International Journal of Agricultural Technology 2014 Vol. 10(6):1509-1521
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Effect Of Humic Acid and Iron Sulphate on Growth and Yield of Zinnia (*Zinnia elegans*)

Memon, S. A.[*], Bangulzai, F. M., Keerio, M. I., Baloch, M. A. and Buriro, M.

Sindh Agriculture University Tandojam.

Memon S. A., Bangulzai, F. M., Keerio, M. I., Baloch, M. A. and Buriro, M. (2014). Effect of humic acid and iron sulphate on growth and yield of Zinnia (*Zinnia elegans*). International Journal of Aricultural Technology 10(6):1509-1521.

Abstract The study was performed during the year 2012 to examine the effect of humic acid and iron sulphate on the growth and yield of zinnia *(Zinnia elegans)*. The treatments comprised of T_1=Control, T_2=4 g humid acid, T_3=40 g humic acid, T_4=40 g Fe SO_4, T_5=4 g Humic acid + 40 g $FeSO_4$ and T_6=40 g Humic acid + 40 g $FeSO_4/2m^2$. The experiment was laid out in a three replicated Randomized Complete Block Design. The results revealed that increasing humic acid level when applied alone and lower humic acid when applied with higher $FeSO_4$ resulted significantly ($P<0.05$) improved the growth and flower yield performance of zinnia. The treatment T_5, where 4 g Humic acid + 40 g $FeSO_4/2m^2$ proved to be an optimum level and performed maximally for all the studied traits with 52.22 cm plant height, 12.55 branches plant^{-1}, 11.55 leaves branch^{-1}, 61.66 days taken to first flower emergence, 14.55 flowers plant^{-1}, 7.14 cm size of flower, 13.11 days life of single flower and 34.77 days total blooming period. The results 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, followed similar growth and flower production trend and similar response to various humic acid and $FeSO_4$. However, days taken to first flower emergence were inversely proportional to increasing humic acid or combination of $FeSO_4$ which was in contrast to rest of all the characters investigated.

Keywords: Humic acid, Iron sulphate , Zinnia *(Zinnia elegans)*, Production

Introduction

Zinnia is a wonderful summer annual flower which is gaining rapid popularity for its variety of colorful blooms. It belongs to family Compositae. It is native to Mexico and Central America. The most cultivated zinnia varieties “Blue Point” and “Oklahoma” are considered best because of their good performance and various color blooms (Dole, 1999). *Zinnia* is genus of 20 species of annual and perennial plants and its flowers exhibit bright, uniform

[*] **Corresponding author:** Memon S. A.**; E-mail:** sabamemonjee@gmail.com, sabamemonjee@yahoo.com

colors, sturdy stems with disease resistant plants and a long vase life. *Zinnia elegans*, also known as *Zinnia violacea*, is the most familiar species and a plant of warm, hot climate. Traditionally, taller varieties of Zinnia are used in borders, beds and for cut flowers but the dwarf varieties in containers and window planters (Jana and Pal, 1991).

In Pakistan, zinnia is grown in many types of soils, soil mixtures, or mixtures of organic matter and materials without soil that may include sand, peat, perlite, bark and wood chips, sludge, or composted leaves. The growing media should be porous, uniform in texture, hold sufficient moisture and should be well drained. Commercial mixtures are often used because they are sterilized, ready to use and may even contain some fertilizer. The beneficial effect of combination of different types of fertilizers containing macro and micronutrients on growth parameters of Zinnia are well recognized (Dhaka *et al*., 1999).

Humic acids are colloids and behave somewhat like clays, even though the nomenclature suggests that they are acids and form true salts (Mart, 2007). There is a growing interest in the use of organic materials as fertilizers or soil amendments. This may be attributed to: 1) an interest in the reduction of the use of chemical fertilizers; 2) public concern for the potential polluting effects of chemicals in the environment; and 3) a pressing need for energy conservation (Jeyabal and Kuppuswamy, 2001). Humic acid can be used as an alternative to synthetic fertilizers to increase crop production (Maggioni *et al*., 1992), or an indirect effect, mainly by changing the soil structure (Biondi *et al*. 1994). HA is also proven to be effective in enhancing the mineral nutrient uptake (Pan and Dong, 1995).

Humic substance supply growing plants with food; makes soil more fertile and productive, increases the water holding capacity of soil; therefore, it helps plants resist droughts and stimulates seed germination. Humic acid reduces other fertilizer requirements, increases yield in crops, improved drainage, increases aeration of the soil, increase the protein and mineral contents of most crops and establish a desirable environment for microorganism development (Hartwigson and Evans 2000).

The use of humic acid has been found in different fertilizers forms. The indirect effects of humic compounds have been attributed to the improvement of physical, chemical and biological conditions of soil (Jariene *et al*. 2008). 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*. 2008). Chen and Aviad (1990) have reported positive effect of humate on crop growth and recommend humic acid at the rate of 5 kg acre.

MacCarthy *et al.* (2001) reported that humates enhanced nutrient uptake, improve soil structure, and increase crop yields. In many studies, humic and fulvic acids preparations were reported to increase the uptake of mineral elements (Maggioni *et al*. 1987; De Kreij and Basar 1995; Mackowiak *et al.* 2001), to promote the root length (Vaughan and Malcolm, 2002), and to increase the fresh and dry weights of crop plants (Kauser *et al.* 1985; Chen *et al.* 2004a, b). Due to the positive effect of humic substances on the visible growth of plants, these chemicals have been widely used by the growers instead of other substances such as pesticides etc.

Iron (Fe) deficiency is a plant disorder also known as "lime-induced chlorosis". It can be confused with manganese deficiency. A deficiency in the soil is rare but iron can be unavailable for absorption if soil pH is not between about 5 and 6.5. A common problem is when the soil is too alkaline (the pH is above 6.5). Also, iron deficiency can develop if the soil is too waterlogged or has been overfertilised (Schuster, 2008).

Plants are prone to iron deficiency in alkaline, calcareous soils, compacted fields, coarse-textured soils, soils low in organic matter, eroded soils in cold weathered area and flooded rice fields being an exception. Some crops sensitive to iron deficiency are citrus, field bean, grapes, groundnut, sorghum, soybean, vegetables and ornamentals. Iron deficiency seems to be one fourth as extensive as that of Zn, amongst the micronutrients. Ahmad *et al.* (2010) reported that foliar application of Fe at 1.00 % concentration on rose (*Rosa hybrida* L.) was helpful to improve flower yield and quality when applied along with other micronutrients; while Le Chang *et al.* (2011) reported that foliar application of Fe on Oriental Lily and reported positive effects on the foliage and flowering. It is estimated that Fe deficiency is widespread occurring in about 30 and 50% respectively of cultivated soils (Cakmak, 2002). Iron is critical for chlorophyll formation and photosynthesis and is important in the enzyme systems and respiration of plants (Havlin *et al.* 1999). This, however, has led to growers using higher amounts of these substances

In view of the facts stated above, the present study was carried out to determine the effect of different humic acid and iron sulphate levels on the growth and yield of Zinnia.

Materials and methods

The field study on the effect of Humic acid and Iron sulphate on the growth and yield of Zinnia was carried out at experimental area in Department of Horticulture, Sindh Agriculture University Tandojam. The experiment was laid out in a three replicated randomized complete block design (RCBD) and six treatments. For conducting this experiment, the whole plot was properly worked and leveled for even distribution of water. Thereafter the plot was divided into 18 sub-plots measuring 1mx 2m ($2m^2$).

Each bed was separated by developing 30 cm bund, and these sub-plots/beds were prepared in such a way to be irrigated feasibly and uniformly. The Zinnia seedlings were transplanted at a distance of 30 cm between rows and 20 cm between plants. All cultural practices were carried out throughout the growing season as recommended.

When the plants attained establishment, 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 emergence of first flower bud and opening of first flower and later life of the flower were cautiously recorded at the field.

The data of all the parameters were individually subjected to the analysis of variance techniques (Steel *et al.*, 1997). Subsequently, the significant means were separated by the Least Significant Difference Test by using the MSTAT-C computer program.

Results

Plant height (cm)

Mean plant height of zinnia was affected by different humic acid and iron sulphate levels is shown in Table-1. The analysis of variance suggested that plant height of zinnia influenced significantly ($P<0.05$) due to different levels of humic acid and iron sulphate. The Zinnia grew maximally taller (52.22 cm) when given 4 g humic acid + 40 g $FeSO_4/2m^2$, followed by average zinnia plant height of 48.88 cm, 46.33 cm and 45.66 cm in plants treated with 40g Humic acid + 40 g $FeSO_4$, 40 g Fe SO_4 and 40 g humic acid, respectively. The plant height of zinnia decreased markedly to 43.44 cm when treated with 4 g humid acid, while the lowest plant height of 41.88 cm was noted in case of control, where no humic acid and iron sulphate were applied. This indicates that increasing humic acid significantly ($P<0.05$) increased plant height in zinnia, and combined application of humic acid and iron sulphate at highest levels showed adverse impacts on plant height, while highest level of iron sulphate alongwith lowest level of humic acid in combination provided significantly positive results in relation to zinnia plant height. However, the differences in plant height between treatments 40 g humic acid and 40 g Fe SO_4 were statistically non-significant ($P>0.05$) and significant ($P<0.05$) when compared with rest of the treatments.

Number of branches plant^{-1}

Number of branches plant^{-1} has straight effect on the flower production of zinnia. The results in regards to the number of branches of zinnia as influenced by different humic acid and iron sulphate levels are presented in Table-1. The analysis of variance indicated that the number of branches plant^{-1} were significantly ($P<0.05$) affected under varied levels of humic acid and iron sulphate.

It is evident from the results in Table-1 that the highest number of branches (12.55) plant^{-1} was observed in plants fertilized with 4 g humic acid + 40 g $FeSO_4$/2m^2, followed by 10.44 and 8.66 average number of branches plant^{-1} recorded in plants treated with 40 g Humic acid + 40 g $FeSO_4$ and 40 g Fe SO_4, respectively. The number of branches decreased to 7.44 and 6.88 plant^{-1} when the plants were treated with 40 g humic acid and 4 g humid acid, respectively ; while the minimum number of branches (5.66) plant^{-1} was recorded in plants given no humic acid and no iron sulphate (control). This higher number of branches plant^{-1} in zinnia plants was mainly associated with increased plant height. However, with each increment in the humic acid level, there was a significant ($P<0.05$) increase in the number of branches plant^{-1}. The combined application of humic acid at lowest level (4 g) and iron sulphate at highest level (40 g) resulted in a maximum performance in relation to the trait under discussion; while branching adversely affected under highest levels of humic acid iron sulphate. The LSD test suggested that the differences in branches plant^{-1} between treatments 4 g humic acid and 40 g humic acid applied alone, were non-significant ($P>0.05$) and significant ($P<0.05$) when compared with other treatments.

Number of leaves branch^{-1}

The data regarding the number of leaves branch^{-1} of zinnia as affected by different humic acid and iron sulphate levels are shown in Table-1. The analysis of variance suggested that the effect of different levels of humic acid and iron sulphate on the number of leaves branch^{-1} were significant ($P<0.05$).

The results indicated that the maximum number of leaves (11.55) branch^{-1} was observed in plants fertilized with 4 g humic acid + 40 g $FeSO_4$/2m^2, followed by 10.22 and 9.33 average number of leaves branch^{-1} recorded in plants treated with 40 g Humic acid + 40 g $FeSO_4$ and 40 g $FeSO_4$, respectively.

The number of leaves branch^{-1} diminished to 8.21 and 7.33 when the zinnias were treated with 40 g humic acid and 4 g humid acid, respectively; while the lowest number of leaves (6.22) branch^{-1} was recorded in control where plants were given no humic acid and no iron sulphate. This higher number of leaves branch^{-1} was mainly associated with increased plant height. It was noted that increasing humic acid level significantly ($P<0.05$) increased the number of leaves branch^{-1} and combined application of 4 g humic acid and 40 g iron sulphate resulted in remarkably increased number of leaves branch^{-1}; while the number of leaves branch^{-1} decreased with 40 g humic acid and 40 g iron sulphate. Hence, 4 g humic acid and 40 g $FeSO_4$ was an optimum level for zinnia production. The LSD test showed that the differences in leaves branch^{-1} between treatments 4 g humic acid and 40 g humic acid applied alone, were non-significant ($P>0.05$) and significant ($P<0.05$) when compared with other treatments comprising humic acid and iron sulphate.

Days taken to first flower

The results pertaining to number of days taken to first flower of zinnia as influenced by different humic acid and iron sulphate levels are given in Table-4. The analysis of variance indicated that the effect of various humic acid and iron sulphate levels on days to first flower of zinnia were statistically significant ($P<0.05$).

It is apparent from the data (Table-1) that the control zinnia plants (no Humic acid and $FeSO_4$) maximally delayed to initiate flowering (65.22 days), while the plants took 64.10 and 63.44 days to initiate flowering when zinnia plants were treated with 4 g and 40 g Humic acid/2m^2, respectively. The period to initiate flowering further diminished to 62.77 and 61.66 days, when the zinnias were treated with 40 g $FeSO_4$ and 4 g Humic acid + 40 g $FeSO_4$, respectively; while the minimum days (60.66) to first flower was observed in zinnia plants treated with 40 g Humic acid + 40 g $FeSO_4$.

The results indicated an earliness of flowering initiation in zinnia with increasing humic acid level alone or when applied in combination with $FeSO_{4;}$ while in control plants, the flowering initiation was delayed significantly ($P<0.05$).

Table 1. Effect of by various combinations of Humic acid and iron sulphate on Plant height (cm), Number of Branches, Number of leaves branches^{-1} and Days taken to first flower of zinnia

Treatments	Plant Height	Number of Branches	Number of Leaves branches^{-1}	Days taken to first flower
Control	41.88 e	5.66 e	6.22 e	65.22 f
4 g Humic acid/2m^2	43.44 d	6.88 d	7.33 d	64.10 e
40 g Humic acid/2m^2	45.66 c	7.44 d	8.21 d	63.44 d
40 g $FeSO_4$/2m^2	46.33 c	8.66 c	9.33 c	62.77 c
4 g Humic acid + 40 g $FeSO_4$/2m^2	52.22 a	12.55 a	11.55 a	61.66 b
40 g Humic acid + 40 g $FeSO_4$/2m^2	48.88 b	10.44 b	10.32 b	60.66 a
S.E. ±	0.7798	0.3689	0.4625	0.2896
LSD 0.05	1.7376	0.8219	1.0304	0.6453
LSD 0.01	2.4715	1.1690	1.4657	0.9179

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

Number of flowers plant^{-1}

The flower production in zinnia is directly proportional to number of flowers plant^{-1}. The results in relation to number of flowers plant^{-1} of zinnia as affected by different humic acid and iron sulphate levels are shown in Table-2. The analysis of variance illustrated significant ($P<0.05$) effect of humic acid and iron sulphate levels on the number of flowers plant^{-1}.

The zinnias treated with 4 g humic acid + 40 g $FeSO_4$/2m^2 resulted in significantly highest number of flowers (14.77) plant^{-1}, followed by 13.22 and 8.77 average number of flowers plant^{-1} recorded in plants treated with 40 g Humic acid + 40 g $FeSO_4$ and 40 g $FeSO_4$ only, respectively. The number of flowers followed an adverse trend by producing 8.55 and 6.22 flowers plant^{-1} when zinnias were treated with 40 g humic acid and 4 g humid acid, respectively; while the lowest number of flowers (4.44) plant^{-1} was recorded in plants given no humic acid and no iron sulphate (control). This higher number of flowers plant^{-1} in zinnia plants was mainly associated with increased plant height and higher number of branches. The study also indicated that with increasing humic acid level when applied alone or when applied in combination with higher levels of $FeSO_4$. However, highest humic acid (40 g) alongwith highest iron sulphate (40 g) showed adverse effect on number of flowers plant^{-1} over 4 g humic acid + 40 $FeSO_4$. The LSD test indicated that the differences in number of flowers plant^{-1} between 40 g humic acid and 40 g $FeSO_4$ both applied alone, were non-significant ($P>0.05$) and significant ($P<0.05$) when compared with rest of the treatments.

Size of flower (cm)

The size of flower in zinnia has main accumulation to flower production. The data in regards to size of flower as affected by different humic acid and iron sulphate levels are presented in Table-2. The analysis of variance demonstrated significant ($P<0.05$) influence of humic acid and $FeSO_4$ levels on the flower size.

It is obvious from the data (Table-2) that the zinnias treated with 4 g humic acid + 40 g $FeSO_4/2m^2$ produced flowers of maximum in size (7.14 cm), followed by flowers of 6.69 cm and 6.61 cm in size noted on plants treated with 40 g Humic acid + 40 g $FeSO_4$ and 40 g $FeSO_4$ only, respectively. The size of flower responded negatively to lower nutrient levels of 40 g humic acid and 4 g humid acid, by producing flowers of 6.15 cm and5.99 cm in size, respectively. However, the flower of minimum in size (5.73 cm) were obtained from the zinnia plants kept untreated (control). This higher size of flower in zinnia plants was mainly associated healthy growing plants due to application of Humic acid and $FeSO_4$, but the results for the trait under discussion followed the trend of the results noted for plant height, number of branches, number of leaves and number of flowers $plant^{-1}$.

The results further showed that Humic acid at 4 g + 40 g $FeSO_4$ would be optimum level for zinnia because 40 g Humic acid + 40 g $FeSO_4$ resulted relatively poor results when compared with optimum level. The LSD test showed non-significant differences for this trait between 40 g humic acid + 40 g $FeSO_4$ and 40 g $FeSO_4$ only or between 40 g humic acid and 4 g humic acid.

Average flower life (Days)

The average flower life of zinnia was also studied and the results pertaining to average flower life as affected by different humic acid and iron sulphate levels are shown in Table-2. The analysis of variance suggested that the effect of humic acid and iron sulphate levels on average flower life was significant ($P<0.05$).

The average flower life was maximum (13.11 days) when zinnia plants were treated with 4 g humic acid + 40 g $FeSO_4/2m^2$, followed by 12.88 and 11.44 days flower life noted in plants treated with 40 g Humic acid + 40 g $FeSO_4$ and 40 g $FeSO_4$ only, respectively. The average flower life was decreased considerably to 11.22 and 10.44 days when the zinnia plants were treated with 40 g humic acid and 4 g humid acid, respectively. However, the lowest flower life (6.88 days) was noted in flowers collected from control zinnias. This higher average flower life in zinnia plants treated with 4 g Humic acid + 40 g $FeSO_4$ was probably associated with the increasing iron contents in plants and flowers along with humic acid which resulted to survive for relatively a longer period than rest of the treatments and control.

It was noted that Humic acid at 4 g + 40 g $FeSO_4$ was an optimum rate for zinnia because 40 g Humic acid + 40 g $FeSO_4$ resulted relatively lesser average flower life as compared to optimum level. The LSD test showed non-significant differences in average flower life between 40 g humic acid + 40 g $FeSO_4$ and 4 g humic acid + 40 g $FeSO_4$, or between 40 g $FeSO_4$ and 40 g humic acid.

Total blooming period (Days)

The total blooming period of zinnia was examined and the data related to this parameter as affected by various humic acid and iron sulphate levels are presented in Table-2. The analysis of variance indicated that the influence of humic acid and iron sulphate levels on total blooming period of zinnia was significant ($P<0.05$).

It is evident from the data (Table-2) that total blooming period was highest (34.77 days) in zinnia plants treated with 4 g humic acid + 40 g $FeSO_4/2m^2$, followed by 33.33 and 32.10 days total blooming period noted in zinnia plants treated with 40 g Humic acid + 40 g $FeSO_4$ and 40 g $FeSO_4$ only, respectively. The total blooming period decreased to 31.55 and 31.33 days when the zinnia plants were treated with 40 g humic acid and 4 g humid acid, respectively. However, the lowest total blooming period (29.88 days) was noted in control plants (no humic acid and $FeSO_4$). This higher total blooming period in zinnia plants treated with 4 g Humic acid + 40 g $FeSO_4$ may be associated with average flower life; but the results for this parameter showed a similar trend that has been noted in case of plant height, number of branches, number of leaves, number of flowers and flower size.

Table 2. Effect of various combinations of Humic acid and iron sulphate on number of flowers $plant^{-1}$, Size of flower (cm), Average flower life (Days) and Total blooming periods (Days) of zinnia.

Treatments	Number of flowers $plant^{-1}$	Size of flower (cm)	Average flower life (Days)	Total blooming period (Days)
Control	4.44 e	5.73 d	6.88 d	29.88 e
4 g Humic acid/2m^2	6.22 d	5.99 c	10.44 c	31.33 d
40 g Humic acid/2m^2	8.55 c	6.15 c	11.22 b	31.55 d
40 g $FeSO_4$/2m^2	8.77 c	6.61 b	11.44 b	32.10 c
4 g Humic acid + 40 g $FeSO_4$/2m^2	14.55 a	7.14 a	13.11 a	34.77 a
40 g Humic acid + 40 g $FeSO_4$/2m^2	13.22 b	6.69 b	12.88 a	33.33 b
S.E. ±	0.0951	0.1698	0.2812	0.2484
LSD 0.05	0.2119	0.3784	0.6265	0.5534
LSD 0.01	0.3015	0.5382	0.8912	0.8246

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

The results further disclose that Humic acid at 4 g + 40 g $FeSO_4$ proved to be an optimum nutrient level, and increasing humic acid upto 40 g Humic acid + 40 g $FeSO_4$ resulted in diminished total blooming period. The LSD test suggested non-significant differences in total blooming period between 40 g humic acid and 4 g humic acid.

Discussion

The study was performed to examine the effect of humic acid and iron sulphate on the growth and yield of zinnia *(Zinnia elegans)*. The findings of the present study indicated that increasing humic acid level when applied alone and lower humic acid when applied with higher $FeSO_4$ resulted significantly ($P<0.05$) improved the growth and flower yield performance of zinnia. The treatment T_5, where 4 g Humic acid + 40 g $FeSO_4$/2m^2 proved to be an optimum level and performed maximally for all the studied traits with 52.22 cm plant height, 12.55 branches $plant^{-1}$, 11.55 leaves $branch^{-1}$, 61.66 days taken to first flower emergence, 14.55 flowers $plant^{-1}$, 7.14 cm size of flower, 13.11 days life of single flower and 34.77 days total blooming period. 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, followed similar growth and flower production trend and similar response to various humic acid and $FeSO_4$. However, days taken to first flower emergence were inversely proportional to increasing humic acid or combination of $FeSO_4$ which was in contrast to rest of all the characters investigated. The increasing humic acid upto 40 g Humic acid in addition to 40 g $FeSO_4$ showed adverse effects on all the parameters when compared with the optimum level. The findings of the present study are further supported by Chen and Aviad (1990) who have reported positive effect of humic acid on crop growth and recommend humic acid at the rate of 5 kg acre. MacCarthy *et al.* (2001) reported that humates enhanced nutrient uptake, improve soil structure, and increase crop yields. Chen *et al.* (2004a) reported improved plant growth, foliage and yields due to application of humic acid. Similarly, for the effect of iron sulphate, Ahmad *et al.* (2010) reported that foliar application of Fe at 1.00 % concentration improved flower yield and quality when applied alongwith other micronutrients; while Le Chang *et al.* (2011) applied Fe on Oriental Lily and reported positive effects on the foliage and flowering. Studies carried out by Riaz *et al.* (2008) reported that zinnia plant height, number of leaves per plant, number of side branches, days to first flower emergence and number of flowers were affected significantly when plants were grown in leaf manure mix with other micronutrients. El-Naggar (2009) found that foliar application of 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) found that application of micronutrients including ferrous sulfate showed remarkable effect on flowering duration and flower yield of chrysanthemum.

Conclusions

It was concluded that 4 g Humic acid + 40 g $FeSO_4/2m^2$ proved to be an optimum level for zinnia flower production; and increasing humic acid upto 40 g alongwith 40 g $FeSO_4/2m^2$ did not show economic effect on any of the parameters studied, even adverse effects were noted. Hence, for achieving desirable plant growth and high yields of quality flowers in Zinnia, the plants may be treated with 4 g Humic acid + 40 g $FeSO_4/2m^2$.

References

Ahmad, I., Khan, M. A., Qasim, M., Ahmad, R. and Randhawa, M. A. (2010). Growth, yield and quality of *Rosa hybrida* L. as influenced by various micronutrients. Pakistan Journal of Agricultural Sciences 47:5-12.

Biondi, F. A., Figholia, A., Indiati, R. and Izza, C. (1994). Effects of fertilization with humic acids on soil and plant metabolism: a multidisciplinary approach. III: phosphorus dynamics and behaviour of some plant enzymatic activities. Humic Substances in the Global Environment and Implications on Human Health. New York: Elsevier. pp. 239-244.

Cakmak, I. (2002). Plant nutrition research: Priorities to meet human needs for food in sustainable way. Plant Soil 247:3-24.
Chen, Y. and Aviad, T. (1990). Effects of humic substances on plant growth. Humic substances in soil and crop sciences: Selected readings (humicsubstances). pp. 161-186.
Chen, Y., Clapp, C. E. and Magen, H. (2004a). Mechanisms of plant growth stimulation by humic substances: The role of organic-iron complexes. Soil Science and Plant Nutrition, 50:1089–1095.
Chen, Y., Nobili, M. and Aviad, T. (2004b). Stimulatory effect of humic substances on plant growth. Soil Organic Matter in Sustainable Agriculture. Washington: CRC Press.
De Kreij, C. and Basar, H. (1995). Effect of humic substances in nutrient film technique on nutrient uptake. Journal of Plant Nutrition 18:793–802.
Dhaka, R. S., Fageria, M. S., Mohemmed, S., Faroda, A. S., Joshi, N. L., Kathju, S. and Amal, K. (1999). Effect of different levels of N, P and K on floral characters of zinnia. SKN College of Agriculture, Jaipur, India. pp. 379–382.
Dole, H. C. (1999). Zinnias: Colorful, Butterfly-Approved. Butterfly Gardeners Quarterly. BGQ, PO Box 30931, Seattle, WA 98103.
El-Naggar, A. H. (2009). Response of *Dianthus caryophyllus* L. Plants to Foliar Nutrition. World Journal of Agricultural Sciences 5:622-630.
Hartwigson, J. A. and Evans, M. R. (2000). Humic acid seed and substrate treatments promote seedling root development. HortScience 35:1231-1233.
Havlin, J. L., Beaton, J. D. Tisdale, S. L. and Nelson, W. L. (1999). soil fertility and fertilizers-an introduction to nutrient management 6th edition. Prentice Hall, New Jersey.
Jana, B. K. and Pal, A. (1991). Response of nitrogen and phosphorus on growth flowering and yield of Cosmos. Indian Agriculturist 35:113–118.
Jariene, E., Danilcenko, H., Kulaitiene, J. and Gajewski, M. (2008). Effect of fertilizers on oil mustard seeds crude fat, fibre and protein quantity. Agronomy research 5:43-49.
Jeyabal, A. and Kuppuswamy, G. (2001). Recycling of organic wastes for the production of vermicompost and its response in rice-legume cropping system and soil fertility. European Journal of Agronomy 15:153-170.
Kauser, A. M. and Azam, F. (1985). Effect of humic acid on corn seedling growth. Environmental and Experimental Botany 25:245–252.
Kumar, P. N., Misra, R. L., Dhiman, S. R., Ganga, M. and Kameswari, L. (2009). Effect of micronutrient sprays on growth and flowering of chrysanthemum. Indian Journal of Agricultural Sciences 79:426-428.
Le C., Wu, Y., Xu, W. W., Nikbakht, A. and Xia, Y. P. (2011). Effects of calcium and humic acid treatment on the growth and nutrient uptake of Oriental lily. African Journal of Biotechnology 11:2218-2222.
MacCarthy, P., Clapp, C. E., Malcolm, R. L. and Bloom, P. R. (2001). Humic substances in soil and crop sciences: selected readings. Soil Science Society of America. Madison, WI.
Mackowiak, C. L., Grossl, P. R. and Bugbee, B. G. (2001). Beneficial effects of humic acid on micronutrient availability to wheat. Soil Science Society of America Journal 65:1744-1750.
Maggioni, A., Varanini, Z., Nardi, S. and Pinton, R. (1987). Action of soil humic matter on plant roots: Stimulation of ion uptake and effects on ($Mg2+$, $K+$) ATPase activity. Science of the Total Environment 62:355–363.
Mart, I, (2007). Fertilizers, organic fertilizer, plant and agriculture fertilizer. Agro and Food Business Newsletter.
Pan, R. C. and Dong, Y. D. (1995). Plant physiology. Third edition. Beijing, China: High education Press.

Riaz, A., Arshad, M., Younis, A., Raza, A. and Hameed, M. (2008). Effects of different growing media on growth and flowering of *Zinnia elegans* cv. Blue Point. Pakistan Journal of Botany 40:1579-1585.

Schuster, J. (2008). Focus on plant problems-chlorosis. University of Illinois at Urbana. Champaign. pp. 12-22.

Steel, R. G. D., Torrie, J. H. and Dicky, D. A. (1997). Principles and procedures of statistics: A Biometric Approach. Thrid edition. New York: McGraw Hill Book Co. Inc.

Vaughan D. and Malcolm R. E. (2002): Effect of humic acid on invertase synthesis in roots of plants. Soil Biology and Biochemistry 11:247–252.

(Received:26 October 2013;accepted:Accepted 15 September 2014)