at the flowering stage. Ninety plants belonging to both drought resistant and drought susceptible types were dug out from the field with their roots, washed and the weight of root recorded after drying in the sun for eight hours. The number of tillers per plant was also recorded. It was found that the drought resistant types had better development of root system than the drought susceptible form (Plate 1). More of thick healthy roots were noticed in the drought resistant types and the root system had a deeper penetration. The drought susceptible types had shallow root system and less of thick roots but more of thin roots. The mean number of tillers for 45 drought resistant types was 15·7 and the mean weight of root was 2·57 grams, whereas the drought susceptible types had a mean tiller value of 15·5 and a mean root weight of 1·48 gms. It was found that the resistant types had highly significant increase in root weight over the susceptible types as shown in Table 1.

The yields of the F3 and F4 progenies of cross Co. 13 x T. 129 which were grown under restricted irrigations and subjected to drought were recorded. The frequencies of yield as percentage on control in the two generations are given in Table 2. The coefficient of correlation between the yield of F3 and F4 progenies is + 0·392 ± 0·152.

Tables 3 and 4 give the frequencies of yield as percentage on control of the F3 and F4 progenies respectively of cross Co. 13 x T. 129 with light green and dark green foliage. Though light green colour of the foliage was associated with drought resistance no correlation between the colour of the foliage and yield could be seen.

Table 5 gives the frequencies of yield expressed as percentage on control of the F4 progenies with two different duration groups. It is seen that the progenies with 'flowering duration' ranging from 110 to 125 days have significantly higher yield than those with flowerlng duration below 110 days.

(to be continued)

Research Note

Some parasites of *Dactylethra candida*, Meyr., an inspect pest of *Tephrosia purpurea* Pers.

The catepillars of *Dactylethra candida*, Meyr. cause fusiform stem galls on *Tephrosia purpurea* Pers. a valuable and widely cultivated green manure plant. Mani [0] has worked out the life-history of this pest and has also noted that the caterpillars are heavily parasitised by *Brachymeria* sp., *Elasmus* sp. and *Eurytoma* sp.

While studying the stem galls on *T. purpurea* the author of this note noticed a number of parasites on *D. Candida*. The parasites reared from this host were sent to the Commonwealth Institute of Entomology for identification. They were identified as follows:—

1. *Goniozus sp.* (Bethylidae)
2. *Brachymeria sp.* (Chalcididae)
3. *Antrocephalus sp.* (Chalcididae)
4. *Bracon greeni Ash.* (Braconidae)
5. *Eurytoma sp.* (Eurytomidae)
6. *Eupelmus sp.* (Eupelmidae)
7. *Bruchocida orientalis*, Crawford (Eupelmidae)
8. *Neanastatus proximus*, Ferriere (Eupelmidae)