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Artificial screening of BC_3F_2 backcross population of rice (*Oryza sativa* L.) for drought and salinity

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Abstract
The current study was carried out during 2023 at Department of Rice, CPBG, TNAU, Coimbatore, intending to phenotypically screen the BC_3F_2 population derived from a cross between CO 52 and APD 19002 against salinity and drought. Salinity screening was done at seedling stage and drought screening was carried out in reproductive stage. Total of 240 BC_3F_2 plants were utilized from three different high genome recovered plants. These plants are subjected to12 EC and visual salt injury score was taken based on modified SES score given by IRRI. 25% plants were survived from the seedling stage salinity stress. These plants are forwarded to screen for reproductive stage drought stress and leaf rolling, leaf drying and senescence score was taken. In that 90% plants were survived. Eleven plants are identified as tolerant for both salinity and drought based on the score. The selected plants may play a crucial role in addressing the challenges posed by climate change and ultimately benefiting both farmers and consumers.

Keywords: BC_3F_2 backcross population, rice, *Oryza sativa* L., drought, salinity

Introduction

Rice is life for millions of people and it is a source of carbohydrate, protein, vitamins, minerals and disease fighting phyto-compounds for this reason rice is also known as golden cereal (Pradhan *et al.* 2019) [15]. The world's population is expected to reach 9.6 billion by 2050 and with this, there is an urgent need to increase the rice production to meet out the global demand for food (Leridon, 2020) [11]. Modelling simulations predict that agricultural production will need to double by 2050, particularly for high-demand staple foods like rice, in order to feed the growing population (FAO, 2017) [6]. Abiotic stresses cause significant reduction on crop yield which leads to food insecurity. Drought is one of the most destructive abiotic factor and it is predicted that more than 50% of the world's arable land will be damaged by drought in the year 2050 (Singhal *et al.*, 2016) [20]. Worldwide approximately 23 million ha of rainfed land get affected by drought (Ahmad *et al.*, 2020) [1]. Rice is considered one of the most drought-sensitive plant especially during reproductive stage which leads to dramatic reduction of grain yield because of its small root system, thin cuticular wax and swift stomatal closure (Sahebi *et al.*, 2018, Ji *et al.*, 2012) [17, 9]. The second most devasting abiotic stress is salinity. Globally over 80 million hectares of irrigated land, which is 40% of the total irrigated land have become toxic to plants due to salt accumulation (Xiong *et al.*, 2001) [26]. In India around 6.73 million hectares of land deteriorated by salt and by 2050, the total damage is expected to go up to 16.2 million hectares (CSSRI Vision-2050, 2015). Modern high yielding rice varieties showed typical yield loss of 12% at 3 EC and half of the yield reduction was observed at 6 EC (Linh *et al.*, 2012) [12]. Due to the significant yield losses in rice caused by drought and salt stress, as well as the ongoing climate change issues, there is a need to develop more rice lines that are tolerant to both drought and salt.

Marker-assisted backcross breeding (MABC) is a faster and more precise way to transfer genes that confer salinity and drought tolerance to rice plants. Marker-assisted gene/QTL pyramiding has been shown to be a powerful tool to introduce multiple genes/QTLs for broad-spectrum resistance to abiotic and biotic stresses (Muthu *et al.* 2020) [13]. Phenotypic screening is a fundamental tool in rice breeding and agriculture as it enables the selection of rice varieties with desirable traits, adaptation to local conditions, resistance to stresses and improved yield and quality. This process plays a critical role in ensuring food security, sustainability and the continued success of rice farming worldwide.

Hence, the objective of this study was to screen the BC_3F_2 plants artificially for both drought and salinity in a combined manner. The attained results based on the salinity and drought score may provide a useful information to identify superior climate resilient plants to cope with climate change. In future they can then be further evaluated for their superior agronomic performance and quality traits.

Materials and Methods

A popular high yielding fine grain variety CO 52 was used as a recurrent parent and it is crossed with donor parent called APD 19002 which harbors drought (*qDTY1.1* and *qDTY2.1*) and salinity (*Saltol*) tolerant QTLs. Plant number 33-47-13, 33-8-11 and 33-37-10 are identified as a highest genome recovered plants from the previous study and it were used as a material for the current study. These three lines were selfed in third backcross generation to produce BC_3F_2 population. Salinity screening was done at seedling stage based on the guidelines given by IRRI salinity screening manual. A total of 240 BC_3F_2 plants were screened in glass house along with check at Department of rice, CPBG, TNAU, Coimbatore. 70 seeds from 33-47-13, 70 seeds from 33-8-11, 100 seeds from 33-37-10, recurrent parent CO 52, donor parent APD 19002, tolerant check Pokkali and FL478 and the susceptible check ADT 45 were pregerminated in Petri plates for 2-3 days. Each pregerminated BC_3F_2 seeds was placed on each hole in the Styrofoam seedling float. Parents and checks are sowed in each row. The pregerminated seeds were transferred to Styrofoam seedling float without damaging the radicle along with checks. Styrofoam seedling float were suspended on the tray filled with distilled water and kept for 3 days. After 3 days, distilled water was replaced with Yoshida nutrient solution (Yoshida *et al*., 1976) [27]. On 14th day, EC 6 dSm^{-1} was applied by adding 100 mM NaCl. Three days later salinity level was raised to EC 12 dSm^{-1}. The solution was renewed at every eight days and the pH was maintained at 5.0. The response of plants against salinity stress at seedling stage was scored as described in the standard evaluation system (SES) developed at International Rice Research Institute, Manila, Philippines (Gregorio *et al*., 1997) [28].

Those survived plants from seedling stage salinity stress were forwarded to reproductive stage drought stress. Survived plants transferred to pot and maintained as normal plants without any stress. During boot leaf stage irrigation was restricted up to 7 days. Scores were taken at the end day of stress. Leaf rolling, leaf drying, and senescence scores were taken at the end day of stress. Severe leaf rolling and leaf drying were observed at this soil moisture level. At this severe stress, a flash life-saving irrigation was provided, and the excess water was drained out approximately after 24 h. This cycle was constantly repeated until harvest.

Modified standard evaluation score (SES) for seedling stage salinity visual salt injury (Gregorio *et al.*, 1997) [28]

Score	Observation	Tolerance
1	Normal growth, no leaf symptoms	Highly tolerant
3	Nearly normal growth, but leaf tips or few leaves whitish and rolled	Tolerant
5	Growth severely retarded; most leaves rolled; only a few are elongating	Moderately tolerant
7	Complete cessation of growth; most leaves dry; some plants dying	Susceptible
9	Almost all plants dead or drying	Highly susceptible

Scale for leaf drying

Scale	Observation
1	Unrolled, turgid
2	Leaf rim starts to roll
3	Leaf has a shape of a V
4	Rolled leaf rim covers the part of the leaf blade
5	Leaf rolled like onion

Scale of leaf rolling

Scale	Observation
0	Leaves healthy
1	Leaves starts to fold (shallow V shape)
3	Leaves folding (deep V shape)
5	Leaves fully cupped (U shape)
7	Leaf margin touching (O shape)
9	Leaves tightly rolled

Senescence score

Decimal score	Senescence
1	Leaves have natural green colour
3	1/3rd. of leaves fully green
5	Intermediate
7	1/3rd of leaves yellowing
9	All leaves yellow or dead

Results and Discussion

The results from seedling stage salinity screening was given in Table 1. Out of 240 plants, 62 plants were survived at salinity level EC 12 dSm^{-1}. The remaining 178 plants are identified as highly susceptible based on the salinity tolerance score 9. Among the 62 plants, thirty plants scored 3, twenty-nine plants scored 5 and score 7 was observed in three plants. Overall, thirty plants identified as tolerant to salinity, moderately tolerant nature was observed in twenty-nine plants and three plants are susceptible to seedling stage salinity stress. Recurrent parent was highly susceptible to salinity. The donor and the tolerant check Pokkali and FL 478 were found as tolerant in nature. Similar findings were reported by Tin *et al.* (2021) [24], Tam *et al.* (2019) [22], Thanasilungura *et al.* (2020) [23], Thi Lang *et al*. (2019) [10] and Alshiekheid *et al.* (2023) [2]. Within two to three days of salinization, salt stress symptoms began to appear in the rice seedlings. These symptoms included yellowing and drying of leaves. In some cases, the seedlings died. Other symptoms that were observed included leaf rolling and tip whitening. Salinity stress suppresses leaf growth in rice plants, eventually leading to cessation of growth and premature leaf senescence. Overall, the growth of the seedlings was suppressed under salt stress and only 25% plants were survived at 12 dSm^{-1}. From the phenotypic screening, it is clearly visible that the tolerant plants are less sensitive to salinity injury compared to other susceptible plants. Hence, this type of tolerant behavior is the outcome of some physiological, morphological or biochemical mechanism adapted by tolerant plants to withstand salt injury. This theory was also supported by Eti *et al*. (2018) [5].

All the survived 62 plants were transferred to pot for exploiting reproductive stage drought stress. At the end of drought stress screening, 56 plants are survived (Table 2). Leaf rolling, leaf drying and senescence score was taken as drought scores. In leaf rolling, eleven plants are noticed for score 1 (shallow V shape), twenty-two plants are noted for score 3 (deep V shape), fifteen plants are listed for score 5 (U shape) and seven plants are found in score 7 (O shape). Leaf rolling cause reduction in photosynthetic efficiency leads to reduce the assimilate level. Blum (1988) [29] reported that inability of leaves to meet out transpiration demand cause the leaf rolling as drought symptom. Leaf drying symptoms of score 2 was for thirteen plants, score 3 was noticed in sixteen plants, eighteen plants were scored for 4 and nine plants scored in category 5. In senescence score, eleven plants are under score 1, twenty-one plants were scored 3, 16 plants recognized as an intermediate category and eight plants were scored 7. In parents, the donor parent only was forwarded to drought stress and it was scored 2, 3, 1 for leaf rolling, leaf drying and senescence score respectively. The same results were highlighted by Dwiningsih *et al.* (2021) [4], Garrity *et al.* (1994) [7], Sellammal *et al.* (2014) [18], Pavithra *et al.* (2020) [14], Tu *et al.* (2021) [25] and Bunnag *et al.* (2013) [3]. Susanto *et al.* (2019) [21] reported that leaf rolling and leaf drying are highly associated with ability of plant to recover after drought stress. This trait is still widely used to screen drought tolerant materials of rice. About 90% of survived plants from salinity stress were also withstand the drought during reproductive stage.

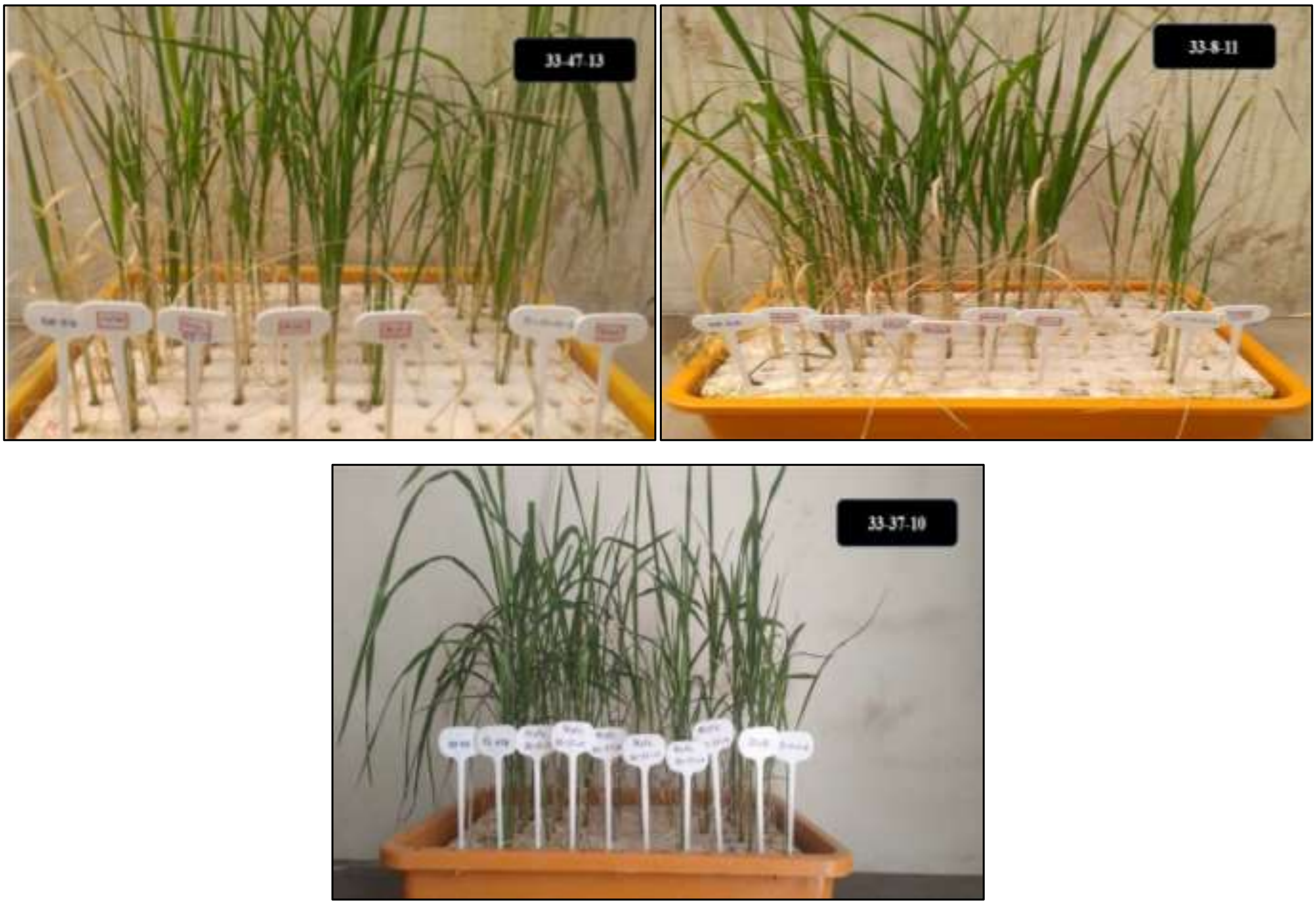

Fig 1: Seedling stage salinity screening in BC_3F_2 at 12 EC

Fig 2: Phenotypic screening for reproductive stage drought stress in BC_3F_2

Table 1: Scores obtained from BC_3F_2 plants for seedling stage salinity stress

Plant no.	33-47-13-1	33-47-13-2	33-47-13-3	33-47-13-4	33-47-13-5	33-47-13-6	33-47-13-7	33-47-13-8	33-47-13-9	33-47-13-10
Score	3	9	5	9	9	9	5	9	5	9
Plant no.	33-47-13-11	33-47-13-12	33-47-13-13	33-47-13-14	33-47-13-15	33-47-13-16	33-47-13-17	33-47-13-18	33-47-13-19	33-47-13-20
Score	9	3	9	9	5	9	7	9	9	9
Plant no.	33-47-13-21	33-47-13-22	33-47-13-23	33-47-13-24	33-47-13-25	33-47-13-26	33-47-13-27	33-47-13-28	33-47-13-29	33-47-13-30
Score	9	9	9	9	9	5	9	5	9	9
Plant no.	33-47-13-31	33-47-13-32	33-47-13-33	33-47-13-34	33-47-13-35	33-47-13-36	33-47-13-37	33-47-13-38	33-47-13-39	33-47-13-40
Score	9	5	9	9	3	9	3	3	9	9
Plant no.	33-47-13-41	33-47-13-42	33-47-13-43	33-47-13-44	33-47-13-45	33-47-13-46	33-47-13-47	33-47-13-48	33-47-13-49	33-47-13-50
Score	9	3	5	9	9	9	9	3	3	9
Plant no.	33-47-13-51	33-47-13-52	33-47-13-53	33-47-13-54	33-47-13-55	33-47-13-56	33-47-13-57	33-47-13-58	33-47-13-59	33-47-13-60
Score	9	3	9	9	9	9	9	3	9	9
Plant no.	33-47-13-61	33-47-13-62	33-47-13-63	33-47-13-64	33-47-13-65	33-47-13-66	33-47-13-67	33-47-13-68	33-47-13-69	33-47-13-70
Score	9	9	9	9	9	9	9	9	9	9
Plant no.	33-8-11-1	33-8-11-2	33-8-11-3	33-8-11-4	33-8-11-5	33-8-11-6	33-8-11-7	33-8-11-8	33-8-11-9	33-8-11-10
Score	3	5	5	9	9	9	3	9	5	9
Plant no.	33-8-11-11	33-8-11-12	33-8-11-13	33-8-11-14	33-8-11-15	33-8-11-16	33-8-11-17	33-8-11-18	33-8-11-19	33-8-11-20
Score	9	9	5	9	9	9	9	3	3	9
Plant no.	33-8-11-21	33-8-11-22	33-8-11-23	33-8-11-24	33-8-11-25	33-8-11-26	33-8-11-27	33-8-11-28	33-8-11-29	33-8-11-30
Score	9	9	3	9	9	9	3	5	3	9
Plant no.	33-8-11-31	33-8-11-32	33-8-11-33	33-8-11-34	33-8-11-35	33-8-11-36	33-8-11-37	33-8-11-38	33-8-11-39	33-8-11-40
Score	9	3	9	9	9	9	9	3	5	9
Plant no.	33-8-11-41	33-8-11-42	33-8-11-43	33-8-11-44	33-8-11-45	33-8-11-46	33-8-11-47	33-8-11-48	33-8-11-49	33-8-11-50
Score	9	3	9	9	5	9	5	3	5	9
Plant no.	33-8-11-51	33-8-11-52	33-8-11-53	33-8-11-54	33-8-11-55	33-8-11-56	33-8-11-57	33-8-11-58	33-8-11-59	33-8-11-60
Score	7	9	9	9	9	9	9	9	9	9
Plant no.	33-8-11-61	33-8-11-62	33-8-11-63	33-8-11-64	33-8-11-65	33-8-11-66	33-8-11-67	33-8-11-68	33-8-11-69	33-8-11-70
Score	9	9	9	9	9	9	9	9	9	9
Plant no.	33-37-10-1	33-37-10-2	33-37-10-3	33-37-10-4	33-37-10-5	33-37-10-6	33-37-10-7	33-37-10-8	33-37-10-9	33-37-10-10
Score	5	5	3	3	9	3	9	9	5	5
Plant no.	33-37-10-11	33-37-10-12	33-37-10-13	33-37-10-14	33-37-10-15	33-37-10-16	33-37-10-17	33-37-10-18	33-37-10-19	33-37-10-20
Score	5	9	9	9	5	3	9	9	9	3
Plant no.	33-37-10-21	33-37-10-22	33-37-10-23	33-37-10-24	33-37-10-25	33-37-10-26	33-37-10-27	33-37-10-28	33-37-10-29	33-37-10-30
Score	9	9	9	9	9	9	9	5	9	9
Plant no.	33-37-10-31	33-37-10-32	33-37-10-33	33-37-10-34	33-37-10-35	33-37-10-36	33-37-10-37	33-37-10-38	33-37-10-39	33-37-10-40
Score	9	9	9	9	9	3	9	9	5	3
Plant no.	33-37-10-41	33-37-10-42	33-37-10-43	33-37-10-44	33-37-10-45	33-37-10-46	33-37-10-47	33-37-10-48	33-37-10-49	33-37-10-50
Score	3	9	9	7	9	9	9	9	5	9
Plant no.	33-37-10-51	33-37-10-52	33-37-10-53	33-37-10-54	33-37-10-55	33-37-10-56	33-37-10-57	33-37-10-58	33-37-10-59	33-37-10-60
Score	9	9	5	9	9	5	9	9	9	9
Plant no.	33-37-10-61	33-37-10-62	33-37-10-63	33-37-10-64	33-37-10-65	33-37-10-66	33-37-10-67	33-37-10-68	33-37-10-69	33-37-10-70
Score	9	9	9	3	9	9	9	9	9	9
Plant no.	33-37-10-71	33-37-10-72	33-37-10-73	33-37-10-74	33-37-10-75	33-37-10-76	33-37-10-77	33-37-10-78	33-37-10-79	33-37-10-80
Score	9	9	9	9	9	9	9	5	9	9
Plant no.	33-37-10-81	33-37-10-82	33-37-10-83	33-37-10-84	33-37-10-85	33-37-10-86	33-37-10-87	33-37-10-88	33-37-10-89	33-37-10-90
Score	9	9	9	9	9	9	9	9	9	9
Plant no.	33-37-10-91	33-37-10-92	33-37-10-93	33-37-10-94	33-37-10-95	33-37-10-96	33-37-10-97	33-37-10-98	33-37-10-99	33-37-10-100
Score	9	9	9	9	9	9	9	9	9	9

Table 2: Scores obtained for drought stress at reproductive stage in BC_3F_2

S.no	Plant No.	Leaf Drying	Leaf Rolling	Senescence score
1	33-47-13-1	2	1	1
2	33-47-13-3	3	3	3
3	33-47-13-7	3	3	3
4	33-47-13-9	4	5	5
5	33-47-13-12	3	3	3
6	33-47-13-15	3	3	3
7	33-47-13-17	5	7	7
8	33-47-13-26	4	5	5
9	33-47-13-28	4	7	7
10	33-47-13-32	3	5	5
11	33-47-13-35	2	1	1
12	33-47-13-37	3	3	3
13	33-47-13-38	2	3	3
14	33-47-13-42	4	5	5
15	33-47-13-43	4	7	7
16	33-47-13-48	2	1	1
17	33-47-13-49	3	3	3
18	33-47-13-52	2	3	3
19	33-47-13-58	2	1	1
20	33-8-11-1	2	1	1
21	33-8-11-2	3	3	3
22	33-8-11-3	3	3	5
23	33-8-11-7	2	1	1
24	33-8-11-9	3	3	5
25	33-8-11-13	3	3	5
26	33-8-11-18	2	1	1
27	33-8-11-19	3	3	3
28	33-8-1-:23	2	1	1
29	33-8-11-27	3	3	3
30	33-8-11-28	3	5	5
31	33-8-11-29	2	1	1
32	33-8-11-32	3	3	3
33	33-8-11-38	2	1	1
34	33-8-11-39	4	5	5
35	33-8-11-42	4	5	7
36	33-8-11-45	4	7	7
37	33-8-11-47	3	3	3
38	33-8-11-48	2	1	1
39	33-8-11-49	4	5	5
40	33-8-11-51	5	7	7
41	33-8-11-1	5	7	9
42	33-37-10-2	5	7	7
43	33-37-10-3	4	3	3
44	33-37-10-4	4	5	3
45	33-37-10-6	4	3	3
46	33-37-10-9	5	9	9
47	33-37-10-10	5	5	5
48	33-37-10-11	5	7	5
49	33-37-10-15	5	7	9
50	33-37-10-16	5	3	3
51	33-37-10-20	4	5	3
52	33-37-10-28	5	5	3
53	33-37-10-36	4	3	5
54	33-37-10-39	5	9	9
55	33-37-10-40	4	5	5
56	33-37-10-41	4	3	3
57	33-37-10-44	5	7	7
58	33-37-10-49	5	3	5
59	33-37-10-53	4	5	5
60	33-37-10-56	5	9	9
61	33-37-10-64	4	5	3
62	33-37-10-78	5	9	9

Conclusion

The current study was aimed to screen the BC3F2 population derived from a cross between CO 52 a popular high yielding variety from Tamil Nadu and APD 19002 harboring salinity and drought tolerant QTLs. In conclusion, eleven plants (33-47-13-1, 33-47-13-35, 33-47-13-48, 33-47-13-58, 33-8-11-1, 33-8-11-7, 33-8-11-18, 33-8-11-23, 33-8-11-29, 33-8-11-38 and 33-8-11-48) are recognized as tolerant to both seedling stage salinity stress and reproductive stage drought stress. Developing drought and salinity-tolerant rice varieties is essential for ensuring food security, adapting to climate change, conserving water resources, reducing environmental impacts, improving livelihoods, and promoting sustainable agriculture. The selected plants play a crucial role in addressing the challenges posed by climate change and ultimately benefiting both farmers and consumers. In future these plants can be further evaluated for its agronomic and quality traits.

References

1. Ahmad MS, Wu B, Wang H, Kang D. Field screening of rice germplasm (*Oryza sativa* L. ssp. *japonica*) based on days to flowering for drought escape. Plants. 2020;9(5):609.
2. Alshiekheid MA, Dwiningsih Y, Alkahtani J. Analysis of Morphological, Physiological, and Biochemical Traits of Salt Stress Tolerance in Asian Rice Cultivars at Different Stages.
3. Bunnag S, Pongthai P. Selection of rice (*Oryza sativa* L.) cultivars tolerant to drought stress at the vegetative stage under field conditions. American Journal of Plant Sciences. 2013;4(09):1701.
4. Dwiningsih Y, Kumar A, Thomas J, Ruiz C, Alkahtani J, Baisakh N, *et al*. Quantitative trait loci and candidate gene identification for chlorophyll content in RIL rice population under drought conditions. Indonesian Journal of Natural Pigments. 2021;3(2):54.
5. Eti I, Rasel M, Hassan L, Ferdausi A. Morphological based screening and genetic diversity analysis of the local rice (*Oryza sativa* L.) landraces at the seedling stage for salinity tolerance. J Biosci Agric Res. 2018;18(1):1496-1511.
6. FAO: The Future of Food and Agriculture—Trends and Challenges. Food and Agriculture Organization of the United Nations, Rome, 2017, p. 163.
7. Garrity DP, O'Toole JC. Screening rice for drought resistance at the reproductive phase. Field Crops Research. 1994;39(2-3):99-110.
8. Gregoria GB, Senadhira D, Mendoza RD. Screening rice for salinity tolerance.
9. Ji K, Wang Y, Sun W, Lou Q, Mei H, Shen S, *et al.* Drought-responsive mechanisms in rice genotypes with contrasting drought tolerance during reproductive stage. Journal of plant physiology. 2012;169(4):336-344.
10. Lang Nt, Ha Pt, Phuoc Nt. Evaluation of rice backcross populations for salt tolerance using phenotypic analysis Nguyen Thi Lang, Pham Thi Thu ha, Nguyen Trong Phuoc and Bui chi Buu. Sabrao J Breed. Genet. 2019;51(3):225-33.
11. Leridon H. World population outlook: Explosion or implosion? Population Societies. 2020;573(1):1-4.
12. Linh LH, Linh TH, Xuan TD, Ham LH, Ismail AM, Khanh TD. Molecular breeding to improve salt tolerance of rice (*Oryza sativa* L.) in the Red River Delta of Vietnam. International journal of plant genomics; c2012.
13. Muthu V, Abbai R, Nallathambi J, Rahman H, Ramasamy S, Kambale R, *et al*. Pyramiding QTLs controlling tolerance against drought, salinity, and submergence in rice through marker assisted breeding. PloS one. 2020;15(1):e0227421.
14. Pavithra S, Vengadessan V. Selection for drought tolerance in rice genotypes based on principal components and seletion indices. Electronic Journal of Plant Breeding. 2020;11(04):1032-1036.
15. Pradhan SK, Pandit E, Pawar S, Baksh SY, Mukherjee AK, Mohanty SP. Development of flash-flood tolerant and durable bacterial blight resistant versions of mega rice variety 'Swarna' through marker-assisted backcross breeding. Scientific reports. 2019;9(1):12810.
16. Price AH, Townend J, Jones MP, Audebert A, Courtois B. Mapping QTLs associated with drought avoidance in upland rice grown in the Philippines and West Africa. Plant molecular biology. 2002;48:683-695.
17. Sahebi M, Hanafi MM, Rafii MY, Mahmud TM, Azizi P, Osman M, *et al*. Improvement of drought tolerance in rice (*Oryza sativa* L.): genetics, genomic tools, and the WRKY gene family. Bio Med research international; c2018.
18. Sellammal R, Robin S, Raveendran M. Association and heritability studies for drought resistance under varied moisture stress regimes in backcross inbred population of rice. Rice Science. 2014;21(3):150-61.
19. Sharma DK, Singh R, Singh A, Bhardwaj AK. CSSRI Annual Report; c2014-15.
20. Singhal P, Jan AT, Azam M, Haq QM. Plant abiotic stress: a prospective strategy of exploiting promoters as alternative to overcome the escalating burden. Frontiers in Life Science. 2016;9(1):52-63.
21. Susanto U, Rohaeni WR, Sasmita P. Selecting traits for drought tolerance screening in rice. InIOP Conference Series: Earth and Environmental Science 2019;383:012049.
22. Tam BP, Tu PT, Van Ut P, Dung PT, Hai PN, Trieu NL, *et al*. Genetic Analysis of Salinity Tolerance in a Rice Backcross Population at Seedling Stage. Journal of Bioscience and Agriculture Research. 2019;19(01):1576-1588.
23. Thanasilungura K, Kranto S, Monkham T, Chankaew S, Sanitchon J. Improvement of a RD6 rice variety for blast resistance and salt tolerance through marker-assisted backcrossing. Agronomy. 2020;10(8):1118.
24. Tin HQ, Loi NH, Labarosa SJ, McNally KL, McCouch S, Kilian B. Phenotypic response of farmer-selected CWR-derived rice lines to salt stress in the Mekong Delta. Crop Science. 2021;61(1):201-218.
25. Tu DX, Huong NT, Giang LT, Thanh LT, Khanh TD, Trung KH, *et al*. Screening Drought Tolerance of Vietnamese Rice Landraces in the Laboratory and Net House Conditions. Advanced Studies in Biology. 2021;13(1):21-28.
26. Xiong LM, Zhu JK. Abiotic Stress Signal Transduction in Plants: Molecular and Genetic Perspectives. Physiologia Plantarum. 2001;112:152-166
27. Yoshida S, Forno DA, Cook JH, Gomez KA. Laboratory Manual for Physiological Studies of Rice. The International Rice Research Institute, 1976, P. O. Box

933, Manila, Philippines.
28. Gregorio GV, Portmann B, Reid F, Donaldson PT, Doherty DG, McCartney M, *et al*. Autoimmune hepatitis in childhood: a 20-year experience. Hepatology. 1997 Mar;25(3):541-547.
29. Blum LA. Gilligan and Kohlberg: Implications for moral theory. Ethics. 1988 Apr 1;98(3):472-491.