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SYNCHRONIZATION OF ZINC RATES THROUGH SOIL AND FOLIAR APPLICATION WITH SYNTHETIC FERTILIZER TO MAXIMIZE GROWTH, YIELD AND QUALITY ATTRIBUTES OF MANGO

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Abstract

Zinc (Zn) deficiency is among the major constraints for reduced fruit production and quality in mango orchards soils. Therefore, the judicious use of Zn in mango orchards is gaining attention. Although, the farming communities are using Zn as a micronutrient fertilizer; however, the synchronization of inorganic fertilizers and Zn application rate is yet to be performed under changing climatic conditions. Therefore, the current experiment was performed to assess better application methods (soil and foliar application) and judicious rates of Zn with recommended doses of nitrogen (N), phosphorus (P) and potassium (K) for mango trees. Zinc was applied as $ZnSO_4$ at the rate of 0, 150, and 300 g plant^{-1} as basal application and 0, 0.5, and 1.0% as a foliar application. Results confirmed with an increase in soil and foliar-applied Zn solely, growth, quality and yield of mango fruit improved. Combined use of soil and foliar Zn gave more positive effects over sole application. Treatment T_7 (recommended NPK + $ZnSO_4$ (150 g plant^{-1} as basal and 1.0% as foliar spray)) followed by T_8 (recommended NPK + $ZnSO_4$ (300 g plant^{-1} as basal and 1.0% as foliar spray)) were statistically alike for the improvement in yield per tree, photosynthetic rate, transpiration rate and sugar contents. In conclusion, recommended NPK + $ZnSO_4$ (150 g plant^{-1} as basal and 1.0% as foliar spray) is a better approach for maximizing the yield, growth attributes and quality of mango fruits.

Key words: Growth attributes, Gas exchange attributes, *Mangifera indica* L., Zinc

Introduction

Mango (*Mangifera indica* L.) is cultivated in nearly 63 countries worldwide. It has been documented that 69 species of genus *Mangifera* are found worldwide and there are 11,595 varieties available on the globe (Bose, 1999). Single mango fruit can deliver up to 40% of everyday dietary fiber requirements (Sing *et al*., 2005). It is a tropical, climacteric fruit liked by all due to its taste, flavor and excellent nutritional properties (Baloch *et al.*, 2017) The mango is the most important fruit of Asia. Pakistan ranks fourth in the total production among major fruit crops worldwide after bananas, citrus, grapes and apples. Pakistani mango is recognized as one of the best of its kind in the world market. Pakistan is among the leading mango producers and is considered the original and natural habitat of mangoes (Madonsela, 2019). Pakistan was the 2nd biggest producer of mango in the world during 1970's (Usman *et al.*, 2003); however, its position is dropped to 4th (Anon., 2010; Memon, 2016) with 1,732 thousand tones annual production under 167.5 thousand hectares of area (Ahmed *et al.,* 2020). The reduction in mango yield and quality is a matter of great concern. Multiple factors or their combination might have contributed to yield and quality reduction. The major factors that can decrease the mango yield are poor fruit setting, malnutrition, plant and irrigation protection measures, poor management of plant, for instance, no pruning, intercropping, dieback, mango malformation, mango sudden death, alternate bearing and poor post-harvest handling (Usman *et al*., 2003; Kazmi *et al*., 2005; Sharma & Singh, 2006). Moreover, mango undergoes numerous disorders like blacktip, internal necrosis, fruit cracking, jelly seed, spongy tissue, leaf scorching, and fruit pitting which further contributed to the loss in yield and quality (Sharma, 2006; Saran & Kumar, 2011).

The use of micronutrients is very important for the achievement of optimum crops yield. These are involved in enzymatic activities, hormones biosynthesis and assimilation. Deficiency of micronutrients occurs in various areas and the majority of the mango growers do not follow the application of micronutrients and eventually, orchards show the hunger signs (Fageria, 2009). The micronutrients are required only in traces from soil or by using chemical sources. The primary reasons for micronutrient deficiencies are intensive agriculture, unbalanced use of inorganic fertilizers, exhaustion of nutrients, and their inadequate supply (Rajendran & Ramamurthy, 2009). The micronutrient deficiency in the mango crop caused poor fruit quality. Low fruit sets and unnecessary fruits drop at numerous stages of fruit development (Siddiq *et al*., 2017). Soils of Pakistan are mostly alkaline, and excessive phosphatic fertilizers can cause an increased level of phosphorous concentration in the soils. Such increase disturbs the solubility and mobility of zinc (Zn) in soil and soils become Zn deficient (Akhtar *et al*., 2019).

When Zn deficiency occurs, plants undergo physiological stresses, which caused abnormalities in crops and then deficiency symptoms. In case of acute deficiency of Zn, plants showed evident symptoms comprising stunted growth, small leaves, spikelet sterility and chlorosis of leaves. Acute deficiency of Zn in field crops has been reported in the literature since 1937 (Brown *et al*., 1993). However, in such condition, the quality of produce, i.e., protein contents, size, and appearance of fruit, may undergo harmful effects and susceptibility increased by injury to light intensity, temperature, and infection of certain fungal diseases (Cakmak, 2000). In hidden deficient conditions of Zn, reduction in crop yields occurred and quality also suffered without the presence of obvious symptoms

Madonsela (2019). Zn regulates growth of plant by reducing the water stresses and tackling the conditions of drought faced by plants (Jan *et al.,* 2019). The current study was designed to explore the optimum application (soil basal dose and foliar) rate of $ZnSO_4$ with inorganic fertilizer. It is hypothesized that combined application of Zn i.e., as basal soil dose and foliar is a better approach than sole application for improving the quality and yield of mango.

Materials and Methods

Experimental site: The experiment was done in a mango orchard (30°09′ N, 71°26′ E) at Multan. Three-years mean annual maximum and minimum temperatures were 35.8 and 10.3 °C with precipitation 82 mm.

Soil characteristics: Experimental soil texture was silt loam having calcareous parent material with pH 8.1. Zinc (Zn) in soil was 0.49 ug g^{-1} with 6–10% $CaCO_3$ equivalent.

Treatments plan: The experiment comprises of 9 treatments and three replications per treatment, where a tree was experimental unit with RCBD arrangement. The following treatments were applied for Zn nutrient management; T_0: recommended dose (RD) of NPK + $ZnSO_4$ (0 g plant^{-1} as basal and 0% as foliar spray), T_1: RD + $ZnSO_4$ (150 g plant^{-1} as basal and 0% as foliar spray), T_2: RD + $ZnSO_4$ (300 g plant^{-1} as basal and 0% as foliar spray), T_3: RD + $ZnSO_4$ (0 g plant^{-1} as basal and 0.5% as foliar spray), T_4: RD + $ZnSO_4$ (150 g plant^{-1} as basal and 0.5% as foliar spray), T_5: RD + $ZnSO_4$ (300 g plant^{-1} as basal and 0.5% as foliar spray), T_6: RD + $ZnSO_4$ (0 g plant^{-1} as basal and 1.0% as foliar spray), T_7: RD + $ZnSO_4$ (150 g plant^{-1} as basal and 1.0% as foliar spray), and T_8: RD + $ZnSO_4$ (300 g plant^{-1} as basal and 1.0% as foliar spray).

Zinc application methods and time: Zn fertilizers were applied into the soil prior to the flowering stage in mango trees. While, the foliar application of Zn was performed twice a year. The first foliar application was made at the time of the inflorescence stage. However, a second foliar spray was applied when fruit size becomes like a pea.

Data collection: After harvesting, soil and leaf samples were collected, stored and processed for further analyses. Attributes such as average fruit weight**,** fruit size**,** number of flowers per panicle**,** number of fruits matured per panicle**,** fresh pulp weight, stone weight, shelf life and yield per tree were noted as per standard procedures after harvesting.

Sugar contents: Total sugars and Non-reducing sugars were determined according to the method of Ranganna (1986). Determination of reducing sugars was according to the method described by Hortwitz (1960).

Statistical analysis: Collected data were examined statistically by applying analysis of variance (ANOVA) and Tukey's test at $p \leq 0.05$. Statistical computer software package (Statistics 8.1) was used for the statistical analysis.

Results

Average fruit weight, fruit length and fruit width: The effect of treatments was significant ordinal for average fruit weight (AFW), fruit length (FL) and fruit width (FW). The effect of treatments was significant for the improvement in AFW, FL and FW. It was observed that all the treatments were significant from control for the improvement in AFW and FW. Treatments T3, T4, T5, T6, T7 and T8 differed significantly over control for the improvement in FL (Table 1). However, T1 and T2 did not differ over control for FL. Chord diagram showed that the percentage share of treatment T7 was highest than T0 for average fruit weight, fruit width and fruit length (Fig. 1). Pearson correlation showed a significant positive correlation between treatments, AFW, FL, and FW (Fig. 6). The maximum increase in AFW, FL and FW were noted where T7 was applied.

Shelf life, number of flowers and fruits matured panicle^{-1}: Application of treatments significantly affected the shelf life (SL), number of flowers per panicle (NFP) and number of fruits matured per panicle (NFMP). Effect of treatments was significant for the improvement in SL, NFP and NFMP. It was observed that all the treatments were significant from control for the improvement in SL and NFMP. Treatments T4, T5, T6, T7 and T8 differed significantly over control for the improvement in NFP (Table 2). However, T1, T2 and T3 did not differ over control for NFP. Chord diagram showed that the percentage share of treatment T7 was highest than T0 for shelf life, number of flowers per panicle and number of fruits matured per panicle of mango (Fig. 2). Pearson correlation showed a significant positive correlation between treatments, SL, NFP and NFMP (Fig. 6). Maximum increase in SL, NFP and NFMP were noted where T7 was applied.

Pulp fresh weight, stone weight and yield tree^{-1} of mango: Treatments differed significantly for pulp fresh weight (PFW) stone weight (SW) and yield per tree of mango (YT). Impact of treatments was significant for the improvement in PFW, SW and YT. It was observed that all the treatments were significant from control for the improvement in PFW and SW. Treatments T2, T3, T4, T5, T6, T7 and T8 differed significantly over control for the improvement in YT (Table 3). However, T1 did not differ over control for YT. Chord diagram showed that the percentage share of treatment T7 was highest than T0 for shelf life, number of flowers per panicle and number of fruits matured per panicle of mango. Chord diagram showed that the percentage share of treatment T7 was highest than T0 for pulp fresh weight, stone weight and yield per tree of mango (Fig. 3). Pearson correlation showed a significant positive correlation between treatments, PFW, SW, and YT (Fig. 6). The maximum increase in PFW, SW and YT were noted where T7 was applied.

Table 1. Effects of Zn as foliar and soil application on average fruit weight, fruit length and fruit width of mango.

Treatment	Average fruit weight (g)	Fruit length (cm)	Fruit width (cm)
T_0	450 g	11.25 d	5.63 f
T_1	480 f	12.00 cd	6.00 e
T_2	499 e	12.475 b-d	6.24 de
T_3	512 de	12.80 bc	6.40 cd
T_4	525 cd	13.125 a-c	6.56 b-d
T_5	531 c	13.275a-c	6.64 bc
T_6	550 b	13.75 ab	6.88 ab
T_7	574 a	14.35 a	7.18 a
T_8	570 a	14.25a	7.13 a

Table 2. Effects of Zn as foliar and soil application on Shelf life, Number of flowers per panicle and Number of fruits matured per panicle of mango.

Treatment	Shelf life (Days)	Number of flowers per panicle -	Number of fruits matured per panicle -
T_0	8 c	630.00 e	1.80 g
T_1	10 b	672.00 de	1.92 f
T_2	10 b	698.60 cd	2.00 e
T_3	11 ab	716.80 cd	2.05 de
T_4	11 ab	735.00 bc	2.10 cd
T_5	11 ab	743.40 bc	2.12 c
T_6	11 ab	770.00 ab	2.20 b
T_7	12 a	803.60 a	2.30 a
T_8	12 a	798.00 a	2.28 a

Table 3. Effects of Zn as foliar and soil application on Pulp fresh weight, Stone weight and Yield per tree of mango.

Treatment	Pulp fresh weight (g)	Stone weight (g)	Yield per tree (kg)
T_0	214.29 g	150.00 f	150.00 e
T_1	228.57 f	160.00 e	160.00 de
T_2	237.62 e	166.33 de	166.00 cd
T_3	243.81 de	170.67 cd	170.00 cd
T_4	250.00 cd	175.00 b-d	175.00 bc
T_5	252.86 c	177.00 bc	177.00 bc
T_6	261.90 b	183.33 ab	183.00 ab
T_7	273.33 a	191.33 a	191.00 a
T_8	271.43 a	190.00 a	190.00 a

Total sugars (TS), reducing sugars (RS) and non-reducing sugars (NRS) of mango: Treatments effect was significantly different for TS, NRS and RS of mango. The effect of treatments was significant for the improvement in TS, RS and NRS. It was observed that all the treatments were significant from control for the improvement in NRS. Treatments T3, T4, T5, T6, T7 and T8 differed significantly over control for the improvement in TS. However, T1 and T2 did not differ over control for TS. In the case of RS, treatments T2, T3, T4, T5, T6, T7 and T8 differed significantly over control for the improvement in TS (Table 4). While only T1 did not differ over control for RS. Chord diagram showed that the percentage share of treatment T7 was highest than T0 for total sugars, reducing sugars and non-reducing sugars of mango (Fig. 4). Pearson correlation showed that a significant positive correlation existed between treatments, TS, RS and NRS. The maximum increase in TS, RS and NRS were noted where T7 was applied.

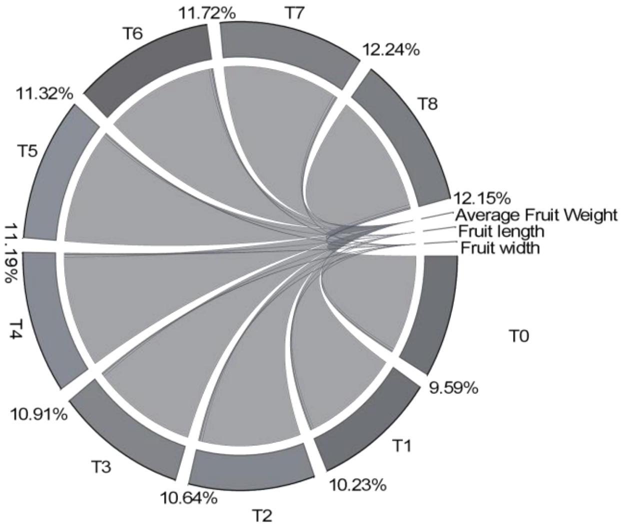

Fig. 1. Chord diagram showing the percentage share of each treatment for average fruit weight, fruit width and fruit length.

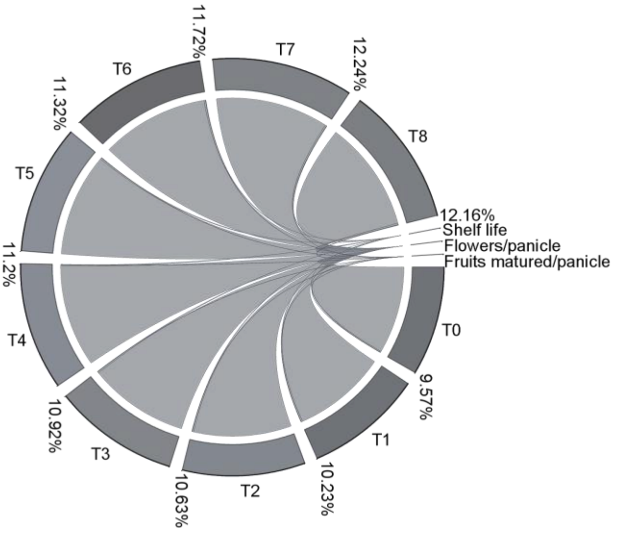

Fig. 2. Chord diagram showing the percentage share of each treatment for shelf life, number of flowers per panicle and number of fruits matured per panicle of mango.

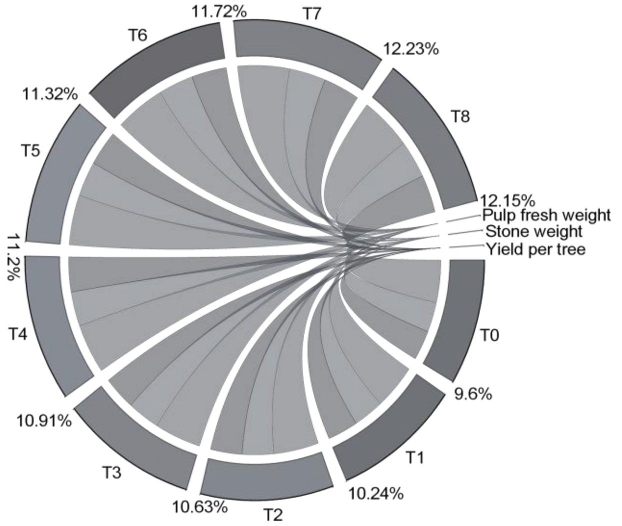

Fig. 3. Chord diagram showing the percentage share of each treatment for pulp fresh weight, stone weight and yield per tree of mango.

Table 4. Effects of Zn as foliar and soil application on Total sugars, Reducing sugars and Non-Reducing sugars of mango.

Treatment	Total sugars	Reducing sugars	Non-reducing sugars
	(%)		
T_0	18.00 d	14.85 e	7.43 g
T_1	19.20 cd	15.84 de	7.92 f
T_2	19.96 b-d	16.47 cd	8.23 e
T_3	20.48 bc	16.90 cd	8.45 de
T_4	21.00 a-c	17.33 bc	8.66 cd
T_5	21.24 a-c	17.52 bc	8.76 c
T_6	22.00 ab	18.15 ab	9.08 b
T_7	22.96 a	18.94 a	9.47 a
T_8	22.80 a	18.81 a	9.41 a

Table 5. Effects of Zn as foliar and soil application on Photosynthetic rate, Transpiration rate and Stomatal conductance of mango.

Treatment	Photosynthetic rate	Transpiration rate	Stomatal conductance
	(µmol/m/s)	(mmol /m/s)	(mol /m/s)
T_0	14.85 g	4.50 f	0.23 e
T_1	15.84 f	4.80 e	0.24 d
T_2	16.47 e	4.99 de	0.25 d
T_3	16.90 de	5.12 cd	0.26 cd
T_4	17.33 cd	5.25 b-d	0.26 bc
T_5	17.52 c	5.31 bc	0.27 bc
T_6	18.15 b	5.50 ab	0.28 ab
T_7	18.94 a	5.74 a	0.29 a
T_8	18.81 a	5.70 a	0.29 a

Photosynthetic rate, Transpiration rate and Stomatal conductance of mango: Effect of treatments was significant for photosynthetic rate (Pn), transpiration rate (E) and stomatal conductance (SC) of mango. The influence of treatments was significant for the improvement in TS, RS and NRS. It was observed that all the treatments were significant from control for the improvement in Pn, E and SC (Table 5). Chord diagram showed that the percentage share of treatment T7 was highest than T0 for photosynthetic rate, transpiration rate and stomatal conductance of mango (Fig. 5). Pearson correlation showed a significant positive correlation between treatments, Pn, E and SC (Fig. 6). The maximum increase in Pn, E and SC were noted where T7 was applied.

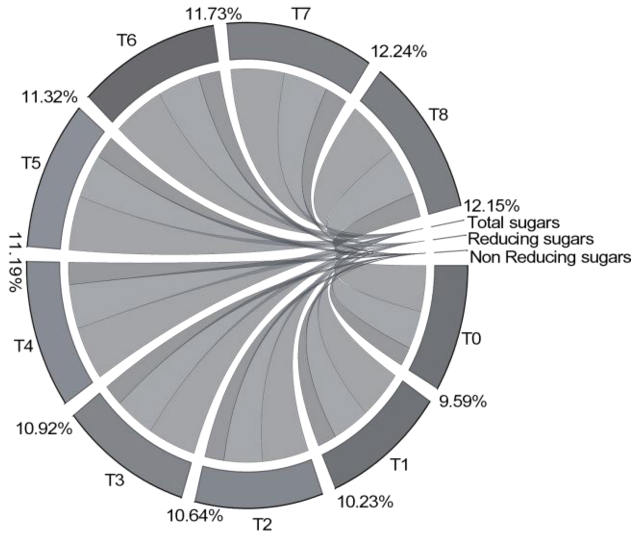

Fig. 4. Chord diagram showing the percentage share of each treatment for total sugars, reducing sugars and non-reducing sugars of mango.

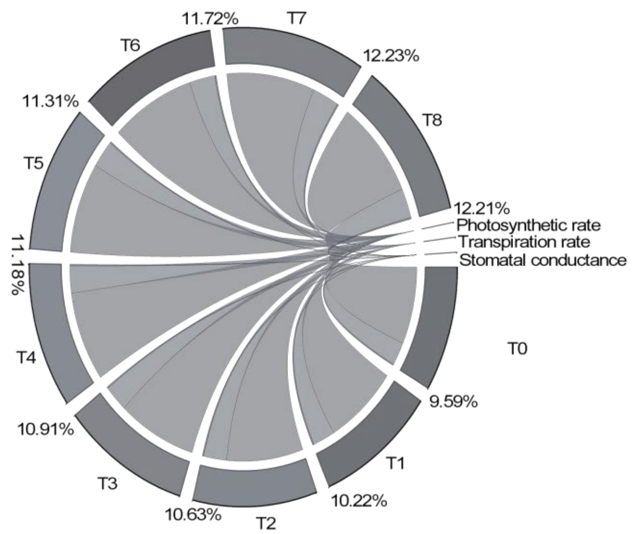

Fig. 5. Chord diagram showing the percentage share of each treatment for photosynthetic rate, transpiration rate and stomatal conductance of mango.

Discussion

In the current experiment, the application of T7 and T8 maximized the growth and yield attributes of mango. The improvement in fruit width and length, average fruit weight, stone weight, TSS, and yield per tree might be due to better regulation of gas exchange attributes and nutrient uptake. These results can be correlated with the findings of Ahmad *et al.*, (2018). Zn-finger transcription factors regulate the physiological processes that developed the floral parts, i.e., anthers, pollen, pistil and secretory tissues in many plant species (Kobayashi *et al.*, 1998). It has been observed that deficiency of Zn disrupts the development of flowers and fruits (Epstein & Bloom, 2005). Rodraguez *et al.*, (2005) added Zn + KCl in 'Valencia' orange trees and observed that K and Zn foliar concentrations positively affect the production of medium and large-sized fruits. These results are in agreement with the work of Bariya *et al.*, (2014), and Ahmad *et al.*, (2018). They found that Zn improved the growth of mango by activating the enzymatic reactions. Zinc is a co-factor of more than 300 enzymes and proteins and has a quick and precise effect on cell division, protein synthesis and nucleic acid metabolism (Marschner, 1986). Zinc is an important micronutrient for plants as it is involved in numerous enzymatic reactions and is necessary for good growth and development. Zinc is also involved in regulating carbohydrate and protein metabolism (Swietlik, 1999). Furthermore, Zn uptake in mango plants will be more if $ZnSO_4$ is applied as foliar application than soil application (Bahadur, 1998). The positive correlation of its foliar application in enhancing the mango productivity was cited by Singh & Maurya (2004); Ranjit *et al.*, (2008) and elevating the mango fruit quality in terms of total sugar and total soluble solids

(TSS) (Rashmi & Singh, 2007). However, the balanced use of Zn and the best application method needs more attention to synchronize the application rate of Zn with inorganic fertilizers. Hasani *et al.*, (2016) also found similar results of enhancement in yield via Zn over control. The enhancement of mango fruit yield, vitamins, sugar concentrations, and some physiological features and improvement in quality was due to the use of Zn. In the current experiment, improvement in total sugar, reducing sugar and non-reducing sugar also validated the efficacious functioning of Zn. The application of Zn regulated the rate of photosynthesis in plants. Improvement in photosynthesis increase the synthesis of carbohydrates, i.e., sugar contents. According to Hegde & Venkatesh, (2007) Zn positively affects the biochemical activities of plants by establishing or stimulating enzymes, cells osmoregulation and altering membrane permeability. Zinc also played an imperative role in better mineral nutrition uptake by catalyzing the macronutrient uptake (Phillips, 2004). A rise in the TSS and SC of fruits via foliar Zn has been documented in pomegranate and mango cv. Dusehri (Khorsandi *et al.*, 2009; Anees *et al.*, 2011). The improvement in fruit quality might be via catalytic activation caused by micronutrients mainly at high concentrations. Hence, the foliar application of micronutrients quickly increased the uptake of macronutrients in the tissues and organs of the mango plants, decreased the nutritional deficiencies and improved the fruit quality. The increase of mango fruit quality and yield in response to the combined application of Zn may be due to improvements in sugar concentrations, vitamins and some physiological features Hegde & Venkatesh, (2007). Anees *et al.*, (2011) detected improved fruit ascorbic acid and sugar via $ZnSO_4$ addition. They also documented enhancement in total sugars of fruit by increasing zinc rates.

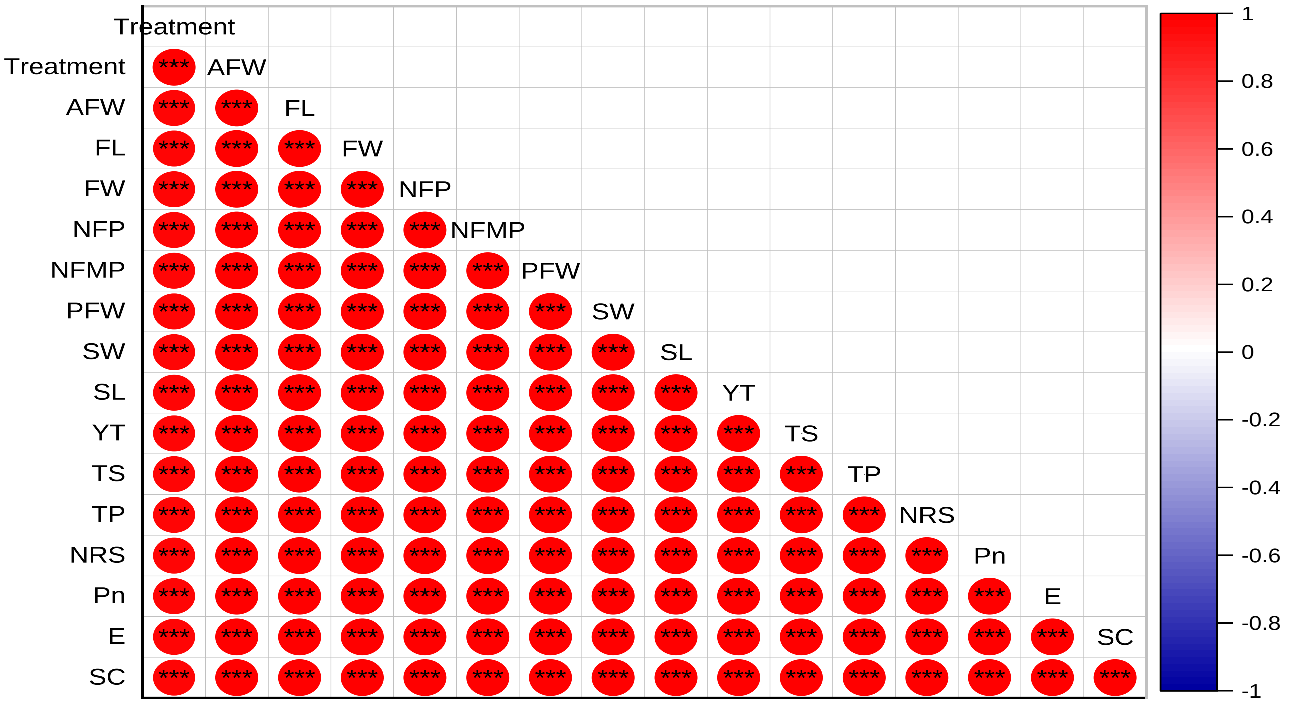

Fig. 6. Pearson correlation for treatments and different attributes. * = 0.05, ** = 0.01, *** = 0.001

Conclusion

It is concluded that applying both soil and foliar application of $ZnSO_4$ has the potential to improve the growth and yield attributes of mango. Treatments T_7 (RD + $ZnSO_4$ + 150 g plant^{-1} as basal and 1.0% as foliar spray) followed by T_8 (RD + $ZnSO_4$ + 300 g plant^{-1} as basal and 1.0% as foliar spray) should be applied to maximize the fruit length, fruit width, average fruit weight, stone weight, total soluble solid and yield per tree of mango. In addition, T7 and T8 were also capable of modifying the gas exchange attributes, i.e., photosynthetic rate, stomatal conductance and transpiration rate of mango. It is recommended to use T7 for maximizing the growth, yield and quality of mango, keeping in mind the efficacious use of fertilizer.

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