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Irak-Süleymaniye Koşullarında Farklı Hümik Asit Dozlarının Mısırın (*Zea mays* L.) Verim ve Kalite Özellikleri Üzerine Etkisi

Tamer ERYİĞİT[1*], Aso Hashm HUSAMALDDIN[2]

Öne Çıkanlar:
- Çeşitler arasında fark bulunmamıştır.
- Hümik asitin bitki büyümesi üzerinde olumlu etkileri olmuştur.
- Hümik asite çeşitlerin tepkisi farklı olmuştur.

Anahtar Kelimeler:
- Hümik asit
- Kalite özellikleri
- Mısır
- Organik gübre
- Verim

ÖZET:

Araştırma, 2020 yaz büyüme sezonunda Irak, Süleymaniye eyaletinin Ranya bölgesi ekolojik koşullarında yürütülmüştür. Çalışmanın amacı, hümik asidin mısır büyümesi ve verimi üzerindeki etkisini araştırmaktır. Deneme, iki ticari çeşit (DKC6050 ve DKC6664) ve dört hümik asit dozunun (HA1: 0 kg/ha, HA2: 60 kg/ha, HA3: 120 kg/ha ve HA4: 180 kg/ha) toprağa uygulanmasını içermektedir. Çalışmada, çeşitler ana parsellere ve hümik asit dozları ise çeşitlerin üzerindeki etkilerini daha doğru bir şekilde incelemek için alt parsellere yerleştirildiği bir deneme deseni kullanılmıştır. Deneyde, büyüme, verim ve verim bileşenlerinin özellikleri incelenmiştir. Elde edilen sonuçlara göre hümik asit uygulamasının çimlenme süresi, koçan çapı, protein oranı ve yağ oranı dışındaki tüm bitkisel ve verim parametrelerini olumlu etkilediği belirlenmiştir. Çeşitler ile hümik asit dozları arasındaki etkileşim sonucunda, tohum verimi, 100 tohum ağırlığı, bitki başına verim, koçan çapı, hasat indeksi, yaprak alanı indeksi, gövde çapı ve püsküllenme süresi için hümik asit dozları arasında önemli farklar gözlenmiştir. En yüksek tane verimi DKC6050 çeşidinden (9844.8 kg/ha) alınmıştır. Çeşitlerin hümik aside tepkileri aynı olmuş ve bu nedenle çeşitler arasında karşılaştırma için kayda değer farklılıklar gözlenmemiştir. Ancak, pek çok özellik yönünden DKC6050 çeşidinin ümitvar bir çeşit olduğu ve araştırmanın yürütüldüğü ekolojide yetiştiriciliğinin yapılabileceği tespit edilmiştir.

Effects of Different Humic Acid Doses on Yield and Quality Properties of Corn (*Zea mays* L.) in Iraq-Sulaymaniyah Conditions

Highlights:
- There was no difference between the varieties.
- Humic acid had positive effects on plant growth.
- The response of cultivars to humic acid was different.

Keywords:
- Humic acid
- Quality properties
- Maize
- Organic fertilizer
- Yield

ABSTRACT:

The research was carried out in the ecological conditions of the Ranya region of Sulaymaniyah province, Iraq in the summer growing season of 2020. The goal of the study was to investigate the impact of humic acid on the growth and yield of corn. The trial included two commercial cultivars (DKC6050 and DKC6664) and soil application of four rates of humic acid (HA1: 0 kg/ha, HA2: 60 kg/ha, HA3: 120 kg/ha and HA4: 180 kg/ha). The experiment was conducted according to the split-plot experimental design in randomized blocks. In the study, a trial pattern was designed so that varieties were placed in the main plots, and doses of humic acid were placed in the subplots for a more precise investigation of their effects on the cultivars. In the experiment, the characteristics of growth, yield, and yield components were examined. According to the results, it was determined that applying humic acid positively affected all vegetative and yield parameters except for the germination time, cob diameter, protein ratio, and oil ratio. As the result of the interaction between the cultivars and the humic acid doses, significant results were obtained for seed yield, 100 seeds weight, yield per plant, cob diameter, harvest index, leaf area index, stem diameter, and silk appearance time. The highest grain yield was obtained from the DKC6050 variety (9844.8 kg/ha). Responses of cultivars to humic acid were the same and therefore no appreciable differences were observed between cultivars for comparison. However, it has been determined that the DKC6050 variety is a promising variety in terms of many characteristics and can be cultivated in the ecology where the research is carried out.

[1] Tamer ERYİĞİT (**Orcid ID:** 0000-0001-5069-8206), Van Yuzuncu Yil University, Gevaş Vocational School, Department of Plant and Animal Production, Van, Türkiye

[2] Aso Hashm HUSAMALDDIN (**Orcid ID:** 0000-0001-8084-9300), University of Raparin, College of Science, Department of Biology, Iraq

***Sorumlu Yazar/*Corresponding Author**: Tamer ERYİĞİT, e-mail: tamyigit@hotmail.com

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INTRODUCTION

Corn (*Zea mays* L.) is an herbaceous plant belonging to the (Poaceae) family. The cultivated corn counted as the most productive forage crop. Its photosynthesis is the kind of C4, with its highest capability of producing carbohydrates per unit area per day. Corn is planted in most environments from 58^{o} latitude in north Canada and Russia to 40^{o} latitude in south America (Darrah et al., 2019).

In the world, cereals are the first-ever source of energy. The world population relies on foods that are cereal-based for their staple foods. Cereals such as maize, rice, and wheat are the most commonly used plants in food production along with vegetables, roots, and tubers. They are the major meals of developing countries, due to their high carbohydrate content, availability, and affordability (García-Lara and Serna-Saldivar, 2019). Maize has a higher average yield in unit area than wheat, that's why maize is the first in production worldwide, but, wheat is the most planted cereal (FAO, 2018).

Ten millenniums ago, maize was domesticated in Mesoamerica in what is now Mexico by native people. After the Discovery of the American continent, it spread to the world (García-Lara and Serna-Saldivar, 2019). Nowadays, maize is the most important cereal, beating rice and wheat in production a decade ago, because of the genetic remodeling and improvement in the yielding regulars (FAO, 2018). Maize production has increased the most because of its higher adaptation ability to different ecological conditions and strong demand for use in the production of human food (Scott et al., 2018), bioethanol (Kumar and Singh, 2018), feedstock (Loy and Lundy, 2018), sweeteners, and other nonfood industrial products.

The world population rises day by day, farmers have to plant more and increase the population per unit area. The increase in production and yield depends on soil fertility and its capability to provide elements (macro, micro, and trace), but the soil has its own limits, it cannot nourish plants forever. The soil loss of elements can be compensated by adding chemical fertilizers and adding organic matter (von Wirén et al., 2000; Soobhany, 2019). Organic matter directly or indirectly affects the growth and production of crops. Supplying nutrients or modifying soil's physical properties, which leads to promoting the root system surrounding the environment, results in better plant growth (Chang et al., 2007).

Humic Substances are found in the sources that contain organic matter, such as soil and water. Due to biological and chemical operations, they exist more in the soil than in the water. Humic substances generally consist of humin, which is not soluble in any PH, Humic Acid which is soluble in alkaline mediums and partially in water, and Fulvic Acid which is soluble in any PH. They are defined as; A common division of congenitally existing various organic substances, which are identified by their dark colour, resistance, and high molecular weight (Dvies et al., 2012). Humic Acids (HA) are common final products of chemical and microbial deterioration of dead biologicals in soil all over the world. They can be carried to the soil as a diverse, high molecule, and colloid aggregates (Asli and Neumann, 2010). Generally, humic acid affects the plant by enhancing growth, increasing yield, and uptake of nutrients. In Soil, they have many important roles such as making nutrients available, regulating carbon and oxygen traffic between air and soil, and the conversion and transport of toxic chemicals. In addition to their effects on Plant Physiology and Soil specifics, they affect the role of microorganisms in the soil (Calvo et al., 2014).

In the Ranya district, no other similar studies have been carried out, that studied corn and humic acid together in order to study the growth, yield, and yield quality of corn. During this investigation I found that farmers lack knowledge about the importance of corn and humic acid, they still use higher doses of NPK fertilizers to improve their productivity, while, they can raise their yield by using lesser amounts of NPK with using humic acid. The following aspects can be answered and make recommendations by the study:

i. The possibility of cultivating corn in this area.

ii. To determine the effects of humic acid on growth, yield, and yield components.

iii. To show how the application of humic acid to the soil can affect the growth and yield of plants.

In this study, it is aimed to show the importance of the maize plant in human life today and the importance of humic acid applied at different levels as an organic fertilizer, and also its effect on the yield and quality characteristics of maize. The target of the research is to increase the total yield, and then increase of protein ratio and oil content of the seeds through the enhancing growth of the crop during the period of germination until the maturity of the plant.

MATERIALS AND METHODS

The experiment was conducted in the 2020 growing season under farmer conditions in the Ranya district of Sulaymaniyah, 36° 13' North latitude and 44° 55' East longitude, and an altitude of 853 m above sea level, Iraq (Figure 1). This area is famous for good arable lands and many crops are grown by the farmers.

Figure 1. Ranya District Location

The Soil of Study Area

The soil sample was taken from 15 different spots in a zig-zag shape layout, at the depth of (0 – 30 cm), then dried and mixed properly. According to the soil analysis done in Zanko laboratories, the soil texture is clay loam, and the properties of the surface (0 – 30 cm) were: PH 7.91, salt content 0.0%, EC 142 mmhos/cm, organic matter 1.94 $CaCO_3$ 41.41%, available plant nutrient forms; P_2O_5 13.15 PPM, K_2O 158.4 PPM. The trial area is salt-free, limy, slightly alkaline, enough in K_2O, P_2O_5, and enough organic matter as shown in (Table 1).

Table 1. Some Chemical and Physical Properties of The Trial Soil

Depth	Soil Texture	EC mmhos/cm	Salt %	PH	Lime $CaCO_3$ %	Organic matter %	Available Plant Nutrients (ppm)	
							K_2O	P_2O_5
0-30 cm	Clay-Loam	142	0%	7.91	41.41	1.9	13.15	158.4

Ecology and meteorology of the area

Ranya District is placed in northern Iraq. It is well known for with humid and hot summer temperatures and its bloodless winters. Average temperatures range from -1 °C to 43 °C. It is a region that receives a significant amount of rain with little snow in winters. The location is in fact known for its artificial lake "Darband" in the region and is surrounded by mountains. The precipitation values for the last ten years of Ranya District are given in Table 2 for a preview of the precipitation conditions before the trial season.

Table 2. Precipitation in Ranya District Over the Last Decade

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
mm/year	844	661	547	836	581	691	947	561	850	1618

Source: Ranya agriculture directory

The average annual precipitation for the last decade was 814.12 mm, which starts in October and continues to the end of May. Most of the rain comes in December, January, February, and March. With a low ratio of snow usually in December and January in the town center, but the mountains around the city almost turn white from November to May. The four seasons are really shown in the Ranya district, with cold winter in which the temperature goes below 0 °C, and a hot summer sometimes temperature boosts until 45 °C with a medium level of humidity. The temperature degrees usually start to rise in the middle of February and in March it's about 15 °C. From April to June the temperature degrees start to get warmer, starting from 20 to 38 °C. In July and August, temperature degrees range from 40 to 45 °C. From the beginning of September, they will decrease slowly until it reaches 0 to 5 °C in December and January with some frost as shown in (Figure 2).

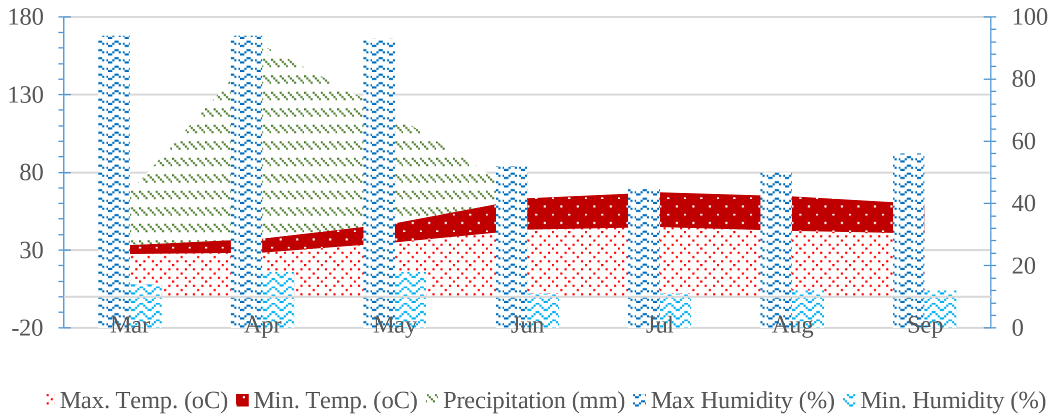

Figure 2. Meteorological Data for 2020 in the Ranya District

Experimental treatments

The experimental treatments included two hybrids of corn (DKC6050 and DKC6664) which are commercial hybrids developed and breed in Türkiye. The varieties were applied to the main plot and the four levels of 32% HA granules form (PERLHUMUS®) was applied to the sub-plots. The HA doses were calculated and weighted properly, then mixed with the soil of each plot evenly before fixing irrigation pipelines except for control plots.

Experimental design and analysis

The study was conducted based on a split-plot experimental design in randomized blocks with four replications. The blocks were set up with two main plots each of which contained four treatments of humic acid (HA) doses (HA1: 0 kg HA/ha, HA2: 60 kg HA/ha, HA3: 120 kg HA/ha, and HA4: 180 kg HA/ha) in sub-plots, respectively. Each plot's size was 2.4 m in width and 5 m in length. The distance between the main plots was 2m, and 1m between subplots. Each plot contained four rows 60 cm apart, and each row consisted of 20 cm apart intra-row spacing. The all of HA doses were applied before sowing. In the trial, as the source of nitrogen, 200 kg/ha pure nitrogen (Urea (46% N), half of which was applied during sowing and the other after the plants reached 15 cm long. Additionally, 200 kg/ha pure phosphorus (Triple Super Phosphate (P_2O_5)) fertilizer was applied to all plots before sowing by mixing with the soil. Sowing was performed on the 30th of July 2020. Irrigation and weed control treatments were performed based on need. The observations of yield and yield attributes and some other agronomic properties were recorded on 10 plants which were randomly selected from two middle rows in each subplot. The harvest was performed after the deletion of the plot sides and 50cm from two middle head rows.

Statistical analysis

The variance analysis of data for each of the properties was performed by using the IBM SPSS (v. 23.0) software according to the split-plot in randomized block design. In addition, the means of the examined features were grouped according to the LSD multiple comparison test at the 5% significance level with the CoStat-C (v. 6.303) software.

RESULTS AND DISCUSSION

The Anova analysis of data recorded for plant height, stem diameter, leaf number, leaf area index, harvest index, seed per cob, and rows per cob obtained from applying different doses of HA and two cultivars were shown in Table 3 and their averages values and LSD groups were presented in Table 4.

Plant Height

In Table 3, it is seen that there are significant (P<0.01) differences between HA doses in terms of the effects of maize on plant height, but there is no significant (P>0.05) difference between varieties and their interactions with HA doses.

Table 3. Variance Analysis Results Regarding the Observed Attributes' Average Values Obtained As A Result of Humic Acid Fertilizer Application in Corn Varieties

Variation Sources	DF	Plant height		Stem diameter		Leaf number		Leaf area index		Harvest index		Seed per cob		Rows per cob	
		M.S.		M.S.		M.S.		M.S.		M.S.		M.S.		M.S.	
Block	3	565.300		0.070		7.809		0.241		26.869		279.959		0.630	
Cultivar (C)	3	450.750		0.001		0.403		0.001		19.375		321.818		0.160	
Error 1	9	225.669		0.001		0.601		0.001		11.006		498.960		0.867	
Humic acid (HA)	1	296.027	**	0.068	**	6.656	**	0.290	**	147.016	**	3309.195	**	5.658	**
C X HA	3	44.719		0.012	*	0.180		0.123	**	21.526	**	111.940		0.260	
Error 2	12	21.062		0.004		0.318		0.009		2.950		342.120		0.433	
CV (%)		**2.773**		**2.836**		**4.263**		**5.268**		**8.615**		**5.747**		**2.839**	

*: Statistically significant (P<0.05); **: Statistically very significant (P<0.01)

In the experiment, it was determined that the plant height values of both varieties varied between 161.73 - 169.23 cm (Table 4). It can be said that this situation arises from the morphological and genetic similarity of the cultivars. The height of plants increased in accordance with the increase of humic acid doses. It was found that the maximum plant height was obtained from the fourth HA dose (180 kg/ha) as 171.48 cm, while the minimum plant height was obtained from the control (0 kg/ha) as 157.23 cm. In the comparison of the doses, the height of the plants in the fourth rate increased by 2% and 4% compared to the third and second humic doses respectively.

The plant height increase associated with HA application may have been caused by the physiological effects of humic acid, including increased cell membrane permeability, acceleration of cell division, and root system development (Khaled & Fawy, 2011). Similar results that support these findings were demonstrated by Balbaa & Awad, 2013, Daur & Bakhashwain, 2013, El-Saber et al., 2014, Moghadam et al., 2014, Banitamim & Shokuhfar, 2017, Hussain et al., 2018, Aseres et al., 2019, and Hassan et al., 2019).

Table 4. Average Values of Observed Parameters Obtained in Corn Varieties as A Result of Different Humic Acid Dose Applications

CULTIVARS (C)	**HA Doses**	**Plant height (cm)**		**Stem diameter (cm) ***		**Leaf number (pieces)**		**Leaf area index (LAI) ***		**Harvest index (%) ***		**Number of seeds per cob (pieces)**		**Number of rows per cob (pieces)**	
DKC6050	**HA1**	153.03		2.02	c	12.17		1.70	cd	16.84	d	287.87		22.17	
	HA2	164.78		2.12	bc	12.67		1.61	d	18.28	d	317.20		22.67	
	HA3	162.30		2.13	bc	13.47		1.84	bc	19.22	cd	336.53		23.33	
	HA4	166.80		2.18	b	14.13		2.23	a	28.52	a	333.13		24.23	
	Mean	**161.73**		**2.11**		**13.11**		**1.84**		**20.71**		**318.68**		**20.02**	
DKC6664	**HA1**	161.43		2.02	c	12.20		1.60	d	15.77	d	303.10		22.23	
	HA2	165.48		2.05	c	12.83		1.92	bc	16.12	d	315.17		22.90	
	HA3	173.88		2.13	bc	14.13		1.86	bc	21.70	bc	339.57		23.90	
	HA4	176.15		2.30	a	14.17		1.96	b	23.04	b	342.27		23.93	
	Mean	**169.23**		**2.12**		**13.33**		**1.84**		**19.16**		**325.03**		**19.00**	
Humic Acid (HA) Doses' Means **	**HA1**	157.23	*C*	2.02	*C*	12.18	*B*	1.65	*C*	16.30	C	295.48	*C*	22.20	B
	HA2	165.13	*B*	2.08	*BC*	12.75	*B*	1.77	*B*	17.20	C	316.18	*B*	22.78	B
	HA3	168.09	*AB*	2.13	*B*	13.80	*A*	1.85	*B*	20.46	B	338.05	*A*	23.62	A
	HA4	171.48	*A*	2.24	*A*	14.15	*A*	2.10	*A*	25.78	A	337.70	*A*	24.08	A
LSD (%5) C		**ns**		**ns**		**ns**		**ns**		**ns**		**ns**		**ns**	
LSD (%5) for HA		**4.821**		**4.821**		**0.592**		**0.102**		**1.804**		**19.430**		**0.691**	
LSD (%5) for C x HA		**ns**		**0.178**		**ns**		**0.288**		**5.10**		**ns**		**ns**	

*- The means shown with the same small letter in the same column have no statistically (P>0.05) significant difference.
**- The means shown with the same *italic capital* letter in the same column have no statistically (P>0.05) significant difference.

Stem Diameter

In the study, no statistical (P>0.05) difference was observed between the varieties in terms of stem diameter (Table 3), and it was determined that the average values of stem diameter varied between 2.11 - 2.12 cm (Table 4). While very significant differences (P<001) were determined between HA doses in Table 3, significant differences were found between the interactions of cultivar x humic acid doses (P>0.05).

As a result of the applications of humic acid doses, it was found that the maximum stem diameter observed was obtained from the fourth dose (180 kg/ha) application as 2.24 cm and the minimum stem diameter was obtained from the control treatment as 2.02 cm (Table 4). The humic substances have been determined to have a positive effect due to their impact on providing nutrients, for better plant growth through absorbing more ions such as nitrogen and potassium, which in turn increase photosynthesis efficiency, cell development, and increase in number and size of the vascular bundles which leads to more growth in stem diameter (Shahryari et al., 2011). As seen in Table 4, it was determined that cultivars showed different responses to HA application doses, and therefore, the maximum stem diameter (2.30 cm) was obtained from the interaction between HA4 x DKC6664 cultivar, while the lowest stem diameter (2.02 cm) was measured from the control application in both cultivars (Figure 3). The results of the research are in line with the results of Eldardiry et al., 2012, Ragheb, 2016, and Hassan et al., 2019, who reported that the increase in HA doses made the stem diameter thicker.

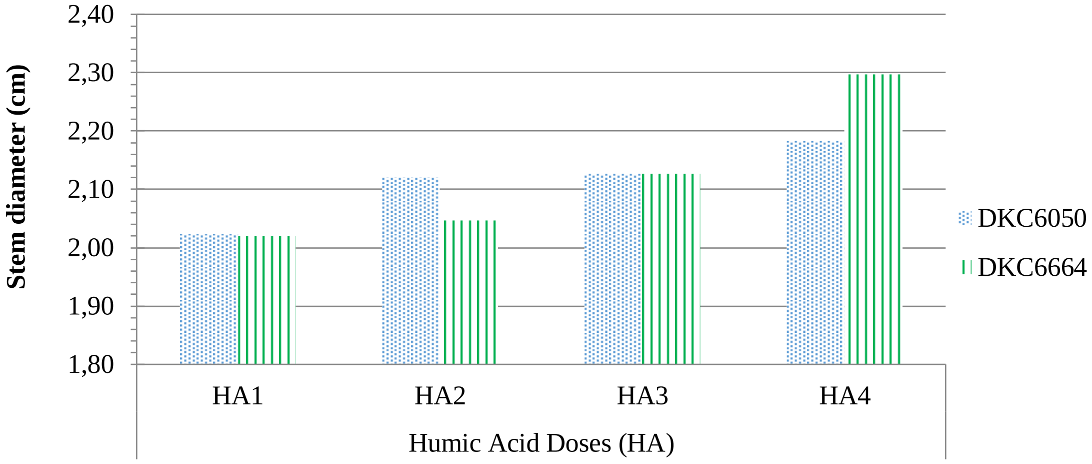

Figure 3. Cultivar and Humic Acid Doses' İnteraction for Stem Diameter

Number of Leaf

As seen from Table 3, in terms of leaf number, the differences between the two cultivars and their interactions with HA doses were statistically nonsignificant (P>0.05). On the other hand, it was determined that there were statistically very significant (P<0.01) differences between the four doses of HA applied. It was determined that the leaf number of both varieties varied between 13.11 - 13.33 pieces as in Table 4. Here it can be said that the main reason was the similarity of the cultivar based on genetics and morphology. In the study, it was found that the maximum number of leaves (14.15 pieces) was obtained from the fourth dose (180 kg/ha) application, while the minimum leaf number (12.18 pieces) was counted from the control dose (Table 4).

The increase in the leaf number of corn plants could have been related to the positive effects of humic acid on the growth of the plant through the enhancement of root growth, and its architecture (Zandonadi et al., 2019), which results in more increase in root size, branching, root hair density increased, and larger surface area. Which leads to more nutrient uptake and boosted the major biochemical pathways (Canellas and Olivares, 2014; Aseres et al., 2019).

As seen from Table 4, it was determined that the numbers of leaf were varied between 12.17 - 14.17 pieces in terms of varieties x humic acid doses' interactions. The results of the study were found to be in accordance with the results obtained by Daur & Bakhashwain, (2013) who reported with an increase in HA doses the number of leaves has been increased.

Leaf Area Index (LAI)

As seen in Table 3, it was observed that the treatment of HA significantly affected the LAI of the corn plants. In terms of leaf area index, while there wasn't a significant difference between cultivars, the HA doses and the interaction between the varieties x HA had statistically significant (P<0.0) differences. It was determined that the leaf area indexes were calculated as 1.84 for both varieties (Table 4).

As a result of the significant effects of different doses of humic acid on the leaf area index, it was found that the maximum leaf area index (2.10) was obtained from the fourth dose (180 kg/ha) application, and the minimum leaf area index was obtained from the control dose (0 kg/ha) as 1.65 (Table 4 and Figure 4).

It was thought that the increase of LAI with the increase of HA dose was related to the effects of HA due to the improving the soil around the root zone (Daur and Bakhashwain, 2013), uptake of macronutrients and micronutrients (El-Saber et al., 2014). Therefore, it was determined that the maximum leaf area index was obtained from the HA4 x DKC6050 interaction as 2.23, while the minimum leaf area index was obtained from the control x DKC6664 interaction as 1.60 (Figure 4). The results of the study were found to be in accordance with the results reported by Daur & Bakhashwain, 2013, El-Saber et al., 2014, Aseres et al., 2019 and Sharif & AL-Rawi, 2019, who stated that with the increase in HA rates, the LAI have been increased positively.

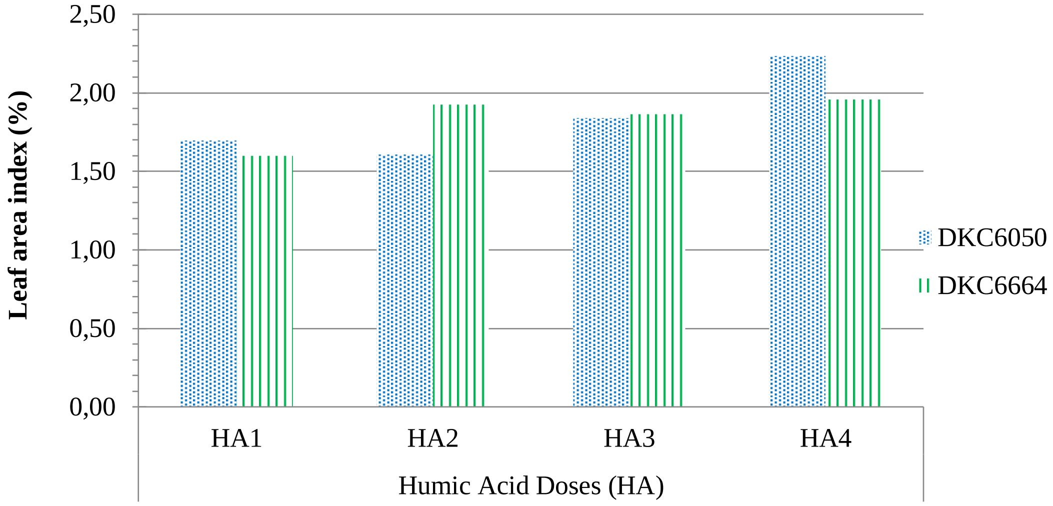

Figure 4. Cultivar and Humic Acid Doses' İnteraction for Leaf Area İndex

Harvest ındex (HI)

The analysis of variance of the harvest index presented in Table 3 showed that there was no significant difference in harvest index between cultivars ($P>0.05$), but very significant ($P<0.01$) differences between the interactions of humic acid doses and cultivar x HA doses.

In the study, it was observed that the average values of the harvest indexes varied between 19.16 - 20.71 % in terms of varieties (Table 4). It was also determined that with the increase in HA doses, the harvest index had increased significantly. The highest harvest index percentage has been recorded in the fourth dose of HA (180 kg/ha) as 25.78%, while the minimum harvest index has been obtained from the control plot as 16.30% (Table 4).

Due to the humic acid's crucial effects on plant metabolism of cells, expanded leave area, more root growth, acting as growth hormones, and more photosynthesis rates, it resulted in increasing the harvest index (Maruf and Mam-Rasul, 2019). Therefore, it was determined that the maximum HI value (28.52%) was obtained from the HA4 x DKC6050 interaction, while the minimum HI value (15.77%) was obtained from the control x DKC6664 interaction (Figure 5). The study results were found to be consistent with the results of many previous studies reporting the effects of humic acid on the harvest index of the corn plant (El-Saber et al., 2014; Moghadam et al., 2014; Aseres et al., 2019; Maruf and Mam-Rasul, 2019).

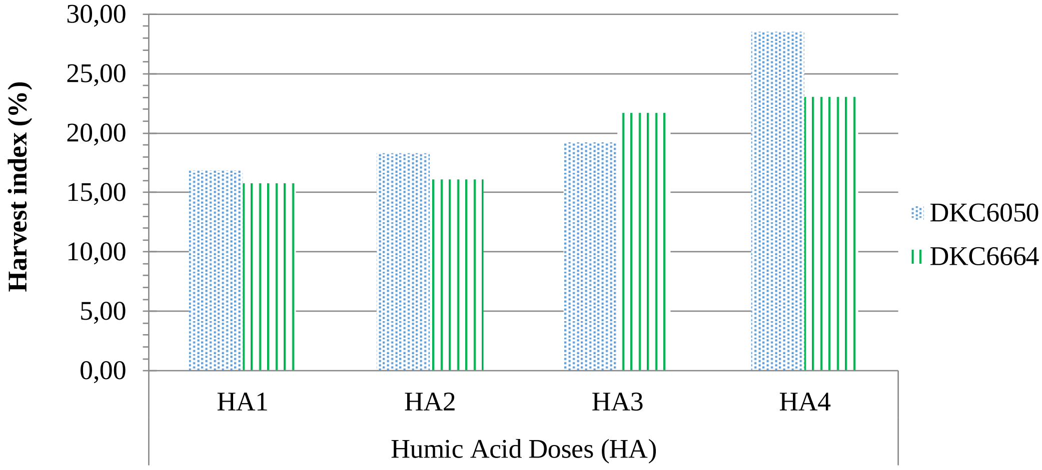

Figure 5. Cultivar and Humic Acid Doses' İnteraction for Harvest İndex

Number of Seeds per cob

The results of the study indicated that there was no statistically significant (P>0.05) difference between the two cultivars in terms of the number of seeds per cob. It was determined that the values of both cultivars were counted as 318.68 pieces for DKC6050 and 325.03 pieces for DKC6664 (Table 4). As seen in Table 3, there was a statistically significant (P<0.01) difference between the HA doses' effects on the number of seeds per cob.

In Table 4, it was shown that the maximum number of seeds per cob was recorded from the third (120 kg/ha) and fourth (180 kg/ha) doses of humic acid as 338.05 and 337.70 pieces, respectively, while the minimum number of seeds was recorded from the control plot as 295.48 pieces/cob. The results can be related to the positive effects of humic acid application. Because, HA improves soil structure conditions (Çelik et al., 2010), enhancing absorption and abundance of nutrients through promoting the nutrient chelating process (Berbara & Garcia, 2014), and also there are physiological processes such as promoting plant cell metabolism and increasing leave area (Nardi et al., 2009).

According to Table 3, there wasn't any significant (P>0.05) difference between the interaction effects of the cultivar x HA doses. As seen in Table 4, it was determined that the number of seeds per cob ranged from 342.27 pieces (control plot x DKC6050 variety) - 287.87 pieces (the fourth dose of HA x DKC6664 variety). It was determined that the results of the study were consistent with the results of previous studies (Azeem et al., 2014; El-Saber et al., 2014; Moghadam et al., 2014; Hussain et al., 2018; Maruf and Mam-Rasul, 2019; Oktem and Oktem, 2020), which indicated that with the increase of HA doses the number of seeds per cob increased.

Number of rows per cob

As observed in Table 3, there was a very statistically significant (P<0.01) difference for the different doses of HA on the number of rows per cob of the corn, while there were no statistically significant (P>0.05) differences observed for the cultivars and their interaction with the HA doses. In Table 4, it was determined that the values of the number of rows per cob in both cultivars were 23.10 pieces/cob for DKC6050 and 23.24 pieces/cob for DKC6664.

In the study, it was seen that the highest values of the number of rows per cob were obtained from the fourth (180 kg/ha) and third (120 kg/ha) doses of HA as 24.08 and 23.62 pieces, respectively. And, the minimum values of the number of rows per cob with 22.78 and 22.20 pieces were counted from the second (60 kg/ha) and first (0 kg/ha) doses of HA (Table 4). As shown in Table 4, the mean values for the varieties x humic acid doses' interactions ranged from 24.23 to 22.17 pieces/cob.

The cobs and their number of rows are one of the most important features of the corn plant related to the yield. The number of rows determined at the beginning of cob formation (El-Sahookie, 1990), the increase of rows, and other features of the cob can be related to the positive effects of humic acid on the increasing soil fertility, enhancing crop performance and finally, production increased (Jahan et al., 2019). Similar outcomes to the presented results of the number of rows per cob related to HA application were reported in the previous studies (Moghadam et al., 2014; Banitamim and Shokuhfar, 2017; Maruf and Mam-Rasul, 2019).

Cob diameter

In the study, no statistical (P>0.05) difference was observed between the varieties in terms of cob diameter (Table 5), and it was determined that the average values of cob diameter ranged between 3.88 - 3.92 cm for both cultivars, respectively (Table 6). When the variance analysis of cob diameter was examined in Table 5, the differences between the HA doses were not statistically significant (P>0.05). These results may be caused by external and environmental factors such as high temperatures, which affect the tassels and cob of the corn.

The temperature especially at the time of cob formation was very high and most of the time it was over 40 °C. As seen in Table 5, it was determined that there were very significant statistical (P<0.01) differences among the common effects of both factors, and the reactions of cultivars to the different doses of HA were different.

Table 5. Variance Analysis Results Regarding the Observed Parameters' Average Values Obtained As A Result of Humic Acid Fertilizer Application in Corn Varieties

Variation Sources	DF	Cob diameter		Yield per plant		100 seeds weight		Husk ratio		Seed yield		Protein ratio	Oil ratio
		M.S.		M.S.		M.S.		M.S.		M.S.		M.S.	M.S.
Block	3	38.99		32.99		2.69		5.680		229196.1		2.295	0.066
Cultivar (C)	3	31.84		2.35		11.52		9.570		16276.6		1.488	0.113
Error 1	9	57.85		74.38		2.54		9.405		516086.4		2.359	0.174
Humic acid (HA)	1	425.55		3060.83	**	26.84	**	14.001	*	21255152.0	**	5.665	0.100
C X HA	3	4.05	**	290.51	**	11.37	**	8.414		2017010.5	**	2.460	0.118
Error 2	12	26.52		15.15		2.07		3.076		105229.9		2.320	0.097
CV (%)		**6.891**		**4.421**		**3.868**		**15.189**		**4.421**		**17.678**	**9.107**

*: Statistically significant (P<0.05); **: Statistically very significant (P<0.01)

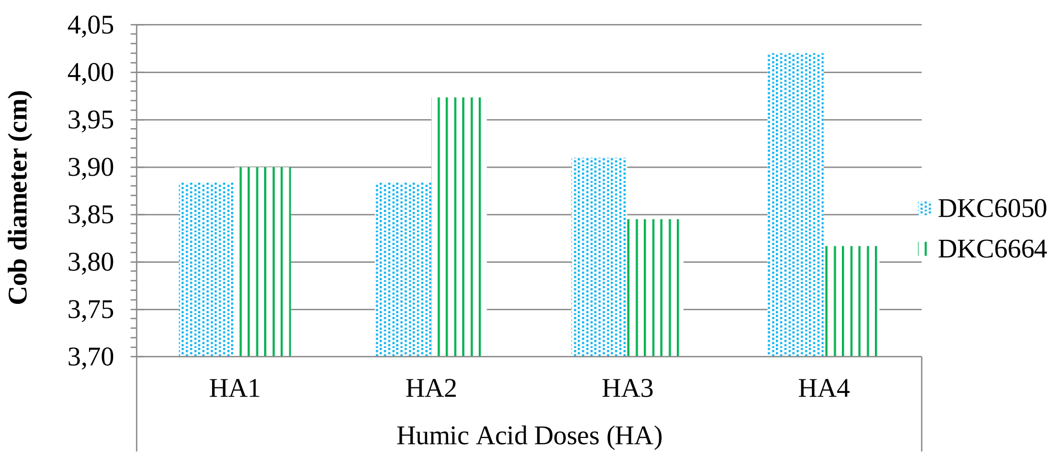

Figure 6. Cultivar and Humic Acid Doses' İnteraction for Cob Diameter

The DKC6050 cultivar showed a positive response to the increase of HA, so the maximum diameter of the cob was obtained as 4.02 cm from the fourth dose of HA, while the DKC6664 variety showed a negative response to the HA dose increased and the lowest cob diameter was obtained in HA4 with 3.82 cm (Table 6 and Figure 6). According to some previous studies (Ertani et al., 2011; Maruf and Mam-Rasul, 2019), the using of HA doses alone without interaction with other factors didn't show any notable difference.

Yield per plant

As seen in Table 5, it was determined that there was no statistically significant (P>0.05) difference between the cultivars, while there were statistically very significant differences (P<0.01) between the HA doses applied and between the effects of interactions of factors in terms of yield per plant. In the research, the yield of a plant has been studied as one of the most important yield parameters, and it has directly related to the whole biological processes and the final yield of the plant, thus it can be affected by both genetics and growth factors (El-Sahookie, 1990).

In Table 6, it was seen that the yields per plant were 87.77 g/plant for DKC6050 and 88.32 g/plant for DKC6664. The maximum average yield per plant value (110.82 g/plant) was obtained from the application of the fourth dose of HA (180 kg/plant), while the minimum yield per plant was recorded in the control dose as 68.17 g/plant. When it was compared to the third and second doses of HA, it produced 12% and 31% more yield, respectively. As seen in Table 6, it was determined that the maximum yield per plant (118.14 g/plant) was measured from the interaction of the fourth dose of HA (180 kg/ha) with the DKC6050 cultivar, while the minimum values of the yield per plant (67.55 and 77.68 g/plant) were obtained from the interaction of H1 and H2 dose of HA and DKC6664 variety (Figure 7).

Application of organic substances including humic acid increased nitrogen availability in soil and other micro and macronutrients which leads to increased yield and enhanced seed quality. As known, the nutrients that come from organic sources are working more efficiently in different functions in plants (Ahmad et al., 2014; Du et al., 2016). Additionally, the increased yield per plant could be related to the enhancing cell development, regulating enzymes, and triggering photosynthesis (Gao et al., 2020) by increasing chlorophyll content, light absorption, and fine structure of the chloroplast as a result of adding organic substances (Fan et al., 2014). The results of this study were in accordance with the results of previous studies reported by Sharif and AL-Rawi, 2019, and Wulandari et al., 2019.

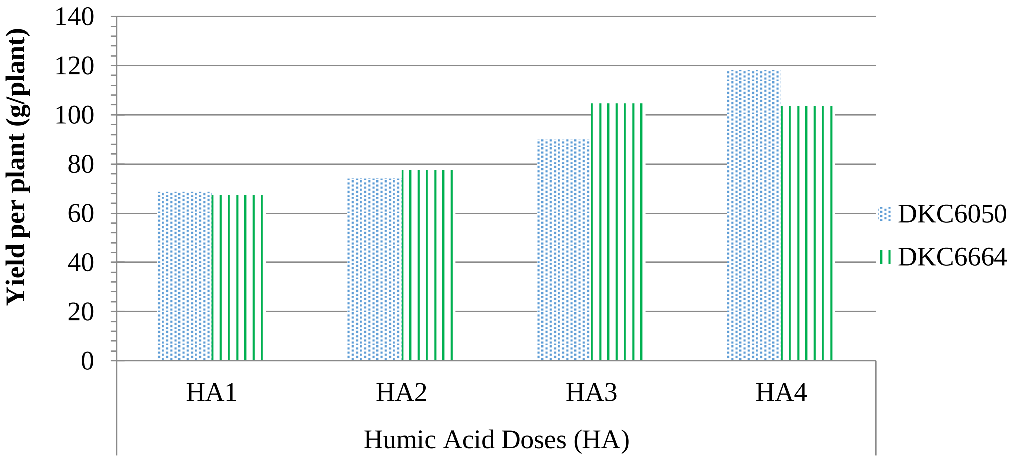

Figure 7. Cultivar and Humic Acid Doses' İnteraction for Yield Per Plant

100 seeds weight

As seen in Table 5, there wasn't a statistically significant (P>0.05) difference between the cultivars in terms of the 100 seeds weight, while their interaction with HA doses and applying HA doses alone had statistically very significant (P<0.01) different effects on 100 seeds weight. In the study, it was determined that the 100 seeds weight values of both cultivars DKC6050 and DKC6664 were 36.61 g and 37.81 g, respectively (Table 6).

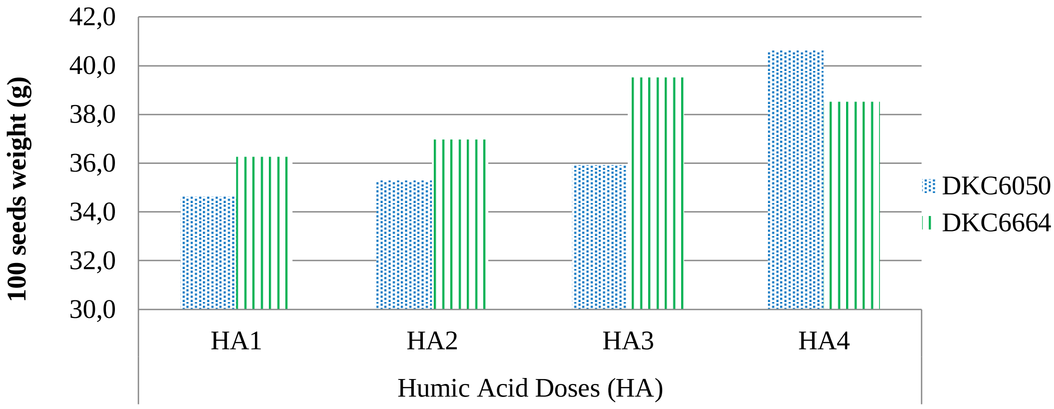

Figure 8. Cultivar and Humic Acid Doses' Interactions for 100 Seeds Weight

Table 6. Average Values of Observed Parameters Obtained in Corn Varieties As A Result Of Different Humic Acid Dose Applications

CULTIVARS (C)	HA Doses	Cob diameter (cm) *		Yield per plant (g/plant) *		100 seeds weight (g) *		Husk ratio (%)		Seed yield (kg /ha) *		Protein ratio (%)	Oil ratio (%)
DKC6050	**HA1**	3.88	a-c	68.79	de	34.63	c	10.19		5732.4	de	6.40	3.30
	HA2	3.88	a-c	74.08	de	35.30	c	11.78		6173.3	de	8.57	3.33
	HA3	3.91	a-c	90.09	c	35.92	c	10.89		7507.8	c	9.06	3.54
	HA4	4.02	a	118.14	a	40.61	a	11.14		9844.8	a	9.53	3.29
	Mean	**3.92**		**87.77**		**36.61**		**11.00**		**7314.6**		**8.39**	**3.37**
DKC6664	**HA1**	3.90	a-c	67.55	e	36.25	bc	9.60		5628.8	e	8.45	3.22
	HA2	3.97	ab	77.68	e	36.98	bc	11.70		6473.6	d	8.72	3.50
	HA3	3.85	bc	104.53	b	39.53	ab	12.00		8710.6	b	9.17	3.47
	HA4	3.82	c	103.51	b	38.51	ab	15.09		8625.7	b	8.97	3.71
	Mean	**3.88**		**88.32**		**37.81**		**12.10**		**7359.7**		**8.83**	**3.48**
Humic Acid (HA) Doses' Means **	**HA1**	3.89		68.17	*D*	35.44	*C*	9.90	*B*	5680.6	*D*	7.42	3.26
	HA2	3.93		75.88	*C*	36.14	*C*	11.74	*AB*	6323.5	*C*	8.64	3.42
	HA3	3.88		97.31	*B*	37.72	*B*	11.44	*AB*	8109.2	*B*	9.12	3.51
	HA4	3.92		110.82	*A*	39.56	*A*	13.11	*A*	9235.3	*A*	9.25	3.50
LSD (%5) C		**ns**		**ns**		**ns**		**ns**		**ns**		**ns**	**ns**
LSD (%5) for HA		**5.41**		**4.09**		**1.51**		**1.84**		340.76		**ns**	**ns**
LSD (%5) for C x HA		**ns**		**11.57**		**4.28**		**ns**		963.82		**ns**	**ns**

*: The means shown with the same small letter in the same column have no statistically (P>0.05) significant difference.
**: The means shown with the same *italic capital* letter in the same column have no statistically (P>0.05) significant difference.

When 100 seeds weight were observed in terms of HA efficiency in Table 6, the lowest seed weight was recorded in the control plot (35.44 g), which in comparison to the second dose difference was not significant. On the other hand, the highest 100 seeds weight (39.56 g) was recorded in the fourth (180 kg/ha) HA dose (Table 6). The mean values showed that with the increase of HA applied the seed weight was increased. The reason of seeds weight increased belongs to the improvement of the physical and chemical features of the soil, and also, it increased due to the biomass increase as a result of acceleration in productivity of plants, physiology, and biochemistry (Canellas and Olivares, 2014). The study results were approved by results of some previous studies (Balbaa and Awad, 2013; El-Saber et al., 2014; Moghadam et al., 2014; Hussain et al., 2018; Aseres et al., 2019; Maruf and Mam-Rasul, 2019). As shown in Table 6 and Figure 8, the highest weight of 100 seeds (40.61 g) was recorded in the interaction of DKC6050 with the fourth dose of HA (180 kg/ha), while the minimum mean value among the interactions was recorded within DKC6050 interaction with the control plot (34.63 g) which had no statistically significant difference with the second and third dose of HA x DKC6050 interactions.

Husk ratio

In Table 5, there was a statistically significant ($P<0.05$) difference between HA doses in terms of the husk ratio of the corn, while no significant ($P>0.05$) differences were observed between the cultivars and between their interactions with the HA doses.

In the experiment, it was determined that the husk ratio of both cultivars was determined as 11.00 - 12.10 % (Table 6). When the mean values of the husk ratio were examined in Table 6, it was seen that the minimum husk ratio was obtained from the control plot as 9.90%, while the maximum husk ratio was obtained from the fourth dose of HA (180 kg/ha) as 13.11%.

In Table 6, the range of mean values among the interaction varied between 9.60 - 15.09%. The husk ratio participated in the C_4 photosynthesis of the corn plant, and its structure is similar to the other leaf of the plant with lesser vascular bundles and veins (Pengelly et al., 2011). The results of the study related to husk ratio could be evaluated that as a green part of a plant and its structure husk leaf could have been affected by genetic and growth factors that affected the whole plant. Humic acid has a positive effect on photosynthesis, chlorophyll content, respiration, and nuclear acid formation (Kim, 2003), thus, it may be, the increase in the husk ratio was related to the application of the humic acid.

Seed yield

As seen in Table 5, there was no statistically significant ($P>0.05$) difference between the effects of cultivars on the seed yield of the corn, while their interactions with HA doses and Ha acid doses had statistically very significant ($P<0.01$) effects on seed yield. In the research, it was determined that the seed yield values of both cultivars were obtained as 7314.58 and 7359.69 kg/ha, respectively (Table 6). When the mean values of seed yield were examined in Table 6, the highest seed yield was determined from the fourth dose of HA as 9235.30 kg/ha, while the lowest seed yield was recorded in the control plot as 5680.59 kg/ha. The increase in seed yield could have been caused by the uptake of macro and micronutrients, and their stimulating effects on photosynthesis, respiration, protein, and nuclear acids, which were affected by HA Kim, 2003, and Tejada and Gonzalez, 2003. Additionally, HA increases root growth, improved soil structure, enhances microorganisms' life in the soil, and acts as plant growth hormone (Maruf and Mam-Rasul, 2019). From the above information, it could be determined that these factors have positively affected the seed yield of corn. Many previous studies indicated that with the increase of humic acid the seed yield of corn had been increased (Azeem et al., 2014; Banitamim and Shokuhfar, 2017; Aseres et al., 2019; Maruf and Mam-Rasul, 2019; Oktem and Oktem, 2020). As shown in Table 6 and Figure 9, the highest seed yield was recorded in the interaction of DKC6050 with the fourth dose of HA (180 kg/ha) as 9844.84 kg/ha, while the minimum mean value (5628.82 kg/ha) among the interactions was recorded within DKC6664 interaction in the control plot. Thus, the mean values indicated that DKC6050 responded better than DKC6664 with the increase in HA doses.

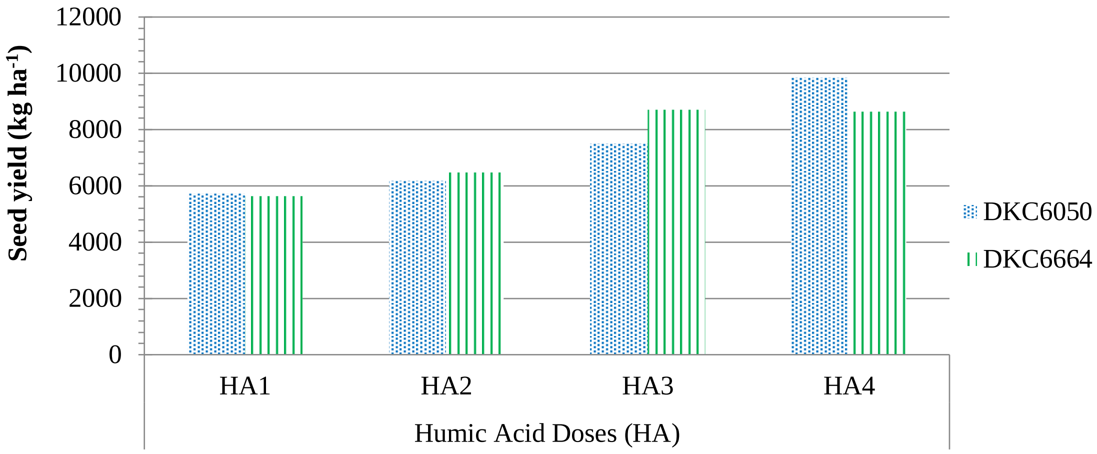

Figure 9. Cultivar and Humic Acid Doses' Interaction for Seed Yield

Protein ratio

According to the variance analysis in Table 5, there were no statistically significant (P>0.05) differences between cultivars, HA doses, and their interaction effects on the protein ratio of corn seeds. As seen in Table 6, it was determined that the mean values of protein ratio for both varieties were found as 8.39 and 8.83%.

When the mean values of the protein ratio were examined in Table 6, it was seen that the average values of the protein ratio obtained as a result of each HA dose application varied between 7.42 and 9.25 %. Contrary to the study, some previous studies' results reported by Rajpar et al., (2011), El-Saber et al., (2014), Esmaili et al., (2016), and Oktem and Oktem, (2020), the protein ratio should have been increased in accordance with the increase of the humic acid doses. It could be stated that the environmental effects such as extreme heat and drought affected the results of this study, due to the temperature during protein formation stages being very high in the Ranya district.

As seen from Table 6, it was observed that the average protein ratio obtained from interactions of both factors ranged from 6.40 to 9.53 %. It could be evaluated that this was due to the varieties showing the same reaction to each of the HA doses.

Oil ratio

As seen in Table 5, there were no statistically significant (P>0.05) differences between cultivars, HA doses, and their interaction effects on the oil ratio of corn seeds. According to Table 6, it was determined that the germination values of both varieties were monitored as 3.37 and 3.48 %.

When the mean values of the oil ratio were examined in Table 6, it was seen that the average oil values obtained as a result of each HA dose application varied between 3.50 and 3.26%. Although the difference between them was not statistically significant, it was observed that the oil ratio increased numerically as the HA dose increased.

As seen from Table 6, it was determined that the average oil ratio obtained from interactions of both factors ranged from 3.22 to 3.71 %. Contrary to the findings of the study, in some previous studies which evaluated the effects of humic acid on the oil ratio, it was reported that with the application of HA, the oil ratio was increased (Khazaie et al., 2011; Rajpar et al., 2011; Alireza, 2012; Esmaili et al., 2016; Noroozisharaf and Kaviani, 2018). The results of the study could be affected by environmental factors such as extreme heat in the summer of the Ranya district, in which most of the days reached above 40 °C.

CONCLUSION

Based on the results of the field experiment, it can be concluded that DKC6050 and DKC6664 varieties didn't show any notable difference in most traits tested. However, the DKC6050 cultivar stood out for many of the properties examined. Additionally, it was determined that the reactions of the cultivars to humic acid doses were the same for many of the investigated traits. As a result of the study, it was seen that the applied humic acid positively affected most of the observed parameters, especially seed yield. However, humic acid applied to the soil did not show any notable difference in the oil ratio of corn seeds, while it increased the protein in a non-significant way. Greater attention and work should be considered to develop corn production and reach a sustainable level that would fulfil local needs. For better suggestions, different forms of humic acid (liquid and powdered), application methods (foliar), and rates of humic acid should be studied with more hybrids and cultivars of corn. Humic acid testing needs further research, especially in the spring, in order to be able to recommend the best variety and dose of humic acid for corn cultivation in Ranya, Sulaymaniyah.

Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have contributed equally to the article.

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