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Performance and Genotypic and Phenotypic Variations of Half Diallel Crosses in Yellow Maize Crop Zea Mays L

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Abstract

The experiment was conducted the 2023-2024 agricultural season. Ten yellow maize genotypes, were evaluated using a Randomized Complete Block Design (RCBD) with three replicates. The analysis of variance revealed significant differences ($P \leq 0.01$) for all studied traits. The results demonstrated the superiority of sire (8), while the hybrids exhibited the highest averages across all measured traits. Hybrid (4×8) excelled in ear number per plant, ear diameter (cm), grain number per row, and grain yield per plant (g). Hybrid (2×8) showed superiority in ear length (cm), while hybrid (6×8) was superior in the number of rows per ear and the total number of grains per ear. Additionally, hybrid (3×8) had the highest weight for 300 grains (g). The additive genetic variance values were higher than the dominant genetic variance for all traits, while environmental variance values were lower than both additive and dominant variance values. Regarding genotypic variation, its values increased for all traits compared to environmental variation. Similarly, phenotypic variation values were higher across all traits compared to both genetic and environmental variations.

Keywords:

Performance, variation, half diallel crosses, yellow maize.

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Introduction

Yellow maize (Zea mays *L.*) is a vital cereal crop cultivated worldwide, including in Iraq, this prominence is due to its diverse applications in both human and animal nutrition, as its seeds contain 81% carbohydrates, 10.6% protein, and 4.6% oil (Ramadan, 2015).

Global corn production in 2019 reached approximately 1.077 billion tons (Al-Sahoki, 1990), with the United States leading at 370.096 million tons (Paul et al., 2020), followed by China with 259.007 million tons, and Brazil (Arab Organization for Agricultural Development, 2019). In Iraq, the total cultivated area for maize during the spring and autumn seasons of 2020 was around 405.4 thousand dunams (Balamurugan et al., 2023) yielding 419.3 thousand tons (Central Statistical Organization, 2020).

The yellow maize production rate per unit area, to the weakness of crop service operations (Tao et al., 2024) the researchers in the field of this crop to search for all scientific means, includes breeding and improving individual hybrids, distinguished by its superior grain yield (Davarpanah et al., 2016) by developing cultivars to produce pure hybrids and cross-breeding them using one of the breeding methods (Al-Zuhairi, 2014), Therefore, finding genetic compositions appropriate to the conditions of agricultural areas that include the presence of high-yield genes of good quality is one of the basic components for the sustainability of agricultural production (Bosco et al., 2018; Al-Jubouri et al., 2011). The idea of this study came for the purpose of genetically evaluating the characteristics of new genetic combinations introduced for the first time into Iraq and their hybrids (Balavandi et al., 2017) then additional (inherited, environmental, genetic, and phenotypic) variances are estimated (Hasan et al., 2023; Hasan et al., 2024).

Materials and Methods

In this study, ten pure yellow maize (Al-Hamdani, 2012) cultivars were utilized (Table 1). These cultivars were incorporated into a half-diallel (Shull, 1910) hybridization program following Griffing's second method (1956) during the fall season of 2020, resulting in the production of 45 individual hybrids.

Table 1. Cultivars used in the study

Cultivars No.	Cultivar name	Source	Obtain source
1	Gimbson	Italy	Agriculture College, Mosul University
2	Saganto	Turkey	Agriculture College, Dohuk University
3	DK 6050	Turkey	Agriculture College, Dohuk University
4	Agr-183	Local	Agriculture College, Dohuk University
5	ZM47W	America	Agriculture College, Mosul University
6	CML494	Mexico	Agriculture College, Mosul University
7	IK58	Hungaria	Agriculture College, Dohuk University
8	ZP505	Yugoslavia	Agriculture College, Dohuk University
9	ZP670	Yugoslavia	Agriculture College, Dohuk University
10	ZP197	Yugoslavia	Agriculture College, Dohuk University

Genetic Statistical Analysis

Statistical analysis of all studied traits was performed using a Randomized Complete Block Design (RCBD) with three replicates to assess the differences among genotypes, following the methodologies of (Al-Rawi & Khalafallah, 2000; Griffing, 1956).

Results and Discussion

The analysis of variance results for eight traits (Table 2) showed that the mean squares for parents, hybrids, and the combined parents and hybrids were significant at the 1% probability level for all studied traits.

Table 2. Analysis of variance for (parents), (hybrids), and (parents and hybrids) for the studied traits

S.O.V	d.f	M.S (Parents)							
		Ear No./ Plant	**Ear length**	**Ear diameter**	**Row No/ Ear**	**Grain No./ Row**	**Grain No./ ear**	**300 grain weight**	**Individual plant yield**
Replicates	2	1.03	261.68	71.87	300.62	758.33	461926.54	5334.00	17679.10
Parents	9	**0.10	**9.90	**1.29	**7.46	**24.83	**6577.85	**187.10	**608.25
Exp. error	18	0.01	1.53	0.21	1.77	0.94	1530.67	23.20	136.88
S.O.V	**d.f**	**M.S (Hybrids)**							
		Ear No./ Plant	**Ear length**	**Ear diameter**	**Row No/ Ear**	**Grain No./ Row**	**Grain No./ ear**	**300 grain weight**	**Individual plant yield**
Replicates	2	6.44	1147.93	417.28	1075.27	3888.59	2033661.71	21116.85	72582.35
Hybrids	44	**0.11	**7.18	**3.92	**6.94	**18.24	**7235.53	**136.97	**574.72
Exp. error	88	0.02	1.48	0.75	1.13	1.33	1127.89	46.80	181.35
S.O.V	**d.f**	**M.S (Parents and Hybrids)**							
		Ear No./ Plant	**Ear length**	**Ear diameter**	**Row No/ Ear**	**Grain No./ Row**	**Grain No./ ear**	**300 grain weight**	**Individual plant yield**
Replicates	2	7.46	1409.58	255.116	1372.99	4643.53	2492291.99	26390.09	90050.07
Parent and Hybrids	54	**0.11	**7.79	**0.175	**6.91	**20.01	**7072.82	**144.36	**590.55
Exp. error	108	0.02	1.47	0.035	1.27	1.31	1235.18	43.13	174.49

Tables (3 and 4) present the averages of the genotypes and their individual hybrids for the studied traits. Regarding the number of ears per plant, genotype (8) recorded the highest value with 1.292 ears, while parent (2) exhibited the lowest with 0.542 ears. Among the hybrids, (4×8) outperformed the others, producing the highest number of ears (1.414), whereas hybrid (1×2) recorded the lowest (0.599 ears). In most yellow maize plants, ear primordia are naturally present at the axil of each leaf, albeit in a vestigial form. When favorable growth factors are available, hybrid vigor plays a crucial role in stimulating the development of multiple ears per plant (Al-Sahuki, 1990).

Table 3. Averages of parents' performance for the studied characteristics

Parents	**Traits**							
	Ear No./ Plant	Ear length	Ear diameter	Row No/ Ear	Grain No./ Row	Grain No./ ear	300 grain weight	**Individual plant yield**
1	0.966	11.266	3.874	13.133	25.778	413.460	59.084	117.927
2	0.542	9.789	4.014	10.322	19.856	297.328	44.691	99.251
3	0.610	12.744	3.516	13.911	27.789	413.921	57.611	125.435
4	0.848	12.633	3.969	13.222	27.566	434.150	61.296	126.529
5	0.817	12.422	4.002	12.977	28.244	412.003	58.437	120.521
6	0.865	12.433	4.030	13.011	28.367	379.129	59.971	116.242
7	0.839	12.133	4.073	12.644	26.289	387.500	60.798	114.111
8	1.292	16.888	6.021	16.611	31.044	470.593	77.443	155.123
9	0.873	12.177	3.975	12.711	26.711	370.658	59.289	123.620
10	0.894	11.311	3.819	11.955	25.867	362.351	56.336	113.849
Mean	0.85	12.38	4.13	13.05	26.75	394.11	59.50	121.26
$L.S.D_{0.01}$	2.1	2.11	2.12	2.28	1.67	67.11	8.26	20.07

Table 4. Shows the averages of the first generation hybrids for the studied traits

Hybrids		Traits							
		Ear No./ Plant	Ear length	Ear diameter	Row No/ Ear	Grain No./ Row	Grain No./ ear	300 grain weight	**Individual plant yield**
2×1		0.599	10.111	4.049	9.466	19.367	294.751	57.158	112.533
3×1		0.964	13.200	3.909	12.900	28.845	412.864	65.424	112.611
4×1		1.033	13.222	4.219	12.644	28.967	400.071	63.344	128.929
5×1		0.826	13.322	4.088	12.955	27.944	392.379	60.391	115.860
6×1		0.839	12.455	4.160	12.622	28.167	370.779	55.878	108.242
7×1		0.799	12.111	3.847	12.255	27.589	368.891	59.638	99.873
8×1		1.381	16.096	6.973	16.244	30.852	505.809	73.762	144.576
9×1		0.861	11.933	3.859	12.044	28.122	402.013	54.527	104.516
10×1		0.940	12.355	3.964	13.000	28.055	418.246	61.889	124.753
3×2		0.739	10.344	4.033	10.577	19.422	300.041	58.229	110.044
4×2		0.988	13.111	4.029	13.144	28.467	377.846	57.303	105.347
5×2		0.837	13.888	4.021	13.444	29.955	389.918	58.569	111.624
6×2		0.839	13.133	4.067	12.911	28.756	391.859	57.089	108.451
7×2		0.810	12.622	4.011	12.444	26.933	385.863	55.105	97.332
8×2		1.392	16.555	6.908	15.944	31.400	494.920	73.618	127.273
9×2		1.055	13.011	4.143	11.844	28.544	380.183	58.158	114.689
10×2		0.815	11.955	4.113	12.155	27.189	404.018	62.740	115.073
4×3		0.772	12.111	4.061	12.133	27.600	367.138	52.918	89.569
5×3		0.810	12.178	4.031	13.678	26.789	394.289	57.256	105.840
6×3		0.815	12.422	4.139	14.244	25.733	401.371	60.862	115.549
7×3		0.966	12.511	3.988	12.777	27.489	386.390	58.263	110.252
8×3		1.347	16.400	6.918	16.222	31.300	473.693	76.767	141.573
9×3		0.905	13.277	3.858	12.366	29.067	392.586	61.102	128.631
10×3		0.832	13.177	3.917	12.400	27.922	389.587	59.212	110.942
5×4		1.010	13.644	4.008	13.278	28.633	407.914	58.752	118.412
6×4		0.892	12.377	4.033	12.711	27.366	421.559	61.286	106.518
7×4		0.817	13.099	4.041	13.222	28.511	416.541	59.036	122.593
8×4		0.794	13.566	4.103	13.066	29.678	428.602	74.371	155.722
9×4		0.910	12.577	3.951	12.767	28.622	391.689	58.062	119.476
10×4		0.826	11.799	3.877	11.933	27.244	369.507	53.298	99.076
6×5		0.794	12.322	3.876	12.689	28.289	387.674	55.556	104.453
7×5		0.843	12.622	3.832	11.622	28.911	364.009	58.052	103.773
8×5		1.336	16.244	6.106	15.311	31.267	480.421	71.539	124.481
9×5		0.870	12.455	3.743	12.455	28.811	392.856	58.887	114.407
10×5		0.794	11.589	4.126	12.533	27.333	396.382	57.364	103.791
7×6		0.865	12.111	3.588	12.844	28.844	408.437	57.824	98.452
8×6		1.314	14.944	6.447	16.488	30.500	507.010	73.094	117.987
9×6		0.870	12.422	3.997	12.955	27.422	380.454	56.433	105.055
10×6		0.817	11.889	3.905	12.433	24.733	334.059	52.154	84.729
8×7		1.236	16.199	6.522	15.688	31.000	471.991	58.462	118.829
9×7		0.865	12.477	4.129	13.444	28.211	418.891	59.949	104.020
10×7		1.414	15.977	7.399	16.200	31.900	483.554	75.695	131.634
9×8		0.965	15.766	6.787	15.177	31.111	499.198	71.591	128.293
10×8		1.070	14.111	6.935	15.066	30.322	486.776	72.442	118.224
10×9		0.843	13.200	3.997	13.311	27.844	392.231	57.900	127.664
Hybrids	**Mean**	0.94	13.18	4.55	13.24	28.25	407.45	61.35	114.48
	L.S.D$_{0.01}$	0.24	1.97	1.40	1.73	1.87	54.49	11.10	21.85
Parents and Hybrids	**Mean**	0.92	13.03	4.47	13.20	27.97	405.02	61.02	115.71
	L.S.D$_{0.01}$	1.98	1.96	1.98	1.82	1.85	56.88	10.62	21.37

For ear length (cm), parent (8) exhibited a significant increase, with an average length of 16.888 cm, while genotype (2) recorded the shortest length at 9.789 cm. This was not significantly different from hybrids (1×8), (3×8), (5×8), and (7×8), which had lengths of 16.096 cm, 16.400 cm, 16.244 cm, and 16.199 cm, respectively. Among the hybrids, (1×2) had the shortest ear length, averaging 10.111 cm. The overall lowest ear length observed was 12.38 cm, while the average for hybrids was higher at 13.18 cm, with a general mean of 13.03 cm for both parents and hybrids. These findings highlight the importance of parent (8) and its resulting hybrids in enhancing yield components, ultimately leading to an increase in final production. Regarding stem diameter (cm), parent (8) also showed the highest significant increase, reaching 6.021 cm, while genotype (3) had the smallest diameter at 3.516 cm. The hybrids had a larger average stem diameter of 4.55 cm, while the overall average for parents and hybrids was 4.47 cm. A greater stem diameter contributes to increased nutrient storage in the grains, resulting in larger and fuller kernels (Alatawi et al., 2024; Muhanna et al., 2015).

In rows number /ears, the parent (8) had the largest value (16,611 rows), while parent (2) showed the smallest value (10.322 rows). As for hybrids, the hybrid (6×8) gave the largest value 16,488 rows), it did not differ significantly from the hybrid (1×8), (3×8), and (4×8), reaching 16.244, 16.222 and 16.200 rows, respectively. The lowest hybrid was (1×2), which had a value of 9.466 rows, it was noted that the average of hybrids reached 13.24 rows, higher than the average of parents (13.05 rows), as the general average of parents and hybrids (13.20 rows). The superiority to its moral superiority over the rest of the camels in the ear country, there was also a highly significant positive relationship between the number of rows in the ear and the diameter of the ear.

For the number of grains per row, parent (8) demonstrated significant superiority, achieving an average of 31.044 grains, while parent (2) recorded the lowest value at 19.856 grains. Among the hybrids, (4×8) exhibited the highest significant value, averaging 31.900 grains. This was not significantly different from hybrids (2×8), (3×8), (5×8), (7×8), and (8×9), which recorded 31.400, 31.300, 31.267, 31.000, and 31.111 grains, respectively (Al-Nasiri, 2016).

For the number of grains per ear, parent (8) showed significant superiority, with an average of 470.593 grains, while parent (2) had the lowest value at 297.328 grains. The hybrid (1×2) recorded the lowest average at 294.751 grains. When comparing the average of parents to the average of hybrids, the hybrids had a higher value at 407.45 grains. The overall average for parents and hybrids was 394.11 and 405.02 grains, respectively. This trait is crucial for grain yield and is influenced by both the plant's genetic makeup and environmental factors. The significant differences observed indicate that these hybrids responded positively to an increase in this trait. The superior performance of parent (8) and its hybrids can be attributed to the accumulation of net photosynthesis and dry matter, which positively impacted this characteristic and, consequently, the final yield (Al-Nasiri, 2016).

The weight of 300 grains (g) is a crucial characteristic, with parent (8) showing a significant improvement, reaching 77.443 g, while parent (2) recorded the lowest value at 44.691 g. Among the hybrids, (3×8) exhibited significant superiority with an average of 76.767 g, and did not significantly differ from hybrids (1×8), (2×8), (4×8), (5×8), (6×8), (7×10), (8×9), and (8×10), which had values of 73.762 g, 73.618 g, 75.695 g, 71.539 g, 73.094 g, 74.371 g, 71.591 g, and 72.442 g, respectively. The hybrid (6×10) recorded the lowest average at 52.154 g. When comparing the average of parents to hybrids, the hybrids had a higher average at 61.35 g, compared to the parents' average of 59.50 g, with the overall average for both sires and hybrids being 61.02 g. This may be attributed to the superiority of parent (8) and its hybrids, which positively influenced this trait and, in turn, the final yield (Abu Dahi et al., 2001). The results align with those of (Abdullah & Hasan, 2020;

Hasan & Abdullah, 2021; Hasan &Abdullah, 2020; Hasan et al., 2022; Muhammad et al., 2021; Younis et al., 2022).

For grain yield per plant (g), parent (8) produced the highest average at 155.123 g, while parent (2) had the lowest average at 99.251 g. Among the hybrids, (4×8) showed the highest yield at 155.722 g, with no significant difference from hybrids (1×8) and (3×8), which yielded 144.576 g and 141.573 g, respectively. On the other hand, hybrid (6×10) had the lowest yield, at 84.729 g, compared to the other hybrids. The average yield of the parents was significantly higher than that of the hybrids, with an average of 121.26 g. The overall average for both parents and hybrids was 114.48 g, with the general average reaching 115.71 g (Elsahookie, 2007).

From the above, it is evident that parent (8) outperformed all other parents in all the studied characteristics. Among the hybrids, (4×8) was distinguished for its superiority in ear number per plant, ear diameter (cm), grains per row, and grain yield per plant (g). Hybrid (2×8) excelled in ear length (cm). The results clearly show variations in the performance of the hybrids across all traits, which can be utilized in (Ali,1988). breeding and improvement programs to develop synthetic varieties or to benefit from hybrids with strong hybrid vigor, particularly those that showed superior grain yield and its components. These findings were further validated by conducting additional studies to confirm their reliability, and are consistent with the results of researchers such as (Al-Bayati, 2013; Al-Zuhairi, 2014; Al-Karkhi, 2015; Younis et al., 2022b).

Table 5 shows estimate of the additional variance σ^2A, sovereign σ^2D, and environmental σ^2E for all studied traits, therefore, the most appropriate breeding method is pure breed selection or mass selection, while the traits in which the dominant genetic variance values are greater than the additive genotype values. The dominant genetic action is more influential than the additional genetic action in controlling the inheritance of these traits, therefore, as for genetic variance σ^2G, the value of genotype has increased for all traits compared to the values of environmental variance. An increase in genetic variation for any of these traits leads to a decrease in environmental variation for it, phenotypic variance values increased in all traits compared to genetic and environmental variances, this was consistent with what he reached and the result was consistent with Abdullah and (Hasan, 2020; Younis et al., 2022 a, b; Muhammad et al., 2021).

Table 5. Variance values for the studied traits

Variance	**Traits**							
	Ear No./ Plant	**Ear length**	**Ear diameter**	**Row No/ Ear**	**Grain No./ Row**	**Grain No./ ear**	**300 grain weight**	**Individual plant yield**
σ^2A	0.329	23.517	11.746	21.375	40.528	19085.332	375.255	969.461
σ^2D	0.014	0.767	0.230	0.630	3.955	920.598	20.220	139.277
σ^2e	0.009	0.491	0.180	0.425	0.437	411.727	14.378	58.167
σ^2G	0.343	24.284	11.976	22.005	44.483	20005.930	395.475	1108.737
σ^2P	0.352	24.775	12.156	22.431	44.920	20417.657	409.853	1166.904

Conclusions

Superiority of Lines and Varieties: The results showed that Line No. (8) exhibited significant superiority in the studied traits, indicating its high genetic potential for improving crop productivity.

Genetic Variation: Additive genetic variance was higher than dominance genetic variance for all traits, indicating that the studied traits are primarily influenced by additive genes.

Environmental Effect: Environmental variance values were lower than genetic (additive and dominance) variance values, reflecting a lesser environmental influence compared to genetic effects.

Genotypic and Phenotypic Variations: The study revealed increased genotypic and phenotypic variance values for all traits compared to environmental variance values, emphasizing the role of genetics in enhancing productivity traits.

References

Abdullah, R. M., & Hasan, S. A. (2020). Estimation of components of genetic variance using jinks-hayman method analysis on the crop of faba bean (Vicia faba L.). *International Journal of Agricultural & Statistical Sciences*, *16*.

Abu Dahi, Y. M., Lahmoud, A. M., & Al-Kawaz, G. M. (2001). The effect of foliar nutrition on yellow maize yield and its components. *Iraqi Journal of Soil Science, 1*(1), 122-137.

Alatawi, M., Alhajoj, Y. A. A., & Abdullah, R. M. (2024). Evaluation of the performance of several cultivars of bean (Vicia faba L.) for yield and its components under three different cultivation distances. *Tikrit Journal for Agricultural Sciences*, *24*(3), 256-266. https://doi.org/10.25130/tjas.24.3.20

Al-Bayati, H.A. (2013). Inheritance of individual hybrids in different mating systems for pure lines of yellow maize (Zea mays L.). Doctoral thesis, College of Agriculture and Forestry, University of Al Mosul. Iraq.

Al-Hamdani, Z. B. F. (2012). *The nature of gene action in complete reciprocal crosses of yellow maize (Zea mays L.)* (Doctoral thesis). College of Agriculture and Forestry, University of Mosul, Iraq.

Ali, H. C. h. (1988). *Foundations of breeding and genetics of field crops*. Ministry of Higher Education and Scientific Research, University of Baghdad.

Al-Jubouri, J. M. A., Al-Jubouri, A. H., & Al-Qaisi, I. K. (2011). Correlations and path analysis for quantitative traits in barley (Hordeum vulgare L.). *College of Agriculture, Tikrit University, Iraq*.

Al-Karkhi, M. K. H. (2015). *Estimating some genetic parameters and hybrid strength in hemicrosses for introduced genotypes of yellow maize (Zea mays L.)* (Master's thesis). College of Agriculture, Tikrit University, Iraq.

Al-Nasiri, A. S. (2016). *The effect of some spring varieties, fertilization, and moisture levels at harvest on the growth and yield of yellow corn (Zea mays L.)* (Doctoral thesis). College of Agriculture, Tikrit University, Iraq.

Al-Rawi, K. M., & Khalafallah, A. (2000). *Design and analysis of agricultural experiments*. Ministry of Higher Education and Scientific Research, University of Mosul, Iraq.

Al-Sahoki, M. M. (1990). Yellow corn production and improvement Ministry of Higher Education and Scientific Research University of Baghdad p 400.

Al-Zuhairi, N. S. A. (2014). *The nature of the function of genes using single, triple, and double crosses between pure cultivars of yellow corn (Zea mays L.) and predicting the characteristics of even crosses* (Doctoral thesis). College of Agriculture and Forestry, University of Mosul, Iraq.

Arab Organization for Agricultural Development. (2019). *Yearbook of agricultural statistics*. Youm7 website.

Balamurugan, P., Santhosh, J., & Arulkumaran, G. (2023). Real-time multi-view image-based FPC plant management with SS data security and low-rate attack detection for efficient smart agriculture in WSN. *Journal of Intelligent & Fuzzy Systems, 44*(1), 91–100. https://doi.org/10.3233/JIFS-220594

Balavandi, S. (2017). Further study industrial production in hemp crops agriculture. *International Academic Journal of Science and Engineering, 4*(1), 123–127.

Bosco, N. J., Ildephonse, M., & Alexandre, N. (2018). Agriculture and food security in Gicumbi District, Northern Province of Rwanda. *International Academic Journal of Social Sciences, 5*(1), 154–168. https://doi.org/10.9756/IAJSS/V5I1/1810014

Central Statistical Organization. (2020). *Ministry of Planning and Development Cooperation, Iraq*.

Davarpanah, S., Bonab, S. H., & Khodaverdizadeh, M. (2016). Assessment and comparison of sustainable agriculture approach using a combination of AHP and TOPSIS. *International Academic Journal of Economics, 3*(9), 7-18.

Elsahookie, M. M. (2007). Dimentions of SCC theory in a maize hybrid-inbred comparison. *Iraqi Journal of Agricultural Sciences, 38*(1).

Griffing, B. (1956). A generalised treatment of the use of diallel crosses in quantitative inheritance. https://doi.org/10.1038/hdy.1956.2

Hasan, S. A., & Abdullah, R. M. (2020). Estimating the performance and gene action of a number of individual genotypes and hybrids on the crop of faba bean (Vicia faba L).

Hasan, S. A., & Abdullah, R. M. (2021). Characterization of genetic variability through the use of RAPDS markers of a group of native and commercial genotypes of bean species. *International Journal of Agricultural & Statistical Sciences, 17*.

Hasan, S. A., Abdullah, R. M., & Hanoon, M. B. (2022). Effect of foliar application with proline on growth, yield, and quality of faba bean (Vicia faba l.) A review. *Eur. J. Agric. Rur. Edu, 3*(3), 15-21.

Hasan, S. A., Abdullah, R. M., Hanoon, M. B., & Sahi, M. K. (2023). Genetic and path coefficient analyses of quality-related traits of oat (Avena sativa L.) with potassium application. *SABRAO J. Breed. Genet, 55*(5), 1526-1535. http://doi.org/10.54910/sabrao2023.55.5.7

Hasan, S. A., Khadhum, M. K., Hanoon, M. B., & Abdullah, R. M. (2024). Genetic analysis of the phenotypic and molecular correlations among the rapd-pcr markers in peanut (arachis hypogaea l.). *SABRAO Journal of Breeding & Genetics, 56*(3). http://doi.org/10.54910/sabrao2024.56.3.19

Muhammad, N. I., Humada, Y. H., & Abdullah, R. M. (2021). Using phenotypic and molecular indicators RAPD-PCR to evaluate the performance and genetic dimension of a number of genotypes and their individual hybrids in the chickpea plant Cicer arietinum L.

Muhanna, A. A., Suleiman, M. M., & Khadr, W. S. (2015). The effect of humic acid and nitrogen fertilization on some characteristics of yellow maize (Zea mays L.) crop components and its productivity. *Jordanian Journal of Agricultural Sciences*, *11*(1), 229–242.

Paul, P. K., Sinha, R. R., Aithal, P. S., Aremu, B., & Saavedra, R. (2020). Agricultural informatics: an overview of integration of agricultural sciences and information science. *Indian Journal of Information Sources and Services*, *10*(1), 48-55. https://doi.org/10.51983/ijiss-2020.10.1.2832

Ramadan, A. S. A. (2015). Estimating some genetic parameters for grain yield and its components in yellow maize (Zea mays L.). *Al-Anbar Journal of Agricultural Sciences*, *31*(2), 189–198.

Shull, G. H. (1910). Hybridization methods in corn breeding. *Journal of Heredity*, *1*(2), 98-107. https://doi.org/10.1093/jhered/1.2.98

Tao, C., Abd Razak, M. R., Jingjing, L., & Mingqian, P. (2024). Sustainable and Bio-based Food Packaging Design of Chinese Agricultural Products Under the "Internet Plus" Mindset. *Natural and Engineering Sciences*, *9*(2), 1-18. https://doi.org/10.28978/nesciences.1567827

Younis, H. S., Abdullah, R. M., Hasan, S. A., & Abdul-Sattar, A. A. (2022). Systemic resistance indicators study and seed gall nematode disease caused by Anguina tritici affecting of biological and varietal treatments on bread wheat (Triticum aestivum L.). *Int. J. Agric. Stat. Sci*, *18*(1), 289-296.

Younis, H. S., Abdullah, R. M., Hassan, S. A., Sattar, A. A. A., & Amer, K. Z. (2022). Effect of biological and cultivar control to Ear-Cockle Nematode disease caused by the nematode (Anguina tritici) on different genotypes of bread wheat (Triticum aestivum L.). *Ann. For. Res*, *65*(1), 916-930. https://doi.org/10.5281/zenodo.7262806