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Transgressive segregation studies in F_2 generation for fruit yield and it's contributing traits in okra

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Abstract
Okra is a tropical and subtropical regional crop that belongs to the family Malvaceae. An experiment was conducted to identify the transgressive segregants for yield and yield contributing characters in F_2 population of three crosses in Okra. In most of the transgressive segregants of three crosses, better parent (increasing parent) yield was transgressed concurrently with the transgression of one or several other trait. Simultaneous transgression of fruit yield per plant with plant height, number of nodes on main stem, fruit length, fruit weight and number of fruits per plant was observed more frequently. One could conclude that either these attributes were necessary for fruit yield or that there was linkage drag in the genes causing these traits, which caused the genes controlling these traits to be inherited together. The most promising transgressive segregants *viz.*, transgressive segregants No.88, 211, 258 of cross C1, No. 204, 297 of cross C2 and No.63,114 of cross C3, transgressed fruit yield per plant in addition to the higher expression of other five or six characters than the better parent in F_2 generation. They surpassed their respective increasing parents in regards to fruit yield by 36.95 (Cross C1), 40.00 (Cross C2), and 33.37 (Cross C3) percent.

Keywords: Okra, transgressive segregation, F_2 generation, *Abelmoschus esculentus*, fruit yield, segregating population, transgressive breeding

Introduction
Okra [*Abelmoschus esculentus* (Linnaeus) Moench] is an annual plant belongs to family Malvaceae. Ethiopia is the place of origin. The world's tropics and subtropics are where it is primarily cultivated. It is a significant vegetable crop that is primarily grown for its edible, nutritious, green, tender and non-fibrous fruits. Okra is an excellent source of vitamins, calcium, antioxidants, protein, and other minerals. The benefits of okra or Bhendi include its great nutritional content, popularity, good market value, therapeutic value, and export potential. Despite the fact that India is the world's leading producer of okra, a number of causes might potentially contribute to the crops' poor quality and low yield. Crop improvement in okra needs to be focused on higher yield, plant height, early flowering, more branching, short and maximum number of internodes, fruit length, and more number of fruits, tenderness and disease and pest resistance.

On other hand, several plant breeders have noted transgressive segregants in hybrid progeny and hypothesised that transgressive segregation would be a valuable tool in plant breeding. Studies on quantitative characters in segregating populations have revealed being present phenotypes that are extremely comparable to those of either parental line (De Vicente and Tanksley, (1993), Rieseberg and Ellstrand, (1993) and Cosse *et al.*, (1995)) [4, 15, 18]. The segregating generation of these extreme phenotypes is referred to as transgressive segregation. The basic concept behind hybridization is to blend the advantageous traits already exist in two parents to create a new derivative. Breeding lines from more recent generations are frequently employed as parental lines to create heterotic hybrids that are commercially feasible. However, due of their wider genetic base, early generations, particularly F_2, F_3, F_4, F_5, and F_6 segregating populations, typically have more potential for high success (Mallikarjun and Savitramma, (2017)) [9].

A more innovative method of plant breeding would involve exploring the potential for transgressive segregation. This is a key mechanism by which innovative or extreme adaptations have evolved. The notion of hybridization in evolution is easier to understand if transgressive segregation is frequent. The studies on transgressive segregants also help a way to learn their proportions for various yield contributing characters and these characters having high variability and heritability, will be highly useful in population development and other breeding programmes. Therefore, transgressive breeding aims at improving yield contributing trait through transgressive segregation.

Material and Methods

The field research was carried out at the Post Graduate Farm at the Mahatma Phule Krishi Vidyapeeth in Rahuri, where three crosses *viz*., Arka Anamika x IC-48948 (Cross C1), VRO-6 x IC-45814 (Cross C2) and Parbhani Kranti x Narendra (Cross C3) were evaluated using a randomised block design with three replications. Recommended doses of fertilizers and cultural practices were adopted. Sowing was done in rows of 6.0 m length and 30 cm apart accommodating 20 plants at 45.00 cm distance between plants. Two rows were assigned to P_1 and P_2 and 20 rows for F_2 generation for each cross. From each replication at random 300 plants from F_2 generation and 15 plants from parent plot were tagged for recording observations on eight characters *viz*., plant height (cm), number of nodes on main stem, number of branches per plant, days to flowering, fruit length (cm), fruit weight (g), number of fruits per plant, yield per plant (g).

The procedure given by Panse and Sukhatme (1995) [12] was followed for performing the statistical analysis. Transgressive segregants were estimated by calculating threshold value (T.V.) by the following formula.

$$\text{T.V.} = \bar{P}^{(+)} + 1.96 \times б\ \bar{P}^{(+)}$$

Where,

$P^{(+)}$ and $б\ \bar{P}^{(+)}$ are the mean and standard deviation of increasing parent, respectively.

The individuals transgressed this threshold limit were considered as the transgressive segregants.

Results and Discussion

In the present investigation, transgressions were recorded in each of the three crosses in F2 generation for all the eight characters (5.66 to 24.33%). In case of fruit yield per plant 12.00 to 22.00% individuals transgressed beyond the increasing parent in three crosses. Transgressive segregants were 17.00 to 24.33% for plant height, 15.00 to 22.33% for number of nodes on main stem, 16.33 to 19.33% for number of branches per plant, 5.67 to 9.33% days to flowering, 11.67 to 21.67% for fruit length (cm), 9.67 to 17.67% fruit weight (g) and 12.67 to 21.67% for number of fruits per plant in three crosses. The highest proportion of transgressive segregants were observed for fruit yield per plant 22.00%, plant height 24.33%, number of nodes on main stem 22.33%, number of branches per plant 19.33%, fruit length 21.67%, fruit weight 17.67%, number of fruits per plant 21.67%in cross C1. For days to flowering 9.33% in cross C2. Ugale and Bahl (1980) [17] suggested transgressions for all these characters except pod length and cluster per plant with the highest proportion of individuals for plant spread (30.77%). Kant and Singh (1998) [7] reported highest frequency of transgressive segregates in the F_2 generation for yield per plant 47% followed by 33% and 27% in lentil. Girase and Deshmukh (2002) [5] identified transgressive segregants in green gram for seven characters like plant height, plant spread, pods per plant, fruiting branches per plant, seeds per pod, 100-seed weight and yield per plant. In both the F_2 and F_3 generations of three crosses, they found that plant height (27%) had the maximum transgressive segregation, later by pods per plant, fruiting branches per plant and yield per plant. Pradeep and Sumalini (2003) [14] reported transgressive segregates for number of bolls per plant and kapas yield in F_2 and F_3 the generations. Sogalad *et al*., (2009) [16] analysis for superior segregants for important metric traits revealed that plant No. 25 from the BH-13 single cross population 880.56 g fruit yield per plant and was tall with short inter-nodal length and four branches. Meena M. (2011) [10] recorded the highest percentage of transgressive segregants in okra for fruit yield per plant (24.67%), followed by fruit length, fruit weight, days to flowering, number of branches, fruits per plant, plant height and nodes per plants. As per Aminu *et al*, (2016) [1], plant height, the number of primary branches per plant, days to 50% flowering, pod diameter, pod length, number of pods per plant and the fresh weight per pod could all be considered when selecting and improving high pod yielding okra varieties. Anusha *et al.,* (2017) [2] identified most promising transgressive segregants in cross yielded the parent by 79.70 per cent in addition to higher intensity of expression for, average boll weight, bolls per plant, sympodia per plant and ginning percentage. Nimbalkar and Totre (2018) [11] were observed transgressive segregates in the cross Hisar Navin x Arka Abhay for the character plant height (27.33%) followed by green fruit yield per plant (24.67%). The largest proportion of transgressive segregants were identified by Kavya V. N. (2019) [8] in F_2 and F_3 population for the number of branches per plant (62.18%), average fruit weight (41.17%), number of fruits per plant (21.88%) and total yield per plant (21.00%).

The highest number of simultaneous transgressive segregants were observed in cross C1 (66 plants) followed by cross C3 (45 plants) and cross C2 (36 plants). In each of the cross C2 and C3, one transgressive segregants transgressed the fruit yield along-with other six other characters. Comparatively more number of simultaneous segregants were observed for fruit yield along-with plant height, number of nodes on main stem, number of fruits per plant, number of branches per plant, fruit weight (Table 2). The transgressions identified concurrently transgressing for the traits mentioned above and those reported for fruit yield suggest that these traits are interdependent or that there may be linkage drag among their genes. In plant breeding, this form of dependency or desired linkage drag is important for simultaneous improvement. These results are in conformity with the results of Guddadamath *et al*., (2012) [6], Pithiya *et al*., (2017) [2] and Nimbalkar and Totre (2018) [11].

Apart from the frequency of transgressions, it will be of great interest to examine the intensities of the characters expression achieved in the transgressions in each of the crosses. This will provide an insight into the extended limits and intensities of desired characters expression achieved by transgressive breeding. In the present investigation, the highest yielding transgressed fruit yield per plant in addition to the higher expression of other five or six characters than the better parent in F_2 generation. They surpassed their respective increasing parents in regards to fruit yield by 36.95 (Cross C1), 40.00 (Cross C2), and 33.37 (Cross C3) percent (Table 3).

If we consider transgressive segregants for fruit yield per plant in the cross Arka Anamika x IC-48948, Plant No. 88 was found to be most promising as it has given 36.95 percent more fruit yield per plant in addition to plant height, number of nodes on main stem, number of branches per plant, fruit weight and number of fruits per plant compared to the increased parent. Plant No. 204 was identified as the most promising transgressive segregant for fruit yield per plant in the cross VRO-6 x IC-45814 because it produced 40.00 percent more fruit per plant. There was evidence of simultaneous transgression in desire direction for plant height, number of nodes on main stem, fruit length, fruit weight and number of fruits per plant .Similar to this, the transgressive segregant No. 63 in the cross Parbhani Kranti x Narendra exceeded the increasing parents with a 33.37 percent higher fruit yield per plant. In comparison to the increasing parent, it also shows enhanced plant height, number of nodes on main stem, days to flowering, fruit length, fruit weight and number of fruits per plant (Table 3).

The findings shown in Table 3 illustrate that the most promising transgressive segregants require substantial evaluation. If later generations demonstrate their superiority, they may be recommended for multi-location evaluation before being released as a variety or exploited as parent in future genetic improvement.

Table 1: Threshold value (T.V.), normal deviation value (N.D.), percentage and range in the values of transgressive segregants (T.S.) in three crosses of Okra

Characters	**F2 generation**				
	Threshold value	**N.D.**	**Frequency**	**T.S.%**	**Range in values of T.S.**
Cross (C1) Arka Anamika x IC-48948					
Plant height (cm)	137.44	0.99	73	24.33	139-154
No. of Nodes on Main stem	19.39	1.07	67	22.33	20-23
No. of branches per plant	3.39	0.65	58	19.33	4-6
Days to flowering	44.28	-1.78	17	5.67	41-44
Fruit length (cm)	12.46	0.94	65	21.67	12.48-14.54
Fruit weight (g)	13.19	0.80	53	17.67	13.21-15.46
No. of Fruits per plant	16.39	0.88	65	21.67	17-21
Fruit yield per plant (g)	209.85	0.91	66	22.00	210.08-263.20
Cross (C2) VRO-6 x IC-45814					
Plant height (cm)	120.56	1.07	51	17.00	121-135
No. of Nodes on Main stem	18.89	1.11	45	15.00	19-22
No. of branches per plant	3.15	1.07	49	16.33	4-5
Days to flowering	43.21	-1.70	28	9.33	39-43
Fruit length (cm)	12.10	1.10	59	19.67	12.13-14.31
Fruit weight (g)	12.84	0.98	46	15.33	12.87-15.18
No. of Fruits per plant	15.62	1.16	38	12.67	16-20
Fruit yield per plant (g)	192.43	1.42	36	12.00	192.45-247.86
Cross (C3) Parbhani Kranti x Narendra					
Plant height (cm)	128.62	1.11	60	20.00	129-141
No. of Nodes on Main stem	19.29	1.20	54	18.00	20-23
No. of branches per plant	3.59	0.92	51	17.00	4-6
Days to flowering	43.03	-1.82	22	7.33	39-43
Fruit length (cm)	12.23	1.30	35	11.67	12.27-13.63
Fruit weight (g)	13.03	1.22	29	9.67	13.05-14.73
No. of Fruits per plant	16.48	1.44	53	17.67	17-20
Fruit yield per plant (g)	205.67	1.79	45	15.00	206.08-252.32

Table 2: Number of simultaneous transgressive segregants for yield in combination with other characters in three crosses of Okra

Character combinations Fruit yield with	Number of simultaneous transgressive segregants in F2 generation		
	Cross 1 (C1)	Cross 2 (C2)	Cross 3 (C3)
PH+NN+NBP+DF+FW+NFP	-	1	-
PH+NN+ DF+FL+FW+NFP	-	-	1
PH+NN+NBP+FW+NFP	1	-	3
PH+NN+FL+FW+NFP	3	3	4
NBP+DF+FL+FW+NFP	-	2	-
PH+NN+FL+NFP	-	1	-
PH+NN+FW+NFP	4	3	-
PH+NN+NBP+NFP	2	2	1
PH+NN+FL+FW	-	-	2
PH+NBP+FL+FW	2	-	-
PH+NBP+FW+NFP	3	-	-
PH+FL+FW+NFP	2	-	-
NN+FL+FW+NFP	-	2	-
NBP+ DF+FW+NFP	-	1	1
NBP+ FL+FW+NFP	3	2	3
PH+NN+FW	-	-	2
PH+NN+NFP	7	5	6
PH+ NBP+NFP	2	-	-
PH+FW+NFP	1	-	-
NN+ NBP+NFP	-	-	2
NN+FL+FW	2	1	-
NN+FW+NFP	4	2	-
NBP+FL+FW	-	-	1
NBP+FL+NFP	3	-	-
NBP+FW+NFP	3	2	-
FL+FW+NFP	2	1	2
PH+NN	1	-	2
PH+FW	2	-	-
PH+ NFP	1	-	2
NN+NFP	4	2	3
NBP+FW	1	-	1
NBP+NFP	4	-	2
FL+FW	2	2	1
FW+NFP	1	1	1
FW	2	1	1
NFP	2	1	1
Only Yield	2	1	3
Total simultaneous transgressive segregants	66	36	45

Table 3: Promising transgressive segreagants having combinations of desirable attributes

Characters	Pl No.	PH (cm)	NN	NBP	DF	FL (cm)	FW (g)	NFP	FYP (g)	% yield increased over increasing parent
Cross (C1) Arka Anamika x IC-48948										
F_2	88	147+	22+	4+	46	12.24	13.18+	20+	263.20+	36.95
	271	144+	20+	3	45	12.95+	13.75+	19+	261.25+	35.93
Arka Anamika		121.67	18.40	2.40	45.80	11.79	12.48	15.40	192.19	
IC-48948		133.33	16.60	1.73	50.20	11.34	11.98	13.00	155.74	
Cross (C2) VRO-6 x IC-45814										
F_2	204	129+	21+	3	46	13.01+	13.77+	18+	247.86+	40.00
	97	125+	21+	4+	42+	12.08	12.87+	19+	244.53+	38.11
VR0-6		116.87	17.93	2.13	44.47	11.53	12.07	14.67	177.06	
IC-45814		102.73	15.67	1.60	48.93	11.17	11.90	12.00	142.80	
Cross (C3) Parbhani Kranti x Narendra										
F_2	63	141+	22+	2	43+	12.30+	13.28+	19+	252.32+	33.37
	114	137+	21+	3	45	12.77+	13.91+	18+	250.38+	32.34
Parbhani Kranti		125.27	18.33	2.60+	44.67	11.58+	12.23+	15.47+	189.19+	
Narendra		117.35	17.27	1.80	47.13	10.03	10.87	13.87	150.76	

+Intensity of expression of character higher than the increasing parent, Pl. No. = Plant number, PH = Plant height NN = No. of nodes on main stem, NBP = Number of branches per plant, DF = Days to flowering, FL= Fruit Length, FW= Fruit Weight, NFP = No. of fruits per plant, FYP = Fruit yield per plant.

Conclusion

Better parent yield (increasing parent) was transgress concurrently with the transgression of one or a few other characteristics in the majority of the transgressive segregants of three crosses. It was more frequently observed that the fruit yield per plant transgrets simultaneously with plant height, number of nodes on main stem, fruit length, fruit weight and the number of fruits per plant. For ensuring consistency in their performance, these transgressive segregants require to be analysed further. They might be categorized as improved varieties after a thorough evaluation or utilised in breeding strategies to combine genetic constellations if it turns out that they perform better in subsequent generations.

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