

Evaluation of MTU 1121 introgressed lines for direct-seeded conditions in rice (*Oryza sativa* L.)

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ABSTRACT

Early seedling vigour (ESV) is a key determinant of successful crop establishment in direct-seeded rice systems. The present study evaluated genetic variability and mean performance of BC₂F₂ lines for ESV related traits using analysis of variance (ANOVA). The experimental material consisted of BC₂F₂ lines derived from MTU1121 as the recurrent parent and evaluated under a completely randomized design with three replications. Observations were recorded on shoot length, root length, seedling length, shoot and root fresh weight, total fresh weight, root-to-shoot ratio and seedling vigour index (SVI). ANOVA revealed highly significant differences among BC₂F₂ lines for all traits, indicating substantial genetic variability. Mean performance analysis identified several introgressed lines with superior root growth, biomass accumulation and higher SVI compared to MTU1121. These superior BC₂F₂ lines offer valuable breeding material for improving early seedling vigour in direct-seeded rice systems.

Keywords: ANOVA, Direct-seeded, Early Seedling Vigour, Mean performance and Rice

Rice (*Oryza sativa* L.) is the staple food for a major proportion of the global population. In recent years, rice cultivation has increasingly shifted from transplanting to direct seeding due to reduced labour requirements, lower cultivation costs and earlier crop maturity (Pandey and Velasco, 2002). However, poor crop establishment caused by low early seedling vigour remains a major limitation of direct-seeded rice (DSR). Early seedling vigour is a complex trait governed by rapid germination, enhanced shoot and root growth and early biomass accumulation, which together improves establishment, weed competitiveness and stress tolerance (Balasubramanian and Hill, 2002 and Cairns *et al.*, 2009). Backcross-derived populations such as BC₂F₂ lines are effective resources for assessing genetic variability and identifying superior recombinants for complex traits (Sing *et al.*, 2017). Therefore, the present investigation aimed to assess variability through ANOVA and to evaluate the mean performance of BC₂F₂ lines for early seedling vigour traits in rice.

MATERIAL AND METHODS

Experimental Material and Design

The study was conducted under laboratory conditions at the Regional Agricultural Research Station

(RARS), Maruteru, during Summer 2024-25. Thirty-five BC, F, introgressed lines of MTU 1121, along with the parental lines and a check (AC39416A), were evaluated using a completely randomized design with three replications. MTU 1121 (Sri Druthi) is a popular high-yielding, medium-duration rice variety widely cultivated in Andhra Pradesh due to its good grain quality, adaptability and farmer preference; however, it exhibits relatively poor early seedling vigour and limited tolerance to anaerobic conditions, which restrict its suitability for direct-seeded rice systems. Therefore, introgressed lines of MTU 1121 were developed to incorporate favourable alleles associated with early seedling vigour with the aim of improving its performance under direct sowing conditions. The standard germination test was conducted using the paper towel method following ISTA, 2018 guidelines. Seeds were pre-treated to break dormancy and incubated at 38 °C under saturated conditions. Germination was recorded up to 14 days and mean values across replications were used for subsequent analysis.

Traits Recorded

On the 14th day of the standard germination test, five normal seedlings were randomly selected from

each replication to record early seedling vigour traits. Shoot length was measured from the collar region to the tip of the top-most leaf, while root length was measured from the collar region to the tip of the longest root, and both were expressed in centimeters. Seedling length was recorded from the root tip to the shoot tip. Shoot fresh weight and root fresh weight were determined by weighing the respective shoot and root portions of the sampled seedlings, and the average values were expressed in grams. Total fresh weight was calculated as the sum of shoot fresh weight and root fresh weight. The root-to-shoot ratio was computed as the ratio of root length to shoot length. Seedling vigour index (SVI) was calculated by multiplying the germination percentage with the mean seedling dry weight, following Vijay *et al.* 2010.

Statistical Analysis

The data were subjected to analysis of variance (ANOVA) to test the significance of genotypic differences. Mean performance was used to identify superior BC₂F₂ lines for early seedling vigour traits.

RESULTS AND DISCUSSION

Analysis of Variance (ANOVA) revealed highly significant differences ($p < 0.01$) among BC₂F₂ lines and parental genotypes for all eight ESV traits, indicating substantial genetic variability. High treatment mean squares relative to error and low coefficients of variation (2.45–4.87%) confirmed good experimental precision and reliable discrimination among genotypes Table 1. Similar results for ESV traits were reported earlier (Maiti *et al.*, 2009).

Mean performance of the BC₂F₂ lines revealed wide phenotypic ranges and clear divergence from both parents for several ESV traits Table 2, 3 and Fig. 1-8.

Shoot length (cm)

Shoot length is a key indicator of early seedling vigour in direct-seeded rice, reflecting rapid seedling elongation that promotes timely emergence, improved weed competitiveness and successful crop establishment under adverse conditions (Bharamappanavara *et al.*, 2023).

Across lines, shoot length ranged from 10.75 cm (P2 1 5) to 16.42 cm (P3 2 14) with a mean of 14.08 cm, whereas MTU1121, Anjali and AC39416A recorded around 22–23 cm, indicating that all introgressed lines had shorter shoots than the parents and check.

Root length (cm)

Root length is a key indicator of early seedling vigour in direct-seeded rice, as a vigorous root system enhances water and nutrient uptake, stress tolerance and early crop establishment (Panda *et al.*, 2021).

Root length varied from 11.92 cm (P2 1 1) to 19.68 cm (P2 1 9) with an average of 15.39 cm; most BC₂F₂ lines exceeded Anjali (11.46 cm) and many surpassed MTU1121 (12.59 cm), reflecting improved root elongation.

Total fresh weight (g)

Total fresh weight ranged from 0.32 g (P3 2 5) to 0.534 g (P3 2 14), with an overall mean of

Table 1. Analysis of variance for early seedling vigour (ESV) traits in rice

S. No	Characters	Mean Sum of Squares	
		Treatment (df = 37)	Error (df = 76)
1	Shoot length (cm)	25.747**	0.302375
2	Root length (cm)	13.790**	0.44315
3	Total fresh weight (g)	0.0163**	0.00037
4	Seedling length (cm)	46.596**	0.9081
5	Shoot fresh weight (g)	0.00459**	0.000083
6	Root fresh weight (g)	0.002036**	0.00001125
7	Root to shoot ratio	0.0972**	0.0030097
8	Seedling vigour index	4.6917**	0.01186

**Significant at 1% level

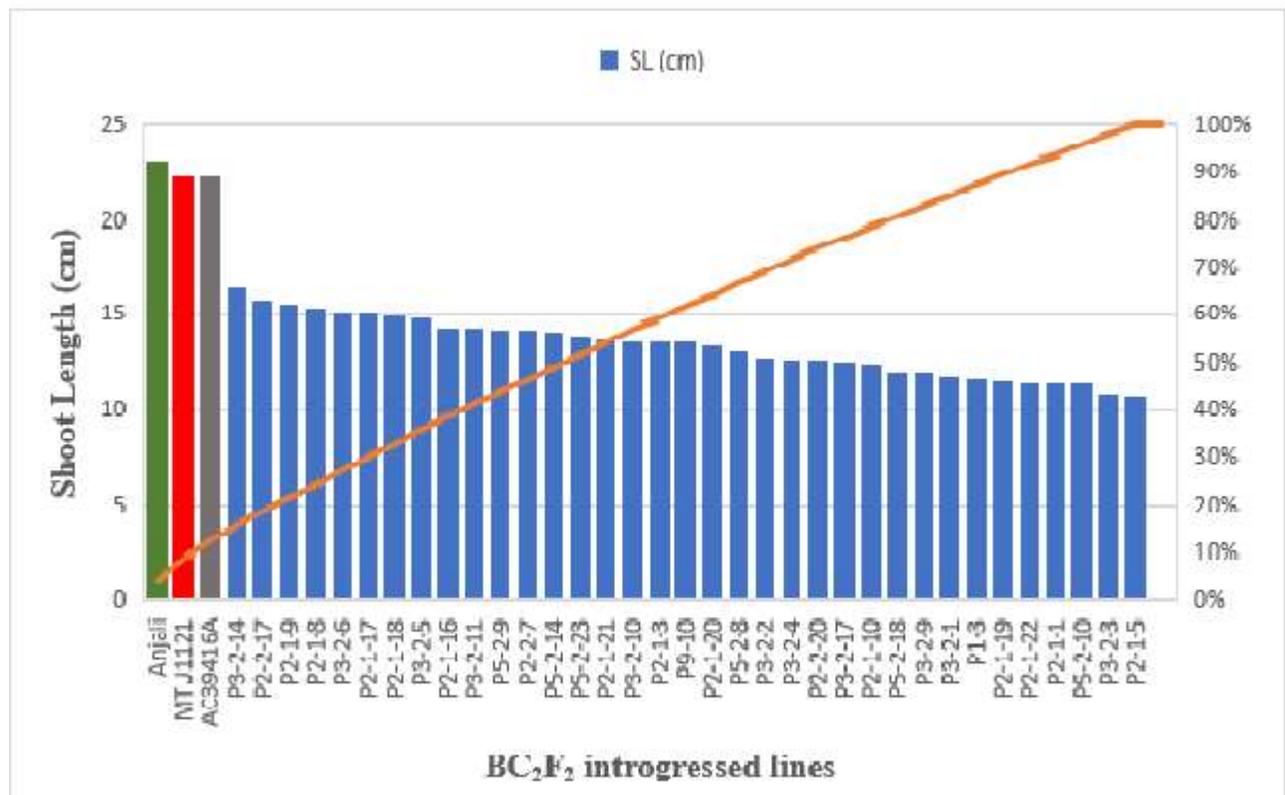
Table 2. Mean performance of 35 BC₂F₂ lines, two parents along with check variety for early seedling vigour (ESV) trait

S. No	BC ₂ F ₂ lines	SL (cm)	RL (cm)	TFW (g)	SDL (cm)	SFW (g)	RFW (g)	R/S	SVI
1	P1-3	11.64	12.91	0.45	24.55	0.19	0.057	1.13	2.77
2	P2-1-1	11.39	11.92	0.49	23.31	0.19	0.051	1.08	3.94
3	P2-1-3	13.54	14.36	0.49	27.9	0.23	0.056	1.05	4.18
4	P2-1-5	10.75	12.44	0.43	23.19	0.23	0.061	1.16	3.86
5	P2-1-8	15.38	18.52	0.44	33.8	0.19	0.054	1.21	6.23
6	P2-1-9	15.53	19.68	0.42	35.21	0.2	0.019	1.27	4.42
7	P2-1-10	12.41	14.99	0.41	27.4	0.2	0.07	1.21	3.95
8	P2-1-16	14.38	18.14	0.4	32.52	0.21	0.055	1.26	4.33
9	P2-1-17	15.16	18.09	0.49	33.26	0.22	0.034	1.2	5.27
10	P2-1-18	14.96	19.18	0.5	34.14	0.18	0.053	1.28	4.01
11	P2-1-19	11.5	16.13	0.39	27.62	0.18	0.057	1.4	4.11
12	P2-1-20	13.42	17	0.5	30.42	0.19	0.131	1.27	3.25
13	P2-1-21	13.82	15.76	0.49	29.58	0.2	0.141	1.15	4.38
14	P2-1-22	11.45	12.61	0.39	24.06	0.18	0.049	1.1	3.55
15	P2-2-7	14.22	14.51	0.5	28.72	0.19	0.055	1.02	3.65
16	P2-2-17	15.79	14.53	0.5	30.32	0.18	0.069	0.92	4.87
17	P2-2-20	12.65	15.65	0.39	28.3	0.19	0.045	1.24	4.04
18	P3-2-1	11.8	15.01	0.48	26.8	0.22	0.096	1.27	4.68
19	P3-2-2	12.74	14.44	0.47	27.18	0.21	0.085	1.14	6.87
20	P3-2-3	10.84	14.15	0.49	24.98	0.22	0.089	1.31	4.04
21	P3-2-4	12.66	16.19	0.47	28.85	0.26	0.087	1.28	3.86
22	P3-2-5	14.78	16.9	0.32	31.68	0.22	0.078	1.14	3.87
23	P3-2-6	15.18	15.67	0.43	30.84	0.22	0.067	1.04	4.28
24	P3-2-9	11.99	13.77	0.42	25.76	0.17	0.077	1.14	4.04
25	P3-2-10	13.61	16.51	0.39	30.12	0.21	0.064	1.21	4.87
26	P3-2-11	14.3	17.11	0.44	31.41	0.22	0.067	1.19	4.75
27	P3-2-14	16.42	17.66	0.53	34.08	0.3	0.089	1.07	6.93
28	P3-2-17	12.6	13.8	0.41	26.4	0.19	0.053	1.09	4.27
29	P5-2-8	13.13	14.59	0.42	27.72	0.21	0.068	1.11	4.52
30	P5-2-9	14.26	16.83	0.49	31.08	0.25	0.086	1.18	5.66
31	P5-2-10	11.39	13.84	0.44	25.23	0.22	0.074	1.21	5.11
32	P5-2-14	14.08	16.61	0.43	30.69	0.2	0.085	1.18	2.79
33	P5-2-18	12	13.85	0.38	25.86	0.15	0.042	1.15	3.54
34	P5-2-23	13.88	13.05	0.5	26.93	0.24	0.088	0.94	4.49
35	P9-10	13.54	15.57	0.38	29.11	0.21	0.087	1.14	4.96
36	MTU1121	22.33	12.59	0.75	34.92	0.22	0.141	0.71	3.47
37	Anjali	23.22	11.46	0.53	34.69	0.17	0.084	0.66	1.92
38	AC39416A (Check)	22.28	19.15	0.62	41.44	0.38	0.079	0.86	8.95
Min.	10.753	11.92	0.32	23.19	0.15	0.019	0.924	2.77	2.77
Max.	16.42	19.68	0.53	35.21	0.3	0.14	1.401	6.93	6.93
	Mean	14.08	15.39	0.46	29.47	0.21	0.072	1.13	4.44
	CD (0.05)	0.89	1.083	0.031	1.55	0.015	0.005	0.08	0.17
	CV (%)	3.9	4.32	4.16	3.23	4.21	4.63	4.87	2.45

SL: Shoot Length (cm); **RL:** Root Length (cm); **TFW:** Total Fresh Weight (g); **SDL:** Seedling Length (cm); **SFW:** Shoot Fresh Weight (g); **RFW:** Root Fresh Weight (g); **R/S:** Root to Shoot ratio; **SVI:** Seedling Vigour Index; **CD:** Critical Difference; **CV:** Coefficient of Variation; Min: Minimum; Max: maximum

Table 3. List of promising lines identified for early seedling vigour (ESV) trait

S. No.	Trait	Promising Lines
1	Shoot length (cm)	P3-2-14 (16.42), P2-2-17 (15.79), P2-1-9 (15.53), P2-1-8 (15.38), P3-2-6 (15.18), P2-1-17 (15.166), P2-1-18 (14.96), P3-2-5 (14.786), P2-1-16 (14.386), P3-2-11 (14.306), P2-2-7 (14.22)
2	Root length (cm)	P2-1-9 (19.68), P2-1-18 (19.18), P2-1-8 (18.52), P2-1-16 (18.14), P2-1-17 (18.09), P3-2-14 (17.66), P3-2-11 (17.11), P2-1-20 (17), P3-2-5 (16.9), P5-2-9 (16.83)
3	Total fresh weight (g)	P3-2-14 (0.534), P2-2-7 (0.507), P2-1-20 (0.506), P2-2-17 (0.504), P5-2-23 (0.502), P2-1-18 (0.5), P2-1-3 (0.495), P3-2-3 (0.492), P5-2-9 (0.491), P2-1-17 (0.491)
4	Seedling length (cm)	P2-1-9 (35.213), P2-1-18 (34.14), P3-2-14 (34.08), P2-1-8 (33.8), P2-1-17 (33.26), P2-1-16 (32.526), P3-2-5 (31.686), P3-2-11 (31.413), P5-2-9 (31.086), P3-2-6 (30.846)
5	Shoot fresh weight (g)	P3-2-14 (0.306), P3-2-4 (0.264), P5-2-9 (0.257), P5-2-23 (0.244), P2-1-5 (0.233), P2-1-3 (0.23), P3-2-1 (0.225), P2-1-17 (0.225), P3-2-3 (0.223), P3-2-11 (0.222)
6	Root fresh weight (g)	P2-1-21 (0.141), P2-1-20 (0.131), P3-2-1 (0.096), P3-2-14 (0.089), P3-2-3 (0.089), P5-2-23 (0.088), P9-10 (0.087), P3-2-4 (0.087), P5-2-9 (0.086), P5-2-14 (0.085), P3-2-2 (0.085)
7	Root to shoot ratio	P2-1-19 (1.401), P3-2-3 (1.31), P2-1-18 (1.285), P3-2-4 (1.28), P3-2-1 (1.273), P2-1-9 (1.272), P2-1-20 (1.27), P2-1-16 (1.269), P3-2-(-1) (1.245), P5-2-10 (1.218), P2-1-10 (1.217)
8	Seedling vigour index	P3-2-14 (6.93), P3-2-2 (6.872), P2-1-8 (6.239), P5-2-9 (5.662), P2-1-17 (5.278), P5-2-10 (5.112), P9-10 (4.969), P3-2-10 (4.874), P2-2-17 (4.87), P3-2-11 (4.75), P3-2-1 (4.688)

**Figure 1. Performance of BC₂F₂ plants for shoot length**

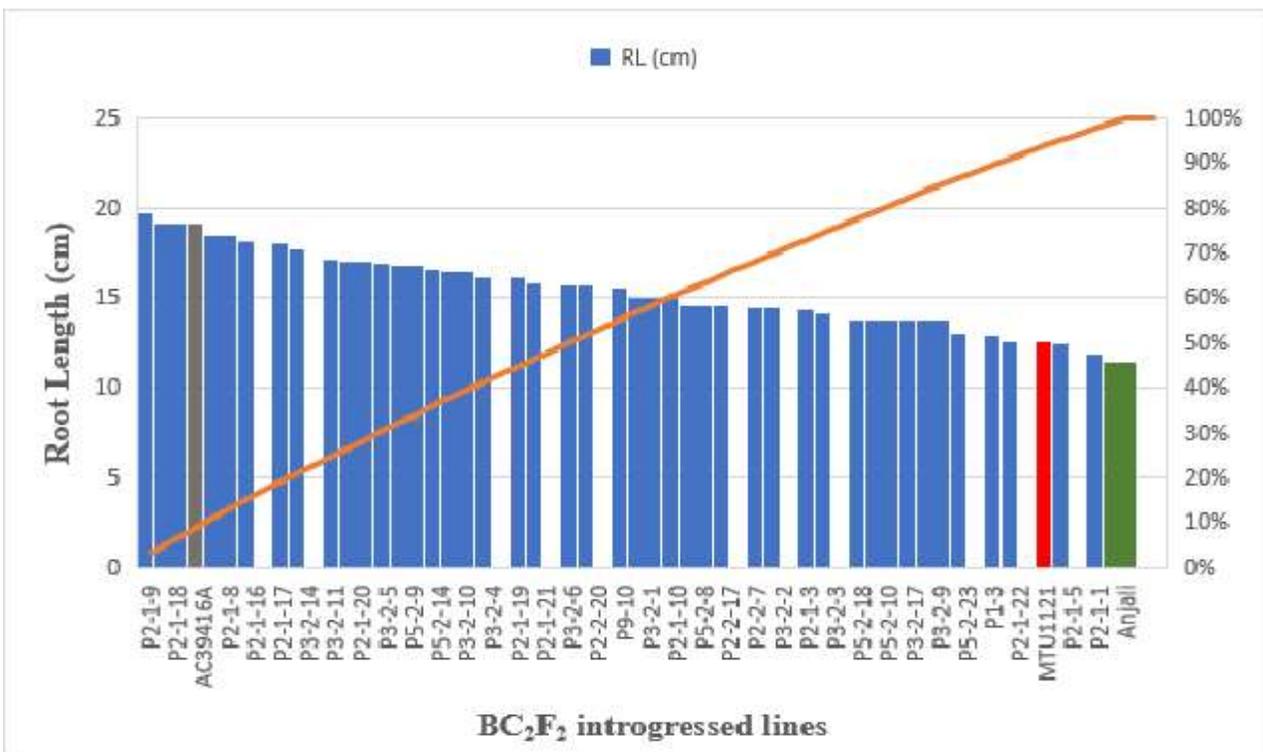


Figure 2. Performance of BC₂F₂ plants for root length

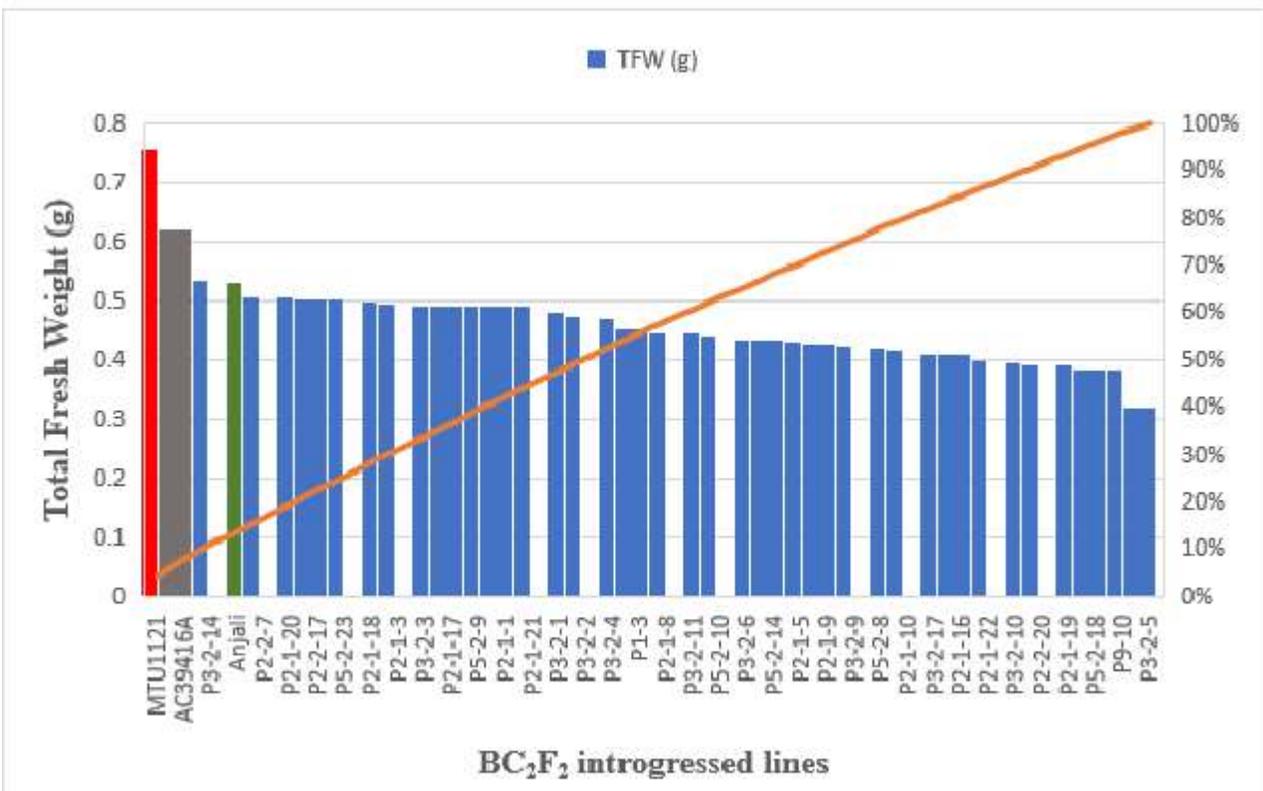


Figure 3. Performance of BC₂F₂ plants for total fresh weight

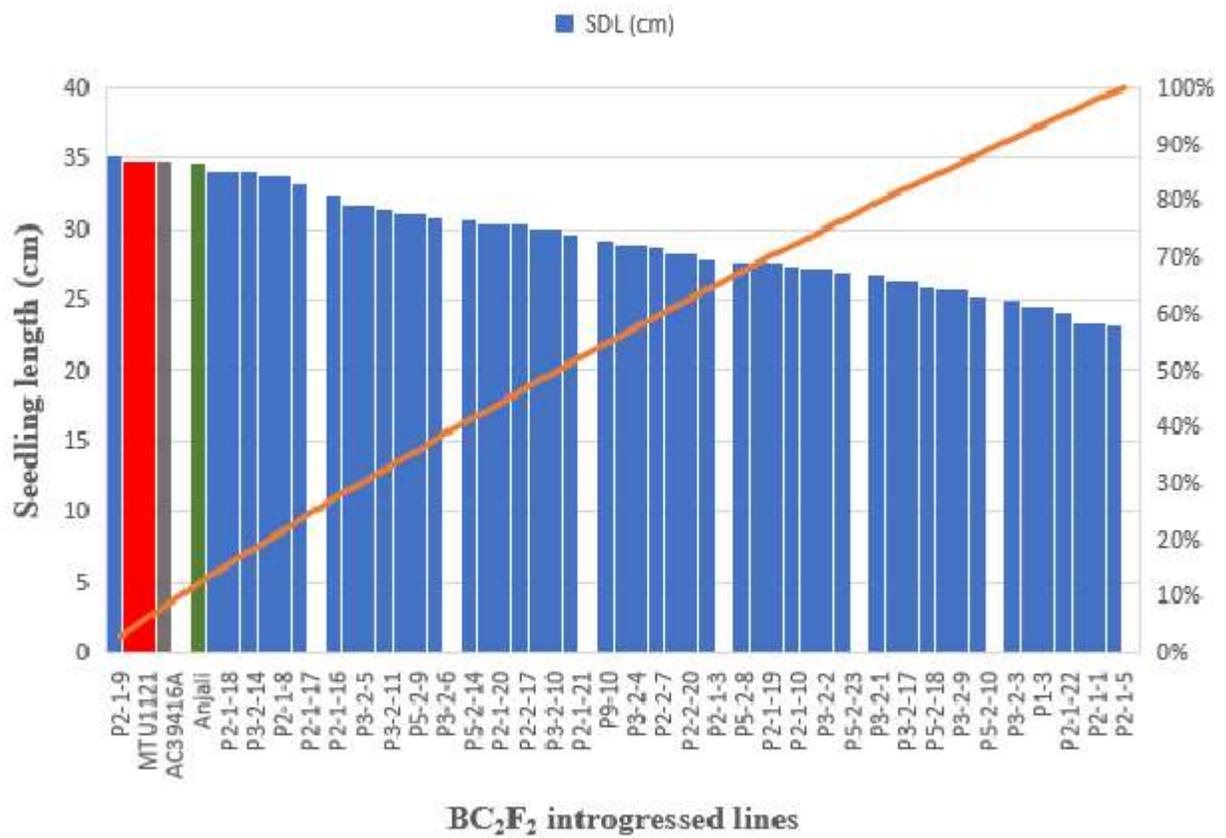


Figure 4. Performance of BC₂F₂ plants for seedling length

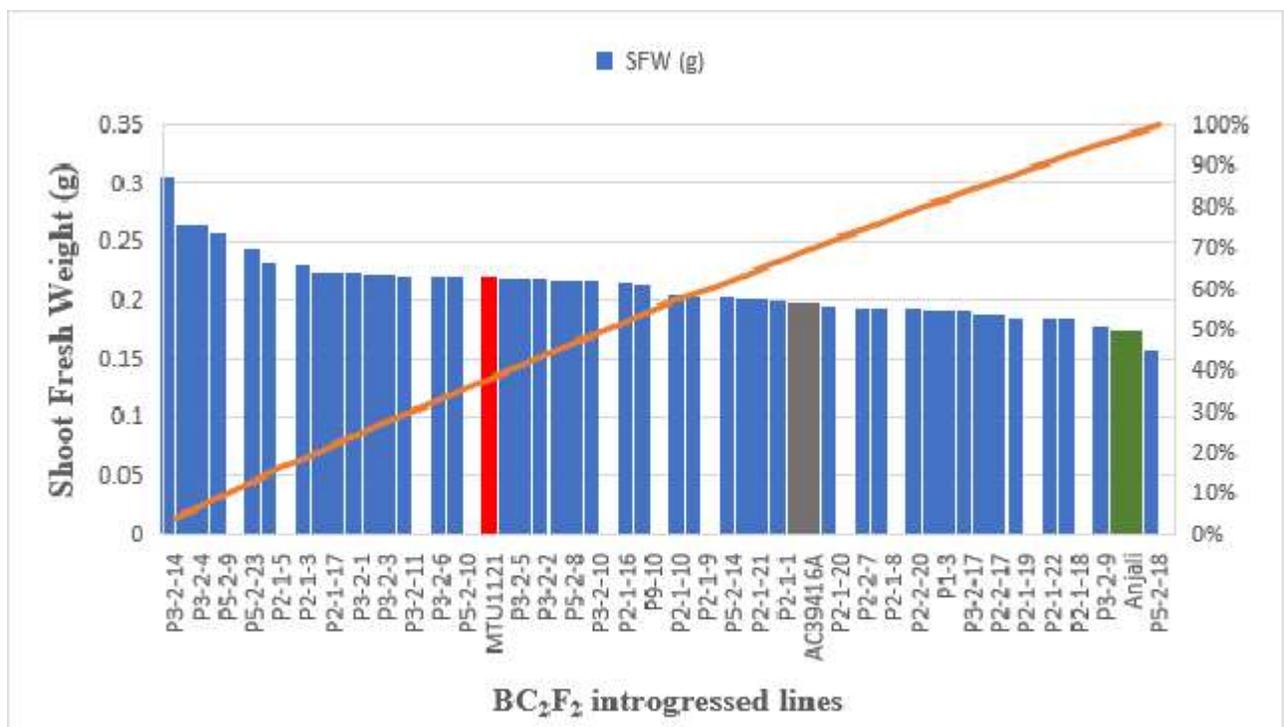


Figure 5. Performance of BC₂F₂ plants for shoot fresh weight

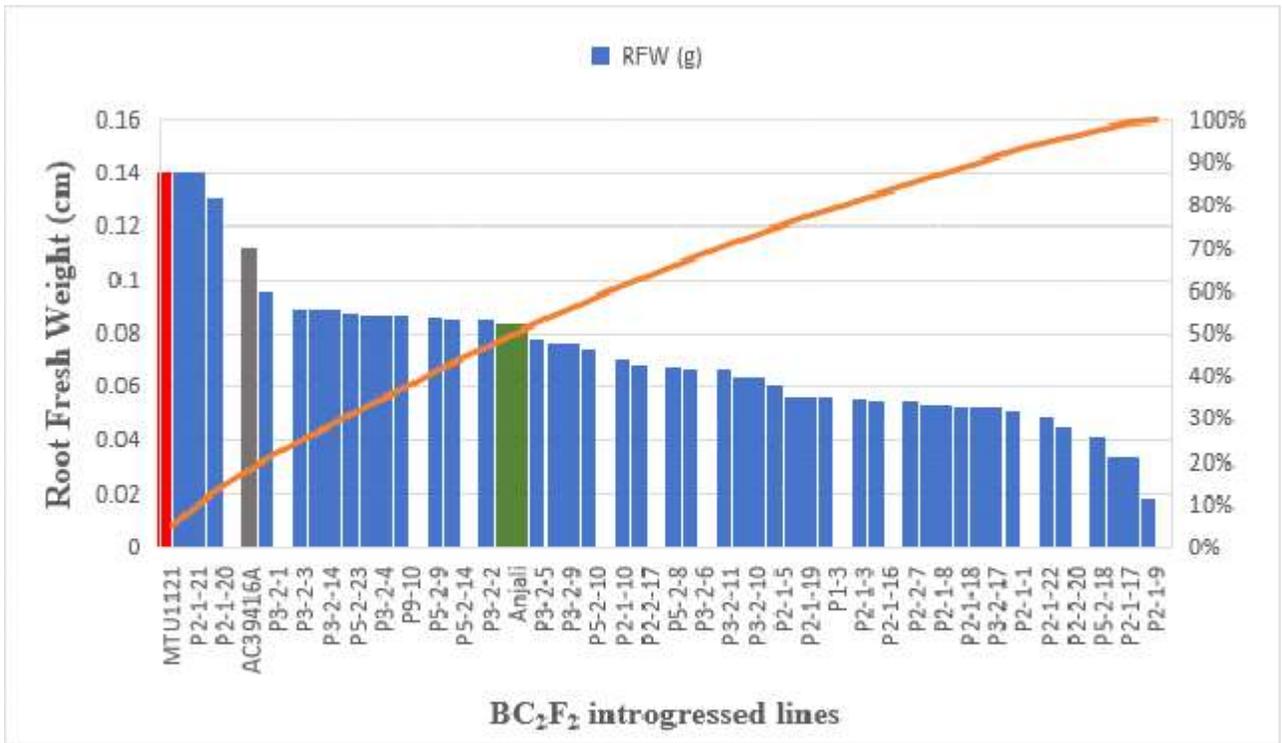


Figure 6. Performance of BC₂F₂ plants for root fresh weight

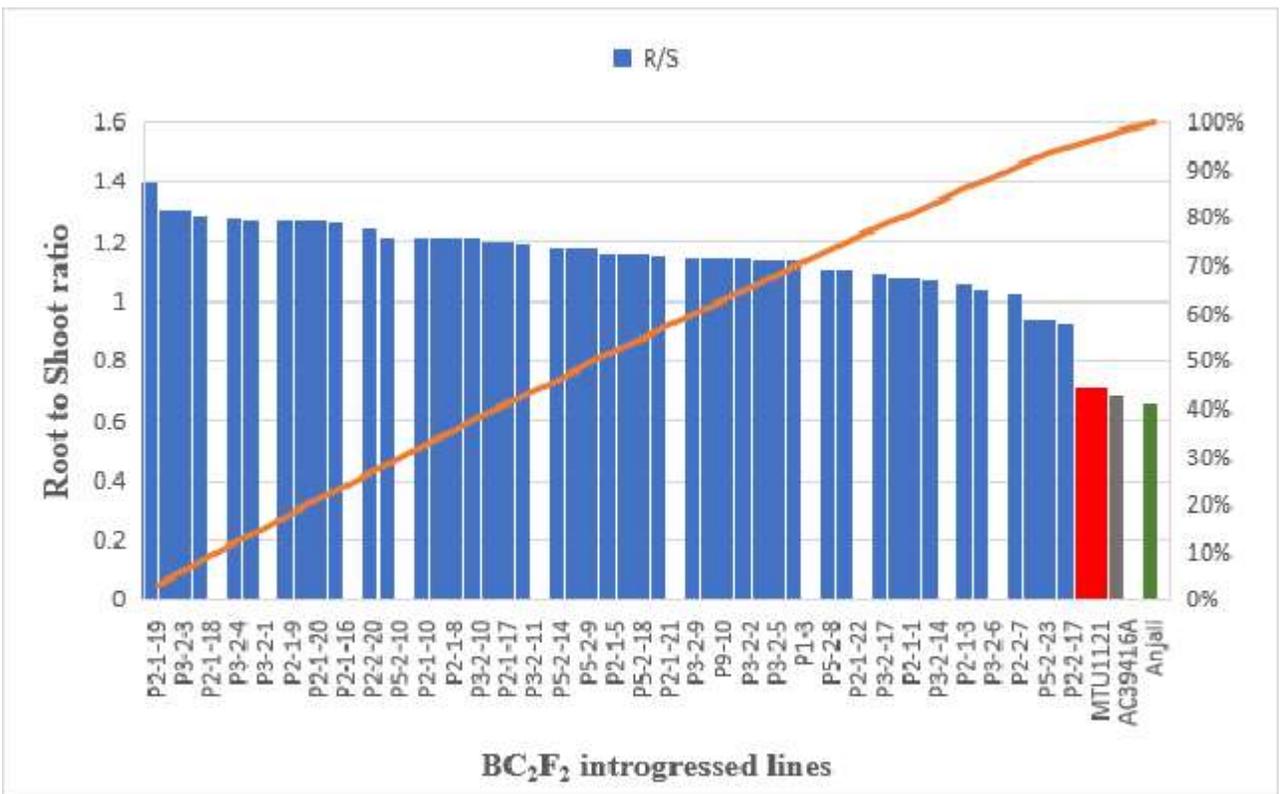


Figure 7. Performance of BC₂F₂ plants for root to shoot ratio

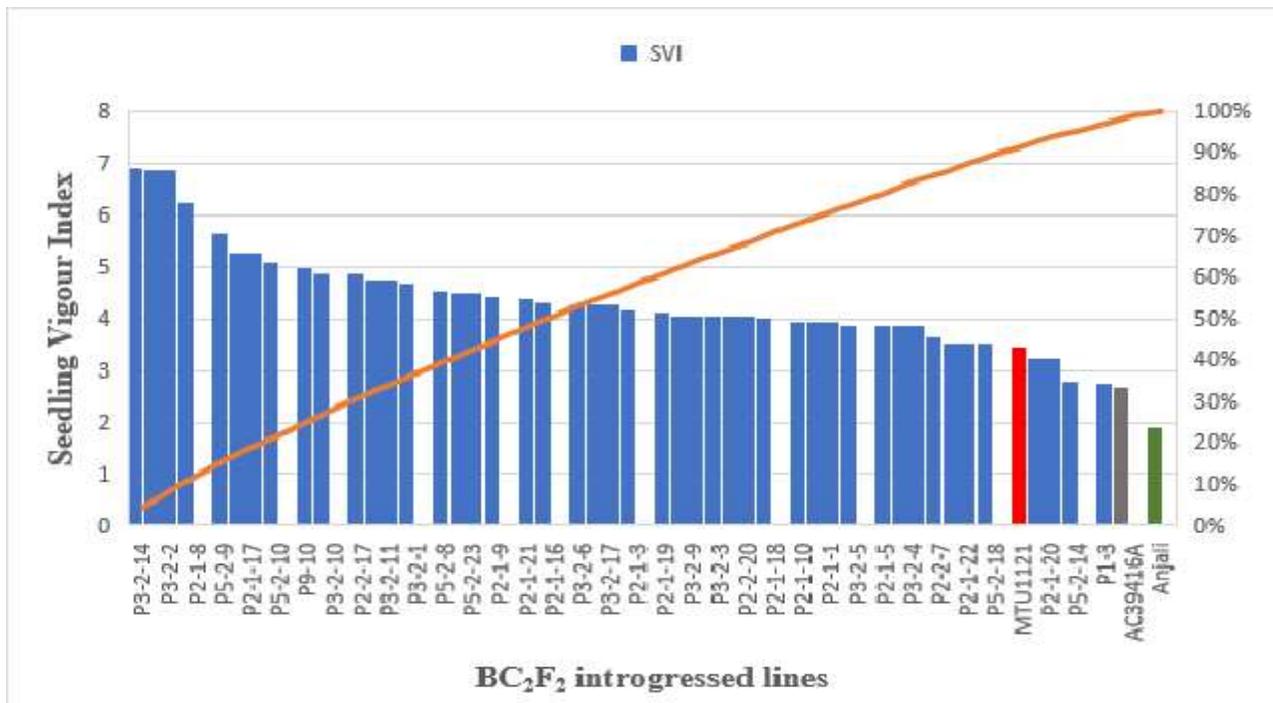


Figure 8. Performance of BC₂F₂ plants for seedling vigour index

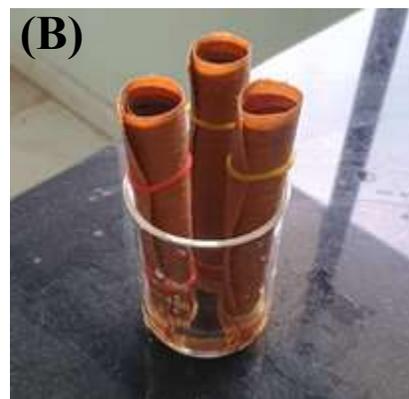




Plate 1. Phenotypic screening for early seedling vigour, (A) Screening for ESV by paper towel method, (B) Labelling of genotypes, (C) Germination of seedling after 7 days, (D) Germination of seedlings after 14 days.

0.463 g and while none of the lines equalled the higher biomass of MTU1121 (0.755 g), most matched or approached the donor Anjali (0.532 g).

Seedling length (cm)

Seedling length is a key indicator of early seedling vigour in direct-seeded rice, as it reflects combined shoot and root growth, enabling rapid emergence, early establishment and improved weed competitiveness (Sagar *et al.*, 2025).

Seedling length, integrating shoot and root growth, ranged from 23.19 cm (P2 1 5) to 35.21 cm (P2 1 9), with a mean of 29.48 cm; lines P2 1 8, P2 1 9, P2 1 17, P2 1 18 and P3 2 14 were comparable to MTU1121 (34.92 cm) and Anjali (34.69 cm).

Shoot fresh weight (g)

Shoot fresh weight ranged between 0.159 g (P5 2 18) and 0.306 g (P3 2 14), averaging 0.216 g and many derivatives (e.g. P3 2 14, P3 2 4, P5 2 9, P5 2 23) equalled or exceeded MTU1121 (0.221 g), while all surpassed Anjali (0.174 g).

Root fresh weight (g)

Root fresh weight showed larger proportional variation (0.019–0.141 g; mean 0.072 g); P2 1 21 matched MTU1121 (0.141 g) and several lines exceeded Anjali (0.084 g) and the check AC39416A (0.079 g).

Root-shoot ratio

Root to shoot ratio ranged from 0.92 (P2 2 17) to 1.40 (P2 1 19) with a mean of 1.13 and all BC₂F₂ lines and AC39416A showed higher ratios than MTU1121 (0.71) and Anjali (0.66), indicating stronger allocation to roots at early stages.

Seedling vigour index (SVI)

The seedling vigour index (SVI), derived from germination percentage and seedling dry weight (Vijay *et al.*, 2010), reflects seed energy reserves, physiological strength and the capacity for early establishment and resilience in direct-seeded rice (Sagar *et al.*, 2025).

The SVI ranged from 2.77 (P1 3) to 6.93 (P3 2 14), with a population mean of 4.44; the majority of lines recorded higher SVI than MTU1121 (3.47) and far exceeded Anjali (1.93), while AC39416A showed the highest SVI (8.95). This pattern indicates that many lines combined moderate to high biomass and length traits into superior overall vigour.

Breeding Implications

The significant variability observed confirms the effectiveness of marker-assisted backcrossing in improving early seedling vigour within the MTU1121 background. The identified BC₂F₂ lines combine favourable vigour traits with high recurrent parent

genome recovery, making them valuable pre-breeding material for DSR-oriented rice improvement.

The BC₂F₂ population exhibited highly significant genetic variation for all early seedling vigour traits. Several lines, notably P3-2-14, P3-2-2, P2-1-9 and P5-2-9, demonstrated superior root growth, biomass accumulation and higher seedling vigour index compared to MTU1121. The results confirm that early seedling vigour can be substantially enhanced through marker-assisted backcrossing and the identified BC₂F₂ lines can constitute promising material after further evaluation under direct-seeded rice conditions.

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