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IMPACT OF HUMIC ACID AND NITROGEN FERTILIZATION TREATMENTS ON PRODUCTIVITY AND GRAIN QUALITY OF SOME BARLEY VARIETIES

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ABSTRACT

Field experiment was carried out at a private farm in Abu-Hammad District, Sharqia Governorate, Egypt, during two successive winter seasons of 2018/2019, 2019/2020. The study aims at evaluating humic acid application and nitrogen fertilization treatments *viz*., control, nitrogen foliar application (4%), 30 kg N fad^{-1}, 30 kg N fad^{-1} + N foliar application (4%) and 60 kg N fad^{-1} on productivity, grain quality and nitrogen use efficiency (NUE) of three barley varieties. In addition, the yield analysis of the three barley varieties *viz*., Giza129, Giza131 and Giza135 was investigated. Humic acid application enhanced barley productivity, quality and NUE. Giza131 surpassed the other two varieties in grain yield, some components and NUE in both seasons except protein content. Raising N level up to 60 kg Nfad^{-1} had a significant impact on all studied traits compared with control treatment, except NUE. Co-application of 30 kg N fad^{-1}+N foliar application improved barley yield, most of its attributes, grain quality and NUE, which reflect the efficacy of N foliar application in fulfilling barley nitrogen requirements with the soil N applications. Additionally, path analysis indicated that: the grain number spike^{-1} had the highest direct effect on the grain yield among the varieties Giza129 and Giza131, the highest indirect effects on grain yield were assigned for grain weight spike^{-1} and spike number m^{-2}, while spike number - m^{-2} had the greatest direct effect on the yield of Giza135, which demonstrates the importance of these traits in improving barley grain yield.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the ancient cereal crops in the world, especially in Mediterranean region (**Moustafa *et al*., 2021**). It ranked fourth in acreage and production after wheat, maize and rice (**FAOSTAT 2021**). It is widely cultivated in arid and semiarid regions (**Jarošová *et al*., 2016**). Moreover, it can grow in marginal environments which are unfavorable for other cereals (**Moustafa *et al*., 2021**). Barley grains are used for human food and livestock feed and malting process. In addition, barley straw is used as roughage for animals **(Wali *et al*., 2018**). Increasing barley productivity could be attained by cultivating high-yielding cultivars and implement recommended cultural practices especially fertilization.

Nitrogen (N) is essential factor for high yielding because of its role in building plant canopy and promoting yield formation **(Hawkesford, 2014; Ladha *et al*., 2016)**. Globally, N demand is predicted to increase by about 6.13% in 2022 compared to N demand in 2016 **(Randive *et al*., 2021)**. Farmers around the world use high levels of nitrogen fertilizers to produce high yields **(Mansour *et al*., 2017**; **Omara *et al*., 2019**). Application of nitrogen fertilizer may decrease grain yield by increasing the chances of lodging occurrence and incidence of disease **(López-Bellido *et al*., 2006).**

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Furthermore, over-application of nitrogenous fertilizers is associated with the increase in nitrogen losses which may cause negative environmental influences (**Bingham *et al.*, 2012; Hawkesford, 2014; Tabak *et al.*, 2020)**, and decrease nitrogen use efficiency **(Omara *et al.*, 2019)**.

Moreover, cereals require nitrogen for synthesizing proteins stored in grains (**Hawkesford, 2014**). Many investigations indicated that increasing nitrogen fertilizer levels significantly enhanced barley productivity and quality, particularly under soil nitrogen limitations **(Zeidan, 2007; Bingham *et al.*, 2012; Wali *et al.*, 2018**). Varietal differences were observed among barely varieties and genotypes in their response to nitrogen level and nitrogen use efficiency **(Zeidan, 2007; Bingham *et al.*, 2012; Noworolnik *et al.*, 2014).** Enhancing nitrogen use efficiency is important for both food production and the environment **(Omara *et al.*, 2019).** Nitrogen foliar application (NFA) promotes nitrogen utilization than soil application. Foliar urea application is an efficient method of N fertilization in cereal crops (**Barut, 2019**). **(Saleem *et al.*, 2013)** pronounced that under limitation of N supply, urea foliar application can integrate with the soil application of N to fulfill wheat requirements of N. The recommended concentration of urea solution for foliar application on wheat ranged between 1-5% **(Khan *et al.*, 2009; Saleem *et al.*, 2013; Wagan *et al.*, 2017). (Bingham *et al.*, 2012)** pronounced that increasing nitrogen use efficiency of cereal crops can be achieved by nitrogen management strategies, producing high nitrogen use efficiency varieties by plant breeding, and increasing crop productivity.

Humic acid is one of the humic substances which are a major component of soil organic matter (**Jarošová *et al.*, 2016**). Humic acid is water-soluble at alkaline pH **(Pignatello,1998; Pettit, 2004)**. Humic acid improved soil physical and chemical properties and improved fertilizers use efficiency in addition to improving plant growth **(Fahramand *et al.*, 2014; Li, 2020)**. The efficacy of humic acid in promoting plant growth and productivity may be attributed to its influence on enzyme activities, photosynthesis, water absorption, nutrient uptake, and protein synthesis **(Fahramand *et al.*, 2014; Belal *et al.*, 2019). Zancani *et al.* (2009)** resolved that humic acid promotes plant growth by chelating unavailable nutrients and buffering pH. Many investigators revealed its role in increasing crop productivity such as **(Delfine *et al.*, 2005; Sarir *et al.*, 2005; Khan *et al.*, 2018; Wali *et al.*, 2018; Belal *et al.*, 2019; Dulaimy and El Fahdawi, 2020)**. Moreover, humic acid alleviates the deleterious effects of salinity and water stress **(Çavuşoğlu and Ergin, 2015; Jarošová *et al.*, 2016; Hatami, 2017; Bijanzadeh *et al.*, 2019; Shen *et al.*, 2020)**. Humic acid has a positive role in the rationalization of fertilizers amount used, without a significant decrease in crop yield **(Asal *et al.*, 2015**). Humic acid application could be effective as a foliar application or soil supply or pre-sowing seed treatment **(Çavuşoğlu and Ergin, 2015; Wali *et al.*, 2018; Dulaimy and El Fahdawi, 2020)**.

The investigation aims to (1) evaluate the influence of humic acid application and nitrogen fertilization treatments on productivity and grain quality of three barley varieties, (2) study the possibility of partial replacement of soil nitrogen supply by nitrogen foliar application to rationalize fertilizer consumption without significant reduction in barley yield and grain quality and (3) study the yield performance analysis of the three barley varieties.

MATERIALS AND METHODS

Experimental Site

A field experiment was carried out at Abu-Hammad District, Sharkia Governorate, Egypt (30°32′ N, 31°36′ E), during winter seasons of 2018-2019 and 2019-2020.The field experiment investigated the influence of humic acid application and nitrogen fertilization treatments *viz.*, control (without suppling nitrogen), N foliar application (4%), 30 kg N fad^{-1}, 30 kg N fad^{-1} + N foliar application (4%) and 60 kg N fad^{-1} (as the recommended nitrogen level) on productivity and grain quality of three barley varieties *viz.*, Giza 129, Giza 131 and Giza 135. In addition, the yield analysis of the three barley varieties was performed using principal component analysis, as well simple correlation and path analysis were calculated.

Weather data of the experimental site during the two growing seasons of 2018-2019 and 2019-2020 were listed in Table 1. Accordingly, the weather in the experiment region is arid, with total annual precipitations less than 20 mm during the period from November to April. Table 2 shows that the experimental field soil was sandy clay in texture with low available nitrogen content.

Experimental Design and Treatments

Split-split plot experiment in randomized complete block design with three replicates was perfected in both seasons, the foliar application of humic acid (1g L^{-1}) along with control were assigned to main plots, the sub plots were devoted to the three six-rowed naked barley varieties *viz.* Giza 129, Giza 131 and Giza 135, while five nitrogen fertilization treatments were randomly distributed in the sub-sub plots as follows: control (without nitrogen), N foliar application in form of urea solution (4%), 30 kg N fad^{-1}, 30 kg N fad^{-1} + N foliar application and 60 kg N fad^{-1} (the recommended nitrogen level).

The sub-sub plot area was 10.5 m^2 (1/400 faddan), 3.5 × 3 m long and wide. Humic acid foliar application was performed thrice after 30, 60 and 90 days after sowing (DAS), while N foliar application was performed after 25, 55 and 85 DAS. The foliar application treatments were performed using a hand-operated compressed air sprayer. The volume of spraying solution per sub-sub plot was almost 4, 5 and 6 liters for first, second and third application times, respectively. The soil nitrogen fertilization levels were applied in three splits *i.e.*, 25%, 50% and 25% after 25, 55 and 85 DAS, in respective order, as granular ammonium sulfate (20.6% N).

Crop Management

Barley seeds were sown in rows, 15 apart cm on 24th November in both seasons using a seeding rate of 300 seeds m^{-2}. The preceding crop was maize (*Zea mays* L.) in both seasons. Surface irrigation system was applied. The other agronomic practices were performed as recommended for barley. The tested varieties differed in the date of maturity, as variety Giza 129 was earlier in maturity than the other two varieties. Therefore, the harvest was done at two different dates. Giza 129 was harvested during 1st week of April, while the other varieties were harvested during 3rd week of April in both seasons.

Field Measurements

At harvest, ten productive tillers were randomly selected from each experimental plot to estimate: plant height (cm), spike length (cm), grain number $spike^{-1}$, grain weight $spike^{-1}$ (g). Three random samples of dried grains were taken from each plot to estimate the average of 1000- grain weight (g). All plants in one guarded square meter were harvested from each experimental plot to measure spike number m^{-2}, grain and straw yields (kg m^{-2}) then converted into fad. Harvest index (%) was calculated as follows ((grain yield ÷ biological yield) ×100)) according to **Abdel-Gawad *et al.* (1987)**. Nitrogen use efficiency (NUE) was calculated according to Fageria (2013) as follows:

Table 1. Weather data of the experimental site during barley growing seasons of 2018-2019 and 2019-2020

Month	2018–2019				2019–2020			
	Maximum temperature	Minimum temperature	Relative humidity	Total precipitation	Maximum temperature	Minimum temperature	Relative humidity	Total precipitation
November	25.46	15.70	44.57	3.00	26.72	14.16	42.65	2.00
December	21.12	10.90	47.93	3.00	20.41	12.38	55.98	4.00
January	19.41	7.74	59.28	6.90	16.96	9.58	58.77	8.00
February	20.39	11.50	55.55	3.01	20.66	12.00	62.27	4.50
March	26.61	13.58	53.13	2.00	24.55	13.70	54.39	1.10
April	28.50	12.63	48.52	1.00	27.13	12.73	41.04	0.35

Table 2. The experimental field soil characters (averaged over the two growing seasons of 2018-2019 and 2019-2020).

Soil depth (cm)	Soil particle distribution			Textural class	Field capacity (%)	Wilting point (%)	Bulk density (g cm^{-3})	Calcium carbonate (%)	Organic matter (%)	pH (Suspension of 1:2.5 soil: water)	EC (dS m^{-1})
	Sand (%)	Silt (%)	Clay (%)								
0–30	48.23	13.87	37.90	Sandy clay	13.51	6.75	1.47	0.42	0.47	7.95	1.63
30–60	47.95	14.03	38.02	Sandy clay	12.23	6.11	1.52	0.40	0.35	7.91	1.60
60–90	48.19	13.81	38.00	Sandy clay	12.10	6.05	1.53	0.40	0.30	7.80	1.56
Soil depth (cm)	Soluble cations and anions in the soil paste extract (mmolc L^{-1})								Available nutrient (mg kg^{-1} Soil)		
	Calcium	Sodium	Magnesium	Potassium	Carbonate	Bicarbonate	Chloride	Sulphate	Nitrogen	Phosphorus	Potassium
0–30	5.52	3.12	4.77	2.89	0	6.57	4.04	5.69	20.46	11.31	167.5
30–60	5.57	3.08	4.43	2.92	0	6.25	4.99	4.76	16.76	9.27	154.5
60–90	5.43	3.10	4.31	2.77	0	6.10	4.89	4.62	15.57	8.82	141.2

(grain yield ÷ (soil available N + applied N as fertilizer)). The soil available N was calculated in 90 cm depth.

A random pure sample of dried grains was collected from each plot to estimate grain protein and carbohydrate contents (%). Grain nitrogen content (%) was estimated using the modified Kjeldahel method according to **Helrich (1990)** then grain protein content was calculated by multiplying grain nitrogen content by 5.9. Grain carbohydrate content (%) was determined according to **Dubois *et al.*, (1956**).

Statistical Analysis

The collected data was subjected to split split-plot analysis as described by **Snedecor and Cochran (1967)**. Duncan's multiple range test was performed to compare treatments means by **Waller and Duncan (1969),** where means denoted with different letters are significantly differed. The yield performance of the three barley varieties was evaluated by principal component analysis, phenotypic correlation coefficients according to **Kwon and Torrie (1964)** and path analysis among yield and yield components according to **Dewey and Lu (1959)**.

RESULTS

Humic Acid Application

Humic acid application enhanced all investigated traits in both seasons, except spike length and harvest index (Tables 3, 4 and 5).

Varietal differences

Results obtained from Tables 3,4 and 5 show that Giza 131 surpassed the other two varieties in plant height, spike length, grain weight spike^{-1}, grain number spike^{-1}, 1000-grain weight, grain yield, and NUE in both seasons. However, Giza131 grains had the lowest protein content compared to Giza129 and Giza135 which achieved best values in both seasons. Giza 135 exceeded Giza129 in spike length and grain weight spike^{-1}in both seasons. The varietal differences did not reach the level of significance at 0.05 for spike number m^{-2}, straw yield, harvest index, and grain carbohydrate content in both seasons.

Nitrogen fertilization treatments

Nitrogen fertilization treatments had a significant influence on all studied traits compared with control treatment (Tables 3, 4 and 5). Suppling of the recommended nitrogen level *i.e.,* 60 kg N fad^{-1} increased all studied traits, except NUE which decreased. Partial replacement of N level by N foliar application (NFA) in 30 kg N fad^{-1} + N foliar application treatment failed to give the same statistical values for all traits compared to the addition of the recommended nitrogen level except carbohydrate content (%) in the first season, the rate of increase in the grain yield was about 12.58% and 16.32% for the 1st and 2nd seasons, respectively compared to the treatment of 30 kg of N fad^{-1} + NFA. Co-application of 30 kg N fad^{-1} + N foliar application improved all traits and ranked second in both seasons, except harvest index in the first season compared to the sole application of 30 kg N fad^{-1}. The increment valued as much as 6.22 and 6.60% for grain yield (kg fad^{-1}), 9.23 and 9.74% for straw yield (tonne fad^{-1}), 21.52 and 17.51% for grain protein content as well as 9.18 and 4.80% for grain carbohydrate content (%) in the first and second seasons, respectively.

Compared to sole N foliar application treatment, the addition of 30 kg N fad^{-1} increased grain weight spike^{-1}, grain number spike^{-1}and grain yield in both seasons as well as straw yield and grain carbohydrate content in the first season and 1000-grain weight in the second season. Compared to N foliar application treatment, increasing nitrogen fertilization level decreased NUE.

Table 3. Impact of humic acid application and nitrogen fertilization treatments on plant height, spike length, grain weight spike^{-1} and grain number spike^{-1} of three barley varieties during two successive winter seasons of 2018-2019 and 2019-2020

Main effects and interactions	Plant height (cm)		Spike length (cm)		Grain weight spike^{-1} (g)		Grain number spike^{-1}	
	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	2019-2020
Humic acid application (H):								
Without humic acid (control)	117.87	121.09	17.14	17.09	2.14	1.94	45.02	44.28
Humic acid	124.64	127.16	17.64	17.64	2.29	2.14	47.32	46.84
F. test	*	*	NS	NS	*	*	*	*
Barley varieties (V):								
Giza 129	124.40 a	125.43 a	16.76 c	16.83 c	2.04 c	1.88 c	45.16 b	45.15 b
Giza 131	125.06 a	127.38 a	18.30 a	18.05 a	2.37 a	2.16 a	47.49 a	46.38 a
Giza 135	114.30 b	119.56 b	17.11 b	17.22 b	2.24 b	2.08 b	45.86 b	45.15 b
F. test	*	*	*	*	*	*	*	*
Nitrogen fertilization treatments (F):								
Control(without supplying nitrogen)	103.18 d	103.43 d	15.03 d	14.97 d	1.90 e	1.43 e	41.19 e	40.24 e
NFA (4%) †	120.22 c	124.02 c	17.12 c	17.27 c	2.00 d	1.62 d	43.51 d	43.11 d
30 kg N fad^{-1}	120.82 c	124.76 c	17.69 bc	17.28 c	2.16 c	2.22 c	46.28 c	45.36 c
30 kg N fad^{-1}+ NFA (4%)	129.33 b	132.13 b	18.22 b	18.33 b	2.41 b	2.40 b	48.19 b	47.75 b
60 kg N/fad	132.71 a	136.28 a	18.89 a	18.98 a	2.60 a	2.53 a	51.68 a	51.38 a
F. test	*	*	*	*	*	*	*	*
Interaction								
H×V	NS	NS	NS	NS	NS	NS	NS	*
H×F	*	*	*	*	*	*	*	*
V×F	*	*	NS	NS	*	*	*	*
H×V×F	NS	NS	NS	NS	NS	*	NS	NS

†NFA is N foliar application (4%).

Means followed by different letters at the same factor differ significantly by LSD (P <0.05).

Table 4. Impact of humic acid application and nitrogen fertilization treatments on 1000-grain weight, spike number m-^{2}, grain yield, and straw yield of three barley varieties during two successive winter seasons of 2018-2019 and 2019-2020

Main effects and interactions	1000-grain weight (g)		Spike number m^{-2}		Grain yield (kg fad^{-1})		Straw yield (tonne fad^{-1})	
	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	2019-2020
Humic acid application (H)								
Without humic acid(control)	42.51	43.10	361.21	369.27	2143.2	2142.9	4.47	4.16
Humic acid	43.90	43.72	374.48	385.75	2282.4	2250.9	4.65	4.42
F. test	*	*	*	*	*	*	*	*
Barley varieties (V)								
Giza 129	42.38 b	41.75 b	365.06	377.03	2150.3 b	2121.7 b	4.50	4.26
Giza 131	44.74 a	45.41 a	366.35	378.92	2309.7 a	2318.3 a	4.55	4.41
Giza 135	42.49 b	43.08 b	372.12	376.58	2178.4 b	2150.6 b	4.63	4.20
F. test	*	*	NS	NS	*	*	NS	NS
Nitrogen fertilization treatments (F)								
Control (without supplying nitrogen)	35.91 d	38.02 e	328.35 d	339.14 d	1640.0 e	1706.5 e	3.62 e	3.56 d
NFA (4%) †	43.17 c	41.73 d	357.51 c	365.89 c	2106.4 d	2079.5 d	4.26 d	4.15 c
30 kg N fad^{-1}	44.22 c	43.53 c	364.47 c	370.88 c	2246.1 c	2177.4 c	4.55 c	4.21 c
30 kg N fad^{-1}+ NFA (4%)	45.37 b	45.76 b	385.13 b	399.89 b	2385.7 b	2321.1 b	4.97 b	4.62 b
60 kg N fad^{-1}	47.37 a	48.02 a	403.77 a	411.75 a	2685.9 a	2699.8 a	5.41 a	4.94 a
F. test	*	*	*	*	*	*	*	*
Interaction								
H×V	NS	*	NS	NS	NS	NS	NS	*
H×F	*	*	*	*	*	*	NS	NS
V×F	NS	NS	*	*	*	*	NS	NS
H×V×F	NS	NS	NS	NS	NS	NS	NS	NS

†NFA is N foliar application (4%).

Means followed by different letters at the same factor differ significantly by LSD ($P < 0.05$).

Table 5. Impact of humic acid application and nitrogen fertilization treatments on harvest index, grain protein content, carbohydrate content and NUE of three barley varieties during two successive winter seasons of 2018-2019 and 2019-2020

Main effects and interactions	Harvest index (%)		Grain protein content (%)		Grain carbohydrate content (%)		NUE (kg kg^{-1})	
	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	2019-2020
Humic acid application (H)								
Without humic acid (control)	32.34	33.88	9.19	8.74	47.56	49.78	37.52	37.73
Humic acid	32.93	33.56	9.50	9.25	49.06	51.14	40.11	39.69
F. test	NS	NS	*	*	*	*	*	*
Barley varieties (V)								
Giza 129	32.12	33.08	9.73 a	9.25 a	47.76	49.91	37.30 c	37.22 b
Giza 131	33.74	34.39	8.81 b	8.68 b	49.12	50.93	40.83 a	41.12 a
Giza 135	32.05	33.69	9.50 a	9.06 a	48.04	50.53	38.31 b	37.80 b
F. test	NS	NS	*	*	NS	NS	*	*
Nitrogen fertilization treatments (F)								
Control (without supplying nitrogen)	31.18 b	32.47 c	7.53 e	7.29 e	44.34 c	44.41 d	47.84 b	49.78 a
NFA (4%) †	33.22 a	33.35 b	9.49 c	9.25 c	48.35 c	51.01 c	49.82 a	49.18 a
30 kg N fad^{-1}	33.15 a	34.03 b	8.27 d	8.28 d	46.21 b	50.23 c	34.94 c	33.87 b
30 kg N fad^{-1}+ NFA (4%)	32.44 ab	33.44 b	10.05 b	9.73 b	50.45 a	52.64 b	33.00 d	32.11 c
60 kg N fad^{-1}	33.19 a	35.31 a	11.39 a	10.44 a	52.18 a	53.98 a	28.48 e	28.63 d
F. test	*	*	*	*	*	*	*	*
Interaction								
H×V	NS	NS	*	*	*	*	*	*
H×F	NS	NS	*	*	NS	*	*	*
V×F	NS	NS	*	*	NS	NS	NS	*
H×V×F	NS	NS	NS	NS	NS	NS	NS	NS

†NFA is N foliar application (4%).

Means followed by different letters at the same factor differ significantly by LSD (P <0.05).

Interactions

The interaction effect between humic acid application and barley varieties was significant on grain protein content, carbohydrate content and NUE (Table 6). Humic acid application enriched grain protein and carbohydrate content in all varieties. In addition, it enhanced NUE in Giza 129 and Giza 131 compared to non-addition of humic acid (control treatment). On contrary it decreased NUE in Giza 135. Giza 131 had the lowest grain protein content under addition and/or non-addition of humic acid. No significant differences were observed in grain carbohydrate content among the tested barley varieties under humic acid application, which reflect the efficacy of humic acid application in enriching grain carbohydrate content.

Table 7 shows the significant interaction impact between humic acid application and nitrogen fertilization treatments (H×F) on plant height, spike length, grain weight spike^{-1}, grain number spike^{-1}, spike number m^{-2}, grain yield fad^{-1}, grain protein content, and NUE. In most cases, humic acid application improved grain weight spike^{-1}, grain number spike^{-1}, grain yield/ fad, grain protein content and NUE under all fertilization treatments. Moreover, humic acid application increased spike length and spike number m^{-2} under control (without N fertilizer addition) and N foliar application. With or without humic acid application, nitrogen fertilization treatments increased plant height, spike length, grain weight spike^{-1}, grain number spike^{-1}, spike number m^{-2}, grain yield fad^{-1}, grain protein content compared with treatments without supplying nitrogen. Addition of 60 kg N fad^{-1} ranked first, while 30 kg N fad.$^{-1}$ + N foliar application treatment ranked second and followed by the addition of sole 30kg N fad^{-1} in the third rank with or without humic acid application. No significant differences were observed between sole 30 kg N fad^{-1} treatment and N foliar application (NFA) treatment in plant height under non-addition of humic acid as well as in plant height, spike length under humic acid application. With the exception of control treatment which treated with humic acid, N foliar application increased NUE compared with other nitrogen fertilization treatments.

The significant interaction between barley varieties and nitrogen fertilization treatments (V×F) was listed in Table 8. Generally, Giza 131 variety exceeded the other two varieties in grain yield and NUE under all nitrogen fertilization treatments. On the contrary, Giza 131 grains contained the lowest protein content compared with the other varieties under all fertilization treatments. In general, Giza 129 produced the lightest grain weight spike^{-1} compared with Giza 131 and Giza 135 under all fertilization treatments. Compared to N foliar application treatment, increasing nitrogen fertilization level decreased NUE in all tested varieties. The triple interaction was insignificant for all traits studied.

Yield Performance for the Three Barley Varieties

Principal component analysis

Principal component analysis (PCA) revealed the relationship among the measured traits in each variety as shown in Fig. 1.

The PCA consists of two components, the first (PC1) is related to humic acid application and the second (PC2) is related to nitrogen fertilization treatments. In PCA, the traits are presented by vectors. The more adjacent vectors the more related traits. The increased angle between vectors reveals a weak relationship. In the case of opposite vectors, a negative relationship found between traits.

Generally, a positive correlation was found among grain yield and the other measured traits in each of the three tested varieties, except NUE. A negative relationship was found between grain yield and NUE in the tested varieties.

Table 6. Impact of humic acid application on grain protein content, carbohydrate content and NUE of three barley varieties over the two growing seasons of 2018-2019 and 2019-2020

Humic acid application	Varieties	Grain protein content (%)	Grain carbohydrate content (%)	NUE ($kg\ kg^{-1}$)
Without Humic acid(control)	Giza 129	9.22 ^{bc}	47.95 ^{c}	36.25 ^{d}
	Giza 131	8.58 ^{e}	49.69 ^{b}	36.59 ^{d}
	Giza 135	9.10 ^{cd}	48.36 ^{c}	41.91 ^{a}
Humic acid	Giza 129	9.76 ^{a}	49.72 ^{ab}	40.04 ^{b}
	Giza 131	8.91 ^{d}	50.36 ^{a}	38.27 ^{c}
	Giza 135	9.46 ^{b}	50.21 ^{ab}	39.52 ^{b}

Table 7. Interaction effect between humic acid application and nitrogen fertilization treatments (H×F) on barley plant height, spike length, grain weight spike^{-1}, grain number spike^{-1}, spike number m^{-2}, grain yield, grain protein content and NUE (over the two growing seasons of 2018-2019 and 2019-2020)

Humic acid application(H)	Nitrogen fertilization treatment (F)	Plant height (cm)	Spike length (cm)	Grain weight spike^{-1} (g)	Grain number spike^{-1}
Without Humic acid (control)	Control	92.01 ^{g}	14.31 ^{f}	1.54 ^{f}	40.22 ^{g}
	NFA (4%) †	120.64 ^{e}	16.73 ^{d}	1.77 ^{e}	42.79 ^{f}
	30 kg N fad^{-1}	121.46 ^{e}	17.38 ^{c}	2.08 ^{d}	44.06 ^{e}
	30 kg N fad^{-1}+ NFA (4%)	129.14 ^{c}	18.23 ^{b}	2.30 ^{c}	46.49 ^{d}
	60 kg N fad^{-1}	134.13 ^{ab}	18.93 ^{a}	2.50 ^{b}	49.69 ^{b}
Humic acid	Control	114.61 ^{f}	15.68 ^{e}	1.79 ^{e}	41.23 ^{g}
	NFA (4%) †	123.6 ^{d}	17.67 ^{c}	1.86 ^{e}	43.82 ^{e}
	30 kg N fad^{-1}	124.12 ^{d}	17.58 ^{c}	2.30 ^{c}	47.58 ^{c}
	30 kg N fad^{-1}+ NFA (4%)	132.31 ^{b}	18.32 ^{b}	2.51 ^{b}	49.45 ^{b}
	60 kg N fad^{-1}	134.86 ^{a}	18.93 ^{a}	2.63 ^{a}	53.32 ^{a}
Humic acid application(H)	**Nitrogen fertilization treatment(F)**	**Spike number m^{-2}**	**Grain yield (kg fad^{-1})**	**Grain protein content (%)**	**NUE (kg kg^{-1})**
Without Humic acid (control)	Control	313.18 ^{f}	1610.4 ^{h}	7.07 ^{g}	46.97 ^{c}
	NFA (4%) †	354.07 ^{e}	2040.6 ^{f}	9.08 ^{d}	48.26 ^{b}
	30 kg N fad^{-1}	364.6 ^{d}	2139.6 ^{e}	8.15 ^{e}	33.28 ^{e}
	30 kg N fad^{-1}+ NFA (4%)	389.61 ^{c}	2291.2 ^{d}	9.76 ^{bc}	31.69 ^{f}
	60 kg N fad^{-1}	404.74 ^{ab}	2633.5 ^{b}	10.78 ^{a}	27.93 ^{h}
Humic acid	Control	354.31 ^{e}	1736.1 ^{g}	7.75 ^{f}	50.64 ^{a}
	NFA (4%) †	369.33 ^{d}	2145.2 ^{e}	9.66 ^{c}	50.73 ^{a}
	30 kg N fad^{-1}	370.75 ^{d}	2284.0 ^{d}	8.40 ^{e}	35.53 ^{d}
	30 kg N fad^{-1}+ NFA (4%)	395.41 ^{bc}	2415.6 ^{c}	10.02 ^{bc}	33.42 ^{e}
	60 kg N fad^{-1}	410.77 ^{a}	2752.2 ^{a}	11.05 ^{a}	29.19 ^{g}

†NFA is N foliar application (4%).

Table 8. Interaction effect between barley varieties and nitrogen fertilization treatments (V × F) on plant height, grain weight spike^{-1}, grain number spike^{-1}, grain yield, grain protein content and NUE (over the two growing seasons of 2018-2019 and 2019-2020).

Variety (V)	Nitrogen fertilization treatment (F)	Plant height (cm)	Grain weight spike^{-1} (g)	Grain number spike^{-1}	Grain yield (kg fad^{-1})	Grain protein content (%)	NUE (kg kg^{-1})
Giza 129	Control	105.82 g	1.53 j	38.68 l	1547.9 i	7.47 h	45.15 e
	NFA (4%) †	126.39 de	1.65 i	42.23 jk	2016.4 g	9.83 c	47.69 d
	30 kg N fad^{-1}	126.80 de	2.04 f	45.59 gh	2141.1 ef	8.51 f	33.30 g
	30 kg N fad^{-1}+ NFA (4%)	131.17 c	2.23 e	48.75 cd	2296.5 d	10.25 b	31.77 h
	60 kg N fad^{-1}	134.38 b	2.35 de	50.52 b	2678.2 ab	11.39 a	28.4 ij
Giza 131	Control	100.32 h	1.84 h	42.26 jk	1843.1 h	6.96 i	53.76 a
	NFA (4%)	127.06 de	1.97 fg	44.28 hi	2191.2 ef	8.91 e	51.82 b
	30 kg N fad^{-1}	129.40 cd	2.3 e	46.38 fg	2304.8 d	7.95 g	35.85 f
	30 kg N fad^{-1}+ NFA (4%)	135.93 ab	2.5 bc	47.74 de	2465.3 c	9.57 d	34.10 g
	60 kg N fad^{-1}	138.40 a	2.71 a	54.03 a	2765.7 a	10.33 b	29.33 i
Giza 135	Control	103.77 g	1.63 i	41.21 k	1628.8 i	7.80 gh	47.51 d
	NFA (4%)	112.91 f	1.82 h	43.42 ij	2071.2 g	9.37 d	48.98 c
	30 kg N fad^{-1}	112.17 f	2.24 e	45.49 gh	2189.5 e	8.38 f	34.06 g
	30 kg N fad^{-1}+ NFA (4%)	125.08 e	2.48 cd	47.42 ef	2298.4 d	9.84 c	31.79 h
	60 kg N fad^{-1}	130.70 c	2.63 ab	49.97 bc	2634.6 b	11.02 a	27.94 j

†NFA is N foliar application (4%).

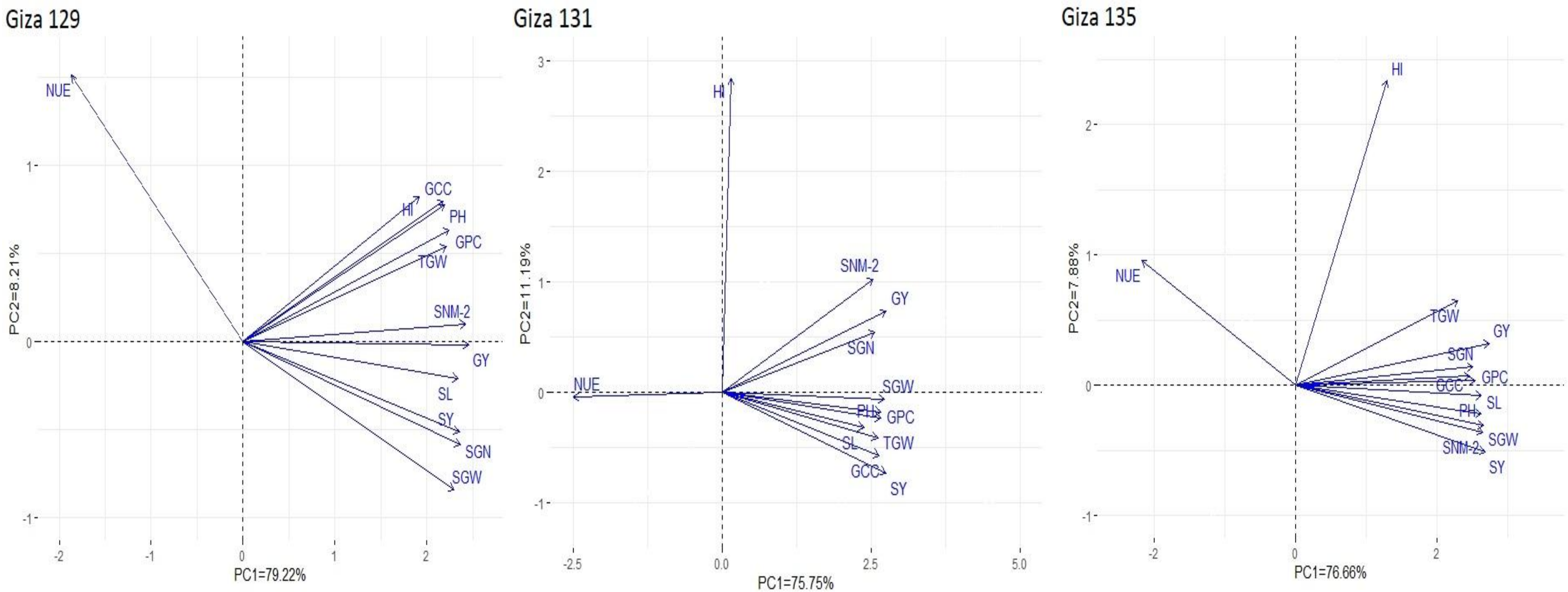


Fig. 1. Principal component analysis biplot for the studied measurements of three barley varieties (Giza 129, Giza 131 and Giza 135) which influenced by humic acid application and fertilization treatments over the two growing seasons of 2018-2019 and 2019-2020, where PH is plant height, SL is spike length, SGW is spike grain weight , SGN is spike grain number spike^{-1}, TGW is 1000-grain weight, SNM-2 is spike number m^{-2}, Gy is grain yield, Sy is straw yield, HI is harvest index, GPC is grain protein content, GCC is grain carbohydrate content and NUE is nitrogen use efficiency.

In Giza 129 variety, the PC1 expounded 79.22% of the variations, while the PC2 displayed 8.21%. The most related yield component to Giza 129 grain yield was spike number m^{-2}.

The PC1 explicated 75.75% of the variability and the PC2 exposed 11.19% of the variations in Giza 131. Giza 131 grain yield was more correlated with grain number $spike^{-1,}$ and spike number m^{-2}. Regarding barley variety Giza 135, the PC1 expounded 76.66% of the variations; meanwhile, the PC2 explicated 7.88% of variability. Grain yield of Giza 135 variety was more related to grain number spike $^{-1}$ and 1000-grain weight as the most associated yield

Path coefficient analysis

The partitioning of simple correlation coefficient into direct and indirect effects of studied traits (spike grain weight (SGW), 1000-grain weight (TGW), spike grain number (SGN) and spike number m^{-2} (SNM^{-2}) between grain yield and its components, for three barley varieties (Giza129, Giza 131 and Giza135) are listed in Table 9 and Figs. 2, 3 and 4.

All studied traits for the three varieties presented positive direct effect on grain yield except spike grain weight (SGW) for Giza 129, which had a negative effect (-0.0733). Each of spike grain number (SGN) exhibited the highest positive direct effect on grain yield (0.4585, 0.5543 and 0.2397 for Giza 129, Giza 131 and Giza135, respectively). Also, spike number m^{-2} (SNM^2) exhibited the highest positive direct effect on grain yield (0.4093 and 0.4763 for Giza 129 and Giza135, respectively). Furthermore, the correlation coefficients between these traits and grain yield were positive and highly significant for the three varieties. The previous results confirm the effectiveness of direct selection of these traits for achieving high grain yield.

The highest indirect effects on grain yield were assigned for each of spike grain weight (0.4119 and 0.5033), spike number m^{-2} (0.3496 and 0.4904) and 1000-grain weight (0.3096 and 0.4072) through spike grain number for Giza 129 and Giza 131, respectively, also spike grain weight *via* spike number m^{-2} (0.3384) for Giza 129. While the highest indirect effects on grain yield were assigned for each of spike grain weight (0.3866), 1000-grain weight (0.3072) and spike grain number (0.3809) *via* spike number m^{-2} for Giza 135.

It can be noticed that spike grain weight SGW, spike grain number SGN, spike number m^{-2} (SNM^{-2}),1000-grain weight (TGW) and their interaction played an important role in barley grain yield fad^{-1} determination, since they made the most notable direct or indirect effects estimated by 90.75%, 93.35% and 90.36% for Giza 129, Giza131 and Giza 135, respectively. This indicates that direct and indirect selection through these traits is very useful for developing high yielding. These results are in agreement with **Khan and Dar (2010), Janmohammadi *et al*. (2014), Bhutto *et al.* (2016)** as well as **Ebrahimnejad and Ramech (2016)**.

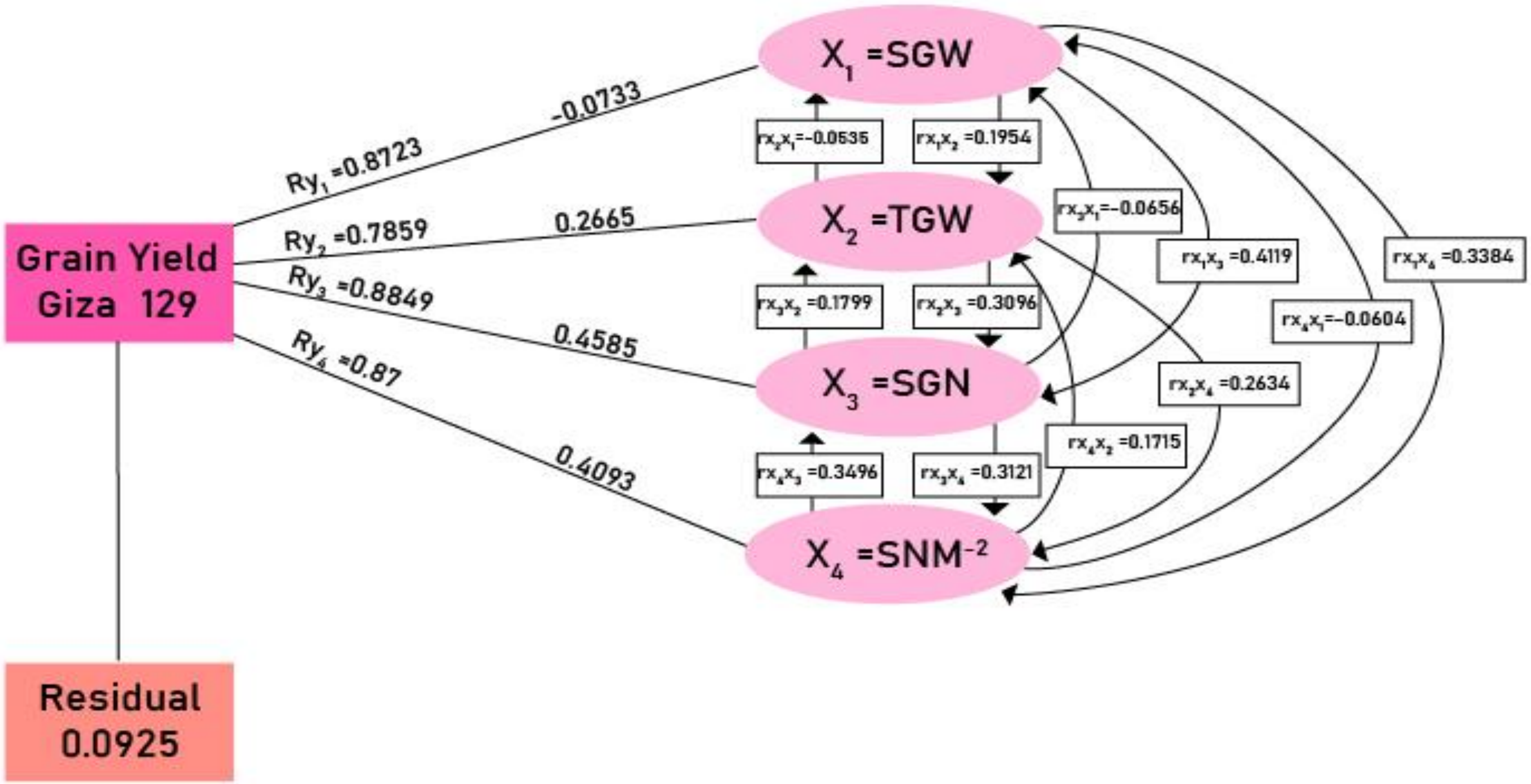
In addition, the residual effects of the other grain yield attributes and any other factors were 9.25%, 6.65% and 9.64% for Giza 129, Giza131 and Giza 135, respectively of the total yield diversity. It means that the main contributors to final grain yield variation were actually chosen in this study. These results are in agreement with those reported by **Abderrahmane *et al.*,(2013)** and **Bhutto *et al.* (2016).**

DISCUSSION

Recently, humic acid received increasing attention due to its positive effect in enhancing crop growth and productivity, alleviating environmental stresses, increasing fertilizer use efficiency, and improving soil properties. Its positive role in promoting plant growth and productivity may be attributed to its influence on enzyme

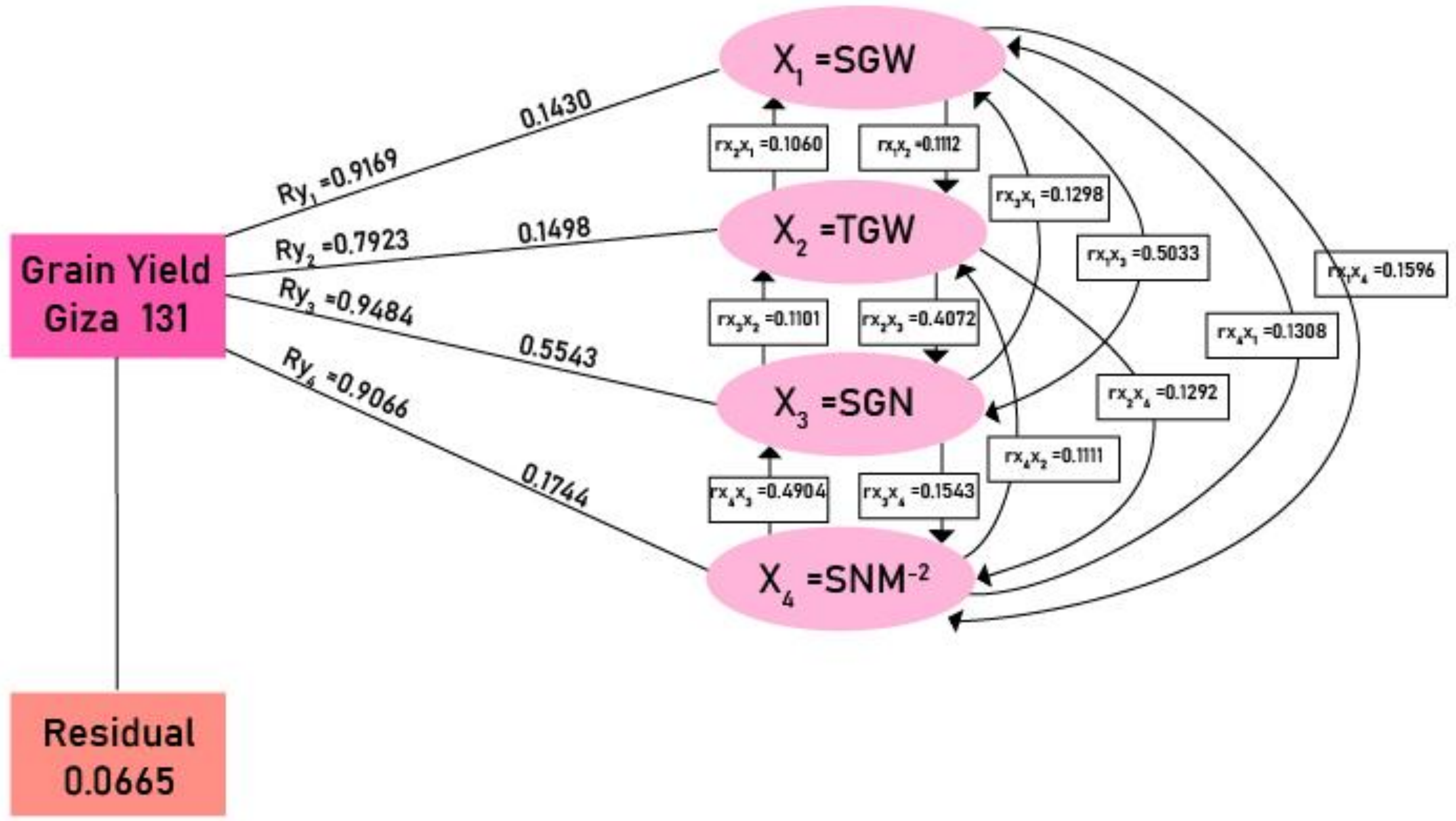
Table 9. Partitioning of simple correlation coefficient between barley grain yield and spike grain weight (SGW), 1000- grain weight (TGW), spike grain number (SGN) and spike number m^{-2} (SNM^{-2}) traits in varieties Giza 129, Giza 131 and Giza 135

Characters	SGW	TGW	SGN	SNM^{-2}	Correlation with grain yield
Giza 129					
SGW	-0.0733	0.1954	0.4119	0.3384	0.8723 **
TGW	-0.0535	0.2665	0.3096	0.2634	0.7859 **
SGN	-0.0656	0.1799	0.4585	0.3121	0.8849 **
SNM^{-2}	-0.0604	0.1715	0.3496	0.4093	0.87 **
Giza 131					
characters	**SGW**	**TGW**	**SGN**	**SNM^{-2}**	**Correlation with yield**
SGW	0.1430	0.1112	0.5033	0.1596	0.9169 **
TGW	0.1060	0.1498	0.4072	0.1292	0.7923 **
SGN	0.1298	0.1101	0.5543	0.1543	0.9484 **
SNM^{-2}	0.1308	0.1111	0.4904	0.1744	0.9066 **
Giza 135					
characters	**SGW**	**TGW**	**SGN**	**SNM^{-2}**	**Correlation with yield**
SGW	0.1558	0.1294	0.2156	0.3866	0.8873 **
TGW	0.1214	0.1664	0.1619	0.3072	0.7569 **
SGN	0.1405	0.1124	0.2397	0.3809	0.8735 **
SNM^{-2}	0.1267	0.1073	0.1917	0.4763	0.9021 **



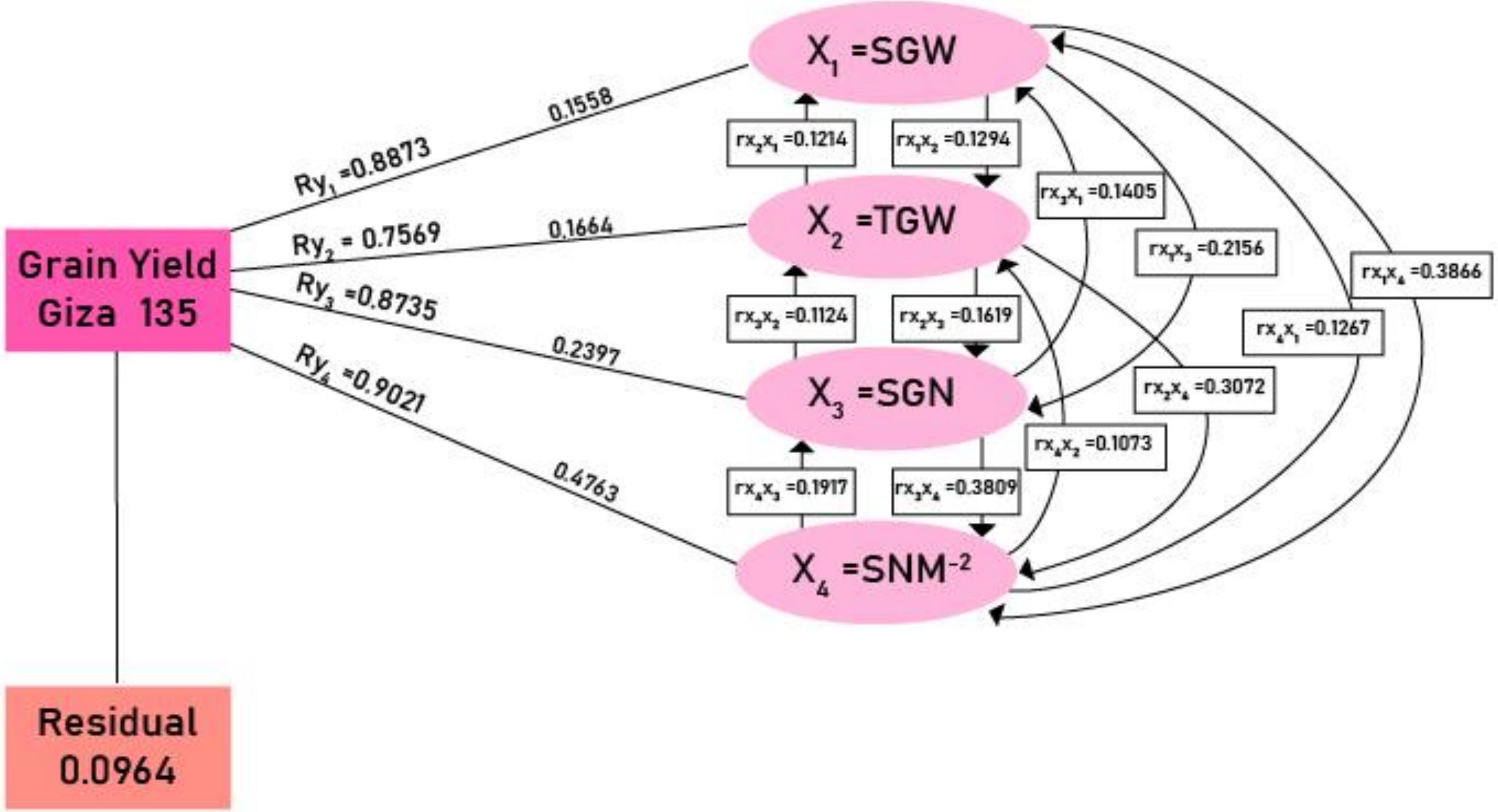
Where: SGW = Spike grain weight TGW = 1000 – grain weight SGN = Spike grain number SNM^{-2} = Spike number m^{-2}

Fig. 2. Direct and indirect effect of some grain yield components for barley variety Giza 129



Where: SGW = Spike grain weight TGW = 1000 – grain weight SGN = Spike grain number SNM^{-2} = Spike number m^{-2}

Fig. 3. Direct and indirect effect of some grain components for barley variety Giza 131



Where: SGW = Spike grain weight TGW = 1000 – grain weight SGN = Spike grain number SNM^{-2} = Spike number m^{-2}

Fig. 4. Direct and indirect effect of some grain components for barley variety Giza 135

Results revealed that nitrogen fertilization treatments had a significant influence on all studied traits compared with control treatment. Moreover, the addition of the recommended nitrogen level *i.e.*, 60 kg N fad^{-1} increased all studied traits, except NUE. Furthermore, partial replacement of N level by N foliar application in 30 kg N fad^{-1} + N foliar application treatment failed to give the same statistical values given by the addition of recommended N level for any trait. N is one of the most limiters affecting cereals growth and productivity, especially barley **(Zeidan, 2007; Bingham *et al.*, 2012; Wali *et al.*, 2018)**. Moreover, cereals require N for synthesizing proteins stored in their grains **(Hawkesford, 2014). (Zeidan, 2007)** pronounced that increasing N level from 30 to70 Kg N fad^{-1} increased barley flag leaf area, plant height, 1000-grain weight, spike number m^{-2}, grain yield and grain protein content. In addition, **Seadh *et al.* (2017)** found that increasing N fertilization level from 40 to 80 kg N fad^{-1} increased barley yield, its attributes and grain quality. So, the reduction in the amount of applied N led to significant reduction in yield and its attributes as shown in the current study results.

Comparing to the sole application of 30 kg N fad^{-1}, the co-application of 30 kg N fad^{-1} + N foliar application improved all traits in both seasons, except spike length and harvest index in the first season. **Barut (2019**) noted that N foliar application in the form of urea is an efficient method of N fertilization in cereal crops. Besides, **Saleem e*t al*.(2013**) pronounced that under limitation of N supply, urea foliar application can integrate with the soil application of N to fulfill wheat requirements of N.

Conclusion

Humic acid application promoted barley productivity, grain quality and NUE. Giza 131 barley variety exceeded the other two varieties in plant height, spike length, grain weight spike^{-1}, grain number spike^{-1}, 1000-grain weight, grain yield and NUE. Increasing N level up to 60kg N fad^{-1} had a positive significant impact on barley yield, its attributes and grain quality but it decreased NUE. The study revealed the efficacy of N foliar application in fulfilling barley nitrogen requirements with the soil N applications. We should try again using other N levels with N foliar application to minimize the N amount used without significant decrease in barley productivity and quality.

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الملخص العربي

تأثير حامض الهيوميك ومعاملات التسميد النتروجيني على إنتاجية وجودة الحبوب لبعض أصناف الشعير

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قسم المحاصيل، كلية الزراعة، جامعة الزقازيق، مصر

أجريت تجربة حقلية خلال الموسمين الشتويين 2019/2018 و2020/2019م بمركز أبو حماد- محافظة الشرقية، لدراسة تأثير إضافة حامض الهيوميك والإحلال الجزئي للنيتروجين بالرش الورقي وتأثيره على إنتاجية وجودة حبوب أصناف الشعير جيزة 129، جيزة 131 وجيزة 135؛ تضمنت الدراسة الرش بحمض الهيوميك بتركيز 1 جم/لتر مقارنة بعدم اضافته، واشتملت معاملات الإحلال الجزئي للنيتروجين على معاملات: كنترول، الرش بالنيتروجين (4%) على صورة يوريا، 30 كجم نيتروجين/فدان، 30 كجم نيتروجين/فدان+ الرش بالنيتروجين (4%)، و60 كجم نيتروجين/للفدان. أدت إضافة الهيوميك إلى تفوق جميع الصفات تحت الدراسة، لوحظ وجود اختلافات صنفية في كلا الموسمين، حيث تفوق الصنف جيزة 131 في معظم صفات الدراسة فيما عدا محتوى الحبوب من البروتين، كما لم تظهر فروق بين الأصناف في محصول القش، وعدد السنابل/م^2، دليل الحصاد ونسبة الكربوهيدرات بالحبوب. تفوقت إضافة 60 كجم نيتروجين/فدان على باقي معاملات التسميد الأخرى في جميع الصفات المدروسة فيما عدا كفاءة استخدام النتروجين، يليها معاملة إضافة 30 كجم نيتروجين فدان+ الرش بالنيتروجين، حيث أدت إلى تحسين المحصول ومعظم مكوناته وكفاءة استخدام النيتروجين مقارنة بالإضافة المنفردة لـ 30 كجم نيتروجين/فدان، مما يوضح فعالية إضافة النيتروجين رشا مع الإضافة الأرضية في استكمال متطلبات النباتات من النيتروجين. وجد ارتباط موجب بين محصول الحبوب/فدان ووزن حبوب السنبلة، وعدد حبوب السنبلة، وزن الألف حبة وعدد السنابل/م^2 في الثلاثة أصناف. كان لصفة عدد حبوب السنبلة أعلى تأثيرً مباشر على محصول الحبوب قي صنفي جيزة 129 وجيزة 131، بينما كان لصفة عدد السنابل/م^2 أكبر تأثير مباشر في الصنف جيزة 135. مما يؤكد أهمية هذه المؤشرات كمكونات لمحصول الحبوب في أصناف الشعير المختلفة.

الكلمات الاسترشادية: أصناف الشعير، حمض الهيوميك، مستويات النيتروجين، الرش الورقي للنيتروجين.

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