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The Role of Sprayer`s Characteristics and Foliar Spraying for Improving the Maize Growth and Yield

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Abstract: The field experiment was performed during the autumn growing season 2019 in Al Khyoot village of the Qurna town which is located at 75 km northern Basrah city centre. For improving the maize growth and yield, the effect of foliar spraying with iron and zinc and the most important technological characteristics of the knapsack sprayer such as nozzle types was studied. Three nozzle types were investigated as standard Flat fan nozzle, Hollow cone nozzle, and Tip nozzle (as reference nozzle in this study). Three foliar concentrations (0, Zn30 + Fe100 and Fe100+ Zn30) as well as a 16- litre capacity of the knapsack sprayer were used for fertilizer spraying experiments. All field experiments were carried out using the complete randomized block design (RCBD) with three replications. The results of the statistical analysis showed that there was a significant effect of the nozzle type and foliar spraying on the plant growth and yield characteristics as plant height, stem diameter, number of leaves, leaf area, number of grains, and yields (152.39 cm, 1.88 cm, 13.98, 4559 cm^2, 376.51 and 5.51 Mg ha^{-1} respectively). Also, these characteristics showed an increase percentage as following (2.79%, 2.25%, 0.60%, 3.11%, 3.70%, and 1.73% respectively) when the hollow cone nozzle was used compared to the reference nozzle. In addition, an interaction between the studied factors also appeared a significant difference in the grain number and yield characteristics.

Keywords: Knapsack sprayer, nozzles, Micronutrients, Maize.

Introduction

Maize crop (*Zea mays* L.) considers one of the most important cereal crops grown in the large areas of Iraq. It is a global and local economic crop coming as a third plant after wheat and barley crops and the first in the term of grain yield (FAO, 2015). It is also estimated as multi-benefit crop for human and animal nutrition containing high amounts of vitamins (Al-Dogachi *et al*., 2015; Mandic *et al*., 2016). However, this crop is sensitive for nutrients deficiency especially the micronutrients during the growth, flowering, and harvest stages (Palai *et al*., 2020). Among of the most important micronutrients required in sufficient quantities during the crop growth stages are iron and zinc. They are essential elements for the metabolic processes of the plant (Marschner, 2012). The role of zinc is necessary for nitrogen building, absorption, protein quality, chlorophyll synthesis, and carbonic anhydrase enzyme activity

(Suganya et al., 2020). It also has an effective role in the production of biomass as a consequence of its resistance against oxidative damage. For iron, it plays a prominent role in the chlorophyll building and synthesis of the electron- transporting proteins such as cytochrome (Soleymani & Shahrajabian, 2012).

The maize crop cultivation directly relates to variety of factors including environmental conditions, crop variety, physical and chemical soil properties, and others. Therefore, the crop production still diminishes in the Iraqi fields compared to the global production. In Iraq, the total cultivation area of this crop was estimated at approximately 515,160 donums with a total yield of about 1.1757 tons. don^{-1}(CSO, 2019). Improving the total yield should compensate for the deficiency of necessary nutrients at the different growth stages using traditional or foliar spraying methods. The foliar method is directly applied on the leaves of the plant and has advantages including reducing the percentage of the losses and increasing the absorption rate especially in suitable conditions for spraying as temperature, relative humidity, and wind speed (Ferandez *et* al., 2013). During the foliar spraying, the spray droplet size determines the deposited amount of the micronutrients to deliver into the plant. On the other hand, selecting the appropriate nozzle type for spraying is another important factor to compensate for the deficiency of nutrients (Rajawat, 2019; Farias *et al*., 2020) as a result of controlling droplets size and impacted droplet numbers. There are three common nozzle types used in the fields including a flat fan nozzle, hollow cone nozzle, and tip nozzle. The first type produces droplet sizes ranged from medium to coarse with a low coverage percentage in comparison to other types; The second type is characterized by smaller droplet sizes with greater coverage percentage than the first type; The third nozzle type produces droplet characteristics intermediate between the two previous types (Grisso *et al*., 2013). Thus, the aim of present study is focusing on the foliar spraying method using different nozzle types that play important role in the micronutrients absorption by the plants as a first attempt for improving the characteristics of maize growth and yield

Materials & Methods

Site of the field experiments

A field experiment was performed in one of the farmers' fields located in the Al-Khyoot Village, Qurna town, northern Basrah city (31º02'27''N, 47º25'37''E), during the autumn agricultural season 2019 to study the effect of the factors represented by the different nozzle types and foliar spraying using zinc and iron for improving the characteristics of maize growth and yield (*Zea mays* L.). For the cultivation of the maize, the field was prepared then the soil samples were randomly taken at a depth from 0-30 cm to investigate some physical and chemical properties of the soil as shown in table (1).

Table (1): Some physical and chemical properties of the studied soil

Character		Mean value	Measuring unit
Electrical Conductivity (EC)		8.20	dS. m^{-1}
Soil pH		8.12	-
Organic Matter (OM)		1.03	g. kg^{-1}
Total available of	N	31.02	g. kg^{-1}
	P	15.32	g. kg^{-1}
	K	76.46	g. kg^{-1}
	Fe	2.26	g. kg^{-1}
	Zn	0.32	g. kg^{-1}
Soil structure (clay loam)	Sand	214.20	g. kg^{-1}
	Silt	326.19	g. kg^{-1}
	Clay	459.61	g. kg^{-1}

Knapsack sprayer properties

The foliar spraying application was carried out using a knapsack sprayer with a capacity of 16 litres in all field experiments as shown in fig. (1). This sprayer is available in the local Iraqi markets, cheap price, easy to maintain, and has small number of moving parts, in addition to its large use by farmers in the small and medium fields. The most important characteristics of the knapsack sprayer are shown in table (2).

Fig. (1): A side view of the knapsack sprayer.

Table (2): Main characteristics of the knapsack sprayer.

Model	Max. tank capacity (l)	Number of nozzle	Power type	Piston pump location	Color
XF-16B	16	1	Manual	Internal	Blue

According to the study of Alheidary *et al*. (2019), all spraying processes in the present study using knapsack sprayer achieved at a nozzle height of 25 cm from the top of plant as shown in fig. (2) and 2 bar as a maximum operating pressure.

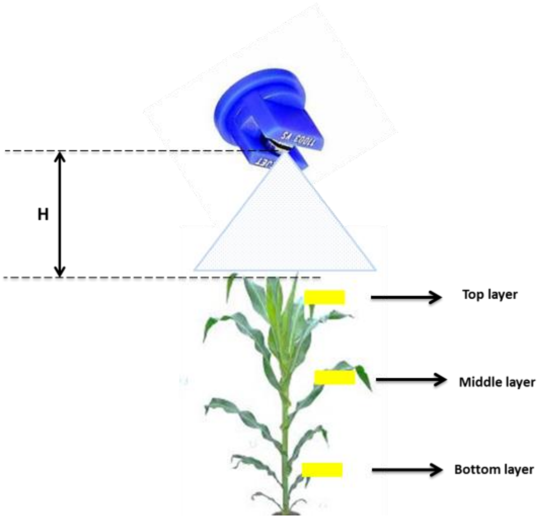

Fig. (2): Diagram of the maize plant and the nozzle height during field spraying.

Experimental setup of the treatments

The field experiment included experimental units for maize cultivation on 1/8/2019. The recommended traditional fertilization was applied by adding 240 kg N. ha^{-1} with 100 kg. K. ha^{-1} to the soil in three equal steps. The first addition was supplemented at soil preparing for cultivation. The second and third additions were done at the vegetative growth stage (after 21 days of planting) and at the beginning of flowering stage respectively (Elsahookie & Cheyed, 2013). For the phosphorus, 120 kg P ha^{-1} was added one time to the soil at planting.

After that, the spray was performed using foliar spraying. The spray treatments consisted of four different concentrations of zinc and iron as following: Control (F1) contains water only, the second concentration (F2) contains 30 mg. L^{-1} Zinc, the third (F3) contains 100 mg. L^{-1} Fe, and the fourth (F4) contains 30 mg. L^{-1} Zn and 100 mg. L^{-1} Fe. The plant was treated with these concentrations three times at different growth stages. When the plant contained 6-8 leaves, the first spray was accomplished. While, the second spray was carried out in the flowering stage (the plant contains about 12-15 leaves). When the plant reached to the stage of grains (12-15 leaves), the fourth spray was carried out. All foliar spraying processes were performed during the early morning because of a low temperature, a high relative humidity and a stable wind speed to reduce the spray evaporation at the time of spraying or after. Thereby, this allows the stomata on the leaves to absorb the droplets.

The second factor in this study was the nozzle type which was mounted on the knapsack sprayer. Three nozzles types were investigated including a Tip nozzle (N1) considered as a reference nozzle in the present study. The other types were standard flat fan nozzle (N2) and hollow cone nozzle (N3). These nozzle types have differences in the flow rate, droplet size, spray pattern, and application rate (Table 3). All these types are shown in the fig. (3). At the end of agricultural season, the maize harvesting was on 16/11/2019.

Fig. (3): A side view of the nozzle types used in the foliar spraying.

Table (3): Nozzles characteristics.

Nozzle type	Nozzle angle size	spray swath (cm)		application rate (L. ha^{-1})
		Theoretical	Actual	
Flat fan	110-03	71.41	70	453.65
Hollow cone	80-03	41.95	39	224.39
Tip nozzle(Reference)	80-04	41.95	40	419.51

Properties of the spray droplets

The properties of spray droplets were measured using water paper cards (5 x 8.5 cm) in both the field and laboratory. White paper cards (WPCs) were placed on the plant at different levels (top, middle, and bottom) as shown in the fig. (4) to calculate the sedimentation rate obtained on the plant and determine the density of the droplets.

Fig. (4): Positions of the WPCs on the plant.

For measuring the properties of the spray droplets in the control treatment (size; µm, density; number. cm^{-2}, coverage percentage) that deposited on the WPCs, brilliant sulfa flavin tracer (1gm. L^{-1}) was used. After completing the foliar spraying in the field, the WPCs were left on the plant for 15min to dry the deposited droplets and then the data were recorded. After that, the WPCs were kept in a box and then analyzed in the laboratory using Image J software after scanner it with a HP scanner. The spray droplets properties were calculated according to the studies of Alheidary (2018, 2019)

Meteorological conditions

The weather conditions such as temperature, relative humidity, and wind speed were recorded at the same time of foliar spraying using the meteorological device (Anemometer), Model MS 6253B with accuracy of ∓0.02 (Fig. 5).

Fig. (5): A side view of the anemometer device.

This device has important features including data storage in the device's memory, transferring and storing data on a computer through a special program, and it is possible to deal with data statistically. The weather data were represented in the table (4).

Table (4): Weather data during foliar spraying.

Date of the field spraying	Average temperature ºC	Average relative humidity (%)	Average wind speed ($km.h^{-1}$)
1 Sept. 2019	31	44	15
2 Oct. 2019	29	42	11
23 Oct. 2019	28	36	10

Statistical analysis

The experiments were designed using a complete random block design (R.C.B.D) then data were analyzed using Genstat software and the differences between the treatments were statistically analyzed using L.S.D test at a level 0.05 to show the significant differences among them.

Results & Discussion

Properties of spray droplets

Table (5) illustrated the results of spray droplets properties including size, coverage percentage, and d density on the WPCs samples at three positions of the plant (top, middle, and bottom). There were significant differences in these properties due to the differences in nozzle types. Higher droplet size (240µm) and lower spray coverage percentage (5.54%) recorded in the samples of WPCs using flat fan nozzle that led to reduce in the density of droplet per centimeter square (4.26 droplet. cm^{-2}) comparing to other nozzles. The reason behind that is the large size and high speed of droplets leading to acceleration them then the spray droplets have not a sufficient time to impact WPCs.

Table (5): The average and SD values of the spray droplet properties at different positions of the plant based on nozzle type.

Nozzle type		Droplet size (µm)	Spray coverage %	Droplet density ($number.cm^{-2}$)
Flat fan nozzle	Top	240^{a}±3.63	10.6^{cd}±0.67	4.26^{e}±0.75
	Middle	165^{d}±9.25	7.66^{de}±0.56	4.26^{e}±0.58
	Bottom	137.66^{f}±3.64	5.54^{e}±0.67	7.34^{c}±0.51
Hollow cone	Top	199^{c}±4.05	33.36^{a}±2.72	8.02^{c}±1.84
	Middle	133.7^{f}±7.6	21.26^{b}±0.25	8.02^{c}±0.73
	Bottom	120.6^{h}±4.05	18.67^{b}±2.72	10.92^{a}±0.93
Tip nozzle	Top	214^{b}±7.28	12.06^{c}±0.18	5.25^{d}±0.87
	Middle	154^{e}±7.2	8.22^{de}±0.46	5.25^{d}±0.87
	Bottom	126.2^{g}±7.28	7.96^{de}±0.19	9.53^{b}±1.28

Whereas, the smallest spray droplets can impact WPCs (Minov *et al.*, 2016; Alheidary, 2019). The results also showed that these properties were significantly affected by the positions of WPCs on the plant. Higher values of the droplet size, coverage percentage, and droplet density were observed on the top WPCs compared to other positions (42.65%, 47.73%, and 41.96% respectively) for all studied nozzle types. This result is axiomatic; the top position of the plant is closed to the nozzle orifice.

Characteristics of the plant growth and yield

Plant height

The results of statistical analysis showed that plant height was significantly affected by adding zinc, iron, or both together (136.72, 142.44, and 152.39 cm) respectively. These values exceeded from the control treatment with increase percentages 6.15, 1.60, and 18.32% respectively. These increases are due to the effective role of the zinc and iron in many vital processes of the plant including chlorophyll synthesis, maintaining the chloroplasts composition, building and activating many enzymes such as cytochrome which is necessary for photosynthesis, and tryptophan synthesis which is responsible for the oxen hormone production and stimulation of the cell elongation (Taghi Tavakoli *et al*., 2014). Also, the outcomes appeared no significant difference between the foliar spraying of F2 (zinc only) and F4 (zinc and iron). As well as, the F2 did not significantly differ from F3 (iron only). This result agrees with the results of many researchers (Iqbal *et al.*, 2019; Xia *et al.*, 2019). For the nozzle type effect, the table (6) illustrated that the nozzle type has a significant effect on the plant height. The highest average of the height (143.66 cm) was recorded by using a hollow cone nozzle (N3) with a significant increase percentage from tip nozzle (N1) and flat fan nozzle (N2) (2.79% and 4.98% respectively). The variation in the values is due to the different designs of the nozzles that led to differences in the properties of spray droplets deposited on the leaves of the plant. Thereby, the N3 exceeded because it can provide the leaves with an appropriate size, density, and coverage percentage of the droplets included the iron and zinc that are easily absorbed via stomata for critical processes of the plant (Rodrigues, 2018). The results also appeared no interactive effect on the plant height between the foliar spraying and nozzle types.

Table (6): Correlation between foliar spraying and nozzle types in the plant height.

Foliar spraying	Nozzle type					
	N1	N2	N3	Average	SD	CV%
F1	129.72^{fg}	129.60^{fg}	127.05^{g}	128.79^{c}	±1.23	0.96%
F2	136.65^{ef}	133.57^{efg}	139.93^{cde}	136.72^{bc}	±2.59	1.90%
F3	142.03^{bcd}	137.69^{def}	147.61^{bc}	142.44^{b}	±4.06	2.85%
F4	150.62^{b}	146.50^{bcc}	160.05^{a}	152.39^{a}	±5.67	3.72%
Average	139.75^{b}	136.84^{b}	143.66^{a}			
	7.95	3.34	ns			

N1: Tip nozzle, N2: Flat fan nozzle, N3: Hollow cone nozzle, and CV: Coefficient variance

Stem diameter

Stem diameter was significantly influenced by the foliar spraying, nozzle types, and their interaction (Table 7). The foliar spraying with a mixture of zinc and iron (F4) significantly increased the stem diameter (1.88 cm as the highest average) with an increased percentage (13.25%) compared to others. This increase is similar to the findings of some studies (Kumar & SR, 2018; Sudhagar *et al*., 2019; Rafsanjani *et al*., 2019) as a consequence of the enhancement of plant efficiency to absorb the water and necessary nutrients via stomata for critical vital processes such as increasing the photosynthesis and nitrogen thereby increasing vegetative growth.

For the nozzle type effect, the stem diameter was also affected by the nozzle type. The hollow cone nozzle type (N3) recorded the highest average (1.82 cm) of stem diameter with an increasing percentage of 2.25% in comparison to others. The optimal size, density, and coverage percentage of droplets deposited on the leaves by using a hollow cone nozzle in the spraying enhance the absorption of important nutrients to increase the vegetative growth including stem diameter (Forney *et al*., 2017).

Table (7): Correlation between foliar spraying and nozzle types in the stem diameter.

Foliar spraying	Nozzle type					
	N1	**N2**	**N3**	**Average**	**SD**	CV%
F1	1.67^{g}	1.63^{g}	1.66^{g}	1.66^{d}	±0.02	1.00%
F2	1.75^{def}	1.70^{efg}	1.79^{cd}	1.75^{c}	±0.04	2.19%
F3	1.80^{cd}	1.75^{def}	1.86^{bc}	1.80^{b}	±0.04	2.49%
F4	1.89^{ab}	1.78^{cde}	1.97^{a}	1.88^{a}	±0.08	4.00%
Average	1.78^{a}	1.72^{b}	1.82^{a}			

N1: Tip nozzle, N2: Flat fan nozzle, N3: Hollow cone nozzle, and CV: Coefficient variance

The same table (7) also showed that there was no interaction between the foliar spraying and nozzle type in their effecting on the stem diameter.

Number of leaves

The results as shown in the table (8) showed significant differences in the leaves number using foliar sprayings and different nozzle types. The spraying with Zn and Fe (F4) recorded the highest average of the leaves number (13.98) compared to the others, but F4 did not significantly differ from spraying of the iron only (F3). This result is in agreement with the results of(Eskandari, (2011) and Arak (2017). It is normal, the leaves number increases by absorbing the zinc and iron which supports photosynthesis.

Also, the results in table (8) revealed the prominent role of the nozzle type in influencing the leaves' number. As usual, the hollow cone nozzle type (N3) significantly appeared the largest number of leaves compared to the others. The results of Guler *et al*. (2012) conformed to the results of this study. It is noteworthy there was no interaction between the foliar spraying and nozzle type in the effecting on the leaves number.

Table (8): Correlation between foliar spraying and nozzle types in the number of leaves

Foliar spraying	Nozzle type					
	N1	**N2**	**N3**	**Average**	**SD**	CV%
F1	12.26^{g}	12.22^{g}	12.24^{g}	12.24^{d}	±0.02	0.14%
F2	13.31^{e}	13.11^{f}	13.43^{de}	13.28^{c}	±0.13	0.99%
F3	13.59^{cd}	13.39^{e}	13.69^{bc}	13.56^{b}	±0.13	0.92%
F4	14.01^{a}	13.79^{b}	14.13^{a}	13.98^{a}	±0.14	1.03%
Average	13.29^{b}	13.13^{c}	13.37^{a}			

N1: Tip nozzle, N2: Flat fan nozzle, N3: Hollow cone nozzle, and CV: Coefficient variance

Leaf area

As shown in table (9), leaf area was significantly affected by foliar spraying and nozzle type. The highest average of leaf area recorded 4559 cm^2 and 4243 cm^2 for F4 (the foliar spraying with zinc and iron) and N3 (hollow cone nozzle) respectively in comparison to the others. This increase is caused by the same effective role previously mentioned of both zinc and iron deposited on the leaves by using a hollow cone nozzle. This result is in agreement with some previous studies (Anees *et al*., 2016; Liu *et al*., 2016; Saleem *et al*., 2016; Shivay *et al*., 2016; Alheidary, 2019).

Table (9): Correlation between foliar spraying and nozzle types in the leaf area.

Foliar spraying	Nozzle type					
	N1	**N2**	**N3**	**Average**	**SD**	CV%
F1	3584^{ef}	3561^{f}	3439^{f}	3528.00^{c}	±63.63	1.80%
F2	4042^{cde}	3837^{def}	4321^{abc}	4066.67^{b}	±198.36	4.88%
F3	4321^{abc}	4151^{bcd}	4467^{abc}	4313.00^{ab}	±129.13	2.99%
F4	4513^{ab}	4421^{abc}	4744^{a}	4559.33^{a}	±135.87	2.98%
Average	4115^{ab}	3992^{b}	4243^{a}			

N1: Tip nozzle, N2: Flat fan nozzle, N3: Hollow cone nozzle, and CV: Coefficient variance

In the context of the interaction, the foliar spraying and nozzle type no significantly interaction between them in effecting on the leaf area. Although, the highest percentage (32.35%) was between F4 and N3 compared to the others.

Grains number and yield

The finding of this study related to grains number and yield as shown in the tables (10 and 11) revealed a significant effect of F4 (the foliar spraying with zinc and iron) and N3 (the hollow cone nozzle type) on both of the number and yield of the grains. The largest number (376.51 as average) and yield amount (5.51Mg. ha^{-1} as average) of grains using foliar spraying in comparison to the others. When the nozzle type studied by fixing the foliar spraying, the hollow cone nozzle scored the largest average of the number (374.19) and the yield (5.15 Mg. ha^{-1}) comparing to the other nozzles. For explanation, this result, increasing the vegetative growth as a result of the abundance of nutrients using F4 and N3 that led to an increase in the number and yield of the grains (Czaczyk, 2012; Farshid, 2012; Alheidary, 2018; Filipović *et al*., 2019). Herein, the foliar spraying and nozzle type also interacted in their effect on both the number and yield of the grains. The largest average of number and yield recorded 392.51 and 5.66 Mg. ha^{-1} respectively for the interaction between the F4 and N3.

Table (10): Correlation between foliar spraying and nozzle types in the grain number.

Foliar spraying	**Nozzle type**					
	N1	**N2**	**N3**	**Average**	**SD**	**CV%**
F1	300.64^{g}	295.56^{g}	310.77^{fg}	302.32^{c}	±6.32	**2.09%**
F2	332.75^{de}	321.54^{ef}	337.55^{de}	330.61^{b}	±6.71	**2.03%**
F3	340.87^{cd}	329.51^{de}	357.87^{bc}	342.75^{b}	±11.65	**3.40%**
F4	374.57^{b}	362.46^{b}	392.51^{a}	376.51^{a}	±12.34	**3.28%**
Average	337.21^{b}	327.27^{c}	349.67^{a}			

N1: Tip nozzle, N2: Flat fan nozzle, N3: Hollow cone nozzle, and CV: Coefficient variance

Table (11): Correlation between foliar spraying and nozzle types in the grain yield

Foliar spraying	Nozzle type					
	N1	**N2**	**N3**	**Average**	**SD**	CV%
F1	4.15^{e}	4.07^{e}	4.21^{e}	4.14^{c}	±0.06	1.38%
F2	4.63^{cd}	4.51^{d}	4.70^{cd}	4.62^{b}	±0.08	1.67%
F3	4.72^{cd}	4.63^{cd}	4.80^{c}	4.72^{b}	±0.07	1.44%
F4	5.53^{ab}	5.34^{b}	5.66^{a}	5.51^{a}	±0.13	2.39%
Average	4.76^{b}	4.64^{c}	4.84^{a}			

N1: Tip nozzle, N2: Flat fan nozzle, N3: Hollow cone nozzle, and CV: Coefficient variance

Conclusions

This current study unveiled from the robust correlation between the foliar spraying and nozzle type in effecting positively on the growth and yield characteristics of the maize crop. The foliar spraying with zinc and iron by using a hollow cone nozzle emerges as a potential method for improving the vegetative growth and yield. These results will contribute to enhancing the qualitative production of the maize crop by selecting the appropriate nozzle type for foliar spraying.

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Conflicts of interest

The authors declare that they have no conflict of interests.

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References

Al-Dogachi, K. A. J., Al-Asady, K. K., & Askar, M. A., (2015). Effect of nitrogen fertilizer and spraying with iron growth and yield for corn *Zea mays* L. *Basrah Journal of Agricultural Sciences 28*. 56-66. https://www.iasj.net/iasj?func=issueTOC&isId=7981&uiLanguage=ar

Alheidary, M. H. R. (2018). Effect of the operating pressure and nozzle height on droplet properties using knapsack sprayer. *Iraqi Journal of Agricultural Sciences*, *49*, 360–366. https://doi.org/10.36103/ijas.v49i3.105.

Alheidary, M. H. R. (2019). Influence of nozzle type, working pressure, and their interaction on droplets quality using Knapsack sprayer. *Iraqi Journal of Agricultural Sciences, 50,* 857–866. https://doi.org/10.36103/ijas.v50i3.702.

Alheidary, M. H. R., Al-shaheen, M. Sh. R., & Abdulah, S., A. M. (2019). Sprayer setup and foliar application effect on maize growth characteristics using different urea concentrations. *Farm Machinary and Processes Management in Sustanable Agriculture*. vol? 19-23. DOI:10.24326/fmpmsa.2019.1.

Anees, M. A., Ali, A., Shakoor, U., Ahmed, F., Hasnain, Z., & Hussain, A. (2016). Foliar applied potassium and zinc enhances growth and yield performance of maize under rainfed conditions. *International Journal of Agriculture and Biology*, *18*, 1025–1032. https://doi.org/10.17957/IJAB/15.0204

Arak, R. (2017). Response of some vegetative growth ponitars maize zea mays l. To spray potasium and zinc. *Journal Kerbala of Agricultural Sciences, 4*., 74–87. https://jkas.uokerbala.edu.iq/article_160313.html

CSO, (2019). Central statistical organization, Ministry of planning, Iraq. http://cosit.gov.iq/

Czaczyk, Z. (2012). Spray classification for selected flat fan nozzles. *Journal of Plant Protection Research*, *52*, 180–183. https://doi.org/10.2478/v10045-012-0027-2Elsahookie, M. M., & Cheyed, S. H. (2013). Tables to estimate maize leaf area by measuring one leaf length. *Iraqi Journal of Agricultural Sciences 44,* 164–167. https://www.iasj.net/iasj?func=issueTOC&isId=4350&uiLanguage=ar

Eskandari, H. (2011). The importance of iron (Fe) in plant products and mechanism of its uptake by plants. *Journal of Applied Environmental and Biological. Sciences, 1*, 448–452. https://www.textroad.com/JAEBS-October,%202011.html

FAO. (2015). FAOSTAT. Online statistical database: Production (available at http://faostat3.fao.org/download/Q/QC/E).

Farias, M. A. G. L., Raetano, C. G., Chechetto, R. G., Ferreira-Filho, P. J., Guerreiro, J. C., Bonini, C. S. B., Firmino, A. C., Lima, R. C., & Prado, E. P. (2020). Spray nozzles and droplet size effects on soybean canopy deposits and stink bugs control in west region of São Paulo state- Brazil. *Phytoparasitica*, *48*, 203–213. https://doi.org/10.1007/s12600-020-00786-8

Farshid, A. (2012). Manganese, iron and copper contents in leaves of maize plants (*Zea mays* L.) grown with different boron and zinc micronutrients. *African Journal of Biotechnology*, *11*(4). https://doi.org/10.5897/AJB11.165

Fernandez, V., Sotiropoulos, T., Brown, P. (2013). Foliar fertilization scientific principles and field practices. International fertizer Industry association (IFA), Paris, France. PP.78. https://www.fertilizer.org/images/Library_Downloads/2013_foliar_fertilization_HR.pdf

Filipović, A., Stanić, G., Kajić, N., Mandić, A., & Vasilj, V. (2019). Production of forage maize yield under the zinc foliar fertilization and irrigation system. *Agriculturae Conspectus Scientificus*, *84,* 159–164. https://hrcak.srce.hr/acs

Forney, S. H., Luck, J. D., Kocher, M. F., & Pitla, S. K. (2017). Laboratory and full boom-based investigation of nozzle setup error effects on flow, pressure, and spray pattern distribution. *Applied Engineering in Agriculture*, *33*, 641–653. https://doi.org/10.13031/aea.12043

Grisso, R., Hipkins, P., Askew, S. D., Hipkins, L., &

Mccall, D. (2013). Nozzles : Selection and Sizing. *Verginia Corporative Extension*, *12*. https://doi.org/doi:http://pubs.ext.vt.edu/442/442-032/442-032_pdf.pdf

Guler, H., Zhu, H., Ozkan, H. E., & Ling, P. (2012). Characterization of hydraulic nozzles for droplet size and spray coverage. *Atomization and Sprays*, *22*, 627–645. https://doi.org/10.1615/AtomizSpr.2012006181

Iqbal, M. A., Abdul, H., Muzammil, H. S., Imtiaz, H., Tanveer, A, Saira, I., & Anser, A. (2019). A meta- analysis of the impact of foliar feeding of micronutrients on productivity and revenue generation of forage crops. *Planta Daninha*, *37*. e019189237. https://doi.org/10.1590/s0100-83582019370100046

Kumar, N., & SR, S. (2018). Agronomic Biofortification of Maize with Zinc and Iron Micronutrients. *Modern Concepts & Developments in Agronomy*, *1*. https://doi.org/10.31031/mcda.2018.01.000522

Liu, H., Gan, W., Rengel, Z., & Zhao, P. (2016). Effects of zinc fertilizer rate and application method on photosynthetic characteristics and grain yield of summer maize. *Journal of Soil Science and Plant Nutrition*, *16*, 550–562. https://doi.org/10.4067/S0718-95162016005000045

Mandic, V., Bijelic, Z., Krnjaja, V., Tomic, Z., Stanojkovic-Sebic, A., Stanojkovic, A., & Caro-Petrovic, V. (2016). The effect of crop density on maize grain yield. *Biotechnology in Animal HusbandryBiotehnologija u Stocarstvu*, *32*, 83–90. https://doi.org/10.2298/bah1601083m

Marschner, H. (2012). *Marschner's Mineral Nutrition of Higher Plants*. 3rd edition. School of Agriculture, Food and Wine, The University of Adelaide, Australia. https://doi.org/10.1016/C2009-0-63043-9

Minov, S. V., Cointault, F., Vangeyte, J., Pieters, J. G., & Nuyttens, D. (2016). Spray droplet characterization from a signle nozzle by high image analysis using an in-focus droplet criterion. *Sensors 16*, 218. doi: 10.3390/s16020218

Palai, J. B., Jena, J., & Lenka, S. K. (2020). Growth, yield and nutrient uptake of maize as affected by zinc application – A Review. *Indian Journal of Pure & Applied Biosciences*, *8*, 332–339. https://doi.org/10.18782/2582-2845.8054

Rafsanjani, K., Madani, A., & Vazin, F. (2019). Effect of iron on yield of corn (*Zea mays* L.) in drought stress. *Cercetari Agronomice in Moldova*, *52*, 34–43. https://doi.org/10.2478/cerce-2019-0004

Rajawat, M. S. (2019). Plant Nutrients and It's Impact. *ACTA SCIENTIFIC AGRICULTURE* 3(6), 31–33. DOI: 10.31080/ASAG.2019.03.0470

Rodrigues, A. de O. (2018). *The Effect of Physical application parameters on herbicide efficacy and droplet size*. Faculty of the Graduate College, University of Nebraska. Nebraska, U.S.A. PP.93. https://core.ac.uk/download/pdf/188132601.pdf

Saleem, A., Iqbal, A., & Fahad, S. (2016). Foliar phosphorus and Zinc application improve growth and productivity of maize (*Zea mays* L.) under moisture stress conditions in semi-Arid climates. *Journal of Microbial & Biochemical Technology*, *8*. DOI:10.4172/1948-5948.1000321

Shivay, Y. S., Prasad, R., & Singh, U. (2016). Micronutrient fertilizers for zinc and iron enrichment in major food crops: A practicable strategy. *In Biofortification of Food Crops* (pp. 229–236). https://doi.org/10.1007/978-81-322-2716-8_17

Soleymani, A., & Shahrajabian, M. H. (2012). The effects of Fe, Mn and Zn foliar application on yield, ash and protein percentage of forage sorghum in climatic condition of Eesfahan. *International Journal of Biology*, *4*. https://doi.org/10.5539/ijb.v4n3p92

Sudhagar Rao G.B., R. Rex Immanuel*, S. Ramesh, G. B., & S. M. S. (2019). Effect of zinc and iron fertilization on growth and development of rice. *Plant Archives*, *19*, 1877–1880. http://www.plantarchives.org/SPL%20ISSUE%20SUPP%202,2019/327%20(1877-1880).pdf

Suganya, A., Saravanan, A., & Manivannan, N. (2020). Role of zinc nutrition for increasing zinc availability, uptake, yield, and quality of maize (*Zea Mays L.*) grains: An overview. Communication in soil Science and Plant Analysis 51(15), 2001-2021. https://doi.org/10.1080/00103624.2020.1820030

Tavakoli, M. T., Chenari, A. I., Rezaie, M., Tavakoli, A., Shahsavari, M., & Mousavi, S. R. (2014). The importance of micronutrients in agricultural production. *Advances in Environmental Biology*, *8*, 31–35. http://www.aensiweb.net/AENSIWEB/aeb/aeb/June%202014/31-35.pdf

Xia, H., Kong, W., Wang, L., Xue, Y., Liu, W., Zhang, C., Yang., S., & Li, C. (2019). Foliar zn spraying simultaneously improved concentrations and bioavailability of zn and fe in maize grains irrespective of foliar sucrose supply. *Agronomy*, 9, 386. doi:10.3390/agronomy9070386

دور الخصائص التكنلوجية للمرشة والرش الورقي في تحسين صفات النمو والانتاج لمحصول الذرة الصفراء

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المستخلص: نفذت تجربة حقلية خلال الموسم الزراعي الخريفي 2019-2020 في منطقة الخيوط التابعة لقضاء القرنة 75 كم شمال محافظة البصرة، لدراسة تأثير اهم الخصائص التكنلوجية للمرشة والمتمثلة بنوع الفوهة والرش الورقي بالحديد والزنك في تحسين صفات النمو والانتاج لمحصول الذرة الصفراء(.*Zea mays* L) .اختبرت ثلاثة انواع من الفوهات وهي الفوهة المروحية والفوهة المخروطية المجوفة والفوهة الحلقية والتي اعتبرت فوهة مرجعية في هذه الدراسة. كما استخدمت اربعة تراكيز (0 , Zn30 , Fe100 , Zn30 + Fe100). استخدمت المرشة الظهرية ذات السعة 16 لتر في اجراء التجارب الزراعية بالرش الورقي. نفذت جميع التجارب الحقلية باستخدام تصميم القطاعات العشوائية الكاملة (R.C.B.D) ضمن نظام القطع المنشقة وبثلاثة مكررات. أظهرت نتائج التحليل الاحصائي لهذه الدراسة الى وجود تأثير معنوي لنوع الفوهة والرش الورقي بالحديد والزنك والخلط بينهما بين المعاملات التي درست. فقد تفوقت المعاملة الرش الورقي بالحديد والزنك في معظم الصفات المدروسة حقليا والتي أعطت أفضل المتوسطات في ارتفاع النبات وقطر الساق وعدد الأوراق والمساحة الورقية وعدد الحبوب والحاصل والتي بلغت 152.39 سم و 1.88 سم و 13.98و 4559 سم^2 و 376.51و 5.63 ميكا غرام.ه$^{-1}$ على التوالي. كما اظهرت النتائج ايضا الى تفوق المعاملة التي رشت بالفوهة من النوع المخروطي المجوف في معظم الصفات التي درست وبنسبة زيادة قدرها (3.5 و 3.29 و 0.58 و 9.14 و 9.41 و 8.19%) على التوالي عند المقارنة مع الفوهة المرجعية. اما التداخل بين العوامل المدروسة، فقد بينت النتائج ايضا الى وجود فارق معنوي في حاصل عدد الحبوب والحاصل الاجمالي عند استخدام الفوهة المخروطية المجوفة والرش الورقي بالحديد والزنك معا.

كلمات مفتاحية: المرشة الظهرية، الفوهة، عناصر صغرى، الذرة الصفراء.