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# GENETIC STUDIES IN SOYBEAN. III. INHERITANCE AND LINKAGE STUDIES

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## ABSTRACT

**Inheritance and linkage relation of nine morphological characters in four intervarietal crosses of soybean suggest growth habit, hypocotyl colour, petal colour, pubescence type, pubescence colour, and pod colour to be governed by a single pair of genes. However, seed coat colour is controlled by either one or two genes and hilum colour by one, two or three pairs of genes. Out of 46 joint segregations, significant linkages have been observed in nine cases. Crossover percentage was in the range of 15.2 to 49.4 for different alleles.**

**Key words:** Inheritance, linkage, morphological characters, *Glycine max*.

Morphological characters are considered as marker characters in identification of soybean varieties as they are least affected by environmental fluctuations. Earlier work on these aspects have been periodically reviewed by [1–3]. An attempt has been made to study inheritance and linkages in four intra-specific hybrids.

## MATERIALS AND METHODS

Morphological characters of seven parents are given in Table 1. In subsequent years, data on hypocotyl colour, petal colour, growth habit, pod colour, presence of pubescence on pod, pubescence colour, seed size, seed coat colour and hilum colour characters in $F_1$ and $F_2$ generation were recorded. The test for goodness of fit was applied. The $F_2$ data were processed further to detect linkage relationships and estimate linkage intensities by product ratio method.

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## RESULTS AND DISCUSSION

Data recorded on inheritance and linkages have been presented in Tables 2 and 3.

**Table 1. Characters of parental genotypes of soybean under study**

| Characters | Parents | | | | | | |
|---|---|---|---|---|---|---|---|
| | EC 13005 | EC 30196 | Ankur | MACS-13 | MACS-36 | MACS-38 | MACS-40 |
| Hypocotyl colour | Pink | Pink | Green | Pink | Green | Green | Green |
| Petal colour | Pink | Pink | White | Pink | White | White | White |
| Growth habit | — | Indeter-minate | Determi-nate | — | — | — | — |
| Pod colour | — | Brown | Tan | Brown | Tan | Tan | — |
| Pubescence type | Glabrous | — | — | — | — | — | Pubescent |
| Pubescence colour | — | Tawny | — | Tawny | Gray | Gray | — |
| Seed size | Bold | — | -- | Bold | Small | — | Small |
| Seed coat colour | — | Black | Yellow | — | — | Yellow | — |
| Hilum colour | Black | Black | — | Black | Brown | Brown | Brown |

*Hypocotyl and petal colour.* It may be seen from Table 2 that both these characters are governed by a single pair of alleles with dominance of pink colour, thus confirming the earlier reports [4–6]. Monogenic control of these characters with minor genes resulting in wide range of colour intensity was observed by Peters [7]. Digenic control with complementary gene action was noticed by Chaudhari et al. [8].

*Growth habit.* Most of the related species and wild varieties have indeterminate growth habit due to vegetative growth of terminal bud. In two combinations studied, this character appeared to be monogenically controlled with dominance of indeterminate habit, thus confirming the earlier report [9].

*Pod colour.* Pod colour in soybean may be black, brown or tan. Majority of soybean varieties have brown pod and wild types have black pod. This character was governed by a single pair of genes with dominance of brown colour over tan pod colour. However, digenic control with duplicate dominance was reported by Raut et al. [6].

*Presence of pubescence on pods.* In the EC 13005 x MACS-40 cross, glabrousness of pods was found to be dominant over pubescent pods with one gene difference. Similar situation

**Table 2. Character expression in $F_1$ and $F_2$ generations in four soybean crosses**

| Character | $F_1$ | Dominant | Recessive | $F_2$ segregation ratio | P-value |
|---|---|---|---|---|---|
| **Hypocotyl colour:** | | Pink | Green | | |
| Ankur x EC-30196 | Pink | 347 | 102 | 3:1 | 0.30–0.20 |
| MACS-36 x MACS-13 | Pink | 141 | 44 | 3:1 | 0.80–0.70 |
| MACS-38 x EC-30196 | Pink | 368 | 110 | 3:1 | 0.50–0.30 |
| **Petal colour:** | | Pink | White | | |
| Ankur x EC-30196 | Pink | 335 | 114 | 3:1 | 0.90–0.80 |
| MACS-36 x MACS-13 | Pink | 151 | 34 | 3:1 | 0.05–0.02 |
| MACS-38 x EC-30196 | Pink | 359 | 119 | 3:1 | 0.98–0.95 |
| EC.13005 x MACS-40 | Pink | 423 | 137 | 3:1 | 0.80–0.70 |
| **Growth habit:** | | Indeterminate | Determinate | | |
| Ankur x EC. 30196 | Indeterminate | 351 | 98 | 3:1 | 0.20–0.10 |
| **Pod Colour:** | | Brown | Tan | | |
| Ankur x EC.30196 | Brown | 323 | 126 | 3:1 | 0.20–0.10 |
| MACS-36 x MACS-13 | Brown | 140 | 45 | 3:1 | 0.90–0.80 |
| **Pubescence type:** | | Glabrous | Pubescent | | |
| EC.13005 x MACS-40 | Glabrous | 409 | 151 | 3:1 | 0.30–0.20 |
| **Pubescence colour:** | | Tawny | Gray | | |
| MACS-36 x MACS-13 | Tawny | 133 | 52 | 3:1 | 0.50–0.30 |
| MACS-38 x EC.30196 | Tawny | 336 | 142 | 3:1 | 0.02–0.01 |
| **Seed size:** | | Bold | Small | | |
| EC.13005 x MACS-40 | Bold | 408 | 152 | 3:1 | 0.30–0.2 |
| MACS-36 x MACS-13 | Bold | 153 | 32 | 3:1 | 0.02–0.01 |
| **Seed coat colour:** | | Yellow | Black | Brown | |
| Ankur x EC.30196 | Yellow | 342 | 107 | 0 3:1 | 0.70–0.50 |
| MACS-38 x EC.30196 | Yellow | 368 | 77 | 33 12:3:1 | 0.5–0.3 |
| **Hilum colour:** | | Black | Brown | | |
| EC. 13005 x MACS-40 | Black | 320 | 240 | 9:7 | 0.8–0.7 |
| MACS-36 x MACS-13 | Black | 138 | 4 | 3:1 | 0.9–0.80 |
| MACS-38 x EC.30196 | Black | 202 | 276 | 27:37 | 0.95–0.90 |

was reported earlier [10] with exception of pubescent type being dominant as noticed by Stewart and Wentz [11].

*Pubescence colour.* Pubescence colour may be tawny (yellowish brown) or gray and often used in the varietal identification at maturity. The present study reveals tawny

pubescence as dominant with monogenic control, as also observed earlier [8]. However, Raut et al. [6] noted digenic control with duplicate action.

*Seed size.* This has been classified as bold or small based on the seed size of the parents used. MACS-13 and EC 13005 have bold seeds and MACS-36 and MACS-40 have small seeds. In the crosses Ec 13005 x MACS-40 and MACS-36 x MACS-13, bold seed was dominant over small seed with a single gene difference. Miku [12] also reported similar results.

*Seed coat colour.* There is wide range of variation in soybean seed coat colour and pattern. It may be green, yellow, black, brown and mottled (spotted). In the cross, Ankur x EC 30196, yellow seed coat colour was dominant over black with monogenic control (3 yellow : 1 black). Raut et al. [6] and Mikhailov [13] have noticed yellow seed coat colour to be dominant over black with monogenic and trigenic control, respectively. However, epistatic gene interaction was noticed in the cross MACS-38 x EC 30196 where yellow colour was epistatic to black. This confirms the earlier report [4].

*Hilum colour.* It is an important character in varietal identification. Black, brown and gray are the commonly occurring hilum colours though buff imperfect black and colourless hilum are also noticed in some varieties. Black hilum colour was dominant over brown with monogenic control in the cross MACS-36 x MACS-13. Similar observations were reported earlier [6, 14]. However, digenic (9:7) and trigenic (27:37) control with complementary gene action with dominance of black over brown hilum colour was observed in the crosses EC 13005 x MACS-40 and MACS-36 x EC 30196, respectively, thus confirming the observations of Mikhailov [14].

Out of 46 joint segregations for nine characters, only in nine cases significant linkages were noted (Table 3). Genes for hypocotyl colour and petal colour appear to be linked with a crossover value of 17.7%, 34.1% and 15.2% in the crosses Ankur x EC 30196, MACS-36 x MACS-13 and MACS-38 x EC 30196 respectively. Similar situations have been reported by Raut et al. [6]. However, Raut et al. [5] reported pleiotropic complex for those characters. Likewise, the genes for pubescence colour and hilum colour were found to be linked with 28.6% and 34.4% crossover values in the crosses MACS-36 x MACS-13 and MACS-38 x EC 30196, respectively. Linkage among these genes was also reported by Woodworth [15] with pleiotropic action.

Linkage was recorded between the genes for presence of pubescence and hilum colour, seed coat colour and hilum colour with 39.1%, 34.7% and 49.4% crossover values, respectively.

**Table 3. Significant linkages in four soybean crosses**

| Character pair | XY | Xy | xY | xy | $X^2$ | P value | d.f. |
|---|---|---|---|---|---|---|---|
| **EC.13005 x MACS-40:** | | | | | | | |
| Pubescence type (3:1) with | | | | | | | |
| Hilum colour (9:7) | 247 | 162 | 73 | 78 | 8.06 | 0.05–0.02 | 3 |
| Exp. L. 39.05% C.O. | 249.01 | 170.99 | 65.99 | 74.01 | 1.45 | 0.5–0.3 | 2 |
| **Ankur x EC-30196:** | | | | | | | |
| Hypocotyl colour (3:1) with | | | | | | | |
| Petal colour (3:1) | 316 | 31 | 19 | 83 | 207.59 | < 0.001 | 3 |
| Exp. L. 17.71% C.O. | 311.99 | 24.75 | 24.75 | 87.50 | 3.19 | 0.30–0.20 | 2 |
| **MACS-36 x MACS-13:** | | | | | | | |
| (i) Hypocotyl colour (3:1) with | | | | | | | |
| Petal colour (3:1) | 122 | 19 | 29 | 15 | 12.15 | 0.01–0.001 | 3 |
| Exp. L. 34.06% C.O. | 112.61 | 26.14 | 26.14 | 20.11 | 4.35 | 0.2–0.10 | 2 |
| (ii) Pubescence colour (3:1) with | | | | | | | |
| Hilum colour (3:1) | 112 | 21 | 26 | 26 | 26.22 | < 0.001 | 3 |
| Exp. L. 28.56% C.O. | 116.11 | 22.64 | 22.64 | 23.61 | 1.01 | 0.70–0.50 | 2 |
| (iii) Seed size (3:1) with | | | | | | | |
| Hilum colour (3:1) | 121 | 32 | 17 | 15 | 13.01 | 0.01–0.001 | 3 |
| Exp. L. 33.98% C.O. | 112.67 | 26.09 | 26.09 | 20.16 | 6.45 | 0.05–0.02 | 2 |
| **MACS-38 x EC.30196:** | | | | | | | |
| (i) Hypocotyl colour (3:1) with | | | | | | | |
| Petal colour (3:1) | 330 | 38 | 29 | 81 | 172.09 | < 0.001 | 3 |
| Exp. L. 15.19% C.O. | 324.94 | 33.56 | 33.56 | 85.94 | 1.57 | 0.50–0.30 | 2 |
| (ii) Pubescence colour (3:1) with | | | | | | | |
| Seed coat colour (12:3:1) | 257 62 | 17 | 111 15 | 16 | 19.53 | 0.01–0.001 | 5 |
| Exp. L. 32.65% C.O. | 341.39 | 17.11 | 106.74 | 12.76 | 5.76 | 0.10–0.05 | 2 |
| (iii) Pubescence colour (3:1) with | | | | | | | |
| Hilum colour (27:27) | 158 | 178 | 44 | 98 | 17.35 | < 0.001 | 3 |
| Exp. L. 32.02% | 163.38 | 195.12 | 38.29 | 81.21 | 5.78 | 0.10–0.05 | 2 |
| (iv) Seed coat colour (12:3:1) with | | | | | | | |
| Hilum colour (27:37) | 156 | 212.45 | 32 | 1.32 | 32.42 | < 0.001 | 5 |
| Exp. L. 49.37% C.O. | 151.76 | 206.74 | 49.90 | 69.59 | 1.01 | 0.70–0.50 | 2 |

Thus the present study has analysed the inheritance of nine characters and their linkage relationships. Most of the characters appeared to be monogenically controlled except for seed coat colour and hilum colour.

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