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Influence of Humic Acid and Micronutrients (Zinc + Manganese) Application on Growth and Yield of Phlox (*Phlox Paniculata*)

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Abstract A field investigation was performed during 2013 to assess the growth and yield response of phlox to different levels of humic acid and Zn + Mn. Treatments comprised of T_1=Control, T_2=300 g Humic Acid, T_3=600 g Humic Acid, T_4=150 g Zinc + 150 g Mn, T_5=300 g Humic Acid + 150 g Zinc + 150 g Mn and T_6=600 g Humic Acid + 150 g Zinc + 150 g Mn. The experiment was laid out in a three replicated Randomized Complete Block Design. The present study showed that growth and flower yield of phlox were affected significantly ($P<0.05$) due to different levels of humic acid in addition to Zn+Mn levels. The phlox treated with 600g Humic Acid + 150g Zn+150g Mn resulted in 48.00 cm plant height, 9.33 branches plant^{-1}, 27.67 flowers plant^{-1}, 12.00 leaves branch^{-1}, 0.0280 g weight of flowers plant^{-1}, took 21.33 days to opening of first flower and 5.33 days total blooming period. The results showed that application of 600g Humic Acid + 150g Zn+150g Mn resulted in significantly better performance than rest of the treatments with 27.67 flowers plant^{-1} and 12 .00 leaves branch^{-1}. The humic acid at lower rate of 300g resulted in lower values for all the parameters studied; while control remained the least in performance. It was concluded that there was positive and significant impact of humic acid + Zn + Mn combination on the growth and flower yield of phlox and humic acid @ 600g + 150g Zn+150g Mn resulted in highest values for all the growth and flower yield parameters and increased blooming period. Moreover, humic acid at higher rates either applied individually or in combination with Zn+Mn proved to be beneficial in improving the growth and flower production pholox; while individual application of Zn+Mn did not prove to be highly effective.

Keywords: *Phlox Paniculata,* humic acid, zinc + manganese, flower production

Introduction

Phlox are perennials and a favorite choice among wildflowers. These plants are star-shaped, colorful flowers when in bloom and there are so many varieties. *Phlox* is a genus of 67 species of perennial and annual plants in the

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family Polemoniaceae. Phlox are valued in the garden for their ability to attract butterflies (Craigmyle, 2002). Phlox can be propagated from stem cuttings.

Among the various factors responsible for poor growth and flowering of flowers and ornamental plants, imbalanced application of nutrients and improper management practices are of primary importance. Micronutrient deficiency and inadequacy of humic substances also cause poor growth of the plants. Humic acids are colloids and behave somewhat like clays, even though the nomenclature suggests that they are acids and form true salts (Senn and Kingman, 1973). The manifold effect of humic substances on the plant, shown both in the external medium and in the biochemical processes occurring in the plant, has been well demonstrated (Senn and Kingman, 1973). There is a growing interest in the use of organic materials as fertilizers or soil amendments (Jeyabal and Kuppuswamy, 2001). Its direct effect on plant growth has been attributed to the increase in chlorophyl content, the acceleration of the respiration process, hormonal growth responses, increasing penetration in plant membranes or a combination of these processes (Jariene *et al.,* 2007; Chen and Aviad, 1990); while MacCarthy *et al.,* (2001) reported that humates enhanced nutrient uptake, improve soil structure, and increase crop yields.

Humic acid also helps the soil retain the nutrients, which provides a "timed released" fertilizer, making plants healthier. Healthy plants are often less susceptible to insect and disease problems, a beneficial side effect. The colour and foliage of plants such as abelias, daylilies, licorice plants, phlox, mock orange, sage, stonecrop, weigela, New Zealand flax and ornamental grasses are improved with application of humic acid. (Timrod, 2011)

Among micronutrients, the role of zinc for plant growth cannot be tolerated. Zn is classified as a micronutrient and if the deficiency of Zn is severe, the symptoms may last throughout the entire season. A deficiency of Zn is characterized by the development of broad bands of striped tissue on each side of the midrib of the leaf. These stripes begin on the part of the leaf closest to the stalk and appear first on the upper part of the plant (Asad and Rafique, 2000). A Zn deficient plant also appears to be stunted. Almost 50 percent of the world soils are Zn deficient (Torun *et al.,* 2001); as a result (Asad and Rafique, 2002). The plant growth, flowering and biomass yield can be improved by addition of Zn fertilization (Maqsood *et al.,* 2009; Parandian and Samavat 2012).

Manganese is now recognized as an essential element for normal plant growth, and most soils contain sufficient of it in an available form to supply the needs of all vegetation. There are certain soils, however, mainly reclaimed swamp soils and soils with a very high calcium carbonate content, in which manganese is either not present in sufficient quantity or not in an available enough form, to support the growth of certain plant species. The manganese value of a soil should always be determined before liming, especially in the case of sandy soils, so that a calculation can be made of the largest allowable increase in pH. There is conflicting research that high soil Zn can either increase or decrease Mn uptake by various plant species. Until more definite evidence is available, the relation of soil Zn level cannot be concluded with Mn availability (Anon, 1936). Rahman *et al.* (2000) reported that response of phlox to humic acid in different forms was positive and significant resulting in improvement growth and flower yields. Timrod (2011) concluded that humic helps chelate and improve the effects of many fertilizers; and helps the soil retain the nutrients, which provides a timed released fertilizer, making plants healthier. Healthy plants are often less susceptible to insect and disease problems, a beneficial side effect. Parandian and Samavat (2012) reported that humic acid have increasing effects on flower production of ornamental plants and commercial flowers. El-Naggar (2009) revealed that plant treated with micronutrients (including Zn and Mn) showed significant increase in the growth characteristics of plants such as stem length, stem diameter, stem fresh and dry weight, number of leaves plant^{-1}, fresh and dry weight of leaves. Kumar *et al.* (2009) reported that Mn foliar application (0.4%) resulted in maximum average flower weight and more flower plant^{-1} in chrysanthemum. Sloan *et al.* (2010) used three phlox cultivars and reported that more flowers were obtained in plants receiving higher amounts of micro- and macronutrients in phlox which also improved the quality phlox plants and flowers. Foliar application of micronutrients produced beneficial effect on the phlox flower production. Mahdi *et al.* (2011) reported that Zn and Mn foliar application had positive impact on the flower yield. Jorjette (2012) concluded that phlox is highly responsive to foliar application of micronutrients which increased the plant growth and flower production. Agronomic Library (2013) discussed the plant manganese requirements and deficiency symptoms and stated that because Mn is not translocated in the plant, deficiency symptoms appear first on younger leaves. The most common symptoms on most plants are interveinal chlorosis. On high pH soils, the use of acid-forming fertilizers in the row can increase the uptake of Mn, and other micronutrients. One example of an acid-forming fertilizer blend would be one based on monoammonium phosphate and ammonium sulfate; where foliar Mn is used, multiple applications throughout the season are often needed to compensate for soil deficiencies. Bangulzai (2013) indicated that all the zinnia traits examined including plant height, number of branches plant^{-1}, number of leaves branch^{-1}, days taken to first flower emergence, number of flowers plant^{-1}, size of flower, average flower life and total blooming period with the exception of days to first flower emergence. In order to examine the role of humic substances and micronutrients, the experiment was conducted to investigate the influence of humic acid and Zinc + Manganese application on yield and growth of phlox.

Materials and methods

The experiment was conducted in a three replicated Randomized Complete Block design and six treatments at Department of Horticulture, Sindh Agriculture University Tandojam. Initially the experimental land was plowed up with disc plow to remove the hard pan of the soil. However, after soaking dose, the land was properly worked and leveled for uniform distribution of irrigation water. The main plot was divided into 18 sub-plots measuring in a plot size of 4ft x 5ft ($20ft^2$). Each sub-plot was separated by 30 cm bund; and these plots were prepared keeping in view the feasible application of irrigation. The distance between rows was maintained at 30 cm, while phlox seedlings were spaced at 20 cm.

The irrigation water was regularly applied keeping in view the drought sensitivity of phlox. The distribution of water to all ends of the sub-plot equally was the objective during the seed bed preparation process. For this purpose precision land leveling was carried out. Pre-emergence weedicides were applied, so that the weeds are killed in the field before planting of the phlox. However, flower beds were strictly monitored for development of any weeds when the phlox plants were under their development process. Plots were kept clean, and a periodical weeding was performed to allow the experimental plants to utilize nutrients and moisture optimally. Moreover, the presence of weeds could also cause insect pest infestation; so cultural practices were performed in each bed uniformly. For recording observations on various growth and flower yield parameters, five normal looking plants in each sub-plot were randomly selected and marked by different labels to avoid any confusion in recording observations. The observations on the number of days taken to opening of first flower of phlox and total blooming period in days were recorded carefully for in each plot.

The data of all the parameters were subjected to the analysis of variance techniques (Steel *et al.,* 1997). Subsequently, the significant means were separated by the least significant difference (LSD) test by using the MSTAT-C computer program.

Results

Plant height (cm)

The results regarding the response of phlox for its plant height to different humic acid + Zn + Mn levels are given in Table-1. The analysis of variance indicated that the plant height of phlox was significantly ($P<0.05$) affected by humic acid in addition to zinc + Manganese at different levels. It is evidnt from the data (Table-1) that maximum plant height of 48.00 cm was recorded in plots under T_6 (600 g Humic Acid + 150 g Zinc + 150 g Mn), followed by T_5 (300 g Humic Acid + 150 g Zinc + 150 g Mn) resulting average plant height of 45.33 cm. The phlox plants treated under T_3 (600 g Humic Acid), T_4 (150 g Zinc + 150 g Mn) and T_2 (300 g Humic Acid) ranked 2nd, 3rd and 4th with average plant height of 38.33 cm, 37.00 and 36.67 cm, respectively. However, the minimum plant height of 34.00 cm was recorded under T_1 (control), where neither humic acid and nor Zn + Mn were applied. Statistically, the differences in plant height under T_2 (300 g Humic Acid), T_3 (600 g Humic Acid) and T_4 (150 g Zinc + 150 g Mn) were non-significant ($P>0.05$) indicating a similarity in response towards plant height when humic acid and Zn+Mn were applied separately. However, combined application of humic acid and Zn+Mn showed a marvelous impact on this trait and the phlox plantation treated with 150g Zn+ 150g Mn in combination with highest humic acid level of 600 g maximized the plant height.

Number of branches plant^{-1}

The data in relation to response of phlox for number of branches plant^{-1} to different levels of humic acid + zinc (Zn) + Manganese (Mn) are presented in Table-1 .The analysis of variance demonstrated that the number of branches plant^{-1} of phlox varied significantly ($P<0.05$) due to different levels of humic acid in addition to a certain rate of Zn + Mn.

The results in Table-1 indicated that highest number of branches plant^{-1} (9.33) was recorded from the plots under T_6 (600 g Humic Acid + 150 g Zinc + 150 g Mn), closely followed by T_5 (300 g Humic Acid + 150 g Zinc + 150 g Mn) producing 8.67 average number of branches plant^{-1}. The phlox plantation under T_3 (600 g Humic Acid) and T_4 (150 g Zinc + 150 g Mn) ranked 2nd and 3rd with 6.33 and 6.00 average number of branches plant^{-1}, respectively. The phlox plantation under and T_2 (300 g Humic Acid) showed reduced number of branches (5.33) plant^{-1}, while the number of branches plant^{-1} was lowest (3.00) when the phlox plantation was kept untreated of humic acid, zinc as well as Mn application (control). Statistically, the differences in the number of branches plant^{-1} under T_6 (600 g Humic Acid + 150 g Zinc + 150 g Mn) and T_5 (300 g Humic Acid + 150 g Zinc + 150 g Mn) were non-significant ($P>0.05$) suggesting that 300g humic acid in addition to 150g Zn + 150g Mn would be an optimum level to achieve economically most efficient results in phlox for the number of branches plant^{-1}. Moreover, separate use of Zn and Mn was less effective against branching as compared to their application at certain doses in addition to humic acid.

Number of flowers plant^{-1}

The results regarding the response of phlox to various levels of humic acid + zinc (Zn) + Manganese (Mn) for number of flowers plant^{-1} are shown in Table-1 The analysis of variance illustrated a significant ($P<0.05$) effect of different humic acid levels in addition Zn + Mn on the number of flowers plant^{-1}.

It is apparent from the results in Table-1 that maximum number of flowers plant^{-1} (27.67) was achieved in plots under T_6 (600 g Humic Acid + 150 g Zinc + 150 g Mn), followed by T_3 (600 g Humic Acid) and T_5 (300 g Humic Acid + 150 g Zinc + 150 g Mn) with 25.33 and 24.00 average number of flowers plant^{-1}, respectively. Similar performance in regards to number of flowers plant^{-1} was observed in plots under T_4 (150 g Zinc + 150 g Mn) and T_2 (300 g Humic Acid) with equal 21.33 flowers plant^{-1}, respectively. However, the minimum number of flowers plant^{-1} (15.33) was recorded in control plots, where neither humic acid and nor Zn + Mn were applied. This higher number of flowers plant^{-1} was mainly associated with the increased number of branches plant^{-1}. Statistically, the differences in the number of flowers plant^{-1} under T_4 (150 g Zinc + 150 g Mn) and T_2 (300 g Humic Acid) or between T_3 (600 g Humic Acid) and T_5 (300 g Humic Acid + 150 g Zinc + 150 g Mn) were non-significant ($P>0.05$) and sitgnificant ($P<0.05$) when these treatment groups were compared with each other or with control. The results further suggested that in absence of humic acid, the flowering in phlox adversely affected; while higher humic acid levels in addition to Zn+Mn showed best results for this parameter.

Number of leaves branch^{-1}

The results related to the number of leaves branch^{-1} of phlox in response to various levels of humic acid + zinc (Zn) + Manganese (Mn) are presented in Table-1. The analysis of variance suggested a significant ($P<0.05$) effect of various humic acid levels in addition Zn + Mn on the number of leaves branch^{-1}.

The results (Table-1) showed that the maximum number of leaves branch^{-1} (12.00) was obtained in plots under T_6 (600g Humic Acid + 150g Zinc + 150g Mn), closely followed by T_5 (300g Humic Acid + 150g Zinc + 150g Mn) and T_3 (600g Humic Acid) with 10.33 and 10.00 average number of leaves branch^{-1}, respectively. Similar performance in regards to number of leaves branch^{-1} was observed in plots under T_4 (150g Zinc + 150g Mn) and T_2 (300g Humic Acid) with equal 8.67 leaves branch^{-1}, respectively. However, the minimum number of leaves branch^{-1} (6.00) was observed in control plots, neither supplied with humic acid nor added Zn + Mn. This higher number of leaves branch^{-1} was mainly influenced by the number of branches plant^{-1}. Statistically, the differences in the number of leaves branch^{-1} under T5 (300g Humic Acid + 150g Zn + 150g Mn) and T6 (600g Humic Acid + 150g Zn + 150g Mn) or amongst T_2 (300g Humic Acid), T_3 (600g Humic Acid) and T_4 (150g Zinc + 150g Mn), suggesting that 300g Humic Acid + 150g Zn + 150g Mn would be an optimum level for achieving maximally economical results in phlox plantation; while separate use of Zn+Mn did a little effect, but higher level of humic acid even without Zn+Mn showed good results for this parameter. However, combined application of humic acid, Zn and Mn showed remarkable impact on this trait.

Table 1. Plant height (cm) , Number of branches plant^{-1}, Number of flowers plant^{-1}and Number of leaves branch^{-1} of phlox as influenced by humic acid and micronutrients (zinc + manganese)

Treatments	Plant height (cm)	Number of branches	Number of flowers	Number of leaves branch^{-1}
T1=Control	34.00 d	3.00 d	15.33 d	6.00 c
T2=300 g Humic Acid	36.67 c	5.33 c	21.33 c	8.67 b
T3=600 g Humic Acid	38.33 c	6.33 b	25.33 b	10.00 b
T4=150 g Zn + 150 g Mn	37.00 c	6.00 b	21.33 c	8.67 b
T5=300 g Humic Acid + 150g Zn + 150g Mn	45.33 b	8.67 a	24.00 b	10.33 a
T6=600 g Humic Acid + 150g Zn + 150g Mn	48.00 a	9.33 a	27.67 a	12.00 a
S.E.	1.2620	0.3549	0.6831	0.8389
LSD 0.05	2.8119	0.7907	1.5221	1.8691
LSD 0.01	3.9996	1.1246	2.1650	2.6586

In a column means followed by same letters are not significantly different at P=0.05 as suggested by LSD test.

Weight of flowers (g plant^{-1})

The data in case of weight of flowers plant^{-1} in phlox as influenced by different levels of humic acid + zinc (Zn) + Manganese (Mn) are shown in Table-2. The analysis of variance described that the effect of different levels of humic acid in addition Zn + Mn on the weight of flowers plant^{-1} was statistically significant ($P<0.05$).

It can be seen from the results (Table-2) that highest weight of flowers plant^{-1} (0.0280 g) was achieved from the plots under 600g Humic Acid + 150g Zinc + 150g Mn (T_6), followed by 300g Humic Acid + 150g Zinc + 150g Mn (T_5) and 600g Humic Acid (T_3) with 0.0260 and 0.0247 g average weight of flowers plant^{-1}, respectively. The weight of flowers plant^{-1} reduced to 0.0240 g in plots under T_2 (300g Humic Acid) and further diminished to 0.0223 g plant^{-1} under T_4 (150 g Zinc + 150g Mn). However, the lowest weight of flowers plant^{-1} (0.0167 g) was recorded in control plots, where no humic acid and Zn + Mn were applied. This higher weight of flowers plant^{-1} was mainly associated with the plant vigour that resulted in healthy flowers and hence increased weight of flowers. Statistically, the differences in the weight of flowers plant^{-1} between T_6 (600g Humic Acid + 150g Zinc + 150g Mn) and 300g T_5 (300g Humic Acid + 150g Zinc + 150g Mn) were non-significant ($P>0.05$) which suggested that 300g Humic Acid when applied with 150g Zn + 150g Mn would be an optimum level for phlox. However, absence of humic acid from the treatment plan adversely affected the weight of flowers.

Days to opening of first flower

The period taken for opening of first flower by phlox plantation was also recorded and the results on days taken to opening of first flower under the effect of different levels of humic acid + zinc (Zn) + Manganese (Mn) are presented in Table-2. The analysis of variance demonstrated that the effect of varied levels of humic acid in addition Zn + Mn on the days taken to opening of first flower was significant ($P<0.05$).

The phlox plantation took minimum period to opening of first flower (21.33 days) when fertilized with 600g Humic Acid + 150g Zinc + 150g Mn (T_6), followed by 300g Humic Acid + 150g Zinc + 150g Mn (T_5), 600g Humic Acid (T_3) and 300g Humic Acid (T_2) where the phlox plantation took equally 24.00, 24.00 and 24.00 days to opening of first flower, respectively. The opening of first flower delayed under T_4 (150 g Zinc + 150g Mn) when humic acid was not applied. However, the maximum number of days (31.00) taken to opening of first flower was observed in control plots, neither where humic acid and nor Zn + Mn were applied. Statistically, the differences in the days taken to opening of first flower amongst treatments, T_2 (300g Humic Acid), T_3 (600g humic acid) and T_5 (300g Humic Acid + 150g Zinc + 150g Mn) were statistically non-significant (P>0.05). It is clear from the results that application of humic acid caused earliness in opening of first flower, while the effect of Zn + Mn was not pronounced on this parameter.

Total blooming period (days)

The total blooming period of the phlox was observed and the results on the effect of different levels of humic acid + zinc (Zn) + Manganese (Mn) on total blooming period are shown in Table-2. The analysis of variance indicated that the effect of varied levels of humic acid in addition Zn + Mn on the total blooming period was significant (P<0.05).

Table 2. Weight of flowers plant^{-1}, Number of days taken to opening of first flower and Total blooming period (days) of phlox as influenced by humic acid and micronutrients (zinc + manganese)

Treatments	Weight of flowers plant^{-1}	Days to opening of first flower	Total blooming period (days)
T1=Control	0.0167 d	31.00 d	3.00 c
T2=300 g Humic Acid	0.0240 b	24.00 b	4.00 b
T3=600 g Humic Acid	0.0247 b	24.00 b	5.00 a
T4=150 g Zn + 150 g Mn	0.0223 c	25.33 c	4.00 b
T5=300 g Humic Acid + 150g Zn + 150g Mn	0.0260 a	24.00 b	5.00 a
T6=600 g Humic Acid + 150g Zn + 150g Mn	0.0280 a	21.33 a	5.33 a
S.E	0.0011	0.4635	0.1925
LSD 0.05	0.0022	1.0327	0.4288
LSD 0.01	0.0032	1.4689	0.6099

In a column means followed by same letters are not significantly different at P=0.05 as suggested by LSD test.

It is obvious from the results that the total blooming period in phlox was maximum (5.33 days) when fertilized with 600g Humic Acid + 150g Zinc + 150g Mn (T_6), followed by 300g Humic Acid + 150g Zinc + 150g Mn (T_5) and 600g Humic Acid (T_3) with equally 5.00 and 5.00 days total blooming period, respectively. The total blooming period decreased to equally 4.00 and 4.00 days in phlox under T_4 (150 g Zinc + 150g Mn) and T_2 (300g Humic Acid), respectively. However, the lowest blomming period (3.00 days) was observed in control plots, neither where humic acid and nor Zn + Mn were applied. Statistically, the differences in the total blooming period amongst treatments, T_3 (600g humic acid) and T_5 (300g Humic Acid + 150g Zinc + 150g Mn) and T_6 (600g Humic Acid + 150g Zinc + 150g Mn) were statistically non-significant ($P>0.05$), suggesting that higher humic acid alongwith Zn+Mn resulted in increased blooming period. However, application of humic acid was of more importance than the application of Zn+Mn.

Discussion

The present study showed that growth and flower yield of phlox were affected significantly ($P<0.05$) due to different levels of humic acid in addition to Zn+Mn levels. The phlox treated with 600g Humic Acid + 150g Zn+150g Mn resulted in 48.00 cm plant height, 9.33 branches plant^{-1}, 27.67 flowers plant^{-1}, 12.00 leaves branches^{-1}, 0.0280 g weight of flowers plant^{-1}, took 21.33 days to opening of first flower and 5.33 days total blooming period. Under 300 g Humic Acid + 150 g Zinc + 150 g Mn treatment, phlox produced 45.33 cm plant height, 8.67 branches plant^{-1}, 24.00 flowers plant^{-1}, 10.33 leaves branches^{-1}, 0.0260 g weight of flowers plant^{-1}, took 24.00 days to opening of first flower and 5.00 days total blooming period. The plants fertilized only with 150 g Zn + 150 g Mn produced 37.00 cm plant height, 6.00 branches plant^{-1}, 21.33 flowers plant^{-1}, 8.67 leaves branches^{-1}, 0.0223 g weight of flowers plant^{-1}, took 25.33 days to opening of first flower and 4.00 days total blooming period. Phlox plantation given only humic acid at higher rate of 600g resulted in 38.33 cm plant height, 6.33 branches plant^{-1}, 25.33 flowers plant^{-1}, 10.00 leaves branches^{-1}, 0.0247 g weight of flowers plant^{-1}, took 24.00 days to opening of first flower and 5.00 days total blooming period. The humic acid at lower rate of 300g resulted in lower values for all the parameters studied; while control remained the least in performance. These results are further supported by Rahman *et al.* (2000) who found that the growth of phlox on humic acid through compost, vegetable compost + sand m^2, vegetable compost + compost + garden soil m^3 and vegetable compost + sand + garden soil m^4 was applied. The maximum number of days (32.67) to branching was recorded in substrate m^4 while minimum number of days (26.0) to branching was noted in substrate m^2. The plant height recorded in substrate m^2 was maximum (16.0 cm) while that was minimum (10.87 cm) in substrate m^4. Henry Timrod (2011) concluded that humic helps chelate and improve the effects of many fertilizers. Humic acid also helps the soil retain the nutrients, which provides a "timed released" fertilizer, making plants healthier. Healthy plants are often less susceptible to insect and disease problems, a beneficial side effect. The colour and foliage of plants such as abelias, daylilies, licorice plants, phlox, mock orange, sage, stonecrop, weigela, New Zealand flax and ornamental grasses are improved with application of humic acid. Parandian and Samavat (2012) reported that humic acid have increasing effects on on lilium flowers. The effects of fulvic acid on lilium petals color was more clear with respective to humic acid. With increasing the amounts of humic and fulvic acid, the lilium quality indices increased too but its trend in fulvic acid was more obvious. In case of response of phlox to different micronutrients, El-Naggar (2009) revealed that plant treated with micronutrients showed significant increase in the growth characteristics (stem length, stem diameter, stem fresh and dry weight, number of leaves/plant, fresh and dry weight of leaves). Kumar *et al.* (2009) reported that treatment $MnSO_4$ (0.4%) also resulted in maximum average flower weight (2.17 g) and more number of flowers/plant (200). At Solan, foliar spray with $MnSO_4$ (0.6%) thrice recorded significantly maximum number of side shoots/plant over all the other treatments. $FeSO_4.7\ H_2O$ at 0.2% recorded the maximum number of flowers/spray, followed by $ZnSO_4$ at 0.6 or 0.2% and $FeSO_4$ at 0.6% which were at par with each other. Sloan *et al.* (2010) used three phlox cultivars and reported that produced more flowers in heated frames than plants grown in the cold frame and indicated that growers can use cold frames to produce quality phlox plants. Foliar application of micronutrients produced beneficial effect on the phlox flower production. Mahdi *et al.* (2011) reported that Mn foliar application had the highest positive effect on yield components. The highest concentration of these two components was found on the flowering stage. Jorjette (2012) concluded that phlox is highly responsive to foliar application of micronutrients which increased the plant growth and flower production. Agronomic Library (2013) discussed the plant manganese requirements and deficiency symptoms and stated that because Mn is not translocated in the plant, deficiency symptoms appear first on younger leaves. The most common symptoms on most plants are interveinal chlorosis. On high pH soils, the use of acid-forming fertilizers in the row can increase the uptake of Mn, and other micronutrients. One example of an acid-forming fertilizer blend would be one based on monoammonium phosphate and ammonium sulfate; where foliar Mn is used, multiple applications throughout the season are often needed to compensate for soil deficiencies.

Conclusions

It was concluded that there was positive and significant impact of humic acid + Zn + Mn combination on the growth and flower yield of phlox and humic acid @ 600g + 150g Zn+150g Mn resulted in highest values for all the growth and flower yield parameters and increased blooming period. Moreover, humic acid at higher rates either applied individually or in combination with Zn+Mn proved to be beneficial in improving the growth and flower production pholox; while individual application of Zn+Mn did not prove to be highly effective. Hence, it is suggested that for achieving desired results in phlox, the plantation may be given 600g humic acid in addition to 150g Zn+150g Mn.

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