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Response to selection through introgression breeding in onion (*Allium cepa* L.)

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Abstract

Development of suitable varieties of onion with high yield as well as good shelf life through crossing between long and short-day onion was carried out at the Research Farm of ICAR-Directorate of Onion and Garlic Research, Rajgurunagar, Pune in collaboration with ICAR-CITH, Srinagar. A total of 135 crosses were made between available 15 exotic onion varieties and 9 short day lines at ICAR-CITH, Srinagar. The crosses were evaluated in their F_2 generation and further selection were continued up to F_5 generation. The experiment was laid out in randomized block design with three replications during *rabi* seasons to investigate the genetic variability and response to selection among all the crosses. Top seven progenies which were selected on the basis of high yield in F_2 generation which were also good performers in F_3 generation with high yield and other desirable traits. The selected crosses were found free from doubles and bolters in F_3 generation. This indicates the selection done from F_2 to F_3 generation is effective for double and bolter bulbs which certainly helps to increase the marketable bulb yield. High degree of variation was observed for all the traits studied and the difference between phenotypic and genotypic coefficient of variation was found to be narrow for most of the traits. More than 30% marketable yield enhancement was observed in four progenies *viz*., Couger × DOGR-595, Reforma × DOGR-595, Mercedes × Bhima Super and Collina × DOGR-597 in comparison with best check Bhima Shakti (41.17 t/ha) in F_3 generation whereas, more than 50 t/ha marketable yield was recorded in four progenies *viz*., Basic × RGO-53, Couger × DOGR-595, Mercedes × Bhima Super and Reforma × DOGR-595 in F_3 generation.

Key words: Hybridization, segregating population, progeny selection, F_2 & F_3 generation, short-day, onion.

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Introduction

Onion (*Allium cepa* L.) is an important vegetable cum spice crop grown in India as well as world. India is the second largest producer of onion after China in the world. World's onion production has steadily increased, and onion has become the most important horticultural crop, after tomatoes (Lawande 2015). In India, onion occupies an area of 1.31 million hectares with the production of 22.43 million tonnes during 2017-18. Even though India ranks first in the area under onion in the world, but its productivity is low (17.17 t/ha) as compared to worlds productivity (19.39 t/ha) (FAOSTAT, 2017). The growth and development of onion are greatly affected by the temperature and light regimes of latitude and season. Hence, varieties differ in photo-thermal requirement depending on the latitude for which it is adapted and are classified as long day, short day and intermediate types based on their light requirement. Long day types are high yielder but have poor shelf life whereas, short day types have better shelf life but with the low yielding capacity. Indian onions mainly in sub-tropical and tropical regions are grouped under short day onion and are grown in three seasons in *kharif*, *late kharif* and *rabi*. It is mainly a *rabi* season crop but can be cultivated in *kharif* and *late kharif* season also. Accordingly, varieties are developed and recommended for different seasons (Gupta et al. 2017). Improvement in Indian short-day onion reached plateau due to narrow genetic base within the Indian short-day onion germplasm. The yield difference between the short day and long day varieties are substantial. Thus, it is imperative to cross the long day varieties with short day lines for improvement in yield by transfer of traits like bigger bulb size, non-bolting behavior, thin neck and good bulb storability. Crop improvement depends on the magnitude of genetic variability and extent to which the desired characters are heritable (Gupta and Singh 2017). This has in turn attracted the attention of biometrician to study the genetic aspects of economically important characters, such as yield and its components. Segregating populations are more important for improving plant types by operating further selection for improvement (Bhushan et al. 2017). The present study was aimed to develop populations by crossing long day and short-day lines in temperate Northern hills because long day onion does not flower under short day conditions and further selection was done based on the desired traits like high yield, neck thickness, good storability and bolting tolerance in short day conditions. It was formulated to quantify the extent of genetic variation available for yield and its components in the segregating generations of onion and to assess the genetic gain that can be made by selection.

Generally, productivity can be determined by selection of suitable varieties as per seasonal requirement, balanced nutrition, optimum water management as well as need-based plant protection measures. Among all these factors, selection of suitable variety plays an important role (Tripathy and Sahoo 2018). Therefore, it is need to develop and improve variety which is high yielding as well as having better quality and longer shelf life. To improve the bulb yield through selection, information on nature and magnitude of variability and heritability pertaining to population is the most important pre-requisite during breeding programmes. Early generation testing helps breeder to increase the breeding efficiency by choosing superior genotypes and eliminating inferior lines from heterozygous population (Bhushan et al. 2019). Heterozygosity, which is maximum at F_2 stage decreases in F_3 generation, as with every advancement in generation, it decreases by 50% in a population (Acquaah, 2012). Keeping this in view, the progenies obtained in F_2 and F_3 generation were also evaluated on the basis of nature and magnitude of genetic variability as well as the extent of heritability in association with genetic advance and selected in the subsequent populations in desirable direction.

Materials and Methods

Selection breeding programme for onion by ICAR-DOGR was initiated in collaboration with ICAR-CITH, Srinagar in 2009-10. A total of 135 crosses were made between available 15 exotic onion varieties and 9 short day lines at ICAR-CITH, Srinagar (Table 1). All the crosses were evaluated at ICAR-DOGR, Rajgurunagar, Pune as well as ICAR-CITH, Srinagar in 2010-11 and desirable bulbs were selected progeny-wise from different crosses at ICAR-DOGR and grown for their F_2 generation during *rabi* season. From the F_2 population, progenies with desired traits were further selected and grown for their F_3 generation. The design used for planting F_1 and further generations was Randomized Block Design and the seedlings of the selected progenies were transplanted in three replications with one square meter plot size. Recommended package of practices as well as plant protection measures were followed to raise a good crop. The crop was harvested at maturity when more than 70% tops had fallen and became withered. Five randomly selected plants in each plot were used for recording data on fourteen important growth, yield and quality parameters *viz*. plant height (cm), number of leaves, polar diameter (mm), equatorial diameter (mm), neck thickness (mm), doubles (%), bolters (%), marketable yield (t/ha), total yield (t/ha), total soluble solids (%), marketable bulb weight (g), days to harvest after transplanting, colour of bulb and bulb storability. Selection from segregating populations was carried out on the basis of bulb colour, bulb size, bulb shape, neck thickness, bulb storability and free from double and bolter bulbs at ICAR-DOGR as well as at ICAR-CITH in 2012-13, 2014-15 and continued up to 2018-19. Selected bulbs of each cross at short day conditions were again sent to ICAR-CITH for seed production. Evaluation of crosses was continued at ICAR-DOGR and advancement of selected bulbs from F_2 to F_3 and subsequent generation were done at ICAR-CITH as well as ICAR-DOGR as the seed setting of long day varieties is not possible under short day conditions. Advancement of the selected bulbs of each progeny was continued even after F_4 generation to obtain desirable ones.

Table 1: List of long-day varieties and short-day lines as parents under hybridization programme

Long-day Exotic Varieties	Bulb Skin Colour	Short-day Lines	Bulb Skin Colour
Mercedes	Yellow	Bhima Super	Medium Red
Basic	Yellow	RGO-53	Dark Red
Couger	Yellow	N-2-4-1	Light Red
Linda Vista	Yellow	DOGR-597	Medium Red
Reforma	Yellow	DOGR-595	Medium Red
Collina	Yellow	W-448	White
Carta Blanca	White	White Elite Composite	White
Early Supreme White	White	W-009	White
Kalahari 1200	Medium Red	Phule Suwarna	Yellow
Serengeti 1202	Yellow		
Lucifer	Dark Red		
Juni (3800)	Dark Red		
Onion Flaro	Medium Red		
Onion Orient	Medium Red		
V-12	White		

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) in percentage were calculated according to Burton and De Vane (1953). The estimates of PCV and GCV were classified as low (<10%), moderate (10-20%) and high (>20%) according to Sivasubramanian and Madhavamenon (1973). Heritability in broad sense (h^2b) is defined as the proportion of the genotypic variance to the total variance (phenotypic variance) and was estimated by using the formula given by Hansen et al. (1956). The broad sense heritability estimates were classified as low (<50%), moderate (50-70%) and high (>70%) as suggested by Robinson (1966). Expected genetic advance (GA) was calculated as per the method suggested by Johnson et al. (1955). The magnitude of genetic advance as percent of mean was categorized as high (>20%), moderate (20-10%) and low (<10%).

Results and Discussion

Genetic variability is a pre-requisite for successful selection of superior progenies from segregating generations for further selection. It can be created by hybridization or mutation. F_2 generation is an ideal generation in which segregation and recombination are maximum for imposing selection. Even though variability is found to decrease in the F_3 generation as there is opportunity for selection (Gautham and Balamohan 2018). The magnitude of recombination potential depends on the genetic diversity of the parents (Bhushan et al. 2017). A population is said to be superior when it shows high mean coupled with high variability (Savitha and Usha 2015). The present investigation aims at determining the magnitude and extent of variability in F_2 and F_3 generation of the crosses between exotic and short-day onion lines. All the crosses made between exotic onion lines with short day lines were evaluated at ICAR-DOGR and wide range of variability in the crosses was observed in case of foliage colour, foliage vigour, bulb colour, bulb shape, bulb size, double bulbs, bolting behaviour and bulb storability. Vigorous foliage growth was also observed in some of the crosses in comparison to short day lines with presence of waxiness. Bolter bulbs were not found in the selected segregating progenies. Bolting being an undesirable trait in bulb crop, is strongly selected against by breeders during adaptation of germplasm (Gupta et al. 2015).

On the basis of mean performance of top seven segregating populations in F_2 generation (Table 2), maximum plant height was recorded in Reforma × N-2-4-1 (60.19 cm) followed by Reforma × DOGR-595 (59.94 cm) and Mercedes × RGO-53 (59.10 cm) whereas, number of leaves were recorded maximum in Reforma × N-2-4-1 (9.93) followed by Mercedes × RGO-53 (9.73) and Couger × DOGR-595 (9.60). Polar diameter was recorded maximum in Reforma × N-2-4-1 (54.6 mm) followed by Collina × DOGR-597 (54.45 mm) and Mercedes × Bhima Super (54.21 mm) whereas, equatorial diameter was recorded maximum in Basic × RGO-53 (59.78 mm) followed by Collina × DOGR-597 (58.86 mm) and Mercedes × Bhima Super (58.79 mm). Neck thickness was recorded minimum in Basic × RGO-53 (2.86 mm) followed by Collina × DOGR-597 (3.17 mm) and Reforma × N-2-4-1 (3.21 mm). Double bulbs were absent in Reforma × DOGR-595 and Couger × DOGR-595 whereas, bolters were absent in progeny of all the crosses. Marketable yield was recorded maximum in Basic × RGO-53 (56.47 t/ha) followed by Collina × DOGR-597 (35.57 t/ha) and Couger × DOGR-595 (35.55 t/ha) whereas, total yield was recorded maximum in Basic × RGO-53 (65.67 t/ha) followed by Mercedes × RGO-53 (40.18 t/ha) and Mercedes × Bhima Super (39.45 t/ha). TSS was recorded maximum in Reforma × N-2-4-1 (12.29%) followed by Mercedes × Bhima Super (12.28%) and Collina × DOGR-597 (12.27%). Marketable bulb weight was recorded maximum in Basic × RGO-53 (110.31 g) followed by Reforma × DOGR-595 (77.1 g) and Couger × DOGR-595 (73.61 g). Days to harvest were recorded minimum in Couger × DOGR-595 (105.67 days) followed by Mercedes × Bhima Super (106.67 days), Basic × RGO-53, Reforma × N-2-4-1, Reforma × DOGR-595 and Collina × DOGR-597 (107.00 days).

In F_3 generation (Table 3), maximum plant height was recorded in Basic × RGO-53 (54.65 cm) followed by Reforma × N-2-4-1 (53.56 cm) and Mercedes × RGO-

Table 2: Mean performance of top seven segregating population in F_2 generation

Entries	PH (cm)	NOL	P (mm)	E (mm)	N (mm)	% Doubles	% Bolters	MY (t/ha)	TY (t/ha)	% TSS	MBW (g)	DTH	COB	Bulb storability
Mercedes × Bhima Super	57.59	9.47	54.21	58.79	3.31	4.05	0.00	34.30	39.45	12.28	70.46	106.67	LR	Medium
Mercedes × RGO-53	59.10	9.73	52.57	58.48	3.23	13.71	0.00	31.92	40.18	11.84	67.22	107.67	MR	Medium
Basic × RGO-53	53.19	8.40	53.59	59.78	2.86	12.99	0.00	56.47	65.67	11.42	110.31	107.00	MR	Medium
Reforma × N-2-4-1	60.19	9.93	54.60	58.30	3.21	0.45	0.00	32.56	36.55	12.29	71.75	107.00	LR	Good
Reforma × DOGR-595	59.94	9.53	52.85	58.20	3.40	0.00	0.00	32.87	34.55	11.72	77.10	107.00	LR	Good
Collina × DOGR-597	58.88	9.20	54.45	58.86	3.17	2.33	0.00	35.57	38.58	12.27	67.24	107.00	MR	Good
Couger × DOGR-595	56.49	9.60	53.58	58.38	3.48	0.00	0.00	35.55	37.85	11.59	73.61	105.67	LR	Good
ALR (C)	57.67	9.73	53.95	57.94	3.54	5.48	0.98	28.10	32.77	12.09	68.26	103.00	LR	Good
Bhima Kiran (C)	58.47	9.60	50.25	56.57	3.22	0.00	0.00	32.51	34.42	11.96	61.14	107.67	LR	Good
Bhima Shakti (C)	56.92	9.00	51.92	57.87	3.14	0.00	0.00	36.74	38.29	12.00	63.62	109.00	MR	Good
CV (%)	4.91	6.62	4.74	3.85	9.03	15.45	5.87	12.05	11.82	3.02	7.34	2.72	-	-
LSD (P=0.05)	4.64	1.02	4.04	3.60	0.48	7.09	2.66	2.64	2.51	0.57	10.41	4.25	-	-

53 (51.74 cm) whereas, number of leaves were recorded maximum in Basic × RGO-53 (10.00) followed by Mercedes × RGO-53 (9.00) and Couger × DOGR-595 (8.67). Polar diameter was recorded maximum in Basic × RGO-53 (50.01 mm) followed by Collina × DOGR-597 (47.86 mm) and Mercedes × Bhima Super (46.62 mm) whereas, equatorial diameter was recorded maximum in Basic × RGO-53 (57.26 mm) followed by Couger × DOGR-595 (54.97 mm) and Collina × DOGR-597 (54.32 mm). Neck thickness was recorded minimum in Basic × RGO-53 (2.59 mm) followed by Reforma × DOGR-595 (2.64 mm) and Mercedes × Bhima Super (3.16 mm). Double and bolter bulbs were absent in progenies of all the crosses. Marketable yield was recorded maximum in Basic × RGO-53 (66.67 t/ha) followed by Couger × DOGR-595 (61.11 t/ha) and Mercedes × Bhima Super (56.67 t/ha) whereas, total yield was recorded maximum in Mercedes × Bhima Super and Basic × RGO-53 (66.67 t/ha) followed by Couger × DOGR-595 (63.11 t/ha) and Reforma × DOGR-595 (56.00 t/ha). TSS was recorded maximum in Basic × RGO-53 (12.4%) followed by Mercedes × RGO-53 (11.8%) and Collina × DOGR-595 (11.4%). Average marketable bulb weight was recorded maximum in Basic × RGO-53 (120 g) followed by Couger × DOGR-595 (116.67 g) and Reforma × DOGR-595 (102.5 g). Days to harvest was recorded minimum in Basic × RGO-53 (103 days) followed by Reforma × N-2-4-1 and Collina × DOGR-597 (105 days).

Storability of bulbs was also observed for the top seven promising crosses. Reforma × N-2-4-1, Reforma × DOGR-595, Collina × DOGR-597 and Couger × DOGR-595 were found having good bulb storability whereas, Mercedes × Bhima Super, Mercedes × RGO-53 and Basic × RGO-53 were having medium bulb storability in both F_2 and F_3 generation. Regarding colour of the bulbs, progenies of Mercedes × Bhima Super, Reforma × N-2-4-1, Reforma × DOGR-595 and Couger × DOGR-595 were observed to have light red bulbs whereas, progenies of Mercedes × RGO-53, Basic × RGO-53 and Collina × DOGR-597 were observed having medium red bulbs (Table 2 and Table 3).

The improvement in any crop is proportional to the magnitude of the genetic variability present in its genotypes (Mallor et al. 2011). Experimental results revealed a wide range of variation among the crosses made between long day varieties and short-day lines. The phenotypic coefficient of variation (PCV) values were higher than the genotypic coefficient of variation (GCV) values for all the traits which indicates the environmental role in trait expression. Higher PCV values than the GCV values have also been reported by Dangi et al. (2018), Khosa and Dhatt (2013), Singh et al. (2013), Arya et al. (2017), Dwivedi et al. (2017) and Santra et al. (2017). Selection from one generation to next generation changes the gene frequency (Ahmad et al. 2017). The coefficient of variation indicates only the extent of variability which does not reflect on heritable proportion of variation. Hence, estimation of heritability coupled with genetic advance as percent over mean permits greater effectiveness for selection by separating out the environmental influence from the total variability and thereby allowing accurate selection of a potential phenotype (Aditika et al. 2017).

Since heritability depends on gene frequency, any change in it causes change in heritability in next generation. Decrease in heritability in next generation is due to decrease in segregation and increase in homogeneity (Wallace et al. 1972). The parameter genetic advance in per cent of mean is a more reliable index for understanding the characters because its estimate is

Table 3: Mean performance of top seven segregating population in F_3 generation

Entries	PH (cm)	NOL	P (mm)	E (mm)	N (mm)	% Doubles	% Bolters	MY (t/ha)	TY (t/ha)	% TSS	MBW (g)	DTH	COB	Bulb storability
Mercedes × Bhima Super	39.20	7.00	46.62	53.32	3.16	0.00	0.00	56.67	66.67	11.20	100.00	110.00	LR	Medium
Mercedes × RGO-53	51.74	9.00	45.80	52.64	4.02	0.00	0.00	37.27	37.27	11.80	93.17	110.00	MR	Medium
Basic × RGO-53	54.65	10.00	50.01	57.26	2.59	0.00	0.00	66.67	66.67	12.40	120.00	103.00	MR	Medium
Reforma × N-2-4-1	53.56	8.60	46.22	52.85	3.99	0.00	0.00	36.44	36.44	10.60	54.67	105.00	LR	Good
Reforma × DOGR-595	46.52	7.60	44.59	51.76	2.64	0.00	0.00	54.67	56.00	10.80	102.50	106.00	LR	Good
Collina × DOGR-597	42.66	7.40	47.86	54.32	4.02	0.00	0.00	46.67	55.33	10.60	87.50	105.00	MR	Good
Couger × DOGR-595	45.57	8.67	46.98	54.97	3.69	0.00	0.00	61.11	63.11	11.40	116.67	106.00	LR	Good
ALR (C)	55.94	10.27	46.58	52.93	3.44	0.53	0.00	38.09	39.53	12.48	68.92	101.67	LR	Good
Bhima Kiran (C)	55.34	8.53	50.76	57.08	3.90	0.00	0.00	34.46	35.05	11.60	67.63	103.00	LR	Good
Bhima Shakti (C)	60.09	9.27	46.89	54.94	3.54	0.00	0.00	41.17	41.83	12.17	74.94	105.67	MR	Good
CV (%)	10.56	11.20	6.34	5.46	10.16	17.41	1.39	10.61	11.35	4.60	10.98	3.19	-	-
LSD (P=0.05)	4.87	2.28	7.04	7.15	1.47	7.95	0.00	2.90	3.50	1.26	8.57	8.29	-	-

PH: Plant height, NOL: Number of leaves, P: Polar Diameter, E: Equatorial Diameter, N: Neck Thickness, MY: Marketable yield (t/ha), TY: Total yield (t/ha), %TSS: Total soluble solids, MBW: Average marketable bulb weight, DTH: Days to harvest after transplanting, COB: Colour of Bulb derived by involvement of deviation and intensity of selection (Aditika et al. 2017). Expected genetic advance in percentage over mean was estimated for different characters and indicated that the expected genetic advance over mean observed in the range of 0.13 to 112.21% for different traits in F_2 generation whereas, it was found in range of 0.00 to 27.67% for different traits in F_3 generation.

In F_2 generation, high genotypic as well as phenotypic coefficient of variation was observed for doubles (81.02 and 120.51%) and bolters (80.71 and 129.42%) whereas, moderate genotypic coefficient of variation with high phenotypic coefficient variation was observed for marketable yield (19.95 and 23.21%) and total yield (18.06 and 20.91%) (Table 4). Moderate genotypic coefficient of variation and phenotypic coefficient of variation was observed for average marketable bulb weight (13.55 and 16.18%) whereas, low genotypic coefficient of variation and phenotypic coefficient of variation were observed for plant height (0.82 and 2.95%), number of leaves (0.49 and 3.85%), polar diameter (0.73 and 2.83%), equatorial diameter (0.61 and 2.30%), neck thickness (1.81 and 4.88%), TSS (1.74 and 2.46%) and days to harvest (0.65 and 1.70%). High heritability coupled with high genetic advance as percent of mean was observed in marketable yield (73.91 and 35.33%), total yield (74.62 and 32.14%) and average marketable bulb weight (70.08 and 23.37%). Based on mean performance of segregating crosses in F_2 generation, only one cross *i.e*, Basic × RGO-53 (56.47 t/ha) produced significantly higher marketable yield with other desirable traits and showed superiority over best check Bhima Shakti (36.74 t/ha). Selected progenies of F_2 generation were advanced and further evaluated in F_3 progenies and found that few of the crosses were in desired direction with high yield.

Table 4: Estimates of genetic parameters for important traits in F_2 generation

Trait	Mean	GCV (%)	PCV (%)	H^2 bs (%)	GA	GAPM (%)
Plant height (cm)	58.68	0.82	2.95	7.76	0.27	0.46
No. of leaves	9.55	0.49	3.85	1.68	0.01	0.13
Polar diameter (mm)	52.88	0.73	2.83	6.68	0.20	0.39
Equatorial diameter (mm)	57.98	0.61	2.30	7.10	0.33	0.19
Neck thickness (mm)	3.30	1.81	4.88	13.78	0.04	1.38
Double bulbs (%)	2.85	81.02	120.51	45.20	3.19	112.21
Bolter bulbs (%)	0.28	80.71	129.42	6.00	0.11	40.74
Marketable yield (t/ha)	38.17	19.95	23.21	73.91	13.49	35.33
Total yield (t/ha)	42.53	18.06	20.91	74.62	13.67	32.14
TSS (%)	11.79	1.74	2.46	50.17	0.30	2.55
Av. marketable bulb wt. (g)	82.56	13.55	16.18	70.08	19.29	23.37
Days to harvest	106.82	0.65	1.70	14.76	0.50	0.47

In F_3 generation, high genotypic as well as phenotypic coefficient of variation was observed for marketable yield (19.54 and 29.16%), total yield (13.49 and 28.41%) and average marketable bulb weight (18.86 and 26.48%) whereas, low genotypic coefficient of variation coupled with high phenotypic coefficient of variation was observed in plant height (9.31 and 11.93%) and number of leaves (8.05 and 11.29) (Table 5). Rest of the characters showed low genotypic and phenotypic coefficient of variation. Low heritability with high genetic advance as percent of mean was observed in marketable yield (44.00 and 26.99%) and low heritability with medium genetic advance as percent of mean was observed in total yield (22.57 and 13.20%). Medium heritability with high genetic advance as percent of mean was observed in average marketable bulb weight (50.73 and 27.67%). Heritability of marketable yield and total yield decreased to low level in F_3 generation as compared to F_2 generation (Fig. 1). Similar decrease in heritability of some characteristics in F_3 generation from F_2 generation was reported by Ahmad et al. (2017) in tomato and Bhushan et al. (2017) in linseed.

Table 5: Estimates of genetic parameters for important traits in F_3 generation

Trait	Mean	GCV (%)	PCV (%)	H^2 bs (%)	GA	GAPM (%)
Plant height (cm)	49.82	9.31	11.93	60.00	7.45	14.96
No. of leaves	8.33	8.05	11.29	50.00	0.98	11.82
Polar diameter (mm)	45.43	1.84	4.84	14.00	0.65	1.45
Equatorial diameter (mm)	53.54	2.26	3.12	19.62	4.76	8.89
Neck thickness (mm)	3.95	7.14	7.99	79.83	0.51	13.14
Double bulbs (%)	3.05	0.00	26.45	0.00	0.00	0.00
Bolter bulbs (%)	0.00	0.00	0.00	0.00	0.00	0.00
Marketable yield (t/ha)	38.76	19.54	29.16	44.00	10.46	26.99
Total yield (t/ha)	40.51	13.49	28.41	22.57	5.35	13.20
TSS (%)	11.15	1.19	3.46	11.96	0.09	0.85
Av. marketable bulb wt. (g)	76.22	18.86	26.48	50.73	21.09	27.67
Days to harvest	106.07	0.96	2.45	15.44	0.82	0.78

Top seven progenies which were selected on the basis of high yield and free from doubles and bolters in F_2 generation, were also good performer in F_3 generation with high yield and other desirable traits. More than 30% marketable yield enhancement was noted in four progenies *viz.*, Couger × DOGR-595, Reforma × DOGR-595, Mercedes × Bhima Super and Collina × DOGR-597 in comparison with the best check Bhima Shakti having marketable yield of 41.17 t/ha in F_3 generation (Table 6). Couger × DOGR-595 showed an increment of 71.91% with marketable yield of 61.11 t/

Table 6: Performance of marketable yield (t/ha) of F_2 and F_3 generation in the selected crosses

Entries	F_2 Gen.	F_3 Gen.	% Increase
Basic × RGO-53	56.47	66.67	18.06
Collina × DOGR-597	35.57	46.67	31.18
Couger × DOGR-595	35.55	61.11	71.91
Mercedes × Bhima Super	34.30	56.67	65.19
Reforma × DOGR-595	32.87	54.67	66.31
Reforma × N-2-4-1	32.56	36.44	11.92
Mercedes × RGO-53	31.92	37.27	16.75
CV (%)	12.05	10.61	-
LSD (P=0.05)	2.64	2.90	-

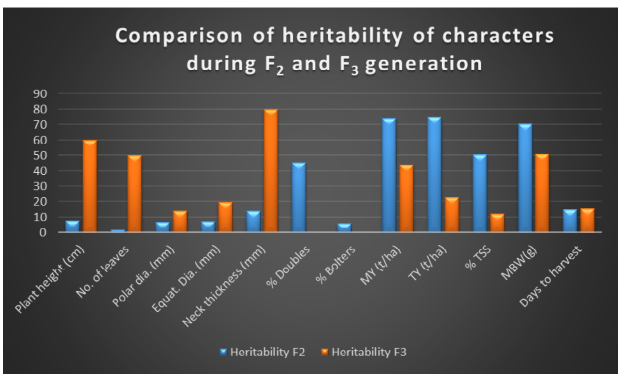

Fig. 1: Comparison of heritability of different traits in F_2 and F_3 generation

ha in F_3 generation while Reforma × DOGR-595 showed an increment of 66.31% with marketable yield of 54.67 t/ha in F_3 generation. Mercedes × Bhima Super showed an increment of 65.19% with marketable yield of 56.67 t/ha whereas, Collina × DOGR-597 showed an increment of 31.18% with marketable yield of 46.67 t/ha. Basic × RGO-53 showed an increment of 18.06% with marketable yield of 56.47 t/ha in F_2 generation and 66.67 t/ha marketable yield in F_3 generation. Reforma × N-2-4-1 showed an increment of 11.92% with marketable yield of 32.56 t/ha in F_2 generation and 36.44 t/ha marketable yield in F_3 generation. Mercedes × RGO-53 showed an increment of 16.75% with marketable yield of 31.92 t/ha in F_2 generation and 37.27 t/ha marketable yield in F_3 generation. More than 50 t/ha marketable yield was recorded in four progenies *viz.*, Basic × RGO-53 (66.67 t/ha), Couger × DOGR-595 (61.11 t/ha), Mercedes × Bhima Super (56.67 t/ha) and Reforma × DOGR-595 (54.67 t/ha) in F_3 generation. Moreover, Fig. 2 depicts the graphical comparison of the marketable yield in F_2 generation and F_3 generation. It is clearly visible that the F_3 generation progenies were more or less the high yielders as compared to the progenies of F_2 generation. The selection in F_2 generation was also done to decrease the double and bolter bulbs in the next generation as they hamper the marketable yield. The progenies of F_3 generation were found to be totally free from doubles and bolters.

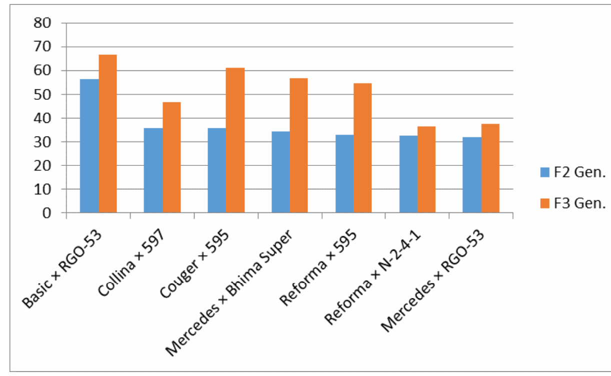

Fig. 2: Comparison of marketable yield (t/ha) of F_2 and F_3 generation

It can be concluded from the findings that crosses made were successful and showed improvement in the bulb yield, quality as well as shelf life of the bulbs. Selected progenies of crosses *viz.* Couger × DOGR-595, Reforma × DOGR-595 and Collina × DOGR-597 were found promising for yield and bulb storability. Further improvement work can be done on these progenies to achieve desirable lines and new crosses involving new lines can be developed to create variability for further selection in desired direction.

Ikjka'k

भा.कृ.अनु.प.–प्याज एवं लहसुन अनुसंधान निदेशालय, राजगुरूनगर, पुणे (महाराष्ट्र) के अनुसंधान प्रक्षेत्र में लम्बे और छोटे दिनमान के प्याज के बीच संकरण करके उच्च उपज के साथ–साथ अच्छी भण्डारण क्षमता हेतु प्याज की उपयुक्त किस्मों का विकास आईसीएआर–सीआईटी, श्रीनगर के सहयोग से किया गया। कुल 135 संकरणों जिनमें उपलब्ध 15 विदेशी प्याज किस्मों और 9 छोटे दिन की वंशक्रमों के बीच संकरण करके आईसीएआर–सीआईटीएच, श्रीनगर में विकसित किए गए। एफ$_2$ पीढ़ी में संकरणों का मूल्यांकन किया गया और आगे चयनकर एफ$_5$ पीढ़ी तक जारी रखा गया। आनुवांशिक परिवर्तनशीलता और सभी संकरणों के बीच चयन प्रतिक्रिया की जांच के लिए रबी मौसम के दौरान तीन बार प्रतिकृति कर यादृच्छिक ब्लॉक डिजाइन में परीक्षण किया गया। शीर्ष सात संतानें जिन्हें एफ$_2$ पीढ़ी में उच्च उपज के आधार पर चुना गया था, वे सभी उच्च उपज और अन्य वांछनीय लक्षणों के साथ एफ$_3$ पीढ़ी में भी अच्छा प्रदर्शन करते पाए गए। चयनित एफ$_3$ पीढ़ी के संकरणों में डबल्स और बोल्टर से मुक्त पाए गये। यह इंगित करता है कि एफ$_2$ से एफ$_3$ पीढ़ी तक किया गया चयन डबल और बोल्टर शल्क कंदों के लिए प्रभावी है जो निश्चित रूप से विपणन योग्य शल्क कंद की उपज बढ़ाने में मदद करता है। अध्ययन किए गए सभी लक्षणों के लिए उच्च स्तर की भिन्नता देखी गयी और अधिकांश लक्षणों के लिए वाह्यदृश्य प्रारूप (फेनोटाइपिक) और अनुवांशिक प्रारूप (जीनोटाइपिक) भिन्नता के गुणांक के बीच का अंतर संकीर्ण पाया गया। सबसे अच्छी नियंत्रक भीमा शक्ति (41.17 टन प्रति हेक्टेयर) की तुलना में चार संतानों अर्थात् कौगर x डीओजीआर–595, रेफोर्मा x डीओजीआर–595, मर्सिडीज x भीमा सुपर और कोलीना x डीओजीआर–595 में 30 प्रतिशत से अधिक विपणन योग्य उपज वृद्धि एफ$_3$ पीढ़ी में देखी गयी

जबकि एफ$_3$ पीढ़ी में 50 टन प्रति हेक्टेयर से अधिक विपणन योग्य उपज चार संतानों अर्थात् बेसिक x आरजीओ–53, कौगर x डीओजीआर–595, मर्सिडीज x भीमा सुपर और रेफोर्मा x डीओजीआर–595 में दर्ज की गई।

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