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Studies in the Barnyard Millet—*Echinochloa colona* var. *frumentacea*, C. E. C. Fischer.

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The Barnyard millet, known in Tamil as *Kuthiraivali* (=horse-tail), is one of the less important millets of the Madras Presidency. Except in certain restricted tracts its importance as a food crop in India is not much. In view of the fact that it forms a good famine crop and also comes to the rescue of very poor cultivators, some of its characters were studied at the Millets Breeding Station and are presented below:—

This plant is considered to have been first brought into cultivation in India. That it has been grown all over India since very remote times is seen by the fact that it has a name in Sanskrit, as well as in every one of the other Indian languages.

Werth (1937) mentions this plant occurring as a weed of cultivation in the temperate and tropical zones of both hemispheres, particularly the Northern and that it is cultivated as a millet (as a poor man's millet) in India, China, Japan, Dutch India and in smaller quantities in Africa. In China and Japan particularly it is said to be used as a substitute crop when paddy fails.

Its composition is given by Church (1886) as follows:—

		In 100 parts.
Water	...	12·0
Albuminoids	...	8·4
Starch	...	72·5
Oil	...	3·0
Fibre	...	2·2
Ash	...	1·9

The nutrient ratio here is 1 : 9·5 and the nutrient value is 88.

This millet is used in India either boiled in water like rice, or parched or boiled with milk and sugar.

As a fodder it seems to have attracted greater attention especially in the U. S. A. Bressman and Fry (1932) consider this plant as the best late season feed, taking the place of maize in certain parts, which are unsuitable for maize. Thatcher (1900) gives the following composition of this plant as a forage crop.

Composition of feeding stuff at different stages of growth.

Feeding stuffs	Water	Protein	Albuminoids	Ether extracts	Nitrogen free extracts	Crude fibre	Ash
Millet: Heads just appearing	10·24	8·41	5·79	2·54	32·03	35·86	10·92
Headed out seeds near ripe.	10·47	6·12	4·49	1·52	43·33	29·10	9·41

He concludes that here the protein decreases rapidly while heading out and to obtain a fodder having as narrow a ratio of flesh-forming to fat-forming foods as possible the crop should be cut at as early a stage as it can be well cured. As a roughage it can be allowed to grow till seeds are formed.

Lindsey (1900) gives the following coefficients of digestibility of this plant: green, as hay and as silage with soybean, obtained with sheep.

Coefficients of digestibility of millet, millet hay etc.

	Dry matter	Protein	Fat	Nirogen free extracts	Crude fibre	Ash.
	%	%	%	%	%	%
Green millet, early to late bloom	71	69	63	72	73	64
Millet hay, full bloom	56·5	47·5	48	53·5	62	43·5
Millet and Soy bean silage	59	57	72	59	69	—
Corn and soy bean silage	69	65	82	75	65	—

He points out that when harvested early, in blossom, the fodder contains less nitrogen-free extract matter, more fibre or woody matter and rather more ash than corn fodder and so it must be cut when in blossom, to secure it in the most desirable condition for feeding.

On well-manured soils it gave 11,297 lbs. of straw and 66·7 bu. per acre and 12—15 tons per acre of green forage. Wood (1928) gives the yield of straw as 2,000 lbs. per acre, Mukerji (1915) records 800 lbs. and Mollison (1901) 1,500 lb. Watt (1889) states that the straw is used much in the Madras Presidency and Mysore as cattle fodder, though considered inferior to ragi as well as to paddy straw.

Kuthiravali is sown mostly as a rainfed crop. In the drier districts, it is grown as a subordinate crop to sorghum (Duthie and Fuller 1882) or maize (Watt l. c.) The plant can be grown either on light sandy soils (Duthie and Fuller. l. c.; Mollison. l. c.) with fair rainfall or in water-logged areas (Wood. l. c ; Watt. l. c.), such as lowlands or banks of rivers that often get submerged. Mukerji (l. c) reports that rough jungle land could be used. It withstands transplanting (Mollion l. c.) The crop requires little or no manuring.

The seed rate is generally 8—10 lbs. per acre and when sown with a drill about 6—8 lbs. per acre. Wood (l. c.) quotes 35 lbs. per acre. The July sown crop is harvested in October

In Punjab this plant is said to be ploughed into the soil as a green manure.

Systematics. Hooker (1897) brings this plant under the sub-section Echinochloa of the genus Panicum. He recognises two very closely allied species viz. *Panicum crusgalli*, Linn. and *Panicum colonum*, Linn. The cultivated species is regarded as a variety of *P. crusgalli*. In his species of *P. crusgalli*, Linn. he finds innumerable forms so that it became "impossible to find characters constant enough for their limitation". He finds that *P. colonum* Linn. exhibits a gradual transition into *P. crusgalli* and *vice versa*. The cultivated variety *furmentaceum* has been assigned to both. Cosson and Thwaites are reported having regarded *colonum* as a form of *crusgalli*.

Cook (1908) mentions that the *Panicum crusgalli* of Linnaeus does not occur in the Bombay Presidency. He considers the cultivated form as a variety of P. *stagnium*, Retz.—P. *stagnium*, Retz., var. *frumentacea*, Trinn. The species *crusgalli* has no ligule. P. *frumentaceum*, Roxb. and *Oplismenus frumentaceus* Dalz. and Gibs. are given as synonyms of P. *stagninum* var. *frumentacea*. He remarks that P. *colonum* is very similar to var. *frumentaceum*, Roxb. but a more slender plant with smaller spikelets.

Chevalier (1922) quotes the following synonyms for this plant: P. *frumentaceum* Roseb., P. *grossum*, L. P. *segetale*, Roxb., *Echinochloa frumentacea*, Link., *Oplismenus frumentaceus*, Kunth. P. *frumentaceum* is said to be a variety of P. *crusgalli*, L. It is considered by most authors that P. *frumentaceum* possesses characters intermediate between those of P. *crusgalli*, L. and P. *colonum*, L.

Bressman and Fry (1932) distinguish the weed *crusgalli* from the cultivated millet by its greater hairiness of the glumes, and the longish seeds. The millet is less hairy and has broader seeds.

Fischer in Gamble (1934) removes the group from *Panicum* and gives the plants a separate generic stand, viz., *Echionochloa*. Under this genus he ennumerates 3 species:—

1. *Echinochloa colona*, Link. = *P. colonum*, L.
2. *Echinochloa crusgalli*, Beauv. = *P. crusgalli*, L.
3. *Echinochloa stagnina*, Beauv. = *P. crusgalli*, L.

The cultivated species is treated as a variety of *colonum* viz. *E. colona* var. *frumentacea*, C. E. C. Fischer=P. *crusgalli*, Linn.var. *frumentaceum*, Hook.

The following is the description of the species as given by Gamble:—

Echinochloa, Beauv. Annual or perennial, often tall herbs. Leaves narrow. Inflorescence of crowded panicles of loosely arranged, secund, spiciform branches bearing spikelets from the base or near it; rachis triquetrous. Spikelets ovate

to elliptic or lanceolate—oblong, 2-nate or clustered, articulated on and falling entire from the pedicels.

Glumes membranous, unequal; the lower much the shorter, mucronate, cuspidate or awned, the upper coincident in outline with the spikelet, acute, cuspidate or shortly awned. Lemmas: Dissimilar; the lower equalling the upper glume (excluding cusp or awn) its palea 2-keeled, empty or containing a male floret; the upper subcoriaceous or crustaceous, ovate, to elliptic-oblong, obtuse or apiculate, polished, very convex on the back, its pales as long, with rounded sides and flaps, containing a bi-sexual floret. Lodicules 2. Stamens 3. Styles free. Grain broadly elliptic, plano-convex.

Racemes simple, rather distant ·3–1·25 in. long; lower glumes and upper glumes about equal, obtuse or cuspidate. Annual, up to 2 ft. high; leaves 2-8 in long, ·1–·45 in. wide, ligule 0; spikelets ovoid ·1–·12 in. long; lower glume ·04–·05 in. long; upper ·09–·11 in. long; lemmas ·08–·1 in. long lower with male floret.....*colona*.

Racemes usually more or less branched ·8–2 in. long; lower glume and upper lemma cuspidate or awned, the latter the longer; lower lemma often awned:

Annual, up to 3 ft. high leaves 3–21 in. long; ·2–·5 in. wide, ligule 0, junction of blade and sheath glabrous, usually marked by a brown zone; spikelets ·15–·18 in. long; lower glume ·07–·12 in. long, upper ·15–·17 in. long; lower lemma empty, ·14—·17 in. long, upper ·12–·15 in. long; awn of lower lemma up to 2 in. long..... *crusgalli*.

Usually perennial, up to 6 ft. high; culms rooting and often branching from submerged nodes; leaves 3–18 in. long, ·2–·4 in. wide, ligule a fringe of stiff hairs, sometimes absent on the uppermost leaf; lower lemma empty or with a male floret. Otherwise as in the last species.....*stagnina*.

Echinochloa colona (link.) var. *frumentacea*, C. E. C. Fischer: a taller and more robust plant with dense, sometimes corymbose panicle, cultivated.

Observations on flower pollination. Hildebrand (in Knuth 1909) reports that only self-pollination is possible in this species, owing to the simultaneous protrusion of stigma and anthers, but crossing may be effected when the anthers have fallen, as the stigmas are persistant.

Youngman and Roy (1923) found the flowers opening between 7-30 and 8-30 a. m. They observed that the stigmas and anthers emerge simultaneously. The stigmas spread out immediately on emerging, while the anthers dehisce only after about 1—1½ minutes. The glumes are observed to close back after half an hour.

Observations made at the Millets Breeding Station, Coimbatore on two types of panicle shapes, viz., open and compact, gave the following results The plants were grown under irrigated conditions. The observations were done on three plants in each type. The plants commenced to flower in about two months after sowing. The tip of the leaf subtending the panicle (flag leaf) appears first and takes about 10 to 14 days for the complete emergence of the flag. The appearance of the panicle is almost simultaneous with that of the flag, but its emergence is gradual, taking from 9 to 13 days.

The flowers begin to open in the same order as they emerge out of the sheath. The first flowers open as soon as the panicle tip emerges out. The order of flowering is thus from the tip of the panicle to the base. But in the

individual spikes the spikelets along the two margins open earlier than those at the middle. The flowering period is 19—22 days in the open panicles and 2 or 3 days more in the *compact* ones. The largest number of flowers open during the sixth to eighth day from the commencement of flowering. The opening of the individual flowers is between 5-10 a. m. The maximum number of flowers open between 6 and 7 a. m.

The glumes open out very gradually and at the mouth of the gaping glumes the two stigmas and the anthers stand out like a column. Two to four minutes later the stigmas emerge out of the lemma in a column and spread out on either side. The stamens thus come to occupy the central position. The filaments begin to elongate gradually in about 1 to 8 minutes after the spreading of the stigmas. The dehiscence occurs only when the filaments have elongated to their maximum. The dehiscence is by lateral sutures. It begins at both ends and meets in the centre. The glumes close again in about 5 to 10 minutes after the dehiscence. The stamens and stigma remain outside the closed glumes. The whole process, from the opening of the glumes to their complete closing, takes about 24 minutes.

Inheritance of characters.

I. *Anthocyanin pigmentation.* The only anthocyanin pigmentation met in this plant is purple. When the plants do not show any trace of the pigmentation they are designated as 'green through-out' (abb. GT.) The purple pigment normally manifests itself in the following regions of the plant:

(a) Vegetative parts—nodes, internodes, as two bands on the upper and lower sides of the nodes, leaf margins, midrib, sheath, panicle-rachis, glumes.

(b) Reproductive parts:-- lemmas, anthers and stigma

Three grades of pigmentation designated P3, P2, P1, in descending order of their intensities, are met with. The anthers and stigmas show various colorations on drying corresponding to the grade of the plant-pigmentation. The following gives the chief differences between the various types:

Class of pigmentation.	Character and incidence of pigmentation				
	Vegetative Parts.	Reproductive parts			
		Anthers		Stigma	
		fresh	dry	fresh	dry
P.3	Deepest purple of all types	deep purple	deep blue	deep purple	black
P.2	Pigmentation less than in P_3	purple	a blue ring around the sutures	purple less than in P_3	dark brown
P.1	Pigmentation less than in P_2	yellowish brown	brown	light purple	brown
GT	No purple pigmentation, all green	yellow	brown	colourless	pale brown

A certain amount of fluctuation in the depth of pigmentation occurs in each of the three types. In the following segregations it was found that P.3 and P.2 groups were often rather difficult of separation and in certain cases the P.1 almost approached P.2.

(a) *Purple and green segregations:—*

Two kinds of segregations were met with, viz., a monofactorial and a bifactorial one.

The bifactorial segregations gave the following F_2 proportions.

Female parent = Green throughout
F_1 = P.2
F_2:—

	P.3	P.2	P.1	GT
Observed	266	80	88	44
Expected on 9:3:3:1	268·9	89·6	89·6	29·9

$X^2 = 7{\cdot}73$ $P > {\cdot}05$

In the monofactorial segregations the following F_2 proportions were obtained :—

Female parent = green throughout.
F_1 = P. 1
F_2:—

	P. 2	P. 1	GT
Observed	29	71	33
Expected on 1:2:1	33·25	66·5	33·25

$X^2 = 0{\cdot}84$ $P > 0{\cdot}50$

The same proportions were met with in the further progeny of the hybrid. (Total of 9 families gave P. 2 = 330; P. 1 = 628; GT = 329. calculated P.2 = 321·75; P.1 = 643·5; GT = 321·75). This clearly indicates a 1:2:1 ratio. According to expectations all the P.1 selections proved to be heterozygous.

(b) In segregations between the three pigmentation groups, the 1:2:1 proportions were again met with :—

	P. 1	P. 2	P. 3
Total of 20 lots	751	1540	890

The P. 2 group is smaller and the P. 3 group larger than they should be for an exact 1:2:1 ratio, because their separation is not quite easy, the obvious P. 2 alone going into the middle group. Subsequent selections however showed that the P. 2 were all heterozygous and the P. 3 and P. 1 selections bred true.

It is evident from these that there are only two factors responsible for pigmentation in this plant. Further, it is evident that pigmentation differences between the heterozygotes and the pure ones are easier to be noted in the monofactorial segregations than in the two factor ones.

The factors may be designated as follows:—

$P_2P_2P_1P_1$	P. 3	$p_2p_2P_1P_1$	P. 1
$P_2P_2p_1p_1$	P. 2	$p_2p_2p_1p_1$	G. T

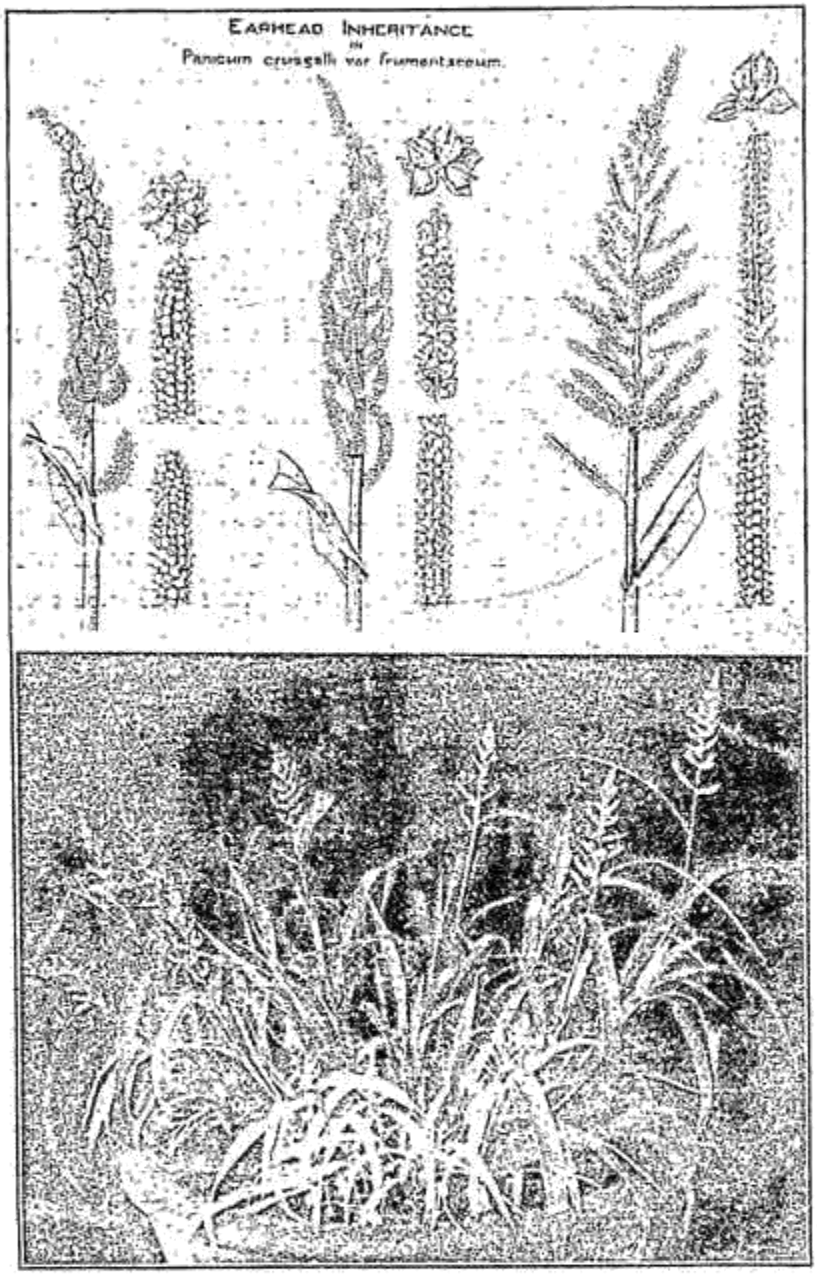

Fig. 1. (Top) Inheritance in ear-head shape. (Left) Compact head; (Right) Open head; (Middle) F_1; Single branches:— Top—cross section; Middle—rear and bottom—front view.

Fig. 2. (Bottom) Striped plant.

II. *The Panicle* (Plate I, Fig. 1). The panicle is conical in appearance. The number of panicles on a plant depends on its branching and tillering capacity. Each panicle is peduncled.

The peduncle is cylindrical and is continuous with the rachis, which however is angular. The spikes arise in whorls of 2 or more often 3—4, or sometimes 5. Each whorl thus constitutes more or less a node. The disposition of the whorls is more distant at the base and becomes less distinct and more congested towards the apex. The spikes arise on the face and not on the angle itself. They alternate in successive whorls so as to give a $\frac{1}{2}$ taxis. Thus the panicle shows a tetraquetrous arrangement. Consequent on the congestion towards the apex the whorls may become disturbed but still the tetraquetrous nature is kept up. The length of the spikes reduces gradually from the base towards the apex and the ultimate apex ends in a spike. This arrangement is responsible for the conical shape of the panicle.

The spikes are more or less ascending. The base of the rachis is somewhat pulvinate. The node at the base of the pulvinus is pubescent. Hairs, isolated or in tufts of 2—3 are found on the rachis, at the base of the spikelets. Groups of spikelets are arranged distichously along the dorsal side of the rachis. These groups consist of 3—4 spikelets distichously arranged on a short rachilla. The spikelets are all more or less equal in size. In general design they appear to be arranged in horizontal rows of 4 to 5 spikelets. The rachis attenuates towards the apex. The number of spikelet groups, however, remains the same and consequently the spikes tend to curve on their ventral side. This becomes more pronounced as the grains begin to mature. The spike ends may be seen almost spirally twisted and bent towards one side to avoid overlapping the upper one, so that the panicle gets a plaited appearance.

Two distinct types in head-shape could be distinguished, viz., Open and Compact.

In an open panicle the spikes are more or less horizontal and may or may not be curved towards the tip. The interval between the whorls is greater than in a compact panicle. The length of the spike is also greater and the spikelet groups are more spread out.

The compact panicle on the other hand shows the spikes much plaited. The spikes are much shorter and spikelets are very close together.

Further, the spikes in the 'opens' have a greater number of spikelet groups with usually 2—3, often 4, and rarely 5 spikelets per group. The 'compacts' on the other hand have usually only 3-4 spikelets per group, often 2 and very rarely 5.

An intermediate condition between the lax-ness of the 'opens' and the plaited appearance of the 'compacts' is met with. This is termed the 'semi-compact' head. In this the spikes do not completely overlap one another so that the main rachis becomes visible.

An analysis of typical heads gave the following results :—

Panicle type	Average number of spikelets	Average length of spike	Average number of spikelets per cm.
Open	26	2.8	9
Compact	22	1.9	12

Thus it becomes apparent that the headshapes are distinguished by the difference in the length of the spike and secondly the denseness of packing of the spikelets, i. e. the number of spikelets per cm. A similar experience is met with in the *E. coracana* also. (Ayyangar *et. al.* 1932).

III. *Sterility*. A case of male sterility was noted in a purple-pigmented plant. The emerging anthers instead of being purple were seen to be yellow and shrivelled up later without dehiscing. The anther sacs were devoid of free, healthy, pollen. This character was found to behave as a monogenic recessive to the normal condition.

IV. *Striped plant* (Plate I, Fig. 2). A single case of albino-striping was met with. This plant produced 31 tillers. The first was half albino and half green. The next six were all green and 4 white. Then again were formed seven green and the rest 10 white. Three tillers developing from the first were found to be green, though the parental one was half green and half albino. This is probably due to a chimaera, the mutation having taken place very early, probably even in the seed itself and affecting one half of the embryonal growing point, so that about half of the tillers is striped or white and the other half is green.

Seeds were collected from 27 tillers individually and progenies raised. The seed-setting in the heads from the green tillers was better (average 293 grains per head) than in those from the white ones (average 159 grains per head). The viability of the seeds was good (88% germination in seeds from green and 84% from those of white tillers). The progeny in either case (i. e., from the heads from green portion and that from white portion) gave green and pale seedlings. The proportions of green to pale seedlings were widely different :—

		Green	Pale	Ratio
i. Progeny from green tillers				
Total of 7 tillers	...	1074	350	3:1
" 3 "	...	511	57	15:1 (approx)
" 1 "	...	144	102	9:7
" 3 "	...	254	327	7:9
ii. Progeny from white tillers				
Total of 4 tillers	...	414	168	3:1
" 5 "	...	658	46	15:1
" 1 "	...	58	50	9:7
" 2 "	...	95	119	7:9
iii. Progeny from the half green and half white tiller	...	103	206	1:3 (approx)

On the total the progenies of this plant gave 3311 green seedlings and 1425 pale seedlings. Some of the pale seedlings that were allowed to

grow further put forth only green leaves. Neither the green nor the pale seedlings produced tillers with striping or albino.

Cytology:—Hector (1936) gives the following resume. "The chromosome number was first reported as ca. 48 (2n). According to Church (1929) the haploid number is 21. Avdulov (1931) found 54 (2n). Hunter (1934) 36. As the basic number of the Paniceae is 9, Avdulov's and Hunter's figures would appear to indicate polyploidy."

Echinochloa colona, Link. is a close relation of this plant which is cultivated as a millet in several parts of India and occurs wild all over the country.

E. colona appears to hybridize spontaneously with *E. colona*, var. *frumentacea*. The two plants can be distinguished easily by means of their panicle characters:

	E. colona	var. *frumentacea*
Rachis	Flat, triquetrous	Tetraquetrous
Arrangement of spikes	Bilateral, alternating	Whorled to spiral
Disposition of the spikes	Almost vertical and adpressed to rachis	Horizontal to ascending, divergent
Spikelets	Solitary or in twos, pedicelled	Always in groups of 3–5, sub-sessile.

The *colona* species itself sometimes shows a tendency to whorling. The weaker and later-formed panicles of *frumentacea* tend to be less whorled. The progenies of some natural hybrids gave in the F_2 a large number of intermediates with regard to the number of spikes and also the manner of arrangement.

Summary. *Echinochloa colona* var. *frumentacea*, originally classified under Paniceae (*Panicum crusgalli* var. *frumentaceum*), though one of the less important millets of India forms a good famine time fodder and grain plant.

It can be fed green or as hay, or as silage. The plant has the advantage that it can grow in poor soils, as also under water-logged conditions.

Three pigmentation types P. 3, P. 2, P. 1 and one non-pigmented type GT. have been described. These show a two factor difference.

The panicle-shapes are of three types—Open, semi-compact, and compact. These are considered to be due to differences in the length of spikes and density of the spikelets. The relationships of these three types are yet not fully clear.

A type of male-sterility, simple recessive to the normal condition has been described. Albino-striping was met with and its progeny has given seedlings with green and pale colours in various proportions.

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The Cultivation of Betel vine (*Piper betel*) in Poonamallee village.

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Introduction. In view of their proximity to Madras City, where there is a great demand for the leaves, betel vine cultivation is very important in the villages of Poonamallee and Kunnathoor. The area under this crop at present is about 350 acres. The crop is cultivated entirely under well irrigation, except for a few months in the year (October to March) when water from the Chembarambakkam tank is utilised. Unlike other crops which are raised by the efforts of individual farmers, a plot of betel vine garden is managed by a group comprising 15 to 20 men, who pool their resources to meet the cultivation expenses and likewise share the profit. The land is generally taken on lease, and the lease amount ranges from Rs. 75 to Rs. 100 per acre. About ten years ago, gardens when once started, used to flourish and yield well, even up to six years. Lately, the life of a garden has become shortened and now-a-days no garden thrives for more than three years. This is attributed to wilt disease, common in all the gardens in this tract. The gardens go by the name *Illangal thottam* in the first year, *Sambakkal thottam* in the second year, and *Muthukal thottam* in the third year. Each cultivator will have a share in each of the three stages of maturity, so that he may have a steady income.

Varieties cultivated. The main variety cultivated is the *Ravesi*. The leaves of this variety are of medium size, light green and not too pungent. The other varieties which are very sparingly cultivated in these parts are