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Research Article

Parent progeny regression analysis in segregating generations of drought QTLs pyramided rice lines (*Oryza sativa* L.)

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Abstract
The present study was undertaken to estimate the effectiveness of selection for the yield and yield contributing traits in the BC_2F_3 and BC_2F_4 generations of drought QTL introgressed progenies of Improved White Ponni (IWP) x Apo. A positively skewed and negatively skewed platykurtic curve was observed in many of the traits in both generations indicating the influence of a large number of genes. Significant and positive intergenerational correlation and regression coefficient values were obtained for all the yield contributing characters indicating that selection can be done in these generations for isolating superior genotypes. Narrow sense heritability estimates obtained high values for the traits days to 50 per cent flowering, the number of productive tillers, filled grains per panicle and single plant yield indicating that selection will be effective for these traits in these early generations.

Key words: Drought, parent progeny, regression, skewness, kurtosis, intergenerational correlation, heritability

INTRODUCTION

The majority of the world's food consumption is based on rice diet and its productivity is severely affected due to frequent droughts in recent years (Khan *et al.,* 2021) which requires the development of drought tolerant varieties to secure food availability in the future. Drought is the main abiotic stress in rice crops (Rasheed *et al.,* 2020). More regions are expected to become drought prone in the future in India and the percentage of drought risk areas in India, China and Japan are estimated to be above 55% (Guo *et al.,* 2021). Marker assisted selection (MAS) is a quick, effective and economical approach to improve drought tolerance in rice. The availability of elite lines with heritable target traits and the assessment of the stability of the pyramided genes evaluated in field experiments provide a better avenue for drought tolerance breeding in rice (Rasheed *et al.,* 2020). Drought tolerance, governed by many complex traits, is linked to many undesirable traits like a late flowering, tallness, low tillers and reduced yield. For example, the drought QTL *qDTY3.1* is known to affect the yield under non-stress conditions (Dixit *et al.,* 2014). The high yielding ability under non-stress conditions is a desirable trait in drought tolerance because the plants with high yield and drought tolerance could produce relatively better yield under drought stress. Hence, selection for high yield in the earlier generations is necessary for achieving the target of yield improvement under drought tolerance. A high mean with a large amount of variation in the segregating generations is needed for the development of elite cultivars (Govintharaj *et al.,* 2017). Hence, to know the association and heritability of the traits contributing to yield in the drought QTLs introgressed segregating population of rice, parent progeny regression analysis was carried out.

MATERIALS AND METHODS

Improved White Ponni (IWP) is a medium duration, popular rice variety of Tamil Nadu due to its fine grains and good cooking quality but it is drought susceptible. APO is an upland rice variety identified to harbour the QTLs *qDTY1.1, qDTY2.1, qDTY3.1*, and was used as the donor for improving the drought tolerance of IWP. The QTLs *viz*., *qDTY1.1, qDTY2.1, qDTY3.1* contribute for grain yield up to 58 per cent (Venuprasad *et al.,* 2012), 16.3 per cent and 30.7 per cent, genetic variation, respectively (Venuprasad *et al.,* 2009). In this study, foreground selection for all the three QTLs was done in a total of 195 progenies belonging to 65 families in the BC_2F_3 generation. Fifty one positive homozygous plants identified were forwarded to BC_2F_4 generation by selfing. Quantitative traits *viz.,* days to 50 per cent flowering (DFF), plant height (PH), the number of productive tillers per plant (PT), the number of filled grains per panicle(FG), the number of chaffy grains per panicle(CG), panicle length(PL), grain yield(Yld) and thousand grain weight (TGW) were recorded on five plants and their average values were taken for analyses. Intergenerational correlation and parent progeny regression analyses were done using Origin software version 10. The mean values were used for calculating skewness and kurtosis using Microsoft excel and graphs using R software to understand gene interactions.

Narrow sense heritability (Smith and Kinman, 1965)

$$h^2 = \frac{byx}{2rxy} \text{ x } 100$$

byx= regression coefficient of BC_2F_4 progeny means on BC_2F_3 parental values for respective characters

rxy= Intergenerational correlation coefficient between the parent “x” and its offspring “y”

RESULTS AND DISCUSSION

Variation in the segregating generations provide opportunities for the selection of superior plants for the traits like earliness with high tillering ability and yield. A wide range of variation was expressed in the BC_2F_3 and BC_2F_4 generations. Mean and range values for the different traits were obtained for parents, BC_2F_3 (**Table 1**) and BC_2F_4 (**Table 2**) generations. Mean values for days to 50 per cent flowering in both generations were intermediate between the parents. Plant height recorded mean closer to the height to Apo parent, whereas for the trait productive tillers the mean values in BC_2F_3 and BC_2F_4 were nearer to the mean value of IWP parent. Mean values of both the generations for the number of filled and chaffy grains per panicle, panicle length and thousand grain weight were intermediate between both parents while for the trait single plant yield the mean values in BC_2F_3 and BC_2F_4 were highly similar to the IWP parent.

Positive skewness was observed for the traits days to 50 per cent flowering (0.06) and single plant yield (1.09) in BC_2F_3 generation. In BC_2F_4 generation, the traits number of productive tillers (0.59) and single plant yield (0.53) were positively skewed. Similarly, negative skewness was observed for plant height (-0.56), the number of productive tillers (-0.32), number of filled grains per panicle (-0.21), panicle length (-0.27), thousand grain weight (-0.71) in the BC_2F_3 generation and the traits days to 50 per cent flowering (-0.08), plant height (-0.93), the number of filled grains per panicle (-0.31), panicle length (-0.08), thousand grain weight (-0.34) in the BC_2F_4 generation (**Table 3**). In the BC_2F_3 generation, platykurtic curve was observed for the traits days to 50 per cent flowering (kurtosis = 0.14), plant height (kurtosis = -0.14), thousand grain weight (kurtosis = 0.11) and single plant yield (kurtosis = 0.49) and leptokurtic curve was observed for the traits number of filled grains per panicle (kurtosis = -1.31) and panicle length (kurtosis = 1.71). Mesokurtic curve was observed for the number of productive tillers (kurtosis = -0.06) (**Fig.1**). Similarly, in the BC_2F_4 generation, the traits days to 50 per cent flowering (kurtosis = 0.10), plant height (kurtosis = 0.21), the number of productive tillers (kurtosis = -0.17), the number of filled grains per panicle (kurtosis = -0.76) and panicle length (kurtosis = -0.10), single plant yield (kutosis = 0.19) showed platykurtic curve while thousand grain weight showed leptokurtic curve (**Fig.2**).

Skewness and Kurtosis are used to analyse the variation in the segregating generations (Nadarajan *et al.,* 2016). Skewness gives information about gene interaction. While skewness values greater than zero indicates the presence of complementary interactions, its value lesser than zero indicates duplicate interactions for the specific traits (Choo and Reinbergs, 1982). Leptokurtic and platykurtic curves indicate the influence of a relatively fewer and larger number of genes in controlling a trait, respectively (Aananthi, 2018). In the present study, a positively skewed and platykurtic curve was observed for days to 50 per cent flowering, chaffy grains per panicle and single plant yield in BC_2F_3 and for chaffy grains, productive tillers, single plant yield in BC_2F_4 generations. This suggests that these traits are governed by a large number of genes with dominance based gene interactions. Intense selection is needed for faster genetic gains in these traits. Similar findings were reported by Hosagoudar *et al.* (2018), Harijan *et al.* (2021) for days to flowering, the number of tillers, days to maturity and yield per plant. The negatively skewed platykurtic curve for the

Table 1. *Per se* performance of yield and yield contributing traits in the BC_2F_3 progenies

Line number	Days to 50 per cent flowering	Plant height (cm)	Number of Productive tillers	Number of chaffy grains per panicle	Number of filled grains per panicle	Panicle length (cm)	1000 grain weight (g)	Single plant yield (g)
1	115.0	115.0	23.0	90.0	180.0	21.0	18.5	43.2
2	114.0	137.1	19.0	32.5	147.3	22.8	19.5	37.0
3	96.0	77.7	20.0	41.3	85.0	19.9	19.1	22.0
4	95.0	77.3	18.0	65.3	96.3	20.9	19.5	18.1
5	110.0	135.0	20.0	45.0	102.0	23.0	18.5	21.5
6	112.0	127.9	17.9	28.6	126.9	22.7	22.0	29.0
7	106.0	138.0	20.0	10.0	90.0	21.0	15.2	31.7
8	108.0	136.0	16.0	40.0	90.0	21.1	15.7	35.8
9	108.0	140.0	20.0	31.0	115.0	22.5	19.8	28.8
10	108.0	143.5	20.9	24.0	123.3	20.8	20.5	35.0
11	107.0	139.9	18.9	58.0	97.5	24.0	20.2	20.7
12	97.0	96.9	18.4	59.0	87.5	18.0	16.4	23.4
13	105.0	139.2	23.1	33.0	135.0	22.4	24.5	44.8
14	105.0	142.0	18.0	25.0	145.0	27.2	23.5	33.6
15	105.0	135.8	21.2	31.0	121.0	23.2	20.3	31.3
16	109.0	140.0	27.0	80.0	95.0	22.0	14.8	32.8
17	96.0	142.3	22.5	34.5	145.5	20.9	21.7	30.7
18	97.0	93.5	15.0	39.5	158.5	23.5	14.5	45.4
19	95.0	91.3	14.1	30.0	85.5	21.6	24.0	25.0
20	107.0	136.8	20.9	20.0	162.0	23.5	19.4	33.1
21	95.0	140.3	21.4	57.3	146.3	22.5	24.4	22.1
22	95.0	93.1	12.3	63.0	122.0	22.9	23.7	27.3
23	100.0	139.6	23.7	83.3	100.5	22.4	21.4	30.4
24	108.0	132.2	22.4	46.7	127.3	21.7	20.6	41.9
25	105.0	77.3	18.7	63.5	95.0	17.0	20.2	26.4
26	94.0	77.4	21.0	57.3	87.5	15.6	17.6	15.1
27	118.0	115.0	13.0	22.0	168.0	20.8	22.6	24.0
28	118.0	125.0	20.0	21.0	190.0	25.0	23.6	19.5
29	119.0	125.0	28.0	29.0	187.0	23.0	21.9	14.9
30	120.0	125.0	20.0	15.0	184.0	22.6	22.9	18.8
31	116.0	112.0	9.0	23.0	122.0	22.3	23.5	18.1
32	108.0	115.0	27.8	37.0	166.3	25.1	21.3	21.6
33	105.0	105.0	27.6	48.0	167.0	19.0	23.0	22.7
34	108.0	108.0	29.1	30.0	186.3	23.0	24.3	21.6
35	106.0	115.0	28.9	33.0	128.0	24.0	24.1	20.4
36	105.0	110.0	25.2	35.0	157.2	21.6	22.2	22.0
37	107.0	116.0	26.5	31.0	151.7	19.0	23.9	22.1
38	108.0	114.0	23.5	23.0	178.0	29.0	21.3	21.5
39	105.0	108.0	22.5	25.0	176.3	21.0	19.5	18.6
40	105.0	122.0	20.0	12.0	143.0	24.5	23.8	15.9
41	105.0	126.0	25.0	10.0	110.0	22.1	22.0	19.3
42	105.0	117.0	20.0	12.0	114.0	22.3	18.6	19.6
43	106.0	115.0	24.0	37.0	175.0	25.8	19.8	23.5
44	105.0	108.0	24.0	31.0	162.0	25.2	20.5	21.3
45	105.0	110.0	30.5	34.0	173.2	22.7	22.3	22.5
46	108.0	110.0	28.0	17.0	166.2	22.0	23.4	22.5
47	106.0	109.0	17.0	32.0	164.0	23.4	21.0	20.4
48	105.0	119.0	28.0	22.0	158.9	24.3	20.1	20.1
49	107.0	109.0	28.6	25.0	146.6	23.8	19.8	22.5
50	105.0	108.0	25.5	12.0	180.0	25.1	20.7	20.4
51	105.0	116.0	25.2	13.0	173.0	24.3	21.6	21.1
Mean	105.92	117.79	21.77	35.64	139.11	22.45	20.85	25.51
Range	94-120	77.3-143.5	9 -30.5	10 -90	85-190	15.5 -29	14.5-24.5	14.8-45.4
IWP	124	147.2	32.1	32.7	211.9	23.2	16.2	25.2
Apo	98	95.7	18.2	40.8	142.4	31.0	22.1	18.6

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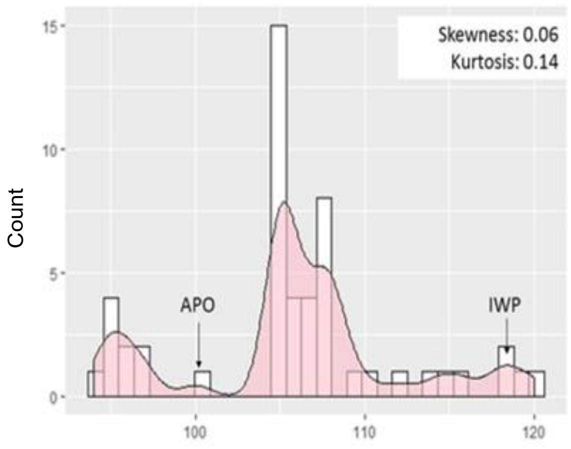
Table 2. *Per se* performance of the yield and yield contributing traits in the BC_2F_4 progenies

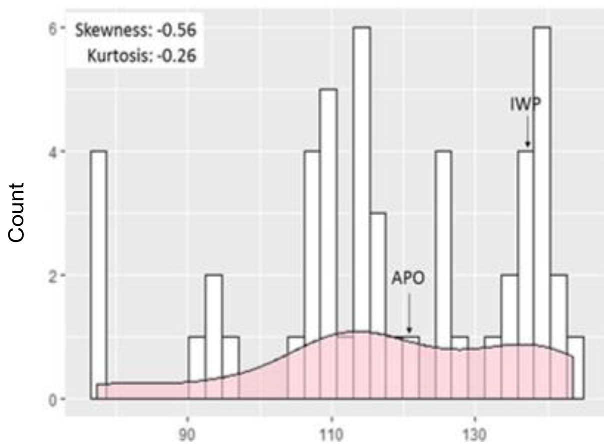
Line number	Days to 50 percent flowering	Plant height (cm)	Number of Productive tillers	Number of chaffy grains per panicle	Number of filled grains per panicle	Panicle length (cm)	1000 grain weight (g)	Single plant yield (g)
1	114.00	97.64	20.20	58.00	177.40	26.87	16.9	48.50
2	113.00	95.20	17.30	48.00	134.40	23.80	20.5	36.83
3	97.00	86.35	17.13	29.00	86.70	22.45	20.1	19.08
4	98.00	79.24	17.50	38.00	100.20	21.90	20.8	21.81
5	108.00	88.00	20.00	58.00	114.50	22.45	19.5	20.00
6	104.00	105.25	21.25	49.00	137.90	24.64	19.5	22.13
7	105.00	102.90	15.60	59.00	125.90	25.68	20.1	30.05
8	106.00	108.46	15.24	29.00	162.18	22.45	21.1	33.57
9	105.00	109.28	16.00	42.00	146.50	25.60	19.6	18.98
10	105.00	105.15	17.20	46.00	100.70	23.87	20.5	35.01
11	105.00	106.16	13.24	63.00	150.24	20.78	19.6	18.09
12	105.00	71.64	20.70	46.00	114.90	18.29	18.9	24.26
13	105.00	110.00	18.00	24.00	161.00	22.50	23.4	38.00
14	102.00	98.28	16.50	41.00	133.80	23.19	22.9	28.00
15	104.00	98.27	17.50	42.00	134.90	24.65	21.6	28.00
16	108.00	61.67	16.67	52.00	94.00	21.58	15.40	30.00
17	97.00	63.25	22.00	54.00	136.50	20.50	20.50	24.25
18	97.00	79.27	14.90	42.00	149.00	24.50	19.6	31.00
19	94.00	82.65	17.70	45.00	100.00	20.46	22.6	17.70
20	108.00	82.00	14.10	22.00	108.00	22.60	18.6	26.40
21	98.00	96.34	16.90	63.00	136.00	23.48	25.4	17.56
22	96.00	81.29	11.90	28.00	118.00	26.40	24.6	11.90
23	102.00	90.89	18.89	52.00	102.00	23.34	20.6	34.51
24	106.00	88.50	16.00	38.00	105.00	23.40	19.6	31.00
25	106.00	73.64	16.80	76.00	106.00	19.70	21.5	16.80
26	98.00	65.25	20.70	60.00	79.00	19.45	15.6	20.70
27	115.00	89.50	9.00	19.00	176.80	23.40	19.4	14.50
28	116.00	86.33	11.67	18.00	134.90	21.70	21.2	14.07
29	115.00	97.00	16.00	24.00	167.50	22.80	19.8	16.75
30	116.00	100.00	18.00	19.00	182.60	26.00	22.1	17.30
31	115.00	92.50	14.50	29.00	145.20	22.60	21.6	21.00
32	109.00	108.98	24.00	19.00	146.30	25.46	20.50	28.57
33	108.00	98.00	18.00	20.00	158.90	21.67	22.40	32.25
34	108.00	97.67	24.00	21.67	167.60	23.54	21.40	21.67
35	110.00	110.56	19.00	20.67	105.60	24.60	20.40	25.33
36	104.00	92.00	28.00	16.00	135.40	20.57	22.50	41.84
37	107.00	109.87	32.00	16.89	164.90	20.54	20.80	20.97
38	107.00	110.58	19.00	15.25	154.90	22.45	23.50	26.50
39	108.00	93.75	21.00	13.25	167.70	21.85	23.50	25.00
40	107.00	102.00	12.00	4.00	136.00	22.30	20.50	37.10
41	106.00	100.00	14.00	15.00	172.00	22.80	21.60	46.30
42	108.00	105.00	16.00	18.00	188.00	24.00	21.50	25.50
43	103.00	108.00	30.00	16.00	167.90	21.24	19.50	31.20
44	105.00	105.24	29.00	14.33	147.10	24.69	21.30	33.21
45	104.00	107.20	27.00	18.24	152.70	22.45	19.80	32.80
46	109.00	100.50	22.00	16.45	147.05	22.65	19.30	30.70
47	105.00	108.24	29.00	17.67	149.10	22.49	20.60	25.90
48	106.00	109.64	27.00	18.33	137.50	23.54	23.40	24.80
49	108.00	108.94	24.00	16.36	134.90	21.87	22.90	27.94
50	105.00	94.40	25.00	17.60	176.80	25.45	21.90	32.35
51	105.00	110.58	26.00	15.00	167.90	24.67	24.40	24.36
Mean	105.78	95.55	19.32	32.21	139.22	22.94	20.88	26.71
Range	94-116	61.6-110.5	9-32	4-76	79-188	18.2-26.8	15.4-25.4	11.9-48.5
IWP	125	128.1	25.4	35.1	209.7	22.9	15.8	27.9
Apo	98	90.5	16.9	68.2	134.8	26.3	21.9	20.2

Table 3. Skewness and Kurtosis values for the quantitative traits in BC_2F_3 and BC_2F_4 progenies

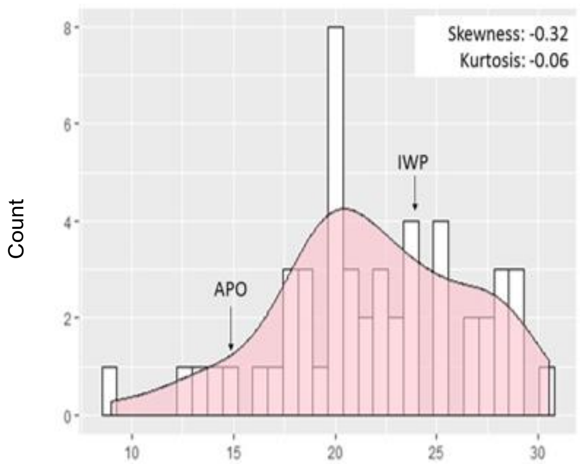
Traits	BC_2F_3		BC_2F_4	
	Skewness	Kurtosis	Skewness	Kurtosis
Days to 50 per cent flowering	0.06	0.14	-0.08	0.10
Plant height	-0.56	-0.26	-0.93	0.21
Number of productive tillers	-0.32	-0.06	0.59	-0.17
Number of chaffy grains per panicle	1.05	0.79	0.62	-0.79
Number of filled grains per panicle	-0.21	-1.31	-0.31	-0.76
Panicle length	-0.27	1.71	-0.08	-0.10
Thousand grain weight	-0.71	0.11	-0.34	1.08
Single plant yield	1.09	0.49	0.53	0.19



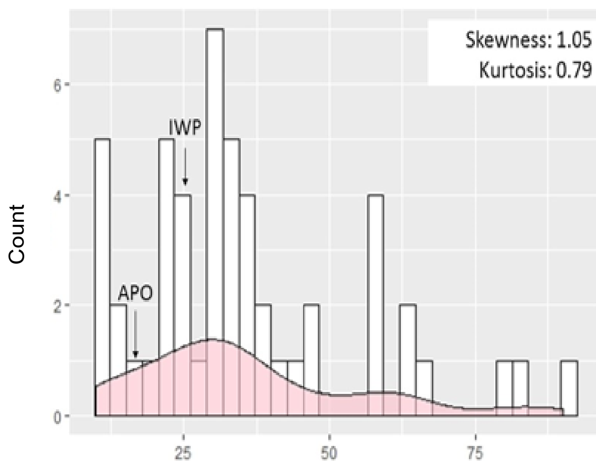
Days to 50 per cent flowering



Plant height (cm)



Number of productive tillers



Number of chaffy grains per panicle

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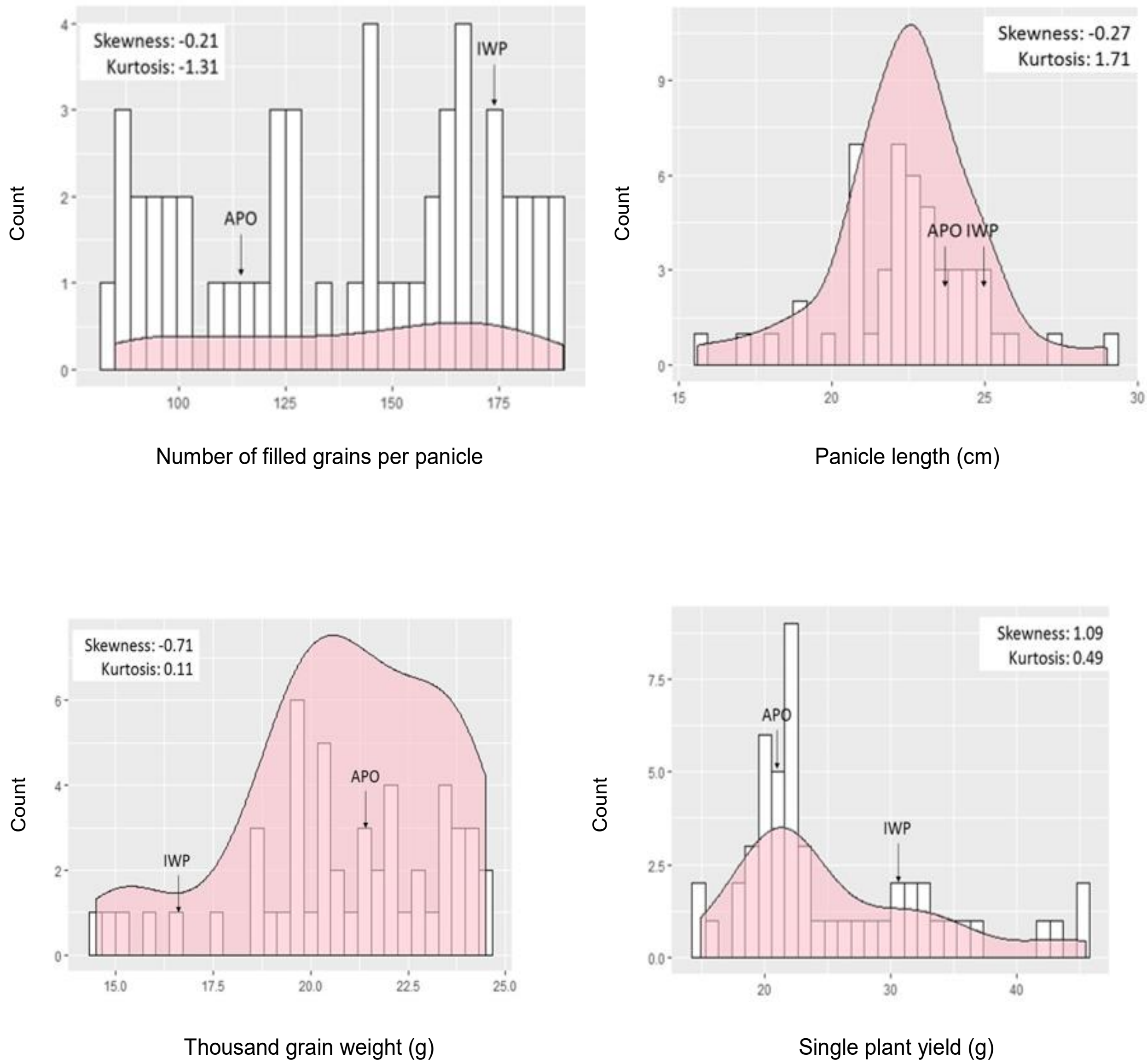


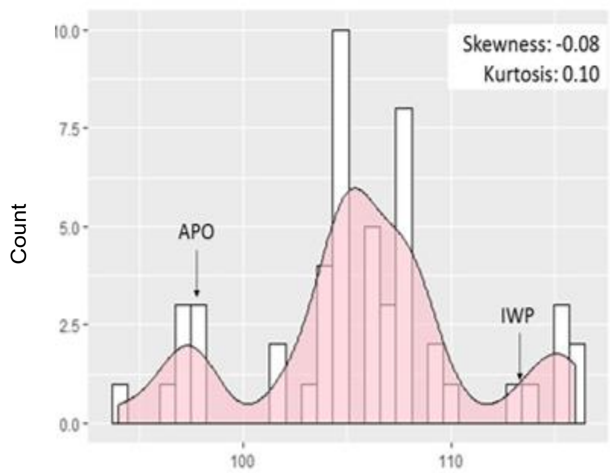
Fig. 1. Frequency distribution patterns of different traits in the BC_2F_3 generation

traits plant height and thousand grain weight in the BC_2F_3 generation and plant height, filled grains per panicle, panicle length in BC_2F_4 generation indicated that these traits are under the control of many genes with duplicate gene action. Mild selection will help in achieving faster genetic gain in these traits.

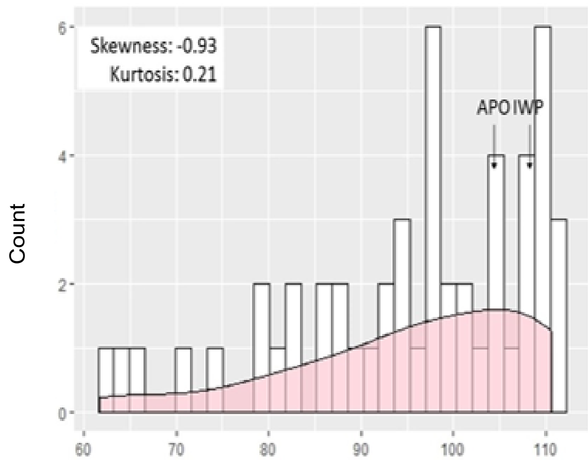
The parent progeny regression analysis was estimated using the mean values of BC_2F_4 individuals on BC_2F_3 for all the traits (**Fig. 3**). The results showed a strong association between the traits in BC_2F_3 and BC_2F_4 generations. Regression coefficients were highly significant ($p<0.01$) for the traits days to 50 per cent flowering, the number of productive tillers, the number of chaffy grains per panicle, the number of filled grains per panicle, panicle length, thousand grain weight and single plant yield. The maximum regression coefficient was obtained for days to 50 per cent flowering (1.12) followed by the number of productive tillers (0.60), filled grains per panicle (0.52) and single plant yield (0.43) indicating that selection is effective for these traits in these early generations for obtaining high yield along with earliness (**Table 4**). Similar results were obtained for single plant yield by Anilkumar *et al.* (2011), for days to 50 per cent

Table 4. Intergenerational correlation and regression values for the quantitative traits

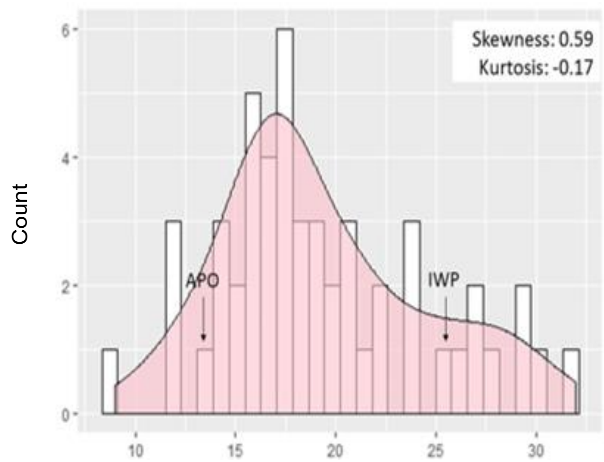
Traits	Correlation coefficient (r)	Regression coefficient (b)	Heritability h^2 (%)
Days to 50 per cent flowering	0.92**	1.12**	60.9
Plant height	0.30*	0.21*	35.0
Number of productive tillers	0.55**	0.60**	54.5
Number of chaffy grains per panicle	0.60**	0.56**	46.7
Number of filled grains per panicle	0.63**	0.52**	41.3
Panicle length	0.41**	0.32**	39.0
Thousand grain weight	0.51**	0.40**	39.2
Single plant yield	0.41**	0.43**	52.4



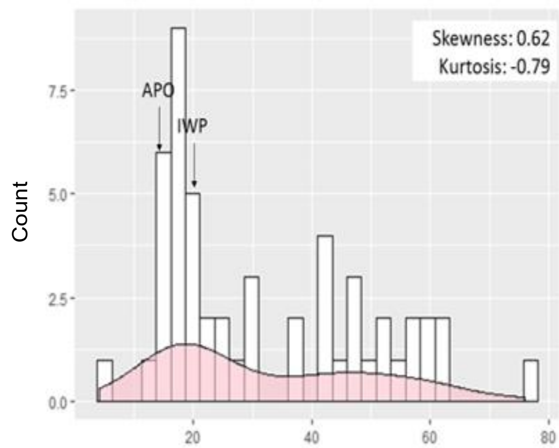
Days to 50 per cent flowering



Plant height (cm)



Number of productive tillers



Number of chaffy grains per panicle

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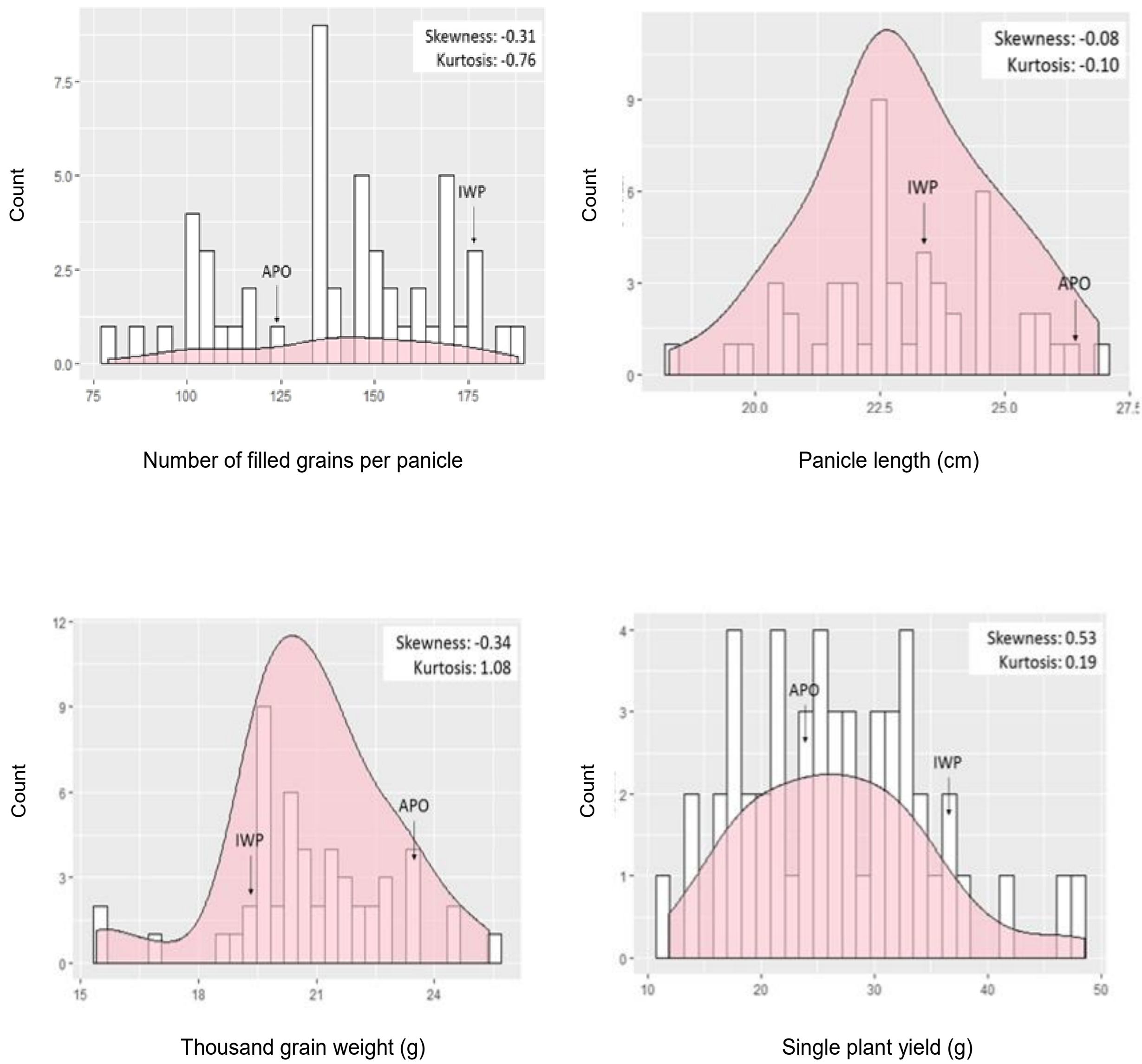
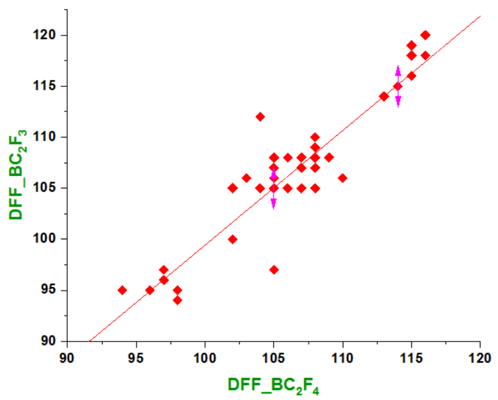


Fig. 2. Frequency distribution patterns of different traits in the BC_2F_4 generation

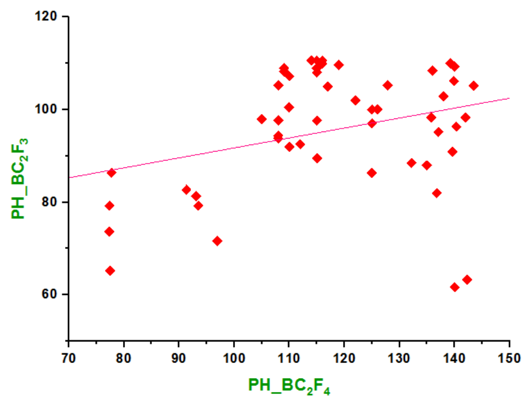
flowering, plant height and the number of productive tillers by Kavithamani *et al.* (2013) and for panicle length by Lalitha *et al.* (2018). Higher values of regression indicate greater genetic influence and less environmental effects (Palanisamy *et al.,* 2018). Real heritability should be known for the improvement of a trait (Dubey *et al.,* 2019). Regression estimates in this study indicated less environmental influence on these traits and selection based on their phenotypes in these generations is heritable. Parent-progeny regression method is used to know the narrow-sense heritability of the traits which is due to the additive genetic variance (Rani *et al.,* 2021). Correlation coefficients were highly significant for the traits days to 50 per cent flowering, the number of productive tillers, the number of chaffy grains per panicle, the number of filled grains per panicle, panicle length, thousand grain weight and single plant yield and significant for the trait plant height. Intergenerational correlation studies help to understand the extent to which the genetic potential of the trait will be transferred to further generations (Kumar *et al.,* 2020; Rani *et al.,* 2021). In the present study, intergenerational correlation coefficient was maximum for days to 50 per cent flowering (0.92) followed by The number of filled grains per panicle (0.63), the number of productive tillers (0.55), thousand grain weight (0.51) and single plant yield (0.41) showing that these traits have high heritability. Similar positive and significant results for plant height, the number of filled grains per panicle, hundred grain weight and panicle length were obtained by Savitha *et al.* (2015).

Narrow sense heritability estimated based on parent progeny regression method revealed high heritability for the trait days to 50 per cent flowering (60.9%), the number of productive tillers (54.5%), single plant yield (52.4%), the number of chaffy grains per panicle (46.7%), the number of filled grains per panicle (41.3%), thousand grain weight (39.2%), panicle length (39%) and plant height (35%). Similar results were obtained by Kavithamani *et al.* (2013).

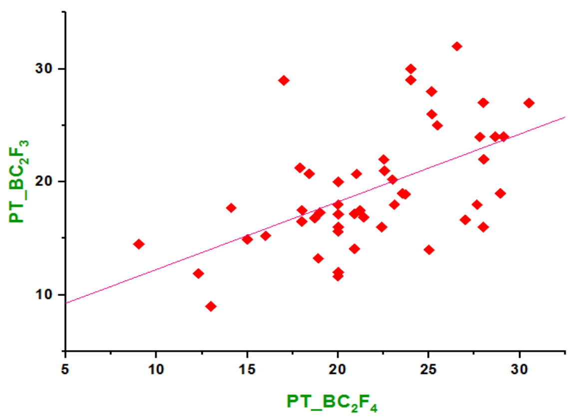
Drought tolerant upland cultivars are generally low tillering and low yielding with bold grains. These donors are crossed with the locally adapted cultivars for improving their drought tolerance. Hence, the developed segregating generations need to be carefully evaluated for improved tolerance for drought without compensating for the high yielding ability of the varieties. In the present study, high values of heritability, correlation and regression coefficients for the traits flowering, number of productive tillers, grain yield indicate that these traits can be used for the selection of elite genotypes in early generations.



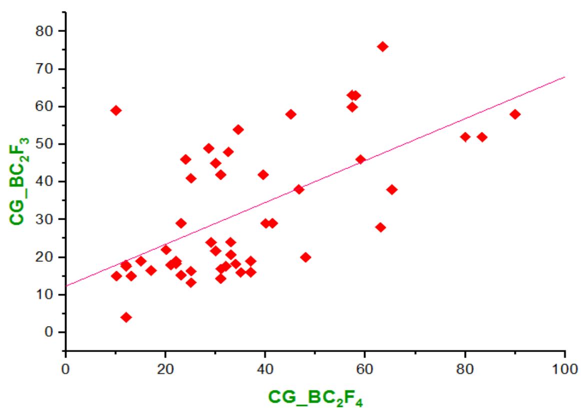
Days to 50 per cent flowering



Plant height (cm)



Number of productive tillers



Number of chaffy grains per panicle

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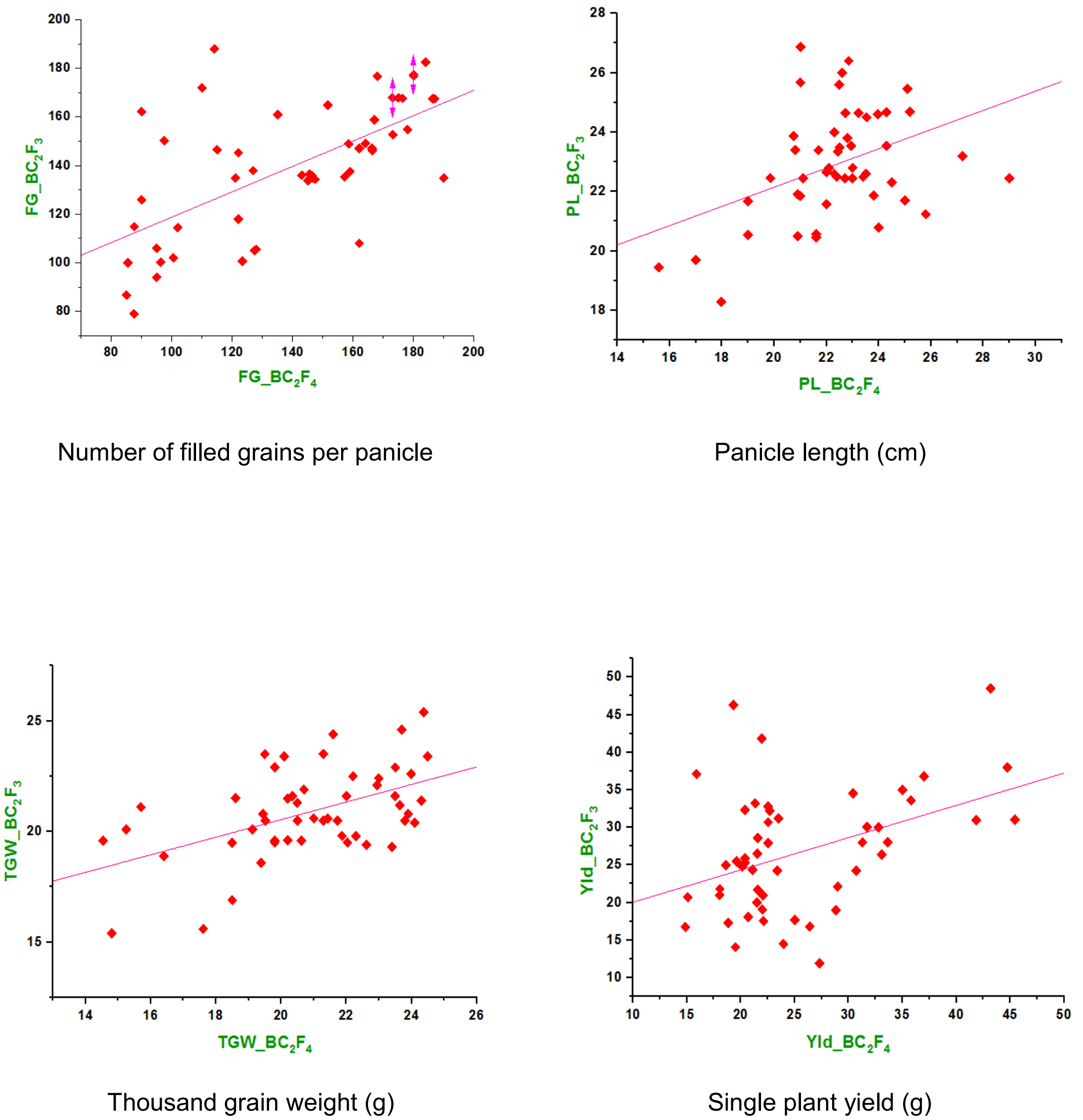

Fig. 3. Parent offspring regression for the quantitative traits

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