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Genetic diversity of native rice cultivars in terms of germination component

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Rice (Oryza sativa L) is the major crop in most Asian countries and more than half of the lands in this continent are dedicated to this crop. In Iran, rice is the second major crop after wheat. Therefore, in the present study, germination components were used to investigate the genetic diversity of 11 native rice cultivars. The research trial was conducted by a randomized complete block design with three replicates in the city of Rezvashahr during the first half of 2021. The ANOVA results for germination components showed that the genotype mean squares were significant for all traits except for coefficient of velocity of germination and mean germination time, which is indicative of a significant difference between genotypes in terms of all traits. Final germination percentage (FGP), germination index (GI) and mean germination time (MGT) had the highest heritability value (73, 61 and 82%) respectively. Heritability index was medium for germination rate index (GRI), Germination velocity (Rs) and mean daily germination (MDG) had medium heritability. The results also showed that coefficient of velocity of germination (CVG) had insignificant genetic diversity. Genotypes 1, 2, 3, 4, 5, 7, 8, 9 and 10 were assigned to the first group (genotypes with maximum trait values). Genotypes 5 and 11 showed maximum germination rate (Rs) values but lower intermediate values for other traits. According to the results, intercrossing of genotypes, especially the genetically distant genotypes in two groups, can help create high-yielding cultivars and increase germination power and germination-related traits of rice cultivars in the northern region of Iran.

Keywords: Native rice, Genetic diversity, Germination components, Cluster analysis

INTRODUCTION

Rice (Oryza sativa L) is a major crop in most Asian countries (Mahabub, 2005) and is recognized as a strategic crop used to achieve sustainable food security across the country. More than half of the lands in this continent are dedicated to this crop (Gholamin and Khayatnezhad 2020, Si, Gao et al. 2020, Bi, Chen et al. 2021, Guo, She et al. 2021, Huang, Wang et al. 2021, Ma, Khayatnezhad et al. 2021, Sun, Lin et al. 2021). In Iran, rice is the second major crop after wheat (Park et al, 2014). Taking into account the population bulge in Asia which is recognized as the continent wherein 90% of the world's rice is cultivated and consumed, annual rice yield must increase by 1.7% to meet the future needs of consumers (Zuo and Li, 2014). The national demand for rice is anticipated to reach about 4 million tons by 2020. This volume of rice can't be supplied except through a national endeavor to maximize the utilization of available resources (FAO, 2019). Rice has the smallest genome size among all cereal crops and that's why it is used as an ideal crop in the evolutionary research on cereals and significant crop species (Dash et al. 1996). Due to its ability to grow in different environmental conditions, this crop can be subjected to investigations in different environments (Gholamin and Khayatnezhad 2020, Jia, Khayatnezhad et al. 2020, Khayatnezhad and Gholamin 2020, Chen, Khayatnezhad et al. 2021, Ma, Ji et al. 2021, Xu, Ouyang et al. 2021). The rice cultivars are more diverse than those of other crops. It is a diploid crop with a short genome (Derierwala et al., 2000 and Zhu et al., 2003). Since diversity provides raw materials of plant breeding and rice is characterized by broad genetic diversity and a high compatibility range, adoption of a suitable breeding mechanism and introduction of high quality cultivars calls for adequate knowledge of rice's genetic diversity and nature (Second, 1991).

High germination rate and vigorous seedling components are the most important traits in direct seeding-rice systems. Today, high germination energy is one of the traits that is taken into account in creation and development of GM rice cultivars (Alizadeh 2021, Alizadeh 2021, Karasakal 2021, Mohammadzadeh 2021, Radmanesh 2021). Although germination energy and germination-related traits in rice are associated with considerable genetic diversity (Mgonja et al, 1993; Redona and Mackill, 1996; Wan et al., 2006; Zeng et al., 2006; and Zhang et al., 2005) rice breeders' success has been limited with regard to modification of these traits through classical methods (Karasakal, Khayatnezhad et al. 2020, Cheng, Hong et al. 2021, Hou, Li et al. 2021, Ren and Khayatnezhad 2021, Zhao, Wang et al. 2021, Zheng, Zhao et al. 2021). Various reports are indicative of genetic diversity for seedling vigor in different rice cultivars (Gholamin and Khayatnezhad 2020, Karasakal, Khayatnezhad et al. 2020, Liu, Wang et al. 2021, Peng, Khayatnezhad et al. 2021, Li, Khayatnezhad et al. 2022, Zhang, Khayatnezhad et al. 2022). In some of these studies, seedling weight, stem length and radicle length under different environmental conditions were found to be the best indicators of rice seedling vigor (Khayatnezhad and Gholamin 2021, Wang, Ye et al. 2021, Zhu, Liu et al. 2021). Genetic diversity can be used to distinguish different cultivars and Indica cultivars have higher seedling vigor than Japonica cultivars (Gholamin and Khayatnezhad 2020, Khayatnezhad and Gholamin 2020, Wang, Shang et al. 2021, Tao, Cui et al. 2022, Wang, Khayatnezhad et al. 2022). Okelola et al. (2007) reported that genetic diversity, germination rate and germination energy were among the most important factors that should be taken into account in identification of rice cultivars with stronger seedling vigor. On the other hand, Some researchers used morphological traits to investigated genetic diversity of seedling vigor in different wheat cultivars, and found that seed dry weight is significantly correlated with seedling vigor traits such as germination rate, germination uniformity and plant dry weight (Gholamin and Khayatnezhad 2021, Li, Mu et al. 2021, Shi, Khayatnezhad et al. 2021, Sun and Khayatnezhad 2021, Yin, Khayatnezhad et al. 2021, Zhu, Saadati et al. 2021).

Therefore, investigation of genetic diversity of different cultivars of this plant is of vital importance in eugenics programs. Mahfoozi et al., 2004, investigated breeding methods used to increase wheat yield in cold and arid regions of Iran and reported that genetic diversity among genotypes may help increase grain yield in arid regions. The present study was an attempt to investigate the genetic diversity of native rice cultivars in terms of germination components and identify distant and close-knit groups. The results of the present study can be used to perform successful intercrosses (Karasakal 2021, Mohammadzadeh 2021, Radmanesh 2021, Radmanesh 2021). The study was conducted in the city of Rezvashahr during 2021. Plant material included 11 native rice genotypes collected from the Research institute of Rasht (Table 1). The randomized complete blocks design with three replicates were used to conduct the study. 10 seeds were planted in each petri dish. Germination test was performed inside the germinator at a temperature of 25 ° C, relative humidity of 70% under alternating light and dark conditions (16 hours light and 8 hours darkness). In order to measure germination indices, germinated seeds were tally counted on a daily basis and germination indices and seedling growth indicators such as final germination percentage (FGP), coefficient of velocity of germination (CVG) Germination index (GI), germination rate index (GRI), mean germination time (MGT), germination rate (Rs) and mean daily germination (MDG) were measured at the end of each day using the following formulas

Coefficient of Velocity of Germination (CVG):
$\sum NiTi / \sum Ni \times 100 = CVG$

Ni = number of germinated seeds per day
Ti = number of days from the beginning of the experiment
Germination index (GI):
$)N_{13} \times 1) + ... + (N_2 \times 12) + (N_1 \times 13 = (GI$
Where N1, N2,.. denote the number of germinated seeds on the first, second and … days, and numbers 9, 10, ….denote weights given to the number of germinated seeds on the first, second and … days.
Germination rate index (GRI):
$)N_{13} \times 1) + ... + (N_2 \times 12) + (N_1 \times 13 = (GI$

G1 = germination percentage on the first day
G2 = germination percentage on the second, …. days
Mean germination time (MGT): (Andalibi et al., 2005):
$\sum Ni = 100 / CVG / \sum NiTi = MGT$

Ni = number of seeds germinated per day
Ti = number of days from the beginning of the experiment

Final germination percentage (FGP): (Gharineh et al., 2004):
$100 \times Ng / Nt = FGP$
Ng = total number of germinated seeds
Nt = total number of evaluated seeds

Germination rate (Rs) was computed using the equation proposed by Maguire (Rajabi and Poostini, 2005):
$Si / Di \sum = Rs$

Si = number of seeds germinated on the nth day
Di = number of days after the start of the experiment (up to the nth day)
Mean daily germination (MDG), which is an indicator of daily germination, was calculated from the following equation:
$FGP/d = MDG$

FGP = final germination Percentage (seed viability)
d = Number of days before maximum final germination (Kafi, 2011).

In order to classify the genotypes, cluster analysis was performed for all traits using the WARD standardized data. MSTAT-C, SPSS-16 and Minitab-15 software were used to perform computations. Graphs and statistical tables were also sketched using office program (Excel and Word)

Table 1- Names of native and GM rice genotypes

Number	Genotype
1	Hashemi
2	Shahpasand
3	Mousajo
4	Anbarbooy
5	Mousa Tarom
6	Hashemi Zoodras
7	Hasani
8	Dom Zard
9	Sangjo Tarom
10	Anbar boo
11	Dom Sefid

RESULTS

The ANOVA results (Table 2) showed that the genotype mean squares have been significant for all traits except for germination rate and mean germination time, and this is indicative of a significant difference between genotypes in terms of all traits. Estimation of phenotypic and genotypic coefficients (Table 3) showed significant genetic diversity for final germination percentage (FGP), germination index (GI) and mean germination time (MGT) which were found to be heritable by 73, 61 and 82% respectively. Other traits such as germination index (GRI), germination rate (Rs) and mean daily germination (MDG) had moderate heritability. Coefficient of velocity of Germination (CVG) was associated with negligible genetic diversity. According to the findings which are found to be consistent with the literature, germination rate and seedling growth can be recognized as phenotypic keys used to differentiate seedling vigor in different cultivars (Brocard-Gifford et al., 2003 and Finch-Savage et al., 2010). Sabouri (2010) reported that rice cultivars are associated with significant genetic diversity in terms of most germination traits related to seedling vigor and showed that seedling length (87%) and seedling weight (81%) have the highest broad sense heritability. Sikuku et al. (2010) showed that traits related to rice seedling vigor during the germination stage include germination rate, germination percentage and germination index. The afore-mentioned traits had higher values in Indica cultivars compared to the Japonica cultivars. Cui et al., (2002) showed that germination rate and seedling growth rate in rice cultivars are significantly correlated (Khayatnezhad and Gholamin 2021, Khayatnezhad and Nasehi 2021, Zhang, Khayatnezhad et al. 2021, Wang, Ma et al. 2022). Farzi and Shekari Most'ali Begloo (2010) showed that the highest broad sense heritability can be observed in peduncle length and peduncle weight (87% and 81%, respectively) and the lowest board sense heritability can be observed in plant weight (31%) and harvest index. Also, in their study, they also found that broad sense heritability value for grain yield was 65%. The studied genotypes were classified (using cluster analysis method) in terms of final germination percentage (FGP), coefficient of velocity of germination (CVG), germination index (GI), germination rate index (GRI), Mean germination time (MGT), Germination rate (Rs) and mean daily germination (MDG) (Figure 1). The genotypes were assigned to three groups in terms of the afore-mentioned traits. The classification was confirmed by discriminant function analysis (Figure 1). CA-induced Mean squares for final germination percentage (FGP), coefficient of velocity of germination (CVG), germination index (GI), germination rate index (GRI), Mean germination time (MGT) Germination rate (Rs) and mean daily germination (MDG) were significant (p=1%). Genotypes 1, 2, 3, 4, 5, 7, 8, 9 and 10 were assigned to the first group. These genotypes were in optima conditions in terms of all traits (highest trait values) and genotypes 5 and 11 had the highest value only in terms of germination rate (Rs) but were at lower intermediate levels in terms of other traits (Table 4). According to the results, intercrossing of genotypes, especially the genetically distant genotypes in two groups, can help create high-yielding cultivars and increase germination power and germination-related traits of rice cultivars in the northern region of Iran.

Table 2: Variance analysis of the measured traits in 11 genotypes rice landraces of northern Iran

S. O. V	df	MS						
		Final Germination Percent	Coefficient of Velocity of Germination	Germination Index	Germination Rate Index	Mean Germination Term	Germination speed	Mean daily germination
Replication	2	157.56 ns	1.277*	604.13 ns	1095503 ns	7.388 ns	0418 ns	7.354 ns
Genotypes	10	1541.8**	0.842 ns	2186.5**	3585636**	4.203 ns	1.945**	25.61**
Error	22	170.91	0.399	387.7	690676	0.284	0.466	6.341
CV (%)		16.59	5.9	26.49	28.23	4.8	28.8	27.04

* and ** Significantly at $p < 0.05$ and < 0.01, respectively.

Table 3: Mean of traits, diversities extent, diversity coefficients and general heritability of traits in 11 genotypes rice landraces of northern Iran

	Final Germination Percent	Coefficient of Velocity of Germination	Germination Index	Germination Rate Index	Mean Germination Term	Germination speed	Mean daily germination
Mean	78.79	10.69	74.32	2943.03	11.07	2.37	9.31
Rang	80	1.68	85.69	3420	3.73	2.69	9.53
δ^2_e	170.91	0.4	387.7	690676	0.28	0.47	6.34
δ^2_g	456.96	0.15	599.6	964986.67	1.31	0.49	6.42
δ^2_{ph}	627.87	0.55	987.3	1655662.6	1.59	0.96	12.76
PCV	31.8	6.93	42.27	43.72	10.77	41.34	27.21
GCV	27.13	3.62	32.94	33.37	10.33	29.53	56.02
h^2 (%)	73	27	61	58	82	51	50

Table 4 -:Comparison of groups given from cluster analysis for different traits

Traits	Means		
	The 1 group	The 2 group	Oneway Anova
Final Germination Percent	87.41^a	40^b	**
Coefficient of Velocity of Germination	10.86^a	9.9^b	**
Germination Index	84.51^a	28.5^b	**
Germination Rate Index	2.68^a	1^b	**
Mean Germination Term	3352.5^a	1100^b	**
Germination speed	10.59^b	13.2^a	**
Mean daily germination	10.39^a	4.4^b	**
Differences between averages of each column which have common characters are not significant at probability level of 5%.			

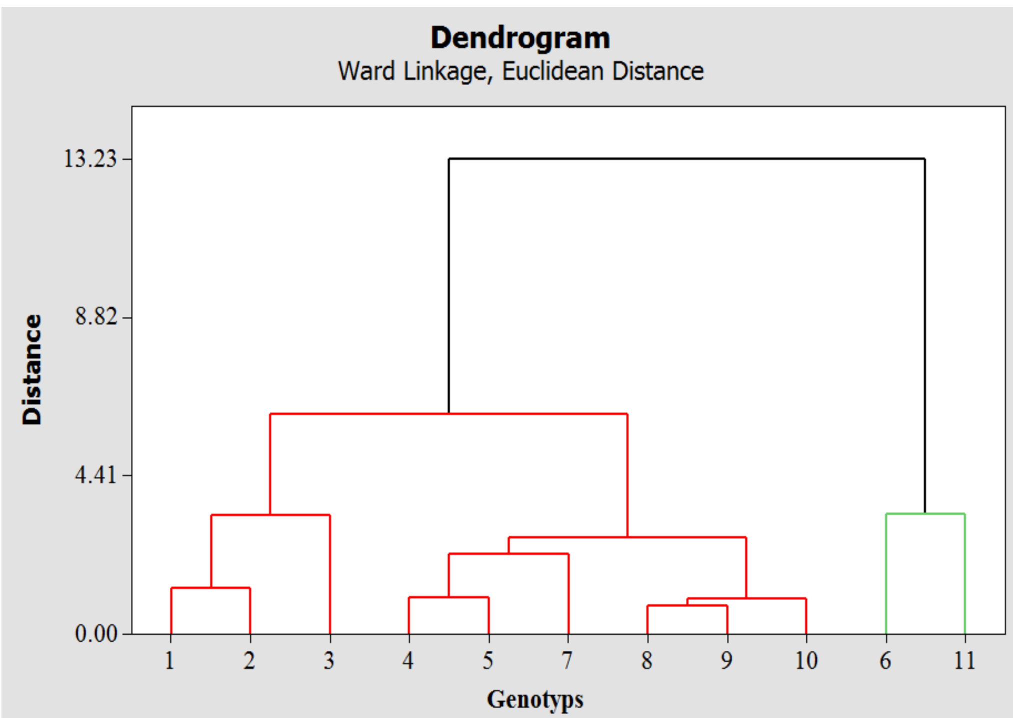

Figure 1; Dendrogram from WARD-based cluster analysis of significant traits according to ANOVA of 11 rice cultivars native to northern Iran

CONCLUSION

According to the results, intercrossing of genotypes, especially the genetically distant genotypes in two groups, can help create high-yielding cultivars and increase germination power and germination-related traits of rice cultivars in the northern region of Iran.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Sina Mohammadzadeh conducted, planned, Analyzed the data, wrote manuscript and interpreted the results and involved in manuscript preparation. All authors read and approved the final version.

REFERENCES

Alizadeh, M. (2021). "Enhanced Imazethapyr Activity on Jimsonweed using natural Additives." Bioscience Research 18(4): 3080-3086.

Alizadeh, M. (2021). "Protein profile and seeds storage proteins changes in wheat genotypes under control and drought stress conditions." Bioscience Research 18(3): 2164-2169.

Andalibi B, Zangani E, Haghnazari A (2005) Effects of water stress on germination indices in six repeseed cultivars (*Brassica napus* L.). Iran J. Agric. Sci. 36: 457-463.

Bi, D., D. Chen, M. Khayatnezhad, Z. S. Hashjin, Z. Li and Y. Ma (2021). "MOLECULAR IDENTIFICATION AND GENETIC DIVERSITY IN Hypericum L.: A HIGH VALUE MEDICINAL PLANT USING RAPD MARKERS MARKERS." Genetika-Belgrade 53(1): 393-405.

Brocard-Gifford I.M., Lynch, T.J., and Finkelstein, R.R. 2003. Regulatory networks in seeds: integrating developmental, abscisic acid, sugar, and light signaling. Plant Physiol. 131: 78–92.

Chen, W., M. Khayatnezhad and N. Sarhadi (2021). "PROTOK GENA I STRUKTURA POPULACIJE KOD ALLOCHRUSA (CARYOPHYLLOIDEAE, CARYOPHYLLACEAE) POMOCU MOLEKULARNIH MARKERA." Genetika-Belgrade 53(2): 799-812.

Cheng, X., X. Hong, M. Khayatnezhad and F. Ullah (2021). "Genetic diversity and comparative study of genomic DNA extraction protocols in Tamarix L. species." Caryologia 74(2): 131-139.

Cui, K.H., Peng, S.B., Xing, Y.Z., Yu, S.B., and Xu, C.G. 2002. Molecular dissection of relationship between seedling characteristics and seed size in rice (Oryza sativa L.). Acta. Bot. Sin. 44: 702-707.

Dang, X., Thi, T.G., Dong, G., Wang, H., Edzesi, W.M., and Hong, D. 2014. Genetic diversity and association mapping of seed vigor in rice (Oryza sativa L.). Planta. 239:1309-1319

Dash, S.K., J. Sigh, M. Tripathy and D. Mishra. 1996. Association of quantitative traits and path analysis in medium landrice. Environment and ecology, 14: 99-102.

Derierwala, A.P., W. Ramakrishna, P.H. Ranjekar and V.S. Gupta. 2000. Sequence variations at a complex microsatellite locus in rice and its conservation in cereals. Theoretical and Applied Genetic, 101: 323-341.

Finch-Savage, W.E., Clay, H.A., Lynn, J.R. and Morris, K. 2010. Towards a genetic understanding of seed vigour in small-seeded crops using natural variation in Brassica oleracea. Plant Sci. 179: 582–589

Gharineh MH, Bakhshandeh A, Ghasemi-Golezani K (2004) Vigor and seed germination of wheat cultivar in Khuzestan environmental condition. The Sci. J. Agric. 27:65-76.

Gholamin, R. and M. Khayatnezhad (2020). "Assessment of the Correlation between Chlorophyll Content and Drought Resistance in Corn Cultivars (Zea Mays)." Helix 10(5): 93-97.

Gholamin, R. and M. Khayatnezhad (2020). "Study of Bread Wheat Genotype Physiological and Biochemical Responses to Drought Stress." Helix 10(5): 87-92.

Gholamin, R. and M. Khayatnezhad (2020). "The effect of dry season stretch on Chlorophyll Content and RWC of Wheat Genotypes (Triticum Durum L.)." Bioscience Biotechnology Research Communications 13(4): 1829-1833.

Gholamin, R. and M. Khayatnezhad (2020). "The Study of Path Analysis for Durum Wheat (Triticum durum Desf.) Yield Components." Bioscience Biotechnology Research Communications 13(4): 2139-2144.

Gholamin, R. and M. Khayatnezhad (2021). "Impacts of PEG-6000-induced Drought Stress on Chlorophyll Content, Relative Water Content (RWC), and RNA Content of Peanut (Arachis hypogaea L.) Roots and Leaves." Bioscience Research 18(1): 393-402.

Guo, L.-N., C. She, D.-B. Kong, S.-L. Yan, Y.-P. Xu, M. Khayatnezhad and F. Gholinia (2021). "Prediction of the effects of climate change on hydroelectric generation, electricity demand, and emissions of greenhouse gases under climatic scenarios and optimized ANN model." Energy Reports 7: 5431-5445.

Hou, R., S. Li, M. Wu, G. Ren, W. Gao, M. Khayatnezhad and F. Gholinia (2021). "Assessing of impact climate parameters on the gap between hydropower supply and electricity demand by RCPs scenarios and optimized ANN by the improved Pathfinder (IPF) algorithm." Energy 237.

Huang, D., J. Wang and M. Khayatnezhad (2021). "Estimation of Actual Evapotranspiration Using Soil Moisture Balance and Remote Sensing." Iranian Journal of Science and Technology-Transactions of Civil Engineering 45(4): 2779-2786.

Jia, Y., M. Khayatnezhad and S. Mehri (2020). "POPULATION DIFFERENTIATION AND GENE FLOW IN Erodium cicutarium: A POTENTIAL MEDICINAL PLANT." Genetika-Belgrade 52(3): 1127-1144.

Kafi M, Goldani M (2001) Effect potential water and material causing the on germination three crops wheat, sugar beet and peas. Journal of agriculture and Industries. Vol 15. P. 121-135.

Karasakal, A. (2021). "Gladiolus vegetative, floral, and yield characteristics in response to corm size and gibberellic acid." Bioscience Research 18(4): 3272-3279.

Karasakal, A. (2021). "The Technology of Biogas production by current urban solid waste landfills." Bioscience Research 18(3): 2117-2126.

Karasakal, A., M. Khayatnezhad and R. Gholamin (2020). "The Durum Wheat Gene Sequence Response Assessment of Triticum durum for Dehydration Situations Utilizing Different Indicators of Water Deficiency." Bioscience Biotechnology Research Communications 13(4): 2050-2057.

Karasakal, A., M. Khayatnezhad and R. Gholamin (2020). "The Effect of Saline, Drought, and Presowing Salt Stress on Nitrate Reductase Activity in Varieties of Eleusine coracana (Gaertn)." Bioscience Biotechnology Research Communications 13(4): 2087-2091.

Khayatnezhad, M. and F. Nasehi (2021). "Industrial Pesticides and a Methods Assessment for the Reduction of Associated Risks: A Review." Advancements in Life Sciences 8(2): 202-210.

Khayatnezhad, M. and R. Gholamin (2020). "A Modern Equation for Determining the Dry-spell Resistance of Crops to Identify Suitable Seeds for the Breeding Program Using Modified Stress Tolerance Index (MSTI)." Bioscience Biotechnology Research Communications 13(4): 2114-2117.

Khayatnezhad, M. and R. Gholamin (2020). "Study of Durum Wheat Genotypes' Response to Drought Stress Conditions." Helix 10(5): 98-103.

Khayatnezhad, M. and R. Gholamin (2021). "Impacts of Drought Stress on Corn Cultivars (Zea mays L.) At the Germination Stage." Bioscience Research 18(1): 409-414.

Khayatnezhad, M. and R. Gholamin (2021). "The Effect of Drought Stress on the Superoxide Dismutase and Chlorophyll Content in Durum Wheat Genotypes." Advancements in Life Sciences 8(2): 119-123.

Li, A., X. Mu, X. Zhao, J. Xu, M. Khayatnezhad and R. Lalehzari (2021). "Developing the non-dimensional framework for water distribution formulation to evaluate sprinkler irrigation." Irrigation and Drainage 70(4): 659-667.

Li, W., M. Khayatnezhad and A. Davarpanah (2022). "Statistical Analysis of Treated Flow-Back Water Measurements: An Industrial Insight for a Shale Reservoir." Geofluids 2022.

Liu, S., Y. Wang, Y. Song, M. Khayatnezhad and A. A. Minaeifar (2021). "Genetic variations and interspecific relationships in Salvia (Lamiaceae) using SCoT molecular markers." Caryologia 74(3): 77-89.

Ma, A., J. Ji and M. Khayatnezhad (2021). "Risk-constrained non-probabilistic scheduling of coordinated power-to-gas conversion facility and natural gas storage in power and gas based energy systems." Sustainable Energy Grids & Networks 26.

Ma, S., M. Khayatnezhad and A. A. Minaeifar (2021). "Genetic diversity and relationships among Hypericum L. species by ISSR Markers: A high value medicinal plant from Northern of Iran." Caryologia 74(1): 97-107.

Mahfoozi, S., M. Roustaii, S. H. Jasemi, H. Ketata, and B. David Flower. 2004. Breeding for increasing wheat yield in the cold dryland regions of Iran. Proceeding of the 4th International/Crop Science Congress Brisbane, Australia, 26 Sep-1 Oct 2004/ ISBN 1 9208420 9/ www.Crop Science. Org. au

Ministry of Agriculture-Jahad. 2019. Crop Statistic. (In Persian)

Mohammadzadeh, S. (2021). "Effect of mineral nutrient solutions on secondary metabolites of German chamomile in Hydroponics system." Bioscience Research 18(4): 3143-3151.

Mohammadzadeh, S. (2021). "The impact of trellising strategies on the production and quality of determinate tomato types." Bioscience Research 18(4): 3264-3271.

Okelola, F.S., Adebisi, M.A., Kehinde, O.B., and Oluwole, A.M. 2007. Genotypic and Phenotypic variability for seed vigour traits and seed yield in West African Rice (Oryza sativa L.) genotypes. J. Amer. Sci. 3: 34- 41.

Okelola, F.S., Adebisi, M.A., Kehinde, O.B., and Oluwole, A.M. 2007. Genotypic and Phenotypic variability for seed vigour traits and seed yield in West African Rice (Oryza sativa L.) genotypes. J. Amer. Sci. 3: 34- 41

Park, G. H., Kim, J. H. and Kim, K. M. 2014. QTL analysis of yield components in rice using a cheongcheong/nagdong doubled haploid genetic map. American Journal of Plant Sciences 5: 1174-

1180.
Peng, X., M. Khayatnezhad and L. J. Ghezeljehmeidan (2021). "RAPD PROFILING IN DETECTING GENETIC VARIATION IN Stellaria L. (Caryophyllaceae)." Genetika-Belgrade 53(1): 349-362.
Radmanesh, M. (2021). "Impacts of salinity, Pseudomonas and salicylic acid on seed bean physiological properties and yield (Phaseolus vulgaris)." Bioscience Research 18(4): 3023-3030.
Radmanesh, M. (2021). "The Impact of Various Planting Timelines on the Makings of Harvested Wheat Grains Triticum aestivum of Cultivars in Lorestan Province of Iran." Bioscience Biotechnology Research Communications 14(2): 680-685.
Rajabi R, Poustini K (2005) Effects of NaCl salinity on seed germination of 30 Wheat (*Triticum aestivum* L.) cultivars. The Sci. J. Agriculture. 28: 29-44.
Redona, E.D., and Mackill, D.J. 1996. Genetic variation for seedling vigor traits in rice. Am. Soc. Agro. 36: 285-290.
Ren, J. and M. Khayatnezhad (2021). "Evaluating the stormwater management model to improve urban water allocation system in drought conditions." Water Supply 21(4): 1514-1524.
Sabouri, H. 2010. Positioning of QTLs for germination characters in rice genotypes using micro markers of satellite under salinity condition. Iran. J. Biol. 23: 333-342
Second, G. 1991. Molecular markers in rice systematics and the evaluation of genetic resources in Y. P.S. Bajaja (ed). Biotechnology in agriculture and forestry, 4: 468-490
Shi, B., M. Khayatnezhad and A. Shakoor (2021). "The interacting effects of genetic variation in Geranium subg. Geranium (Geraniaceae) using scot molecular markers." Caryologia 74(3): 141-150.
Si, X., L. Gao, Y. Song, M. Khayatnezhad and A. A. Minaeifar (2020). "Understanding population differentiation using geographical, morphological and genetic characterization in Erodium cicunium." Indian Journal of Genetics and Plant Breeding 80(4): 459-+.
Sikuku, P.A., Netondo, G. W., Musyimi, D.M. and Onyango, J.C. 2010. Effects of water deficit on days to maturity and yield of three NERICA rainfed rice varieties. ARPN J. Agric. Biol. Sci. 5: 1- 9.
Soltani, A., and Maddah, V. 2010. Simple, applied programs for education and research in agronomy. Shahid Beheshti University Press. (In Persian).
Soltani, A., Zeinali, E., Galeshi, S. and Latifi, N. 2001. Genetic variation for and interrelationships among seed vigor traits in wheat from the Caspian Sea coast of Iran. Seed Sci. Technol. 29: 653-662.
Sun, Q., D. Lin, M. Khayatnezhad and M. Taghavi (2021). "Investigation of phosphoric acid fuel cell, linear Fresnel solar reflector and Organic Rankine Cycle polygeneration energy system in different climatic conditions." Process Safety and Environmental Protection 147: 993-1008.
Sun, X. and M. Khayatnezhad (2021). "Fuzzy-probabilistic modeling the flood characteristics using bivariate frequency analysis and alpha-cut decomposition." Water Supply 21(8): 4391-4403.
Tao, Z., Z. Cui, J. Yu and M. Khayatnezhad (2022). "Finite Difference Modelings of Groundwater Flow for Constructing Artificial Recharge Structures." Iranian Journal of Science and Technology-Transactions of Civil Engineering 46(2): 1503-1514.
Tekrony, D.M. and Egli, D.B., 1991. Relationship of seed vigor to crop yield: a review. Crop Sci. 31: 816- 822.
Wang, C., Y. Shang and M. Khayatnezhad (2021). "Fuzzy Stress-based Modeling for Probabilistic Irrigation Planning Using Copula-NSPSO." Water Resources Management 35(14): 4943-4959.
Wang, H., M. Khayatnezhad and N. Youssefi (2022). "Using an optimized soil and water assessment tool by deep belief networks to evaluate the impact of land use and climate change on water resources." Concurrency and Computation-Practice & Experience 34(10).
Wang, J., Q. Ye, C. Wang, T. Zhang, X. Shi, M. Khayatnezhad and A. Shakoor (2021). "Palynological analysis of genus Geranium (Geraniaceae) and its systematic implications using scanning electron microscopy." Caryologia 74(3): 31-43.
Wang, S., J. Ma, W. Li, M. Khayatnezhad and B. D. Rouyendegh (2022). "An optimal configuration for hybrid SOFC, gas turbine, and Proton Exchange Membrane Electrolyzer using a developed Aquila Optimizer." International Journal of Hydrogen Energy 47(14): 8943-8955.
Xu, Y.-P., P. Ouyang, S.-M. Xing, L.-Y. Qi, M. Khayatnezhad and H. Jafari (2021). "Optimal structure design of a PV/FC HRES using amended Water Strider Algorithm." Energy Reports 7: 2057-2067.
Yin, J., M. Khayatnezhad and A. Shakoor (2021). "EVALUATION OF GENETIC DIVERSITY IN Geranium (Geraniaceae) USING RAPD MARKER." Genetika-Belgrade 53(1): 363-378.
Zhang, H., M. Khayatnezhad and A. Davarpanah (2021). "Experimental investigation on the application of carbon dioxide adsorption for a shale reservoir." Energy Science & Engineering 9(11): 2165-2176.
Zhang, J., M. Khayatnezhad and N. Ghadimi (2022). "Optimal model evaluation of the proton-exchange membrane fuel cells based on deep learning and modified African Vulture Optimization Algorithm." Energy Sources Part a-Recovery Utilization and Environmental Effects 44(1): 287-305.
Zhao, Y., H. Wang, W. Liang, M. Khayatnezhad and Faisal (2021). "GENETIC DIVERSITY AND RELATIONSHIPS AMONG SALVIA SPECIES BY ISSR MARKERS." Genetika-Belgrade 53(2): 559-

574.

Zheng, R., S. Zhao, M. Khayatnezhad and S. A. Shah (2021). "Comparative study and genetic diversity in Salvia (Lamiaceae) using RAPD Molecular Markers." Caryologia 74(2): 45-56.

Zhu, H., Z. Xie and S. Ge. 2003. Microsatellite analysis of genetic diversity and population genetic structure of a wild rice (Oryza rufipogon Griff.) in China. Theoretical and Applied Genetic, 107: 332- 339.

Zhu, K., L. Liu, S. Li, B. Li, M. Khayatnezhad and A. Shakoor (2021). "Morphological method and molecular marker determine genetic diversity and population structure in Allochrusa." Caryologia 74(2): 121-130.

Zhu, P., H. Saadati and M. Khayatnezhad (2021). "Application of probability decision system and particle swarm optimization for improving soil moisture content." Water Supply 21(8): 4145-4152.

Zuo, J. R. and Li, J. Y. 2014. Molecular dissection of complex agronomic traits of rice: A team effort by Chinese scientists in recent years. National Science Review 1 (2): 253-276.