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

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(Continued from page 160 of the July issue.)

(17). *Seed coat colours.* As in other pulses, cow-pea exhibits several seed coat colours. These colours may be spread uniformly over the whole of the seed coat or may occupy particular zones. The farmer is called whole colour or solid colour while the latter goes under several names, "speckling", "eye colour" etc., according to the nature and spread of the colouration.

Spillman and Sandow (1930) described ten types of whole colours (1) purple, (2) black, (3) dull black, (4) blue, (5) coffee, (6) maroon, (7) buff, (8) red, (9) pink and (10) white. Harland (l. c.) mentioned black, brown or buff, maroon, red and white. The white or *para* type of Harland contains no pigment in the shape of eye or speckling. Spillman et al. find that in the absence of all factors the seeds become weak and small. Harland assumes four factors for colour of the seed coat whose interactions produce the several types mentioned by him. Thus, B is the factor for black, N for buff, M for maroon and R for red. The several genotypes are:—

Black	...	BNMR
		BNmR
		BnMR
		Bnmr
Brown	...	bNMR
Buff	...	bNmR
Maroon	...	bnMR
Red	...	bnmR
White	...	absence of R.

Black is dominant over all other colours, brown is dominant over red and in the F_1 maroon appears. R is a basic colour factor in the absence of which other colours are expression-less.

Spillman and Sando find that their ten whole-colour types are produced as a result of the action of eight factors either singly or in combination. These factors are:—

B Brown seed coat
F Very fine dense speckling giving rise to the blue seed coat
N Anthocyanin pigment factor
P Purple seed coat
R Red seed coat (general factor for colour)
T Less dense speckling characteristic of the Tylor variety

U Buff or clay coloured seed coat spotting

X Tylor inhibitor, cancells out the effect of T.

At the Millet Breeding Station the following types were noted : black, purple, brown, maroon and chocolate. The inheritance of black, brown and maroon was found to agree with Harland's experiences. Black was dominant to all the other colours.

In the second category of seed coat colouration the pigment may be distributed from very small specks to large blotches. These patterns may appear in all the pigments mentioned above. They may conveniently, though arbitrarily, be divided into

1. Eye colouration—Background white or cream. Colour round the hilum (solid), sometimes a few dots.
2. Eye colouration with mottling--Colour round the hilum (solid), and fine dotting on the whole body.
3. Mottling—Ground-colour brown. On this may appear large blotches of dark brown, maroon or black. On the dark brown or maroon patches of some types fine dots of black may also be present. In all these the eye is solid coloured.

Eye colour :—Spillman (l c) distinguished four kinds of patterns viz. (1) small eye, (2) holstein eye, (3) large eye, (always heterozygous) and (4) watson eye. Spillman and Sando (l. c.) described five types of "eyes" (1) watson, (2) holstein, (3) small eye, (4) narrow eye and (5) very small eye. Harland (1919) recognises the four types described by Spillman (l. c.). In addition, in 1922 he described a type called "very small eye". Both Spillman and Harland find the large eye heterozygous, especially the large eye, spotted (Harland). Our experiences with the large eye is also in accordance with their observations. Spillman (l. c.) ascribed three factors W, S, E as producing the four types but later Spillman and Sando (l. c.) changed them into I, H and E. Harland (1919) proposed three factors W, H_1 and H_2. Later (1919) he showed that a factor D converts small eye to watson eye and Holstein to solid cour. This factor was supposed to be effective only in the presence of L, factor for pale flower.

At the Millet Breeding Station the following new types were observed.

Smoky:—The hilum colour is black. On the remaining seed coat area there are minute black dots densely distributed. The density of distribution of these dots varies to a considerable extent even in seeds of the same plant. This kind of distribution of black was observed in the background colours brown and maroon.

Khaki:—This is a whole or solid colour type. The hilum colour is yellow and the rest of the seedcoat blackish khaki in colour.

Olive green:—This has black 'watson eye' and minute black dots over the rest of the seedcoat. The background colour is white.

White patch:—This type has a long narrow white patch above the caruncular streak, running down more or less parallel to the hilum on either side. It has been met with in the brown and New Era seed coat colours.

Some experiences obtained with the smoky and khaki seed coats at this station are given below :—

Smoky seed coat colour :—The following are experiences obtained with two natural crosses.

1. ♀—Maroon ;	*Natural cross*—Smoky on Maroon	Total
F. 2—Smoky on maroon 29 ;	Maroon—10	39

2. ♀—Maroon ;	*Natural cross*—Smoky on Brown		
F. 2—Smoky	Non-smoky		Total
Brown	Maroon	Brown	Maroon	
12	5	19	4	40

F_3 selections gave the following behaviour.

TABLE XI

	Smoky		Nonsmoky		Total
	Brown	Maroon	Brown	Maroon	
Smoky on Brown :					
Total of 9 selections	307	70	102	25	504
do 5	118	..	40	...	158
do 1	9	8	...	...	17
do 7	pure				
Smoky on Maroon :					
Total of 2 selections	...	66	...	21	87
do 1	...	pure			
Brown :					
Total of 6 selections	...	...	209	70	279
do 1			pure	...	
Maroon :					
Total of 3 selections	...	...	...	pure	

Thus smoky (Sm) is a monogenic dominant to nonsmoky (sm).

The Khaki seedcoat. A cross made between a khaki seed coat and a brown resulted in a type with khaki speckling on a brown back ground. In the F_2 this segregated in a 1:2:1 ratio giving 101 khaki, 194 speckled and 108 brown (total of 5 segregating families). From one of these F_2 families 4 selections for the khaki seed coat, 8 selections for the speckled seed coat and 4 selections for the brown seed coat were carried forward to the F_3 generation. As expected the 4 khaki selections as well as the 4 brown bred true while all the 8 selections with speckled seed coat segregated, giving khaki 213, speckled 393 and brown 170. It may therefore be assumed that a factor Kh is responsible for the khaki colour which produces a speckled pattern in its heterozygous condition.

Colour correlations. Spillman (1913) noted certain colour correlations in cow-peas. (i) cow-peas having any part of the seed coat black have anthocyanin in the stems and leaves and unless the factor for narrow eye be present there is also anthocyanin in flowers ; (ii) cowpea varieties having coffee coloured seeds have no anthocyanin in stems, leaves or

flowers (iii) cowpeas having buff or red seed coats may or may not have anthocyanin in the stems and leaves and in the flowers as the special factor for black or the factor for 'narrow eye' is present. 'Narrow eye' inhibits development of anthocyanin in the flowers though it permits of its development in stems and leaves These are not fully borne out in our observations.

The correlations between seed coat colours and purple pigmentation on the floral and vegetative parts observed in about 200 types grown at the Millet Breeding station are given below :

i. The para or white seeded variety has no purple in the vegetative and floral parts.
ii. All other testa colour types studied have purple colour in vegetative and floral parts in varying degrees.
iii. Whole colours on the seed coat are observed in types with deep purple flowers (except C. 515).
iv Eye coloured types do not have deep purple flowers (except Watson eye).
v. Speckled seed coat colours occur along with deep purple or light purple flowers according as they are whole or eye coloured.
vi. Black seeds, whole coloured or eye coloured, occur with purple in calyx, pod tip and back of standard.

Some Abnormalities. The following are a few abnormalities that were met with in the course of this study.

i. *Three cotyledons with a cup-shaped first leaf.* A seedling was found to have three cotyledons and three first leaves instead of the normal two. One of the first leaves was cup-shaped. This was the only case in which three cotyledons were observed to match the three first leaves, and a repetition of the phenomenon has not been met with.

ii. *Larger number of first leaves.* Normally, a cowpea plant throws out only two first leaves which are entire and not trifoliolate as the later formed leaves. But a few plants with 3 and rarely 4 first leaves, which were entire and slightly smaller than the normal first leaf were observed in a number of varieties. These however had only 2 cotyledons as usual. The lots when sown separately occasionally threw the abnormal seedlings in subsequent generations.

iii. *Heterophylly.* Tetra-foliolate leaves and rarely penta-foliolate leaves were found to occur instead of the normal trifoliolate leaves in a few varieties. The forked leaflet generally occurred in the first or second compound leaf rarely being found in the later formed leaves. The forking is common in the leaflets on the sides and occurs only rarely in the central leaflet. The percentage of plants showing the forking varied from 22 to 64. The phenomenon is repeated in subsequent generations also to a greater or lesser extent, irrespective of the plant selection taken. The chances of forked leaflets occuring was, however, greater in tertrafoliolate selections than in the normal tri-foliolate selections.

iv. *Floral abnormalities* (a) *Differentiation by positive dedoublement.* In C. 1207, one of the flowers gave rise to two standards, one behind the other. Cases of double standard have been recorded in *Erythrina indica*. Both the standards faced the keel and were of the same size and colour and akin to each other in every respect. There was no duplication of the wing petal or keel petal. The calyx had the normal 5 lobes. Along with this doubling, there was a doubling of the single free stemen. The other 9 united ones were normal so that there were in all 11 stamens. The anthers did not dehisce, though they were normal in appearance. Another instance of the doubling of the standard also occurred but was peculiar in that the standards were back to back. The extra standard was a bit smaller than the normal one. There was no doubling of the free anther but there was the non-dehiscence of the anther all the same.

(b) *Differentiation by dialysis.* A flower was found to have its keel petal divided into the two components instead of being united and boat-shaped and protecting the androecium and gynoecium This is reversionary in that the keel petal arises by the fusion of two adjoining floral parts.

(c) *Differentiation by metomorphosis.* (1) Phyllody. One plant was observed to show this abnormality. The plant was stunted and trailing on the ground, the internodes shortened, leaves reduced in size and the modified flowers in clusters.

(d) *Floral modifications.* (1) Peduncle—nil or much reduced; (2) Calyx—enlarged, lobes normal in number, five, large and green. They continued their growth till they were about twice the size of the normal; (3) Corolla—leaflike with veins, five in number corresponding to the five petals of a normal flower. The standard could be distinguished by its obovate shape. Slightly hooded. The other two pairs of petals were lanceolate and fairly similar to each other. The petals grew to about an inch in length and were green and leaf-like. (4) Androecium—Diadelphous, anthers 10, filaments—nil to very short; anther sacs reduced in size and empty; (5) Pistill—leaf-like and folded on its midrib, about $\frac{1}{2}$ cm. long by 2 mm. broad. The end of the leaf-like structure was pointed and slightly hooded, appearing like the style and stigma. (6) Ovary—The ovary was in the form of a folded leaf which grew to about $\frac{1}{3}$ inch in length with the margins split up. Along the margins there were small modified funicular attachments. No ovules were present; (7) Petalody—The flower had a wing-petal-like growth from the androecium of the 9 united stamens. The filament of one of the end stamens was turned into a wing-petal-like structure forming a flange of the staminal tube. The petaloid stamen had a normal anther, so had the other 8 stamens and the 10th free stamen. None of the anthers dehisced; (8) Pelory—In one flower, one of the wing petals turned into a standard-like structure, there being no excess of floral parts. The double standard in this case was inside the normal standard. In another instance along with this conversion the united staminal tube had one anther less and the inner standard had the imprint of the single wing petal on it.

(v) *Plant Chimera.* A sectorial chimera was met with in one of the F_3 selections. The plant was partially green and partially albino. In the axils of the albino leaves 4 pods developed that were also albino. These pods were gathered separately as also the pods from the normal green sectors. When sown separately the normal pods gave rise to normal green seedlings while the albino pods gave albino seedlings which grew up a little and then dried up.

Known 'genes' of Cow-pea and genic symbols.

A	Dry pod curved	Spillman and Sando, 1930.
B	Brown seed coat	» » »
	Black seed coat	Harland, 1919.
D	Dense speckling characteristic of the New era variety	Spillman and Sando, (l. c.
	Dark flowers—much anthocyanin to more or less deep reddish violet	Harland, 1918-19.
E	Small eye	Spillman, 1911.
	Narrow eye	Spillman and Sando (l. c.)
	New Era pattern; colour in vegetative parts	Harland, 1919.
F	Very fine dense speckling giving rise to the blue seed coat	Spillman and Sando (l. c.)
G	Dotting—converts Holstein spots into numerous small ones	» »
	Produces tinged flowers; recessive to D	Harland, 1920.
H	Holstein eye	Spillman, 1911.
	Holstein type of seed coat spotting	Spillman and Sando (l. c.)
H_1 H_2	Holstein eye factors	Harland, 1919.
I	Eye with indefinite margin	Spillman and Sando (l. c.)
L	Longitudinal furrowing of the surface of the seed	»
	Factor for pale flowers	Harland.
M	Maroon Seed coat	»
N	Brown Seed coat	»
	Presence of anthocyanin pigment factor	Spillman and Sando (l. c.)
P	Purple Seed coat	»
	Purple pod	Harland.
R	Basal factor for seed coat pigmentation	»
	Red seed coat, general factor for colour	Spillman and Sando (l c.)
S	Black spotting on certain types	» »
T	Less dense speckling characteristic of Tayler variety	» »
U	Buff or clay coloured seed coat	Spillman and Sando (l. c.)
W	Whipoorwill type of seed coat spotting	» »
	Watson eye	Harland.
X	Tayler inhibitor cancels effect of T	Spillman and Sando (l.c).
Y	Small eye pattern	» »
Z	Responsible for changing yakko eye into solid	Sasaki 1922.

New genes and their symbols proposed in this study.

A_x —factor inhibiting activity of buds in the axils of cotyledons; dominant to a_x which activates bud growth in the axils of cotyledons.

C_{br} —factor which converts straw yellow pod into cocoa brown. C_{br} has visible effect only in the presence of I_1 I_2.

C_y —factor for the cylindricus type of pod; C_y with S_p gives the sinensis type of pod.

H_s —factor for solid seeds; dominant to h_s—hollow seeds.

I_1, I_2 —complementary factors for the production of straw yellow colour in the dry pod. In the absence of either I_1 or I_2, the pod is ivory yellow.

K_h —factor for khaki seed coat. The heterozygous condition produces speckling.

L_1 —factor for lanceolate type of leaf; dominant to l_1 which gives the more common ovate type of leaf.

L_g —green colour in pods; dominant to l_g—light green colour.

L_s —factor for large leaf; dominant to l_s—factor for small leaf.

L_t —tight testa; dominant to l_t—loose testa.

Pa_1, Pa_2 —complementary factors for the production of smooth pods. In the absence of either Pa_1 or Pa_2 the pods are wrinkled.

P_{cot} —purple cotyledon dominant to p_{cot}-white cotyledon.

P_n —factor for long peduncle dominant to p_n—short peduncle.

S_m —fine speckling producing the smoky type of seed coat; dominant to s_m—nonsmoky.

S_p —factor for the sesquipedalis type of pod.

S_t —gives full colouration on the dorsal side of the standard petal.

X_n —factor for green seedlings; dominant to x_n—producing xantha seedlings.

Summary. 1. The historical, taxonomical, and agricultural aspects of the cow-pea are described.

2. A detailed account of the anthesis is given. It is interesting that moonlight has a definite influence on the time of anther dehiscence.

3. The inheritance of some of the characters in this plant has been studied. The following behave as simple dominants.

P_{cot}—purple cotyledon to p_{cot}-white cotyledon.
Ax —inhibition of activity of buds in the axils of cotyledons to a_x-activity of buds.
X_n —green seedlings to x_n—xantha seedlings.
L_s —large leaf to l_s—small leaf.
L_1 —lanceolate type of leaf to l_1—ovate type of leaf.
P_n —long peduncle to p_n—short peduncle.
S_t —full colouration on the dorsal side of the standard petal to s_t-partial colouration.
L_g —normal green colour in pods to l_g—light green colour.
H_s —solid seeds to h_s—hollow seeds.

L_t —light tests to l_t—loose tests.

S_m —smoky colour of seeds to s_m – non-smoky colour.

A factor K_h gives the khaki seed coat colour. In the heterozygous condition this factor produces speckling.

Bifactorial segregations were observed in the following:—

A factor S_p is responsible for the sesquipedalis type of pod and C_y for the cylindricus type ; S_p C_y gives the sinensis type of pod.

Pa_1 and Pa_2 are two complementary factors for the production of smooth pods.

I_1 and I_2 are two other complementary factors producing straw colour in the dry pod. A factor C_{br} converts this straw colour into cocoa brown.

4. Some interesting abnormalities observed in the course of the study are described.

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