Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2022 19(2): 1267-1273. **OPEN ACCESS**

Evaluating links between production and 15 distinct genotypic characteristics of bread wheat

Arda Karasakal

Department of Science and Engineering, Yildirim Beyazit University, Ankara, **Turkey**

***Correspondence:** icnfsci@gmail.com **Received 09-05-2022, Revised: 17-06-2022, Accepted: 19-06-2022 e-Published: 23-06-2022**

An investigation was carried out in Miyaneh city in the 2020-21 farming year employing 15 wheat genotypes during a randomized complete block design with three replications in order to elucidate the link between various characteristics and wheat grain yield and to identify the proportion of those characteristics having the largest influence on grain yield, as well as to explore the direct and indirect impacts between grain yield and its constituents in wheat. Plant height, spike length, spike weight, frequency of seeds per spike, seed weight per spike, 1000-seed weight, physiological yield, and straw yield varied significantly across genotypes by 5 and 1% probability levels. Grain yield correlated positively and significantly with spike length, spike weight, 1000-grain weight, and harvest index. During the stepwise regression analysis, the findings revealed that physiological yield, spike weight, and frequency of grains per spike were the factors that described the greatest variation in grain production with a 97% coefficient. Physiological yield (3.208) had the greatest direct impact on grain yield, according to an etiological examination of grain yield and its components. The chosen plant community possesses the requisite diversity since the tested cultivars differed significantly in consideration of all traits. This means that it may also be utilized as a basic community for the objectives of breeding. Results from this research suggest that selection factors, including physiological yield, may be used to enhance wheat grain yields in the future. The features of grain weight per spike, frequency of grains per square meter, and physiological yield may all be utilized in selection procedures to increase wheat grain yields, for example.

Keywords: Wheat, Trait correlation, Stepwise regression, Etiological analysis

INTRODUCTION

Breeding for higher wheat grain yields and better yield components may be successful strategies in breeding projects. As a result, it is critical to investigate the connection between functional constituents and effectiveness. One of the most essential and crucial crops globally is wheat Triticum aestivum L. (Alizadeh 2021, Karasakal 2021, Mohammadzadeh 2021, Radmanesh 2021). Global wheat output in 2017 was estimated by the FAO at 771.1 million tons, with a cultivated surface of 218.5 million hectares. Iran, too, has the potential to produce 14 million tons of grain and cultivate 6.7 million acres of land, according to some estimates(Gholamin and Khayatnezhad 2020, Bi, Chen et al. 2021, Hou, Li et al. 2021, Khayatnezhad and Nasehi 2021, Xu, Ouyang et al. 2021, Zhao, Wang et al. 2021, Zhang, Khayatnezhad et al. 2022). Direct and indirect impacts of correlation coefficients on other qualities may be separated using path coefficient analysis. It may also provide light on the interrelationships between characteristics and their interaction(Gholamin and Khayatnezhad 2020, Khayatnezhad and Gholamin 2020, Chen, Khayatnezhad et al. 2021, Huang, Wang et al. 2021, Wang, Ye et al. 2021, Wang, Khayatnezhad et al. 2022). It is possible that other components have an indirect effect on the participation of each functional component in the rationalization of grain yield (Heidari et al., 2008). There are several physiological systems that have an impact on cereal grain yield, which makes it a dependent variable in crop production. Selecting grain yield-related morphological features that are both directly and favorably associated with grain yield and that is also simple to assess may boost this trait's selection effectiveness. (Blum, 1997). It is possible to exclude the influence of ineffective qualities in the regression model on effectiveness, and only those features that explain a considerable proportion of performance variations may be evaluated using stepwise regression analysis (Agrama, 2016). The direct and indirect influences of independent factors on the dependent variable may be explored via etiological analysis(Gholamin and Khayatnezhad 2020, Karasakal, Khayatnezhad et al. 2020, Si, Gao et al. 2020, Cheng, Hong et al. 2021, Shi, Khayatnezhad et al. 2021). Through the use of this approach, the correlation coefficient between two characteristics is split into components measuring both direct and indirect impacts

(Farshadfar, 2004). The findings of the etiological analysis regarding grain yield revealed that the characteristics with the greatest direct influence on grain production were vegetative development rate and harvesting index, showing that these features are important for grain yield (Bahram Nejad and Taleei, 2000). A stepwise regression assessment using wheat genotypes by Naderi and colleagues (2000) revealed that biomass and harvesting index are among the variables that influence grain performance, with choosing based on these features is effective in boosting the grain yield during drought conditions. Sepanlu et al. (2004) used multiple linear regression to study 25 bread wheat genotypes and found that choosing for more spikes per unit area during drought tension increased grain yield (Gholamin and Khayatnezhad 2020, Karasakal, Khayatnezhad et al. 2020, Guo, She et al. 2021, Ma, Ji et al. 2021, Ma, Khayatnezhad et al. 2021, Peng, Khayatnezhad et al. 2021). According to research on bread wheat, Moghaddam et al. indicated that the frequency of spikes per plant, count of seeds per spike, 1000-seed weight, and harvesting index had the greatest direct influence on grain output. Etiological research performed by Hoxha and Sulovari (1999) revealed a direct link between grain output and plant height, vegetative development duration, and average spike weight in their study of the connection between production and several quantitative features of hard wheat. Additionally, they demonstrated that leaf surface, fertile tiller count, spike length, spikelet count, harvesting index, and leaf orientation all had an indirect influence on performance (Jia, Khayatnezhad et al. 2020, Gholamin and Khayatnezhad 2021, Ren and Khayatnezhad 2021, Sun, Lin et al. 2021, Wang, Shang et al. 2021, Yin, Khayatnezhad et al. 2021). Employing 12 quantitative variables on 298 indigenous wheat cultivars, research revealed that clustering duration was positively and significantly associated with physiological maturation, plant elevation, and the frequency of spikelets inside the cluster (Khayatnezhad and Gholamin 2020, Li, Mu et al. 2021, Liu, Wang et al. 2021, Zhang, Khayatnezhad et al. 2021, Zheng, Zhao et al. 2021, Zhu, Liu et al. 2021). Physiological yield, grain output, and the weight of 1,000 seeds all showed a negative relationship with this trait. Cluster length and chlorophyll concentration were shown to be positively and significantly related, according to the research conducted by Shahid Masood et al. (2005). As part of etiological analysis research, plant elevation and grain weight exhibited a direct and positive impact on yield, whereas the duration of clustering showed a direct and negative impact. Using these characteristics in selecting genotypes to boost yield was also demonstrated (Aycicek and Yildirim, 2006). Etiological examination of wheat grain yield components conducted by Ely-el and Bana (2018) revealed that the frequency of spikes per square meter, the count of grains per spike, and the 1000-seeds weight accounted for 98.9 percent of yield fluctuations. They also found that the higher the number of spikes per square meter, the greater the direct impact.

MATERIALS AND METHODS

This investigation employing 15 genotypes in a randomized full block format with three replications has been conducted in the 2020-21 cultivation year in Miyaneh city, which is situated at longitude and latitude of 48.2 East and 38.15 North, respectively, and at an altitude of 1350 meters above the sea surface (Table 1). Three rows, 20 cm apart and three meters long, made up each experimental plot. Two irrigations were done in the fall and three in the spring. In the fall, the land was prepped, and the culture medium was developed. Planting was completed after plowing and disk installation. Using an average seed weight of 1000 and a seed density of 400 seeds per square meter, we calculated the total quantity of seeds needed. Irrigation occurred once during the fall and twice during the spring, whereas urea fertilization occurred once in the fall and twice in the spring.

Table 1- List of genotypes

Number	Genotype
1	Alamout
2	Viking/5/Gds/4/Anza/3/Pi/Nar//Hys/6/Spn/Mcd//
3	Navid
4	Shahriar
5	Viking/5/Gds/4/Anza/3/Pi/Nar//Hys/6/Spn/Mcd//
6	Aghbugda/90Zhong87/4/Spn/Mcd//Cama/3/Nzr
7	Sardari
8	Toos
9	Zarrin
10	Sabalan
11	SARDARI-HD39/6/SN64//SKE/2*ANE/3/SX/4/BEZ/5/SERI
12	Alvand
13	Pasteur
14	GB254
15	SARDARI-HD39/6/SN64//SKE/2*ANE/3/SX/4/BEZ/5/SERI

In accordance with local tradition and at an ideal level throughout the growth season, we controlled weeds, pests, and probable illnesses. Analysis of variance was carried out in a randomized full block design after assessing and documenting vegetative characteristics and determining yield-associated traits. Afterward, straightforward correlation coefficients between all of the qualities were figured out. Stepwise regression was also used to determine the characteristics with maximum influence on grain performance. Eventually, the influence of characteristics and components on grain yield was evaluated using path coefficients and simple correlation, and the etiological explanations for this were discussed. Plant elevation, frequency of fertile tillers, spike length, spike weight, frequency of seeds per spike, spike weight, 1000-seed weight per spike, physiological yield, straw yield, harvesting index, and grain yield were among the traits examined during this research. Analysis of variance, simple correlation coefficients, stepwise regression

analysis, and etiological analysis were performed as part of the statistical analysis procedure. SPSS-16, MSTAT-C, and Minitab-15 were all used in this process.

RESULTS AND DISCUSSION

In terms of plant elevation, spike length, spike weight, frequency of seeds per spike, grain weight per spike, 1000-seed weight, physiological yield, and straw yield, there was a significant difference in genotypes connected to bread wheat (Table 2) at the threshold of probability of 5 and 1 percent, according to an analysis of variance. To be effective, any breeding strategy for selection must take into account many factors, including tuber functioning, as well as how each of these factors relates to quality, pathway, size, and the relative significance of these factors. Using correlation coefficients, numerous studies and investigations examine the two-way link between a couple of characteristics, particularly tuber activity and associated characteristics (Khayatnezhad and Gholamin 2021, Li, Khayatnezhad et al. 2022, Wang, Ma et al. 2022).

Table 2- Analysis of variance of evaluated traits

Source	df	Mean of Squares									
		Plant height	Length of spike	spike weight	Grains number	Grain weight	1000 grain weight	Biological yield	Straw yield	Harvest index	Grain yield
Replication	**2**	308.2**	0.145	0.185**	10.28	15.4*	44.5**	13.22*	0.164*	78.568	0.325
Genotypes	**14**	207.4**	0.401**	0.201**	90.22**	13.8**	108.2**	11.92*	0.158*	201.22*	0.86*
Error	**28**	20.98	0.165	0.05	11.85	3.8	7.3	3.6	0.04	22.85	0.254
C. V %		7.1	4.28	14.28	10.85	11	4.64	18.22	20.28	14.85	15.22
* and ** Significantly at p < 0.05 and < 0.01, respectively.											

Table 3- Simple correlation coefficients between the studied traits

	Plant height	Length of spike	spike weight	Grains number	Grain weight	1000 grain weight	Biological yield	Straw yield	Harvest index	Grain yield
Length of spike	-0.246	1								
spike weight	-0.601*	0.014	1							
Grains number	-0.643*	0.032	0.765**	1						
Grain weight	0.670*	0.045	0.942**	0.780**	1					
1000 grain weight	0.302	-0.065	-0.518*	-0.752**	-0.800*	1				
Biological yield	-0.012	0.201	0.342	0.272	0.105	-0.222	1			
Straw yield	0.180	0.14	0.135	0.251	0.023	0.248	0.94**	1		
Harvest index	-0.546*	0.100	0.102	-0.02	0.142	0.264	-0.452	-0.55*	1	
Grain yield	-0.502	0.705*	0.268	0.702**	0.264	0.725**	0.068	-0.100	0.648*	1
* and ** Significantly at p < 0.05 and < 0.01, respectively										

Table 4- Regression coefficients of standard component and coefficients describing the characteristics related to grain yield

Stage	Model	Standardized Coefficients	t	sig	Tolerance
		Beta			
1	GY = f(BY)	3.208	38.22	0.000	0.106
3	GY = f(BY &SW)	1.105	5.058	0.002	0.285
4	GY = f(BY & SW & NGS)	0.138	1.68	0.004	0.346

In determining the degree to which two or more variables are related, the correlation coefficient measures the amount of symmetrical correlation between them, rather than the degree to which one variable is dependent on the other (Sun and Khayatnezhad 2021, Zhu, Saadati et al. 2021, Tao, Cui et al. 2022). Determine the relative relevance of various qualities and their utility as a selection criterion for grain yield may be done by analyzing correlation coefficients between these characteristics and tuber yielding (Khodadadi et al. 2011). As can be seen in Table 3, a positive and substantial association was found between grain yield and the following characteristics: spike length, spike weight, 1000-grain weight, and harvesting index. There was a substantial and positive correlation between grain weight per spike, spike weight, and the frequency of grains per spike. This association with plant elevation, on the other hand, was negative and substantial (Khayatnezhad and Gholamin 2021). There was a positive and significant correlation between the frequency of seeds per spike and the weight of seeds per spike, while an unfavorable and substantial correlation has been found with the weight of 1000-seeds.

This study found a positive and substantial association between biological production and straw production; however, the opposite was true for the straw output and harvesting indices. According to Sadeghzadeh et al. (2012), plant elevation and 1000-seeds weight were positively correlated with grain yielding. Grain yield was characterized as a function variable (Y), while other characteristics were regarded as independent variables during stepwise regression analysis. With a 97 percent coefficient, the findings of stepwise regression (Table 4) revealed that physiological yield, the weight of spikes, and frequency of grains per spike described the highest variations in grain yielding. The following equation may be derived using physiological yield (x_1), spike weight (x_2), and frequency of grains per spike (x_3):

$Y = 0.218 + 0.942 ** X_1 + 7.515 ** X_2 + 0.221 ** X_3$

These features are beneficial in increasing grain production, as shown by a substantial explanatory coefficient in the acceptable regression equation. There was a positive correlation between spike weight and the frequency of grains per spike and grain yield in the aforementioned formula. When it comes to identifying the link between significant characteristics and economic efficiency, etiological analysis is quite crucial. Etiological analysis (path) is a better method for determining how qualities impact directly and indirectly on performance than correlation coefficients since they don't take into account how traits interact with each other (Ibrahim, K. 1994). The findings (Table 5) indicated that physiological yield, spike weight, and frequency of grains per spike with values of 3.208, 1.05, and 0.138 all exhibited a direct and favorable influence on grain yielding. Directly measured, the highest beneficial impact was ascribed to physiological yielding (+ 3.208). Grain yield variations may be explained by factors other than the model's remaining effects (0.98). These observations are congruent with the findings of Naderi et al. (2000), who found two particular features and presented biomass yield as valuable traits in their research. Among tall and medium cultivars, enhancing plant yield and the frequency of spikes per plant is more relevant than the yield in each cluster and the 1000-seed weight in previous experiments, according to coefficient analysis. Dwarf cultivars, on the other hand, have shown the importance of seed characteristics per plant and 1000-seeds weight (Huang et al. 1989). It is advised that the width of the leaf be used to pick the yield characteristic based on outcomes. Grain yield was shown to be positively associated with the frequency of spikes per square meter by Okuyama et al. (2004). The researchers also found that, towards the completion of the growth period, the frequency of spikes per square meter demonstrated a direct and beneficial impact on grain performance. Plant elevation and seed weight in the cluster were shown in one research to have a direct and positive influence on yield, whereas clustering duration has been shown to have a direct and negative effect. Genotypic selection for increased yield may also benefit from applying these features (Alizadeh 2021, Karasakal 2021, Mohammadzadeh 2021, Radmanesh 2021).

Table 5: Direct and indirect impacts of independent traits on grain yield according to correlation coefficients

Traits	Direct effect	Indirect effect			Total correlation
		Biological yield	spike weight	Number of grains per spikes	
Biological yield	3.208	-	0.026	0.002	0.94**
spike weight	1.105	0.685	-	0.004	0.268
Number of grains per spikes	0.138	0.408	0.011	-	0.702**
R-Sq(adj) = 0.98					

CONCLUSION

Since there was a considerable variation in all parameters across the tested cultivars, the chosen plant ecosystem possesses favorable biodiversity and may be utilized for breeding objectives. The selection of high-yielding wheat genotypes may be aided by using physiological yield and spike weight as criteria. The attributes of grain weight per spike, frequency of grains per square meter, and physiological yielding may all be employed in selection procedures to enhance wheat grain performance.

CONFLICT OF INTEREST

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

ACKNOWLEDGEMENT

This paper was from University project 5849 YBU-5011, 2021.

AUTHOR CONTRIBUTIONS

Arda Karasakal 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

Agrama, H.A.S., 2016. Sequential path analysis of grain yield and its components in maize. Plant Breading. 115, 343- 346.

Alizadeh, M. (2021). "Maize residue management effect on nitrogen fertilizer and canola grain yield." Bioscience Research 18(4): 3098-3104.

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.

Aly, R.M., El-Bana, A.Y., 2018. Grain yield analysis for nine wheat cultivars grown in newly cultivated sandy soil under different n fertilization levels. Journal of Agricultural Research. 21, 67-77.

Aycicek, M. And T. Yildirim, 2006. Path coefficient analysis of yield and yield components in breed wheat (Triticum aestivum L.) Genotypes. Pakistan Journal of Botany, 38: 417-424.

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.

Blum, A., 1997. Crop responses to drought and the interpretation of adaptation. Plant Growth Regulation. 20, 135- 148

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.

FAO, 2017. Fao.org/faostat/en/#data/QC.

Farshadfar, E., 2004. Multivariate principles and procedures of statistics. Taghbostan Publication. [In Persian].

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.

Heidari, B., G. Saeidi and B. E. Sayed-Tabatabaei. 2008. Factor analysis for quantitative traits and path analysis for grain yield in wheat. J. Sci. & Technol. Agric. & Nature. Resour. 42: 135-144.

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.

Hoxha, S., and H. Sulovari. 1999. The relation of the production with some quantitative characteristics hard wheat. Literature up data on wheat barley and Triticale. CIMMYT, November-December. Vol. 5. No. 6.

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.

Huang, Z., Z. Meixue, and Yousheng, H., 1989. Analysis of genetic advance, genetic correlation and path coefficient for yield characters in wheat. Jiangsu Journal of Agricultural Sciences (China), 5: 18-23

Ibrahim, K. 1994. Association and path coefficient analysis of some traits in bread wheat. Annals of Agricultural science Moshtohor. 32(3): 1189-1198.

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.

Karasakal, A. (2021). "Effects of pre-and post-harvest putrescine applications on water relations and pot duration of cut alstroemeria flowers." Bioscience Research 18(4): 3162-3170.

Karasakal, A. (2021). "Production of Wheat Seed Through Various Plantation Practices in Maternal Environment." Bioscience Biotechnology Research Communications 14(2): 549-552.

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.

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.

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). "The Combined and Isolated Effect of Spinosad and Nuclear Polyhedrosis Virus on the Mediterranean Brocade Spodoptera littoralis in laboratory Conditions." Bioscience Biotechnology Research Communications 14(2): 692-696.

Radmanesh, M. (2021). "The Effects of various enrichment treatments on the chemical characteristics of maturated vermicompost." Bioscience Research 18(4): 3048-3056.

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.

Shahid Masood, M., A. Javaid, M. Ashiq rabbani, And R. Anwar, 2005. Phenotypic diversity and trait association in bread wheat (*triticum aestivum* L.) Landraces from baluchistan, pakistan. Pakistan Journal of Botany, 37(4): 949- 957

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-+.

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.

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, 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.