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Studies in Cow-Pea (*Vigna unguiculata*, (L) Walp.)*

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Cow-pea has been known and cultivated all over India since very remote times. We find an indigenous name for it in all the native languages of India (Watt, 1908). Cow-pea cultivation was introduced into China and other Eastern countries from India in very ancient times. Africa is considered to be the original home of this plant, since the wild forms are found only there. Till recently its spread was confined to Africa, India, Burma, China, Malaya Peninsula, Java and other Asiatic countries. On account of its use as an excellent green manure crop and also as a mixture in hay and fodder its cultivation has now spread to the warm temperate zones and tropical possessions of all the civilized countries of the world. The name cow-pea was first used for this pulse in America. The earliest known English name is 'Cavalance' used first in the West Indies.

In India cow-pea has been grown mostly as a pulse crop. The grains are either made into flour or eaten as *dhal* or whole without being broken. The young pods are used as vegetable. A long podded variety is grown in gardens specially for the vegetable market (Duthie and Fuller 1882. Watt. l. c). Mukerji (1915) mentions two kinds of cow-peas grown, one tender legumed *barbate* and the other harsh legumed *ghangra*.

Aykroyd (1938) gives the following composition of cow-peas (*Vigna catjang*).

		Cow-gram	Rawan
Moisture	...	12·0%	12·7%
Protein	...	24·6%	23·4%
Fat	...	0·7%	1·3%
Mineral matter	...	3·2%	2·9%
Fibre	...	3·8%	—
Carbohydrates	...	55·7%	59·7%
Calcium	...	0·07%	0·08%
Phosphorous	...	0·49%	0·43%
Iron	...	3·8%	4·3%
Calorific value per 100 grms.		327	344
Carotene (International vitamin A units per 100 grams.)		60	—
Vitamin B_1 (International units per 100 grams.)		—	—
Vitamin B_2		good source.	—
„ C mgs. per 100 grams.		—	—

The work reported in this paper was done during 1933—42, under the direction of the then Millet Specialist, Rao Bahadur G. N. Rangaswami Ayyangar.

Niyogi et al (1932) remark that "of the three pulses—*Lens esculenta*, *Vigna catjang*, *Phaseolus aconitifolium*—Vigna has a high biological value". They give the composition of the grain as Ash—3·99; Ether Extracts—1·24; Crude fibre—4·38; Crude Protein N × 6·25—26·02. Carbohydrates (by difference)—64·37; and true protein (determined separately) 24·74.

The net protein values of the several pulses studied by them are as follow:—

Dolichos biflorus	...	10·43
Cicer arietinum	...	16·68
Dolichos lablab	...	10·65
Lens esculenta	...	12·86
Vigna catjang	...	11·05
Phaseolus aconitifolium	...	9·04

Cow-pea is considered to be inferior to *urid* or *mung* as a food, being difficult of digestion and apt to be heating (Duthie & Fuller l. c.).

While in India it is cultivated mostly for its grain, in America it forms one of the most successful and largely cultivated fodder crops. Mann (1916) has found that this crop gives excellent yields under Indian conditions also, both as a pure crop and in mixtures. He recommends its greater cultivation as a green fodder as well as hay. It is very rich in proteins and makes a very suitable balancing mixture with cereals

Extensive experiments in the culture and in the feeding values of cow-pea have been conducted by a host of workers in America, Australia etc. Cow-pea hay is considered to be very nutritious and nearly equal to wheat bran as part of ration. It can be fed to work or milch cattle. Piper (1914) gives the following analysis of completely dry cow-pea hay.

	Cut when in full bloom %	Cut when pods forming %	Cut when pods formed %
Ether extract (fat etc.)	4·04	3·06	5·01
Proteids	17·86	19·93	21·38
Digestible carbohydrates etc.	52·28	50·58	32·59
Fibre	18·29	18·52	29·05
Ash	7·43	7·91	11·97

The proteids increase after the pods are formed. The coefficients of digestibility in cow-pea are as follows (Voorhees):—

Dry matter	...	68%
Fat	...	59%
Proteids	...	76%
Digestible carbohydrates	...	81%
Fibre	...	60%

Thus there is practically no waste in feeding cow-pea fodder. For conversion into hay, the crop is cut when the first pods are well formed. Curing the hay is difficult, since with too much drying the leaves may drop off. So it has to be stacked as soon as the leaves wilt (Piper 1931). Cow-pea hay has been used with success to enrich maize or sorghum silage (Piper, l. c.; Leppan and Bosman, l. c.)

Cultivation. Cow-pea forms a common member in the mixed cropping practised in the dry lands of India. As such the preparation of the seed-bed etc., is the same as for the general sowing of the mixed crops. It is scarcely grown by itself.

The seed-rate in mixtures is 7—10 lb. and as a pure crop 15 – 20 lb. per acre. It is sown in April and May or October and November. As a pure crop it may be either broadcast or drilled. The latter is preferable since it can be intercultivated. The cow-pea does well on a wide range of soils, provided they are well drained but it prefers loams. The best growth of cow-pea is obtained on rich soils and therefore the seed-rate has to be increased in lighter soils. The optimum planting distance between plants is about 9". The viability of the seeds does not last more than two years.

Cow-pea produces freely the bacterial root nodules and has a good herbage. It thus forms one of the best green manures. Fortunately it does surprisingly well on comparatively impoverished soils. The crop has to be ploughed in before it is completely ripe and whilst the soil is sufficiently moist. It serves also to smother weeds. The ripe pods are usually hand-picked. The life period of cow-pea is very varying. "In general early varieties will mature their first pods in 70—90 days and medium ones in 90—100 days. Beyond this are all degrees of lateness." (Piper 1931).

The yield of grain is 300 – 400 lb. per acre (Wood. l. c.) while the yield of green fodder per acre when grown under irrigation is about 12,000—16,000 lb. and 10,000 lb. when grown in the rains (Mann. l. c.). Mukerji (l. c.) gives 50 mds. of legumes (*barbati*) or 10 mds. of *dal* (*ghangra*).

Systematics. Cow-pea is truly a bean and not a pea. It is classified under *Phaseoleae*. Hooker (1879) places this genus under the subtribe IV *Euphaseoleae* of his tribe VIII *Phaseoleae*. He distinguishes two main subgenera (1) Vigna proper and (2) *Plectotropis*.

Gamble (1918) gives the following classification of Indian Species :—

Tribe VI Phaseoleae
Leaves not gland dotted
Leaflets stipellate. Style not bearded below the stigma. 33. shutteria to 43 Pueraria
Style bearded below the stigma ; stamens diadelphous.
Stigma oblique :—
Keel spiral—44 *Phaseolus*
Keel not spiral—45 *Vigna*.

45. *Vigna* Savi—Twining, rarely sub-erect, herbs or under-shrubs. Leaves pinnately 3—foliolate ; stipules basifixed or rarely peltate ; stipels subulate. Flowers in racemes at the end of an axillary peduncle, fascicles on a nodose rachis ; bracts small, deciduous ; bracteoles sometimes large and subpersistant. Calyx campanulate, the teeth distinct or the 2 upper more or less connate. Corolla exserted ; standard orbicular, auricled at base ; wings obovate falcate, slightly adnate to the keel ; keel petals

equalling the wings, incurved, acute or if beaked, not spirally. Stamens diadelphous; anthers uniform. Ovary sessile, many-ovuled; style filliform or thickened upwards, longitudinally bearded on the inner face; stigma oblique. Pod linear, straight or incurved, usually acuminated, septate between the seeds. Seeds reniform or subquadrate, the hilum short, lateral; strophiole 0.

Keel not beaked, a sub-erect or twining annual with white, pink or yellowish flowers and long glabrous pods with many seeds.

Catjang. Walp.

Keel beaked but not spiral as in Phaseolus:—

1. *Vexillata* Benth
2. *Wightii* Benth
3. *Pilosa* Bak
4. *Bourneae* Gamble.

There are several synonyms for this plant:— *Vigna sinensis* End. ex Hassk; *Vigna unguiculata* (L) Walp; *Dolichus unguiculatus* Linn; *Vigna tranquebarica*. D.

Piper (1914) describes this plant as *V. sinensis* Endl. and discards V. *ungniculata* (L) Walp. He distinguishes three varieties.

(1) *Vigna sinensis*—Cow-pea.
(2) » » var. cylindrica—Catjang.
(3) » » var. sesquipedalis—Asparagus bean.

A communication from Kew however, prefers the name *Vigna Unguiculata* (L) Walp on the ground that Piper's statement that the type specimen in the Linnaean herbarium is *Phaseolus antillanum* Urban, is incorrect and that only one plant of this affinity has been found in the herbarium which is undoubtedly the plant which has been called *V. unguiculata* (L) Walp.

The chief distinguishing characters of the three species may be summarised according to Piper (l. c.) as follows:—

	Cow-pea	Catjang	Asparagus
Seed length	6—9 mm.	5—6 mm.	8—12 mm.
Seed shape	Sub-reniform to sub-globose	Nearly as thick as broad, oblong or cylindric, slightly reniform	Reniform
Pod length	8—12 in.	3—5 in.	1—3 ft.
Position of pod	Early becoming pendent	Erect or ascending when green. Remaining so or becoming spreading or deflexed when dry	Pendent, fleshy brittle
Pod flabby or inflated when green	Neither	Neither	Inflated, flabby shrinking between seeds before drying

Anthesis and pollination. (1) *Observations on flower opening.* Haig and Lochrie (1929) made detailed observations on the production of

the flowers. They found that under their experimental conditions the cow-pea had a definite flowering period, followed by a more or less non-flowering period, which might again be followed by a second and even a third flowering period. The frequency curves showed that the first flowering period had a mean of 23 days and the non-flowering 12 days. The period from pollination of flowers to mature pod corresponded to this non-flowering period, being 12—15 days. They remarked further that "flowering begins again when the first flush of pods has been fully developed, as by that time the drain on the resources of the plant body has greatly lessened." They noted also that only 3 – 4 pods set in any one head and all the other heads produced, shed.

Detailed observations on the flower opening and anthesis were made at the Millet Breeding Station, Coimbatore. Under this condition we observed that it takes 11—14 days for the flower initial to develop and bloom and the flowers open between 7 and 9 A. M., the maximum being at about 8 A. M. This seems to vary slightly with varieties as is evidenced by the following table.

TABLE I.

Cow-pea variety No.	Date of observation.	No. of flowers opened at 6-30 A.M.	7 A.M.	7-30 A.M.	8 A.M.	8-30 A.M.	9 A.M.	9-30 A.M.	10 A.M.
C. 521									
Cow-pea	15-12-38	–	1	1	44	–	5	–	–
Type	16-12-38	–	15	23	12	12	3	5	–
	17-12-38	–	10	6	15	7	6	1	–
	Total	–	26	30	71	19	14	6	–
C. 422									
Cylindricus	16-12-38	2	24	5	1	–	–	–	–
Type	17-12-38	6	6	8	3	–	–	–	–
	Total	8	30	13	4	–	–	–	–

This is of course subject to further confirmation since it has been tested on only two varieties. In the same variety the flowers may open from as early as 6 A. M. to as late as 10 A. M.

(2) *Anthesis.* Though the blooming takes place between 7 and 8 A. M. it was observed that the anthers dehisce much earlier. This time of dehiscence fluctuated from 10 P. M. on some days to as late as 0-45 A. M. on certain other days This difference was noted to be in no way connected with the progression of the days of the flowering period. So other environmental factors were examined for the cause of this divergence. This led to the rather interesting conclusion that moon-light tends to hasten anther dehiscence in the cow-pea. It was also noticed that on moon-lit nights the anthesis is earlier if the sky is clear and the atmosphere warm and dry than if it is cloudy, cold and humid. The time of anthesis in relation to the phases of the moon observed during a period of 9 weeks in the summer of 1937 is given below.

TABLE II. Time of anther dehiscence

Date	Time of dehiscence	Date	Time of dehiscence	Date	Time of dehiscence
1-4-37	0-45 A. M.	24-4-37	11-15 P. M.	17-5-37	11-55 P. M.
2-4-37	0-30 ,,	25-4-37	11-35 ,,	18-5-37	11-40 ,,
3-4-37	0-30 ,,	26-4-37	11-15 ,,	19-5-37	11-45 ,,
4-4-37	0-15 ,,	27-4-37	11-15 ,,	20-5-37	10-30 ,,
5-4-37	0-45 ,,	28-4-37	11-45 ,,	21-5-37	10-45 ,,
6-4-37	0-30 ,,	29-4-37	11-20 ,,	22-5-37	10-45 ,,
7-4-37	0-45 ,,	30-4-37	11-20 ,,	23-5-37	10-45 ,,
8-4-37	0-45 ,,	1-5-37	11-45 ,,	24-5-37	10-35 ,,
9-4-37	0-45 ,,	2-5-37	0-20 A. M.	25-5-37	10-45 ,,
10-4-37	0-45 ,,	3-5-37	0-45 ,,	26-5-37	10-30 ,,
11-4-37	0-30 ,,	4-5-37	0-45 ,,	27-5-37	10-30 ,,
12-4-37	0-30 ,,	5-5-37	0-45 ,,	28-5-37	10-40 ,,
13-4-37	0-45 ,,	6-5-37	0-30 ,,	29-5-37	10-45 ,,
14-4-37	0-30 ,,	7-5-37	0-45 ,,	30-5-37	11-30 ,,
15-4-37	0-30 ,,	8-5-37	0-30 ,,	31-5-37	11-30 ,,
16-4-37	0-45 ,,	9-5-37	0-30 ,,	1-6-37	11-30 ,,
17-4-37	0-45 ,,	10-5-37	0-45 ,,	2-6-37	0-15 A. M.
18-4-37	0-00 ,,	11-5-37	0-30 ,,	3-6-37	0-40 ,,
19-4-37	11-45 P. M.	12-5-37	0-00 ,,	4-6-37	0-30 ,,
20-4-37	11-30 ,,	13-5-37	0-00 ,,	5-6-37	0-30 ,,
21-4-37	10-45 ,,	14-5-37	11-35 P. M.	6-6-37	0-40 ,,
22-4-37	1-15 ,,	15-5-37	11-45 ,,	7-6-37	0-40 ,,
23-4-37	1-15 ,,	16-5-37	11-40 ,,	8-6-37	0-40 ,,

NEW @ MOON — FULL O MOON — NEW @ MOON — FULL O MOON — NEW @ MOON

Remarks: 20-4-37—clear moonlit night.
22-4-37 to 27-4-37—cloudy and rainy nights.
20-5-37 to 29-5-37—clear moonlit nights.

Certain experiments were conducted with a view to ascertain whether it is the presence of the light or some other lunar radiations that influence the anthesis. If the inflorescence is cut sufficiently early complete with its peduncle and kept in water the flowers behave similar to those undetached as to opening, anthesis etc. Taking advantage of this, a few inflorescences were cut on the previous evening and kept in dark chamber. The anthesis times were as follows:—

TABLE III.

Date	Moon-rise H. M.	Moon-set H. M.	Time of anthesis In field P. M.	Time of anthesis Inside dark chamber P. M.
23-5-37	17-12	4-14	9-45	10-30
24-5-37	18-1	4-56	9-35	10-45
25-5-37	18-51	5-42	9-45	10-45

In a second experiment two sets of inflorescences were cut and brought to the laboratory. One set was kept in a dark chamber while the other was exposed to artificial light from an incandescent lamp of 60 C. P. from 6 P. M. onwards. The night was clear and moon-lit. The results are given below:—

TABLE IV.

Date of observation	Moon-rise	Moon-set	Time of anthesis		
			In field	In laboratory	
				In dark chamber	Exposed to artificial light
	H. M.	H. M.	P. M.	P. M.	P. M.
25-5-37	18-51	5-42	9-45	10-45	9-45
26-5-37	19-40	6-29	9-30	10-30	9-30
28-5-37	21-16	8-9	9-40	10-30	9-45

This experiment was repeated during dark nights. The hours of moon-shine during the nights was nil

TABLE V.

Date of observation	Moon-rise	Moon-set	Time of anthesis		
			In field	In laboratory	
				In dark chamber	Exposed to artificial light
	H M.	H. M.	P. M.	P. M	P. M.
2-6-37	0-8	12-24	11-15	11-15	10-35
3-6-37	0-50	13-16	11-40	11-30	11-00
4-6-37	1-34	14-12	11-30	11-30	10-50
5-6-37	2-20	15-10	11-30	11-30	10-30
6-6-37	3-10	16-12	11-45	11-45	10-50
7-6-37	4-6	17-16	11-45	11-45	11-00
8-6-37	5-6	18-21	11-45	11-45	11-00

It may be concluded from the above that shutting out the moon-light delays the time of anthesis and that exposure to an artificial light of good intensity tends to make the anthers dehise earlier. The stimulus of artificial light is seen to be effective even when there is total absence of the moon during the time of anthesis. However it is interesting that with artificial light also the dehiscence is early (9-30 to 9-45 P. M.) in the presence of moon-light whereas it is much later (10-30 to 11 P. M.) on a night without moon.

The information as to the influence of lunar radiation on the activities of the plant is very meagre. Ingen-Hans found that moon-light is not intensive enough for the carbohydrate assimilation (Kostyts Chew 1926). Tyler (1938) finds that lunar influence is more one of belief than fact. Donald et al (1937) and Ayyar and Panicker (1937) do not find any correlation between sexual processes and lunar periodicity. Fox (1932) finds the intensity of moon-light too weak to have any effect but is of opinion that "the moon may perhaps cause lunar cycle in reproduction not through its relatively small intensity of light compared with the sun, but by the additional total number of hours of illumination per 24 hours at full moon over and above threshold light value". Fox (1924), however, tested the possibility of moon-light for photosynthesis. Carlon (1934) while testing the influence of light with light intensity, light quality, length of day and photoperiodism, considered also the possible influence of moon-light.

Note :—The timings are according to old I. S. T.

(3) *Technique of hybridization.* It has been shown that the flowers open some hours later than the anthesis. Therefore flowers for hybridization purposes must be selected and anthers removed sometime before anthesis. This is best done on the previous day evening. Such buds as are mature enough are larger in size, the back of the standard yellowish in colour and the corolla yields itself to easy manipulation. Oliver (1910) (in Hayes & Garber 1927) gives a detailed account of the method of emasculation. A similar method was adopted in this station also. "Hold the bud between the thumb and the fore-finger with the keeled side uppermost; then run a needle along the ridge where the two edges of the standard unite. Bring down one side of the standard, securing it in position with the thumb; then do the same with one of the wings which will leave the keel exposed. This must be slit on the exposed side about $\frac{1}{16}$ inch from the stigma, which can be seen through the tissue of the keel. Bring down the section of the keel and secure it under the end of the thumb. This will expose the immature stamens, 10 in number. With a pair of fine pointed forceps seize the filaments of the stamens and pull them out, counting them as they are removed to make certain that none are left. Allow the disturbed parts of keel, wings and standard to assume their original positions as far as possible. Next detach a leaflet from the plant, fold it once, place it over the emasculated flower bud, and secure it in position with a pin or tooth-pick. This prevents drying out and gave large percentage of success". The pollination is done the next morning. Pollen from a protected freshly opened flower is dusted over the stigma and the flower covered with the leaflet as before.

Cow-pea flowers are liable to be cross-pollinated to a high degree. The growth form of the plant renders it convenient for the whole plant to be enclosed inside a bag. Further, cow-pea flowers are sensitive and drop off with the slightest mechanical disturbance or injury. Even though the inflorescence produces a number of buds only a few mature and set pods. However, about 80 per cent of the buds mature and open into flowers and about 67 per cent of the opened flowers set into pods. The pods form and mature at different times, consequently much labour and time have to be spent in obtaining enough quantity of selfed seeds of a plant.

Inheritance of characters. (1) *Xantha seedlings.* Chlorophyll deficiencies are of rare occurance in the cow-peas. A type of deficiency (xantha) resulting in yellow seedling leaves was met with in the progeny of a natural hybrid. The green seedlings developed into normal plants while the yellows died within a week after germination. Whereas at the beginning, all seedling leaves are more or less yellowish, the normal ones change into green very rapidly but the xanthas continue to remain yellow and eventually die.

The progeny of this natural hybrid gave 40 greens and 11 yellows. Out of 15 selections carried forward, only 2 segregated again for green and yellow (9 green and 3 yellow; 7 green and 9 yellow respectively).

Further selections from these two families gave 944 green to 253 yellow and 346 green to 129 yellow seedlings respectively—thereby proving that the xantha character is a simple recessive to green. (total green 1,290; yellow 382; $P > 0.02$). A factor Xn produces green seedlings and its allelomorph xn produces xantha seedlings and proves lethal.

(2). *Cotyledon colour*. The cotyledons in cow-pea are usually greenish-white in colour when fresh and turn white on drying. A few types were noted which showed cotyledons turning purple towards drying and the colour persisting in the dry cotyledons. They were at first noted in certain types collected from Africa (Nigeria, Kenya and Uganda). These three happened to have purple or black colour in the seeds. Later, however, more types were obtained in which the seeds were brown.

A cross between C 577 (purple cotyledon) and C. 57 (white cotyledon) gave an F_1 with purple cotyledons. The F_2 gave 161 plants with purple cotyledons and 61 with white cotyledons, ($P > 0.30$ for 3:1 ratio). F_3 conformed to the monogenic segregation. The factors may be designated as Pcot—purple cotyledon and pcot—white cotyledon.

(3) *Buds in axils of cotyledons.* Usually in the cow-peas the buds in the axils of the cotyledonary leaves remain dormant. Similarly in the first seminal leaves the axillary bud is suppressed. In one instance (C. 121—a variety from Vizagapatam), the dormant buds became activated. These axillary branches produce one large simple leaf and another similar but small one. When selections from this lot were carried forward they gave (in two of them, C. 121 and 121 B) a segregation for dormant and active axillary buds (146 dormant buds, 41 active buds). An F_3 of 15 selections gave six pure for dormant buds, 4 pure for active buds and 5 segregating giving a total of 200 dormant to 70 active. It is evident from this that a single factor inhibits the activity of buds in the axils of the cotyledons, (total dormant 346: active 111; $P > 0.70$). The factor Ax inhibits the bud growth and with ax the axillary buds are activated into growth.

(4) *Ribbon leaves.* The leaves of the cow-pea are trifoliolate. The terminal leaflet is ovate, the basal leaflets are ovate asymmetrical. Of the many African varieties of cow-pea, one from Tanganyika, C. 525, had leaflets that were very long and lanceolate. This was crossed with the ordinary local ovate type. The F_1 was lanceolate and in the F_2 (family C. 660) there was a monogenic segregation of 82 lanceolate to 24 ovate leaflets. ($P > 0.50$). The F_3 confirmed the F_2 behaviour. The lanceolate shape of the leaf 'L_1' is thus a simple monogenic dominant to the more common ovate leaf shape 'l_1'. The first seedling leaf which is simple and not trifoliolate shows this character and it is therefore possible to study its inheritance even in the very early stages.

(5) *Leaf size and peduncle length* A single plant selection from Tanganyika (C. 527) had small leaves. Measured with the planimeter the average area of the leaf was found to be 2 sq. in. The length of the peduncle was 10 cms. Generally the large leaved plants have a leaf area varying from 3 to 7 sq. in. and a peduncle length of above 15 cms.

A cross was made between the small leaved type and a large leaved type. The F_1 gave an average leaf area of 5 sq. in. and length of peduncle 15 cms. The behaviour of the progeny is given below :—

Table VI

Selection	Progeny				
	Large leaf		Small leaf		
	Long peduncle	Short peduncle	Long peduncle	Short peduncle	
F2 Large leaf, long peduncle	73	20	26	9	P>·05 for 9:3:3:1 ratio
F3 do do (total of 7 families)	202	74	62	27	P>·05 do. do
F3 Large leaf, short peduncle (total of 4 families)	...	145	...	47	P>·9 for 3:1 ratio
F3 Small leaf, long peduncle (total of 3 families)	...	...	104	37	P>·7 do. do.
F3 Large leaf, long preduncle (3 families)	Pure	...	...	...	
F3 Small leaf, short peduncle (2 families)	...	...	...	Pure	

It is evident from the above that the length of peduncle is inherited independently of the area of the leaf blade. The factors may be assigned as :— Pn—Long peduncle, pn—short peduncle ; Ls- Large leaf, ls—small leaf.

(6) *Scented flowers.* Very few leguminous flowers are scented. Sweet peas are the best example of legumes with scent Among pulses no scented flowers are on record. Scent in the flowers of the cow-pea has not been mentioned so far. In the large collection at the Millet Breeding Station, a selection, C 515, from a variety from the Sudan proved to have flowers that emitted a jasmine-like scent. The flowers are white in colour. The plants are delicate in growth and the setting and germination of the seed are rather poor, so much so that the stand in the rows is always sparse. The best time for examining the flowers for scent is between 7 and 9 A. M. By 10 A. M. the scent fades off. The stage at which scent is best felt is just when the flowers open out. The wings had the strongest scent, next the standard, and then the keel. There was no scent in the dry petals. No other part of the plant is scented. Attempts to cross this delicate variety with sturdy local varieties proved futile, as the pods did not set and grow well and the few seeds that were obtained were very shrivelled.

Apart from this variety from Sudan, two other varieties with purple flowers had a fainter scent and on a close examination traces of very faint scent could be made out in odd local varieties.

(7) *Pigmentation of vegetative parts.* Harland (1919 and 1920) found that the pigmentation in the vegetative parts was due to the action of

a single main gene A. X is a simple dominant to x, unpigmented type. However, X was supposed to act only in the presence of R a gene for red seed coat. In addition to this, two other seed coat colour factors viz. E (New Era pattern) and B (Black eye) also produce colouration on stem, leaf, stalk etc. (Harland 1919). E is without effect except when R is present.

Sasaki (1923) reported three factors Z, H_1 and H_2 responsible for pigmentation in vegetative parts. Factor Z converts eye colour to solid, also produces plant pigmentation The factors H_1 and H_2 (Holstein factors of Harland l. c.) in combination with Z produce pigmentation in vegetative parts.

Spillman and Sando (1930) give only one factor R, a general factor, for colour as also producing red seed coat. They use the symbol X for an inhibitor of the factor T (less dense speckling characteristic of the Taylor variety). They conclude that flower colour is correlated with colour in the seed coat, peduncle, stipules, and petioles.

Harland et al (1926) and Haigh and Lochrie (1929) found that segregation ratio from selfing of the X X plants showed a progressive variation with age. There was an excess of recessives which gradually diminished up to the 10th day after flowering when an excess of dominants were produced. This persisted for 15 days. They adduced the deviation of 0·24 from the normal ratio in the dominants due to an excess of recessives caused by the early flowers.

The anthocyanin pigmentation occurs in cow-pea as purple or sometimes purple wash. An unpigmented group also occurs. An examination of about 200 pure line selections at the Millet Breeding Station showed that the pigmentation could occur in

(a) Seedlings :— Hypocotyl, cotyledons, epicotyl, stipule base and main veins of the first foliage simple leaf,

(b) Adult plant :— Stipules, petiole, petiolule, base and main veins of the trifoliolate leaves, axils, internodes, peduncles, calyx, corolla and unripe pods.

Based on the depth and distribution of pigmentation in the seedlings the following groups could be made.—

TABLE VII

Plant organs	Class of pigmentation in decreasing depths of colour					Non-pigmented
	P_1	P_2	P_3	P_4	P_5	G
Stipules	P wash	P dots	G	G	P tip	G
Petiole and petiolules	P wash	P wash	P wash	P wash	P wash	G
do ends	P	P	P	P	G	G
Leaf base	P	P	P	G	G	G
Main veins	P	P	G	G	G	G
Between veins	P	G	G	G	Occasionally P	G

P = purple. G = green.

When classified according to the seed colour it was seen that these pigmentation groups may occur in all the seed coat colours. A number of crosses were made amongst the several pigmentation groups to study the inheritance in detail, but the work had to be discontinued.

(8) *Flower colour.* Harland (1919) describes in the main three flower colours—deep reddish violet, pale violet and white. The white flower is found in seeds white and with no patterns on the seed coat. This type, he finds, can carry factors for dark colour of flowers, Watson or Holstein patterns of the seed coat and also for black eye. He defines the three flower types as follows :—

Dark (LL DD)—Anthocyanin deeply pigmented. Flowers reddish violet at throat, wings greatest, keel faintly streaked or 0.

Pale (LL dd)—Less than in dark ; standard almost white, wings streaked faintly with violet, keel no colour.

White (ll DD, ll dd)—No anthocyanin. Flowers pure white except for faint primose tinge on standard at the throat.

A gene L (para) is responsible for pale flowers and has visible effect in types with Holstein and small eye patterns.

The Watson eye factor 'W' and the black eye 'B' both have dark coloured flowers. The allelomorphs are monogenic. 'B' also produces colour in the pod tip.

Again (1919) he reports that 'E' the New Era pattern also produces anthocyanin in flowers. But this factor has effect only in the presence of 'R' ; further that B, P and E all produce colour in calyx, peduncle, and tip of young pods. P produces full colouration in ripe pods.

Sasaki (1923) gives the factor 'Z' as one of those producing flower colouration.

Spillman and Sando (1930) however find that flower colour is correlated with colouration in the seed coat, etc. They suggested that factor 'R' is a general factor for colour and 'r' has white flowers.

Capinpin (1935) finds single factor difference in flower colour as also pod colour. He finds white flower and white seed and coloured seed and coloured flower closely linked. This is borne out in experiences at the Millet Breeding Station, Coimbatore.

A new type of flower colour in which the whole of the dorsal side of the standard is coloured was met with at this station. An examination of about two hundred pure lines showed that the purple colouration of the standard may be of three kinds :—

(1) The whole of the dorsal side of the petal coloured uniformly. (new type),

(2) Pigmentation confined to the apex of the petal, the rest being colourless.

(3) The whole of the dorsal surface unpigmented, the apex of the petal greenish.

It was also seen that colour of the calyx is closely related to the colour of the dorsal side of the standard, the first two types of standard having a purple calyx while the third has a green one.

In a cross made between class (1) and class (3) the F_1 was like class (1). The F_2 gave a monogenic ratio which was confirmed in the F_3.

According to Harland the dark coloured flowers have the genic composition R D L, while pale violet flowers are R d l, the other combinations resulting in white (Matsuura 1933). The factor D increases the pigmentation in L. L and D are supplementary. A third factor 'G' is responsible for a tinging of the flowers and is hypostatic to D. A spreading factor 'St' appears to be responsible for the full expression of the colour on the dorsal surface of the standard petal. Thus the full expression of standard colour is R D L St and the apex colouration is produced by R D l st while the completely non-coloured flowers by R d l st.

(9) *Colour of the immature pod.* Generally in early stages the pod tip is coloured purple while the rest of the wall is green. At maturity purple splashes or streaks may appear on the pod wall. Types are present in which the wall is fully coloured purple. Pods without any colouration also exist. The following types were met with at this station.

(1) The whole pod as well as the pod tip coloured.

(2) the pod-tip alone coloured while the body is not coloured.

(3) the pod-tip not coloured while the body of the pod is splashed with purple pigment.

(4) Complete absence of pigment in the pod.

It was observed that as in the case of the calyx, the colour of the pod tips is closely related to the colour on the dorsal surface of the standard.

Tabulated, the colouration on the standard, calyx and pod resolve themselves into the following five classes.

TABLE VIII

Class of Pigmentation	Standard	Calyx	Pod
I	Apex Purple, whole dorsal surface purple	Purple	Tip purple, body purple splashed
II	Apex purple, dorsal surface no colour	Purple	" "
III	" "	"	Tip purple, body not coloured
IV	Apex and surface no colour	Green	Tip Green, body purple splashed
V	No colour	Green	Both green

The above characters behave as though closely correlated in segregations between various classes of pigments. They behave as unit characters.

Harland (1919 and 1920) found that the pod colouration is produced by several factors some of them being primarily seed coat colour factors.

B. Factor for black-seed coat, also produces purple tip in young pods but less than in P.

E. factor for New-Era pattern seed coat colour, produces purple tip in young pods But the colour is weaker than in B.

R. Basic factor for pigment in seed coat, also produces purple in pods.

P. has no effect on seed coat colour but produces purple in young pods and intense purple (maroon) in mature pods. This is the most intense purple in pods.

b, e, p, r—produce green pods.

He is not, however, quite certain whether the purple pod is not due to more than one factor. He finds evidence that B and P, and B and E are linked but suggests that B, P and E all may belong to a triple series of multiple allelomorphs.

Spillman and Sando (l. c) ascribe a single factor R for the general pigment in the plant.

Capinpin (l. c.) finds pod colour and seed coat colours are loosely linked.

(10) *Pod shape* Spillman and Sando (l. c.) find that curvature in dry pods is due to a factor A.

(11) *Dry pod colour.* Cow-pea pods exhibit three main kinds of colouration on drying These colours are independent of the green colour of the immature pod and also of any purple pigmentation that might occur in the immature stages. These three types are (1) cocoa brown (2) straw yellow and (3) ivory yellow (Ridgeway, 1912).

Capinpin (l. c) has noted only two dry pod colours, black and white. He obtained a monogenic difference between them.

The following is the inheritance of the three pod colours studied at the Millet Breeding Station.

(1) Parents.....Straw yellow × Cocoa brown

F_1.....Cocoa brown

F_2.....Cocoa brown Straw yellow

416 134

P>0·7 for 3 : 1 ratio.

The F_3 behaviour confirmed the F_2 figures.

(2) Parents.....Ivory yellow × Straw yellow

F_1.....Straw yellow

F_2 and F_3.....Straw yellow Ivory yellow

867 634

P>0·05 for 9 : 7 ratio.

In the F_3 of the above cross, segregations were also obtained giving a monogenic difference between straw yellow and ivory yellow (straw yellow 117 ; ivory yellow 42 (P>0·9 for 3 : 1 ratio).

It is evident that complementary factors I_1 I_2 give rise to straw yellow colour. A factor C_{Br} converts the straw yellow pod into cocoa brown so that this factor acts only in the presence of I_1 I_2. The genotypic constitutions would be Cocoa brown—C_{Br} I_1 I_2; Straw yellow—c_{Br} I_1 I_2; Ivory yellow—C_{Br} I_1 i_2; C_{Br} i_1 I_2; C_{Br} i_1 i_2; c_{Br} I_1 i_2; c_{Br} i_1 I_2; c_{Br} i_1 i_2.

(12) *Pod length.* As mentioned elsewhere cow-pea pods are distinguishable into three classes, each characteristic of a sub-species (viz.) *cylindricus* (5—10 cm. long), the *sinensis* type (15—17 cm. long) and the *sesquipedalis* (23—27 cm. long). Apart from the length, the 3 types could be differentiated by the following characters.

TABLE IX.

	Sesquipedalis	Cow-pea (Sinensis)	Cylindricus
Seed	8—12 mm. long Kidney shaped	6—9 mm. long sub-reniform to sub-globose	5—6 mm. long seed small, oblong or cylindrical.
Seed arrangement	Seeds widely separated	Closely packed	Closely packed.
Green pod	Inflated and flabby	Not inflated or flabby	Not inflated or flabby.

With the help of these characters it has been found that phenotypes can be easily distinguished in the segregating families.

A cross between *sesquipedalis* type and *cylindricus* type gave in the F_1, the *sinensis* type of pod; a reciprocal cross also behaved similarly.

The F_2 and F_3 behaviour was as follows:—

TABLE X.

	Sinensis type	Sesqui-pedalis type	Cylin-dricus type	
Total of 7 F_2 families	453	152	204	
Total of 6 F_3 families	213	73	95	
Total	666	225	299	P>0·9 for 9 : 3 : 4 ratio
Total of 6 F_3 families	211	68		P>0·9 for 3 : 1 ratio
Total of 6 F_3 families	248	—	119	P>0·9 for 3 : 1 ratio

From the above it is evident that supplementary factors are responsible for these three pod types. The genotypes may be represented as:—S_p C_y-Sinensis; S_p c_y-Sesquipedalis; s_p C_y-Cylindricus and s_p c_y-Cylindricus.

(13) *Wrinkled pods.* Most of the varieties of cow-pea have their dry pods fairly smooth on the outside. In these the pod is thin and on pressure the dry pod snaps easily at the sutures. There is another type chiefly represented by the long poded vegetable variety, the sesquipedalis, in which the pod coat is thicker and the spaces between the seeds are wider. When dry this type of pod presents a wrinkled appearance.

Reciprocal crosses between smooth and wrinkled pod types made at this station gave F_1s that had smooth pods. In the F_2 these segregated into smooth, 736 and wrinkled, 503 (total of 14 families). This indicates a 9 : 7 ratio ($P > 0.02$). The F_3 behaviour confirmed this. Two factors which may be designated as Pa_1 and Pa_2, complementary to each other are therefore responsible for the production of smooth pods.

(14) *Pod chlorophyll.* There is a difference in the green colour of unripe pods. These may be green or light green. When the pod is green, the colour of the calyx and the ridge tip of the back of standard are also green. When the pod is light green these two places in the flower are also light green. This behaviour is similar to the concurrent response of the pod tip, calyx and standard tip to purple pigmentation.

In crosses made between green and light green, the green condition proved a monogenic dominant to the light green condition. In the F_2 and F_3, twenty-one segregating families gave a total of green, 1,395 and light green, 452. This approximates to a 3 : 1 ratio ($P > 0.08$).

A factor L_g produces green and l_g light green colour in the pods.

(15) *Hollow seeds.* The cow-pea seeds are reniform. The bulk of the seed is made up of thickened cotyledons. These cotyledons are usually two in number. Each is convex externally and plane internally. The plane surfaces are closely appressed. In a few cases seeds were noted in which a hollow space was formed between the cotyledons on drying. In transverse sections the space appears lens-shaped and is best seen at the chalazal end. It is of interest that the hollow seeds are sweeter than the normal solid ones.

In a cross between a typical hollow seed (C. 574—a variety from Nigeria) with a variety with solid seeds (C. 498) the F_1 was found to be solid. The F_2 gave solid seeds 92 and hollow seeds 39 indicating a single factor difference ($P > 0.20$). F_3 and F_4 confirmed this behaviour. The factor may be designated as H_s solid seeds and h_s hollow seeds.

(16) *The Grip of the seed coat.* The grip of the seed coat on the cotyledon is usually tight. In some varieties it is comparatively loose. This looseness tends to go with the bigger size of the seed, though smaller seeds with loose seed coats could also be obtained. Under a good pressure between the thumb and finger, seeds with loose seed coat could be unhusked. In the case of the tight seed coat, the coat can be removed only by scraping with a pen-knife

In a cross between a variety with loose testa (C. 577) and one with tight testa (C. 57), the F_1 had seeds with a tight testa and in the F_2 there was a simple segregation of 163 tight testa ; 59 loose testa. A tight seed coat is thus a monogenic dominant to a loose seed coat. ($P > 0.50$). The factors may be designated as L_t-tight testa ; l_t-loose testa.

(To be continued.)