

BREEDING COCONUTS FOR ADAPTATION TO DROUGHT

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Drought subjects plants to water stresses which may adversely affect their growth and development. Droughts of varying intensity and duration occur in most parts of the world and they invariably cause crop losses. Frequent droughts may also cause postponement of planting, abandonment of land and other changes in land use. Drought may be overcome by irrigation. Where irrigation water is not available, there are two possible solutions, the adoption of soil moisture conservation measures and the development of crop varieties adapted to drought conditions.

Plantation agriculture in Sri Lanka depends on rainfall and crop production fluctuates with rainfall variation. Production under conditions of moisture stress is necessarily less than when there is an ample supply of moisture. So drought has an adverse effect on all crops but certain genetic constitutions may be better adapted to the stresses caused by drought and so continue to give adequate yields. The breeder must identify and propagate these types. It seems necessary to develop varieties with greater environmental resiliency, even at the expense of maximum yields.

Before attempting to develop better adapted crop varieties, some knowledge of the environment in which the crop grows is required. Of the three plantation crops of Sri Lanka, coconut covers the largest extent, a little over 1 m acres, and is less restricted than tea and rubber in its environmental requirements for growth. From Table 1, it is seen that it covers a wide range of habitats with a variety of soil, rainfall and topographic conditions – so land use, soil and water problems and their inter-related aspects are many and varied.

The general environmental requirements for coconut cultivation are listed in order of priority in Table 2. Here, the "length of growing period" refers to the period of time during the year in which the crop requires adequate

moisture for growth and is determined based mainly on requirements of rainfall distribution, humidity and sunshine hours. Rainfall usually occurs during definite periods of the year but there is variability in the total amount of rainfall and in the seasonal distribution patterns. Some semi-arid areas have low relative humidities so that there is rapid cooling after sunset. In other areas, relatively low average temperatures may interact with low soil moisture contents to moderate the effects of drought through reduced growth and evapotranspiration. The response of plants to soil moisture stress also depends on the type and depth of the soil. Topographic conditions are also important. The ideal site for planting coconuts is on flat or gently sloping land. On steep slopes there are often rocky outcrops and soils are shallow causing moisture stress in the palms even though the annual rainfall is quite high. The optimal conditions for coconut cultivation would be about two dry months each year. It is clear that the two most important environmental factors are rainfall and soil type and that rainfall distribution is much more important than total annual precipitation. On the basis of this information maps have been produced showing areas suitable for coconut cultivation under rainfed conditions and under irrigation. Tolerance or resistance to stresses in the less suitable or marginal lands must be developed if these lands are to make a significant contribution to coconut production. Through plant breeding, it may be possible to develop some degree of tolerance to the effects of drought.

Crops respond to water stress in a variety of ways, some of which are listed in Table 3. There is a saying that in responding to drought, a plant is caught between dying of thirst and dying from starvation. Several of the mechanisms for the avoidance of drought damage (or dying of thirst) such as leaf shedding, leaf movements and stomatal closure will decrease photosynthesis and bring about starvation.

Certain other mechanisms such as increased cuticular resistance, root density and osmotic adjustment may not reduce productive processes. Study of drought responses in the coconut palm are still in the preliminary stages. Some of the responses are clearly seen in the coconut palm while others are less obvious. For example, leaf senescence, leaf shedding and leaf angle changes are clear in hybrids with the onset of drought or water stress conditions. As a result, crowns are sparse, fronds droop, petioles seem long and offer no support to the bunches which hang down resulting in a high number of fallen nuts. The contrast is clearly seen in Andigama Farm where hybrid coconuts have been cultivated in both stress and nonstress conditions.

The study of drought responses in coconut requires an interdisciplinary approach with collaboration from physiologists, biochemists and biometricians. We need to devise methods of measuring these responses and then evaluating our germplasm.

Considering crop production under moisture stress, the development of a bunch of coconuts of the tall variety extends over a period of nearly four years from primordia initiation to harvest. Details are outlined in Figure 1. There is a period of 32 months development before opening of the spathe and a further 12 months after. Drought in the early stages may cause abortion of the inflorescence, reduction in the number of flowers ect. but also has a marked effect just after pollination. The susceptibility curve of a bunch of coconuts is shown in Figure 2. The effect of drought is most obvious in crop losses during the subsequent 12 month period.

The response of individual palms to drought shows very wide variation. To the plant breeder, the term drought tolerance is related to the moisture stress environment and means the ability of one genotype to be more productive with a given amount of soil moisture than another genotype. Crop losses incurred from a severe drought can be as much as 80% or even more, since nuts per palm sometimes range from 20 nuts or less per palm in the

year following a severe drought to over 200 nuts per palm, in a year following good rainfall. This range is seen in Table 4.

In some palms production is severely restricted as a result of drought so that a palm which may yield 200 or more nuts in a good year may continue to give no yield at all for one or even two consecutive bad years. With the return of good weather this palm recovers and resumes yielding over 100 or even 200 nuts per year. This type of palm is, of course, quite unsuitable for planting in drought-prone areas; it is adapted to non-stress conditions and may be recommended for regions where the likelihood of drought is low. Certain other palms may be highly adapted only to moisture stress environments. These palms give relatively high yields in the stress environments but their performance in nonstress conditions is mediocre compared to the rest of the population. Yet another type may be adapted to a wide range of environmental conditions, giving high yields under optimal environments and retaining their superior yields even under less favourable conditions.

In general, two breeding approaches are available to the plant breeder when attempting to develop varieties that yield more in a moisture deficit environment:

- (1) to develop varieties highly adapted only to a moisture stress environment
- (2) to develop varieties with adaptation to a wide range of environments.

Since coconut is a perennial growing under conditions where precipitation is quite variable from year to year, a variety developed through the first approach may not be able to respond in years of normal rainfall. Hence, the second approach is preferred.

We have used the method of Finlay & Wilkinson (1968) for measuring adaptation in variable environments and identified palms with wide general adaptation at the isolated coconut seed garden at Ambakelle as **Ambakelle special palms**. The technical details are not included here but Figure 3 illustrates the idea in a simple fashion.

Open-pollinated progeny from the Ambakelle special palms are used for planting in our seed gardens. The best Ambakelle special palms are used as pollen donors for collection of "putative drought - tolerant pollen". Of course, it must be emphasized here that the genetics of drought tolerance is little understood and has not yet been worked out for coconuts. However,

breeders of perennial crops are always fighting against time and so the programme must go on even with our limited information and resources. Once the palms are identified as truly drought tolerant and genetically so, there may still be a certain amount of segregation in the next generation. One way of overcoming this is through tissue culture.

TABLE 1 HABITAT OF THE COCONUT PALM

1. **HALOPHYTIC** conditions extending from the Kalpitiya Peninsula to Hambantota on the West Coast and from Mullaitivu to Arugam Bay and the Jaffna Peninsula on the East Coast.
2. **ALLUVIAL** lands of the North-Western and Western Provinces, mostly on the river valleys of the Ma Oya, Deduru Oya and the Mee Oya.
3. **LATERITIC** lands of the Wet Zone of the Western and the Central Provinces.
4. **HILLY AND UNDULATING** lands of the Kurunegala, Matale and Kandy districts.
5. **SILTED UP ESTUARIES** such as those of Madampe and Mundel lakes where palms grow under water-logged **MESOPHYTIC** conditions.

Source: M. L. M. Salgado (1958)

TABLE 2 GENERAL ENVIRONMENTAL REQUIREMENTS FOR COCONUT CULTIVATION

Land characteristic (in order of priority)	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
1. Length of growing period (days)	≥ 300	≥ 270	≥ 240	Others
2. Soil depth (cm)	≥ 150	≥ 100	≥ 75	Others
3. Soil drainage	Well drained to moderately well drained	Somewhat excessively drained	Imperfectly drained	Excessively drained, poorly drained and very poorly drained.
4. Soil texture	Fine sand, loam and clay loam	Coarse or medium sand	Gravel	Silty clay and finer clays.
5. Mean Annual Temperature (°C)	25	23	21	Others.
6. Dominant slope range	0-2%, 2-8%, 8-16%	16-30%	30-60%	60-90% and 90%
7. Soil reaction (pH)	4.5-6.5	4.0-7.0	3.5-8.0	Others.
8. 75% confidence Mean Annual Rainfall (mm)	1500	1200	1000	Others.

TABLE 3 RESPONSE OF CROP PLANTS TO WATER STRESS

1. MORPHOLOGICAL CHANGES

- (a) Leaf shedding
- (b) Leaf angle changes
- (c) Root factors - greater root/shoot ratio

2. PHYSIOLOGICAL CHANGES

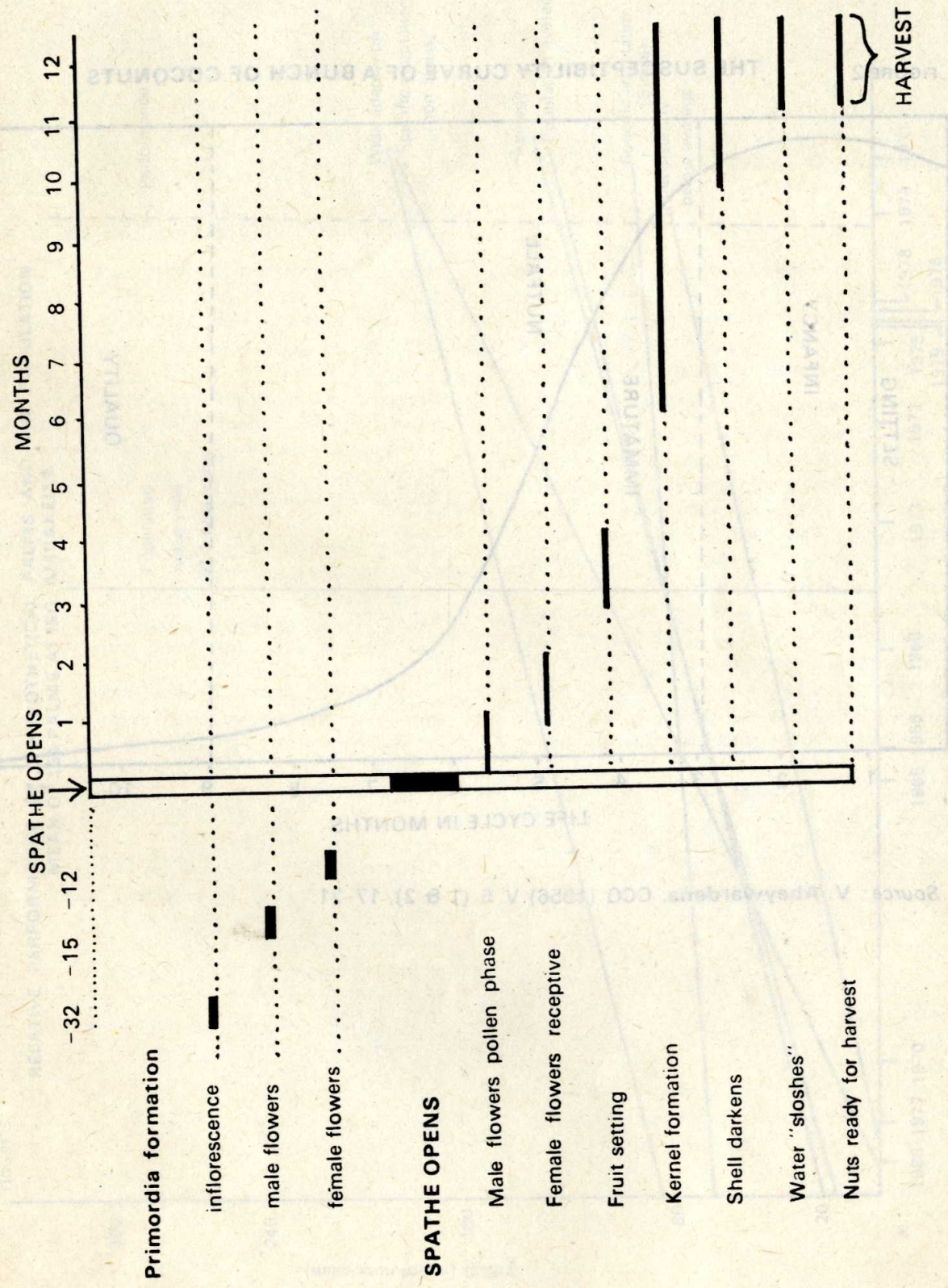
- (a) Leaf cuticular wax
- (b) Osmotic adjustment
- (c) Reduction of leaf enlargement
- (d) Hastening of leaf senescence
- (e) Stomatal behaviour
- (f) Photosynthesis
- (g) Translocation
- (h) Proline accumulation



TABLE 4 YIELD DATA (no. of nuts) FOR SAMPLE OF PALMS AND POPULATION MEAN (1965-1981)

Palm No.	1965	1966	1967	1968	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	Mean	Value
36	60	73	73	79	45	155	112	127	129	109	130	99	143	114	90	112	103.1	0.70
37	90	78	70	106	34	153	118	88	155	133	119	109	117	130	94	116	106.9	0.69
73	83	79	84	114	83	146	90	132	137	154	143	105	149	99	60	173	114.4	0.75
93	67	53	43	112	52	105	110	99	120	140	105	54	103	67	68	67	85.3	0.60
122	89	79	76	101	46	203	90	107	184	109	138	25	234	97	18	175	110.7	1.53
125	61	91	21	102	47	160	99	127	151	141	135	24	154	88	04	184	99.3	1.47
179	77	65	40	68	39	45	119	83	105	98	125	00	107	102	00	44	69.81	0.84
182	61	58	31	53	14	117	66	59	53	44	79	00	51	149	00	73	56.75	0.83
Population mean	61.6	65.4	41.1	75.5	33.9	124.5	97.8	88.2	118.0	105.9	109.3	27.8	110.1	107.6	23.7	108.1		81.1
Grading of years	5	6	4	7	3	16	9	8	15	10	13	2	14	11	1	12		

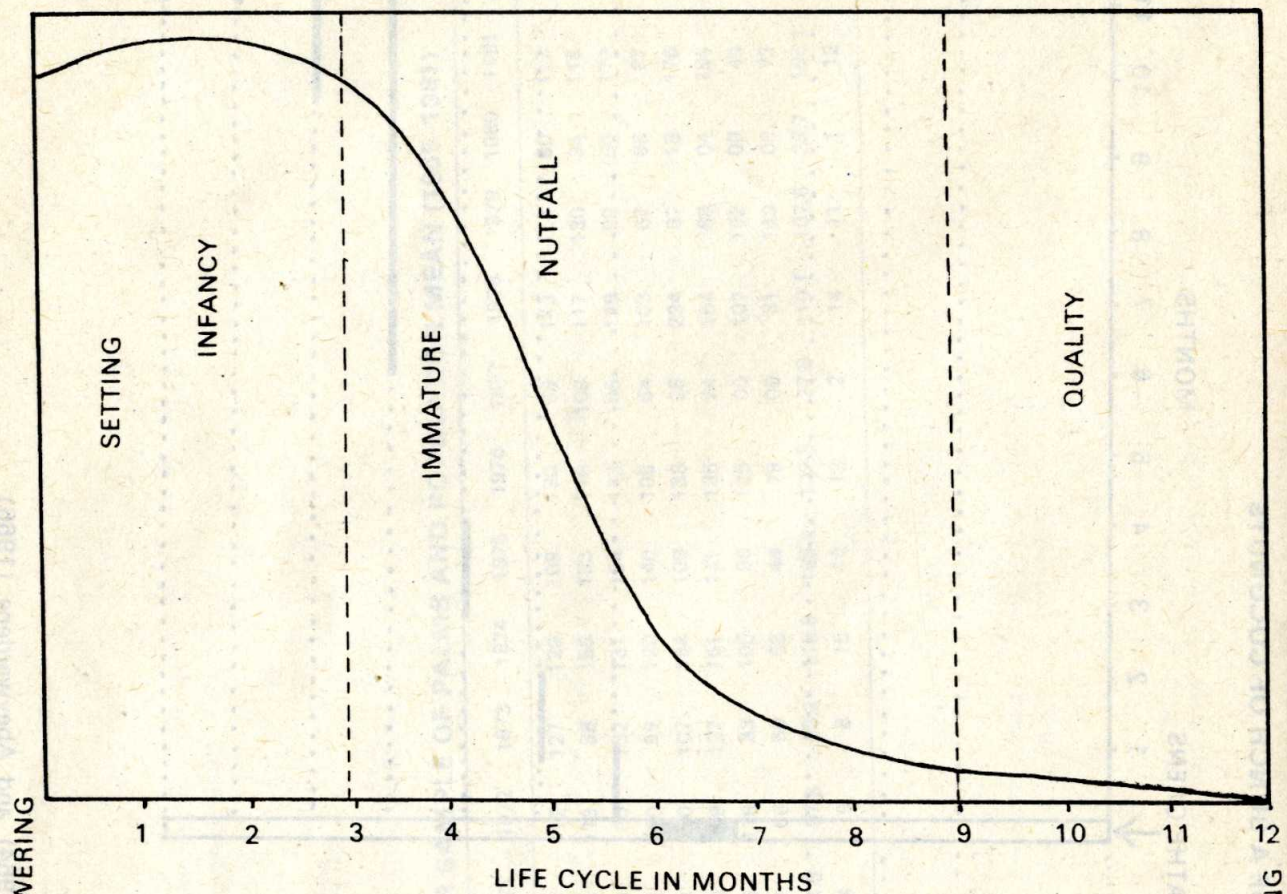
FIGURE 1 DEVELOPMENT OF A BUNCH OF COCONUTS



Source: After Child (1964) and Abeywardene (1966)

FIGURE 2

THE SUSCEPTIBILITY CURVE OF A BUNCH OF COCONUTS



Source: V. Abeywardena, CCQ (1956) V. 6 (1 & 2), 17-21.

FIGURE 3
 RELATIVE PERFORMANCE OF 5 HYPOTHETICAL PALMS AND THE POPULATION
 MEAN OF 184 PALMS AT ISG, AMBAKELLE

