GENETIC ASSESSMENTS OF SOME LOCAL AND IMPORTED GENOTYPES OF RICE IN SULAIMANI GOVERNORATE - IRAQ

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ABSTRACT

This study was carried out at two locations in Sulaimani Governorate, Iraq during 2022 to investigate the genetic potential of thirty-one rice genotypes to highlights the genetic diversity among rice genotypes and emphasizes the importance of considering both genetic and environmental factors in rice breeding programs. The distinct performance of genotypes across different traits and locations provides valuable information for selecting and developing rice varieties with improved characteristics and higher yield potential. The results of the analysis of variance indicate highly significant differences among the genotypes for all studied traits at both Chalakh and Penjwen locations. This suggests a substantial genetic diversity among the studied genotypes, shows their potential as valuable genetic resources for breeding programs. Additionally, the interaction between genotypes and environments was found to be highly significant for most traits, emphasizing the importance of considering both genetic and environmental factors in rice research. G_1 was superior to the other genotypes regarding the grain yield plant^{-1} with 60.909 and 29.004 g at Chalakh and Penjwen locations respectively. Moreover, the impact of location on the studied traits was significant, with Chalakh outperforming Penjwen in all traits. This difference in performance could be attributed to variations in climatic conditions and environmental factors between the two locations.

Keywords: *Oryza sativa* L., genotypes performance, locations, correlation analysis, path analysis.
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لتقييم الوراثي لبعض التراكيب الوراثية المحلية والمستوردة لصنف الرز في محافظة السليمانية – العراق

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المستخلص

إجري هذا البحث في موقعين مختلفين في محافظة السليمانية بالعراق خلال الموسم الزراعي 2022 لبحث القابلية الوراثية لواحد وثلاثين تركيباً وراثيًا للرز، لمعرفة على التنوع الوراثي بين التراكيب الوراثية والتأكيد على أهمية مراعاة العوامل الوراثية والبيئية في برامج تربية الرز. يوفر الأداء المتميز للتراكيب الوراثية عبر الصفات والمواقع المختلفة معلومات قيمة لاختيار وتطوير أصناف الرز ذات الخصائص المحسنة وإمكانات الإنتاج الأعلى. أشارت نتائج تحليل التباين إلى وجود فروقات معنوية بين التراكيب الوراثية و لجميع الصفات المدروسة في كلا الموقعين مما يشير إلى وجود إختلافات وراثية كبير بين التراكيب الوراثية المدروسة، ويظهر إمكاناتها كموارد وراثية قيمة لبرامج التربية. بالإضافة إلى ذلك، وجد أن التفاعل بين التراكيب الوراثية والبيئات له أهمية كبيرة بالنسبة لمعظم الصفات، مما يؤكد أهمية مراعاة العوامل الوراثية والبيئية في أبحاث الرز. تفوقت G_1 على جميع التركيب الوراثية الآخرى فيما يتعلق بإنتاج الحبوب نبات$^{-1}$ حيث بلغت 60.909 و29.004 جم في موقعي جالاخ وبنجوين على التوالي. علاوة على ذلك، كان تأثير الموقع في الصفات المدروسة معنوياً جداً، حيث تفوق جالاخ على بنجوين في جميع الصفات. ويمكن أن يعزى هذا الاختلاف في الأداء إلى الاختلافات في الظروف المناخية والعوامل البيئية بين الموقعين.

الكلمات المفتاحية: *Oryza sativa* L. ، أداء التراكيب الوراثية، المواقع، تحليل الارتباط، تحليل المسار.
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INTRODUCTION

The objective of rice plant breeders in Iraq is to develop rice genotypes that have increased production potential. Iraq's diverse agroecosystems contribute to the development and adaptation of multiple rice cultivars. The breeders strive to create varieties that are well-suited to the different ecological conditions found in Iraq, such as variations in soil types, climate, and water availability. This focus on developing adapted cultivars is important in order to optimize rice production and improve yields across different regions of the country (33). One technique for boosting rice output is to increasing yield per unit area which can be achieved through various approaches such as developing high-yielding varieties, employing effective agronomic practices, and utilizing advanced farming technologies. To achieve significant improvements in rice production, it is crucial to enhance rice genetic improvement. This involves developing new rice varieties that possess desirable traits such as high yield potential, resistance to diseases and pests, tolerance to environmental stresses, and improved agronomic performance. Understanding the link between yield and the qualities contributing to it is vital for developing an efficient selection technique. This helps breeders identify the key traits that positively impact yield and focus on improving those traits during the breeding process. Multivariate analysis is a valuable technique employed by breeders to examine genetic variability in rice. It allows them to assess multiple traits simultaneously and identify patterns of genetic diversity within the rice population. Genetic diversity is essential for sustaining high output levels as it provides a broader genetic base for breeding efforts, enabling the development of improved varieties with diverse genetic backgrounds (34). There are some challenges that contribute to the low average yield per area of land in Iraq compared to other countries. The practice of cultivating wheat after rice can lead to lower soil fertility as both crops have similar nutrient requirements. Continuous rice-wheat cropping without appropriate soil management practices can deplete soil nutrients, negatively affecting rice yields (2). Furthermore, high water consumption during the rice growing season is another challenge, particularly in regions where water availability is limited, especially during the summer months. Insufficient water supply during critical growth stages can result in reduced rice yields and poor crop performance. Efficient irrigation techniques, water management practices, and the use of drought-tolerant rice varieties can help mitigate this challenge. To improve the average yield per area of land in Iraq, it is important to address these factors by implementing sustainable farming practices. This may include the adoption of crop rotation systems, such as introducing leguminous crops or green manure crops after rice, to improve soil fertility (27). A plant breeder's most critical choice is choosing parents to utilize in a hybridization approach. It makes sense to use genetic divergence to choose parents for an efficient hybridization and breeding program (35). Identifying the variables critical for population-level genetic variety, according to Singh and Chaudhary (28), may aid in the selection of diverse parents for hybridization programs. Several scholars have utilized multivariate analysis to discover and assess diversity in a variety of rice using agromorphological features (19, 25). To choose and breed distinct varieties and lines of rice with higher yield potential, a plant breeder must have a solid understanding of the phenotypic and genotypic interactions of many economic elements (3, 23). The intensity and direction of the link between yield and its component features are revealed through correlation analysis of yield and its component traits. Yong-xiang *et al.* (38) examined 20 different varieties of rice based on nine unique characteristics. The number of grain panicle^{-1} and 1000-grain weights were shown to be highly correlated with rice grain yield plant^{-1}. Sabesan *et al.* (26) investigated 54 rice cultivars and discovered that plant height and the number of tillers plant^{-1} were positively related to grain yield plant^{-1}. Hairmansis *et al.* (8) discovered that plant height had a negative influence on grain yield plant^{-1}, although 1000-grain weight had no effect. The study focuses on assessing the genetic characteristics of local and imported rice genotypes in Sulaimani Governorate, Iraq. The aim of this study is to evaluate the genetic diversity and traits of these rice genotypes for potential cultivation in the region. This research likely involves collecting samples of different rice genotypes from both local varieties that have been traditionally grown in the region and imported varieties that have been introduced to Iraq. Various genetic assessments and analyses would then be conducted to evaluate the genetic diversity, phenotypic characteristics, and agronomic traits of these genotypes.

MATERIALS AND METHODS

Thirty-one rice genotypes were collected throughout Iraq for this study; these genotypes were named according to the region from which they were originally sourced as well as the local name (Table 1). The field experiments were conducted at two locations in Sulaimani Governorate, Chalakh Village / Dukan Township (Lat. 35° 48' 59.5"; N, Long. 45° 06' 04.4"; E, 701 MASL, 41.99 Km Northwest of Sulaimani city) in a clay soil and Penjwen Township (Lat. 35° 37' 25.94"; N, Long. 45° 56' 56.93"; E, 1269.65 MASL, 48.88 Km East of Sulaimani city) in a silty-clay soil, Sulaimani Governorate, Iraq, in 2022. The seeds were planted in 9th April 2022 at College of Agricultural Engineering Sciences field in a green house and the seedlings were transfer to the seedling tray in 21st April 2022 then transport and planted in 25th May 2022 at Chalakh location and in 13th June 2022 at Penjwen location respectively. At both locations, Rice was planted at a spacing of 20 cm. The area of the plot was 6 m^2. NPK Fertilizer 18; 18; 18 was used to apply fertilizers at a rate of 100; 40; 40 of N; P; K [nitrogen (N), phosphorus (P), and potassium (K)] Kg ha^{-1}. The entire phosphorus and potassium doses, as well as half of the N dose, were used as an initial dose, and the remaining 50% nitrogenous fertilizer was split into two halves. The first was used during the tillering process, and the second during the booting process. Other cultural operations were carried out in accordance with standard field procedures. At Chalakh location the harvesting was done in 9th September for all of the Japonica genotypes and in 26th September 2022 for all of the Indica genotypes. At Penjwen location the harvesting was done in 25th October for all of the Japonica genotypes and in 5th November 2022 for all of the Indica genotypes. At maturity, five plants from $plot^{-1}$ were randomly picked to record agronomic characteristics, plant height (cm), flag leaf length (cm), number of tillers $plant^{-1}$, number of grains $panicle^{-1}$, 1000-grain weight (g), grain length (mm), grain width (mm), and grain yield $plant^{-1}$ (g). The results were statistically examined as a general test using Randomized Complete Block Design (RCBD) with three replicates; a combined analysis of variance across sites was also performed for the studied characteristics. The Least Significant Difference (L.S.D) test was used to compare all feasible means at significant levels of 0.05 and 0.01. The correlation coefficients were determined in each setting to establish the degree of relationship of traits with yield as well as among the yield components themselves. The phenotypic correlations and the path coefficient analysis were performed by the equations proposed by Singh and Chaudhary (28) using Analysis of Moment Structures (AMOS) Ver. 18 software. Using the IBM SPSS software, Ver. 19, a hierarchical cluster analysis based on Euclidean Distance and Unweighted Pair-group Linkage (UPGMA) was also done to cluster the relatedness of rice genotypes based on agromorphological parameters (9).

Table 1. Description and details of the studied genotypes

Genotypes	Names	Types	Locations
G_1	Barazily 1	Japonica Rice	Sulaimani – Bakrajo
G_2	Tahaluf	Japonica Rice	Sulaimani – Bakrajo
G_3	Tahalif 4 Months	Japonica Rice	Duhok - Bardarash
G_4	Mawlawy Sur Sarda	Japonica Rice	Sulaimani – Shahrazoor – Tapatoka
G_5	Bazian Sur	Japonica Rice	Sulaimani – Bakrajo
G_6	Safa Sur	Japonica Rice	Sulaimani – Peramagroon- Guleja
G_7	Chawtan	Japonica Rice	Sulaimani – Darbandi Khan – Chawtan (Kawa Ahmad)
G_8	6 Months	Japonica Rice	Duhok – Akrea – Harer Batas
G_9	Sarda	Japonica Rice	Sulaimani – Kalar – Sea Tapan
G_{10}	Gull Sur Safa Sur	Japonica Rice	Sulaimani – Peramagroon- Guleja
G_{11}	Chawtan	Japonica Rice	Sulaimani – Darbandi Khan – Chawtan (Anwar Jalal)
G_{12}	6 Months	Japonica Rice	Duhok – Akrea – Bana Sur
G_{13}	Ambar 6 Months	Indica Rice	Sulaimani – Pshdar - Qaladze
G_{14}	Sadry	Indica Rice	Duhok – Akrea – Bana Sur
G_{15}	Anbar	Indica Rice	Duhok – Akrea – Kalat
G_{16}	Sadry	Indica Rice	Duhok – Akrea – Kalat
G_{17}	Sadry 6 Months	Indica Rice	Duhok - Bardarash
G_{18}	Gull Rash	Indica Rice	Sulaimani – Bakrajo
G_{19}	Sadry	Indica Rice	Iran – Tehran - Shamly
G_{20}	Anbar Baghdad	Indica Rice	Baghdad
G_{21}	Anbar Furat	Indica Rice	Baghdad
G_{22}	Yassamin 1	Indica Rice	Najaf - Mshkhab
G_{23}	Anbr 33	Indica Rice	Najaf - Mshkhab
G_{24}	Aba 1	Indica Rice	Najaf - Mshkhab
G_{25}	Bhus 1	Indica Rice	Najaf - Mshkhab
G_{26}	Ghadir	Indica Rice	Najaf - Mshkhab
G_{27}	Furat 1	Indica Rice	Najaf - Mshkhab
G_{28}	Mshkhab 1	Indica Rice	Najaf - Mshkhab
G_{29}	Albaraka	Indica Rice	Najaf - Mshkhab
G_{30}	Barnamij 4	Indica Rice	Najaf - Mshkhab
G_{31}	Mshkhab 2	Indica Rice	Najaf - Mshkhab

RESULTS AND DISCUSSION

Analysis of variance: According to the mean squares of the variance analysis, highly significant differences were detected among the genotypes for all of the studied traits at Chalakh and Penjwen locations which indicates the presence of huge differences among the studied genotypes (Table 2). This illustrates the genotypes' high potential for use as a genetic source for breeding purposes (16). The mean squares of the combined analysis of the variances indicated the presence of highly significant mean squares due to the locations for all of the traits, while the mean squares due to the genotypes were highly significant for all of the studied traits. Concerning the (Genotypes × Environments) interaction they were indicated to be highly significant for all of the traits except for grain length and width which were not significant (Table 3). These findings highlight the significance of genetics, environment, and the interaction effect of genotypes and environment. When investigating rice growth in multi-location research studies, interaction effects have substantial implications that cannot be underestimated (1).

Table 2. The mean squares of the Analysis of Variance at both locations

S.O.V	d.f	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)	Grain yield plant^{-1} (g)
					Chalakh Location					
Blocks	4	1.348	1.539	334.133	514.093	2231.345	0.682	0.032	0.119	814.588
Genotypes	30	705.829 **	338.289 **	284.437 **	249.057 **	5604.001 **	42.728 **	10.259 **	1.559 **	1297.259 **
Exp. Error	120	1.788	1.562	22.648	12.230	294.420	1.007	0.192	0.136	87.418
					Penjwen Location					
Blocks	4	3.332	0.442	0.639	0.992	422.907	0.103	1.765	0.526	162.573
Genotypes	30	1178.445 **	130.949 **	34.642 **	157.974 **	1130.702 **	103.351 **	9.505 **	1.317 **	251.586 **
Exp. Error	120	2.116	1.769	1.923	0.438	55.336	0.237	0.418	0.172	17.649

Table 3. The mean squares of the Combined Analysis of Variance at the average of both locations

S.O.V	d.f	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)	Grain yield plant^{-1} (g)
Location	1	31602.903 **	1180.726 **	7301.678 **	4028.713 **	194723.355 **	12186.909 **	22.761 **	2.713 *	29735.354 **
Block /Locations =E(a)	8	2.340	0.990	167.386	257.543	1327.126	0.393	0.898	0.323	488.580
Genotypes / Locations	60	942.137 **	234.619 **	159.540 **	203.516 **	3367.351 **	73.039 **	9.882 **	1.438 **	774.422 **
Genotypes	30	1587.958 **	335.586 **	155.686 **	187.485 **	5524.683 **	119.171 **	19.636 **	2.823 **	1211.855 **
Genotypes × Locations	30	296.317 **	133.652 **	163.393 **	219.547 **	1210.020 **	26.907 **	0.128 n.s	0.053 n.s	336.990 **
Error / Locations =E(b)	240	1.952	1.665	12.285	6.334	174.878	0.622	0.305	0.154	52.533

Performance of the genotypes

The mean performance of the genotypes at Chalakh location was presented in Table 4, indicating that the mean values for plant height, flag leaf length, no. of tillers plant^{-1}, panicle length, no. of grains panicle^{-1}, 1000-grain weight, grain length, grain width, grain yield plant^{-1} ranged from 50.000 to 92.200 cm, 11.800 to 46.000 cm, 4.400 to 35.100, 9.200 to 38.567cm, 12.117 to 165.191, 19.820 to 31.590 g, 5.800 to 12.000 mm, 2.000 to 4.000 mm, and 3.474 to 60.909 g respectively. G_{18} showed the highest value for plant height with 92.200 cm. Variation in plant height among genotypes is a common feature in rice breeding programs (4). Different genotypes may exhibit varying degrees of height due to genetic factors. G_{24} recorded the maximum values for flag leaf length, panicle length, no. of grains panicle^{-1} with 46.000 cm, 38.567 cm, and 165.191 respectively. Flag leaf length is an important trait affecting light interception and photosynthesis in rice. Variability in flag leaf length can influence the overall growth and yield of the rice crop (20) and Panicle length is an essential trait linked to the number of grains panicle^{-1} and, consequently, grain yield (40). G_{29} showed the maximum value for no. of tillers plant^{-1} reached 35.100 which is a crucial determinant of rice yield potential. Genotypes with a higher tiller count often have the potential for greater grain production (13). G_{25} with 31.590 g was superior to the other genotypes in 1000-grain weight which considered to be an important trait related to grain size and weight and it contributes to grain yield and quality (6). The highest value for grain length was 12.000 mm recorded by $G_{13,}$ G_1 and G_{25} recorded the maximum grain width with 4.000 mm. Grain length and width collectively contribute to grain shape and size, which can impact the market value and utilization of rice (30). G_1 gave the maximum grain yield plant^{-1} with 60.909 g and it is the ultimate goal of rice cultivation, and it is influenced by various agronomic traits. Genotypes with higher grain yield are preferred in crop breeding programs (32). The results revealed a massive increase in rice crop productivity in the Chalakh area.

Table 4. Mean of the studied genotypes at Chalakh location

Genotypes	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)	Grain yield plant^{-1} (g)
G_1	76.200	22.200	23.200	17.400	105.992	24.770	5.800	4.000	60.909
G_2	53.400	13.000	4.800	9.200	27.844	29.905	8.000	3.800	3.474
G_3	68.400	21.000	12.200	17.400	114.257	26.410	7.600	3.800	34.403
G_4	75.800	20.400	11.200	14.400	65.793	23.350	6.000	2.800	18.158
G_5	70.200	31.800	8.600	15.800	94.369	24.180	6.000	2.800	19.627
G_6	78.400	30.800	19.400	20.600	124.176	21.650	6.400	3.200	58.329
G_7	60.200	18.800	16.200	17.800	57.929	21.220	6.600	3.200	23.230
G_8	83.800	20.600	22.200	20.000	74.217	23.215	6.800	3.000	41.531
G_9	65.200	29.200	11.000	18.800	84.502	23.640	6.600	3.000	23.086
G_{10}	84.600	29.200	14.400	16.400	89.498	21.500	6.400	3.000	35.028
G_{11}	88.800	30.200	17.000	17.600	92.136	22.570	6.200	3.000	42.405
G_{12}	83.400	31.400	13.400	18.600	99.974	23.590	6.600	3.000	34.567
G_{13}	68.800	17.200	36.600	28.139	65.505	29.390	12.000	2.000	50.512
G_{14}	57.200	12.400	27.100	24.458	70.967	26.035	8.000	3.000	40.550
G_{15}	58.800	14.600	15.200	25.881	118.591	21.945	8.000	2.000	37.552
G_{16}	89.200	25.400	15.800	30.868	90.486	21.800	7.600	2.800	29.949
G_{17}	90.200	32.000	19.700	31.900	95.984	21.325	7.600	2.600	40.039
G_{18}	92.200	27.600	22.900	32.540	64.528	22.130	8.200	2.200	31.882
G_{19}	71.400	11.800	15.300	24.700	12.117	23.860	9.000	2.800	3.853
G_{20}	87.200	39.000	25.400	33.057	98.065	21.225	7.400	2.200	49.978
G_{21}	78.600	37.600	25.200	32.277	105.451	22.135	7.600	2.400	55.016
G_{22}	64.200	24.800	24.200	27.766	115.049	19.820	8.000	2.800	55.975
G_{23}	83.200	31.400	17.600	32.896	114.352	22.130	7.600	2.200	42.479
G_{24}	84.000	46.000	12.900	38.567	165.191	23.495	9.200	2.800	43.449
G_{25}	61.600	15.200	4.400	19.091	67.304	31.590	8.400	4.000	5.916
G_{26}	72.000	29.200	12.000	31.428	154.611	23.885	10.000	2.400	36.680
G_{27}	50.000	20.800	25.100	25.624	113.563	25.255	9.000	3.000	60.443
G_{28}	61.200	26.200	14.500	28.843	132.900	22.340	9.000	2.800	39.465
G_{29}	74.400	19.200	35.100	29.398	77.143	30.105	10.800	2.200	56.140
G_{30}	61.200	21.200	18.700	27.961	125.413	21.145	8.200	2.000	47.753
G_{31}	64.800	20.000	20.700	23.450	48.678	23.505	8.400	2.400	22.207
L.S.D $_{(p\leq0.05)}$	1.675	1.565	5.959	4.379	21.486	1.257	0.549	0.462	11.708
L.S.D $_{(p\leq0.01)}$	2.214	2.069	7.878	5.789	28.405	1.661	0.726	0.611	15.478

The mean performance of the genotypes at Penjwen location is presented in Table 5. The table indicates the average values for plant height, flag leaf length, no. of tillers plant^{-1}, panicle length, no. of grains panicle^{-1}, 1000-grain weight, grain length, grain width, grain yield plant^{-1} ranged from 26.800 to 71.600 cm, 12.400 to 30.400 cm, 4.100 to 14.500, 6.508 to 24.753cm, 5.268 to 71.906, 8.258 to 14.240 g, 5.400 to 11.000 mm, 2.000 to 4.200 mm, and 1.654 to 29.004 g respectively. G_9 gave the highest values for plant height with 71.600 cm. G_4 recorded the maximum flag leaf length (30.400 cm). The maximum no. of tillers plant^{-1} recorded by G_{29}, whilst G_{21} gave the highest panicle length with 24.753 cm. G_{25} with 71.906 grains recorded the highest value for no. of grains panicle^{-1}, G_2 gave the maximum 1000-grain weight with 14.240 g, G_{13} with 11.000 mm gave the maximum value for grain length and it is closely followed by G_{29} with 10.600 mm. G_{25} recorded the maximum grain width of 4.200 mm. G_1 was superior to the other genotype concerning the grain yield plant^{-1} with 29.004 g.

Table 5. Mean of the studied genotypes at Penjwen location

Genotypes	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)	Grain yield plant^{-1} (g)
G_1	61.200	20.800	10.300	18.910	50.472	11.795	5.400	3.400	29.004
G_2	41.800	12.400	9.900	13.366	13.259	14.240	7.400	3.400	1.654
G_3	50.200	28.600	10.400	20.117	54.408	12.576	7.000	3.400	16.382
G_4	70.000	30.400	10.600	20.945	31.330	11.119	5.600	2.600	8.646
G_5	60.000	28.400	7.700	19.773	44.938	11.514	5.600	2.600	9.346
G_6	60.200	24.800	9.300	20.219	59.132	10.310	6.200	3.000	27.775
G_7	55.800	21.600	11.300	18.106	27.585	10.105	6.200	3.000	11.062
G_8	68.400	23.000	14.500	18.769	35.342	11.055	6.000	2.800	19.777
G_9	71.600	19.200	9.700	19.709	40.239	11.257	6.000	2.800	10.993
G_{10}	70.600	18.800	10.600	18.198	42.618	10.238	5.800	2.800	16.680
G_{11}	65.600	19.000	11.100	18.487	43.874	10.748	5.800	2.800	20.193
G_{12}	66.200	19.400	7.300	19.666	47.607	11.233	6.000	2.800	16.460
G_{13}	38.000	15.000	6.300	7.843	28.480	12.778	11.000	2.000	21.962
G_{14}	29.000	12.400	5.100	16.550	30.855	11.320	7.400	2.800	17.630
G_{15}	26.800	14.200	4.800	11.400	51.561	9.541	7.400	2.200	16.327
G_{16}	68.400	28.400	6.100	23.236	39.342	9.478	7.000	2.600	13.021
G_{17}	66.200	28.400	6.700	22.808	41.732	9.272	7.600	2.400	17.408
G_{18}	55.600	22.600	5.700	22.324	28.056	9.622	7.600	2.000	13.862
G_{19}	67.400	21.800	11.100	23.316	5.268	10.374	8.200	2.600	1.675
G_{20}	63.800	23.200	9.300	24.058	42.637	9.228	6.800	2.000	21.730
G_{21}	56.600	29.200	11.600	24.753	45.848	9.624	6.600	2.200	28.211
G_{22}	27.600	20.200	7.300	11.587	47.937	8.258	7.400	2.600	23.323
G_{23}	68.000	23.400	5.400	24.352	47.647	9.221	7.200	2.000	17.699
G_{24}	51.200	21.600	4.100	10.691	68.830	9.790	8.600	2.600	18.104
G_{25}	50.200	16.200	9.800	21.600	71.906	34.749	8.200	4.200	28.978
G_{26}	29.600	21.600	7.100	13.162	64.421	9.952	9.200	2.200	15.283
G_{27}	30.000	14.400	5.000	7.096	47.318	10.523	8.200	2.800	25.185
G_{28}	29.200	17.400	5.300	11.918	55.375	9.308	8.600	2.600	16.444
G_{29}	56.200	20.000	11.900	8.163	32.143	12.544	10.600	2.000	23.392
G_{30}	33.200	14.600	9.100	11.703	52.256	8.810	7.800	2.000	19.897
G_{31}	44.000	18.200	6.700	6.508	20.283	9.794	7.800	2.200	9.253
L.S.D $_{(p\leq0.05)}$	1.821	1.665	1.736	0.829	9.315	0.610	0.809	0.520	5.261
L.S.D $_{(p\leq0.01)}$	2.408	2.201	2.296	1.096	12.314	0.806	1.070	0.687	6.954

Table 6 represents the average performance of the genotypes for both locations. It gives an overview of the performance of the genotypes at both locations. Genotype 16 produced the maximum value for plant height reached 78.800 cm, whilst G_{24} gave the maximum values for flag leaf length and no. of grains panicles^{-1}with 33.800 cm and 117.010 respectively. The highest value for no. of tillers plant^{-1} was 23.500 recorded by G_{29}. The highest value for panicle length was 28.624 cm recorded by G_{23}. G_{25} gave the maximum values for 1000-grain weight and grain width reached 33.170 g and 4.100 mm respectively. G_{13} recorded the maximum grain length with 11.500 mm. The highest value for grain yield plant^{-1} was 44.957 shown by G_1.

Table 6. Mean of the studied genotypes at the average of both locations

Genotypes	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)	Grain yield plant^{-1} (g)
G_1	68.700	21.500	16.750	18.155	78.232	18.283	5.600	3.700	44.957
G_2	47.600	12.700	7.350	11.283	20.552	22.073	7.700	3.600	2.564
G_3	59.300	24.800	11.300	18.759	84.333	19.493	7.300	3.600	25.392
G_4	72.900	25.400	10.900	17.673	48.562	17.235	5.800	2.700	13.402
G_5	65.100	30.100	8.150	17.787	69.653	17.847	5.800	2.700	14.486
G_6	69.300	27.800	14.350	20.410	91.654	15.980	6.300	3.100	43.052
G_7	58.000	20.200	13.750	17.953	42.757	15.662	6.400	3.100	17.146
G_8	76.100	21.800	18.350	19.385	54.779	17.135	6.400	2.900	30.654
G_9	68.400	24.200	10.350	19.255	62.371	17.449	6.300	2.900	17.040
G_{10}	77.600	24.000	12.500	17.299	66.058	15.869	6.100	2.900	25.854
G_{11}	77.200	24.600	14.050	18.044	68.005	16.659	6.000	2.900	31.299
G_{12}	74.800	25.400	10.350	19.133	73.791	17.412	6.300	2.900	25.514
G_{13}	53.400	16.100	21.450	17.991	46.993	21.084	11.500	2.000	36.237
G_{14}	43.100	12.400	16.100	20.504	50.911	18.677	7.700	2.900	29.090
G_{15}	42.800	14.400	10.000	18.641	85.076	15.743	7.700	2.100	26.939
G_{16}	78.800	26.900	10.950	27.052	64.914	15.639	7.300	2.700	21.485
G_{17}	78.200	30.200	13.200	27.354	68.858	15.298	7.600	2.500	28.723
G_{18}	73.900	25.100	14.300	27.432	46.292	15.876	7.900	2.100	22.872
G_{19}	69.400	16.800	13.200	24.008	8.693	17.117	8.600	2.700	2.764
G_{20}	75.500	31.100	17.350	28.557	70.351	15.227	7.100	2.100	35.854
G_{21}	67.600	33.400	18.400	28.515	75.650	15.879	7.100	2.300	41.613
G_{22}	45.900	22.500	15.750	19.677	81.493	14.039	7.700	2.700	39.649
G_{23}	75.600	27.400	11.500	28.624	80.999	15.675	7.400	2.100	30.089
G_{24}	67.600	33.800	8.500	24.629	117.010	16.642	8.900	2.700	30.776
G_{25}	55.900	15.700	7.100	20.346	69.605	33.170	8.300	4.100	17.447
G_{26}	50.800	25.400	9.550	22.295	109.516	16.919	9.600	2.300	25.981
G_{27}	40.000	17.600	15.050	16.360	80.441	17.889	8.600	2.900	42.814
G_{28}	45.200	21.800	9.900	20.381	94.137	15.824	8.800	2.700	27.954
G_{29}	65.300	19.600	23.500	18.780	54.643	21.324	10.700	2.100	39.766
G_{30}	47.200	17.900	13.900	19.832	88.835	14.978	8.000	2.000	33.825
G_{31}	54.400	19.100	13.700	14.979	34.481	16.649	8.100	2.300	15.730
L.S.D $_{(p\leq0.05)}$	1.231	1.137	3.088	2.217	11.650	0.695	0.487	0.346	6.385
L.S.D $_{(p\leq0.01)}$	1.622	1.498	4.070	2.922	15.356	0.916	0.641	0.456	8.416

Table 7 presents the impact of location on the studied traits. The data suggests that Chalakh location outperformed Penjwen location in all of the studied traits with significant margins. The results indicate that Chalakh is more suitable than Penjwen, likely due to the difference in climatic conditions between the two locations. Chalakh showed an increase of 138.34%, 118.63%, 215.23%, 142.22%, 218.37%, 210.95%, 107.42%, 107.12%, and 213.00% over Penjwen for plant height, flag leaf length, number of tillers per plant, number of grains per panicle, 1000-grain weight, grain length, grain width, and grain yield per plant, respectively. The impact of location on these traits often related to variations in temperature, soil type, nutrient availability, and moisture levels. Different locations can result in differences in plant growth (6, 13, 21, 32, 37, 40).

Table 7. Effect of locations on the studied Characters

Locations	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)	Grain yield plant^{-1} (g)
Chalakh	72.858	24.845	18.129	24.285	92.471	23.842	7.839	2.813	36.922
Penjwen	52.665	20.942	8.423	17.075	42.345	11.302	7.297	2.626	17.334
L.S.D $_{(p\leq0.05)}$	0.401	0.261	3.389	4.204	9.543	0.164	0.248	0.149	5.790
L.S.D $_{(p\leq0.01)}$	0.583	0.379	4.931	6.117	13.885	0.239	0.361	n.s	8.425

Correlation analysis: Table (8) shows the correlation analysis of the studied traits at the Chalakh location. Plant height had a highly significant and positive correlation with flag leaf length (0.632**), indicating that as plant height increase, so does flag leaf length. This association suggests that taller plants may have longer flag leaves. Previous research has shown that plant height can affect various plant traits, including leaf size. For example, a study by Poorter *et al.* (22) demonstrated that taller plants often have larger leaves due to increased light interception. Plant height also has a substantial and negative correlation with

1000-grain weight (-0.380*), implying that as plant height grows, 1000-grain weight tends to decrease. According to this association, taller plants may yield grains that are smaller or lighter in weight. This negative correlation aligns with the concept of trade-offs in plant growth. Taller plants may invest more energy and resources in stem elongation, leaving fewer resources for seed development, which can result in smaller grains (17). A highly significant positive correlation (0.610**) was found between flag leaf length and the number of grains per panicle, implying that as the flag leaf length increases, so does the number of grains per panicle. This positive correlation is consistent with the idea that larger leaves can capture more sunlight and contribute to higher photosynthetic activity, ultimately supporting greater grain production (42). Significant positive correlations also noticed between flag leaf length and panicle length (0.441*) and grain yield plant^{-1} (0.363*) which suggests that as the flag leaf length increases, the length of the panicle and the grain yield per plant also tends to increase. This correlation indicates that longer flag leaves may be associated with longer panicles and may positively impact grain yield. Additionally, a highly significant negative correlation was observed between flag leaf length and 1000-grain weight (-0.487**) which means that as the flag leaf length increases, the 1000-grain weight tends to decrease. This correlation indicates that longer flag leaves could be associated with smaller or lighter grains. No. of tillers plant^{-1} had a highly significant and positive correlation with grain yield plant^{-1} (0.716**). As the number of tillers per plant increases, grain yield per plant also increases. This finding suggests that a greater number of tillers on a plant is associated with higher grain yield, which is consistent with the idea that more tillers can potentially lead to increased grain production (11). No. of tillers plant^{-1} had a significant and positive correlation with panicle length and grain length, reaching 0.452* and 0.425*, respectively implying that as the number of tillers per plant increases, both panicle length and grain length tend to increase (41), while it had a highly significant and negative correlation with grain width (-0.482**). This means that as the number of tillers per plant increases, grain width tends to decrease (36). Panicle length had a highly significant positive correlation with grain length (0.544**), as well as significant positive correlations with no. of grains panicle^{-1} and grain yield plant^{-1} reached 0.451*, and 0.452*, respectively, whilst recorded highly significant and negative correlation with grain width (-0.670**). This results in in accordance with the finding of Liu *et al.* (14). Iftekharuddaula *et al.* (10) were found that panicle length was positively associated with rice grain yield plant^{-1}. A highly significant and positive correlation was detected between no. of grains panicle^{-1} and grain yield plant^{-1} (0.610**) which is in accordance with the finding of Khan *et al.* (12) and Surek and Beser (31), but a substantial and negative correlation with 1000-grain weight (-0.360*) (5). Madhavilatha *et al.* (15) reported that no. of grains panicle^{-1} and 1000-grain weights were positively associated with grain yield plant^{-1}. A significant and positive association was detected between 1000-grain weight and grain length (0.462**) and the association between grain length and grain width was negative and significant (-0.427*).

Table 8. Correlation Analysis at Chalakh Location

Traits	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)
Flag leaf length (cm)	0.632**							
No. of tillers plant^{-1}	0.115	-0.039						
Panicle length (cm)	0.310	0.441*	0.452*					
No. of grains panicle^{-1}	0.129	0.610**	-0.019	0.451*				
1000 grain weight (g)	-0.380*	-0.487**	0.002	-0.286	-0.360*			
Grain length (mm)	-0.260	-0.223	0.425*	0.544**	0.024	0.462**		
Grain width (mm)	-0.208	-0.220	-0.482**	-0.670**	-0.164	0.353	-0.427*	
Grain yield plant^{-1} (g)	0.183	0.363*	0.716**	0.452*	0.610**	-0.261	0.132	-0.293

*. Correlation is significant at the 0.05 level (2-tailed), $t_{0.05}(29)=2.045$

**. Correlation is significant at the 0.01 level (2-tailed), $t_{0.01}(29)=2.756$

Table 9 shows the correlation analysis among the studied traits at Penjwen location. Plant height recorded a highly significant and positive correlations with flag leaf length, no. of tiller plant^{-1}, and panicle length reached 0.603**, 0.494**, and 0.713** respectively. Taller plants often have larger leaves due to increased light interception (22) and the positive correlation between plant height and tiller number is consistent with findings in various crop species (7). The positive association between plant height and panicle length corresponds to the idea that taller plants could be allocate more resources to panicle development (13). Khan *et al.* (12) and Rashid *et al.* (24) also found that plant height showed significant positive correlation with panicle length, highly significant positive correlation with no. of tillers plant^{-1}, whilst plant height shows a highly significant and negative correlation with grain length (-0.533**). Taller plants tend to have shorter grains and this highlights a trade-off between plant height and grain size (17). The association between flag leaf length and panicle length was positive and highly significant (0.628**). The positive correlation between flag leaf length and panicle length suggests that longer flag leaves could support the development of longer panicles (40). whilst had negative significant correlation with grain length (-0.372). The negative correlation between flag leaf length and grain length indicates that longer flag leaves could not necessarily result in longer grains. Panicles length recorded highly significant and negative correlation with grain length reached (-0.585**).The negative correlation between panicle length and grain length is indicative of the fact that while longer panicles may produce more grains, individual grains could be shorter in such cases (39). The correlation between no. of grains panicle^{-1} and grain yield plant^{-1} was highly significant and positive (0.627**) which is agreed with the report of Surek and Beser (31). More grains per panicle are associated with higher grain yield per plant and is consistent with the general understanding that a higher number of grains contribute to increased yield (22). Khan *et al.* (12) found that no. of grains panicle^{-1} and grain yield plant^{-1} had positive correlation. 1000-grain weight recorded a highly significant and positive correlation with grain width (0.659**). Heavier grains tend to be wider and aligns with the idea that grain weight is associated with grain size and dimensions (6).

Table 9. Correlation Analysis at Penjwen Location

Traits	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)
Flag leaf length (cm)	0.603**							
No. of tillers plant^{-1}	0.494**	0.247						
Panicle length (cm)	0.713**	0.628	0.317					
No. of grains panicle^{-1}	-0.190	0.079	-0.239	-0.007				
1000 grain weight (g)	-0.003	-0.215	0.189	0.101	0.254			
Grain length (mm)	-0.533**	-0.372*	-0.352	-0.585**	-0.022	0.136		
Grain width (mm)	0.095	-0.099	0.303	0.184	0.207	0.659**	-0.349	
Grain yield plant^{-1} (g)	-0.139	-0.045	0.032	-0.050	0.627**	0.236	0.095	0.081

***. Correlation is significant at the 0.05 level (2-tailed), $t_{0.05}(29)=2.045$**

****. Correlation is significant at the 0.01 level (2-tailed), $t_{0.01}(29)=2.756$**

Path coefficient analysis

The path coefficient analysis for grain yield plant^{-1} was presented in Table 10 at Chalakh location, which indicated that, the maximum positive direct effect on grain yield recorded by no. of tillers plant^{-1} (0.905) followed by no. of grains panicle^{-1} with 0.683, while the highest positive indirect effect was 0.417 recorded by no. of grains panicle^{-1} *via* flag leaf length followed by no. of tillers plant^{-1} *via* panicle length (0.409). Similar results reported by Abdulkhaleq (1). The residual effect (R=0.011) is quite low, indicating that 98.85% of the variation in grain yield plant^{-1} could be attributed to the traits included in the analysis. This is a high proportion, suggesting that the selected traits have a strong influence on grain yield and suggests that the role of other independent variables (not included in the experiment) in influencing grain yield is expected to be minimal (1.15%). This implies that the chosen traits are comprehensive in explaining grain yield at the Chalakh location.

Table 10. Path Analysis at Chalakh Location

Traits	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)
Plant height (cm)	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Flag leaf length (cm)	0.016	0.025	-0.001	0.011	0.015	-0.012	-0.006	-0.005
No. of tillers plant^{-1}	0.104	-0.035	0.905	0.409	-0.017	0.002	0.385	-0.436
Panicle length (cm)	-0.041	-0.058	-0.059	-0.131	-0.059	0.038	-0.071	0.088
No. of grains panicle^{-1}	0.088	0.417	-0.013	0.308	0.683	-0.246	0.016	-0.112
1000 grain weight (g)	0.013	0.017	0.000	0.010	0.012	-0.034	-0.016	-0.012
Grain length (mm)	0.031	0.027	-0.051	-0.065	-0.003	-0.055	-0.119	0.051
Grain width (mm)	-0.028	-0.029	-0.065	-0.090	-0.022	0.047	-0.057	0.134
Grain yield plant^{-1} (Correlation)	0.183	0.363*	0.716**	0.452**	0.610**	-0.261	0.132	-0.293

- Residual effect =0.011

Table 11 presents the results of the path coefficient analysis for grain yield plant^{-1} at the Penjwen location. The most substantial positive direct effect was observed with no. of grains panicle^{-1} (0.753), followed by no. of tillers plant^{-1} with a coefficient of 0.340. These outcomes align with previous research by Mishra and Verma (18) and Singh *et al.* (29). Additionally, the most significant positive indirect effects, with a value of 0.168, was attributed to no. of tillers plant^{-1} *via* its influence on plant height. Another indirect effect of 0.156 was observed for no. of grains panicle^{-1} *via* grain width. However, these effects are relatively small and may not have substantial practical implications. The traits studied in this experiment account for 64.77% of the variability in grain yield plant^{-1}, as indicated by the residual effect (R=0.352). This means that approximately 35.23% of the changes in grain yield could be attributed to factors not considered in this study. Nevertheless, this finding underscores the importance of the characteristics investigated in this research.

Table 11. Path Analysis at Penjwen Location

Traits	Plant height (cm)	Flag leaf length (cm)	No. of tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain width (mm)
Plant height (cm)	-0.028	-0.017	-0.014	-0.020	0.005	0.000	0.015	-0.003
Flag leaf length (cm)	-0.119	-0.197	-0.049	-0.124	-0.016	0.042	0.073	0.020
No. of tillers plant^{-1}	0.168	0.084	0.340	0.108	-0.081	0.064	-0.120	0.103
Panicle length (cm)	0.070	0.061	0.031	0.098	-0.001	0.010	-0.057	0.018
No. of grains panicle^{-1}	-0.143	0.059	-0.180	-0.005	0.753	0.191	-0.017	0.156
1000 grain weight (g)	0.000	-0.008	0.007	0.004	0.010	0.039	0.005	0.026
Grain length (mm)	-0.068	-0.047	-0.045	-0.075	-0.003	0.017	0.128	-0.044
Grain width (mm)	-0.019	0.019	-0.059	-0.036	-0.040	-0.128	0.068	-0.195
Grain yield plant^{-1} (Correlation)	-0.139	-0.045	0.032	-0.050	0.627**	0.236	0.095	0.081

- Residual effect =0.352

CONCLUSIONS

The results illustrate the considerable variability in agronomic traits among different rice genotypes at the Chalakh location. There was a substantial impact of location on rice crop performance. Chalakh outperformed Penjwen in all studied traits, indicating that it is more suitable for rice cultivation, likely due to differences in climatic conditions between the two locations. These findings are consistent with the understanding that climate, soil, and environmental factors play a crucial role in crop performance and productivity. The correlation analysis reveals several key relationships among different traits in the study. No. of tillers plant^{-1}, panicle length, and no. of grains panicle^{-1} appears to be positively correlated with grain yield at the Chalakh location. At Penjwen location, the correlation analysis reveals various significant relationships among the studied traits. These relationships provide valuable insights into how different traits are interconnected and can potentially inform crop breeding and management strategies. The path coefficient analysis conducted for grain yield plant^{-1} at both Chalakh and Penjwen locations provided valuable insights into the direct and indirect effects of various traits on grain yield. At Chalakh location, it was evident that the number of tillers plant^{-1} exhibited the highest positive direct effect on grain yield. Moreover, the substantial indirect effects observed, especially those mediated by flag leaf length and panicle length, indicated the complex interplay of these traits in influencing grain yield. Likewise, the path coefficient analysis at the Penjwen location revealed that the number of grains panicle^{-1} had the most significant positive direct effect on grain yield, with the number of tillers plant^{-1} also making a substantial contribution. The indirect effects, though relatively smaller in magnitude, demonstrated the inter-connectedness of these traits.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

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