Breeding of Cold Tolerant Rice with High Yield and Desirable Grain Quality Traits

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Abstract

Rice is cultivated all over the world especially Asian countries. Though rice is adaptable to tropical to temperate climate, low temperature is the major limitation in temperate countries. Similarly in India cold stress affects rice production in high altitude regions. Low temperature at various growth stages especially seedling stage and reproductive stage leads to crop failures. Cold stress at seedling stage leads to seedling injury and even seedling mortality in severe cases which leads to poor crop stand. At reproductive stage, severe yield loss due to incomplete exsertion of panicle and spikelet sterility.In Krishnagiri district of Tamilnadu the popular varieties viz., BPT 5204, White Ponni, Paiyur 1 and ADT 43 are highly susceptible to cold stress and hence it is necessary to breed varieties with cold tolerance so as to cultivate rice during September- October sowing. With this aim the popular rice varieties viz.,ADT 43, Paiyur 1, TKM 13, IR 42, IR36, PS2, Karuppu nel and White ponni were screened for cold tolerance. The varieties IR 36, IR 42, PS 2 and Karuppunel were found to be cold tolerant. Hybridization among these varieties yielded 31 hybrids and selection from the segregating population from F1 to F6 generation was done to select the homozygous line PYR 12-07-01. The study on yield and yield attributes of the culture PYR 12-07-01along with other check varieties revealed that it has high yield potential of 6.1tonnes/ha with 24 productive tillers/plant and 260 grains/panicle. The new culture PYR 12-07-01 performed better than the checks IR 20 and IR 36. Yield increase over the checks IR 20 and IR 36 was 11.5 % and 10.1% respectively. From the yield trials conducted, an early maturing high yielding rice culture PYR 12-07-01, a hybrid derivative of the cross ADT 43 x PS 2, maturing in 105 days has been identified. This culture is suitable for cultivation in Northwestern region of Tamil Nadu during cold season (Oct-Jan).

Introduction

Rice is the staple food for nearly 60 per cent world population especially Asia and Africa. Rice is cultivated in many countries around the globe with India being the largest grower while China being the largest producer. Though Rice needs hot and humid climate to produce high yield, it is also adaptable to temperate regions**[1]**. The optimum temperature for rice production is 20°C to 27°C.The stress caused by low temperatures is a major limitation for rice production in temperate and subtropical zones [2], thus developing cold tolerant cultivars is a major focus of some rice breeding programs [6, 7]. Cold stress occurs when the temperature falls below 17°C causing poor germination, seedling injury, poor stand establishment, and reduction of yield stability and productivity [8, 9**].** Low temperature at various growth stages especially seedling stage and reproductive stage leads to crop failures. Cold stress at seedling stage leads to seedling injury and even seedling mortality in severe cases which leads to poor crop stand. At reproductive stage, severe yield loss due to incomplete exsertion of panicle and spikelet sterility [13, 14]. Despite the general sensitivity of rice to low temperatures, a range of cold tolerance exists among rice cultivars (accessions) [10, 11] and overall, *indica* accessions are reported to be more sensitive to cold stress than japonica accessions [3, 12]. Identifying accessions with high levels of cold stress tolerance is an essential step toward developing

cultivars with better cold tolerance and improving rice production in regions where cool temperatures limit rice yield[4,5].Based on the mild climate and water availability from the Krishnagiri river project and both the monsoons, usually farmers choose to cultivate medium duration cultures for two seasons (first season: July-August, second season: Nov-Dec). Wherever assured water is available for more than five months, farmers go for long duration varieties like white ponni and Paiyur-1 during first week of June. July sowing, farmers go for cultivating BPT-5204 in larger areas and during second season it is ADT-39. Farmers who have open wells are able to take up sowing during optimum season (May-June). But 90% of the farmers in KRP area solely depend upon dam water to irrigate the rice crop. The popular varieties are highly sensitive to cold; when the sowing is delayed to sept-oct, pre-booting coincides with low temperature (below 18°C) and causes spikelet sterility and based on initial cold screening most of the popular varieties are sensitive to cold exhibiting higher level of spikelet sterility (>60%). The following varieties are highly sensitive to cold viz., Paiyur-1, BPT-5204, Bhavani, White ponni and moderately tolerant varieties are ADT-39, IR-20 and CO-43. Highly cold tolerant lines are IR-36, Anna-4, karuppu nel, kotta nellu and savulu samba. The evaluation was based on panicle emergence, pollen fertility and spikelet fertility %. It is essential to develop cold tolerant rice lines with short duration to be suitable for sept-oct (late sowing) combined with cooking quality for Krishnagiri and Dharmapuri districts. Cooking quality traits should be similar to white ponni, Paiyur-1 and BPT-5204.

Materials and Methods

Identification of cold tolerant genotypes

The popular rice varieties viz., ADT 43, Paiyur 1, TKM 13, IR 42, IR36, PS2, Karuppu nel and White ponni were exposed to low temperature at pre booting stage and observations were recorded on panicle exsertion, spikelet sterility and single plant yield.

Hybridization

The cold tolerant genotypes were crossed with popular varieties including reciprocals as presented in Table 1.

Table 1. List of Hybrids developed

1. ADT 43 x IR 42	16. IR 36 x Karuppunel
2. ADT 43 x IR 36	17. IR 42 x Karuppunel
3. ADT 43 x PS 2	18. White ponni x Karuppunel
4. Paiyur 1 x IR 42	19. Paiyur 1 x Karuppunel
5. Paiyur 1 x IR 36	20. IR 42 x ADT 43
6. Paiyur 1 x PS 2	21. IR 42 x Paiyur 1
7. TKM 13 x IR 42	22. IR 42 x TKM 13
8. TKM 13 x IR 36	23. IR 42 x White Ponni
9. TKM 13 x PS 2	24. IR 36 x ADT 43

10. White Ponni x IR 42	25. IR 36 x Paiyur 1
11. White Ponni x IR 36	26. IR 36 x TKM 13
12. White Ponni x PS 2	27. IR 36 x White Ponni
13. ADT 43 x Karuppunel	28. PS 2 x ADT 43
14. TKM 13 x Karuppunel	29. PS 2 x Paiyur 1
15. PS 2 x Karuppunel	30. PS 2 x TKM 13
	31. PS 2 x White Ponni

Study of F_1 to F_6 generation and selection

F_1's of thirty one cross combinations was raised during September 2015 and selection was made based on duration, cold tolerance, yield and yield attributing traits. Promising families were forwarded upto F6.

In F_6 selection was made based on duration, cold tolerance, yield and yield attributing traits.

Advanced Yield Trial I:

Under AYT I, new culture PYR 12-07-01 was compared with the popular varieties viz, BPT 5204, Paiyur 1, ADT 43, ADT 39, IR 20, PS 2, Co 51, TKM 13, White Ponni, Bhavani and IR 36 under cold conditions during pre booting for yield and yield attributing traits, duration and cold tolerance.

Advanced Yield Trial II:

Under AYT II, the varieties viz, BPT 5204, Paiyur 1, ADT 43, ADT 39, IR 20, PS 2, Co 51, TKM 13, White Ponni, Bhavani and IR 36 were compared with new culture PYR 12-07-01 under cold conditions during pre booting for yield and yield attributing traits, duration and cold tolerance.

Results and Discussion

Among the popular rice varieties viz., ADT 43, Paiyur 1, TKM 13, IR 42, IR36, PS2, Karuppu nel and White ponni screened for cold tolerance the varieties IR 36, IR 42, PS 2 and Karuppunel were found to be cold tolerant (Table 2).

The culture PYR 12-07-01 selected from F6 generation was evaluated under advanced yield trial and the results are presented in Table 3.The culture is short duration and matures in 105 days. It produced 21 productive tillers/hill, 190 grains/panicle and grain yield of 6.0tonnes/ha. It also showed complete exsertion of panicle from boot leaf sheath and low pollen and spikelet sterility. Based on these traits it is inferred that the culture PYR 12-07-01is tolerant to cold stress.(Table 4). The yield levels of new cold tolerant rice culture PYR-12-07-01 were compared with promising varieties of rice. New culture recorded an yield of 6100 kg/ha and the percentage increase over the checks CO-51 and BPT-5204 were 5.0 and 10.0 % respectively for grain yield

The study on yield and yield attributes of the culture PYR 12-07-01along with other check varieties revealed that it has high yield potential of 6.1tonnes/ha with 24 productive tillers/plant and 260 grains/panicle. The new culture PYR 12-07-01 performed better than the checks IR 20 and IR 36. Yield increase over the checks IR 20

and IR 36 was 11.5 % and 10.1% respectively. From the yield trials conducted, an early maturing high yielding rice culture PYR 12-07-01, a hybrid derivative of the cross ADT 43 x PS 2, maturing in 105 days has been identified. This culture is suitable for cultivation in Northwestern region of Tamil Nadu during cold season (Oct-Jan).

Under Advanced Yield Trial I, new rice culture PYR 12-07-01 was compared with the popular rice varieties viz, BPT 5204, Paiyur 1, ADT 43, ADT 39, IR 20, PS 2, Co 51, TKM 13, White Ponni, Bhavani and IR 36 grown in North western zone under cold conditions (Nov-Jan) during pre booting for yield and yield attributing traits, duration and cold tolerance. In AYT, the new culture recorded a grain yield of 6100 kg/ha and the percentage increase over the checks CO-51 and BPT-5204 were 5.0 and 10.0 % respectively for grain yield.

This culture showed higher pollen fertility than other varieties (Fig.1). Similarly the panicles of this culture showed complete exsertion of panicle from boot leaf sheath (Fig.2.). The grain quality is preferable as white ponni and BPT 5204(Fig.3,4,5). Hence the culture PYR 12-07-01 can be advanced further to release as a cold tolerant variety.

Table 2. Scoring of Genotypes for cold tolerance

Variety	Pollen Fertility (%)	Spikelet fertility (%)	Panicle exsertion (%)	Cold tolerance
Paiyur-1	52	46	76	Susceptible
ADT-43	65	55	70	Susceptible
Karuppunel	82	86	100	Highly tolerant
IR-42	78	75	96	Moderately tolerant
PS-2	76	78	98	Moderately tolerant
TKM-13	68	55	80	Susceptible
White Ponnni	55	48	70	Susceptible
IR-36	80	82	100	Moderately tolerant

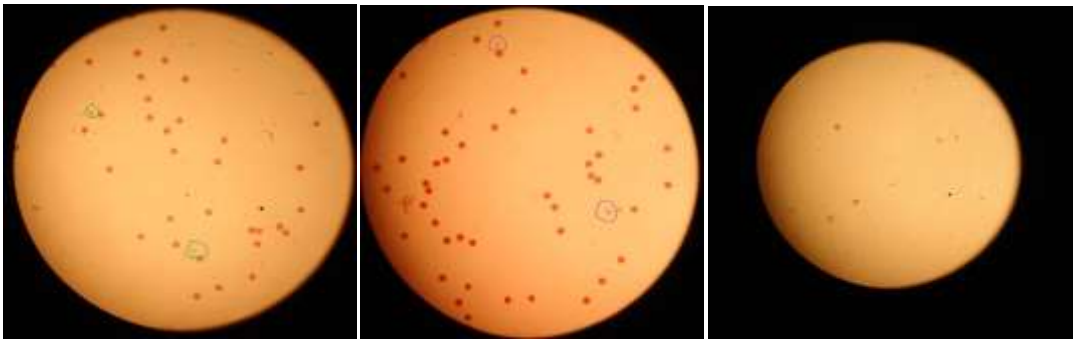
Table 3. Performance of PYR12-07-01under cold condition for yield and yield attributes

Variety	Days to flowering	Days to maturity	Plant height (cm)	No of productive tillers	No of grains/ panicle	Yield/ plant (g)	Yield Kg/ha
BPT-5204 (c)	80	135	60	28	260	50.0	5500
Paiyur-1	90	145	95	18	300	45.0	6100
ADT-43	75	110	64	20	200	35.0	5200
ADT-39	80	120	65	21	140	50.0	5500
IR-20	80	120	100	24	160	56.0	6000
PS-2	80	120	65	25	180	45.0	6200
CO-51 (c)	75	110	60	24	250	48.0	5800
TKM-13	80	120	60	20	100	55.0	6500
White Ponnni	90	150	90	12	145	55.0	5500
Bhavani	90	135	90	14	250	45.0	4500
IR-36	65	105	65	20	180	50.0	5500
PYR12-07-01	65	105	90	24	260	50.0	6100

Table 4. Yield and cold stress tolerant attributes of PYR12-07-01

Variety	Days to flowering	Days to maturity	Plant height (cm)	No of productive tillers	No of grains per panicle	Yield (t/ha)	Cold tolerance	Panicle emergence	Pollen Fertility
BPT-5204	80	120	60	18	50	6.0	Sensitive	Poor	Low
Paiyur-1	90	130	95	14	60	6.0	Sensitive	Poor	Low
ADT-43	75	110	64	20	120	5.8	Moderate	Partial	Moderate
ADT-39	80	120	65	16	140	5.9	Moderate	Partial	Moderate
IR-20	80	120	80	20	160	5.2	Moderate	Partial	Moderate
PS-2	80	120	65	16	80	5.6	Moderate	Partial	Moderate
CO-51	75	110	60	21	150	5.4	Moderate	Partial	Moderate
TKM-13	80	120	60	20	100	5.5	Moderate	Partial	Moderate
WhitePonnni	90	150	90	12	45	5.8	Sensitive	Poor	Low
Bhavani	90	135	90	14	30	5.6	Sensitive	Poor	Low
IR-36	65	105	65	20	180	5.5	Tolerant	Complete	High
PYR12-07-01	65	105	65	21	190	6.0	Tolerant	Complete	High

Fig.1. Pollen fertility under cold stress



Karuppu nel	PYR 12-07-01	ADT 43

Fig 1 & 2: PYR-12-07-01 has complete panicle emergence and high pollen fertility compared to the sensitive variety ADT 43

Fig 2. Panicle exsertion under cold stress

Karuppu nel	PYR 12-07-01	ADT 43

Fig.3 Genetic characters of cold tolerant rice culture PYR 12-07-01:

a. Angular boot leaf

b. Panicles above the boot leaf

c. Super fine grains

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