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Determination of the Optimal Spraying Application Rate for Improving the Vegetative Growth of Maize Crop Using Knapsack sprayer

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Abstract: The most popular and efficient way for fertilization is soil application which needs to be applied in more significant quantities. Nevertheless, foliar fertilization is more practical and cost-effective in some situations. The main diagnostic methods for crop nutrients are foliar and soil fertilization tests to improve crop growth responses. Due to insufficient fertilizer application, particularly when utilizing the usual approach as a soil fertilizer addition, soil degradation will continue and become more expensive and impacting plant growth. To evaluate the influence on the maize vegetative growth, several NPK fertilizer levels were applied using foliar spraying, soil application and their combination treatments at different dosages. Experimental design was factorialal arrangement in a complete randomized block design (CRBD) with three replicates. Data analysis using Genstat softwar (Discovery edition3). The droplet properties such as volume median diameter, droplet deposition, uniformity, and coverage percentage are influenced by the layer of the plant canopy. In addition, the main growth characteristics of maize plants were measured. The upper layers of the plant canopy are the more in the spray deposition (0.529 $\mu l.cm^{-2}$), but the higher coverage percentage (33.36%) and the better deposition uniformity (5.54%) obtained in the bottom layers of the maize canopy. The findings demonstrate also a considerable increase in plant height, leaf number, leaf area, stem diameter, wet weight, dry weight, and percentage of N content in plants treated with foliar application and soil fertilization simultaneously (47.52cm, 14.98 $leaf.plant^{-1}$, 8077, 6.06cm, 52.13gm, 14.31gm, and 2.71%) respectively. The findings imply that soil fertilization and foliar spraying can be used to enhance maize growth.

Keywords: Droplet characteristics, Foliar spraying, Soil fertilizer, *Zea mays* L.

Introduction

Maize (*Zea mays L.*) is considered as one of the most important economic crops in the world after rice and wheat (FAO, 2023). Using chemical products as fertilizers in crop production is one of the most important factors in agricultural production (Bourodimos *et al.*, 2019). These products are administered directly to the soil or leaves using an appropriate manner in the application process to provide vital nutrients to the plant intended at various stages of growth. The crop output is significantly impacted by the addition of various fertilizer types when used properly (Alheidary *et al.*, 2020; Mulyati *et al.*, 2021; Wierzbowska *et al.*, 2022). Because of this, fertilizer applied to agricultural fields is seen to be a crucial component for increasing crop yield and consequently, raising global food production as the world's population continues to grow (Falls & Siegel, 2005). The majority of fertilizers come in a variety of forms and are utilized as N, P, and K fertilizers (Finch *et al.*, 2014). According to the crop type and the reason for planting, the conventional methods of adding these nutrients in many farms applied using soil fertilization two or three times (Baróg *et al.*, 2022). The method of soil fertilization has been widely utilized for a long time to provide mineral nutrients for roots. When soil is fertilized, crops typically cannot absorb the majority of the fertilizers; as a result, 80-90% of the phosphorus, 40-70% of the nitrogen, and 50-70% of the potassium are lost to the environment (Ombodi & Saigusa, 2008). This causes significant resource losses as well as environmental pollution. This method has the advantage of improving both vegetative growth and yield for the intended crop; however, it is more expensive and applied with higher amounts. So, there is an alternative method For evaluating the methods of fertilizer applications on the vegetative plant characteristics, especially with foliar application, The latest way is considered essential in the fields planted, especially by measuring the effects of different spray droplet sizes deposited on the leaves that contain the components of fertilizer added to the plant (Alheidary *et al.*, 2020).

In the agricultural spraying process, the spray droplets permeate the plant canopy depending on several factors, such as plant density, nozzle type, operating pressure, boom height, etc. The maximum plant benefit from foliar fertilizers is achieved when the droplet sizes are between small and medium size. The smallest droplet sizes are deposited as drift far away from the target, which disperses fertilizers, minimizes the impact, and even raises contamination and toxicity (Zhang *et al.*, 2017). The deposition level of spray droplets on the target is a definitive index for evaluating the spraying impacts. Therefore, increasing the spray droplet deposition amount is important to the amelioration of the process (He *et al*., 2018). Spray droplet deposited on the target is significantly affected by the characteristics of the nozzle mounted and its orifice orientation to the plant canopy. The best selection of nozzle on the sprayer with good performance can effectively increase the spray droplet deposition (Alheidary, 2018; 2019; 2023). For example, Fritz *et al*. (2007) and Lan & Chen, (2018) tested the spray droplet deposition impacts of the nozzle types, and calculated the effect of traveling speed and droplet sizes on the deposition. However, the results were significant differences in the spray deposition. Kirk (2007) analyzed the relationship between the spray parameters and the nozzle mounted using a test system supplied with a laser spectrometer for developing a data set in the atomization models. Derksen *et al*. (2008) carried out a spraying experience in a soybean field trial to realize the effect of characteristics of spraying application volume on spray droplet deposition. This research intensified the effectiveness of inseparable factors as application rate and spray droplets on spray droplet size which was deposited after the spray droplets were atomized from the nozzle at known operating conditions.

The most fertilizers used for soil and foliar applications are nitrogen, potassium, and phosphorus (Bhattacharya, 2019; Elekhtyar & Al-Huqail, 2023). The N element is considered an essential constituent of protein, nucleic acids, and other organic as chlorophy II which plays an important role in crop life. The potassium element plays an essential role in a plant's metabolism, then active various enzymes in the plant (Cui & Tcherkez, 2021). In addition, the phosphorus element is interred to plant issues as the form of phosphate ions (Ruttenberg, 2001). This element plays a cuticle role in the energy transfer reactions as well as in the functioning of mitochondria (Guimaraes-Ferreira, 2014).

Field fertilization practices, including soil or foliar fertilizer, can affect nutrient concentrations in plants (Cakmak, 2008). An optimal concentration of Fertilizer in maize as NPK may increase the nutrients of plant concentration thereby improving vegetative growth and crop production (Bojtor *et al*., 2021).

The other parameter related to crop growth during spraying time is the method of fertilization to supply the plants which is also essential and cannot be ignored. Xue *et al.* (2014) analyzed the variance of spray droplet deposition between the top and bottom layers of the rice and recognized the effect of the wind speed on the penetration of the spray droplets. A suitable wind speed during spraying can improve droplet penetrability into plant layers. When the application rate interact with the crop stage growth the spray droplets deposit on the intended crop canopy, so the outcome of this interaction will be an important index at the time of crop production or improvement of crop yield. Several efforts have been made by the researchers on the spray droplet deposition directly below the boom of the sprayer (Alheidary, 2018; Alheidary, 2019; Alheidary *et al*., 2020). However, the effect of these factors on droplet deposition and coverage into and outside the crop has not been covered, which is discussed in this work. So, the main goal of this study was to investigate the effect of the type of NPK fertilizer using foliar spraying, soil application, and them together on the characteristics of vegetative growth dependent on spray droplet behaviour in maize canopy.

Materials & Methods

Pot experiments were performed on a maize crop 34N84 in growth season of 2022. The pots were cultivated at the site of the University of Basrah-Karmat Ali to estimate the content of available nutrients (N, P, and K) in the soil before the set-up of the experiment. Soil samples were dried, then mixed together Thereafter Soil characteristics measured and are shown in table (1) below.

Various spraying applications were done weekly at vegetative crop growth for three months. The experiments were conducted using a knapsack sprayer 16-litre tank capacity. The average nozzle height approximately 25cm above the crop was selected according to the results obtained by Alheidary *et al.* (2020). All measurements were carried out at 2 bar operating pressure. The average worker speed was $1.02 m.sec^{-1}$. The fertilizer treatments were divided into three groups as shown in table (2).

All treatments as shown in table (2) were repeated 12 times (three months). Each pot contained only one plant. The plants in the pots were located in four lines (spacing was 25 cm between two pots adjacent) according to the type of treatment. Each treatment contained 5 plastic pots. For the foliar spraying, all measurements were conducted using full hollow cone nozzle (Agratech Co., UK).

Table (1): Some soil characteristics of the experiments.

Characteristic	Value
Soil reaction (pH)	7.5
Electrical conductivity(Ec) (dS.m^{-1})	10.93
Total phosphorous (P) (mg.kg^{-1})	39.91
Total potassium (K) (mg.kg^{-1})	110.9
Total nitrogen (N) (mg.kg^{-1})	0.23
Soil texture	Loamy sand

Table (2): General description of foliar and soil fertilizer used.

Treatment	Description	Value weekly (kg.ha^{-1})	Symbol
Control	Without any fertilizer	0	T1
Pots A,B, and C	Foliar application only	5	T2
		5.5	T3
		6	T4
Pots D, E, and F	soil fertilizer only	3	T5
		3.5	T6
		4	T7
Pots G, H, and I	Foliar application + soil fertilizer	5/3	T8
		5.5/3.5	T9
		6/4	T10

The angle and size of this nozzle type were 80 03. The actual flowrate was 0.46 l.min^{-1} at 2bar operating pressure. The fertilizer treatments were started when the leaves average on the plants was 6-leaf until the male inflorescence**.**

For evaluation spray droplets deposited on the plant, different samples of kromekote papers were placed at each spraying process, especially on the three parts of plant (up, middle, and bottom). All these papers were placed facing the windward direction. The anemometer model MS 6252B (MASTECH Co., USA) was used in the experiment to record the real-time air temperature, relative humidity, and wind velocity during the spraying experiment every 2 seconds. The values of air temperature were at least 20ºC and relative humidity was up to 75% and wind speed at range (1.3-3.6 m.s^{-1}). The station was placed near plants in the field between 1-2 m above the ground surface.

NPK fertilizer characteristics and their concentrations

Two types of NPK fertilizer were utilized in this study to evaluate their impact on the vegetative growth of maize. Firstly, NPK (20-20-20), VAN IPEREN Co., China, it is ideal for growing crops in the soils. Secondly, NPK fertilizer (10-16-22 w/w) (Pioneers Chemicals Factory Co., KSA) was particularly used for the foliar spraying. The NPK fertilizer was prepared at different concentrations depending on the concentration which is showed in table (2). For spraying processes, it was sprayed immediately after the preparation and adding tween-20 for improving the physical properties of spray liquid (surface tension and viscosity) in the early morning by a 16L knapsack Sprayer on the maize leaves weekly. The total spraying applications and soil additives by NPK fertilizers were 12 times per three months. The first time of foliar applications was performed when the plants have 4-6 leaves in average.

Collection of spray droplets deposited

Spray droplets are collected on the maize crop by its sedimentation and their impact using kromekote papers in the field after adding Brilliant Sulfa Flavine tracer (BSF) at a concentration of $1 g.l^{-1}$. After spraying experience, the operator who is spraying wearing gloves immediately collected the kromekote papers in change after the spray droplets deposited and became dry, placed them in evident envelopes, stored them in a superb condition, and transferred to the laboratory for analyzing. The kromekote papers were analyzed using Image J software. The droplet size, spray deposition, spray coverage, droplet uniformity, and Volume Median Diameter ($DV_{0.5}$) were studied. $DV_{0.5}$ refers to the median for the spray droplet size when the accumulation of all spray droplets from fine to coarse size is equivalent to 50% of the total volume of the spray droplets. Whereas, the coefficient of variation (CV %) for spray droplets was also calculated. The CV percentage for each investigation was calculated to show the uniformity of spray droplet distribution that was deposited among sampling points. The smallest value of CV means the best in the uniformity of droplet deposition. It was calculated by the following equation:

$$CV = \frac{S}{X} * 100 \ldots\ldots\ldots (1)$$

$$S=\sqrt{\sum_{i=1}^{n}(X_i - X)/(n-1)} \ldots\ldots\ldots (2)$$

Where S: is the standard deviation, X: is the average value of each sampling. Xi: is the value of each sample (droplet size, spray deposition, and spray coverage). n: is the number of sampling.

After spraying processes, spray droplet sizes collected on kromekote papers were located on the maize at different levels on the plant (top, middle, and bottom). Three samples of kromekote papers were placed at each level. After completing each spraying investigation, the collectors of kromekote papers placed on the crop were stored in plastic sachets away from the sunlight until their analysis in the laboratory. Then the mean was calculated after scanned it's and analyzing these collectors.

Characteristics of vegetative growth

Different plants were randomly selected at male flowering stage from pots to calculate the following characteristics:

Plant height (cm)

It was calculated by selecting five plants from the intermediate pot lines of the experimental unit by measuring the distance between distance soil surface to the lower node of the inflorescences (Odongo & Bacholt, 1995).

Leaves numbers

The average of leaves number of plant was calculated by randomly selected five plants.

Leaf area (cm²)

It was measured using the formula (Sticker, 1961):

$$\text{Tolal Leaf Area} = K * \text{Leaf length} * \text{Leaf maximum Width} \ldots\ldots\ldots\ldots (3)$$

Where K: is the coefficient Factor 0.75.

Stem diameter (cm)

Mean stem diameter (cm) was calculated at the male inflorescence 12 weeks after sowing from five plants by using Vernea tool, then the stem diameter.

Fresh biomass and dry weight

After plants harvested, directly fresh weight has been measured. Thereafter plants desiccated by oven for two days at 80º C. After plants were harvested, the following plant characteristics were recorded. The moisture content values were used to calculate the fresh biomass of plants (g) and dry weight per plant (g).

Nitrogen content

Nitrogen content was measured from maize leaves according to the Ginsburg method and Kjeldahl distillation (Williams & Chase, 1968).

Statistical analysis

The collected data were analyzed using Genstat software 11 (discovery edition 3). The Treatments arranged according to factorial experiment with three replicates using randomized complete block design in a total of 27 treatments (three different methods of fertilization*three different fertilizer concentrations for each method* three replications). To show the significant differences between treatments, the $L.S.D_{0.05}$ was calculated.

Results & Discussion

Spray droplet distribution

The main important parameters for spray droplet is a volume median diameter ($D_{v0.5}$) of spray droplets that are generated by a spray of nozzle mounted on the lance of sprayer as the smallest droplet size (120.6 µm) in the bottom layer of plant canopy compared to other layers (Fig. 1). Significant differences appeared in VMD values depending on the sampling location on the plant canopy. Higher VMD values were observed on the upper layer compared to other layers.

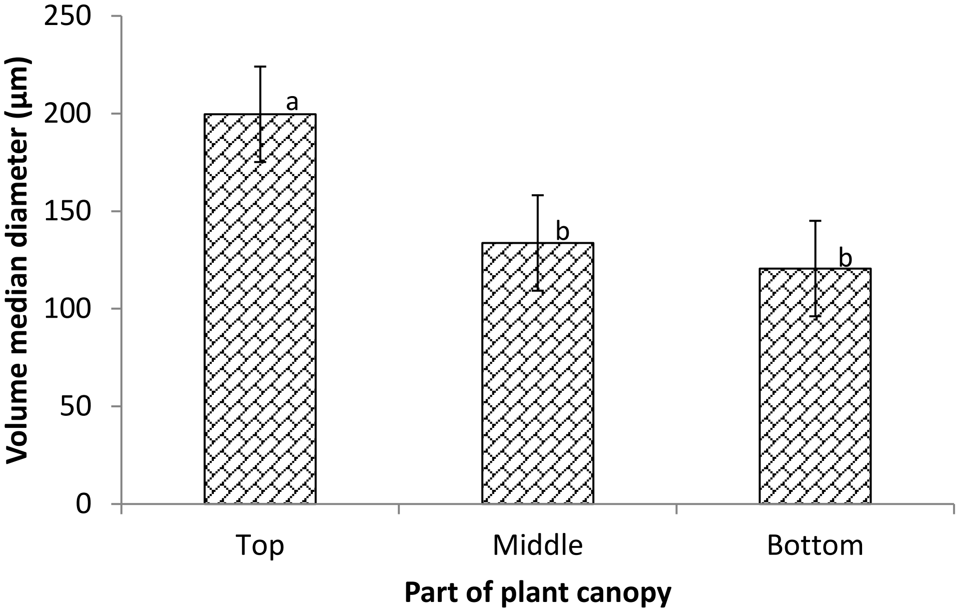

Fig. (1): Values of Volume median diameter deposited on samples at different plant layers.

These results are in line with the result obtained by Alheidary (2019) and Alheidary *et al*. (2020) in studying the spray droplet properties using different nozzle types by the use of knapsack sprayer, who notified that small spray droplets were produced by a hollow cone nozzle as compared to the different nozzle types. The smallest volume median diameter applied at this type of nozzle resulted in the greatest percentage of spray coverage in all plant locations compared to the largest droplet sizes. This type of nozzle is widely utilized with knapsack sprayers; the fine spray droplets ensure that it is very appropriate for the foliar application in agriculture processes.

Spray droplet deposition and coverage percentage

During spraying application, the values of spray droplet deposition and coverage percentage are shown in figs. (2 and 3). Significant differences in the spray droplets that reflect the current spray deposition on the samples. The average spray droplet deposition of each experience obtained by Kromekote papers analysis was ranged from the upper to bottom layers. Generally, results illustrated on the upper layers of plant canopy, the spray droplet deposition level for different sampling locations was a higher than the other layers. Higher spray deposition amount (0.529µl.cm^{-2}) was achieved on the upper layers compared to other layers. The uniformity of spray deposition is another typical indicator to assess the spray deposition effectiveness. The smaller value of the CV percentage is the more well-distributed the spray droplets. The bottom layers of the plant canopy recorded the lowest with the CV percentage (5.54%) of spray deposition uniformity less than 30%, and the upper layer was the worst with the CV percentage of uniformity of the spray deposition as high as 8.59% (fig. 4).

The results also appeared in fig. (3) that the coverage percentage graduated from upper to bottom layers in an acceptable uniformity depending on the droplet sizes deposited. The best visible coverage percentage observed in the bottom layers (33.36%) compared to other layers of maize. The finding agreed with the previous results of Xiao *et al*. (2020), and Wang *et al*. (2019). Another work illustrated that the spraying at the beginning stage of growth, higher spray droplet uniformity on the bottom layers of plant canopy compared to other layers (Qin *et al*., 2018).

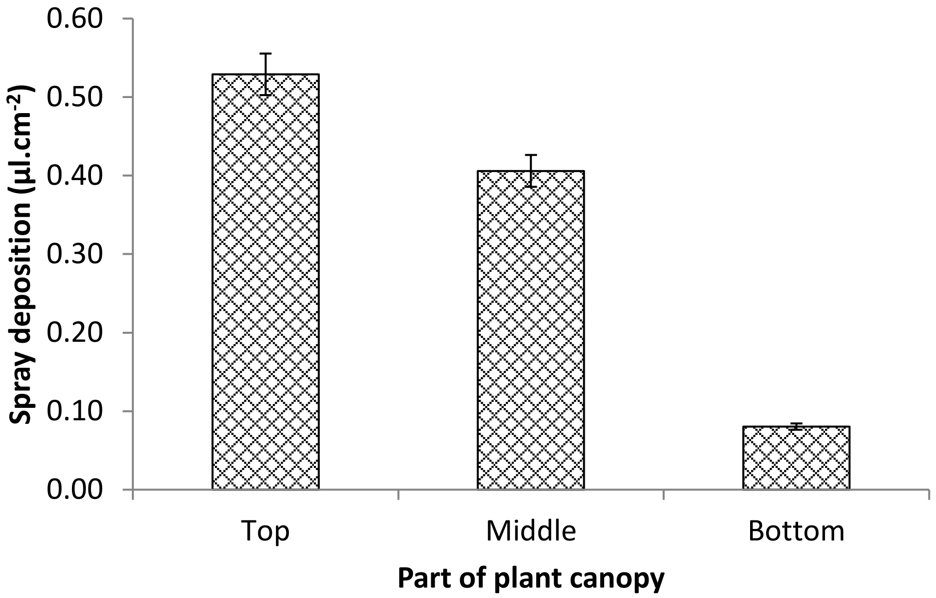

Fig. (2): Amount of spray deposition on the plant layers

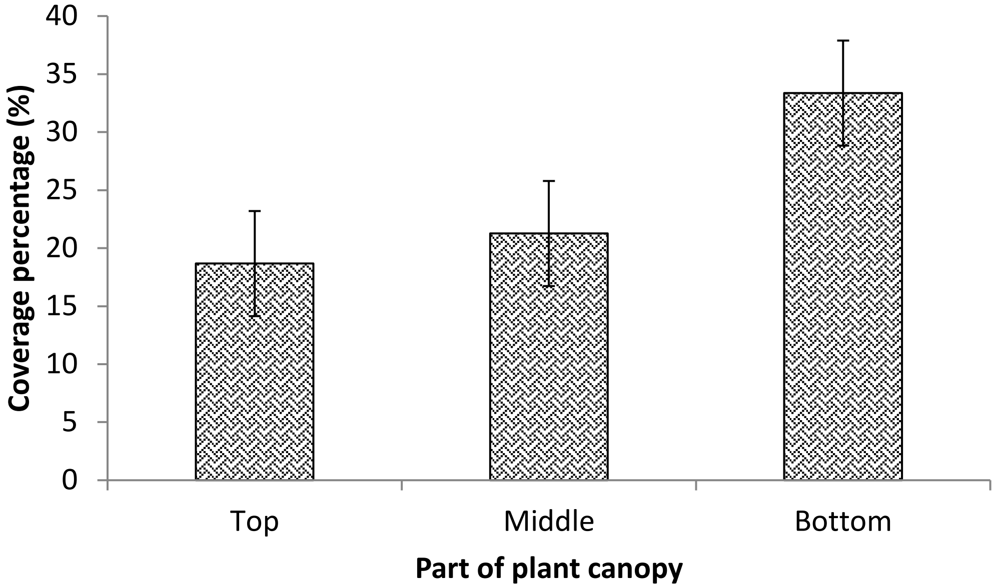

Fig. (3): Spray deposition and coverage at different nozzle types and growth stages.

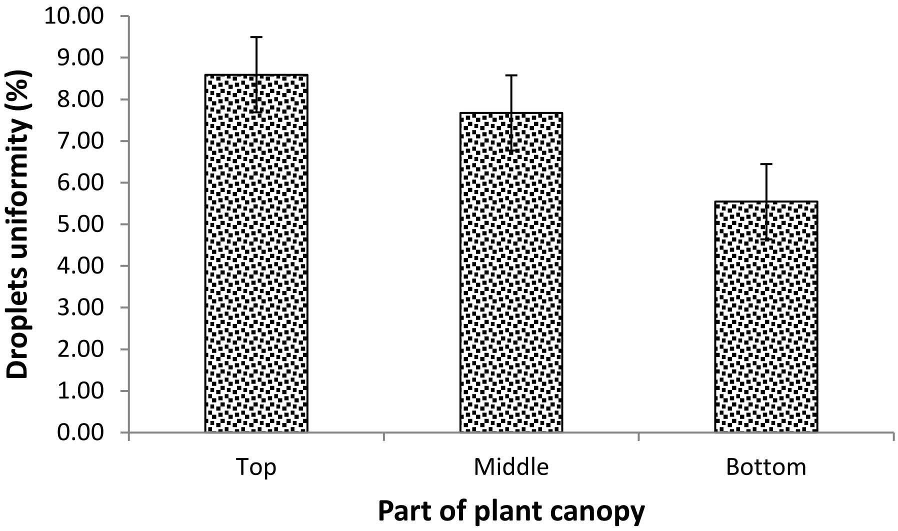

Fig. (4): Droplet uniformity on the plant layers.

Vegetative growth characteristics maize height

As shown in table (3), the outcomes showed that the plant height varied from (20.86± 0.62 cm) to (47.52 ±2.61cm) for T1 (the control) and T10 treatments having the highest and lowest height values, respectively. Table (3) also demonstrated that, as compared to the control treatment, the T10 at different recommended doses considerably ($P \leq 0.05$) varied higher plants, with soil and foliar fertilizer treatment at the highest dose indicating the significant and the best outcome in comparison to other treatments. Because most nutrients in the soil aren't always fully available to crop roots, this increase is achieved by combining both soil and foliar fertilizers. Leaching, soil fixations, obstructions, and other losses resulted from the soil fertilizer. In contrast, these factors can be avoided by following foliar fertilization. To provide the nutrients where the plant needs them, foliar fertilization delivers the nutrients directly to the leaf in a rapid time depending on the fertilizer type added. Therefore, since the leaf absorbs macronutrients,

Table (3): Main characteristics of maize vegetative growth.

Code	Treatments	Plant height (cm)	Leaves number ($leaf.plant^{-1}$)	Leaf area	Stem diameter (cm)	Fresh weight (gm)	Dry weight (gm)	N content %
T1	Control	20.86 ± 0.52^{d}	7.62 ± 0.26^{f}	3978 ± 97.28^{d}	2.67 ± 0.17^{d}	11.31 ± 0.69^{d}	2.08 ± 0.14^{d}	1.45 ± 0.05^{b}
T2	Soil fertilizer (lower dose)	23.85 ± 0.57^{d}	9.16 ± 0.12^{def}	5258 ± 248.65^{c}	2.94 ± 0.04^{d}	15.15 ± 0.47^{d}	4.56 ± 0.16^{cd}	2.39 ± 0.09^{a}
T3	Foliar application (lower dose)	22.45 ± 0.82^{d}	8.38 ± 0.67^{ef}	4095 ± 191.08^{d}	3.02 ± 0.13^{d}	14.42 ± 0.48^{d}	2.38 ± 0.17^{d}	1.77 ± 0.03^{b}
T4	Soil and foliar fertilizer (lower dose)	43.56 ± 0.73^{b}	9.23 ± 0.35^{def}	5697 ± 62.95^{bc}	4.45 ± 0.27^{bc}	50.55 ± 0.99^{a}	13.93 ± 0.90^{a}	1.82 ± 0.03^{b}
T5	Soil fertilizer (middle dose)	22.84 ± 0.44^{d}	9.24 ± 0.60^{def}	6253 ± 168.32^{b}	4.42 ± 0.23^{bc}	23.64 ± 1.14^{c}	6.97 ± 0.22^{bc}	2.55 ± 0.11^{a}
T6	Foliar application (middle dose)	22.94 ± 0.41^{d}	10.34 ± 0.35^{cde}	5226 ± 157.51^{c}	3.30 ± 0.11^{cd}	16.70 ± 0.26^{d}	2.97 ± 0.11^{d}	1.81 ± 0.06^{b}
T7	Soil and foliar fertilizer (middle dose)	40.96 ± 0.43^{b}	11.89 ± 0.17^{bc}	6560 ± 140.61^{b}	4.81 ± 0.38^{ab}	31.04 ± 0.71^{b}	12.61 ± 0.83^{a}	1.60 ± 0.13^{b}
T8	Soil fertilizer (higher dose)	36.56 ± 0.52^{c}	11.24 ± 0.24^{bcd}	6397 ± 30.18^{b}	4.45 ± 0.32^{bc}	29.34 ± 1.81^{bc}	7.88 ± 0.21^{b}	2.66 ± 0.06^{a}
T9	Foliar application (higher dose)	24.26 ± 0.60^{d}	13.49 ± 0.56^{ab}	5384 ± 116.09^{c}	3.61 ± 0.16^{bcd}	28.21 ± 0.93^{bc}	4.38 ± 0.16^{cd}	2.55 ± 0.11^{a}
T10	Soil and foliar fertilizer (max. dose)	47.52 ± 1.00^{a}	14.98 ± 0.55^{a}	8077 ± 58.07^{a}	6.06 ± 0.15^{a}	52.13 ± 1.15^{a}	14.31 ± 0.81^{a}	2.71 ± 0.08^{a}
	$L.S.D_{0.05}$	3.95	2.53	886.1	1.37	6.02	3.03	0.514

it can address any nutritional issue. This result agreed with (Alheidary *et al*., 2020)

Furthermore, it appeared that the plants' height with a higher NPK fertilizer using T10 compared to other treatments as T1 (control) and T8 (the soil fertilizer at a higher NPK dose). Comparing the application of NPK fertilizer at a higher application rate to no application (control), some researchers found that maize height increased due to an increase in the amount of fertilizers (Sugiono & Krismawati, 2020). Other researchers e.g. Studer *et al*. (2017), Peram *et al*. (2018) and Sudding *et al*. (2021) illustrated that higher NPK levels encourage the vegetative growth of crops by improving the nutrient availability in the plant tissues. Researchers showed that applying various NPK foliar spray treatments led to significantly increased maximum plant heights (Rop *et al*., 2019)

Stem diameter

The findings in table (3) showed significant impact of the fertilizer application method on the stem diameter of maize. As it introduced the heights average of stem diameter by 6.06cm) was obtained by soil and foliar application when a high dosage was added, while the control treatment had the smallest average of stem diameter by 2.67cm. Other treatments were statistically different at the least significant difference 5%. The results of this investigation are agreed with (Wulandari *et al.*, 2019; Sihombing *et al.*, 2021) whose reported that appropriately administering NPK dosage increased the plant's growth.

Leaves number

The results showed that there were significant differences between the zero NPK fertilizer (the control treatment) and the higher dosage using soil and foliar fertilizer (7.62 and 14.98) leaves per plant respectively. Even though there was no statistically significant difference among the control, soil fertilizer, and foliar spraying depending on the dosage applied. Table (3) demonstrated that the soil fertilizer and foliar fertilizer at different doses considerably ($P \leq 0.05$) varied from the control treatment. In comparison to the control treatment, which received no fertilizer, each fertilizer application resulted in more leaves on the plants sprayed. Additionally, it was shown that foliar spraying and applying fertilizer to the soil combined produced results that were practically optimal in this characteristic studied. The plants with 20:20:16 NPK foliar sprays at 6gm.l^{-1} and 4gm of soil amount had the most leaves per plant, it was seen (Anburani, 2018). The increase in growth characteristics as a result of NPK foliar spray may be due to the role of NPK as a source of nitrogen for plant growth and development and may play an important role in plant metabolism and protein assimilation which is necessary for cell formation (Rai, 2002) thereby may have increased the rate of photosynthetic metabolism for growth (Romero *et al.*, 2014). In comparison to the control treatment, which received no fertilizer amount, the various fertilization methods increased the number of maize leaves depending on the amount and dose of NPK fertilizer (Gairola *et al*., 2009).

Leaf area

Table (3) introduced the typical crop leaf area and demonstrated the significant differences at ($P \leq 0.05$) effect of the soil and foliar fertilizer combination treatment on the leaf area of maize crops. The treatment of T1 was significantly different from the treatments of T2, T3, T4, T5, T6, T7, T8, and T10, but not significantly different from the treatment of T9. The treatment of T10 was significantly different ($P<0.05$) from all other treatments. In comparison to T1, T5, T6, and T9, the treatment of T7 was significantly different

($P<0.05$), but not significantly different from T2 and T4. The T10 treatment had the largest leaf area, measuring 8077 cm^2, while the T1 treatment had the smallest leaf area, at 3978 cm^2. As one of the most essential components required for the vegetative growth, such as the leaf area, crop fertilizers containing important elements like nitrogen play a significant role (Prayogo *et al*., 2021). The result of the leaf area was in agreement with the finding by Sudding *et al.* (2021) who recommended to use NPK (15:15:15).

Fresh weight

The maize plants were harvested after 91 days of from planting in plastic pots, which corresponded to the time of male inflorescence. The highest and lowest plants were identified for T10 and T0 (the control), respectively, and the fresh weight varied from 11.31gm to 52.13gm. Table (3) demonstrated that there were significant differences between all of the treatments and the control ($P<0.05$) for each. There was no significant difference between treatments T1, T3, T5 and T5. The study's findings also revealed that there are no significant differences between treatments T6, T7, and T8 where fertilizer was applied directly to the soil and twelve times by foliar spraying, the fresh weight value was the highest at 52.13 gm, which may be related to the foliage plant and roots' increased intake of NPK. Similar to this, several studies revealed that the fresh weight was realized by using the recommended NPK fertilizers (Deriak & Abdel-Kader, 2015). Similar findings were seen in their experiment using chemical fertilizers such as NPK (Recommended dosage) fertilizers producing the maximum fresh weight for maize crops (Sihombing *et al.*, 2021). This outcome could be explained by the high and readily available nitrogen in the NPK fertilizer, especially in the recommended fertilizer amount, which made it easier for the maize to maintain vegetative growth. The treatments using foliar fertilization or soil fertilization lonely produced slightly fewer results than those using the combination of soil and foliar application together. Other studies (Ali *et al*., 2016; Alheidary *et al.*, 2020; Gorlach *et al.*, 2021) recommended foliar spraying nutrition as a supplement to the soil treatment because the soil fertilization alone cannot cover all of a plant's nutritional needs during the vegetative growth of maize. Added to that, foliar fertilization, according to Haytova (2013), is also more environmentally friendly because it minimizes the buildup of hazardous nutrient concentrations in the soil (Haytova, 2013).

Dry weight

According to the findings, significant differences were observed in the plant dry weight which ranged from the lowest value (2.08 gm) to the highest value (14.31 gm), with T1 (control) and T10 respectively. This result illustrated that the maize crop sprayed with NPK fertilizer and soil treatment was characterized by the best vegetative growth which may be contributed to improve the plants absorption of NPK by the plants leaves resulted in small droplets and plant roots, then increase the processes of metabolism in the maize crop and thus increase in dry weight. There are no significant differences between treatments T1, T2, T3, T6 and T9. In addition, there were no significant differences observed between T4, T7 and T10. The outcomes in table (3) also demonstrated that there were significant differences between the treatments T4, T5, T7, T10 and the control ($P<0.05$) for each. Similar results were seen in their experiment using NPK fertilizers at the recommended dosage fertilizers producing the highest dry weight for maize crops in comparison to the control treatment

(Sihombing *et al.*, 2021). Moreover, NPK fertilizers were applied by Deriak & Abdel-Kader (2015) to significantly increase the dry weight in maize at harvest time compared to the other treatments.

Percentage of N content

The total N uptake under various fertilization methods is introduced in table (3). When the soil and foliar fertilizer were applied combined together, as opposed to utilizing soil or foliar fertilizer separately, the vegetative growth of maize steadily increased (Table 3). The disparities in maize vegetative growth among the fertilizer treatments grew as the amount of soil and foliar fertilization increased depending on the fertilizer applied dosage. The average nitrogen content in maize's dry biomass ranged from 1.45% to 2.717%, with maize leaves having the highest nitrogen content and maize stems having the lowest. Data variance in the N content depends on the experiment's fertilizer application strategy. To evaluate the overall impact of the fertilization application method and their applied dosage based on the results of this study (Table 3), there were significant differences in the N content values between the treatments T1 (control) and the other treatments ($P \leq 0.05$). The results in table (3) also illustrated that there were no significant differences between the treatments T1 (the control) and the treatments T3, T4, T8, and T9 ($P \leq 0.05$) for each in this characteristic studied. Similar results were found by Makinde & Ayoola (2010) in their experiment by using NPK fertilizers at the recommended dosage fertilizers producing the highest N content for maize crops in comparison to the control treatment (T1). In comparison to NPK dosages as soil fertilizer methods (T2, T5, and T8), the foliar fertilizers of NPK have been proven to be an effective technique of NPK fertilization. The adoption of foliar NPK with the soil fertilizer may help to reduce the fertilizer losses due to denitrification, leaching, and immobilization, often associated with NPK fertilization to the soil application method. Despite notable variances in the results for nitrogen content for the soil and foliar applications individually, the N% content of plants was often lower than in the foliar treatment.

Conclusion

It can be concluded that the droplet characteristics as volume median diameter, droplet deposition, uniformity, and coverage percentage are influenced by the plant layers. The upper layers of the plant canopy are higher in spray deposition, but the higher coverage percentage and the better deposition uniformity are achieved in the bottom layers. Also, using foliar micronutrients with soil fertilizer during maize vegetative growth season achieved good outcomes in the maize growth characteristics. NPK concentrations for leaf growth that occurred after foliar applications were significantly increased for most vegetative maize growth. Thus, the hypothesis is accepted that applied micronutrients will increase their corresponding foliar concentration for these characteristics. The plant height, leaf numbers, leaf area, stem diameter, fresh weight, dry weight, and nitrogen content were significantly affected by the methods of fertilization. Significant differences were established between the control treatment and all the methods applied in fertilization. With increasing the fertilization application rate using a combination of foliar application and soil fertilization, the vegetative growth of maize significantly differs under the type of fertilizer. Higher levels of N (%) when the combination of foliar and soil was established. It can be also concluded that the utilization of the optimal amount of NPK fertilizers in maize not only improves maize vegetative growth via increased nutrient use efficiencies but is also economical for farmers.

Contributions of authors

M. H., Methodology; M. H., and A. M.: formal analysis; M. H.: writing the original draft preparation; M. H.: writing the review and the editing; M. H., S. J., and A. M.: Prepare the final version of manuscript.

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Contributions of authors

M.H.A., methodology, writing the original draft and the editing; M.H., and A.M.: formal analysis; **M.H**., S. J., and A.M.A.: Prepare the final version of manuscript.

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Conflicts of interest

All authors declare no conflict of interest.

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تحديد معدل الرش الامثل لتحسين خصائص النمو الخضري لمحصول الذرة الصفراء باستعمال المرشة الظهرية

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المستخلص: الأسمدة التي تطبق بكميات أكبر، فإن استخدام التسميد الارضي هي الطريقة الأكثر شيوعًا. ومع ذلك، فإن استخدام التسميد الورقي يعد أكثر عملية وفعالية من حيث التكلفة في بعض الحالات. هناك طرق متعددة في اختبارات التسميد الورقي والارضي واستجابة نمو المحاصيل لها. وبسبب عدم كفاية استخدام الأسمدة المضافة خلال زراعة المحاصيل، خاصة عند استخدام الطريقة المعتادة كإضافة التسميد الارضي، مما سيؤدي الى المزيد من تدهور التربة فضلا عن الكلفة العالية، مما يؤثر على نمو النبات. ولتقييم هذا التأثير على النمو الخضري لمحصول الذرة، تم إجراء العديد من التوليفات من الأسمدة المركبة باستخدام الرش الورقي والتسميد الارضي ومعاملاتهم المركبة و بكميات مختلفة. استخدمت التجربة العاملية في اسلوب القطاعات العشوائية الكاملة (CBRD) في ثلاث قطاعات باستخدام برنامج Genstat. أظهرت النتائج تأثر خصائص القطرات كتوسط القطر الحجمي، وترسب القطرات، والانتظام، ونسبة التغطية بطبقات المجموع الخضري للنبات. كانت الطبقات العلوية من النبات هي الأكثر نصيبا في ترسيب الرش ($0.529\ \mu l.cm^{-2}$). كلما زادت نسبة التغطية (33.36%) كان انتظام الترسيب الذي تم الحصول عليه أفضل في الطبقات السفلية للذرة (5.54%). كما أظهرت النتائج أيضًا زيادة كبيرة في متوسط طول النبات، وعدد الأوراق، وقطر الساق، والوزن الرطب، والوزن الجاف، ونسبة محتوى النيتروجين (47.52، 14.98 ورقة.نبات$^{-1}$، 8077، 6.06 سم، 52.13غم، 14.31غم، و 2.71% على التوالي في النباتات المعاملة بالتسميد الورقي والارضي معا عند اقصى كمية مضافة من الاسمدة المركبة. لذا فان نتائج الدراسة اشارت إلى أنه يمكن استخدام التسميد الارضي والرش الورقي معا لتعزيز النمو الخضري للنبات بشكل افضل.

الكلمات المفتاحية: خصائص القطرات، الرش الورقي، التسميد الارضي، محصول الذرة الصفراء.