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Article

Segregation pattern and inbreeding depression in F_2 generation of some hybrid okra varieties

Sonia Akter Laboni[1], S.M. Ahsan[2], Shepon Chandra Ghosh[3], Eftekhar Mahmud[4], MostafizurRahman Talukder[5], Soleh Akram[6],Sayeed Shahriyar[7] and Abdulla-Al-Asif[8*]

[1]Department of Genetics and Plant Breeding, Faculty of Agriculture, Patuakhali Science and Technology University, Bangladesh
[2]Department of Horticulture, Faculty of Agriculture, Patuakhali Science and Technology University, Bangladesh
[3]Department of Crop Botany, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[4]Scientific Officer, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh
[5]Principal Scientific Officer, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh
[6]Department of Genetics and Plant Breeding, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[7]Department of Biotechnology, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[8]Department of Aquaculture, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

*Corresponding author: Abdulla-Al-Asif, Department of Aquaculture, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh. Mobile: +8801716838294; E-mail: jessoreboyhemel@gmail.com

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Abstract: An experiment was conducted in randomized complete block design (RCBD) with three replications in the experimental field of Regional Horticulture Research Station (RHRS), Bangladesh Agriculture Research Institute (BARI), Lebukhali, Patuakhali during April, 2014 to October, 2014 for assessing the inbreeding depression, genetic parameters, gene action and segregation pattern of Okra [*Abelmoschusesculentus* (L.) Moench]. The experiment was comprised of five commercial hybrid Okra genotypes such as Tara sonali, Bimala, Juboraj, Suvo 1and Noor, their respective F_2 progenies along with a check variety named as BARI Dherosh 1. Results of the experiment indicated that there were considerable variability among the F_1 and their F_2. The yield were in-between 14.81 to 7.92 Kg plot^{-1}in case of F_1 generation, which deteriorate to 10.32 to 5.32 Kg plot^{-1} in F_2 generation. Broad sense heritability computed through variance component method showed that all the quantitative traits were moderate to highly heritable. The trait yield per plot exhibited 68.83% broad sense heritability coupled with 50.96% genetic advance suggesting the existence of sufficient amount of genetic variability for improvement of this trait and also indicates that the trait is more amenable to selection and could be improved easily. In case of segregation pattern, plant height and pod pubescence content exhibit as polygenic trait. Leaf shape, fruit base shape and branching pattern showed complete dominance and fruit color displayed incomplete dominance. The present investigation thus provide information about the nature and magnitude of genetic variation, segregation pattern and inbreeding depression for yield and its components in okra so as to formulate suitable breeding strategy and isolate potential parents and promising crosses for further breeding program.

Keywords: segregation pattern; inbreeding depression; F_2 generation; okra

1. Introduction

Okra [*Abelmoschusesculentus*(L.)Moench] is a member under Malvaceae Family and is also known as Lady's finger. It is an annual vegetable crop grown from seed in tropical and sub-tropical parts of the world (Tahkur and Arora, 1986). Okra is a nutritious and delicious vegetable, fairly rich in vitamins and minerals. Per 100 gm. of edible portion of pod have moderate levels of vitamin A (0.01 mg) and C (18 g), calcium (90 mg), phosphorus and potassium. The content of thiamine (0.07 mg), riboflavin (0.08 mg) and niacin (0.08 mg) per 100 g edible portion of pod is higher than that of many vegetables (Rashid, 1990). *Abelmoschus*spp.is predominantly annual. Owing to their floral morphology and the absence of a self-incompatibility system, they are generally regenerated through selfing. However, depending on the species or variety, season and location, varying degree of outcrossing (up to 6(%) occurs in okra. Bees *(Apismelliferaand A. cerana)* appear to be the main vectors of pollen. Such a level of out crossing will maintain a considerable amount of heterozygosity and heterogeneity, eventually resulting in off-type segregants during repeated multiplication cycles. Since okra is an autogamous crop, the breeding methods suitable for the self-pollinated crops can usefully be employed in this crop also. The crop offers several features *viz.* adaptability to wide range of climatic conditions, erect growing habit, short life span, large size flower and monoadelphous and epipetalous nature of stamens which have a great value to breeder in achieving quick genetic results. Large size flowers and monoadephours condition of stamens facilitate hand emasculation. Its capsule produces a large number of seeds which is also a desirable feature for hybrid seed production. Being a short duration crop, it is possible to grow two generations in a year. Despite these qualities, no systematic studies have been made to generate information on quantitative traits which may be directly or indirectly related to yield and further improvement of this crop.Genetic variability in the population is the most important prerequisite of any breeding program. Variability, only accounts for the observable phenotypic differences, which may be of genetic and environmental. Higher variability has better chance for selecting the desirable genotypes. Furthermore, the partitioning of total variability into its heritable and non-heritable components enables us to know the effectiveness of selection. Heritability, which indicates the transmissibility of the character from parent to offspring, is a useful measure for considering the ratio of genetic variance to the total variance. It may be based on total genetic variance and additive genetic variance, where latter is more important in selection breeding. Heritability indicates the possibility and extent to which improvement can be brought about through selection and it may be of broad and narrow senses.However, heritability alone does not provide the true picture of genetic improvement to be made in subsequent generations. It is the genetic advance which predicts speed of genetic improvement for a particular intensity of selection. Heritability coupled with genetic advance is more useful, and as heritability and phenotypic variation increases, the genetic advance also increases. Thus, the primary requirement of a plant breeder is to have information on the genetic advance and direct and indirect influences of the plant characters on yield. The nature and degree of association between yield and its attributes claims distinct importance which assist the breeder to ascertain the actual yield components and furnish an effective basis of phenotypic selection.Inbreeding depression defines to decrease in fitness and vigor due to inbreeding effect. It increases homozygosity in the genotype by continuous selfing. It results due to fixation of undesirable recessive genes in F_2. While in case of heterosis, favorable dominant genes of one parent are masking the effect of recessive genes of other parent. The present investigation was, therefore, undertaken with a set of self-crosses to elicit information about the nature and magnitude of genetic variation, segregation pattern and inbreeding depression for yield and its components in okra so as to formulate suitable breeding strategy and isolate potential parents and promising crosses for further exploitation.

2. Materials and Methods

2.1. Location and description of the experimental site

A field experiment was conducted at the Research field of Regional Horticulture Research Station (RHRS), Lebukhali, Dumki, Patuakhali during the period from may, 2014 to September, 2014 to study on segregating pattern and inbreeding depression of some hybrid okra varieties in Second filial generation (F_2). This region occupies a vast area of tidal floodplain land in the North–West part of Patuakhali district.

2.2. Experimental materials

A total of eleven materials were used in this experiment. Among the materials, five were commercial F_1 okra varieties; five were their F_2 generations and one check variety. The okra variety used in the experiment was Tara Sonali, Bimala, Noor, Suvo-1 and Juboraj and their F_2 derivatives with the cheak variety BARI Dherosh 1.F_2 seeds were collected from Regional Horticulture Research Station (RHRS), Lebukhali, Dumki, Patuakhali and F_1's were collected from different seed retailers of Barisal.

2.3. Layout and design of experiment

The experiment was laid out in RCBD with three replications. The whole field was divided into three blocks and each block consisted of eleven (11) plots. The replications were separated from one another by 1 m. The distance between plots was 50 cm. The treatment was randomly assigned to each of the block. However, Each F_1 and its respective F_2 were planted side by side. Plot size for F_1's and checks variety was 1m x 4m.

2.4. Collection of data

Morphological data were collected from five randomly selected plants for each accession based on International Board for Plant Genetic Resources (IBPGR) recommended descriptor procedures for Okra (Charrier, 1984). Data were collected as specified. These are:

2.4.1. Days to 50% flowering

Recorded as days from sowing to flowering when 50% of the plant of each plot flowered.

2.4.2. First harvesting date

Recorded as days from sowing to 1st harvesting when fruit become edible.

2.4.3. Node order of 1st flowering

Node order of 1st fruiting of ten randomly selected plants was counted at fruit setting from the 1st node of the plant to the 1stfruiting node.

2.4.4. No of fruit per plant

Mean number of green pods of selected plants from each plot was recorded.

2.4.5. Fruit weight

Mean weight of ten randomly selected green fruit from each plot were measured in gram (g).

2.4.5. Plant height

Plant height is measured in centimeter (cm) by a meter scale at harvest from the point of attachment of the leaf to the ground level up to the tip. It was classified into 6 classes namely; 60-90 cm, 90-120 cm, 120-150 cm, 150-180 cm, 180-210cm and 210-240 cm. Number of plant per class were counted and recorded.

2.4.6. Fruit Length

Ten randomly selected pods from each plot were taken and length was recorded by a meter scale in cm and finally mean was calculated.

2.4.7. Fruit Diameter

Mean diameter of 10 randomly selected pods from each plot were measured in cm with the help of slide calipers.

2.4.8. Yield per plot

The weight of individual fruit was recorded during each fruit harvesting and was continued up to final harvesting. Thus, total weight was calculated to get fruit weight per plot and expressed in kilogram.

2.4.9.Internodal length

Recorded as the distance (cm) from the node to node, twenty random internode were selected from different plant of a plot and the average was taken.

2.5. Statistical analysis

Analysis of variance was done for all the characters under study using the mean values (Singh and Chaudhury, 1985). Duncan's Multiple Range test (DMRT) was performed for all the characters to test the difference between the means of the genotypes following Steel and Torrie (1960).

i) Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula given by Johnson *et al.* (1955).

Genotypic variance $\sigma_g^2 = \frac{GMS - EMS}{r}$

Where,

GMS = Genotypic mean square

EMS = Error mean square

r = Number of replication

Phenotypic variance $\sigma_{ph}^2 = \sigma_g^2 + EMS$

Where,

σ_g^2 = genotypic variance

EMS = Error mean square

ii) Estimation of genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV) :

Genotypic and phenotypic co-efficient of variation were estimated according to Burton, 1952; Singh and Chaudhury, 1985.

$$GCV\ (\%) = \frac{\sqrt{\sigma_g^2}}{\bar{x}} \times 100$$

Where

σ_g^2 = Genotypic variance

$\bar{x}$ = Population mean

Similarly,

$$PCV\ (\%) = \frac{\sqrt{\sigma_{ph}^2}}{\bar{x}} \times 100$$

Where,

σ_{ph}^2 = Phenotypic variance

$\bar{x}$ = Population mean

iii) Estimation of heritability

Heritability in broad sense was estimated using the formula suggested by Johnson el al. (1955) and Hanson, *et al.* (1956).

$$heritability\ (h_b^2) = \frac{\sigma_g^2}{\sigma_{ph}^2} \times 100$$

Where

σ_g^2 = Genotypic variance

σ_{ph}^2 = Phenotypic variance

iv) Estimation of genetic advance

Expected genetic advance under selection was estimated using the formula suggested by Johnson *et al.* (1955).

$$Genetic\ advance\ (GA) = \frac{\sigma_g^2}{\sigma_{ph}^2} \times k \times \sigma_{ph}$$

Where

σ_g^2 = Genotypic variance

σ_{ph}^2 = Phenotypic variance

k = selection intensity, the value of which is 2.06 at 5% selection intensity.

σ_{ph} = Phenotypic standard deviation.

v) Estimation of genetic advance in percent of mean

Genetic advance in percent of mean was calculated as proposed by Comstock and Robinson (1952).

$$\text{Genetic advance in percent of mean (GA\%)} = \frac{GA}{\bar{x}} \times 100$$

Where,

GA = genetic advance

X = population mean

2.5.1. Estimation of inbreeding depression

Inbreeding depression was measured using F_1 and F_2 means values according to the following formula:

$$\text{Per cent of inbreeding depression (ID)} = \frac{\overline{F_1} - \overline{F_2}}{\overline{F_1}} \times 100$$

2.5.2. Estimation of segregating pattern

The selfing ratio was tested using a chi-square test (Panse and Sukhatme, 1985). The confirmation of ratios obtained in F_2 segregating populations was done by the ratios obtained fromF_1 generation.

$$X^2 = \sum \frac{(O - E)^2}{E}$$

Where,

O = Observed value

E = Expected value

When the calculated value of χ_2 was less than the table value at (n—1) degree of freedom, the fit was considered to be good or the assumed ratio was correct. Conversely, when the calculated value was more than the table value, the fit was not good and the assumed ratio was not correct. Probability values were recorded for these ratios (Deokar, 1964) for their respective test crosses ratios.

3. Results

3.1. Performance of F_1 and F_2 progenies

Days to 50 % flowering were ranged from 39.00 days after sowing to 62.00 days after sowing with mean value 50.27. Maximum days required for 50% flowering in F_2 generation of Noor which was followed by Noor (F_1) itself. Minimum days for 50% flowering were obtained in F_2 progeny of Juboraj (41 DAS). In most cases, the F_2 progenies took more time for 50% flowering then their respective F_1. However, in Juboraj it was almost similar in two generations.

Table 1. Mean performance of 5 okra genotypes and their F_2 derivative in respect of days to 50% flowering, days to 1st harvesting, node order of 1st flowering, plant height and internodal length.

Variety	50% Flowering	Days to 1st harvesting	Node order of 1st flowering	Plant Height	Internodal length
Tara Sonali (F_1)	43.33	53.67	6.23	130.3	10.37
Bimala (F_1)	52	57	8.43	111.6	7.20
Jubiraj	41.33	55	7	108.7	10.27
Suvi 1	53.67	58.33	9	107.9	8.31
Noor	57.67	61.67	8.6	107.9	8.13
F_2 derivatives of Tara Sonali	43.33	54	8.56	131.8	9.50
F_2 derivatives of Bimala	54.33	59.67	11	127.0	10.50
F_2 derivatives of Juboraj	41	51.33	7.87	116.7	11.13
F_2 derivatives of Suvo 1	55.67	62.33	11.03	125.4	10.20
F_2 derivatives of noor	61	62.33	10.33	126.7	9.07
BARI Dherosh-1	49.67	55.33	7.27	122.0	10.53
LSD (5%)	4.88	2.54	1.86	13.76	2.05

Days to 1st harvest ranged from 62.33 DAS to 51.33 DAS with mean value 57.33. Maximum days required for 1st harvesting was in F_2 progeny of Suvo 1 and Noor which was 62.33 DAS. Minimum days for 1st harvesting were required in F_2 progeny of Juboraj which was 51.33 DAS. In all cases, harvesting took more time in F_2

progenies then their respective F_1 progenies but in Juboraj F_2 progeny took less time than its F_1 for 1st harvesting.Node order for 1st flowering ranged from6.23 to 11.03 and there was significant variation among the genotypes for the characters. 1st flowering was obtained in 11th node in F_2progeny of Bimala and Suvo-1, and in Tara sonali (F_1), it was found in 6th node. Significant variation was observed for the character number of fruit per plant. Number of fruit per plant ranged from 6.93 to 15.37. Maximum fruiting was found in Tara sonali (F_1) and minimum in F_2 progeny of Noor. In all cases, number of fruit was higher in F_1 then their respective F_2 progenies.

There was significant variation among the materials for individual fruit weight. Maximum fruit weight was found in Juboraj (F_1) (21.23g) which was almost similar in Noor (F_1) (21g). Smallest fruit was found in F_2 progeny of Suvo-1 (15.53 g). Mean value for this character was 17.86 g. in all cases F_1 produced larger fruit then their respective F_2 progenies.

Table 2. Mean performance of 5 okra genotypes and their F_2 derivative in respect of number of fruit per plant, fruit weight, fruit length, fruit diameter and yield.

	Number of fruit per plant	Fruit weight	Fruit length	Fruit diameter	Yield
Tara Sonali (F_1)	15.37	15.63	18,78	1.43	12.09
Bimala (F_1)	11.43	18.63	14,57	1.40	10.65
Jubiraj	13.9	21.23	16.06	1.70	14.81
Suvi 1	9.23	17.83	15.37	1.49	8.24
Noor	7.53	21	13.30	1.50	7.92
F_2 derivatives of Tara Sonali	11.97	17.27	13.77	1.63	10.32
F_2 derivatives of Bimala	7.4	16.8	12.99	1.30	6.27
F_2 derivatives of Juboraj	10.43	17.77	13.53	1.40	9.32
F_2 derivatives of Suvo 1	6.96	15.53	13.96	1.42	5.42
F_2 derivatives of noor	6.93	15.27	11.98	1.27	5.32
BARI Dherosh-1	11.23	19.53	12.37	1.31	10.92
LSD (5%)	3.02	2.37	1.93	0.21	3.14

Plant height ranged from 107.9 cm to 131.8 cm and variation for this character was highly significant. Maximum plant height was found in F_2 progeny of tarasonali (131.8 cm and minimum was found in Noor (F_1) and Suvo-1 (F_1) (107.9 cm).in all cases, F_1 produced smaller plant than their respective F_2 progenies.

Significant variation was obtained for intermodal length. This value ranged from 7.20 cm to 11.13 cm. Maximum node length was found in F_2 progeny of Juboraj (11.13 cm) and minimum in Bimala (F_1) (7.20 cm). in Tara sonali, internodal length decreased in F_2. But in all other cases, this value increased in F_2 than their respective F_1.

Table 3. Analysis of variance (mean squares) for different characters.

Source	d.f	50% flowering	1st harvesting date	Node order of 1st flowering	No of fruit per plant	Fruit weight	plant height	internodal length	Fruit Length	Fruit Diameter	Yield
Replication	2	27.36	7.48	1.27	11.65	7.39	250.57	0.61	3.73	0.01	20.73
Treatment	5	147.72**	43.60**	7.59**	24.95	12.97**	254.56**	4.58*	11.13*	0.05*	26.00**
Error	10	8.23	2.22	1.19	3.14	1.94	65.28	1.45	1.29	0.02	3.40

Table 4. Maximum, minimum, mean and standard deviation.

	50% flowering	1st harvesting date	Node order of 1st flowering	No of fruit per plant	Fruit weight	plant height	internodal length	Fruit Length	Fruit Diameter	Yield
Max	62.00	64.00	14.00	18.30	21.90	142.70	13.20	21.41	1.77	19.62
Min	39.00	50.00	5.40	6.20	13.00	94.80	5.00	10.75	1.04	4.58
Mean	50.27	57.33	8.67	10.22	17.86	119.54	9.56	14.24	1.44	9.21
standard deviation	7.17	3.87	1.76	3.19	2.36	11.48	1.52	2.09	0.17	3.35
Variance	51.41	15.01	3.10	10.17	5.55	131.89	2.30	4.38	0.03	11.20

Fruit length showed significant variation among the materials. This value ranged from 11.98 cm to 18.78 cm. longest fruit was obtained in Tara sonali (F_1) (18.78 cm) and shortest fruit was found in F_2 progeny of Noor (11.98 cm). Fruit length was decreased in F_2 progenies then their respective F_1's.
There was significant variation for fruit diameter. Fruit diameter ranged from 1.27 cm to 1.70 cm. maximum fruit diameter was found in Juboraj (F_1) and minimum in F_2 progeny of Noor. In Tara sonali, fruit diameter increased in F_2 progeny but for other cases it was reduced in F_2. Significant variation was obtained for yield per plot. Yield ranged from 5.32 kg per plot to 14.81 kg per plot. Maximum yield was obtained from Juboraj (F_1) (14.81 kg) and minimum yield was found in F_2 progeny of Noor (5.32 kg). Yield reduced in F_2 progenies than their respective F_1's.

3.2. Heritability, genetic advance and genetic advance in percentage of mean

The genotypic, phenotypic and environmental variance, genotypic co-efficient of variation (GCV), phenotypic co-efficient of variation (PCV), heritability in broad sense (h^2b %), genetic advance (GA) and genetic advance in percent of mean (GA %) for all the quantitative characters under study are presented in table 6 respectively. The phenotypic co-efficient of variation (PCV) were higher than their corresponding genotypic co-efficient of variation (GCV) for all the characters studied indicating that they all interacted with the environment to some intent. Genetic parameters in respect of all characters are presented below:

3.2.1. 50% flowering

In case of first filial generation, genotypic (13.56%) and phenotypic (14.72%) co-efficient of variation was moderate for days to 50% flowering in the present study. Days to 50% flowering exhibited low heritability (25.75%) in broad sense (h^2_b) coupled with moderate genetic advance in percentage of mean (12.95).

3.2.2. Days to 1st harvesting

Genotypic (6.48%) and phenotypic (6.98 %) co-efficient of variation was low for days to 1st harvesting in the present study. Days to 1st harvesting exhibited low heritability (12.39 %) in broad sense (h^2_b) coupled with low genetic advance in percentage of mean (7.10).

3.2.3. Node order of 1st flowering

Genotypic (16.86%) and phenotypic (21.03%) co-efficient of variation was moderate for node order of 1st flowering in the present study. Node order of 1st flowering exhibited low heritability (27.83%) in broad sense (h^2_b) coupled with low genetic advance in percentage of mean (2.41).

3.2.4. Number of fruit per plant

Genotypic (26.38%) and phenotypic (31.58%) co-efficient of variation was high for number of fruit per plant. Number of fruit per plant exhibited moderate heritability (45.40%) in broad sense (h^2_b) coupled with low genetic advance in percentage of mean (4.64).

Table 5.Variance, co-variance, heritability, genetic advance and genetic advance in percentage of mean.

	S^2G	S^2E	S^2P	PCV	GCV	GA	% GA	h^2 (Broad Scene)
50% flowering	46.50	8.23	54.73	14.72	13.56	0.85	12.95	25.75
1st harvesting date	13.79	2.22	16.01	6.98	6.48	0.86	7.10	12.39
Node order of 1st flowering	2.13	1.19	3.32	21.03	16.86	0.64	2.41	27.83
No of fruit per plant	7.27	3.14	10.41	31.58	26.38	0.70	4.64	45.40
Fruit weight	3.67	1.94	5.62	13.27	10.73	0.65	3.19	17.88
plant height	63.09	65.28	128.37	9.48	6.64	0.49	11.47	9.60
internodal length	1.05	1.45	2.49	16.51	10.69	0.42	1.36	14.26
Fruit Length	3.28	1.29	4.57	15.01	12.72	0.72	3.16	22.21
Fruit Diameter	0.01	0.02	0.03	11.85	7.84	0.44	0.15	10.68
Yield per plot	7.53	3.40	10.94	35.92	29.81	0.69	4.69	50.96

3.2.5. Fruit weight

Genotypic (10.73%) and phenotypic (13.27%) co-efficient of variation was moderate for fruit weight in the present study. Fruit weight exhibited low heritability (17.88%) in broad sense (h^2_b) coupled with low genetic advance in percentage of mean (3.19) (Table 5).

3.2.6. Plant height
Genotypic (6.64%) and phenotypic (9.48%) co-efficient of variation was low for plant height. Plant height exhibited low heritability (9.60%) in broad sense (h^2_b) coupled with moderate genetic advance in percentage of mean (11.47) (Table 5).

3.2.7. Internodal length
Genotypic (10.69%) and phenotypic (16.51%) co-efficient of variation was moderate for internodal length in the present study. Internodal length exhibited low heritability (14.26%) in broad sense (h^2_b) coupled with low genetic advance in percentage of mean (1.36) (Table 5).

3.2.8. Fruit length
Genotypic (12.72%) and phenotypic (15.01%) co-efficient of variation was moderate for fruit length. Fruit Length exhibited low heritability (22.21%) in broad sense (h^2_b) coupled with low genetic advance in percentage of mean (3.16) (Table 5).

3.2.9. Fruit diameter
Genotypic (7.84%) and phenotypic (11.85%) co-efficient of variation was low for fruit diameter in the present study. Fruit diameter exhibited low heritability (10.68%) in broad sense (h^2_b) coupled with low genetic advance in percentage of mean (0.15) (Table 5).

3.2.10. Yield
Genotypic (29.81%) and phenotypic (35.92%) co-efficient of variation was high for yield per plot. Yield per plot exhibited moderate heritability (50.96%) in broad sense (h^2_b) coupled with low genetic advance in percentage of mean (4.69) (Table 5).

3.3. Inbreeding depression
Inbreeding is a system of mating that leads to an increase in homozygosity, decline in vigor and the reduction in productivity. Inbreeding depression may be defined as the reduction or loss in vigour and fertility as a result of inbreeding. The character wise results of inbreeding depression in F_2 generation are given as under.

Table 6. Inbreeding depression (%) for different characters.

Variety	50% flowering	1st harvesting date	Node order of 1st flowering	No of fruit per plant	Fruit weight	plant height	Internodal length	Fruit Length	Fruit Diameter	Yield
Tara Sonali	0.00	-0.61	-37.39	22.12	-10.49	-1.15	0.38	26.67	-13.99	14.64
Bimala	-4.49	-4.68	-30.49	35.25	9.82	-13.79	-45.83	10.84	7.14	41.12
Juboraj	0.80	6.67	-12.43	24.96	16.29	-7.36	-8.37	15.75	17.64	37.07
Suvo 1	-3.73	-6.85	-22.55	24.59	12.89	-16.22	-22.74	9.17	4.69	34.22
Noor	-5.78	-1.07	-20.12	7.97	27.28	-14.42	-11.5	9.92	15.33	32.82

3.3.1. 50% Flowering
There were no changes in days to 50% flowering in Tara sonali. Days to 50% flowering was increased in bimola, suvo-1 and noor are 4.49%, 3.73% and 5.78% respectively. However, it was slightly decreased in Juboraj (0.8%).

3.3.2. Days to 1st harvesting
Days to 1st harvesting decreased 6.67% in Juboraj. It was increased by 0.61%, 4.68%, 6.85% and 1.07% in Tara sonali, Bimala, suvo-1 and Noor respectively.

3.3.3. Node order of 1st flowering
Node order of 1st flowering was increased by 37.39%, 30.49%, 12.43%, 22.55% and 20.12% in Tara sonali, Bimala, Juboraj, suvo-1 and Noor respectively.

3.3.4. Number of fruit per plant
There was a sharp decrease in number of fruit by 22.12%, 35.25%, 24.96%, 24.59% and 7.97% in Tara sonali, bimala, Juboraj , Suvo-1 and Noor respectively.

3.3.5. Fruit weight
Individual fruit weight was also decreased in Bimala, juboraj, Suvo-1 and Noor by 9.82%, 16.29%, 12.89% and 27.28% respectively. Though it increased in Tara sonali by 10.49%.

3.3.6 Plant height
Plant height increased in F_2 generation in all the hybrids. The increase was 1.15%, 13.79%, 7.36%, 16.22% and 14.42% in Tara sonali, Bimala, Juboraj, Suvo-1 and Noor respectively.

3.3.7. Internodal length
There was slight decrease in internodal length in Tara sonali (0.38%) where it increased by 45.83%, 8.37%, 22.74% and 11.5% in Bimala, Juboraj, Suvo-1 and Noor respectively.

3.3.8. Fruit length
Fruit length decreased in all the F_2 in relation to their respective F_1's. It was 26.67%, 10.84%, 15.75%, 9.17% and 9.92% in Tara sonali, Bimala, Juboraj, suvo-1 and Noor respectively.

3.3.9. Fruit diameter
Fruit diameter increased in Tara sonali by 13.99%. But it decreased by 7.14%, 17.64%, 4.69% and 15.33% in Bimala, Juboraj, Suvo-1 and Noor respectively.

3.3.10. Yield
The results of inbreeding depression for the character Yield per plot are presented in Table 7. Inbreeding depression was very prominent in all the varieties for yield. It was 14.64%, 41.12%, 37.07%, 34.22% and 32.82% respectively in Tara sonali, Bimala, Juboraj, Suvo-1 and Noor respectively.

3.4. Segregation pattern
3.4.1. Plant height
Segregation pattern of plant height of Okra were studied in five selfed F_2 progenies. In Figure 1, it is clear that plant height of Okra cannot be classified into distinct categories. It is probably, due to multiple genes controlling this character.

3.4.2. Leaf shape
It is easy to explain from the Figure 2 that the leaf shape segregated into two major different types of shapes. Almost one fourth number of plants studied exhibited alternate palmately lobed leaf types, while a large number of plants exhibited heart shape leaf in F_2 generation. The dominant and the recessive character for leaf shape: heart shape and alternate palmately lobed leaf types were easily distinguishable (Figure 2). All of the varieties showed fair to very good goodness of fit, which support the expected ratio 3:1.

3.4.3. Pod pubescence content
The pods of Juboraj F_1 and Noor F_1 have pubescence while Tara SonaliF_1, Bimala F_1 and Suvo 1F_1 does not have pubescence. Segregation took place in the F_2 plants giving two phenotypic classes for both types of parents. The ratio of the classes in F_2offspring of Juboraj and Noor is very close to 3:1 ratio. The P value of $\chi 2$ is (P = 0.10-0.25 and 0.25-0.50) indicating that the deviation from the expected frequencies is not significant i.e. there is a good fit to a 3:1 ratio. But the ratio of the classes in F_2 offspring of Tara Sonali, Bimala and Suvo-1is far from3:1 ratio. This is probably due to presence of polygenic gene for this trait.

3.4.4. Fruit base shape
The Fruit base shape of all varieties of F_1 was round. Segregation took place in the F_2 plants giving two phenotypic classes namely, round and ridge. The ratio of the classes in F_2 offspring is very close to 3:1 ratio. The P value of $\chi 2$ is indicating that the deviation from the expected frequencies is not significant i.e. there is a good fit to a 3:1 ratio.

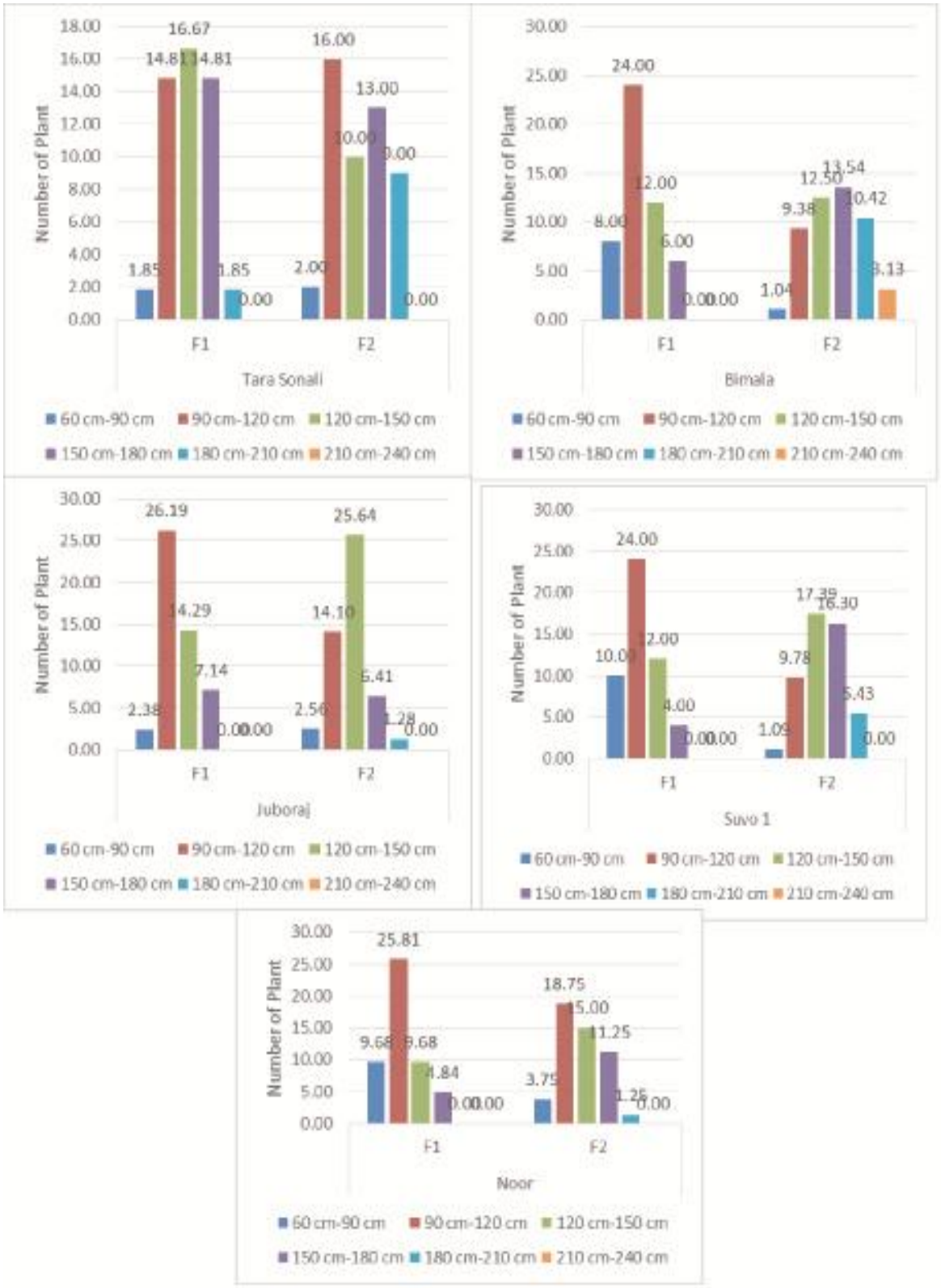

Figure 1. Segregation in F_2 generation for plant height in five genotype of Okra.

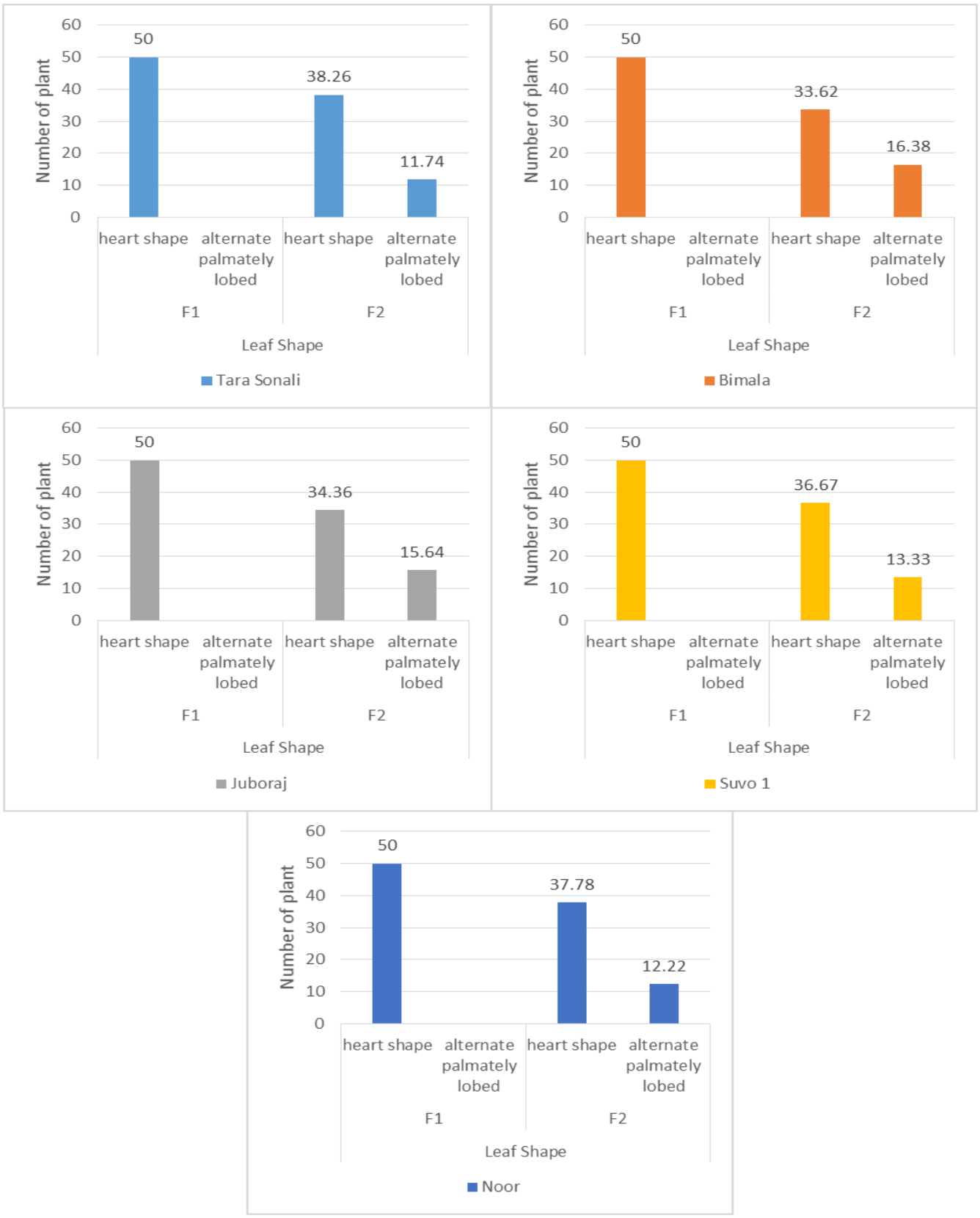

Figure 2. Segregation in F_2 generation for plant height in five genotype of Okra.

Table 7. Chi-Squared values and probabilities of goodness of fit of segregation ratios of F_2 in the study of inheritance of okra leaf shape.

	Leaf shape							
Variety	**F_1**		**F_2 Observed value**		**F_2 Expected value**		**χ^2 value**	**Probability**
	heart shape	**orbic ulate**	**heart shape**	**orbic ulate**	**heart shape**	**orbic ulate**		
Tara Sonali	50	0	38.26	11.74	37.5	12.5	0.093	0.90-0.75
Bimala	50	0	33.62	16.38	37.5	12.5	2.412	0.25-0.10
Juboraj	50	0	34.36	15.64	37.5	12.5	1.579	0.25-0.10
Suvo 1	50	0	36.67	13.33	37.5	12.5	0.111	0.75-0.50
Noor	50	0	37.78	12.22	37.5	12.5	0.012	0.95-0.90

P= 0.60 to 0.80 is very good
P= 0.40 to 0.60 is good
P= 0.20 to 0.40 is fair
P= 0.05 to 0.20 is subjected to further trial/ reject the hypothesis.

Table 8. Chi-Squared values and probabilities of goodness of fit of segregation ratios of F_2 in the study of inheritance of okra pod pubescence content.

Variety	**Pubescence Content**							
	F_1		**F_2**		**F_2 Expected ratio**		**χ^2 value**	**Probability**
	Pubescence Present	**Pubescence absent**	**Pubescence Present**	**Pubescence absent**	**Pubescence Present**	**Pubescence absent**		
Tara Sonali	0	50	21	29	37.5	12.5	29.04	<0.005
Bimala	0	50	27	23	37.5	12.5	11.76	<0.005
Juboraj	50	0	33	17	37.5	12.5	2.16	0.10-0.25
Suvo 1	0	50	26	24	37.5	12.5	14.11	<0.005
Noor	50	0	34	16	37.5	12.5	1.31	0.25-0.50

P= 0.60 to 0.80 is very good
P= 0.40 to 0.60 is good
P= 0.20 to 0.40 is fair
P= 0.05 to 0.20 is subjected to further trial/ reject the hypothesis.

Table 9. Chi-Squared values and probabilities of goodness of fit of segregation ratios of F_2 in the study of inheritance of fruit base shape.

Variety	**Peduncle Shape**							
	F_1		**F_2**		**F_2 Expected ratio**		**χ^2 value**	**Probability**
	Round	**Ridge**	**Round**	**Ridge**	**Round**	**Ridge**		
Tara Sonali	50	0	32.00	18.00	37.5	12.5	3.227	0.10-0.05
Bimala	50	0	39.77	10.23	37.5	12.5	0.551	0.50-0.25
Juboraj	50	0	32.75	16.25	37.5	12.5	1.727	0.25-0.10
Suvo 1	50	0	41.18	8.82	37.5	12.5	1.442	0.25-0.10
Noor	50	0	36.00	14.00	37.5	12.5	0.240	0.75-0.50

P= 0.60 to 0.80 is very good
P= 0.40 to 0.60 is good
P= 0.20 to 0.40 is fair
P= 0.05 to 0.20 is subjected to further trial/ reject the hypothesis.

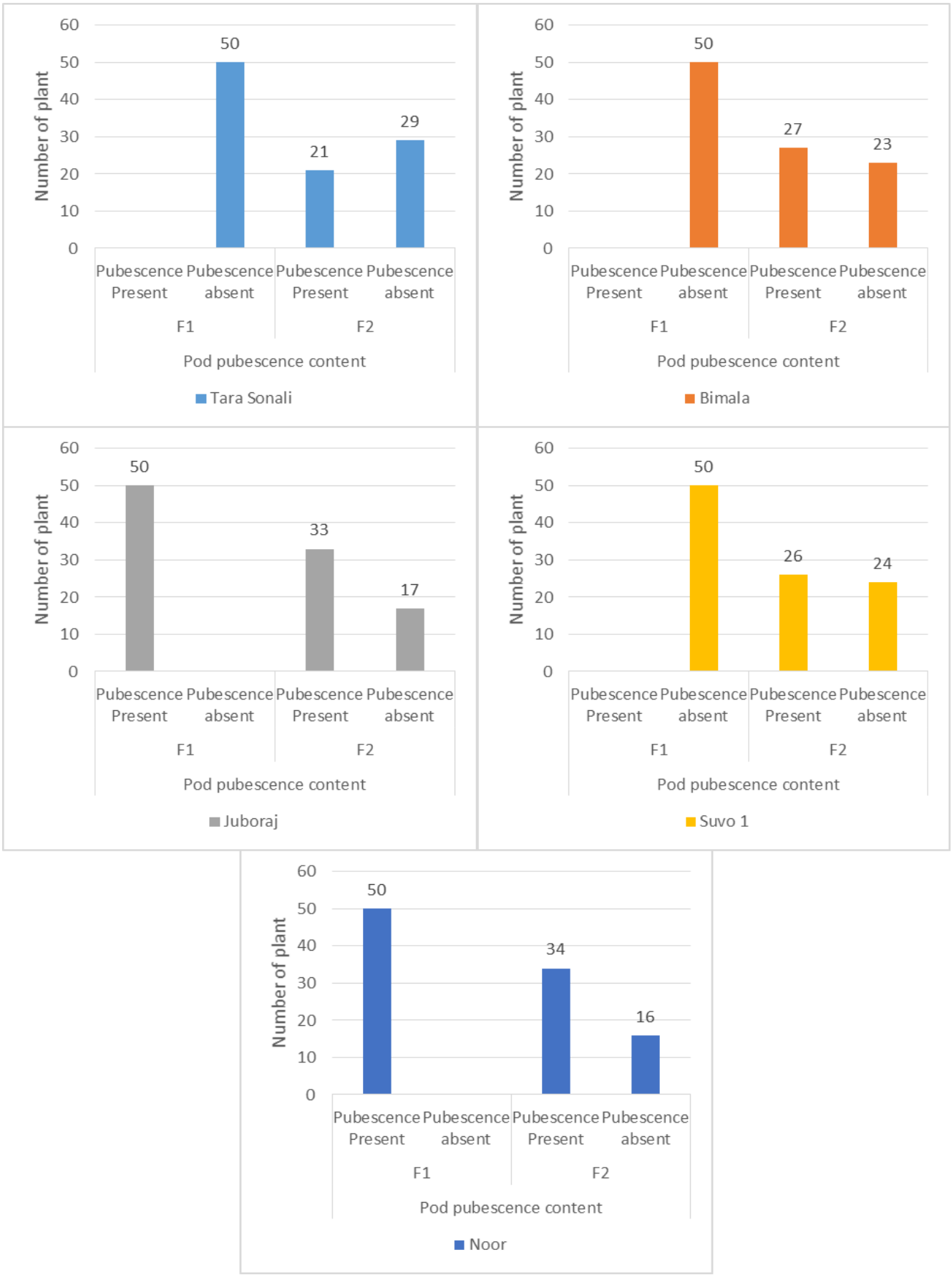

Figure 3. Segregation in F_2 generation for pod pubescence content in five genotypes of Okra.

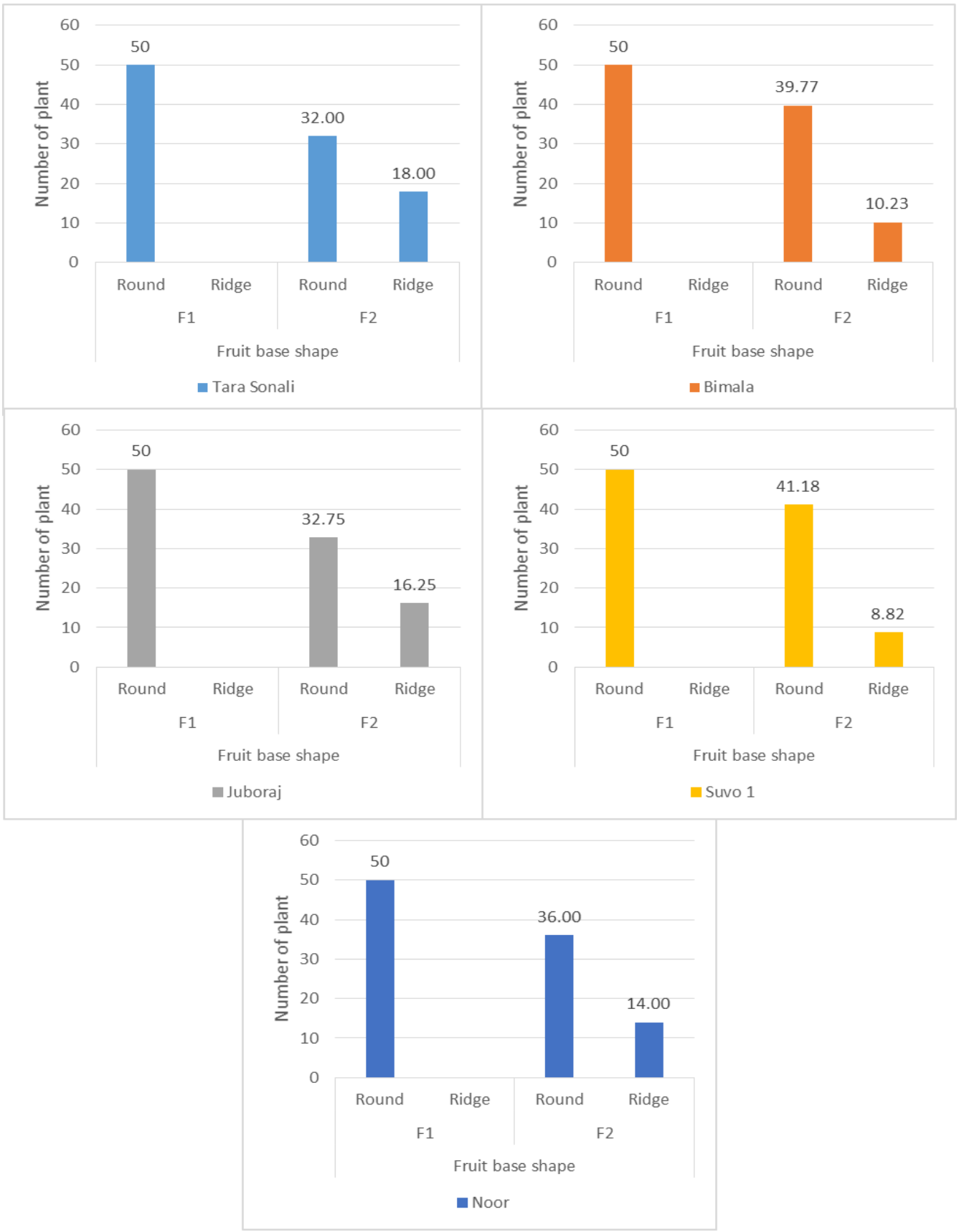

Figure 4. Segregation in F2 generation for fruit base shape in five genotype of Okra.

3.4.5. Branching pattern

The branching pattern of all varieties of F_1 was branched. Segregation took place in the F_2 plants giving two phenotypic classes namely, unbranched and branched. The ratio of the classes in F_2 offspring is very close to 3:1 ratio. The P value of $\chi 2$ is indicating that the deviation from the expected frequencies is not significant i.e. there is a good fit to a 3:1 ratio.

Table 10. Chi-Squared values and probabilities of goodness of fit of segregation ratios of F_2 in the study of inheritance of branching type.

Variety	Branching Type							
	Observed value				Expected value		χ^2 value	Probability
	F_1		F_2		F_2			
	Unbranched	Branched	Unbranched	Branched	Unbranched	Branched		
Tara Sonali		50	18.00	32.00	12.5	37.5	3.227	0.10-0.05
Bimala		50	23.96	26.04	12.5	37.5	14.005	<.005
Juboraj		50	11.22	38.78	12.5	37.5	0.174	0.75-0.50
Suvo 1		50	14.13	35.87	12.5	37.5	0.284	0.75-0.50
Noor		50	16.25	33.75	12.5	37.5	1.500	0.25-0.10

P= 0.60 to 0.80 is very good
P= 0.40 to 0.60 is good
P= 0.20 to 0.40 is fair
P= 0.05 to 0.20 is subjected to further trial/ reject the hypothesis.

3.4.6. Fruit color

Inheritance studies for fruit color were studied in five selfed F_2 varieties. It is easy to explain from the Fig. that the fruit color segregated into three major different colors. Almost an equal number of plants studied exhibited deep green and yellowish green color, while a large number of plants exhibited light green color in the F_2 generation. The two homozygous extremes for fruit color: dark and yellowish green were easily distinguishable. Non significant chi-squared values were observed for the segregating ratios in F_2 generation. Observations of 1 dark green: 2 light green: 1 yellowish green, fruit color was observed in the F_2 populations. The segregation of the fruit color in F_2 generation into three classes: dark green, light green and yellowish green fitting into the theoretical 1:2:1 monohybrid ratio of incomplete dominance.

Table 11. Chi-Squared values and probabilities of goodness of fit of segregation ratios of F_2 in the study of inheritance of fruit color.

Variety	Fruit Color										
	Observed ratio						Expected ratio			$\chi 2$ value	Probability
	F_1			F_2			F_2				
	Deep green	Light Green	Yellowish Green	Deep green	Light Green	Yellowish Green	Deep green	Light Green	Yellowish Green		
Tara Sonali		50		10	31	8	12.5	25	12.5	3.56	0.10-0.05
Bimala		50		13	26	11	12.5	25	12.5	0.24	0.75-0.50
Juboraj		50		12	30	8	12.5	25	12.5	2.64	0.10-0.05
Suvo 1		50		9	32	9	12.5	25	12.5	3.92	0.05-0.025
Noor		50		8	32	10	12.5	25	12.5	4.08	0.05-0.025

P= 0.60 to 0.80 is very good
P= 0.40 to 0.60 is good
P= 0.20 to 0.40 is fair
P= 0.05 to 0.20 is subjected to further trial/ reject the hypothesis.

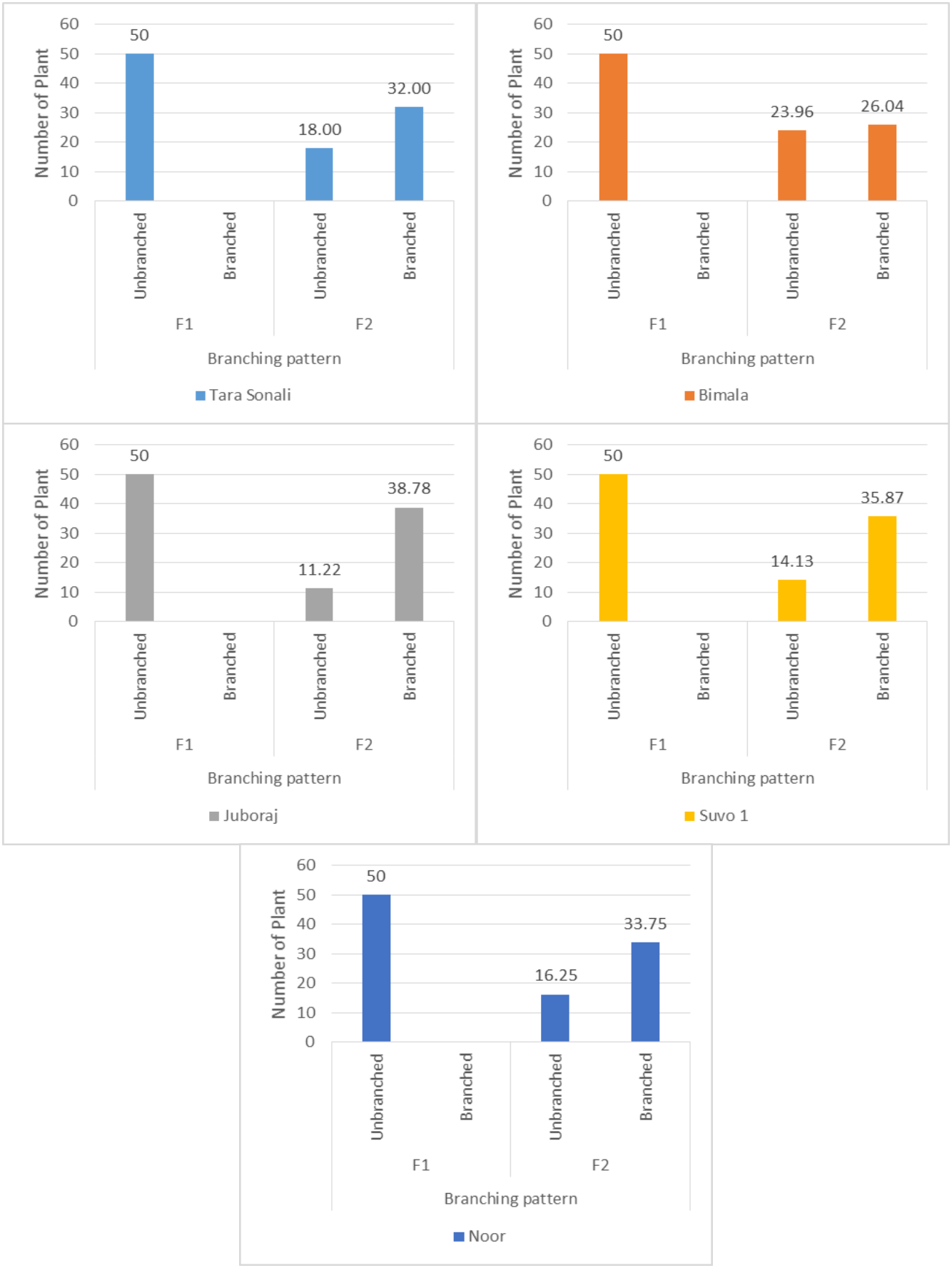

Figure 5. Segregation in F2 generation for branching pattern in five genotype of Okra.

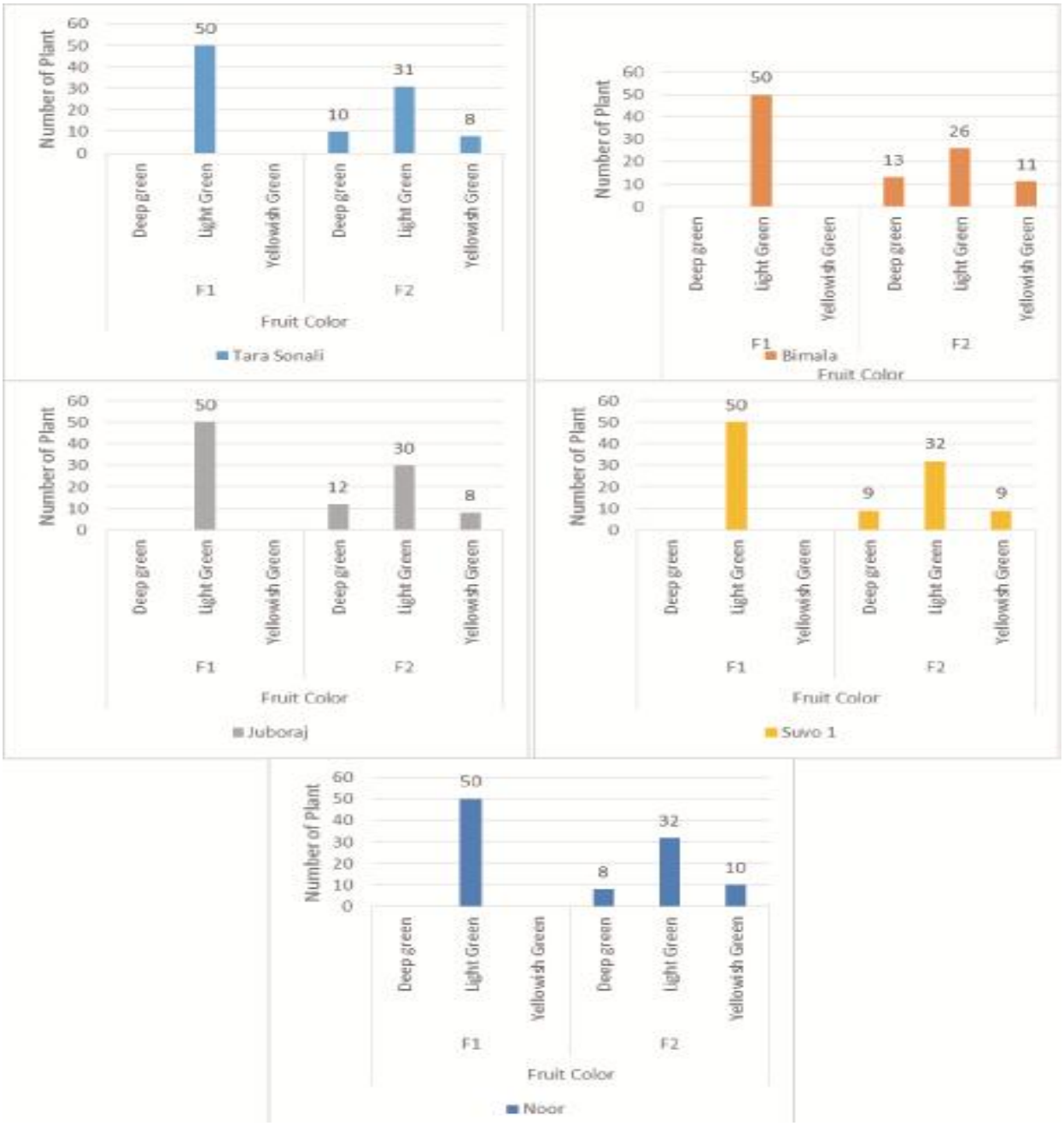

Figure 6. Segregation in F_2 generation for fruit color in five genotype of Okra.

4. Discussion

Genetic improvement of any crop depends upon the nature and extent of genetic variability available and also on the magnitude of interrelationships of heritable and non-heritable variation in yield and its major contributing characters. If such genetic variability is not available locally, plant breeder should have an idea of the availability of genetic diversity of the breeding material. This would ensure organized and systematic hybridization program for creating genetic variability to be exploited for genetic improvement of the trait under consideration. The information about heterotic potential among okra gene pool and early filial populations is essential to optimize the possible use of F_2 hybrid seed in order to reduce the cost of hybrid seed development. In the present study, an attempt has been made to understand the genetic system controlling inheritance of some qualitative characters and heritability and inbreeding depression. Investigations were therefore made on inbreeding depression, genetic selection indices i.e., heritability and genetic advance and segregation pattern of F_2 population using five F_1 and their self-cross derived F_2 generations.

4.1. Analysis of variance

The analysis of variance indicate that experimental hybrids and their F_2 progenies highly differed for 50% flowering, days to 1st harvesting, node order of 1st flowering, plant height, Internodal length, number of fruit per plant, Fruit weight, Fruit Length and Fruit Diameter and yield. This shows the presence of considerable genetic variability among the hybrids and their F_2 progenies for further evaluation and use.

4.2. Performance study

All hybrids performed best than their F_2 progenies in respect of yield. Quality likes fruit weight, fruit length fruit diameter also deteriorated in F_2 generation. On the other side, days to harvesting, days to flowering, days to harvest, node order of fruiting, plant height and internodal length was increased in F_2 generation which clearly shows the negative effect of inbreeding.

4.3. Heritability, genetic advance and genetic advance in percentage of mean

Here h^2 (b.s) is a convenient expression of phenotypic value which serves as a guide for the breeding value of any parent. For improvement of desirable characters, heritability estimate is very essential to assess the relative effect of genotype and environment on a character in order to predict the extent of possible improvement. Therefore, heritability is one of the major indicators of response to selection for a successful breeding program. The heritability estimates above 60% are considered as high, 30% to 60% are moderate and below 30% as poor. Estimation of selection parameters (Table 3) revealed that there was a wide range of genotypic and phenotypic variances. Genotypic variance ranged from 63.09 (Plant height) to 0.01 (fruit diameter) and phenotypic variance ranged from 65.28 (Plant height) to 0.02 (fruit diameter). Comstock and Moll (1963) reported that the more diverse the environmental population the smaller the estimates of genetic variance which supports the present results of low estimates of genetic variance. The knowledge of the genotypic and phenotypic variances for each character is necessary to construct a definite selection index (Sprague, 1966). As for as the broad sense heritability estimates are concerned, Number of fruit per plant and Yield were moderately heritable, whereas, 50% flowering, days to 1st harvest, Node order of 1st flowering, Fruit weight, Plant height, Internodal length, Fruit length and Fruit diameter were low in heritability. The presence of non-allelic interaction played a major role in decreasing h^2 estimates for these traits. Furthermore plant height and sympodia are polygenically controlled. Cumulative environmental effects on each of these polygenes gave poor heritabilities for these traits.

4.4. Inbreeding depression

Inbreeding is a system of mating that leads to an increase in homozygosity, decline in vigor and the reduction in productivity. The degree of inbreeding in any generation is equal to the degree of homozygosity in that generation (Singh *et al.*,, 1990). The results for inbreeding depression for all the quantitative traits presented in Tables 6, which demonstrated that F_2 progenies suffered considerable amount of inbreeding depression. The observed depression varied from-108 to 55.19, the wide range of inbreeding depression could be explained by two factors, linkage disequilibrium and epistasis interaction. Gardner *et al.*, (1953), Gardner (1963) and Baloch*et al.*, (1991) reported that repulsion phase linkages can cause upward or positive biases in the estimation of dominance variance in F_2 population where linkage effects are expected to be maximum. Comstock and Robinson (1948) and Soomro (2000) suggested that if multigenic epistasis were present, the epistasis of dominance will be biased down wards; ultimately the expected inbreeding depression will also go up than is observed. Inbreeding depression in polyploids has been found to exceed than what is expected by the coefficient of inbreeding. Aycock and Wilsic (1968) reported that in alfalfa, an autotetraploid, the yield decreased twice as much as predicted. This response according to them has been attributed to a decrease in favorable interactions among multiple alleles due to inbreeding and abnormal segregation at meiosis due to higher ploidy level.

In present studies, however, maximum positive values for inbreeding depression were observed for yield, where F_2 values less than F_1 means. These results further suggested that in such intercultivar crosses the maximum accumulation of genes resulted in increased fertility in F_2 population, consequently resulted in the higher yield (Paul *et al.*, 1987).

4.5. Segregation pattern

In case of segregation pattern plant height, leaf shape, pod pubescence content, peduncle shape, branching pattern and fruit color were subjected to study. Plant height and pod pubescence content are found to be polygenic trait. Fruit color showed incomplete dominance and other character expressed as Mendelian ratio. This findings are closely associated with the findings of Udengwu (2008), Abdelmageed (2010) and Kerur (2009).

5. Conclusions

The experiments were conducted to observe the genetic variability, inbreeding depression and segregation pattern of Okra among five commercial hybrid varieties along with a local check based on their performance, heritability and inheritance study among the varieties for improvement of yield of Okra. The experiments were carried out at the experimental farm of RHRS, Lebukhali, Patuakhali, during the period of May, 2014 to September, 2014. The results of the studies have been summarized as follows: There was significant variation among the F_1's, their F_2 progenies and the check variety. However, all the F_1's performed better than their respective F_2 progenies for yield and other yield contributing characters. F_1 and F_2 both generations showed low to moderate level of heritability. No of fruit per plant and Yield were moderately heritable, whereas, days to 50% flowering, days to 1st harvesting, node order of first flowering, Fruit weight, Plant height, Internodal length, Fruit length and Fruit diameter were poor in heritability. Due to selfing the progenies become more homozygous and decline in vigor and the reduction in productivity. In case of segregation pattern plant height, leaf shape, pod pubescence content, peduncle shape, branching pattern and fruit color were subjected to study. Plant height and pod pubescence content are found to be polygenic trait. Fruit color showed incomplete dominance and other character expressed as Mendelian ratio.

Conflict of interest

None to declare.

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