Exogenous Application of Growth Regulators Improves the Growth and Quality of *Dahlia variabilis* L.

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Dahlia (*Dahlia variabilis* L.), a bulb crop sold as cut flowers, garden ornamental/potted plant, becomes a popular cut flower in the world. This experiment was designed to study the effects of foliar applied gibberellic acid, zinc, ascobic acid, and thiamine on the growth and flower attributes of dahlia. The study was conducted under greenhouse conditions at the Floriculture Research Area, University of Agriculture, Faisalabad, Pakistan. There were thirteen treatments with three levels each; gibberellic acid, zinc sulphate, ascobic acid, and thiamine. First, foliar application was done at vegetative stage (after 45 d of transplantation) and second, at the flowering stage. Application of gibberellic acid at 100 ppm significantly improved plant height (92.67 cm). Application of zinc at 0.50% produced the maximum number of flowers (28.47), diameter of flower (100.19 mm), and fresh weight of flower (11.16 g). Foliar application of thiamine increased nutrient accumulation in leaves of dahlia. The nitrogen contents (4.43%) increased to maximum in response to treatment comprising ascorbic acid, whereas phosphorus content (1.41 mg g⁻¹) and potassium contents (19.45 mg g⁻¹) were at maximum in response to thiamine. The highest chlorophyll a (4.37 mg g⁻¹) and b (2.04 mg g⁻¹) contents were recorded in treatment comprising thiamine at 150 ppm. The highest carbohydrate contents (35.14%) were recorded in zinc application response. Application of thiamine significantly reduced the days of flowering and flower diameter. Overall, it can be recommended that application of thiamine at 150 ppm is more responsive to improve the growth and quality of dahlia flower as compared to gibberellic acid, zinc, and ascobic acid.

Keywords: ascorbic acid, dahlia, flower, gibberellic acid, thiamine, zinc

INTRODUCTION

Floriculture, as an industrial model, played a pivotal role in uplifting people around the globe including Pakistan. Estimated trade volume of floriculture industry in the world is about USD 55 bn annually. In floriculture, cut flowers are considered as a valuable products for earning more benefits from the horticulture industry. Due to the rapid transportation and storage facilities, global trade of cut flowers increased significantly during the past few decades. However, with the rise in living standards, education and means of earnings, business of cut flowers is also flourishing day by day in Pakistan. The important floricultural crops used as cut flowers in Pakistan are roses, dahlia, lilies, gladiolus, narcissus, tuberoses, iris, gerbera, and freesia.

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Dahlia (Dahlia variabilis L.) is one of the popular and beautiful cut flower in the world which is characterized by its rich variety and attractive colors (Elsadek 2018). It is a famous tuberous-rooted perennial herbaceous flowering plant that is prized for its beautiful and magnificent blossoms. It is grown for its lovely ornamental blooms in a variety of colors for garden and lawn beautification, cult flowers, and as a loose flower in many parts of the world (Sao et al. 2021). This flower attractive due to its different aesthetic attributes such as wide range of plant heights, various flower sizes, diverse attractive forms (boll like, decorative, anemone, collaret, pompon etc.) and extensive color range (single colored, bicolored, blends, and variegated). It has its own laurels as “the pride of garden” among naturalists and ornamentalists.

The quality and growth of flowers and tubers are influenced by numerous environmental factors including soil type, availability of nutrients, and growth regulators. All these elements are essential for an appropriate plant growth (Tariq et al. 2012). Dahlia requires well balanced nutrients like all floricultural crops require for their optimum growth and flower development (Younis et al. 2013). Cut flower cultivation is a very profitable business, as the returns are twice than production cost. Pakistan is among the countries which have suitable climatic conditions for the cultivation of cut flowers year-round (Usman et al. 2014).

Various management approaches are being adapted by the farmers’ community to enhance the productivity of agronomic and horticultural crops (Khasanah and Rachmawati 2020; Bossain et al. 2021; Rehman et al. 2021) including the intercropping, application of mineral elements, synthetic compounds (Nurhidayati et al. 2020; Abello et al. 2021), organic amendments (Iqbal et al. 2020; Tabaxi et al. 2021), plants extracts and biostimulants (Makawita et al. 2021; Khan et al. 2022) via soil (Rahim et al. 2020), seed coating (Javed et al. 2021), seed priming agents and foliar spray (Khan et al. 2017; Batool et al. 2019; Farooq et al. 2021). Foliar feeding is one of the methods to overcome the failure of plants to uptake certain nutrients essential for normal growth (Qamar et al. 2020). Foliar feeding is preferred in soils that have low availability of nutrients (vitamin B1) on the growth and production of gladiolus plant. Abdel et al. (2009) emphasized that application of foliar applied gibberellic acid (GA) in plants enhances the growth, development, and defense (Cabot et al. 2019). Zinc (Zn) plays a vital role in the synthesis of biomass (Cakmak 2008). Moreover, Zn is mandatory for pollen function, chlorophyll production, fertilization and germination (Kaya and Higgs 2002). Zn is also vital for plant growth as it performs a regulatory cofactor of different enzymes, and also important for photosynthesis, protein synthesis, auxin synthesis, cell division, and maintenance of plasma membrane structure.

Ascorbic acid (vitamin C) is ubiquitously present in plants and, it is involved in cell division, cell expansion, photosynthesis and in scavenging of reactive oxygen species by providing electrons in various reactions (Sharma et al. 2012; Shah et al. 2019). It is the most abundant antioxidant found in plants (Blokhina et al. 2003). It effectively maintains the antioxidant system and protects the plant from oxidative damage (Jaleel 2009). Ascorbic acid also plays a key role in the electron transport chain.

Thiamine (vitamin B1) plays an elementary role as an enzymatic cofactor in universal metabolic pathways such as pentose phosphate pathway, the glycolysis, and tricarboxylic acid cycle. Thiamine treated plants showed resistance against viral, bacterial and fungal infections (Ahn et al. 2005). Thiamine is also considered as a stress hormone or stress protectant which enables the plants to survive in the unfavorable environment (Rapala-kozik 2011). Youssef and Talaat (2003) reported that pronounced increases in vegetative growth and chemical constituents of rosemary plants by foliar application of thiamine. Abdel et al. (2009) emphasized that application of thiamine significantly increased growth parameters and yield of gladiolus plant.

Current experimentation was designed to investigate the impact of foliar applied gibberellic acid (GA), zinc sulphate (ZnSO4), ascorbic acid (vitamin C), and thiamine (vitamin B1) on the growth and production of Dahlia variabilis L. as a cut flower.
MATERIALS AND METHODS

Crop Husbandry
The study was conducted under greenhouse condition during the cultivation season of *Dahlia variabilis* L. at The Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad (31.25° N, 73.09° E) Pakistan to elucidate the effect of foliar application of different levels of gibberellic acid (GAs), zinc sulphate (ZnSO₄), ascorbic acid (vitamin C), and thiamine (vitamin B1) on growth, yield, and quality of *Dahlia variabilis* L. Each treatment was replicated thrice having five plants in each replication. During course of experimentation, all treatments were applied twice, 1st at vegetative stage (after 45 d of transplantation) and 2nd at flowering stage (after 25 d of 1st application). Seedlings of *Dahlia variabilis X hybridia*, purchased from the nursery, were transplanted in plastic pots during mid-December. The dimensions of the plastic pots were 30 cm in height and 22 cm in diameter. At the time of transplantations, seedlings were 4 – 5 in height with four leaves stage. Pots were filled with media comprised of silt, leaf manure, and farmyard manure at the ratio of 2:1:1 respectively. Three levels of gibberellic acid (GAs) (25, 50, and 100 ppm), zinc sulphate (ZnSO₄) (0.25, 0.50, and 0.75%), ascorbic acid (vitamin C) (50, 100, and 150 ppm), and thiamine (vitamin B1) (50, 100, and 150 ppm) were applied with control (untreated). All agricultural practices like fertilization, irrigation, weeding, plant protection measures, pinching, staking, and others were kept standard for all treatments.

Growth and Flowering Parameters
The height of the plant was measured from the base to the growing point of the main stem with the help of meter rod at maturity. The diameter of the main stem was measured with the help of a digital Vernier caliper from three different points of the main stem and then the average was taken. In May, after picking the flowers, plants were harvested from the base and weighed on an electronic weight balance. After weighing, plants were dried in the shade and then placed in an oven at a constant temperature of 72°C. After 72 h, they were taken out and dry weight was measured.

For each plant, the total numbers of days taking to flowering were counted from the day of transplantation in the pots to the first flower opening and its average. Then the number of flowers produced per plant was recorded from each treatment and its average was computed. Diameter of first two flowers per plant from each treatment was measured, with the help of digital Vernier caliper, and its average. Fresh flowers were selected randomly and weighed on an electronic weight balance to record the fresh weight of flowers.

**Photosynthetic Pigments and Mineral Elements**
NPK analysis was carried out in order to determine the effect of foliar application on nutrients accumulation and their correlation with vegetative growth, flowering attributes, and chemical constituents. The samples for nutritional analysis were collected week after its second application of treatments. Total N was determined by method of Chapman and Parker (1961). It involved the digestion of plant material with concentrated H₂SO₄ and digestion mixture comprising K₂SO₄:CuSO₄:FeSO₄. The digestion, for estimation of P and K, was done according to the method described by Yoshida et al. (1976). Chapman and Parker (1961) proposed method was used to determine the phosphorus contents. Potassium was determined by flame photometer (Chapman and Parker 1961). To calculate chlorophyll a and b, spectrometer was used (Arnon 1949).

\[
\text{Chlorophyll a contents} = \frac{[12.7 \times (\text{OD 663}) - 2.69 \times (\text{OD 645})]}{V / 1000 \times W}
\]

\[
\text{Chlorophyll b contents} = \frac{[12.7 \times (\text{OD 645}) - 4.68 \times (\text{OD 663})]}{V / 1000 \times W}
\]

where OD = optical density; V = volume of the extract (ml); W = weight of the fresh leaf (mg).

Carbohydrates (sugars) in leaves paste were estimated according to Hortwitz (1960) by following the given formula:

\[
\text{Carbohydrates (b) = 25} \times \frac{X}{Z}
\]

where X = volume (ml) of standard sugar used against 10 ml Fehling solution; Z = volume (ml) of sample aliquot titrated against 10 ml Fehling solution.

**Statistical Analysis**
Collected data regarding growth parameters, flower, quality, and physiological attributes were analyzed and evaluated statistically by using the statistical package “Statistic 8.1” employing Fishers’ analysis of variance (ANOVA) technique under a completely randomized design (CRD). Microsoft excel was used for calculations and graphical presentation. Different letters (a, b, c, etc.) were used to portray the significant differences among treatments effect via Tukey HSD at a 5% probability level (Steel et al. 1997).

**RESULTS**

**Plant Growth Parameters**
Foliar treatments significantly influenced the plant height, stem diameter, plant fresh, and dry weight, days to
Tables 1. Analysis of variance (mean sum of squares) of plant height, stem diameter, plant fresh and dry weight, days to flowering, flower diameter, number of flowers, flower fresh weight, chlorophyll a and b contents, nitrogen, phosphorus, potassium and total soluble sugars in leaves of *Dahlia variabilis* L. in response to foliar application of gibberellic acid (25, 50, and 100 ppm), zinc sulphate (0.25, 0.50, and 0.75%), ascorbic acid (50, 100, and 150 ppm), and thiamine (50, 100 and 150 ppm).

<table>
<thead>
<tr>
<th>SOV</th>
<th>DF</th>
<th>Plant Height (cm)</th>
<th>Stem Diameter (mm)</th>
<th>Plant Fresh Weight</th>
<th>Chlorophyll Content</th>
<th>Nitrogen in Leaves</th>
<th>Phosphorus in Leaves</th>
<th>Potassium in Leaves</th>
<th>Total Soluble Sugars</th>
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<tbody>
<tr>
<td>Treatments</td>
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<tr>
<td>Control</td>
<td>12</td>
<td>67.27 ± 0.493 f</td>
<td>7.31 ± 0.204 a</td>
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<tr>
<td>GA at 25 ppm</td>
<td>12</td>
<td>81.14 ± 0.537 bc</td>
<td>7.43 ± 0.252 h</td>
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<tr>
<td>GA at 50 ppm</td>
<td>12</td>
<td>85.60 ± 0.321 ab</td>
<td>7.91 ± 0.048 d</td>
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<tr>
<td>GA at 100 ppm</td>
<td>12</td>
<td>92.67 ± 0.841 a</td>
<td>8.10 ± 0.163 d</td>
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<tr>
<td>ZnSO₄ at 0.25%</td>
<td>12</td>
<td>79.68 ± 0.562 ded</td>
<td>9.04 ± 0.145 abcd</td>
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<tr>
<td>ZnSO₄ at 0.50%</td>
<td>12</td>
<td>84.87 ± 3.725 abcd</td>
<td>9.04 ± 0.271 abcd</td>
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<tr>
<td>ZnSO₄ at 0.75%</td>
<td>12</td>
<td>83.13 ± 0.477 b</td>
<td>9.32 ± 0.029 ab</td>
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<tr>
<td>ACA at 50 ppm</td>
<td>12</td>
<td>69.74 ± 0.598 de</td>
<td>8.22 ± 0.247 ade</td>
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<tr>
<td>ACA at 100 ppm</td>
<td>12</td>
<td>71.34 ± 0.289 abc</td>
<td>8.41 ± 0.361 cde</td>
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<td>ACA at 150 ppm</td>
<td>12</td>
<td>72.47 ± 0.243 abc</td>
<td>8.74 ± 0.224 cdebc</td>
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<td>Thiamine at 50 ppm</td>
<td>12</td>
<td>77.6 ± 0.317 abc</td>
<td>9.21 ± 0.101 abcde</td>
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<tr>
<td>Thiamine at 100 ppm</td>
<td>12</td>
<td>79.83 ± 0.433 abc</td>
<td>9.52 ± 0.158 abcde</td>
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<td>Thiamine at 150 ppm</td>
<td>12</td>
<td>74.07 ± 0.0836 cmf</td>
<td>8.48 ± 0.239 cmf</td>
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The mean values in column followed the different letters are significantly different at 5% level of significance as *P* < 0.05. Means sharing the same letter did not differ significantly as *P* > 0.05.

Fig. 1. Plant fresh biomass and oven-dry biomass of *Dahlia variabilis* as influenced by gibberellic acid (25, 50 and 100 ppm), zinc sulphate (0.25, 0.50, and 0.75%), ascorbic acid (50, 100, and 150 ppm) and thiamine (50, 100, and 150 ppm).
application), ascorbic acid at 50 and 100 ppm application, and thiamine at 100 ppm, there were no statistical difference within all the mentioned variants.

Flower Parameters

In case of ornamental plants, early maturity was considered a positive attribute. The reason why plants that required less days for flowering are considered as good option for cultivation. In the current study, the application of amendments such as ZnSO₄ (0.25, 0.50, and 0.75%) and thiamine (100 and 150 ppm) brings plants to maturity stage in lesser days as compared to control variants (Fig. 2). All other treatments including control have no statistical difference in terms of days to flowering. Same trend was observed for flower diameter, which showed that the highest flower diameter was recorded in the treatments ZnSO₄ (0.25, 0.50, and 0.75%) and thiamine (100 and 150 ppm). Regarding flower count (secondary axis), the highest value was recorded for ZnSO₄ (0.25, 0.50, and 0.75%), thiamine (100 ppm) (Fig.2). With regard to flower weight, there was no treatment which showed a negative impact when compared to control (Fig. 2). GA at 25 ppm and ZnSO₄ at 0.75% application reduced flower weight slightly, while ACA (100 and 150 ppm) and thiamine (100 and 150 ppm) depicts higher value as compared to control. Nonetheless, the statistical highest flower weight was recorded in the variants such as GA (50 and 100 ppm), ZnSO₄ (0.25 and 0.50%), ACA (50 ppm), and thiamine (50 ppm) as compared to non-amended control (Fig. 3).

Plant Physiological Parameters

The chlorophyll contents (a, b) of *Dahlia variabilis* in all the amended variants as compared to non-amended control was shown in Fig. 4. The results showed different patterns in terms of both chlorophyll types (a, b) for all the studied treatments. However, in chlorophyll a, all forms of nutrients add positive effects as compared to control. For example, GA at 25 and 50 ppm application showed less positive effects on chlorophyll a content (2.67 and 3.04 mg g⁻¹) as compared to control (2.01 mg g⁻¹) while the effect was more pronounced in the treatments applied with GA (100 ppm) and ZnSO₄ (0.25 and 0.50 ppm), ACA (50 ppm) and thiamine (50 ppm). The higher statistical difference in chlorophyll a was recorded on the following treatments; ACA (100 and 150 ppm) as compared to control while highest chlorophyll a were recorded for ZnSO₄ (0.75%) and thiamine (100 and 150 ppm). When we compared chlorophyll b contents within all the studied treatments, the highest values were recorded almost the same as chlorophyll a contents (ZnSO₄ (0.75%) and thiamine (100 and 150 ppm) with slightly less with ACA (150 ppm) but statistically similarly. Statistically lowest values of chlorophyll contents were recorded in variants such as GA (25 ppm) and ACA (50 ppm). All the other variants like GA (100 ppm) and ZnSO₄ (0.25 and 0.50%) have no statistical difference among each other.

Plant Biochemical and Mineral Elements

Nitrogen contents in leaves were determined at the end of the experiment. The highest quantity of nitrogen contents (4.43%) was recorded by the application of ACA at 100 ppm.
ppm followed by 100 ppm while least nitrogen contents was determined in control and lower and medium doses of gibberellic acid respectively. Treatments applied with ascorbic acid and thiamine are significant over zinc and gibberellic acid application (Table 3). Foliar applications of gibberellic acid, zinc, ascorbic acid, and thiamine have significant effect on phosphorus contents in leaves of Dahlia variabilis. Results regarding the effect of foliar spray on phosphorus contents of leaves were presented in Table 3 as treatment means. Means indicated the highest quantity of phosphorus contents by application of thiamine at 100 ppm followed by 150 ppm of thiamine and the least phosphorus contents was determined in control and ACA at 50 ppm respectively.

Regarding potassium contents of leaf, highest quantity of potassium contents was recorded by application of thiamine at 150 ppm followed by ACA at 150 ppm and the least potassium contents was determined in control and gibberellin at 25 ppm respectively. The results regarding effect of gibberellic acid, zinc, ascorbic acid, and thiamine foliar spray on total soluble sugars of Dahlia variabilis were very interesting. Among the treatments highest total soluble sugars was recorded in zinc application (0.75%) followed by GA (100 ppm) and the lowest total soluble sugars was determined in control and thiamine (50 ppm). The results regarding the other treatments were significantly different from one another (Table 3). Treatments comprising zinc and gibberellic acid showed dominance over ascorbic acid and thiamine.

**DISCUSSION**

The results of this study showed that foliar spray of gibberellic acid significantly affected the plant height. This increase in plant height can be attributed to the stimulatory effect of gibberellic acid on the division and elongation of cells formed in dahlia plants. Findings were in concurrence with those of Singh et al. (1994) also reported that spraying dahlia plant treated with gibberellic acid improved plant height. These results were also in line with the findings of El-Naggar et al. (2009) on carnation. Youssef and Gomaa (2008) reported that foliar application of gibberellic acid increased the plant height by enhancing the total sugar contents and the rate of photosynthesis. Application of thiamine by foliar means had pronounced effect on main stem diameter, while producing lower plant height. However, gibberellic acid showed an increase in plant height with decreased stem diameter. Bedour et al. (2011) demonstrated that the application of thiamine led to an increase in carbohydrates percentage and NPK accumulation, which resulted in an increase in the stem diameter. Significant increase in stem diameter after application of thiamine, may be due to improved root portion of plants, which resulted in absorption of more water, nutrients, and its utilization. These results were in accordance with the results of Youssef and Talaat (2003) on rosemary. Maghoub et al. (2011) also reported a significant increase in stem diameter of dahlia by foliar application of thiamine.

Increase in plant fresh weight was due to the potential role of thiamine in biosynthesis of the coenzyme thiamin pyrophosphate, which was essential for carbohydrate metabolism. Nahed et al. (2009) for gladiolus and Maghoub et al. (2011) for dahlia found that the increase in plant fresh weight was attributed to the water and nutrients accumulation in the leaves. The

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Nitrogen (%)</th>
<th>Phosphorus (mg g⁻¹)</th>
<th>Potassium (mg g⁻¹)</th>
<th>Total Soluble Sugars (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.841 ± 0.0083 a</td>
<td>0.0924 ± 0.0035 b</td>
<td>10.25 ± 0.165 h</td>
<td>17.543±0.0321 h</td>
</tr>
<tr>
<td>GA at 25 ppm</td>
<td>0.892 ± 0.0084 a</td>
<td>0.2805 ± 0.0018 cd</td>
<td>11.70 ± 0.179 gb</td>
<td>25.662±0.0345 d</td>
</tr>
<tr>
<td>GA at 50 ppm</td>
<td>0.981 ± 0.0090 a</td>
<td>0.3413 ± 0.0034 c</td>
<td>12.50 ± 0.050 e</td>
<td>31.728±0.0435 b</td>
</tr>
<tr>
<td>GA at 100 ppm</td>
<td>1.301 ± 0.0127 ef</td>
<td>0.3916 ± 0.0031 c</td>
<td>12.95 ± 0.171 f</td>
<td>34.761±0.0747 a</td>
</tr>
<tr>
<td>ZnSO₄ at 0.25%</td>
<td>1.053 ± 0.1452 b</td>
<td>0.1529 ± 0.0025 ab</td>
<td>14.10 ± 0.202 d</td>
<td>29.323±0.0379 c</td>
</tr>
<tr>
<td>ZnSO₄ at 0.50%</td>
<td>1.401 ± 0.0097 a</td>
<td>0.1736 ± 0.0031 ab</td>
<td>15.21 ± 0.108 ab</td>
<td>32.843±0.0716 b</td>
</tr>
<tr>
<td>ZnSO₄ at 0.75%</td>
<td>2.022 ± 0.0245 d</td>
<td>0.1803 ± 0.0034 ab</td>
<td>16.15 ± 0.106 ab</td>
<td>35.142±0.0375 a</td>
</tr>
<tr>
<td>ACA at 50 ppm</td>
<td>3.751 ± 0.0947 b</td>
<td>0.1478 ± 0.0023 ab</td>
<td>13.20 ± 0.118 ab</td>
<td>20.062±0.0365 fg</td>
</tr>
<tr>
<td>ACA at 100 ppm</td>
<td>4.332 ± 0.0113 a</td>
<td>0.1851 ± 0.0011 a</td>
<td>17.56 ± 0.187 bc</td>
<td>21.621±0.0169 e</td>
</tr>
<tr>
<td>ACA at 150 ppm</td>
<td>4.432 ± 0.0211 a</td>
<td>0.2904 ± 0.0030 cd</td>
<td>18.41 ± 0.116 ab</td>
<td>21.599±0.0164 ef</td>
</tr>
<tr>
<td>Thiamine at 50 ppm</td>
<td>1.852 ± 0.0141 bc</td>
<td>0.8902 ± 0.0022 b</td>
<td>14.26 ± 0.215 ef</td>
<td>19.544±0.0193 g</td>
</tr>
<tr>
<td>Thiamine at 100 ppm</td>
<td>2.924 ± 0.0228 a</td>
<td>1.4114 ± 0.0024 a</td>
<td>17.09 ± 0.251 bc</td>
<td>21.890±0.0488 e</td>
</tr>
<tr>
<td>Thiamine at 150 ppm</td>
<td>3.811 ± 0.0188 b</td>
<td>1.4007 ± 0.0978 b</td>
<td>19.45 ± 0.157 a</td>
<td>26.240±0.0209 d</td>
</tr>
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</table>

The mean values in column followed the different letters are significantly different at 5% level of significance as p < 0.05. Means sharing the same letter did not differ significantly as p = 0.05.
increase in plant dry weight by thiamine application can be attributed to its positive effect on growth by enhancing cell division and cell expansion which leads to increased dry matter accumulation in leaves and consequently leaves become thicker and heavier. Nahed et al. (2009), while studying the effect of thiamine on growth and flowering of gladiolus, reported the improved plant growth and dry weight of leaves. The results obtained herein also agree with the findings of Bedour et al. (2011) on gladiolus plant, wherein it was found that application of thiamine at 200 ppm led to increase in plant height, number of leaves and fresh and dry weight of leaves. Zn is involved in the synthesis of plant hormones and hence, induces early maturity of shoot to induce early flowering. Ganga et al. (2008) worked on chrysanthemum, and Kumar and Haripriya (2010) on nerium, who reported early flowering by the use of zinc as foliar spray due to hormonal modification.

Various zinc treatments applied as foliar spray have significant effects on the number of flowers per plant of dahlia. Increase in number of flowers per plant was due to the increased deposition of food material and hormonal changes induced by the zinc, which triggers floral bud induction. These findings were in accordance with those of Khalifa et al. (2011) who mentioned an increase in number of flower per plant through foliar application of zinc, due to higher assimilate synthesis, which led to production of more food material in iris plants. The results showed that the treatments comprising zinc as foliar spray have significant effect on the diameter of flower. Increase in diameter of flower depends on food material, prepared as a result of photosynthesis in leaves. Carbohydrates are the main nutrients taking part in the development of flower and may cause an increase in diameter of flower (Brijendra and Singh 1986). The increase in diameter of flower through foliar spray of zinc was a function of increased nutrients uptake and the efficiency with which they were utilized for growth and flower head development. The improvement in flowering characters through foliar spray of zinc was also reported by Kumar and Haripriya (2010) on Nerium odorum L. Results clearly indicated the effectiveness of different zinc treatments as foliar spray on the fresh weight of flower. The application of zinc increases vegetative growth which in turn resulted in higher assimilate production (carbohydrates and proteins), which might have been utilized for better development of flowers (Bhyalakshmmamma 1998). The results of this study were harmonious with those of Pratap et al. (2005) in gladiolus and Ganga et al. (2008) in chrysanthemum. Phosphorus was involved in higher protein synthesis and improved the vegetative growth and dry matter accumulation in carnation flower (El-Naggar et al. 2009). Beneficial effects of zinc as foliar nutrition on floral characters have been reported in chamomile by Nasiri et al. (2010), in gladiolus by Sharma and Singh (2001) and in Nerium odorum L. by Kumar and Haripriya (2010).

The results of the treatments comprising ascorbic acid as foliar spray had significant effect on nitrogen accumulation in leaves. Increase in nitrogen contents was due to the positive effect of ascorbic acid on root growth and activity which consequently increases nitrate absorption. These results were in harmony with those reported by Nahed et al. (2009) who stated an increase in nitrogen percentage with increasing concentration of ascorbic acid as foliar spray in gladiolus. Thiamine as foliar spray improved phosphorus accumulation in leaves. The increase in phosphorus contents was because of thiamine on plant roots, which excrete organic acids into the soil and consequently increases the solubility of most nutrients which release slowly into the root zone. These results were also align with the results of Hanafy-Ahmed et al. (2002) and Bedour et al. (2011) in gladiolus, wherein it was reported that foliar spray of thiamine was responsible for increased level of phosphorus in leaves. A significant increase in potassium accumulation in dahlia leaves was observed under treatments comprising thiamine. Foliar fertilization of nutrients may increase uptake of nutrients from the soil (Tejada and Gonzalez 2004).

Foliar application of nutrients might be responsible for release of more sugars and other exudates from roots into the rhizosphere. These exudates stimulate the activity of beneficial microbial populations. This biological activity increases the availability of potassium to the plant (Fritz 1978). These results were in line with the finding of Rawia et al. (2010) who reported that increased potassium content by foliar feeding of thiamine in Jasminum grandiflorum L. The results showed that the treatments comprising thiamine as foliar spray had significant effect on chlorophyll a accumulation in leaves. The accumulation of photosynthetic pigments as a result of thiamine (nitrogenous compound) application can be attributed to the important role of nitrogen in the biosynthesis of chlorophyll molecules (Meyer et al. 1968). These findings were in conforming to those of Hassanein (2003) in Foeniculum vulgare L. plants and Abo-Dahab and Abdel-Aziz (2006) in Philodendrom erubescens plants, as they reported that foliar application of thiamine was responsible to increase the chlorophyll contents.
Zn as foliar spray have significant effect on total soluble sugars accumulation in leaves. Plants sprayed with ZnSO\textsubscript{4} had more carbohydrates through effective photosynthesis (Sharma et al. 1980). Such increments might be attributed to the significant increase in photosynthetic pigments which reflect on photosynthesis process and led to an increase in carbohydrates content of dahlia plant. These results were coined with those obtained by Khalifa et al. (2011) who reported an increase in total soluble sugars by the foliar spray of Zn in iris plant. Tanga et al. (2020) reported that application of mineral elements was responsible to improve the morphological and yield of field crops.

CONCLUSION
Outcomes from this study can be concluded that the foliar application of thiamine at 150 ppm was observed more responsive to gibberellic acid, zinc, and ascorbic acid. Application of zinc sulphate either at 0.50 or 0.75% was also found effective to improve the growth and quality of *Dahlia variabilis*. In addition, the maturity period of dahlia plants can be reduced, which in-turn can bring more profitability to the cultivation of dahlia flowers.

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