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# Effect of Zinc Foliar Application Splits and Rates Integrated with Humic Acid on Growth, Yield, and Grain Quality of Broadcast-Seeded Rice (*Oryza sativa* L.) in Northern Nile Delta Region, Egypt

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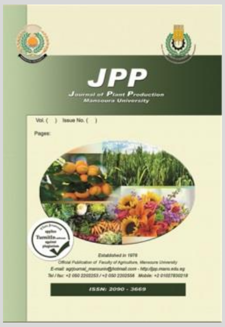


## ABSTRACT

Field experiments were carried out in two successive seasons of 2019 and 2020, Kafr El Sheikh Governorate, Egypt, to find out the effect of Zinc (Zn) application splits and rates without or with humic acid (HA) on rice growth, grain yield and quality. The experiments were laid out in a split-plot based on Randomized Complete Block Design with three replications. Treatments included two application splits were applied in main plots and nine application rates; control ($T_1$), 100% (20 kg $ZnSO_4.7H_2O$ fed.$^{-1}$) soil application traditional recommended fertilizer dose (RFD) ($T_2$), foliar Zn application rates of 12.5% ($T_3$), 25% ($T_4$) and 50% ($T_5$ ) from RFD, HA($T_6$), foliar Zn application rates of 12.5% ($T_7$), 25% ($T_8$) and 50% ($T_9$) from RFD+HA were applied in sub-plots. Results indicated that, Zn application at three splits gave higher rice growth characters, yield components and grain quality than two splits. By increase zinc application rates without or with HA had a significant increase (*P <0.05*) in growth characters; the highest increase mean values of plant height (7.8%) and number of tillers m$^{-2}$ (16.5%) were at 25% RFD+HA while, LAI (22.3%) and chlorophyll content (15.8%) were at 50% RFD+HA compared with control treatment. The highest panicle length (19.6 cm), panicle weight (2.29 g), number of filled grains panicle$^{-1}$ (104.9), grain yield (4.12 t fed$^{-1}$), harvest index (47.9%), elongation percentage (32.6%) and head rice percentage (69.4%**)** recorded at Zn 50% RFD+HA as an average of both seasons.

***Keywords:***Zinc , humic acid, foliar application , rice growth , yield and grain quality.

## INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important human food crops of the world (Fitzgerald *et al*., 2009) and is the staple food of about 3 billion people across the world, predominantly in Asia (Rehman *et al*., 2012). In Egypt, Rice is the main foodstuff for more than 90% of the population (Wissa, 2017) and is mainly growing in summer annually in the Nile Delta. For 2020, the area was set at 1.076 million fed. (452 thousand hectares), similar to the previous year (FAO, 2020). Flooding irrigation is the most common pattern for irrigating rice, which is useful for leaching soil salts, and/or pushing away salty groundwater from the root zone (FAO, 2003).

Zinc is an essential micronutrient for growing plants and optimum yield production, especially for rice growing under waterlogged cultivation (Naik and Das, 2007 and Alloway, 2008). Zinc plays an important role in several physiological processes of plants because it acts as a cofactor of many antioxidant enzymes and a key structural pattern in the synthesis of proteins (Broadley *et al*., 2007 and Ishimaru *et al*., 2011). Moreover, Plants grown on soils low in available Zn generally produce low yield and can reduce rice yield by over 20% with poor nutritional quality (Welch and Graham, 1999 and Sadeghzadeh, 2013). Zinc is generally taken up by plants as $Zn^{2+}$ (Marschner, 1995). Zn deficient soils have extractable Zn concentrations below 0.5 mg Zn/kg as diethylene triamine penta acetic acid (DTPA) extractable Zn. Approximately half of the agricultural soil area in the world has low available Zn or Zn deficiency (Alloway, 2008). For this reason the total Zn in the soil does not represent the Zn bioavailability properly, since the available Zn easily interacts in chemical reactions, which varies according to the soil physical or chemical characteristics parameters resulting changes in available Zn for plants (Impa and Johnson-Beebout, 2012). Brar and Sekhon (1976) as well as Sajwan and Lindsay (1986) summarized the decrease availability of Zn in submerged soil (rice fields) as: formation of insoluble compound as franklinite ($ZnFe_2O_4$), ZnS under intense reducing condition and $Zn(OH)_2$ at a relatively higher pH, subsequently lowering uptake by rice roots. The most widely applied Zn fertilizer source is $ZnSO_4$ for its high solubility and low cost (11 kg Zn ha$^{-1}$) was the most effective Zn fertilization (Coffin and Slaton, 2020). Soil and/or foliar is the most common agronomic practices for applying Zn fertilizer to improve Zn uptake and partitioning into different plant parts and consequently potentially improving grain yield and quality in rice (Stomph *et al*., 2011 and Li *et al*., 2015).

In the recent years, fertilization with humic acids has been improved yield and quality of plants, including grains (Jones *et al.*, 2007 and Ulukan, 2008). Limited number of reports concern with foliar applications of HA in the field such as rice (Tejada and Gonzalez, 2004). Humic acids have positive effects on enzyme activity, plant nutrients and growth stimulant and are considered as a “plant food”. Humic acid based fertilizers increase crop yield stimulate, plant enzymes and hormones (El-Razek *et al*., 2012 and Eshwar *et al*., 2017).

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Low availability of Zn, to plants in the soils of the Nile Delta regions of Egypt is one of the main challenges of farmers and leads to reduced rice crops yield. More than, the study area located in north Delta (Kafr El Sheikh Governorate, Egypt) suffering from alkaline problem, increase in dissolved salts, as well as a decrease in the concentration of available zinc for the plant. Therefore, this study was aimed to evaluate the response of rice to foliar application splits and rates of zinc sulphate alone or with humic acid on growth, yield and grain quality.

## MATERIALS AND METHODS

**Study area and main problems**

A site of an experiment soil was in north Nile Delta, at privet farm in Biyala district (at 31° 12' 39.6" N and 31° 13' 55.5" E), Kafr El Sheikh Governorate, Egypt (studied sites were identified using a "GPS" (Model German)). Selected area had a problem in previous seasons of low rice yield production. In view of the urgent need to cultivate rice plants in these areas since it is considered a healer of soil salinity problems, by growing rice under flooding irrigation system Therefore, it was necessary to search for the reasons and how to improve. So, we started by a first step which collected a composite surface soil samples (0-30 cm depth) during the study years before planting and prepared for analyses in laboratory. The particle size distribution (sand, silt and clay, soil texture), Soil pH measured in 1: 2.5 soil-water suspensions, electrical conductivity (EC) in soil paste extract, cation exchange capacity (CEC), exchangeable sodium percentage (ESP), total $CaCO_3$, organic matter (OM), according to standard methods outlined by Jackson (1973) and Sparks *et al*. (1996). Available Zn extracted by Diethylene Triamine Penta Acetate (DTPA) according to method of Lindsay and Norvell (1978). Obtained analysis data of soil properties are listed in (Table 1).

**Table 1. Soil physical and chemical properties of the experiment site during 2019 and 2020 growing seasons of rice.**

| Soil characteristics | Seasons 2019 | Seasons 2020 |
|---|---|---|
| Physical properties | | |
| Sand (%) | 12.0 | 12.5 |
| Silt (%) | 19.5 | 20.5 |
| Clay (%) | 68.5 | 67.0 |
| Texture | Clay | Clay |
| Chemical properties | | |
| pH | 8.60 | 8.55 |
| Organic matter (%) | 1.60 | 1.67 |
| Calcium carbonate (%) | 1.68 | 1.62 |
| CEC (Cmole/kg) | 49.5 | 52.8 |
| ESP% | 22.5 | 19.6 |
| EC (dS/m) | 2.80 | 2.72 |
| Soluble cations (meq/l) | | |
| $Ca^{2+}$ | 7.50 | 7.35 |
| $Mg^{2+}$ | 6.50 | 6.28 |
| $Na^+$ | 12.00 | 13.55 |
| $K^+$ | 1.77 | 1.65 |
| Soluble anions (meq/l) | | |
| $CO_3^=$ | 0.00 | 0.00 |
| $HCO_3^-$ | 2.50 | 2.45 |
| $Cl^-$ | 18.50 | 19.10 |
| $SO_4^=$ | 6.77 | 5.65 |
| Available zinc (mg/kg soil) | 0.198 | 0.185 |

It became more clearly that, there was alkaline problem, increase in dissolved salts (FAO, 1988), as well as a low concentration of available zinc for the plant. According to our soil analysis and recommendation of Takkar and Singh (1978) for gypsum application markedly decreased the soil pH, and significantly increased the yield and Zn uptake by rice. The farmer applied as recommended (1.5 t fed.$^{-1}$ gypsum ($CaSO_4.2H_2O$)) before preparation soil to rice planting.

**Experiment design and treatments**

Field experiments were carried out in two successive seasons of 2019 and 2020, to find out the effect of Zinc (Zn) application splits and rates alone or integrated with humic acid (HA) on rice growth, grain yield and quality. The experiment was laid out in a split plot design in a randomized complete block design arrangement with three replications. The splits of zinc application in two or three doses were applied in main plots and nine application rates; control ($T_1$), 100% (20 kg $ZnSO_4.7H_2O$/fed 22% Zn) soil application traditional recommended fertilizer dose (RFD) ($T_2$), foliar Zn application rates of 12.5% ($T_3$), 25% ($T_4$), 50% ($T_5$), HA($T_6$), 12.5%+HA ($T_7$), 25%+HA ($T_8$) and 50%+HA ($T_9$) from RFD were applied in sub-plots. Liquid humic acid (as humic plus 20®, Techno green for industrial production company, Egypt) was added as recommended rate of 3L/fed. (fed. = 4200 $m^2$). Plot area was 16 $m^2$.piots were separated by 0.5 m between fallow distance.

The preceding crop was Egyptian clover (*Trifolium alexandrinum* L.) for the two growing seasons. Rice cultivar Giza 178 (bright erect leaves, high tiller capacity, short grain, its duration 130-135 days and Japonica Indica type) was used. The seeds were obtained from Rice Research and Training Center (RRTC) in Sakha, Kafr EL-Sheikh, Egypt. Seeds of Giza 178 rice cultivar at the rate of 70 kg fed.$^{-1}$ were soaked in water for 24 hours, and then incubated for 48 hours to hasten early germination. Pre-germinated grains were uniformity broadcasted by hand in presence of water after puddling on the second week of May in 2019 and 2020 seasons. Zinc fertilizer was divided into two or three equal splits in each treatment, in soil application treatment the first split added as basal immediately after puddling, second and third splits at par with foliar application date. All plants received basal fertilizer to the soil; Phosphorus at 30 kg $P_2O_5$ fed.$^{-1}$ as single calcium superphosphate (15.5% $P_2O_5$) was added to the soil before tillage. Nitrogen at a level of 90 kg N fed.$^{-1}$, as urea ($CO(NH_2)_2$ , 46.5% N), potassium at 30 kg $K_2O$ fed.$^{-1}$ as potassium sulphate (48% $K_2O$) were added in three equal doses at recommended splits. Irrigation water requirements and irrigation intervals as well as all the other agronomic practices have been applied according to the recommended methods of rice production. Zinc fertilizer and humic acid were foliar applied as an aqueous solution at tillering and panicle initiation as two equal splits however, at tillering, panicle initiation and heading as three equal splits. The volume of foliar solution was approximately 200 L fed.$^{-1}$. To prevent contamination, each plot was vertically protected with a plastic sheet during spraying.

**Data collection**

**1- Growth characters**

a. Plant height (cm): height of ten rice plants from soil surface up to the top of the plant and the average of plant height was recorded.

b. Number of tillers $m^{-2}$

c. Leaf area index (LAI): LAI is the ratio between leaves areas of plant ($cm^2$) divided by ground area of plant ($cm^2$).

d. Chlorophyll content (SPAD): At complete heading chlorophyll content (SPAD value) was estimated by using chlorophyll meter (SPAD-502, Minolta, Japan).

**2- Yield and its components**

Ten random panicles were taken from harvested plants in each plot and the following parameters were recorded: panicle length, panicle weight, number of filled grains/panicle, percentage of unfilled grains/panicle and 1000 - grain weight. Rice plants were harvested from one square meter area from the center of each plot at maturity and were manually threshed to determine, number of panicles/$m^2$. After threshing, straw was oven-drying at 70°C for 72 h to constant weight and dry weight of straw was determined. Grain yield was adjusted to 14% moisture content determined according to Yoshida (1981) and calculated biological (grain yield + straw yield), straw and grain yields (t $fed.^{-1}$).

**Harvest index %:** Harvest index was calculated by using the following equation:

$$\textbf{Harvest Index}\ \% = \frac{\textbf{grain yield}}{\textbf{biological yield}}\ \textbf{X 100}$$

**3- Determination of grain quality characteristics**:

The following Grain quality characteristics were estimated at Technology Lab., Rice Research and Training Center (RRTC) Sakha, Kafr El-Sheikh Governorate, Egypt.

**a.Physical characteristics**

One hundred and fifty gram of cleaned rough rice samples at moisture content 12-14% were dehulled using Asatake Laboratory Dehuller. Hulling, milling and Head rice percentage were calculated using the procedure of Khan and Wikramanayake (1971).

**1. Hulling percentage was determined as follows:**

$$\textbf{Hulling percentage} = \frac{\textbf{weight of brown rice}}{\textbf{weight of rough rice}}\ \textbf{X 100}$$

**2. Milling percentage:** Brown rice were consequently milled by experimental milling machine, then the milled rice sample was collected and the weight was taken and percentage of total milled rice was computed according to the following equation.

$$\textbf{Milling percentage} = \frac{\textbf{weight of Milled rice}}{\textbf{weight of rough rice}}\ \textbf{X 100}$$

**3. Head rice percentage:** By grading the milled rice and grains up to 75% were considered as head rice and weight of unbroken grains were taken and calculated as percent from the total weight of the milled rice as follows:

$$\textbf{Head rice percentage} = \frac{\textbf{weight of whole milled grains}}{\textbf{weight of total milled rice}}\ \textbf{X 100}$$

**b. Cooking and eating quality traits**

1. **Amylose content (%):** Amylose content was determined following the method of Williams *et al.* (1958). A scale was used for classifying amylose content (AC %) was very low amylose (7-11 %), low amylose (11-20 %), intermediate (20-25%) and high (>25%) according to IRRI (2009).
2. **Elongation percentage was measured using the following formula:**

$$\textbf{Elongation}\ \% = \frac{\textbf{grain avg. lenght after cooking} - \textbf{grain avg. lenght befor cooking}}{\textbf{grain avg. lenght befor cooking}}\ \textbf{X 100}$$

**Statistical Analysis:** The obtained data were subjected to statistical analysis of variance for each season, for all characters under study according to the procedure described by Snedecor and Cochron (1981) Significance of differences among variables was done according to Least Significant Differences test (LSD) at 5% level of probability. Finally, all statistical analyses were carried out using "MSTAT-C" computer software package (Freed *et al.*, 1989).

## RESULTS AND DISCUSSION

**1.Growth characters:**

Mean values of plant height, number of tillers/$m^2$, LAI and chlorophyll content of rice plants as affected by foliar application of zinc sulphate and humic acid of studied seasons (2019 and 2020) are presented in Table 2 and Fig.1. The data clear that, the main effect of foliar zinc application splits and its rates without or with humic acid had a significant increase ($P < 0.05$) in each of plant height, number of tillers $m^{-2}$, LAI, chlorophyll content in both seasons. Also, the interaction between them had significant effects in both seasons except of plant height and LAI.

The average values of increase in both seasons of fertilizers application splits were higher by 3 than 2 splits for plant height (2.3%), number of tillers $m^{-2}$ (6.0%), LAI (4.3%) and chlorophyll content (3.3%). In a field experiment, Naik and Das (2007) found that split application of $ZnSO_4$ was better than just basal application. Also, results indicated that, by increasing Zn fertilizers application rates led to an increase in plant height (2.7, 3.8 and 7.0%), number of tillers $m^{-2}$ (3.3, 9.9 and 12.7%), LAI (13.8, 16.9 and 30.8%) and chlorophyll content (2.7, 8.3 and 13.8%) for 12.5, 25 and 50% RDF of Zn, respectively without humic acid compared with control treatment in both seasons. However, the highest value of both of plant height (7.8%) and number of tillers $m^{-2}$ (16.5%) at 25% RFD of Zn with humic acid and both of LAI (22.3%) and chlorophyll content (15.8%) at 50% RFD Zn with humic acid compared with control treatment. This may be due to humic acid improve plant physiological processes by enhancing the availability of major and minor nutrients as well as enhancing the vitamins, amino acids, and also auxin and cytokinin contents of the plants (Vanitha and Mohandass, 2014).

The increases in above parameters (Table 2) were achieved at 25 or 50% RFD of Zn foliar application which approximately at par with soil application of 100% RFD Zn treatment in both seasons. The main reason of low available Zn with soil application that easily interacts in chemical reactions resulting decreased in available Zn for plants (Impa and Johnson-Beebout, 2012). The interaction between both of Zn application splits and rates (Fig. 1) recorded the highest value of number of tillers $m^{-2}$ (923) and chlorophyll content (39) as an average of both seasons at 3 application splits of 25% RDF Zn + humic acid and at 3 application splits of 50% RDF Zn+humic acid respectively. The obtained results agree with Vanitha and Mohandass (2014) who reported that the humic acid application led to increase rice tillers number. Noreen and Kamran (2019) reported that zinc sulphate improve growth parameters and had a significant increase in leaf area and plant height. Also, Zn application significantly increased the Chlorophyll contents and tillers $m^{-2}$ (Rana and Kashif, 2014).

**Table 2. The main effect of splits and rates of zinc foliar application with humic acid on plant height, number of tillers/m², LAI and chlorophyll content (SPAD) of rice plant during 2019 and 2020 seasons.**

| Zinc application | | Plant height(cm) | | No of tillers m⁻² | | LAI | | Chlorophyll content(SPAD) | |
|---|---|---|---|---|---|---|---|---|---|
| Splits (A) | Rates* (B) | Seasons | | | | | | | |
| | | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| 2 | | 82.9 | 83.6 | 792 | 803 | 4.97 | 4.93 | 35.0 | 35.6 |
| 3 | | 85.0 | 85.4 | 838 | 853 | 5.17 | 5.16 | 36.1 | 36.7 |
| Rates (B) | T1 | 81.1 | 80.5 | 752 | 747 | 4.41 | 4.37 | 33.0 | 33.5 |
| | T2 | 83.7 | 84.5 | 822 | 840 | 5.09 | 5.04 | 35.6 | 36.3 |
| | T3 | 82.7 | 83.2 | 770 | 778 | 5.00 | 4.99 | 33.7 | 34.6 |
| | T4 | 83.4 | 84.3 | 819 | 829 | 5.14 | 5.12 | 35.7 | 36.3 |
| | T5 | 86.1 | 86.8 | 838 | 851 | 5.32 | 5.29 | 37.6 | 38.1 |
| | T6 | 82.6 | 83.4 | 816 | 823 | 4.98 | 4.95 | 34.7 | 35.1 |
| | T7 | 83.2 | 83.6 | 824 | 839 | 5.10 | 5.09 | 34.8 | 35.4 |
| | T8 | 86.6 | 87.6 | 862 | 884 | 5.23 | 5.22 | 36.8 | 37.5 |
| | T9 | 86.1 | 86.6 | 833 | 859 | 5.38 | 5.36 | 38.2 | 38.8 |
| L.S.D at | A | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. |
| 0.05% | B | 3.11 | 3.12 | 31.7 | 32.8 | 0.25 | 0.24 | 0.63 | 0.74 |

*** control ($T_1$), 100% soil application RFD ($T_2$), foliar Zn application rates of 12.5% ($T_3$), 25% ($T_4$), 50% ($T_5$), HA ($T_6$), 12.5%+HA ($T_7$), 25%+HA ($T_8$) and 50%+HA ($T_9$) from Zn RFD.**

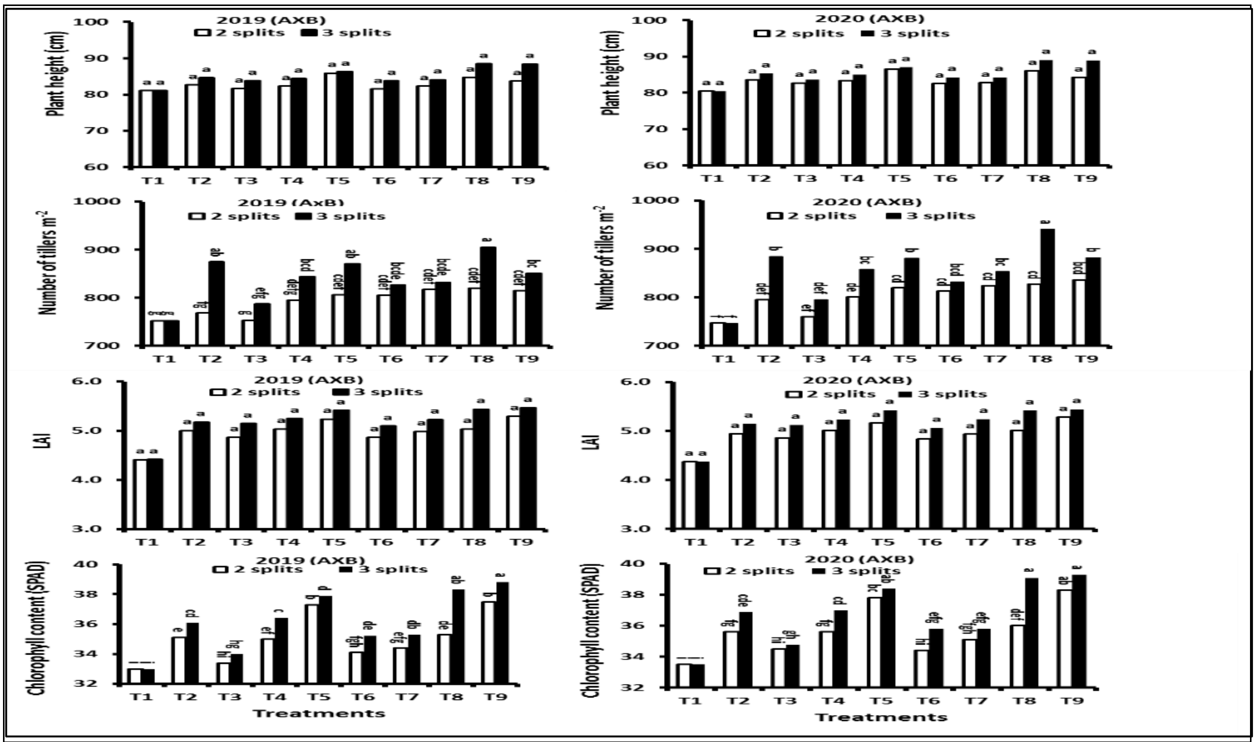


**Fig.1. The interaction between splits and rates of zinc foliar application without and with humic acid on plant height, number of tillers m⁻², LAI and chlorophyll content (SPAD) of rice plant during 2019 and 2020 seasons. Different letters indicate significant differences by the least significant difference (LSD) at p< 0.05.**

**2. Yield and yield components**

Mean values of panicles m⁻², panicle length (cm) and panicle weight (g) of rice plants as affected by foliar application of zinc sulphate and humic acid of studied seasons (2019 and 2020) are presented in Table 3 and Fig.2. The data clear that, the main effect of foliar zinc application splits and its rates without or with humic acid and the interaction between them had a significant effect in both seasons (*P <0.05*) in the mentioned parameters of rice plants.

The average values of increase in both seasons of fertilizers application splits were higher by 3 than 2 splits for number of panicles m⁻² (5.9%), panicle length (3.9%) and panicle weight (9.2%). Also, results indicated that, by increasing Zn fertilizers application rates led to an increase in number of panicles m⁻² (5.4, 13.2 and 14.6%), panicle length (3.5, 10.4 and 8.1) and panicle weight (5.3, 25.4 and 27.8%) for 12.5, 25 and 50% RDF Zn, respectively without humic acid compared with control treatment in both seasons. However, the highest value of number of panicles m⁻² (18.3%) at 25% RFD Zn with humic acid and both of panicle length (9.5%) and panicle weight (23.9%) at 50% RFD Zn with humic acid compared with control treatment. The effect of zinc on previous characters might be due to the increase in metabolites translated from source to sink. These results are in hold true with those reported by Dutta et al. (1987); Zayed *et al.* (2011); Wissa (2017)and Fergany (2018).

The increases in above parameters (Table 3) were achieved at 25 or 50% RFD Zn of foliar application which approximately at par with soil application of 100% RFD Zn treatment in both seasons. The interaction between both of Zn application splits and rates (Fig. 2) recorded the highest value of number panicles m$^{-2}$ (844) at 3 application splits of 25% RFD Zn + humic acid and both of panicle length (19.6 cm) and panicle weight (2.29 g) as an average of both seasons at 3 application splits of 50% RDF Zn + humic acid.

The results cleared that the impact of foliar Zn and humic acid was significant for panicles numbers, panicle length and panicle weight of rice plants. This may be due to the role of zinc for improves the growth and increasing absorption and providing other essential nutrients and act as a cofactor of many antioxidant enzymes. This agree with both Naik and Das ( 2007); Ishimaru *et al*. (2011); Upadhyaya *et al.* (2017) and Saha *et al.* (2017) Who have explained the importance role of zinc in several physiological processes of plants because it acts as a cofactor of many antioxidant enzymes, improving the metabolic process and a key structural pattern in the synthesis of proteins also, by increasing absorption and providing other essential nutrients for the plant uptake.

**Table 3. The main effect of splits and rates of zinc foliar application with humic acid on panicles m$^{-2}$, panicle length and panicle weight of rice plant during 2019 and 2020 seasons.**

| Zinc application | | Panicle number m$^{-2}$ | | Panicle length(cm) | | Panicle weight (g) | |
|---|---|---|---|---|---|---|---|
| Splits (A) | Rates* (B) | Seasons | | | | | |
| | | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| 2 | | 770 | 780 | 18.63 | 18.25 | 1.87 | 1.93 |
| 3 | | 814 | 827 | 19.45 | 18.86 | 2.05 | 2.10 |
| Rates (B) | T1 | 713 | 714 | 18.00 | 17.71 | 1.68 | 1.74 |
| | T2 | 807 | 824 | 18.61 | 18.13 | 1.91 | 1.97 |
| | T3 | 750 | 754 | 18.70 | 18.25 | 1.78 | 1.82 |
| | T4 | 804 | 812 | 19.89 | 19.55 | 2.11 | 2.18 |
| | T5 | 813 | 822 | 19.55 | 19.06 | 2.16 | 2.21 |
| | T6 | 790 | 796 | 18.39 | 18.08 | 1.82 | 1.88 |
| | T7 | 800 | 815 | 18.85 | 18.26 | 1.83 | 1.89 |
| | T8 | 834 | 853 | 19.58 | 18.65 | 2.07 | 2.13 |
| | T9 | 817 | 841 | 19.80 | 19.31 | 2.26 | 2.32 |
| L.S.D at 0.05% | A | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. |
| | B | 32.1 | 31.2 | 0.50 | 0.51 | 0.05 | 0.07 |

*** control (T1), 100% soil application RFD (T2), foliar Zn application rates of 12.5% (T3), 25% (T4), 50% (T5), HA (T6), 12.5%+HA (T7), 25%+HA (T8) and 50%+HA (T9) from Zn RFD.**

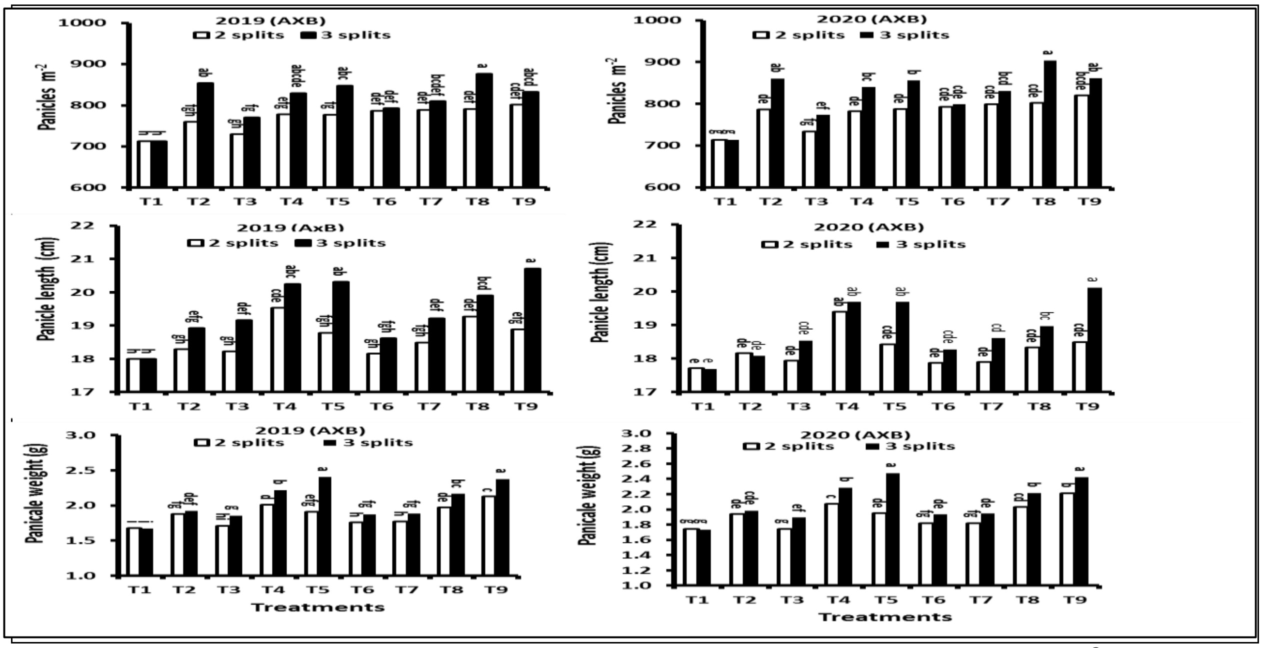


**Fig. 2. The interaction between splits and rates of zinc foliar application with humic acid on panicles m$^{-2}$, panicle length and panicle weight of rice plant during 2019 and 2020 seasons. Different letters indicate significant differences by the least significant difference (LSD) at p< 0.05.**

As for filled grains panicle$^{-1}$, unfilled grains panicle$^{-1}$ (%) and 1000 grain weight (g) of rice plants as affected by foliar application of zinc sulphate and humic acid of studied seasons (2019 and 2020), mean values are presented in Table 4 and Fig.3. The data clear that, the main effect of foliar zinc application splits and its rates without or with humic acid and its interactions had a significant effect in both seasons (*P <0.05*) in the mentioned parameters of rice plants.

The average values of increase in both seasons of fertilizers application splits were higher by 3 than 2 splits for filled grains panicle$^{-1}$ (7.8%), thousand grain weight (1.5%) and decreased unfilled grains panicle$^{-1}$ (14.3%). Also, results indicated that, by increasing Zn fertilizers application rates led to an increase in number of filled grains panicle$^{-1}$ (4.5, 17.9 20.4%), thousand grain weight (3.5, 4.9 and 5.4%) and decreased unfilled grains panicle$^{-1}$ (30.2, 39.4 and 46.2) for

12.5, 25 and 50% RDF Zn, respectively without humic acid compared with control treatment in both seasons. However, the highest increase value of filled grains panicle$^{-1}$ (28.5%) and the highest decrease value of unfilled grains panicle$^{-1}$ (50.2%) at 50% RFD Zn with humic acid and the highest increase value of thousand grain weight (6%) at 25% RFD Zn with humic acid compared with control treatment. These results might be due to the favorable effect of zinc fertilizer application splits and its rates on grains panicle$^{-1}$ and 1000 grain weight by improved rice growth and current photosynthesis and its translocation to rice grain enhanced grain filling. Similar results were reported by

Ionov and Ionova (1977); Zayed *et al.* (2011) and Fergany (2018) who noticed that zinc application increased number of spikelets panicle$^{-1}$, 1000-grain weight and paddy yield. The results are also supported by the findings of Maqsood *et al.* (1999).

The increases in above parameters (Table 4) were achieved at 25 or 50% RFD Zn of foliar application which approximately at par with soil application of 100% RFD treatment in both seasons. The interaction between both of Zn application splits and rates (Fig. 3) recorded the highest value of filled grains/panicle (108.0) as an average of both seasons at 3 application splits of 50% RDF, thousand grain weight (21.4 g) while, the lowest value of unfilled grains/panicle (6.5%) as an average of both seasons at 3 application splits of 50% RDF+humic acid.

The increase in filled grains panicle$^{-1}$ and grain weight of rice plants, may be due to the application of Zn and HA can be attributed to uptake more nutrients by plant and translocate to reproductive parts, such as panicles and increases total dry matter accumulation. This agree with both Farooq *et al.* (2018) and Amanullah and Inamullah (2016) who have mentioned that application of Zn causes the allocation more nutrients to plant reproductive parts, such as panicles and improved fertile tillers which increase the number and weight grains per panicles.

**Table 4. The main effect of splits and rates of zinc foliar application with humic acid on filled grains panicle$^{-1}$, % unfilled grains panicle$^{-1}$ and 1000-grain weight of rice grain during 2019 and 2020 seasons.**

| Zinc application | | No filled grains panicle$^{-1}$ | | % Unfilled grains panicle$^{-1}$ | | 1000- grain weight (g) | |
|---|---|---|---|---|---|---|---|
| Splits | Rates* | Seasons | | | | | |
| (A) | (B) | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| 2 | | 85.2 | 86.8 | 9.92 | 10.39 | 20.70 | 20.83 |
| 3 | | 91.9 | 93.5 | 8.49 | 8.92 | 21.02 | 21.13 |
| Rates (B) | T1 | 79.5 | 80.9 | 13.96 | 14.78 | 20.00 | 20.08 |
| | T2 | 84.4 | 85.8 | 9.43 | 9.86 | 20.85 | 21.06 |
| | T3 | 83.0 | 84.5 | 9.78 | 10.27 | 20.70 | 20.78 |
| | T4 | 93.7 | 95.4 | 8.49 | 8.92 | 20.96 | 21.07 |
| | T5 | 95.6 | 97.5 | 7.56 | 7.89 | 21.08 | 21.16 |
| | T6 | 82.4 | 83.6 | 9.34 | 9.85 | 20.94 | 21.01 |
| | T7 | 83.3 | 84.7 | 9.33 | 9.65 | 20.98 | 21.04 |
| | T8 | 93.1 | 94.8 | 7.99 | 8.35 | 21.11 | 21.36 |
| | T9 | 102.1 | 104.0 | 6.97 | 7.33 | 21.14 | 21.25 |
| L.S.D at | A | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. |
| 0.05% | B | 2.23 | 1.70 | 0.31 | 0.35 | 0.18 | 0.17 |

*** control (T1), 100% soil application RFD (T2), foliar Zn application rates of 12.5% (T3), 25% (T4), 50% (T5), HA (T6), 12.5%+HA (T7), 25%+HA (T8) and 50%+HA (T9) from Zn RFD.**

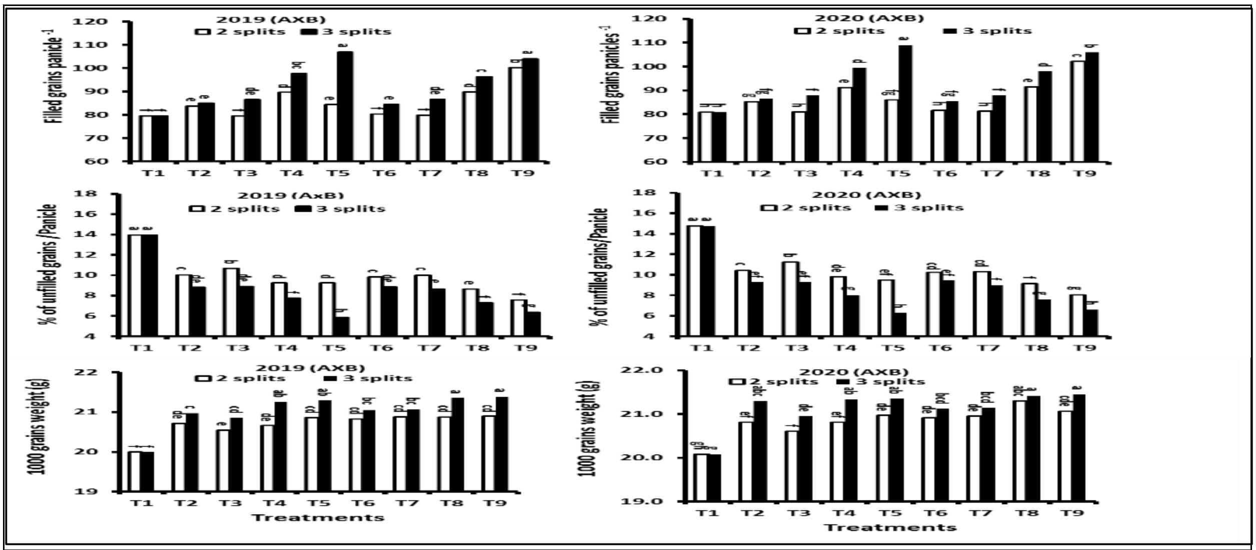


**Fig. 3. The interaction between splits and rates of zinc foliar application with humic acid on filled grains panicle$^{-1}$, % unfilled grains panicle$^{-1}$ and 1000-grain weight of rice grain during 2019 and 2020 seasons. Different letters indicate significant differences by the least significant difference (LSD) at p< 0.05.**

Data of biological yield (t fed.$^{-1}$), grain yield (t fed.$^{-1}$) and harvest index (%) of rice plants as affected by foliar application of zinc sulphate and humic acid of studied seasons (2019 and 2020), mean values are presented in Table 5 and

Fig. 4. The data clear that, the main effect and its interactions of foliar zinc application splits and its rates without or with humic acid had a significant effect in both seasons (*P <0.05*).

The average values of increase in both seasons of fertilizers application splits were higher by 3 than 2 splits for biological yield (11.9%), grain yield (15%) and harvest index (2.8%). Also, results indicated that, by increasing Zn fertilizers application rates led to an increase in biological yield (5.5, 13.9 and 15.8%), grain yield (12.1, 20.1 and 22.6%) and harvest index (3.3, 5.4 and 5.9%) for 12.5, 25 and 50% RDF Zn, respectively without humic acid compared with control treatment in both seasons. However, the highest increase value of biological yield (18.4%), grain yield (26%) and harvest index (6.4%) at 50% RFD Zn with humic acid compared with control treatment. The increases in above parameters (Table 5) were achieved at 25 or 50% RFD Zn of foliar application higher than soil application of 100% RFD Zn treatment in both seasons. The interaction between both of Zn application splits and rates (Fig. 4) recorded the highest value of biological yield (9.2 t fed.$^{-1}$), grain yield (4.4 t fed.$^{-1}$) and harvest index (48.6%) as an average of both seasons at 3 application splits of 50% RDF Zn + humic acid. Singh et al. (1996); Maqsood et al. (1999) and Kausar et al. (2001) also reported similar results.

The increase in yield by zinc and humic acid application might be due to the combined effect of many yield components, like panicles m$^{-2}$, panicle length, panicle weight, filled grains panicle$^{-1}$ and 1000-grain weight. Our results agree with both Khan and Qasim (2007) and Zayed *et al.* (2011) who reported that increasing levels of Zn significantly influenced yield and yield components of rice.

**Table 5. The main effect of splits and rates of zinc foliar application with humic acid on biological yield, grain yield and harvest index of rice plant during 2019 and 2020 seasons.**

| Zinc application | | Biological yield (t fed.$^{-1}$) | | Grain yield (t fed$^{-1}$) | | Harvest index (%) | |
|---|---|---|---|---|---|---|---|
| Splits (A) | Rates* (B) | Seasons | | | | | |
| | | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| 2 | | 7.65b | 7.72b | 3.54b | 3.58b | 46.18b | 46.36b |
| 3 | | 8.54a | 8.66a | 4.06a | 4.13a | 47.48a | 47.68a |
| Rates (B) | T1 | 7.21 | 7.33 | 3.22 | 3.32 | 44.66 | 45.29 |
| | T2 | 7.88 | 8.08 | 3.67 | 3.77 | 46.45 | 46.66 |
| | T3 | 7.85 | 7.93 | 3.64 | 3.69 | 46.37 | 46.53 |
| | T4 | 8.25 | 8.31 | 3.91 | 3.94 | 47.39 | 47.41 |
| | T5 | 8.36 | 8.48 | 3.98 | 4.04 | 47.61 | 47.64 |
| | T6 | 7.95 | 8.08 | 3.71 | 3.79 | 46.67 | 46.91 |
| | T7 | 8.30 | 8.31 | 3.94 | 3.94 | 47.47 | 47.41 |
| | T8 | 8.52 | 8.52 | 4.07 | 4.07 | 47.77 | 47.77 |
| | T9 | 8.57 | 8.64 | 4.10 | 4.14 | 47.84 | 47.92 |
| L.S.D at 0.05% | A | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. |
| | B | 0.36 | 0.36 | 0.19 | 0.19 | 0.50 | 0.54 |

*** control (T1), 100% soil application RFD (T2), foliar Zn application rates of 12.5% (T3), 25% (T4), 50% (T5), HA (T6), 12.5%+HA (T7), 25%+HA (T8) and 50%+HA (T9) from Zn RFD.**

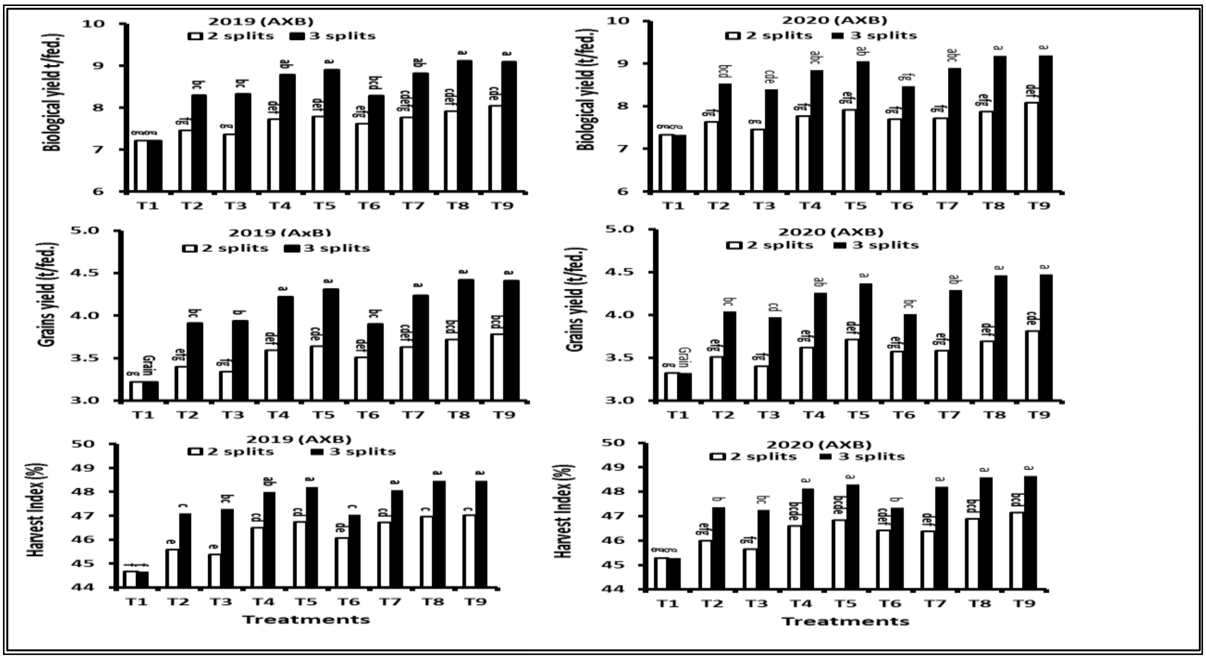


**Fig. 4. The interaction between splits and rates of zinc foliar application with humic acid on biological yield, grain yield and harvest index of rice plant during 2019 and 2020 seasons. Different letters indicate significant differences by the least significant difference (LSD) at p< 0.05.**

**3.Grain quality characteristics**

Mean values of hulling (%), milling (%), head rice (%), amylose (%) and elongation (%) of rice as affected by foliar application of zinc sulphate and humic acid of studied seasons (2019 and 2020) are presented in Table 6 and Fig.5 The data clear that, the main effect of foliar zinc application splits and its rates without or with humic acid had a significant effect in both seasons (*P <0.05*) except milling (%) with application splits. However, the interactions between them had a significant effect in both seasons except hulling (%), milling (%).

The average values of increase in both seasons of fertilizers application splits were higher by 3 than 2 splits for hulling (1.8%), head rice (1.9%) and elongation (6%); however, decrease the amylose content (6.4%). Also, results indicated that, by increasing Zn fertilizers application rates led to an increase in hulling (2.2, 2.0 and 1.1%), milling (2.1, 2.5 and 2.3%), head rice (3.3, 4.4 and 5.3%) and elongation (4.8, 13.3 and 8.4%), however decrease the amylose content (18, 18.2 and 17.6%) for 12.5, 25 and 50% RDF Zn, respectively without humic acid compared with control treatment in both seasons. However, the highest increase value of hulling (82.1%), milling (72.5%), head rice (70%) and elongation (32.6%), while, the lowest value of amylose content (17.3%), recorded at 50% RFD Zn with humic acid compared with control treatment. The increases in above parameters (Table 6) were achieved of both of 25 or 50% RFD Zn of foliar application higher than or at par with soil application of 100% RFD Zn treatment in both seasons. The interaction between both of Zn application splits and rates (Fig. 5 and 6) recorded the highest value of head rice (71.1%), elongation % (32.6) and the lowest value of amylose % (17.2%) as an average of both seasons at 3 application splits of 12.5 + humic acid, 50% RDF Zn + humic acid and 50% RDF Zn respectively.

**Table 6. The main effect of splits and rates of zinc foliar application with humic acid on hulling %, milling %, head rice %, amylose % and elongation % of rice grain during 2019 and 2020 seasons.**

| Zinc application | | Hulling(%) | | Milling(%) | | Head rice(%) | | Amylose(%) | | Elongation(%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Splits (A) | Rates* (B) | Seasons | | | | | | | | | |
| | | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| 2 | | 79.8 | 80.0 | 71.3 | 71.2 | 66.9 | 66.8 | 19.56 | 19.46 | 25.56 | 25.87 |
| 3 | | 81.3 | 81.4 | 71.9 | 71.9 | 67.9 | 68.4 | 18.28 | 18.24 | 27.24 | 27.27 |
| Rates (B) | T1 | 79.3 | 79.5 | 70.4 | 70.3 | 64.3 | 64.4 | 22.37 | 21.86 | 23.75 | 23.50 |
| | T2 | 80.3 | 80.3 | 71.1 | 71.0 | 68.1 | 68.4 | 19.24 | 19.32 | 25.91 | 25.88 |
| | T3 | 81.3 | 81.0 | 71.9 | 71.7 | 67.0 | 67.2 | 18.18 | 18.12 | 24.69 | 24.81 |
| | T4 | 81.0 | 81.0 | 72.1 | 72.1 | 67.0 | 67.3 | 18.12 | 18.06 | 26.44 | 27.08 |
| | T5 | 80.1 | 80.5 | 72.0 | 71.9 | 67.8 | 68.3 | 18.21 | 18.22 | 25.43 | 25.77 |
| | T6 | 80.5 | 80.3 | 71.9 | 71.8 | 66.7 | 66.7 | 18.88 | 18.91 | 25.54 | 25.68 |
| | T7 | 80.9 | 80.9 | 72.1 | 72.2 | 68.3 | 68.3 | 18.71 | 18.67 | 25.87 | 26.25 |
| | T8 | 81.0 | 81.4 | 71.5 | 71.6 | 67.8 | 68.3 | 18.11 | 18.07 | 27.46 | 27.99 |
| | T9 | 81.0 | 81.0 | 71.5 | 71.8 | 69.4 | 69.4 | 18.47 | 18.43 | 32.48 | 32.20 |
| L.S.D at 0.05% | A | Sig. | Sig. | NS | NS | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. |
| | B | 1.19 | 1.10 | 1.01 | 1.10 | 1.83 | 2.04 | 0.47 | 0.62 | 0.65 | 0.45 |

*** control (T1), 100% soil application RFD (T2), foliar Zn application rates of 12.5% (T3), 25% (T4), 50% (T5), HA (T6), 12.5%+HA (T7), 25%+HA (T8) and 50%+HA (T9) from Zn RFD.**

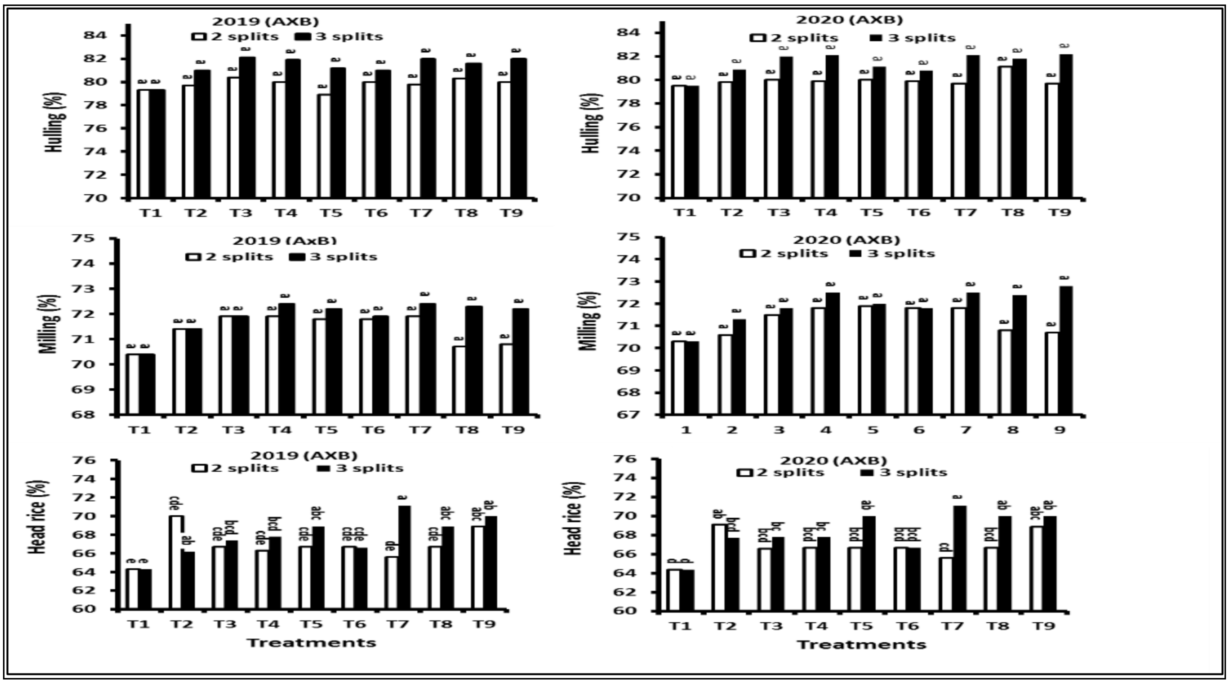


**Fig. 5. The interaction between splits and rates of zinc foliar application with humic acid on hulling %, milling % and head rice % of rice grain during 2019 and 2020 seasons. Different letters indicate significant differences by the least significant difference (LSD) at p< 0.05.**

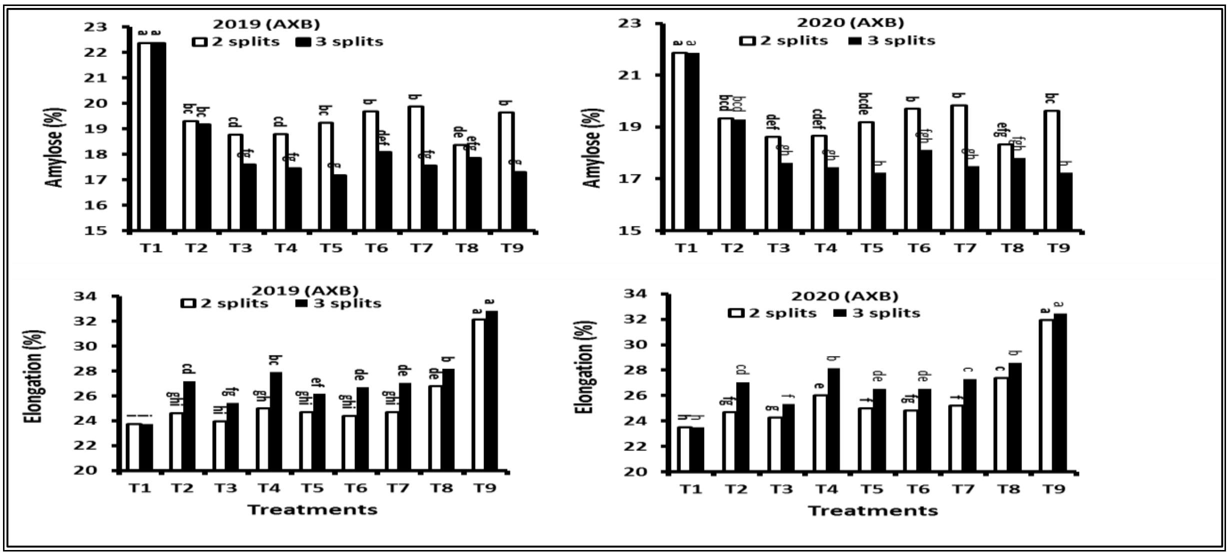


**Fig. 6. The interaction between splits and rates of zinc foliar application with humic acid on amylose % and elongation % of rice grain during 2019 and 2020 seasons. Different letters indicate significant differences by the least significant difference (LSD) at $p< 0.05$.**

The improvement in rice quality parameters might be due to the favorable effect of zinc fertilizer and humic acid application on grain quality characters by improved rice growth and current photosynthesis and its translocation to rice grain resulting into higher biomass production (Shivay, *et al.*, 2008; Pooniya, *et al.*, 2012 and Shivay, *et al.*, 2015) and enhanced grain filling and starch cell of endosperm which improve rice grain quality (Shivay and Prasad, 2012).

Zinc may be cause rice grains to be high filling with maximum density of starchy indosperm of grain led to minimize the thickness and weight of hull consequently increase both hulling and milling percentage. The increase in hardness of the rice grain plays an active role in improving the head rice yield. Moreover, the moisture content in grain or the good storage strongly increases the head rice. These results are in agreement with those found by (Gewaily *et al*., 2018 and Zohoun *et al*., 2018).

Amylose content strongly influences the cooking and eating characteristics of rice. Amylose content higher than 25% gives non-sticky soft rice, whereas rice with intermediate amylose content (20-25% ) tends to be softer and relatively sticky cooked rice and rice with a low amylose content (< 20%) is generally quite soft and sticky (Dipti *et al.,* 2002). Amylose content is important because firmness and stickiness are two properties of cooked rice that influence consumer preference for, and use of different classes of rice. Panhwar *et al.* (2015) and Ghasal *et al.* (2016) reported that application of Zn resulted in better in improving rice cooking and eating quality parameters. Elongation percentages is defined as the ratio of length of cooked rice grain to the length of milled rice grain (El-Kady, 1992) So, elongation is the expansion of rice grains upon cooking. Grain elongation is considered important cooking quality for some special consumers.

## CONCLUSION

Applications of foliar zinc fertilizers with humic acid were found to be beneficial for rice plant growth parameters, enhancing rice yield production and grain quality. Three splits of fertilizers were more effective than two splits. Approximately, 50% RFD was at par with soil application of traditional 100% RFD in the most of studied parameters.

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**Author's Contributions**

Rabeh, H.A.: Contributed to research planning and designing, collect samples, introduction, data analysis, results, discussion and conclusion.

Abd El-Salam, R.M.: Designed to collect samples and re-write introduction, methodology, results and discussion and conclusion part.

Badawy, S. H: reviewed introduction, results, discussion and conclusion.

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## تأثير عدد مرات ومعدلات اضافة الزنك وحامض الهيومك رشا على نمو ومحصول وجودة حبوب الأرز المزروع بدارا فى منطقة شمال الدلتا بمصر

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**[1] قسم المحاصيل – كلية الزراعة – جامعة القاهرة**

**[2] فسم الاراضى – كلية الزراعة – جامعة القاهرة**

أجريت التجارب الحقلية في موسمين متتاليين (2019 و 2020) بمحافظة كفر الشيخ - مصر ، بهدف معرقة تأثيرعدد مرات ومعدلات اضافة الزنك رشا بدون أو مع حمض الهيوميك على نمو ومحصول وجودة حبوب الأرز المنزرع بدار. استخدم تصميم القطع المنشقة وفق تصميم القطاعات الكاملة العشوائية فى ثلاث مكررات. تضمنت المعاملات عدد مرات الاضافة في القطع الرئيسية وتسعة معدلات اضافة شملت: معاملة المقارنة (م1)، 20 كجم/فدان من كبريتات الزنك تمثل 100% للجرعة الموصى بها كإضافة أرضية (م2) ، معدلات الرش الورقية للزنك بنسبة 12.5٪ (م3) ، 25٪ (م4) و 50٪ (م5) من الجرعة الموصى بها ، معاملة حامض الهيومك (م6) ، معدلات الرش الورقية للزنك بنسبة 12.5٪ (م7) ، 25% (م8) و 50% (م9) من الجرعة الموصى بها + حامض الهيومك في القطع المنشقة. أظهرت النتائج المتحصل عليها أن إضافة الزنك الورقي ثلاث مرات أعطت قيم صفات نمو ومكونات محصول وجودة حبوب الأرز أعلى من الاضافة مرتين. وان زيادة معدلات إضافة الزنك الورقي بدون أو مع حامض الهيومك أدت الى زيادة معنوية (P <0.05) في صفات النمو، حيث كانت أعلى زيادة كمتوسط لقيم ارتفاع النبات (7.8٪)، عدد الأفرع/ متر مربع (16.5٪) عند 25٪+ حامض الهيومك بينما كانت الزيادة فى دليل مساحة الورقة (22.3٪) ومحتوى الكلوروفيل (15.8٪) عند 50٪ + حامض الهيومك مقارنة بالكنترول. وكانت أعلى طول دالية (19.6 سم)، وزن الدالية (2.29 جم)، عدد الحبوب الممتلئة/الدالية (104.9)، محصول الحبوب (4.12 طن/فدان)، دليل الحصاد (47.9%)، نسبة الاستطالة (32.6٪) و نسبة الحبوب السليمة (69.4%) ظهرت عند الرش بالزنك بمعدل 50٪ مع حامض الهيومك كمتوسط لكلا الموسمين.