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Enhancing Potato Productivity and Nutritional Status under Drought Stress: The Role of Humic Acid in Climate-Resilient Agriculture

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A FIELD experiment conducted over two winter growing seasons aimed to assess the nutritional status of potato plants using the Diagnosis and Recommendation Integrated System (DRIS) method and to evaluate the effects of humic acid treatments and water stress on their production in sandy soil. The results indicated that water-stressed plants exhibited significantly reduced tuber weight, length, diameter, and overall yield compared to unstressed plants. The application of humic acid at rates of 60 and 120 kg ha^{-1} generally improved tuber characteristics and yield in both stressed and unstressed conditions, while it did not significantly affect protein content but increased starch content. Since the norms for potato plants were N/P, P/N, and K/P, the DRIS approach was utilized to ascertain them. The Nutrient Balance Index (NBI) is a computed statistic that represents the overall nutrient balance inside the plant. In general, a favorable nutritional balance is indicated by a positive NBI. In comparison to unstressed plants, water-stressed plants typically showed more extreme values for nutritional indices. The study suggests that using humic acid as a soil supplement could enhance potato yield and nutritional status in water-limited environments, supporting sustainable agricultural practices.

Keywords: Potato, Humic acid, Water stress, Productivity, DRIS.

Introduction

Water stress, a critical consequence of climate change, happens when the amount of water needed during a given time period exceeds the amount that is available or when its use is restricted because of its poor quality. Drought, one of the most significant abiotic stressors exacerbated by climate change, severely impact crop plants, impairing their growth and development and lowering crop output **(Farooq *et al*., 2009; Smita** and **Gagan., 2022)**. There will be more food shortages and catastrophic droughts in African nations. If low-income countries in Africa or Asia experience a decline in agricultural output due to climate change, many people will be in danger and food insecurity will worsen **(Mohamed, 2020 and Abd El Lateef et al., 2025)**. Plant growth and biomass accumulation are significantly reduced under water stress, leading to lower agricultural productivity, particularly in regions vulnerable to

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climate variability **(Muhammad and Zoltan., 2022)**. Reduced rate of cell expansion, cell division, leaf area, root proliferation, stem elongation, fluctuation in stomatal oscillations, water retentions, and plant nutrient uptake are the main detrimental effects of water stress on plant growth, which ultimately lowers crop productivity and plants' relative water use efficiency **(Shahzad *et al*., 2016)**. The frequency and intensity of droughts have grown due to ongoing worldwide environmental change, according to climate fluctuation and its representations **(Shahzad *et al*., 2021)**.

Humic acids, which are naturally occurring organic compounds produced from decomposing organic matter, have attracted a lot of attention in agriculture due to their potential to improve soil fertility, plant development, and productivity. By improving metabolism, promoting root formation, and increasing nutrient absorption, humic acid additions enhance plant growth and development. Humic acids also have a significant impact on improving the structure, moisture retention, and nutrient availability of the soil, all of which help to create a favorable growing environment for plants **(Bera *et al*., 2024)**. The phenolic (OH) and carboxylic (COOH) groups are the most common functional groups found in humic acid structure **(Nardi *et al*., 2021)**. These two functional groups serve as important primary groups that support increased plant growth and enhance the chemical and physical characteristics of the soil **(de Melo et al., 2016; Mohammed et al., 2021)**.

The Diagnosis and Recommendation Integrated System (DRIS), a set of standards used to assess a crop's nutritional status using the composition of plant tissues, the chemical fertility of the soil, the climate, and the integrated management practices of such a crop as the reference, was proposed in response to the limitations posed by traditional interpretation methods **(González, 2017 and López-Montoya *et al*., 2018)**. **Beaufils (1973)** established the "Diagnosis and Recommendation Integrated System," or DRIS, based on research on plant nutrition and physiology, first in rubber trees grown in Vietnam and later in South Africa's sugarcane and maize. Sumner first presented DRIS to the US in 1975 **(González, 2017)**. Since then, a number of extensive, forage, fruit, and vegetable crops as well as wood species have had their diagnosis norms established **(Bangroo *et al*., 2010, Kania & Callejas, 2011 and Savita *et al*., 2016)**.

A staple crop in the world's diet, potatoes is farmed all over the world for their tubers **(Aliche *et al*., 2020)**. Given that potatoes are the fourth most important food crop in the world, behind maize, wheat, and rice, their production is very significant economically **(Djebli *et al*., 2020)**. In arid regions, the production of potatoes (*Solanum tuberosum* L.) is largely dependent on water provided by irrigation systems to guarantee a high marketable output and high-quality tubers **(Stark *et al*., 2013)**. Water stress mostly affects potato plants during their most vulnerable growth stage, known as tuber bulking, when a lack of water can lower tuber output, grade, and quality **(Shock *et al*., 2007)**.

This study aimed to evaluate the effect of humic acid on potato yield and nutrient status under drought stress, using the DRIS method to establish nutrient norms (N, P, K) for climate-resilient potato production. The findings highlight humic acid’s potential to enhance drought tolerance and optimize nutrient management in water-limited environments

Material and Methods

Site Description and Plant Material

In order to investigate the combined effects of water stress and humic acid addition via drip irrigation on tuber production and nutritional status of potato plants grown on sandy soils, a fertigation experiment was set up in a private farm in the El-Nubaria district of Egypt (latitude 30° 30°N and longitude 30° 20°E) during the winter seasons of 2022 and 2023. Figure (1) represents the analysis of climatic trends during the growing seasons (August to December) of 2022 and 2023 in Nubaria, Egypt, revealed distinct patterns in temperature, precipitation, solar radiation, relative humidity, and evapotranspiration (ET_0).

Fig. 1. Trends in temperature, precipitation, solar radiation, relative humidity, and evapotranspiration (ET_0) during the growing seasons of 2022 and 2023 in Nubaria, Egypt.

Temperatures were consistently high, with average values ranging between 20.5°C and 30.8°C, peaking in August and September. Precipitation was minimal and sporadic, with total rainfall of 10.3 mm in 2022 and 15.2 mm in 2023, primarily occurring in November and December. Solar radiation remained high throughout the seasons, averaging between 12.5 and 29.1 MJ/m²/day, while relative humidity increased towards the end of the growing period. Evapotranspiration (ET_0), calculated using the FAO Penman-Monteith equation, exhibited a clear seasonal trend, with higher values in the warmer months (August and September) and a gradual decline towards December. These findings highlight the semi-arid climatic conditions of the region, emphasizing the importance of efficient water management for sustainable agricultural practices.

Three replicates of a split plot design were employed in the experiment. The two water stress levels were allocated to main plots. Examples of this include water-stressed plants (irrigation at 45% of available soil moisture depletion (ASMD) and water-unstressed plants (irrigation at 25% of ASMD). The chemical analysis of humic acid is displayed in Table (1), whereas subplots were humic acid treatments administered through fertigation programs at rates of 0, 60, and 120 kg ha^{-1}.

Table 1. Humic acid's chemical characteristics.

Humic acid %	pH	EC dS/m	Organic matter %	Macronutrients (%)			Micronutrients (mg kg^{-1})		
				N	P	K	Fe	Mn	Zn
10.5	7.55	0.90	72.1	1.10	0.33	2.55	544	231	275

In accordance with **Hesse's (1971)** description, a representative soil sample measuring 0–30 cm was gathered and examined for a number of physical and chemical characteristics, including pH, EC, total carbonate, and particle size distribution. Using KCl (2.0 M), available soil-N was collected, and the **Hesse (1971)** micro-Kjeldahl method was used to determine it. According to **Olsen and Sommers (1982)**, available soil-P was extracted using $NaHCO_3$ (0.5 M) at pH 8.5 and measured colorimetrically following treatment with ammonium molybdate and stannous chloride at a wavelength of 660 nm. Lastly, using a flame photometer and ammonium acetate (1.0 M) at pH 7.0, soil was extracted to assess available soil-K, following Hesse's **(1971)** instructions.

The experimental site's soil had a sandy texture (*Entisols-Typic Torripsamments*), with 3.22% clay, 9.44% silt, and 87.34% sand. 4.00 percent non-calcareous $CaCO_3$. With an alkaline $KMnO_4$-N status of 28.00 mg kg^{-1} soil, an NH_4OAC-K of 98.00 mg kg^{-1} soil, an Olsen's P of 3.00 mg kg^{-1} soil, and an OM of 0.80%, it has extremely low fertility. The pH is 8.3, the EC is 2.54 dSm^{-1}, and there are no issues with salinity or alkalinity.

The irrigation water, which came from a nearby well, had good quality; pH of 7.1, EC of 0.4 dSm^{-1}, and sodium absorption ratio (SAR) of 2.7, categorized as C2S1 **(Richards, 1962)**. The drip irrigation lines were GR (built-in) drippers spaced 50 cm apart with a flow capacity of 4 liters $hour^{-1}$ at 1.5 bar working pressure.

Potato tubers were cultivated on August 10, 2022, and August 15, 2023. The row spacing was 0.75 m and spacing between plants in rows was 0.25 m. The area of each plot was 100 m^2; hence, the total area of the field experiment was 1800 m^2.

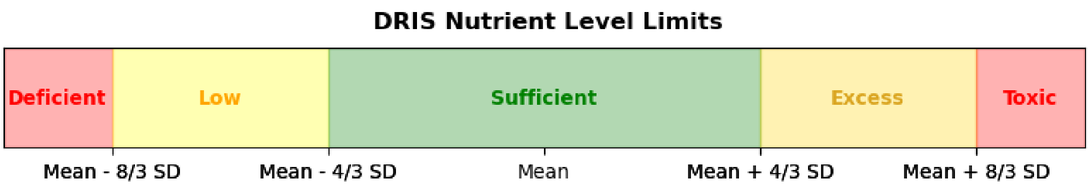
During the plant growth stages, these plants were fertigated with a combination of NPK fertilizers divided into ten sections in accordance with the Egyptian Ministry of Agriculture's recommendations (475 kg N, 85 kg P, and 200 kg K ha^{-1}).

From the second to the seventh week of the plant growth stage, a drip irrigation system was used to apply a combination fertilizer (20N-l0P-5K) with or without humic acid. On the other hand, the 10N-3P-36K form was used from the eighth week until the fertigation program's conclusion.

After 115 days from cultivation, a random sample of three plants from each treatment was chosen and prepared for chemical analysis. Fresh tubers yield was calculated as (Mg ha^{-1}).

To determine N, P and K concentrations in tuber tissues of potato, samples were taken from each plot, dried at 70° and grounded using stainless steel equipment. From each sample 0.2 g was digested using 5 cm^3 from the mixture of sulfuric (H_2SO_4) and perchloric (HClO) acids (1:1) as described by **(Cotteine, 1980)**.

Nutrient concentration data DRIS norms and coefficients of variation (CVs) of the tubers yield and tuber tissue were derived according to the procedure of **Walworth and Sumner, 1987**. Mean values or norms for each nutrient expression together with their associated CVs and population and variances were then calculated for the two sub-populations. The mean values in the high-yielding subpopulation of twenty-one expressions involving three nutrients (N, P and K) were ultimately chosen as the diagnostic norms for potato plants. The sufficiency range for leaf tissues of potato crop was determined by the DRIS technique. The range of ‘sufficiency’ are the values derived from the mean ± 4/3 SD and mean ± 8/3 SD (standard deviation), respectively **(Bhargava, 2002)**. The value of nutrients< (mean-8/3 SD) are considered deficient, whereas their low range included all values between> (mean-8/3 SD) and < (mean - 4/3 SD). Values between > (mean - 4/3 SD) and < (mean + 4/3 SD) are taken as sufficient, whereas the range between > (mean + 4/3 SD and mean + 8/3 SD are expressed as excessive or toxic. Figure (2) below summarize the above-mentioned limits in a graphical way.



Results and Discussion

Data in table (2) presented the results of a study investigating the effects of water stress and humic acid application on potato yield. The data represents a combined analysis of two growing seasons. Water-stressed plants exhibited significantly lower tuber weight, length, diameter, and total yield compared to unstressed plants. This finding underscores the detrimental impact of drought, a growing concern in the context of climate change, on potato production **(Chai et al., 2016)**. As global temperatures rise and precipitation patterns become more erratic, drought stress is expected to intensify, further threatening food security in vulnerable regions. The results highlight the urgent need for strategies to mitigate the effects of water stress on crop productivity **(Egata, 2019 & Muhammad and Zoltan., 2022)**. Application of humic acid at different rates (60, and 120 kg ha^{-1}) generally resulted in increased tuber weight, length, diameter, and total yield in both water-stressed and unstressed conditions compared to the control treatment (0 kg ha^{-1}) . This suggests that humic acid can mitigate the adverse effects of drought stress on potato growth and yield, likely due to its role in improving soil fertility, enhancing water retention, and promoting nutrient uptake **(Yang et al., 2021)**. These findings are particularly relevant in the context of climate change, where sustainable agricultural practices are needed to enhance crop resilience under water-limited conditions. In most cases, higher humic acid rates tended to lead to greater yield improvements. However, the magnitude of the response varied depending on the specific parameter and water stress condition. Humic acid can enhance soil structure, increase water retention, and improve nutrient availability, all of which are beneficial for plant growth and development. It may also stimulate root growth and development, leading to better nutrient and water uptake. Humic acid can act as a source of micronutrients and chelate metals, making them more readily available to plants.

According to **Sanli et al., (2013) and Mohammed et al., (2021),** humic acid is thought to be a medium for supplying vital nutrients for improved potato and tomato plant growth and increased production respectively. **Mahmoud and Hafez (2010)** confirmed that higher humic acid spraying levels resulted in higher tuber production and quality. Numerous profitable crops, including potato plants, have been researched for the stimulatory effects of humic acid on plant vegetative growth yield and nutrient uptake. However, humic acid's ability to improve drought (water stress) tolerance is still in its infancy and requires further research **(Calvo *et al*., 2014)**.

Table 2. Effect of water stress and humic acid rates on yield of potato (combined analysis of two seasons).

Humic acid kg ha^{-1}	Tuber weight kg	Tuber length cm	Tuber diameter cm	Total yield Mg ha^{-1}
Water unstressed plants				
0	1.14_c	7.91_b	5.32_c	35.4_c
60	1.37_b	8.62_a	6.15_b	40.7_b
120	1.44_a	8.91_a	6.93_a	44.4_a
Water stressed plants				
0	0.56_d	4.81_d	3.89_e	31.7_d
60	0.89_d	5.92_c	4.71_d	33.6_d
120	1.00_{cd}	7.01_b	5.27_c	35.1_{cd}

In order to refine root growth and improve the sandy soil's capacity to hold onto and not leach away critical nutrients, humic acid subjoins essential organic material required for water retention **(Loss *et al*., 2013)**. When humic acid was used, the production of potatoes increased. According to **Moghadam *et al*., (2014)**, humic acid helps preserve soil moisture and promote root growth. Humic acid improves root architecture, increases water-holding capacity, increases plant membrane permeability, and promotes nutrient uptake, claim **Calvo *et al*., (2014)**. Water stress tolerance is increased by all of these soil improvements.

Figure (3) presented the results of a study investigating the effects of water stress and humic acid application on the total protein content of potato tubers. The data represents a combined analysis of two growing seasons. Water-stressed plants exhibited a significant lower protein content compared to unstressed plants across all humic acid application rates. This indicates that water stress negatively impacts on protein accumulation in potato tubers. Application of humic acid at different rates (0, 60, and 120 kg ha^{-1}) did not significantly affected on protein content in either water stressed or unstressed plants. This suggests that humic acid may not have a direct impact on protein synthesis in potato tubers under the conditions studied.

Water stress can limit photosynthesis and nutrient uptake, which are essential for protein synthesis. Humic acid may have a greater impact on other yield components, such as tuber size and yield, rather than directly influencing protein content.

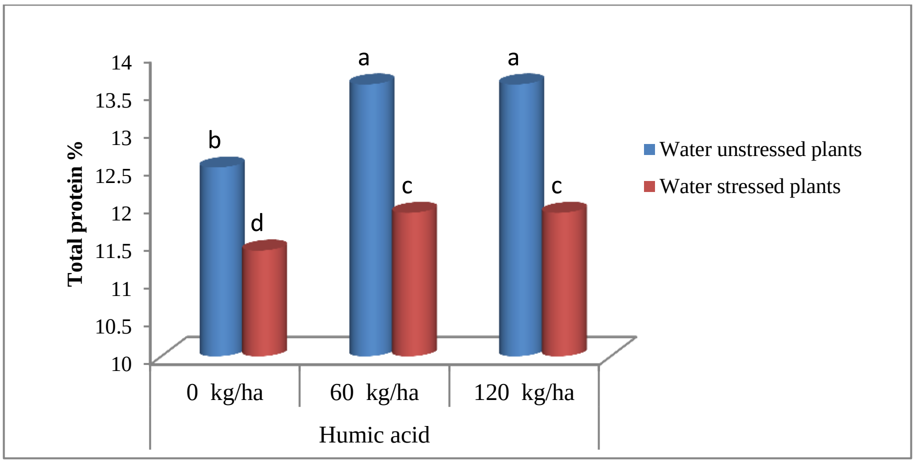


Fig. 3. Effect of water stress and humic acid rates on total protein of potato (combined analysis of two seasons).

in both water-stressed and unstressed plants. The highest starch content was observed in unstressed plants treated with 120 kg ha⁻¹ humic acid. This suggests that humic acid can enhance starch accumulation in potato tubers.

Water stress can limit photosynthesis and carbon fixation, which are essential for starch synthesis. Humic acid can enhance soil structure, increase water retention, and improve nutrient availability, all of which are beneficial for plant growth and development. This can lead to increased photosynthesis and carbon fixation, ultimately resulting in higher starch content in tubers. Humic acid may also stimulate root growth and development, leading to better nutrient and water uptake. This could contribute to increased starch synthesis.

Under drought stress, addition of humic acid led to increasing protein content of faba bean **(Naglaa *et al*., 2023).** By improving growth metrics and protein synthesis in the three maize populations, the administration of humic acid lessened the negative effects brought on by the imposed water stress (**Reinier *et al*., 2021**).

Figure (4) presented the results of a study investigating the effects of water stress and humic acid application on the starch content of potato tubers. The data represents a combined analysis of two growing seasons. Water-stressed plants exhibited significantly lower starch content compared to unstressed plants across all humic acid application rates. This indicates that water stress negatively impacts starch accumulation in potato tubers. Application of humic acid at different rates (60 and 120 kg ha⁻¹) resulted increase starch content

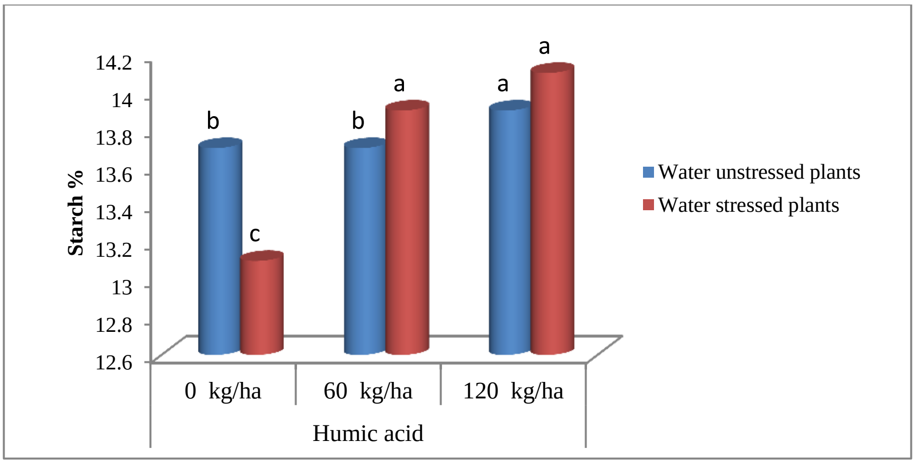


Fig. 4. Effect of water stress and humic acid rates on starch of potato (combined analysis of two seasons).

In both seasons, the average weight of the tuber, yield fed^{-1}, tuber width, and content (%) of tuber starch were all significantly impacted by the interaction between irrigation treatments and humic acid administration **(Ali *et al*., 2019)**. Humic acid compound fertilizers will increase the amount of starch in tuberous roots because they encourage the creation of tuberous roots, which are intimately related to the synthesis and accumulation of starch **(Duan *et al*., 2024)**.

Table (3) presented the statistical analysis of nutrient ratios in potato plants, comparing a low-yielding population to a high-yielding population. It aims to identify nutrient ratios that are most sensitive to yield differences and can be used to develop DRIS norms for potato nutrition. The table analyzes various nutrient ratios, including N/P, P/N, N/K, K/N, P/K, and K/P. These ratios represent the relative proportions of different nutrients in the plant tissue. Variance is a statistical measure that quantifies the dispersion of data points around the mean. Standard deviation is a measure of the variability or spread of data around the mean. The CV is a standardized measure of relative variability, calculated as the ratio of the standard deviation to the mean, expressed as a percentage. A higher CV indicates greater variability. Higher values suggest that the nutrient ratio is more variable in the low-yielding population, indicating a greater potential for using it to differentiate between yield levels. The ratios identified as being most sensitive to yield differences based on the variance ratio. These ratios are considered suitable for inclusion in DRIS norms for potato nutrition.

The table showed that several nutrient ratios exhibit significant differences in variance between the low-yielding and high-yielding populations. Notably, the ratios N/P, P/N, and K/P have high variance ratios (S^2_l/S^2_h), suggesting that these ratios are more variable in the low-yielding population compared to the high-yielding population. This variability implies that these ratios are sensitive to factors that influence yield.

The selection of these ratios for DRIS norms is based on the assumption that nutrient imbalances are more likely to occur in low-yielding plants. By monitoring these specific ratios, farmers and agronomists can identify potential nutrient deficiencies or imbalances that may be limiting yield.

Table 3. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding populations, the variance ratio ($S^2{}_l$ / S^2 h) and the selected ratios for potato DRIS norms.

Nutrients ratios	Low-yielding population			High-yielding population			$S^2{}_l$ / $S^2{}_h$	Selected ratios
	Mean	CV (%)	Variance (S^2_l)	Mean	CV (%)	Variance (S^2_h)		
N/P	11.89	0.086	1.040	11.88	0.0484	0.331	3.147	
P/N	0.085	0.082	0.00005	0.084	0.0476	0.000016	3.063	√
N/K	1.186	0.030	0.001296	0.83	0.0542	0.0020	0.640	√
K/N	0.843	0.030	0.00063	1.207	0.0547	0.0044	0.143	
P/K	0.100	0.100	0.00010	0.070	0.0714	0.000025	4.000	√
K/P	10.03	0.105	1.100	14.33	0.0641	0.845	1.303	

A common statistical method for interpreting plant tissue analysis data and accurately diagnosing plant nutrient requirements before crop production declines is the Diagnosis and Integrated Recommendation System (DRIS). It assists in concurrently detecting crop nutrient surpluses, deficiencies, and imbalances and arranges them according to priority for corrective action. Any crop, at any stage of development, can be subjected to the foliar composition-based DRIS criteria **(Savita *et al*., 2016).** The DRIS norms consist of the mean, variance and coefficient of variation of the dual ratio between nutrients (N/P, P/N, N/K, K/N, etc.) obtained from a crop reference population that shows a high yield population **(Abd El-Rheem *et al*., 2012).**

Table (4) distinguished between water-unstressed and water-stressed plants, highlighting the impact of water availability on plant nutrient status. Different application rates of humic acid (0, 60, and 120 kg ha^{-1}) were used to assess its influence on nutrient indices. The table includes individual nutrient indices for Nitrogen (N), Phosphorus (P), and Potassium (K). These indices likely represent the relative availability or uptake of these nutrients. A calculated value that reflects the overall balance of nutrients within the plant is the Nutrient Balance Index (NBI). A positive NBI generally indicates a favorable nutrient balance.

Water-stressed plants generally exhibited more extreme values for nutrient indices compared to unstressed plants. This suggests that water stress can disrupt nutrient uptake and metabolism in potato plants. Humic acid application had a mixed effect on nutrient indices. In some cases, it appeared to improve nutrient balance (e.g., higher NBI in water-stressed plants), while in others, it led to more extreme values (e.g., lower N index in water-unstressed plants). The impact of humic acid on nutrient indices varied depending on the specific nutrient and the water stress condition.

There appears to be a general trend of higher NBI values being associated with higher total yields, particularly in water-stressed plants. This suggests that maintaining a balanced nutrient status is crucial for achieving optimal potato yields under water-limited conditions. Humic acid can improve soil structure, increase water retention, and enhance nutrient availability. These effects can influence nutrient uptake by plants and subsequently affect nutrient indices and yield. Water stress can disrupt nutrient uptake and metabolism, leading to imbalances in nutrient ratios and reduced yield. Humic acid may help mitigate some of these negative effects by improving nutrient availability and plant water status.

Table 4. Effect of different rates of humic acid under water stress on nutrient indices, NBI and total yield of potato plants.

Water stress	Humic acid kg ha^{-1}	Nutrient index			NBI	Total yield Mg ha^{-1}
		N	P	K		
Water unstressed plants	0	2.075	7.594	-9.668	19.34	35.4
	60	-8.945	1.290	7.655	17.89	40.7
	120	6.432	-2.615	2.483	11.53	44.4
Water stressed plants	0	11.63	18.4	-30.03	60.06	31.7
	60	12.05	14.31	-26.36	52.72	33.6
	120	-16.54	9.095	7.44	33.07	35.1

The limiting sequence of all the nutrients may be found in the DRIS index values, which also indicate which nutrient is the most limiting **(Faquin, 2002)**. A DRIS score of zero or almost zero denotes nutritional balance, while positive and negative indices denote excess or deficiency in nutrition, respectively **(Wadt *et al*., 2012)**. Additionally, the DRIS approach shows nutrient antagonistic relationships and provides more sampling flexibility **(Gopalasundaram *et al*., 2012)**. Nutrient indices show whether nutrients are insufficient (negative indices), in excess (positive indices), or balanced (zero or near zero) **(Nissen and Redpath, 2014)**.

Table (5) presented the sufficiency ranges for three key nutrients (Nitrogen - N, Phosphorus - P, and Potassium - K) in potato tubers, derived from the Diagnosis and Recommendation Integrated System (DRIS). DRIS is a plant analysis-based method that helps interpret nutrient status in relation to plant growth and yield. The table shows separate sufficiency ranges for unstressed and stressed plants, indicating that water stress can significantly affect the optimal nutrient ranges for potato tubers. The ranges are categorized into five levels: Deficient, Low, Sufficient, High, and Exceed. Plants falling within the "Sufficient" range are considered to have an optimal balance of the respective nutrient. The optimal N range is higher in unstressed plants compared to stressed plants, suggesting that water stress may reduce the plant's ability to utilize or require less nitrogen. Similar to N, the optimal P range is lower in stressed plants. The optimal K range is also lower in stressed plants, indicating that water stress may affect K uptake or requirement.

Table 5. Sufficiency ranges of nutrients derived DRIS method of potato tubers under water stress.

Nutrients	Deficient	Low	Sufficient	High	Exceed
Unstressed plants					
N (%)	< 2.143	2.143-2.512	2.512-3.248	3.248-3.617	> 3.617
P (%)	< 0.177	0.177-0.210	0.210-0.276	0.276-0.309	> 0.309
K (%)	< 3.075	3.075-3.269	3.269-3.658	3.658-3.852	> 3.852
Stressed plants					
N (%)	< 1.844	1.844-2.114	2.114-2.653	2.653-2.922	> 2.922
P (%)	< 0.124	0.124-0.163	0.163-0.241	0.241-0.280	> 0.280
K (%)	< 1.713	1.713-1.860	1.860-2.154	2.154-2.300	> 2.300

Abd El-Rheem and Essa (2017) reported that particularly in newly reclaimed soils, the optimal or sufficient ranges of nutrients were a key sign of an ideal management fertilization program, which increased the amount and quality of produce. In addition to an ideal level for Critical Concentration, DRIS suggests five categories for the Sufficiency Ranges in leaf tissue and/or soil: deficiency, tendency to deficiency, sufficient, inclination to excess, and excess. For nutrition diagnosis, the Sufficiency Ranges and the Critical Concentration are both trustworthy tools that allow for the creation of programs that are both environmentally sustainable and economically viable. The likelihood of a reaction to fertilizer administration is determined using DRIS indices **(Herrera, 2015)**.

Conclusion

It was found that adding humic acid to the soil significantly improved the yield, both quantitatively and qualitatively, of potatoes under water stress conditions. These findings are particularly relevant in the context of climate change, where drought stress is becoming more frequent and severe. The use of humic acid as a soil amendment offers a promising strategy to enhance potato productivity and nutritional status under water-limited conditions, contributing to climate-resilient agricultural practices.

This paper can be used as a guide for interpreting plant tissue analysis results for potato. By comparing the nutrient concentrations in potato leaves or stems to the appropriate sufficiency ranges, growers can assess the nutritional status of their plants and identify potential nutrient deficiencies or imbalances. The information can then be used to make informed decisions about fertilizer application, irrigation management, and other cultural practices to optimize yield and quality. The DRIS ranges presented in this paper are specific to the conditions and populations studied. They may not be directly applicable to all potato cultivars, growing environments, and management practices. The DRIS method relies on accurate and representative plant tissue sampling and analysis. Other factors, such as soil type, climate, and pest and disease pressure, can also influence nutrient requirements and plant performance.

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