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Growth, Flowering and Yield of Tuberose (*Polianthes tuberosa* L.) cv. Single as Influenced by Foliar Application of $ZnSO_4$ and $CuSO_4$

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A B S T R A C T

A field experiment on foliar application of $ZnSO_4$ and $CuSO_4$ on growth, flowering and yield of tuberose (*Polianthes tuberosa* L.) cv. Single was carried out at Horticultural Experimental Field, College of Agriculture, Central Agricultural University, Imphal during 2012-13. The result of the study revealed that increasing levels of $ZnSO_4$ upto 0.5% resulted in superior growth, flowering and yield of tuberose. Foliar application of $ZnSO_4$ @ 0.5% gave maximum number of leaves/plant, number of tillers per plant, plant height, number of spike/plant, spike length, rachis length, number of florets/spike, number of bulbs/clump, weight of bulbs/clump, diameter of the largest bulb, yield of spike/ha and yield of bulb/ha. Among different levels of $CuSO_4$ 0.25% $CuSO_4$ recorded significantly higher value for the growth, flowering and yield parameters. Interaction of different levels of $ZnSO_4$ and $CuSO_4$ recorded maximum value for growth, flowering and yield parameters.

Introduction

Tuberose (*Polianthes tuberosa* L.) cv. Single members of Amaryllidaceae family, native of Mexico is one of the most popular bulbous ornamental crop in India and abroad because of its delightful fragrance, attractive spike and high economic value. It has gained considerable popularity and widely grown for aesthetic, aromatic and commercial purposes. Its waxy white flowering spike with pleasant fragrance are in great demand for indoor decoration, garlands, bouquets, cut flower trade and extraction of oil. The single cultivar has a great economic potential in essential oil industry. The essential oil content is 0.08-0.11% which is extracted by solvent extraction method. In Manipur condition, production of tuberose is yet to be popularized because of non- availability of suitable agro techniques. Micronutrients play an important role in growth, flowering and yield of tuberose. Even though the work on major nutrients has been done in tuberose, the information on the use of micronutrients is lacking in Manipur. Hence the present studies was undertaken to find out the best level of $ZnSO_4$ and $CuSO_4$ and their combinations as foliar spray for optimum growth, flowering and maximizing yield of tuberose.

Materials and Methods

The experiment consisted of 9 treatment combinations comprising 3 levels of $ZnSO_4$ (0%, 0.5% and 1.0%) and 3 levels of $CuSO_4$ (0%, 0.25% and 0.5%). Each treatment was replicated thrice in a Factorial Randomised Block Design. The plot size was 1.5 x 1.8 m^2 with a planting distance of 30cm x 30cm. Uniform cultural operations were followed during the course of investigations. Bulbs were lifted at the end of each season. The data on vegetative parameters viz., plant height, number of leaves per plant and number of tillers per plant; flowering parameters like length of rachis, length of spike, number of spike per plant, number of florets per spike, days to flowering, duration of flowering and yield of spikes and bulb parameters viz., number of bulbs per clump, weight of the bulbs per clump, diameter of largest bulb, weight of largest bulb and yield of bulb were recorded.

Results and Discussion

The data presented in table 1 revealed that foliar application of $ZnSO_4$ and $CuSO_4$ had significant influence on growth, flowering and yield of tuberose. $ZnSO_4$ @ 0.5% produced significantly the maximum plant height (60.02 cm) followed by 1.0% $ZnSO_4$ (52.25 cm). The minimum plant height (50.08 cm) was observed in control (0% $ZnSO_4$). This might be due to the role of zinc in synthesis of tryptophan which is a precursor of auxin and is essential in nitrogen metabolism which stimulates the growth (Jat *et al.*, 2007). The results were in agreement with Barman and Pal (1993). Maximum plant height (56.78 cm) was recorded at 0.25% $CuSO_4$. This might be due to the reason that copper is an important component of proteins found in the enzymes that regulate the rate of many biochemical reactions in plants. Results were in agreement with Singh *et al.*, (2001) in aonla and Katiyar *et al.*, (2005) in gladiolus.

The number of leaves per plant of tuberose increased significantly with the increase in $ZnSO_4$ levels upto 0.5%. The maximum number of leaves per plant of tuberose was recorded with the application of 0.5 % $ZnSO_4$ (54.14) while the lowest number of leaves per plant was observed under control (47.21). The finding was in line with the results observed by Munikrishnappa *et al.*, (2002) and Kumar *et al.*, (2003) in tuberose. Foliar application of 0.25% $CuSO_4$ recorded the maximum number of leaves per plant of tuberose (53.67) as compared with 0.5% $CuSO_4$ and 0% $CuSO_4$. The finding was in conformity with that of Katiyar *et al.*, (2005) in gladiolus and Khosa *et al.*, (2011) in gerbera.

Among the different levels of $ZnSO_4$, 0.5% $ZnSO_4$ recorded the maximum number of tillers per plant (4.24). The lowest number of tillers per plant was observed under control (3.40). Similar observations were made by Barman and Pal (1993) and Munikrishnappa *et al.*, (2002) in tuberose. It was also clear from table 1 that lower dose of $CuSO_4$ upto 0.25% resulted the maximum number of tillers per plant (4.32) while minimum was recorded under control (3.23). This was in line with the findings of Barman and Pal (1993) in tuberose and Katiyar *et al.*, (2005) in gladiolus.

The number of days to flowering was significantly affected due to the varying levels of $ZnSO_4$. Earliest flowering was recorded when the plants were applied with 0.5% $ZnSO_4$ (65.38 days) while maximum number of days (73.77 days) to flowering was observed in the control treatment. The reason for early flowering may be due to the fact that zinc promotes flower setting and helps in proper development of flowers. It also helps in regulating auxin concentration in plants. These findings were in close agreement with and Rawia *et al.*, (2010) in tuberose and Bala *et al.*, (2007) and Reddy *et al.*, (2009) in gladiolus. Among the different levels of

$CuSO_4$, 0.25% $CuSO_4$ recorded earliest flowering (66.08 days) which was significantly better than the rest of the treatments including control. This might be due to the reason that copper being an essential component in chlorophyll formation which help to catalyze several plant processes. Plants under control recorded the maximum days (75.03) for flowering. The finding was in favour with the observations of Bandyopadhyay *et al.,* (1994) in marigold and Katiyar *et al.,* (2005) in gladiolus.

The length of spike and length of rachis increased with the increasing level of $ZnSO_4$ upto 0.5%. The maximum spike length (99.69 cm) and rachis length (20.82 cm) was observed under treatment receiving 0.5% $ZnSO_4$ which was significantly higher than the rest of the treatments including control. $ZnSO_4$ @ 0% (control) recorded the minimum length of spike (91.17 cm) and minimum length of rachis (15.10 cm) of tuberose. The finding was found in line with that of Attoa (2002), Jauhari *et al.,* (2003) and Kumar *et al.,* (2003) in tuberose. Different levels of $CuSO_4$ also had a significant effect on the length of spike and length of rachis of tuberose. The longest length of spike (98.49 cm) and the length of rachis (20.35 cm) were observed under the treatment receiving 0.25% $CuSO_4$. Minimum length of spike (89.96 cm) and minimum length of rachis (14.47 cm) of tuberose was recorded under control ($CuSO_4$ @ 0%). These findings were in agreement with Bandyopadhyay *et al.,* (1994) in marigold and Katiyar *et al.,* (2005) in gladiolus.

The number of florets per spike increased with the increasing levels of $ZnSO_4$. The highest number of florets per spike (31.26) was recorded at 0.5% $ZnSO_4$.This increase in number of florets per spike could be attributed to increase in photosynthesis with enhanced carbohydrate fixation in plants which might have caused luxurious vegetative growth (Naik *et al.,* 2009). Plants under control recorded minimum number of florets per spike (23.09). Similar results were obtained by Kumar *et al.,* (2003) and Bala *et al.,* (2007) in tuberose. The maximum number of florets per spike (30.31) was recorded with 0.25% $CuSO_4$. Minimum number of florets per spike (21.21) was recorded under control. Similar results were obtained by Bandyopadhyay *et al.,* (1994) in marigold and Katiyar *et al.,* (2005) in gladiolus.

Table 2 revealed that the number of spikes per plant increased with the increasing levels of $ZnSO_4$. The highest number of spikes per plant (3.68) was recorded under 0.5% $ZnSO_4$ while the lowest number of spikes per plant of tuberose (2.90) was recorded under control. Similar results were observed by Kumar *et al.,* (2003) in tuberose, Sharma *et al.,* (2004) in gladiolus and Nag *et al.,* (2003) in marigold. The foliar application of 0.25% $CuSO_4$ recorded highest number of spikes per plant (3.53) which though on par with 0.5% $CuSO_4$. Plants under control recorded minimum number of spikes per plant (2.84).

The maximum duration of flowering (19.29 days) was recorded at 0.5% $ZnSO_4$ and was found superior to the rest of the treatments. $ZnSO_4$ @ 0% (Control) recorded minimum duration of flowering in tuberose (15.79 days) in the field. This might be due to beneficial effects of zinc on the physiological and other activities of the plant, thereby lengthening the duration. The findings were in agreement with that of Rawia *et al.,* (2010) in tuberose. Different levels of $CuSO_4$ had significant effect on the duration of flowering in tuberose with the foliar application of 0.25% $CuSO_4$. The maximum duration of flowering was recorded by the treatment 0.25% $CuSO_4$ (19.62 days) which was significantly higher than the rest of the treatments while minimum duration of flowering (14.29 days) was recorded under control (0% $CuSO_4$). Copper is essential for many plant functions as it is

important to the formation of lignin in plant cell walls which contributes to the structural strength of the cells and the plant (Katiyar *et al.*, 2005).

Table.1 Effect of foliar application of $ZnSO_4$ and $CuSO_4$ on vegetative parameters of Tuberose cv. Single

Treatment	Plant height (cm)	Number of leaves/plant	Number of tillers/plant
Zn_1 (0%)	50.08	47.21	3.40
Zn_2 (0.5%)	60.02	54.14	4.24
Zn_3 (1.0%)	52.25	47.45	3.44
S.Ed	0.22	0.31	0.04
C.D.0.05	0.48	0.67	0.10
Treatment			
Cu_1 (0%)	50.09	45.49	3.23
Cu_2 (0.25%)	56.78	53.67	4.32
Cu_3 (0.5%)	55.50	49.65	3.52
S.Ed	0.22	0.31	0.04
C.D.0.05	0.48	0.67	0.10

Table.2 Effect of foliar application of $ZnSO_4$ and $CuSO_4$ on floral parameters of Tuberose cv. Single

Treatment	Days taken to flowering	Length of spike (cm)	Length of rachis (cm)	Number of florets/spike	Number of spikes/plant	Duration of flowering	Yield of spikes (˙000/ha)
Zn_1 (0%)	73.77	91.97	15.10	23.09	2.90	15.79	150.90
Zn_2 (0.5%)	65.38	99.69	20.82	31.26	3.68	19.29	251.34
Zn_3 (1.0%)	72.21	91.54	15.54	23.75	3.00	16.50	195.15
S.Ed	0.61	0.38	0.26	0.36	0.01	0.35	2.68
C.D.0.05	1.30	0.81	0.56	0.78	0.02	0.72	5.68
Treatment							
Cu_1 (0%)	75.03	89.96	14.47	21.21	2.84	14.29	167.17
Cu_2 (0.25%)	66.08	98.49	20.35	30.31	3.53	19.62	239.63
Cu_3 (0.5%)	70.25	94.13	16.63	26.59	3.23	17.68	190.59
S.Ed	0.61	0.38	0.26	0.36	0.01	0.35	2.68
C.D.0.05	1.30	0.81	0.56	0.78	0.02	0.72	5.68

Table.3 Effect of foliar application of $ZnSO_4$ and $CuSO_4$ on bulb parameters of Tuberose cv. Single

Treatment	Number of bulbs /clump	Weight of bulbs/clump (g)	Weight of largest bulb (g)	Diameter of largest bulb (cm)	Yield of bulbs (t/ha)
Zn_1 (0%)	11.34	91.57	18.84	2.97	10.78
Zn_2 (0.5%)	16.16	100.48	20.27	3.76	11.40
Zn_3 (1.0%)	12.38	93.89	19.48	3.03	10.90
S.Ed	0.35	0.43	0.32	0.07	0.42
C.D.0.05	0.74	0.89	0.67	0.15	0.09
Treatment					
Cu_1 (0%)	10.75	89.63	19.07	2.79	10.63
Cu_2 (0.25%)	15.62	99.86	20.10	3.64	11.42
Cu_3 (0.5%)	13.51	96.31	19.56	3.27	11.03
S.Ed	0.35	0.43	0.32	0.07	0.42
C.D.0.05	0.74	0.89	0.67	0.15	0.09

Table.4 Interaction effect of foliar application of $ZnSO_4$ and $CuSO_4$ on growth, flowering and yield of tuberose cv. Single

Treatment	Plant height (cm)	No. of leaves/ plant	No. of tillers/ plant	Days taken to flowering	Length of spike (cm)	Length of rachis (cm)	No. of florets/ spike	No. of spikes/ plant	Duration of flowering	Yield of spikes ('000/ha)	No. of bulbs/clump	Weight of bulbs/clump (g)	Weight of largest bulb (g)	Diameter of largest bulb (g)	Yield of bulbs (t/ha)
Zn_1Cu_1	46.15	43.45	3.09	78.28	86.43	12.18	17.76	2.52	12.18	113.71	8.18	84.78	18.18	2.51	10.21
Zn_1Cu_2	52.46	52.70	4.01	69.06	97.09	18.58	28.39	3.17	18.56	205.52	15.31	97.77	19.91	3.42	11.32
Zn_1Cu_3	51.65	46.50	3.12	73.96	90.05	14.55	23.14	3.02	16.64	135.52	10.52	92.17	18.45	2.98	10.81
Zn_2Cu_1	55.74	49.38	3.45	70.78	96.12	17.32	26.78	3.39	17.28	204.90	14.62	96.38	19.39	3.36	11.23
Zn_2Cu_2	63.34	58.47	5.19	60.08	103.63	24.89	35.54	4.09	21.89	309.75	17.14	103.53	20.81	4.18	11.52
Zn_2Cu_3	60.98	54.57	4.06	65.29	99.34	20.27	31.47	3.57	18.73	239.34	16.73	101.10	20.63	3.75	11.45
Zn_3Cu_1	48.38	43.64	3.15	76.03	87.40	13.92	19.09	2.62	13.42	182.91	9.42	87.73	18.42	2.52	10.46
Zn_3Cu_2	54.51	49.82	3.78	69.11	94.75	17.60	27.02	3.34	18.42	203.64	14.42	98.29	20.45	3.32	11.42
Zn_3Cu_3	53.87	48.89	3.39	71.49	92.45	15.06	25.16	3.08	17.67	198.92	13.30	96.67	19.58	3.27	10.83
S.Ed	0.39	0.56	0.08	1.06	1.66	0,45	0.62	0.02	0.59	4.64	0.62	0.73	0.54	0.12	0.73
C.D.0.05	0.83	1.16	0.18	2.26	1.41	NS	1.34	0.04	1.26	9.84	1.29	1.54	NS	0.26	NS

The data presented in table 2 revealed that increase in levels of $ZnSO_4$ significantly increased the yield of spikes/ha. Amongst all the treatments $ZnSO_4$ @ 0.5% recorded maximum yield of spikes/ha (251.33) which was significantly superior to rest of the treatments including control. The lowest yield of spikes/ha was observed under control (150.91). This might be due to influence of zinc on the synthesis of growth promoting substances and at the same time it monitors enzymatic activity within the plant which is ultimately reflected on the yield (Munikrishnappa *et al.,* 2002; Jat *et al.,* 2007). Treatment receiving $CuSO_4$ @ 0.25% recorded maximum yield of spikes/ha (239.63) which was significantly higher than the rest of the treatments. Lowest yield of spikes/ha was observed under control (167.17). Similar findings were observed by Bandhopadhyay *et al.,* (1994) in marigold and Singh *et al.,* (2012) in gladiolus.

The number of bulbs per clump of tuberose increased significantly with the increase in the levels of $ZnSO_4$. The maximum number of bulbs per clump (16.16) was recorded at 0.5% $ZnSO_4$ while minimum number of bulbs per clump (11.34) was observed under control (0% $ZnSO_4$). However, further increase in the dose of $ZnSO_4$ had no additional effect on bulb production. This might be due to the role of zinc that helps in translocation of constituents from one part to other and hence higher production of bulbs (Naik *et al.,* 2009). Similar results were observed by Rawia *et al.,* (2010) in tuberose and Singh *et al.,* (2012) in gladiolus. Different levels of $CuSO_4$ had significant effect on the number of bulbs per clump of tuberose. The maximum number of bulbs per clump (15.62) of tuberose was obtained with the treatment receiving 0.25% $CuSO_4$. Copper has important function in root metabolism as well as utilization of ammoniac nitrogen by the plants. Plants under control (0% $CuSO_4$) recorded minimum numbers of bulbs per clump (10.75). Similar results were also observed by Katiyar *et al.,* (2005) and Singh *et al.,* (2012) in gladiolus.

Table 3 reveals that 0.5% $ZnSO_4$ resulted in maximum weight of bulbs per clump of tuberose (100.46g). There was successive increase of bulbs with the increase in the levels of $ZnSO_4$. However, further increase in the levels of $ZnSO_4$ had no additional effect on bulb production. The lowest weight of bulbs per clump (91.57g) was recorded under control (0% $ZnSO_4$). These findings were in close agreement with the findings of Rawia *et al.,* (2010) in tuberose and Khalifa *et al.,* (2011) in iris. Foliar application of $CuSO_4$ @ 0.25% resulted in maximum weight of bulbs (99.86) per clump which was significantly higher than the rest of the treatments. While the lowest weight of bulbs per clump (89.63) was recorded under control (0% $CuSO_4$). Similar results were observed by Katiyar *et al.,* (2005) and Singh *et al.,* (2012) in gladiolus.

The weight of the largest bulb and diameter of largest bulb of tuberose increased significantly with the increase in levels of $ZnSO_4$ upto 0.5%. The maximum weight of largest bulb was recorded at 0.5% $ZnSO_4$ (20.27g). While minimum weight of the largest bulb was observed under control (18.84g). The maximum diameter of largest bulb was observed with the treatment receiving 0.5% $ZnSO_4$ (3.76cm). This might be due to the fact that $ZnSO_4$ increases the vegetative growth and thus leads to production of more food material, which in turn might have been utilized for better development of diameter (Jat *et al.,* 2007). The result was in close agreement with the observation made by Rawia *et al.,* (2010) in tuberose. Foliar application of $CuSO_4$ @ 0.25% recorded maximum weight of largest bulb (20.10g) and diameter of the largest bulb (3.64 cm) which was significantly higher than

rest of the treatments including control. Minimum weight of the largest bulb (18.67g) and minimum diameter of the largest bulb (2.97 cm) were observed under control ($CuSO_4$ 0%). Similar results were observed by Katiyar *et al.,* (2005) and Singh *et al.,* (2012) in gladiolus.

Table 3 revealed that increase levels of $ZnSO_4$ significantly increased the yield of bulb/ha of tuberose. Amongst all the treatments, $ZnSO_4$ @ 0.5% recorded maximum yield of bulb (11.40 t/ha) which was significantly superior over rest of the treatments including control. The lowest yield of bulb (10.78 t/ha) was observed under control ($ZnSO_4$ @ 0%). This might be due to the fact that zinc plays a vital role in growth and development of plant because of its stimulatory and catalystic effect in various physiological and metabolic processes of plants (Muthumanickam, 1999). Similar findings were reported by Singh *et al.,* (2012) in gladiolus. Among different levels of $CuSO_4$, 0.25% $CuSO_4$ recorded maximum yield of bulb (11.42 t/ha) which was significantly higher than the rest of the treatments including control. Lowest yield of bulb (10.63 t/ha) was observed under control (0% $CuSO_4$).

The difference in plant height due to interaction of different levels of $ZnSO_4$ and in $CuSO_4$ was significant (Table 4). The treatment combination Zn_2Cu_2 produced the maximum plant height (63.34 cm) while the minimum (46.15 cm) was recorded under control (Zn_1Cu_1). The interaction effect of the levels of $ZnSO_4$ and levels of $CuSO_4$ could significantly influence the number of leaves per plant of tuberose. The interaction of Zn_2Cu_2 recorded the maximum number of leaves per plant (58.47) and was significantly superior to other treatment combinations including control. The minimum number of leaves per plant was recorded under control (43.45). Interaction effect of different levels of $ZnSO_4$ and $CuSO_4$ on number of tillers per plant had significant influence on number of tillers per plant. The maximum number of tillers per plant was observed under Zn_2Cu_2 (5.19) while the minimum number of tillers per plant (3.09) was observed under control (Zn_1Cu_1). Table 4 showed that interaction effect of different levels of $ZnSO_4$ and $CuSO_4$ on tuberose had significant effect on the days taken to flowering. The combination of Zn_2Cu_2 (60.08) recorded the earliest days to flowering. Amongst all the treatment combinations, Zn_2Cu_2 (103.63 cm) resulted in longest spike length and longest rachis length (24.89 cm) which was significantly higher than other treatments including control. Shortest spike length (86.43 cm) and shortest rachis length (12.18) was observed under Zn_1Cu_1 (control). The interaction effect of different levels of $ZnSO_4$ and $CuSO_4$ was found significant on the number of florets per spike. Amongst all treatment combinations Zn_2Cu_2 (35.54) gave the maximum number of florets per spike which was significantly higher than other treatment combinations. Minimum number of florets per spike (17.76) was recorded under Zn_1Cu_1 (control). The difference due to interaction effect was significant. Amongst all the treatment combinations Zn_2Cu_2 (4.09) resulted in the maximum number of spikes per plant. Plants under Zn_1Cu_1 recorded the minimum number of spikes per plant (2.52).

Interaction effect of foliar application of $CuSO_4$ and $ZnSO_4$ had significant influence on the duration of flowering in tuberose. Amongst all treatment combinations Zn_2Cu_2 resulted in the longest duration of flowering (21.89 days) which was significantly higher than the rest of the treatments including control. Plants under control (Zn_1Cu_1) recorded the minimum duration of flowering (12.18 days). The interaction effect of foliar application of $ZnSO_4$ and $CuSO_4$ was found significant on the yield of spikes/ha. Amongst

all the treatments, maximum yield of spikes/ ha of tuberose was recorded with the treatment combinations Zn_2Cu_2 (309.75) while the minimum yield (113.71) of spikes/ ha was recorded under control (Zn_1Cu_1). The difference due to interaction effect was significant.

Maximum number of bulbs per clump was recorded under Zn_2Cu_2 (17.14) while Zn_1Cu_1 recorded minimum number of bulbs per clump (8.18). Interaction effect of foliar application of $ZnSO_4$ and $CuSO_4$ had significant influence on the weight of bulbs per clump (g). The maximum weight of bulbs per clump (103.53g) was recorded by Zn_2Cu_2 which was significantly higher than the rest of the treatments including control. The minimum weight (84.78g) was recorded under control (Zn_1Cu_1). Interaction of different levels of $ZnSO_4$ and $CuSO_4$ had no significant effect on weight of the largest bulb. The interaction of different levels of $ZnSO_4$ and $CuSO_4$ had a significant influence on diameter of the largest bulb. The maximum diameter of largest bulb (4.18cm) was recorded by Zn_2Cu_2 which was significantly superior to the rest of the treatments including control. The minimum diameter (2.51cm) was recorded under control. Interaction of different levels of $ZnSO_4$ and $CuSO_4$ had no significant effect on yield of bulb (t/ha).

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