# Developing climate resilient rice varieties suitable to the below sea-level farming regions of Kuttanad

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**Abstract**

Rice farming in below sea-level regions of Kuttanad,which accounts for 20 per cent of Kerala's rice production is under threat due to the untimely heavy rainfall and flash floods occurring as part of climate change.To address this issue, a breeding programme based on pedigree method was initiated at M.S. Swaminathan Rice Research Station, Moncompu aiming to develop rice varieties resilient to these challenges, particularly focusing on submergence tolerance, seed dormancy and lodging resistance. Two cultures namely, KAUM 179-1 and KAUM 180-2 were identified as suitable to this region. Both are medium duration, non-lodging cultures with seed dormancy. KAUM 179-1 is having red kernel with moderate tolerance to submergence in the vegetative stage and KAUM 180-2 is having white kernel with slight tolerance to submergence.

**Key Words**: Climate resilient; KAUM 179-1; KAUM 180-2; Rice variety; Submergence tolerance

## Introduction

Kuttanad wet land agriculture system is a unique farming system where rice cultivation is practiced below sea-level (BSL). It is a deltaic formation located in Kerala, a southern state of India. The Food and Agriculture Organization (FAO) has designated the Kuttanad system as a Globally Important Agricultural Heritage System (GIAHS). The region extends from 9º 17' to 9º 40' N latitude and 76º 19' to 76º 33'E longitude. The economy of the region is primarily dependent on rice cultivation, which is the only viable crop in the BSL area.

Located in the deltaic region of four rivers, rice cultivation in Kuttanad is susceptible to flash floods during the monsoon season (Manorama and Padmakumar, 1999). Climate change has exacerbated this problem, leading to shifts in rainfall patterns and untimely rains throughout the cropping period. Recent years have seen increased yield volatility due to these ecological changes (Jacob, 2020). Developing high yielding rice varieties tolerant to submergence caused by flash floods enhances the region's climate resilience (Bairagi et al. 2021). Apart from this, varieties bred for this region should invariably possess seed dormancy, lodging resistance, pest and diseases tolerance to thrive in this region (Devika et al. 2004).

## Materials and Methods

Hybridisation was carried out between traditional rice variety Thavalakkannan, identified as donor for submergence tolerance through artificial screening and high yielding rice varieties Uma and Gouri. The following four crosses were made; Thavalakannan/ Uma, Uma/Thavalakkannan, Thavalakkannan/ Gouri and Gouri/Thavalakkannan. Pedigree selection method was followed and selections of superior genotypes were made from segregating generations upto F6. Fifty-four stabilized cultures

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were selected for conducting Initial Evaluation Trial (IET). During 2011 and 2012 IET's were conducted in Randomized Block Design (RBD) with two replications. Two most popular rice varieties of Kerala, Uma and Jyothi were used as standard check. Promising 13 cultures identified were forwarded to Preliminary Yield Trial (PYT). During 2013 and 2014 PYT was conducted in RBD design with two replications. Screening for lodging resistance was also done as per Standard Evaluation System for Rice (IRRI, 2002) in the field condition during *Kharif* 2013.The screening was conducted in the PYT trial plot itself at the maturity stage of the crop under severe rainfall condition. Lodging resistance was calculated as lodging incidence percentage [(number of lodged plants/ total number of plants) x 100].

Two superior cultures identified were promoted to Comparative Yield Trial (CYT). From 2015 to 2019, CYT was conducted for eight seasons along with four check varieties *viz.,* Uma, Jyothi, Prathyasa and Shreyas in RBD with three replications. Bartlett's Chi-square test was conducted for testing of homogeneity of variances. Pooled analysis (RBD) of CYT data was performed after data transformation. The grain and cooking quality of the cultures were analyzed at laboratory of Indian Council of Agricultural Research-Indian Institute of Rice Research (ICAR-IIRR), Hyderabad; MS Swaminathan Rice Research Station (MSSRRS) Moncompu and commercial mill. The morphological characteristics and grain quality were studied following Standard Evaluation System for Rice (IRRI, 2002).

The cultures were nominated to All India Coordinated Rice Improvement Programme (AICRIP) during 2016 and were tested in different locations across India. Artificial and field screening for tolerance to major pest and diseases were also conducted during this period following Standard Evaluation System of Rice (IRRI, 2014) at MSSRRS, Moncompu and AICRIP trials. The general 9-point scale ranges from 0 to 9, where '0' indicates no incidence and 9 being most susceptible. Farm trial of these two cultures was done along with the popular rice variety Uma as check during 2020 and 2021 at 16 locations across Kerala.

*Screening for submergence tolerance*

Natural screening for flood tolerance was done during heavy flood experienced in the standing crop of 2013 (PYT), 2019 (CYT) and 2020 (Farm trial). In *Kharif* 2013 flood occurred at the nursery seedling stage and the total rainfall recorded during the month of June was 94.4 cm. Whereas, during *Kharif* 2019 crop was in tillering stage (41 day after transplanting) and was under flood water for 10 days. During *Kharif* 2020, cultures in earlyseedling stage were under submergence for 17 days at the farm trial location-1. The total rainfall received during the four-month crop growth period in 2019 and 2020 was 189 cm and 178 cm respectively.

Artificial screening for submergence tolerance was conducted with cultures advanced to CYT in screening tanks of 1.5 m height using three-week-old seedling. Swarna-Sub1 and IR64-Sub1were used as resistant check; IR64 and Uma were used as susceptible check. Five plants of a single variety were raised in a pot and pots were replicated thrice. The cultures were submerged for 14 days and survivals of plants were scored two weeks after de-submergence.The significance of the experiment was calculated. Arcsine transformation was done on the survival percentage data before testing the significance.

## Results and Discussion

Segregating population from four crosses were stabilized by F6 generation and 54 lines were selected for IET from which 13 cultures identified to be superior in terms of yield and agronomic traits were forwarded to PYT. Mean expression of plant character of the best 13 cultures selected based on yield and agronomic traits are given in the Table 1. Kuttanad, being a low-lying vulnerable land with deep marshy soils prone to frequent flood, the

*Table 1.* Mean expression of plant character during PYT

| Variety/ Culture | Lodging incidence (%) | Grain yield (kgha$^{-1}$) Kharif 2013 | Kharif 2014 | Mean |
|---|---|---|---|---|
| KAUM-179-1 | 10.4 | 5062 | 5188 | 5125 |
| KAUM-179-2 | 52.8 | 5770 | 5195 | 5483 |
| KAUM-179-3 | 10.2 | 6132 | 4265 | 5198 |
| KAUM-179-4 | 10.2 | 6178 | 3661 | 4920 |
| KAUM-179-5 | 5.8 | 5798 | 3307 | 4553 |
| KAUM-179-6 | 13.6 | 5631 | 5121 | 5376 |
| KAUM-179-7 | 75.4 | 4115 | 3958 | 4037 |
| KAUM-180-1 | 100 | 3958 | 4115 | 4037 |
| KAUM-180-2 | 9.8 | 4587 | 5261 | 4924 |
| KAUM-180-3 | 98.7 | 6941 | 3900 | 5420 |
| KAUM-181-1 | 14.6 | 4761 | 3633 | 4197 |
| KAUM-182-1 | 87.8 | 5465 | 3879 | 4672 |
| KAUM-182-2 | 90.2 | 5964 | 4006 | 4985 |
| Uma | 0 | 3817 | 5447 | 4632 |
| Jyothi | 100 | 2735 | 3146 | 2941 |
| CD(0.05) | | 1620 | 1539 | 1580 |

varieties developed for this region should be lodging resistant and tolerant to submergence. The cultures KAUM 179-1 and KAUM 180-2 were forwarded to CYT based on the yield, submergence tolerance and lodging resistance. The mean performance of cultures in station trials (Table 2) shows that KAUM 179-1 (6396 kg ha$^{-1}$) and KAUM 180-2 (7576 kg ha$^{-1}$) has significantly superior yield compared to the check varieties in IET's. The yield of cultures was superior to Jyothi and was on par with the variety Uma in the combined mean of PYT's.

*Table 2.* Mean performance of cultures in station trials

| Variety/ Culture | Grain yield (kg ha$^{-1}$) IET | PYT |
|---|---|---|
| KAUM 179-1 | 6396 | 5125 |
| KAUM 180-2 | 7576 | 4924 |
| Uma | 4001 | 4632 |
| Jyothi | 2014 | 2941 |
| CD (0.05) | 1308 | 1580 |

Pooled mean value of grain yield obtained in CYT, over eight seasons, after transformation is presented in Table 3. Significant differences between cultures were observed in all seasons except *Rabi* 2015 and *Kharif* 2017. Combined analysis of variance for the pooled data shows significant differences between varieties. In the CYT results, KAUM 179-1 exhibited superior yield compared to Jyothi, Prathyasa and Shreyas and comparable yield to KAUM 180-2 and Uma. Similarly, KAUM 180-2 showed superior yield compared to Jyothi, Prathyasa and comparable yield to Uma and Shreyas. Seasons also showed significant impact on yield with *Kharif* 2016 recording highest mean yield followed by *Rabi* 2018 and *Kharif* 2019. Interaction between varieties and season were also found to be significant. KAUM 179-1 showed significantly superior yield in *Kharif* 2016 and 2019 compared to other seasons. Whereas, KAUM 180-2 showed the superior yield in *Kharif* 2016 followed by *Rabi* 2018, *Rabi* 2017 and *Kharif* 2019. The results indicate that both the cultures were able to perform well in *Kharif* and *Rabi* seasons.

Distinguishing morphological traits and grain quality parameters of KAUM 179-1 and KAUM 180-2 are given in Table 4 and 5 respectively. Both are medium duration varieties with intermediate amylose content and medium gel consistency. The

*Table 3.* CYT mean values after data transformion

| Variety/ Culture | Rabi-2015 | Kharif-2016* | Rabi-2016* | Kharif-2017 | Rabi-2017* | Rabi-2018* | Kharif #2019* | Kharif 2020* | Mean |
|---|---|---|---|---|---|---|---|---|---|
| KAUM 179-1 | 2.386 | 13.076 | 7.259 | 6.246 | 9.773 | 7.782 | 12.152 | 7.46 | 8.267$^{a}$ |
| KAUM 180-2 | 2.256 | 12.978 | 6.373 | 6.001 | 8.408 | 9.446 | 8.685 | 7.03 | 7.647$^{ab}$ |
| Uma | 2.178 | 13.647 | 7.67 | 6.024 | 9.448 | 8.052 | 10.211 | 7.915 | 8.143$^{a}$ |
| Jyothi | 2.282 | 7.604 | 3.538 | 4.667 | 6.803 | 8.007 | 4.152 | 2.402 | 4.932$^{d}$ |
| Prathyasa | 1.825 | 12.718 | 3.913 | 5.813 | 10.376 | 5.789 | 7.462 | 4.071 | 6.496$^{c}$ |
| Shreyas | 1.498 | 12.914 | 5.26 | 4.45 | 10.436 | 8.861 | 8.562 | 5.487 | 7.184$^{bc}$ |
| Mean | 2.071$^{e}$ | 12.156$^{a}$ | 5.669$^{d}$ | 5.534$^{d}$ | 9.207$^{b}$ | 7.989$^{c}$ | 8.537$^{bc}$ | 5.727$^{d}$ | |
| CD for treatments | | | | | | | | | 0.762 |
| CD for seasons | | | | | | | | | 0.791 |
| CD for seasons X treatments | | | | | | | | | 2.154 |

# Experienced flood in vegetative phase; *Significant at 5 % level for individual season ANOVA

*Table 4*. Distinguishing morphological characters of KAUM 179-1 and KAUM 180-2

| Descriptors | KAUM 179-1 | KAUM 180-2 |
|---|---|---|
| Maturity (days) | 125 - 130 | 125 - 130 |
| Days to 50% flowering | 95 - 100 | 95 - 100 |
| Photosensitivity | Insensitive | Insensitive |
| Plant height (cm) | 107 | 103 |
| No.of productive tillers/ hill | 10 | 9 |
| Leaf length (cm) | 48 | 43.3 |
| Leaf width (cm) | 1.5 | 2.1 |
| Leaf blade pubescence | Glabrous | Intermediate |
| Blade colour | Green | Green |
| Basal leaf sheath colour | Green | Green |
| Leaf angle | Erect | Horizontal |
| Flag leaf angle | Erect | Erect |
| Collar color | Pale green | Pale green |
| Culm length (cm) | 92 | 90.5 |
| Culm angle | Erect | Erect |
| Culm diameter (cm) | 2.2 | 1.5 |
| Internode colour | Green | Green |
| Panicle length (cm) | 23.8 | 21 |
| No. of seeds/ panicle | 315 | 332 |
| Secondary branching | Clustering | Clustering |
| Panicle exertion | Moderately well exerted | Moderately well exerted |
| Awning | Short and partially awned | Short and partially awned |
| Awn colour | Purple | Purple |
| Thousand seed weight (g) | 21 | 23 |
| Kernel colour | Red | White |
| Grain type | Short-medium | Short-medium |
| Kernel elongation ratio | 1.2 | 1.2 |
| Volume expansion ratio | 3.4 | 3.5 |

cooking qualities of cultures were superior compared to Uma.

*Multi locational trials*

The test results of culture KAUM 179-1 and KAUM 180-2 under AICRIP, detailed in Tables 6 and 7 respectively, highlight their outstanding performance across various locations in India. Specifically, KAUM 179-1 achieved highest yields in Bhuvaneswar (7313 $kgha^{-1}$) and Moncompu (9860 $kgha^{-1}$) while KAUM 180-2 was top yielder in West Bengal (6023 $kgha^{-1}$).

Farm trial results from 16 locations showed that KAUM 179-1 and KAUM 180-2 has significant yield advantage over the check variety Uma (Table 8). KAUM 179-1 had a yield advantage of more than 5% in 11 locations, while KAUM 180-2 had a similar advantage in 9 locations. The mean yield from the farm trials demonstrated that KAUM 179-1 and KAUM 180-2 achieved a yield advantage of 13.18% and 10.16% over the current ruling variety, Uma, respectively.

*Reaction to major pests and diseases*

Field scoring for pests and diseases indicated a low incidence of major pests and diseases in KAUM 179-1 and KAUM 180-2 (Table: 9). The AICRIP

*Table 5*. Mean expression of grain characters

| Variety/ Culture | GL (mm) | GW (mm) | L/B ratio | SD (weeks) | ICAR-IIRR lab (Raw rice) | | | | | Commercial Mill (Parboliedrice) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AC (%) | GC (mm) | Hulling (%) | Milling (%) | HRR | Hulling (%) | Milling (%) |
| KAUM 179-1 | 4.7 | 1.8 | 2.61 | 2 | 21.09 | 45 | 81.7 | 67.8 | 43.6 | 79.72 | 75.94 |
| KAUM 180-2 | 5.1 | 2.0 | 2.6 | 1 | 20.76 | 43 | 81.2 | 67.6 | 50 | 78.5 | 70.61 |
| Uma | 4.9 | 2.0 | 2.45 | 3 | 22.26 | 28 | 81.8 | 68.8 | 51.4 | 80.84 | 75.35 |
| Jyothi | 5.8 | 1.8 | 3.2 | 0 | 21.64 | 55 | 80.9 | 64.8 | 44.6 | 76.7 | 70.44 |

GL: Grain length; GW: Grain width; SD: Seed dormancy; AC: Amylose content; GC: Gel consistency; HRR: Head rice recovery

*Table 6*. AICRIP mean grain yield (kg $ha^{-1}$) data of KAUM 179-1

| IET No. | BBN | CTK | BKG | SBR | CHN | LMB | RPR | JDP | SND | KJT | MNC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| KAUM 179-1 (IET: 26113) | 7313* | 4112 | 4650 | 5012 | 6292 | 5633 | 5683 | 5804 | 5703 | 5294 | 9860* |
| IR 64 | 3571 | 4139 | 3400 | 3088 | 5333 | 3883 | 5308 | 5235 | 4197 | 6061 | 6877 |
| Zonal Check | 3997 | 3849 | 4650 | 2089 | 4792 | 3825 | 5556 | 5238 | 3913 | 3523 | 6659 |
| Local Check | 5952 | 3764 | 4400 | 3548 | 5417 | 5279 | 4055 | 5906 | 4276 | 4923 | 8248 |
| C.D. (0.05) | 1577 | 721 | 1509 | 589 | 633 | 1394 | 1147 | 1186 | 918 | 956 | 1276 |

*Highest yielding variety in particular location *(Source: AICRIP Progress Report 2016)*

BBN:Bhuvaneswar; CTK:Cuttak; BKG:Bikramganj; SBR:Sabour; CHN:Chinsurah; LMB:Lembucherra; RPR:Raipur; JDP:Jagadalpur; SND:Sindewahi; KJT:Karjat; MNC:Moncompu

*Table 7.* AICRIP mean grain yield(kg ha$^{-1}$) data of KAUM 180-2

| IET No. | BBN | CHP | PTN | WB | VRN | WRS | SKL | NVS | RNR | ADT | PTB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| KAUM-180-2 (IET:25996) | 5526 | 6891 | 7363 | 6023* | 5563 | 5695 | 6293 | 4833 | 8995 | 7088 | 6373 |
| NDR 359 (National check) | 5526 | 6218 | 2853 | 4976 | 5875 | 3284 | 6821 | 4636 | 10338 | 5154 | 4070 |
| Zonal check | - | 9846 | 6265 | 5395 | 2625 | 6225 | 6145 | 4465 | 5859 | 6108 | 3931 |
| Local check | 5088 | 5038 | 6540 | 4350 | 2938 | 4945 | 5985 | 4005 | 5554 | 6538 | 5206 |
| CD (0.05) | 1127 | 606 | 692 | 548 | 1040 | 961 | 460 | 686 | 2370 | 2606 | 3501 |

*Highest yielding variety in particular location

CHP:Chiplima; PTN:Patna; W.B:West Bengal; VRN:Varanasi; WRS:Waraseoni; SKL:Sakoli; NVS:Navsari; RNR:Rajendranagar; ADT:Adathurai; PTB:Pattambi

(Source: AICRIP Progress Report 2016)

*Table 8.* Mean value of grain yield obtained from farm trial

| Location | Grain yield (kg ha$^{-1}$) | | |
|---|---|---|---|
| | KAUM 179-1 | KAUM 180-2 | Uma |
| L1# | 1296* (265.1) | 798* (124.8) | 355 |
| L2 | 6116 | 5666 | 6082 |
| L3 | 4890 | 4400 | 5010 |
| L4# | 7533* (44.87) | 7000* (34.62) | 5200 |
| L5 | 7900* (23.44) | 7300* (14.06) | 6400 |
| L6 | 7550* (11.85) | 7400* (9.62) | 6750 |
| L7 | 7450* (14.62) | 7250* (11.54) | 6500 |
| L8 | 7360 | 9600* (20.0) | 8000 |
| L9 | 5875* (27.36) | 7675* (59.87) | 4613 |
| L10 | 3444 | 4200 | 4367 |
| L11 | 6250* (42.8) | 5750* (31.43) | 4375 |
| L12 | 6167* (7.28) | 5667 | 5748 |
| L13 | 7142* (31.58) | 6571* (21.06) | 5428 |
| L14 | 6875* (12.24) | 5000 | 6125 |
| L15 | 7920 | 7400 | 7880 |
| L16 | 7471* (13.07) | 6864 | 6607 |
| Mean | 6327* (13.18) | 6158* (10.16) | 5590 |
| CD (0.05) | | | 535 |
| CV | | | 11.73 |

* More than 5% yield advantage over the check variety; % yield advantage over the check variety given in ( ); # Experienced flood in early vegetative stage

L1:Idayazham; L2:Chambakkulam; L3:Thekkekara; L4:Kareepra; L5:Kareepra; L6:Kareepra; L7:Kareepra; L8:Kainakary; L9:Thakazhy; L10:Nedumudy; L11:Kallara; L12:Pattambi; L13:Pattithara; L14:Nenmeni; L15:Kollengode; L16:Pallavoor

screening trials (Table: 10, 11) revealed that KAUM 179-1 is moderately tolerant to plant hoppers, stem borer, leaf damaging pest and leaf blast. Similarly, KAUM 180-2 exhibited moderate tolerance to plant hoppers, leaf blast, sheath rot and RTD.

*Screening for submergence tolerance*

The natural screening for submergence tolerance conducted during the flood event in *Kharif* 2013 identified three cultures, KAUM 179-1, KAUM 180-2 and KAUM 180-3 as moderately tolerant to submergence during early vegetative phase.Based on yield and agronomic traits KAUM 179-1 and KAUM 180-2 were promoted to CYT. During CYT conducted in *Kharif* 2019, where flood was experienced at vegetative phase, KAUM 179-1 showed 19.0% yield advantage over the best performing check variety Uma.

In farm trial plots, flood was experienced in location-1 and 4.At location-1, where field was submerged for 17 days, KAUM 179-1 and KAUM 180-2 showed 265.1% and 124.8% yield advantage over the check variety Uma respectively. In location-4 also both the cultures had given high percentage yield advantage over the check. This clearly depicts

*Table 9.* Reaction of KAUM 179-1 and 180-2 to major pest and diseases in the field

| Variety/ Culture | Reaction to major diseases (Score value) | | | | Reaction to majorpests | | | |
|---|---|---|---|---|---|---|---|---|
| | BLB | Blast | SB | SR | Stem borer (% DH) | | Gall midge (% SS) | |
| | | | | | 30 DAT | 50 DAT | 30 DAT | 50 DAT |
| KAUM 179-1 | 0.2 | 0 | 0.6 | 0 | 1.92 | 0 | 0 | 1.79 |
| KAUM 180-2 | 0.1 | 0 | 0.7 | 0 | 0.0 | 4.08 | 0 | 0 |
| Uma | 0.4 | 0.0 | 0.9 | 0.1 | 3.7 | 0.0 | 0 | 0 |
| Jyothi | 3.4 | 0.8 | 4.3 | 1.2 | 6.38 | 3.7 | 0 | 0 |
| Prathyasa | 1.4 | 0.4 | 0.8 | 0.1 | 0.0 | 0.0 | 0 | 0 |
| Shreyas | 1.2 | 0.1 | 1.5 | 0.1 | 5.88 | 5.66 | 0 | 0 |
| Pournami | 0.5 | 0.0 | 0.7 | 0.0 | 7.14 | 0.0 | 0 | 0 |

SR: Sheath rot; SB: Sheath blight; DH: Dead heart; SS: Silver shoot; DAT: Days after transplanting

*Table 10.* Reaction to diseases inAICRIP - NSN screening trial

| Variety/ Culture | LB | NB | SB | SR | BS | BLB | RTD |
|---|---|---|---|---|---|---|---|
| KAUM 179-1 | 3.5 | 5 | 5.9 | 6.1 | 4.9 | 6 | 5.7 |
| KAUM 180-2 | 3.7 | 5.6 | 6.1 | 4.8 | 4.9 | 6.5 | 4.3 |
| TN-1 | 5.2 | 6.8 | 6 | 4.9 | 4.7 | 6.9 | 7.7 |
| CO-39 | 6.7 | 7.7 | 6.7 | 5.7 | 6 | 6.7 | 7 |

LB: Leaf blast; NB: Neck blast; BS: Brown spot; BLB: Bacterial leaf blight; RTD: Rice tungro disease
(Source: AICRIP Progress Report 2014)

*Table 11.* Reaction to major pests in AICRIP - NSN screening trial

| Variety/Culture | BPH DS | PH DS | SB WE (%) | LDP DL (%) |
|---|---|---|---|---|
| KAUM 179-1 | 5 | 4 | 3 | 5 |
| KAUM 180-2 | 7 | 4 | 7 | 7 |
| BPT 5204 | 9 | 5 | 14 | 5 |
| Jaya | 9 | 6 | 6 | 9 |

BPH: Brown plant hopper; PH: Mixed population of BPH and WBPH; SB: Stem borer; LDP: Leaf damaging pest; DS: Damage score; WE: White ear; DL: Damaged leaves
(Source: AICRIP Progress Report 2016)

the submergence tolerance property of these two cultures.

Artificial screening results (Table 12) show significant differences in survival percentage and shoot elongation under submergence among the varieties. Swarna-Sub1, the tolerant check, exhibited the experiment's highest survival percentage and lowest stem elongation. KAUM 179-1 showed a 76.9 % survival rate, while KAUM 180-2 had a 23.1 % survival rate under submergence conditions, compared to Swarna-Sub1. The shoot growth of KAUM 179-1 and KAUM 180-2 under submergence was on par with Swarna-Sub 1.

Usually, under flash flood conditions, tolerant rice genotypes restrain elongation growth and conserve carbohydrate reserves to develop new leaves upon de-submergence (Jackson and Ram, 2003). Reduced elongation under flash flood conditions is vital for survival because the elongating plants tend to lodge as soon as the water recedes. Also, the genotypes with reduced elongation are likely to use only a small quantity of available carbohydrates for elongation growth, leaving enough reserve for survival during submergence (Sarkar et al., 1996) and resumption of growth after water recedes (Das et al., 2005). The flood-tolerant landrace identified from India, FR13A, adopts the same strategy that restricts growth, conserving energy until flood waters recede (Xu et al., 2006). The lower elongation rate and high survival rate of KAUM 179-1 under submerged conditions make it highly suitable for flash flood-prone regions.The reduced elongation prevents the variety from lodging after the flood water recedes. The basis of the increased survival ability of KAUM 179-1 might be the carbohydrate reserves; however, further studies need to confirm this fact.

Although KAUM 180-2 has a lower survival rate than KAUM 179-1, it performs better than Uma concerning submergence tolerance, produced on par yield with Uma in station trials, and showed a 10% yield advantage over Uma in farm trials. Also, KAUM 180-2 is white rice, whereas KAUM 179-1

*Table 12.* Results of artificial screening for submergence tolerance

| Variety/ Culture | Survival (%) | Comparative (%) survival with respect to Swarna-Sub1 | Increase in height during submergence (cm) |
|---|---|---|---|
| KAUM 179-1 | 66.7(54.75)[b] | 76.9 | 2.28[a, b] |
| KAUM 180-2 | 20(26.56)[c] | 23.1 | 1.6[a,b] |
| Uma | 2.6(9.28)[d] | 3 | 3.02[a, b] |
| Swarna-Sub1 | 86.7(68.61)[a] | 100 | 0.26[a] |
| IR 64-Sub1 | 60(50.76)[b] | 69.2 | 4.42[b] |
| IR 64 | 0(0) [e] | 0 | 8.14[c] |
| CD (0.05) | 6.686 | | 3.63 |

Transformed value is given in parenthesis and Uma are red rice, indicating the potential advantage of KAUM 180-2 in similar environments where white rice is preferred.

## Conclusion

On a final note, KAUM 179-1 is a high yielding medium duration, non-lodging, red rice culture with moderate submergence tolerance while KAUM 180-2 is a medium duration, non-lodging, white rice culture. Both cultures possess seed dormancy, which helps farmers reduce yield losses due to *in vitro* sprouting of seeds when harvest coincides with rain. Additionally, both varieties demonstrated significant yield advantages and moderate tolerance to submergence, which are crucial for the flood-prone regions of Kuttanad. The photo-insensitivity of both varieties make them suitable for cultivation in both *Kharif* and *Rabi* seasons, providing flexibility and stability in crop planning for farmers. This, combined with their other attributes, can lead to more reliable and increased rice production in the region.

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