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Application of selection index for rice mutant screening under a drought stress condition imposed at reproductive growth phase

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Abstract. *Sarwendah M, Lubis I, Junaedi A, Purwoko BS, Sopandie D, Dewi AK. 2022. Application of selection index for rice mutant screening under a drought stress condition imposed at reproductive growth phase. Biodiversitas 23: 5446-5452.* Drought is a condition of limited availability of water that can reduce rice growth and productivity, and may threaten food security. Therefore, efforts are needed to produce drought-tolerant rice genotypes. This study aimed to select drought tolerant of the M3 mutant upland rice population at the reproductive growth phase. This research was carried out in dryland at BATAN, Indonesia, from September 2020 to February 2021, using an augmented design. The study employed 360 genotypes of mutant upland rice and 5 check varieties, namely Salumpikit, IR20, IR64, Limboto, and Situgintung. The selection index was constructed based on multivariate analyses such as correlation, path, and Principal Component Analysis (PCA). The coefficient of the selected main component can be used as a selection index. Before selecting the character values of each genotype, the values were standardized to obtain the same degree of value. The results showed that grain weight per hill (W.G.), panicle density (P.D.), panicle length (P.L.), and the number of filled grains per panicle (NFG) could be used as selection criteria for mutant upland rice tolerant to drought at reproductive growth phase. The selection index formula was I = (5*0.44*WG) + (2*0.41*PD) + (0.23*PL) + (0.42*NFG). Selection of genotypes of mutant upland rice based on weighted index selection resulted in 89 genotypes with high yields and good agronomic characteristics so that they could be tested in further research.

Keywords: Augmented design, drought, mutant rice, selection index, upland rice

INTRODUCTION

Rice (*Oryza sativa* L.) is an important food crop requiring a lot of water during its life cycle compared to other crops. Therefore, water shortage or drought stress seriously threatens rice production, especially in areas that depend on rainwater as the main source of crop production (Pandey and Shukla 2015). Twenty-three million hectares of the rice area in Asia are prone to drought (Pandey and Bhandari 2009). The current main problems in upland rice cultivation are the decreasing availability of groundwater and erratic climate change, causing a prolonged drought. Upland rice often experiences water shortages because it is planted in dryland. Water availability for crop growth in upland rice is largely determined by rainfall patterns (Prakash et al. 2022). Drought is defined in the plant breeding field of study as an insufficient moisture supply that reduces plant production (Blum 2017). The risk of yield loss grows non-linearly with increasing drought severity (Leng and Hall 2019). Therefore, breeding for drought tolerance is more urgent for upland rice (Mau et al. 2019).

The response of rice plants to drought stress is dependent on the level and phase of rice growth (Moonmoon and Islam 2017). Rice plants are most sensitive to drought at the reproductive phase, as reported by many researchers (Zulfqar et al. 2016; Zhang et al. 2018; Darmadi et al. 2021), which is 20 days before to 10 days after flowering (Kumar 2011). Drought stress in the flowering phase caused a reduction in pollen count per stigma, pollen viability, and pollen germination rate (Gang-Shun et al. 2018). To overcome this problem, selecting rice genotypes tolerant to drought stress (Oladosu et al. 2016; Huang et al. 2019; Mustikarini et al. 2022) is necessary. Increasing grain yield under drought stress conditions is an important breeding goal (Heinemann et al. 2019; Sabouri et al. 2022). Mutation breeding using gamma rays irradiation is one breeding method to obtain the desired rice character (Li et al. 2019).

A study by Mustikarini et al. (2016) showed that gamma-ray irradiation with doses of 150 Gy and 200 Gy in red rice accessions could form mutants with a harvest time of fewer than 115 days after planting, and this treatment made rice more drought tolerant than before. Radiation doses produce responses with varying morphological and biochemical properties (Purwanto et al. 2019). The number of rice varieties that are tolerant to drought is still limited. Gamma irradiation mutation breeding has been proven to encourage more variations and provide opportunities for forming the expected new genotypes. Ionizing radiation has successfully induced genetic variability in Iranian rice germplasm (Hallajian 2014).

The selection of rice through field experiments to obtain mutant upland rice with good agronomic characteristics and tolerance to drought stress requires an effective and efficient selection method. One of the solutions is to use the index selection method. This method involves simultaneous selection for several characters formulated into the regression equation. By using the selected characters, an effective selection index can be formulated. Correlation and path analysis determine the relationship of the resulting character with other characters. Multivariate analysis can determine the characters used in determining the selection index and coefficients for weighting (Cruz 2013). The weighting of the values for each character selection is essential to the selection index creation. The use of multivariate analysis to obtain genotypes tolerant to various stresses has been developed, including that for the selection of salt-tolerant double haploid rice (Anshori et al. 2019; Anshori et al. 2021), selection of drought-tolerant double haploid rice (Akbar et al. 2018) and the determining the selection index of swamp rice lines resistant to bacterial leaf blight (Wening et al. 2018).

Currently, the M3 mutant upland rice has been obtained from gamma-ray irradiation at a dose of 200 Gy from the Situgintung variety. Therefore, the rice mutants need to be selected. This study aimed to select the M3 mutant rice population tolerant to drought at the reproductive phase under upland and controlled irrigation. This selection expected that a number of drought-tolerant mutant lines at the reproductive phase could be produced, which could then be used for further plant breeding programs.

MATERIALS AND METHODS

Genetic materials

The genetic material was the third generation of mutant upland rice (M3), IR20, IR64, Limboto, Salumpikit, and Situgintung. The mutant rice used in this study came from the Situgintung variety irradiated with 200 Gray gamma rays.

Time and location of the experiment

This research was conducted in the field from September 2020 to February 2021 at the BATAN Isotope and Radiation Application Center, South Jakarta ($6^0 17' 40,3''$ S $106^0 46' 26.8''$ E).

Research design

The research used a plastic house to avoid rainwater during drought treatment. The study design used was augmented. An augmented design is an incomplete design without replication in the tested mutants or strain; however, the check varieties were replicated in each block. Screening rice for tolerance to drought stress using an augmented design was also carried out (Shaibu et al. 2018). The number of M3 mutants used consisted of 360 genotypes. Each hole was utilized for one plant. In this study, Salumpikit and Limboto varieties were used as tolerant checks, IR20 and IR64 as sensitive checks and Situgintung as the parents of mutant.

In this experiment, mutant genotypes and check varieties were planted in the same stretch of land and divided into 6 blocks. Each block contained 60 rice mutants and 5 check varieties randomized in each block. Replication was only carried out on the check varieties (six replications), while the genotype number of rice mutant were not replicated. Five check varieties were placed among mutans within each block. Check varieties could be used to recover information lost due to the absence of replication in the design (Jambormias et al. 2013). Information recovery was a form of data adjustment. The spacing used was 25 cm x 25 cm. In each block, a tensiometer was installed to measure the groundwater potential.

Drought stress was imposed on the critical period of rice, which was 16 days before flowering to 10 days after flowering (Kumar 2011). Drought treatment started at 70 DAP, when the rice was in the early reproductive phase, with an estimated average age of all the genotypes was 120 days. Drought treatment was terminated after a sensitive check showed leaf curl with a score of 9 and the groundwater potential reached -35 KPa as measured by a tensiometer. After that phase, the plants were watered again until pre-harvesting. The variables observed were plant height, number of total and productive tillers, days to flowering, panicle length, number of filled and unfilled grains per panicle, panicle density, and grain weight per hill.

Data analysis

The data were analyzed using multivariate analysis using the R package Agricolae. Pearson correlation was used to determine the characters having a high correlation value to the results. Using path analysis, characters with high correlation values were then analyzed for their direct and indirect effects on the yields as the main character. Finally, principal component analysis was performed. The multiple-variable analysis could be used to reduce large amounts of data into a set of linear combinations that were still able to keep most of the information from the original data. The corrected data (adjusted data) was then standardized for calculating the selection index. The equation of the value of the selection index with the weighted selection index (WINDEX) follows Falconer dan Mackay (1996).

$$I = a1Z1 + a2Z2 + a3Z3 + \cdots + anZn$$

Where:
I : selection index for weighting
an : the weight of variable
Zn : phenotype value of every genotype that had been standardized for n variable

RESULTS AND DISCUSSION

The number of mutants selected was 192. They were selected based on phenotypic appearance in the field, such as plant structure, stem and leaf shape, and ability to survive drought conditions. Based on the results of descriptive statistical analysis for the selected mutants (Table 1), panicle density displayed the smallest standard deviation (0.76), followed by the flowering date, panicle length, and the number of productive tillers, 5.37, 7.43, and 9.09, respectively. The number of filled grains per panicle exhibited the highest standard deviation (46.47). Plant height ranged from 117.18 cm to 142.23 cm. The number of productive tillers ranged from 25.42 to 38.27, with an average of 31.84. This indicated an improvement in the mutant trait compared to the parent variety regarding the ability to produce tillers. Situgintung, as the mutant's original/wild type variety, had only 10-14 productive tillers. A high tiller count was related to panicle development between rice genotypes, and various genotypes react differently to water treatments (Sakai et al. 2010). The shortest flowering date was 88.6 days and the longest was 96.2 days, averaging 92.4 days. The maximum and minimum grain weight per hill was 9.38 g and 40.24 g, respectively, and the average grain weight was 24.81 g. The data for each character of the selected mutant rice number was data that had been adjusted to check varieties.

Correlation analysis

Correlation analysis can be used to determine the closeness between two characters. The value of r close to one indicates the closer the relationship between one character and the component of the production. In this study, it was represented by the weight of grain per hill. The results of correlation analysis showed that almost all the observed characters had a significant correlation with the yield, except for the character of days to flowering. Data from Table 2 showed that panicle density had a positive and significant correlation with grain yield which presented correlation coefficients of 0.98. This means that the denser the grain in each panicle, the higher the production. The number of unfilled grains per panicle significantly negatively correlated with the yield (r = -0.30). The fewer unfilled grains per panicle, the higher the grain weight per plant. In addition to these characteristics, the number of total tillers, number of productive tillers, plant height, panicle length, number of filled grains per panicle, and percentage of filled grain also showed a positive and significant correlation with yield. This correlation indicated that the higher the number of tillers, the higher the number of productive tillers, the longer the length of the panicle, and the higher the number of filled grains per panicle and the percentage of filled grain, the higher the yield. Therefore, high-grain yield genotypes will have many filled grains (Akbar et al. 2018).

High-yielding stable lines must be studied further to identify the key mechanism underlying drought tolerance under drought conditions (Saikumar et al. 2016). Under stress conditions, grain yield and related traits were significantly reduced (Gang-Shun et al. 2018). Several studies, such as that conducted by Anshori et al. (2021) showed that the total number of tillers per hill, the number of productive tillers per hill, plant height, panicle length, and the number of total grains per hill were significantly correlated with yield. Similarly, Gang-Shun et al. (2018) stated that greater panicle reduction efficiency and seed set percentage may be associated with decreased grain yield. Days to flowering in this study had an insignificant negative correlation with grain weight per hill. Different results were reported by Alsabah et al. (2019), in which days to flowering had a significant negative correlation with grain yield. The mean grains per panicle, grain weight per panicle, and grain production per plant were all considerably reduced by drought stress (Sharma et al. 2018).

Path analysis

Determination of dominant agronomic characters is also needed. Therefore, further analysis was conducted by utilizing path analysis. Path analysis is a method to partition the correlation results into direct and indirect effects. The high direct influence indicates the large proportion of the influence of these characters on the diversity of the main characters. Figure 1 showed the relationship between the direct and indirect effects of several agronomic characteristics on yield (weight of grain per hill). Based on the analysis results, it is known that not all characters having a significant correlation value had a high direct influence.

Path analysis showed that the panicle length, panicle density, and the number of filled grains per hill had a direct positive effect on the yield. Based on this analysis, panicle density was the character that had the highest direct effect (0.954), followed by panicle length and number of filled grains per hill (0.120 and 0.0064, respectively).

Table 1. Descriptive statistics of results and yield components of 192 selected mutant genotypes

Characters	Minimum	Maximum	Average	Standard deviation
Number of total tillers	24.05	44.10	34.08	14.18
Number of productive tillers	25.42	38.27	31.84	9.09
Plant height	117.18	142.23	129.70	17.71
Days to flowering	88.60	96.20	92.40	5.37
Penicle length	15.41	25.92	20.66	7.43
Number of filled grains per panicle	26.24	91.95	59.09	46.47
Number of unfilled grains per panicle	54.55	81.22	67.88	18.86
Number of total grains per hill	107.46	146.50	126.98	27.61
Percentage of filled grain	19.94	65.24	42.59	32.04
Penicle density	0.48	1.55	1.01	0.76
Weight of grain per hill	9.38	40.24	24.81	21.82

Meanwhile, the total number of tillers, plant height, number of unfilled grains per panicle, and percentage of filled grain had a direct effect with negative and low values (-0.039, -0.053, -0.049, -0.094, respectively). This indicated that the panicle length, panicle density, and the number of filled grains per hill were appropriate agronomic characters to be used as selection criteria for rice mutant selection under drought conditions at the reproductive phase. An increase in the number of filled grains per panicle will be followed by an increase in panicle fertility and seed production per hill. Thus, the results of this study showed that the number of filled grains per hill, penicle length, and penicle density contributed the greatest to seed production per hill.

The residual value of the path analysis showed how large the level of suitability of the path analysis was on the selection criteria for drought-tolerant rice. The residual value of the path analysis (Figure 1) was 0.018, meaning that 1.8% was the influence of other characters that were not included in the path. The value of the residual effect close to zero indicates the stronger the causal relationship from the correlation value. In addition, the observed characters were more complete and could explain direct and indirect effects completely.

Principal component analysis

Based on the results of Principal Component Analysis (PCA) (Table 3), there were 11 main component models. The selection of the right P.C. model was based on the P.C. value of the main character (Kumar et al. 2017), because the general goal of breeding was to obtain genotypes with high productivity. The selected model had the highest yield P.C. value (grain weight per hill). The selected P.C. model also looks at the P.C. value of supporting characters that can be considered, so the coefficients can be used as a model. PC1, PC2, and PC3 have Eigenvalues more than 1 (4.04, 2.40, 1.45, respectively). The principal component with an eigenvalue of more than 1 is a representative model to be used as a selection index because of the highly explainable diversity. PC1 explained 37% of the total variation, followed by PC2 and PC3 (24% and 15%, respectively).

In order to build a selection index, the combination of the eigenvector values of a P.C. can be used as a basis. As a result, the eigenvector value on a P.C. can be utilized as a priority value or initial character weight value on a P.C. (Anshori et al. 2019). Based on this, PC1 was the right model to be used as a determinant of the selection index because the value of the main character (grain weight per panicle) was the largest (0.44) and the three supporting characters were panicle density (0.41), panicle length (0.23), and the number of filled grains per panicle (0.42). Even though the eigenvalues of PC2 and PC3 were more than 1, they could not be used because the yield has a smaller P.C. value than the other characters, we expected that the crop yields have the largest P.C. value. Yield is the main character of selection, so the determination of representative PC is in the direction with the largest yield variance.

Furthermore, the number of empty grains per panicle on PC1 was negative. A negative P.C. on this character will maximize the selection of lines with a high number of empty grains per panicle. The use of principal component analysis is also reported to be effective in forming a selection index in identifying salinity tolerance characters (Farid et al. 2021).

Selection index

A technique for plant breeding for numerous characters is the selection index. This approach integrates the idea of linear regression with all selection characters (Acquaah 2012). The selection index is a genotype selection method tested based on variable values. A weighted selection index is required if the observed variables have different weights or selection pressures. The results of correlation analysis, principal component analysis, and characters used to determine the selection index were panicle density, panicle length, and number of grain contents per panicle. According to Anshori et al. (2018), the characters used as selection criteria are characters that can distinguish tolerant and sensitive genotypes. The selection index was done by assigning a weight based on PC1. Grain yield is an important trait commonly used as a selection criterion for drought tolerance (Shereen et al. 2017). The weight of grain per hill in this study was the main character of the selection, so the highest weight was given, namely 5; panicle density was given a weight of 2; panicle length and the number of filled grains per panicle were given a weight of 1, so that the selection index model was obtained as follows:

$$I = (5*0.44*WG) + (2*0.41*PD) + (0.23*PL) + (0.42*NFG)$$

Where: I: index value, WG: weight of grain per hill, PD: panicle density, PL: panicle length, NFG: number of filled grains per panicle

Selection of drought-tolerant rice mutants utilized this selection model. Each genotype's character values must be standardized to obtain the same degree of value. The results of the weighted selection index in this study showed that the check variety with the best selection index is Salumpikit. The selection of 192 genotypes of mutant upland rice using the existing model resulted in 89 genotypes with positive index values. Sixty-five genotypes have better performance than Salumpikit (Table 4). The 10 highest genotypes resulted from the screening of M3 mutant lines under drought stress conditions at the reproductive phase with a high weight of grain per hill, namely G29 (65.15 g), G197 (65.19 g), G110 (60.89 g), G193 (60.81 g), G27 (60.22 g), G229 (54.90 g), G52 (54.30 g), G70 (52.86 g), G214 (45.50 g), and G89 (49.70 g) had index values of 8.92, 8.87, 8.04, 8.02, 7.97, 6.98, 6.62, 6.60, 5.92 and 5.88, respectively. The development of tolerant varieties is an important effort to increase the production and productivity of dry land.

Table 2. Pearson correlation of all characters of mutant rice genotypes in the reproductive phase of drought stress

Character	TNT	NPT	PH	DF	PL	NFG	NUG	TGN	PFG	PD	WG
TNT	1										
NPT	0.89*	1									
PH	0.00	0.02	1								
DF	-0.51*	-0.53*	0.17*	1							
PL	0.1	-0.06	0.37*	0.17*	1						
NFG	-0.1	-0.11	0.47*	0.23*	0.35*	1					
NUG	0.04	-0.08	-0.08	-0.07	0.08	-0.37	1				
TGN	-0.07	-0.17*	0.44*	0.2*	0.42*	0.8*	0.26*	1			
PFG	-0.04	0.00	0.33*	0.18*	0.27*	0.75*	-0.79*	0.27*	1		
PD	0.4*	0.42*	0.43*	-0.08	0.18*	0.48*	-0.32*	0.29*	0.52*	1	
WG	0.35*	0.36*	0.51*	-0.03	0.30*	0.54*	-0.30*	0.37*	0.54*	0.98*	1

Note: *: significant correlation at α 0.05, TNT: total number of tillers, NPT: number of productive tillers, PH: plant height, DF: days of flowering, PL: panicle length, NFG: number of filled grain per panicle, NUG: number of unfilled grains per panicle, TGN: total grain number per panicle, PFG: percentage of filled grain, PD: panicle density, WG: weight of grain per hill

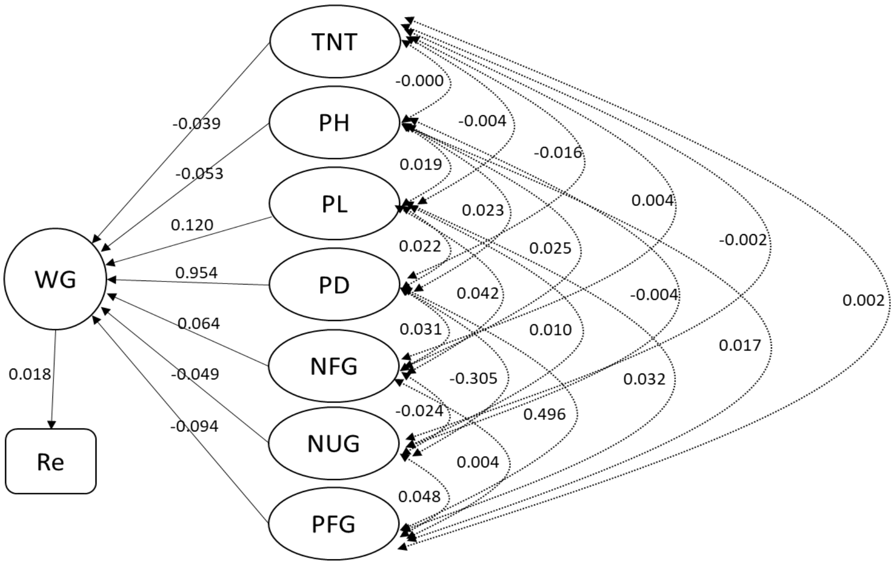

Figure 1. Path analysis diagram of the weight of grain per hill. ⟵: direct effect, ⟵┈┈: indirect effect, TNT: total number of tillers, PH: plant height, PL: panicle length, PD: panicle density, NFG: number of filled grain per panicle, NUG: number of unfilled grains per panicle, PFG: percentage of filled grain, WG: weight of grain per hill, Re: residual

Table 3. Selection results of several genotypes of mutant upland rice based on selection index by weighting

Character	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
TNT	0.10	0.54	0.16	-0.06	0.21	0.17	-0.33	-0.68	0.15	0.03	0.00
NPT	0.10	0.56	0.04	-0.03	0.07	0.06	-0.43	0.68	-0.16	-0.01	0.00
PL	0.32	-0.09	0.22	-0.32	-0.30	-0.74	-0.29	-0.09	-0.01	-0.03	0.00
DF	0.06	-0.44	-0.06	-0.45	-0.23	0.55	-0.50	0.00	0.00	0.01	0.00
PL	0.23	-0.12	0.35	-0.51	0.65	0.04	0.29	0.15	0.08	-0.09	0.00
NFG	0.42	-0.21	0.01	0.42	0.16	0.02	-0.18	0.07	0.32	-0.05	0.66
NUG	-0.22	-0.01	0.67	0.06	-0.19	0.13	0.08	-0.06	-0.51	0.07	0.41
TGN	0.29	-0.23	0.44	0.48	0.04	0.11	-0.14	0.04	0.00	-0.01	-0.63
PFG	0.39	-0.10	-0.39	0.06	0.27	-0.03	-0.04	-0.18	-0.75	0.11	0.00
PD	0.41	0.22	-0.03	-0.06	-0.38	0.23	0.33	-0.03	-0.06	-0.68	0.00
WG	0.44	0.17	0.03	-0.11	-0.32	0.17	0.34	0.06	0.13	0.71	0.00
Deviation standard	2.01	1.64	1.28	0.87	0.86	0.74	0.66	0.30	0.26	0.09	0.00
Diversity proportion	0.37	0.24	0.15	0.07	0.07	0.05	0.04	0.01	0.01	0.00	0.00
Cumulative proportion	0.37	0.61	0.76	0.83	0.90	0.94	0.98	0.99	0.10	1.00	1.00
Eigen value	4.04	2.40	1.45	0.75	0.74	0.06	0.43	0.09	0.07	0.01	0.00

Note: TNT: total number of tillers, NPT: number of productive tillers, D.F.: days to flowering, P.L.: panicle length, NFG: number of filled grains per panicle, NUG: number of unfilled grains per panicle, TGN: total grain number per panicle, PFG: percentage of filled grain, P.D.: panicle density, W.G.: weight of grain per hill

Table 4. Selection results of several genotypes of mutant upland rice based on selection index by weighting

Rank	Genotype	Index				WINDEX	WG
		PL	NFG	PD	WG	(I)	(Gram)
1	G29	-1.50	1.25	3.09	2.82	8.92	65.15
2	G197	0.68	0.66	2.71	2.82	8.87	65.19
3	G110	1.59	0.95	2.08	2.53	8.04	60.89
4	G193	0.80	0.85	2.33	2.53	8.02	60.81
5	G27	-0.63	1.99	2.19	2.49	7.97	60.22
6	G229	1.30	1.45	1.69	2.13	6.98	54.90
7	G52	0.77	0.48	2.00	2.09	6.62	54.30
8	G70	0.77	1.15	1.90	1.99	6.60	52.86
9	G214	1.73	3.48	0.93	1.50	5.92	45.50
10	G89	0.31	1.09	1.75	1.78	5.88	49.70
11	G105	0.35	0.40	1.97	1.75	5.71	49.23
12	G183	0.80	2.06	1.38	1.54	5.58	46.18
13	G165	1.43	1.56	1.08	1.51	5.18	45.67
14	G141	1.47	0.73	1.25	1.58	5.14	46.68
15	G82	-0.44	0.30	1.92	1.54	4.98	46.08
16	G119	-0.21	-0.70	2.13	1.57	4.85	46.56
17	G62	0.15	-0.13	1.76	1.53	4.78	45.96
18	G107	-0.21	-0.22	1.99	1.45	4.69	44.87
19	G77	1.12	0.66	1.08	1.48	4.68	45.31
20	G162	1.80	0.75	0.89	1.45	4.65	44.84
21	G14	-1.50	0.71	1.68	1.49	4.62	45.46
22	G35	-1.62	0.36	1.78	1.52	4.58	45.86
23	G173	0.87	1.71	0.92	1.10	4.09	39.64
24	G20	-0.63	1.19	1.08	1.28	4.06	42.32
25	G169	0.80	0.75	1.04	1.20	4.00	41.17
26	G31	-1.25	1.11	1.30	1.25	3.99	41.84
27	G164	0.80	1.95	0.85	1.00	3.90	38.10
28	G63	0.03	-0.37	1.50	1.24	3.80	41.64
29	G189	0.99	6.78	0.04	0.22	3.60	26.64
30	G99	0.49	0.17	1.01	1.14	3.53	40.24
31	G19	-0.57	-0.12	1.06	1.28	3.50	42.27
32	G86	-0.38	0.13	1.37	1.08	3.47	39.32
33	G171	0.80	0.90	0.83	0.98	3.42	37.92
34	G61	1.40	0.49	0.73	1.04	3.42	38.76
35	G85	0.87	-0.09	0.84	1.13	3.33	40.00
36	G163	0.99	1.01	0.71	0.94	3.31	37.29
37	G120	1.10	0.21	0.87	1.01	3.29	38.36
38	G199	0.98	1.04	0.69	0.92	3.25	36.94
39	G72	0.27	-0.20	1.16	1.04	3.21	38.70
40	G64	1.77	0.66	0.50	0.90	3.08	36.68
41	G106	1.59	0.22	0.58	0.89	2.89	36.46
42	G231	0.05	-0.30	1.12	0.92	2.83	36.96
43	G108	0.54	-0.37	0.94	0.88	2.67	36.30
44	G10	-0.50	0.73	0.66	0.86	2.63	36.10
45	G22	-1.13	0.27	0.90	0.90	2.58	36.70
46	G217	-0.01	-0.11	1.02	0.80	2.54	35.14
47	G101	1.47	0.38	0.48	0.73	2.50	34.15
48	G57	0.52	-0.35	0.81	0.81	2.43	35.38
49	G93	-0.19	0.27	0.87	0.73	2.39	34.10
50	G79	-0.81	0.49	1.06	0.62	2.26	32.53
51	G80	-0.32	-0.18	0.93	0.73	2.21	34.08
52	G60	1.89	1.28	0.13	0.49	2.16	30.61
53	G92	0.68	0.71	0.43	0.61	2.15	32.38
54	G168	0.68	0.89	0.42	0.52	2.02	30.99
55	G167	0.12	0.03	0.75	0.62	2.01	32.44
56	G73	-0.16	-0.18	0.87	0.61	1.94	32.36
57	G125	1.10	1.46	0.25	0.39	1.93	29.09
58	G44	0.65	0.43	0.44	0.49	1.76	30.55
59	G121	1.22	1.34	0.18	0.35	1.75	28.43
60	G118	0.47	0.34	0.51	0.46	1.69	30.16
61	G132	0.41	0.58	0.49	0.41	1.65	29.40
62	G103	0.41	0.82	0.44	0.38	1.63	28.91
63	G148	0.04	0.07	0.67	0.44	1.56	29.88
64	G71	0.52	0.39	0.38	0.39	1.47	29.16
65	G177	0.87	1.17	0.13	0.27	1.40	27.39
66	Salumpikit	-0.65	-0.28	0.78	0.46	1.38	30.09
67	G192	0.87	-0.03	0.27	0.42	1.34	29.60
68	G188	1.05	0.21	0.16	0.37	1.29	28.84
69	G184	0.37	0.00	0.40	0.38	1.25	28.97
70	G126	-1.08	-0.43	1.01	0.30	1.06	27.78
71	G11	-1.00	1.85	0.15	0.18	1.06	25.98
72	G98	0.43	0.76	0.12	0.22	1.00	26.55
73	G129	0.79	0.98	0.08	0.12	0.93	25.15
74	G59	-0.22	-0.13	0.49	0.26	0.87	27.20
75	G115	0.72	0.55	0.10	0.14	0.78	25.34
76	G54	-0.22	-0.10	0.42	0.21	0.70	26.37
77	G53	0.15	0.15	0.25	0.16	0.65	25.70
78	G16	-1.62	0.39	0.39	0.23	0.62	26.78
79	G111	1.47	-0.32	-0.04	0.17	0.55	25.86
80	G211	0.24	0.04	0.18	0.13	0.51	25.27
81	G112	1.03	-0.38	0.06	0.17	0.50	25.81
82	G145	0.54	-0.69	0.22	0.20	0.45	26.27
83	G185	0.00	0.35	0.13	0.01	0.28	23.52
84	G34	-2.25	-0.04	0.53	0.17	0.27	25.84
85	G181	0.74	1.12	-0.22	-0.11	0.23	21.74
86	G30	-3.24	0.11	0.85	0.08	0.17	24.44
87	G136	1.78	0.98	-0.40	-0.16	0.14	20.92
88	G43	0.40	0.08	-0.01	-0.01	0.09	23.14
89	G113	-0.21	-0.88	0.34	0.09	0.06	24.68
90	G191	0.43	0.32	-0.08	-0.06	0.04	22.46

Note: W.G.: weight of grain per hill

This study concluded that the selection index method is useful for assisting in selecting mutant lines with various agronomic characteristics. The characters like grain weight per hill, panicle density, panicle length, and the number of filled grains per panicle could be used as selection criteria for upland rice mutans tolerant to drought at the reproductive phase. The selection index formula was I = (5*0.44*WG) + (2*0.41*PD) + (0.23*PL) + (0.42*NFG). Selection of upland rice mutans based on weighted index selection resulted in 89 genotypes with high yields and good agronomic characters, 65 genotypes of which were better than Salumpikit (1.38). The selected lines had good agronomic performance and were prospective for further testing.

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