

Research Article

Influence of Zinc on Pre and Postharvest Quality of Plum

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Abstract | Pre-harvest application of zinc sulphate enhanced growth and promotes post-harvest quality of fruits during storage. Plum fruit exhibits climacteric behavior and its quality characteristics depending on the harvest stage. The present research study entitles “Influence of zinc on pre and postharvest quality of plum” was conducted at Horticulture Research Farm and postharvest laboratory Department of Horticulture, The University of Agriculture Peshawar. Plum fruits are perishable and cannot be stored for long periods. Plum fruit exhibits climacteric behavior and its quality characteristics depending on the harvest stage. The effect of all experimental treatments result was significant for all studied growth attributes when compared with control. Zn at the rate of 1.1 kg ha⁻¹ applied 15 days after fruit set increased leaf protein content (6.53 %), the total number of fruits plant⁻¹ (916). Among application stages, Zn sprayed 15 days after fruit set increased leaf protein content (6.70 %), total number of fruits plant⁻¹ (932). Various attributes studied for storage duration of plum fruit were significantly affected by zinc concentration less weight loss (11.91%), TSS (13.76 °Brix) were recorded with fruit plant sprayed with zinc sulphate @ 1.1 kg ha⁻¹. The result for various zinc application stages less weight loss (12.75%), TSS (14.18 °Brix) were recorded with fruit plant sprayed 15 days after fruit set. Storage duration means showed lowest TSS (8.99 °Brix) respectively. It is concluded that plum tree could be sprayed with 1.1 kg ha⁻¹ zinc sulfate 15 days of fruit set to improve better yield and prolong the shelf life of plums up to 30 days under low temperature (10±2 °C and RH 80-90%).

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Keywords | Zinc sulphate, Leaf protein content, Plum, Postharvest, Weight loss and storage



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Introduction

Plum (*Prunus domestica* L.) is a deciduous plant, possess fruits usually called as drupe or stone fruit. Plum fruit exhibits climacteric behavior and the quality of plum fruit varies depending on the harvest stage (Valero *et al.*, 2003). Plum can be eaten fresh or dried. In the domestic market, plums are consumed as fresh fruit, while a small amount is exported to other countries. Plum fruit is rich source of vitamin

C, vitamin A and fibers (Gunnes, 2003). Plum fruits are perishable cannot be stored for longer periods as well as transported over long distances under normal circumstances. Post-harvest softening of plums limits their storage periods (Skog *et al.*, 2003). The most effective way to reduce the deterioration of plum fruit after harvest is to apply some pre-harvest treatments of nutrients (Kader and Mitchell, 2002), for the purpose of ripening and degradation (Daverynejad *et al.*, 2013).

Zinc is an essential micronutrient and has many basic functions in plant systems (A and L. Canada Lab. 2002). Pre-harvest application of zinc promotes the post-harvest quality of fruits by increasing total antioxidants and total phenol content in fruits (Nasir *et al.*, 2016). Zinc is the precursor of auxin synthesis in plants (Kramer and Clemens, 2006) and phenolic accumulation increases with auxin increasing which may be due to increased endogenous phenylalanine ammonia-lyase activity (Ertani *et al.*, 2013). Foliar application of zinc plays a vital role in plant growth it produces sugars and carbohydrates that are essential for fruit development (Kumar *et al.*, 2005). Zinc activates the enzyme system that regulates fruit growth which significantly increased the number of fruit plants⁻¹ the reason may be due to Zinc application significantly affecting fruit weight which may lead to the increasing number of fruits plants⁻¹ (Cakmak, 2000). Zinc is required for the synthesis of tryptophan, and is the precursor of indole acetic acid synthesis which is involved in the growth and development of fruits and affects in fruits number (Swietlik, 1999). Zinc promotes growth hormone biosynthesis, maturation and starch development in plants which may be the reason for better fruits number (Brady and Weil, 2002). Zinc plays a key role in DNA polymerase activity, sugar and protein metabolism, and can also increase cell division, thereby increasing fruit numbers and weight significantly (Marschner, 2011). The application of zinc can effectively reduce weight loss. The main reason for the weight loss of fruits is caused by water loss due to evapotranspiration during storage (Nasrin *et al.*, 2008). With the application of zinc, the increase in total soluble solids may be due to more efficient transport of photosynthetic products to fruits and conversion of complex sugars to monosaccharides during storage (Osman, 1999). Zinc significantly increased TSS of fruits this can be attributed to the active role of zinc in photochemical reactions such as nucleic acid, starch metabolism, and the promotion of various enzyme activities in biochemical reactions (Alloway, 2004). Zinc also plays an important role in certain metabolic activities, such as sugar transport and carbohydrate metabolism (Jeyakumar *et al.*, 2001) and the rapid transfer of photosynthetic products which lead to increase TSS (Echeverria *et al.*, 1989). Zinc significantly affects the ripening characteristics of fruits are marked changes in physiology and biochemistry in the fruit, and significant effect in total soluble solids (Brady *et al.*, 2002), leading to changes in carbohydrate composition (Asif *et al.*, 2004).

Materials and Methods

The experiment was conducted at the Horticulture Research Farm and postharvest laboratory of Department of Horticulture, The University of Agriculture Peshawar during 2018-19 (February to August). The experiment was conducted in two phases at 1st phase pre harvest application of zinc was applied to the plants and field data were analyzed and then at in 2nd phase these pre harvested application fruits were kept for storage performance. Different levels of zinc (zinc sulphate ZnSO₄), (0, 0.5, 1.1 and 1.6 kg ha⁻¹) and their application at different intervals (15, 30 and 45 days after fruit set) were studied for various storage duration (0, 15, 30, 45, 60 and 75 days) at a temperature of 10±2 °C and RH 80-90%. The experiment was carried out in Randomized Complete Block Design (RCBD) with three factors replicated three times, while CRD design was used for post-harvest experiment (laboratory experiment) The tested trees were 8-10 years old. Cultivar Fazal-i-Manani was used with plant to plant and row to row distance of 20 feet.

Factor A: Zinc foliar application (kg ha⁻¹)

0 (Control)

0.5 kg ha⁻¹

1.1 kg ha⁻¹

1.6 kg ha⁻¹

Factor B: Different stages after fruit set

15 days, 30 days and 45 days

Factor C: Storage durations (days)

Fruits were kept for 75 days in cool storage and data was recorded with every 15 days intervals

0, 15, 30, 45, 60 and 75

Foliar application

Neutralized zinc sulphate is commonly used for sprays. A typical spray solution contains 0.5 percent zinc sulphate and 0.25 percent lime; about 400 liters of spray solution / ha are generally enough to wet leaves thoroughly (Katyal *et al.*, 2009).

Statistical analysis

The experiment was conducted in RCBD and the data were analyzed by Statistic software (Statistix 8.1 Analytical Software, 2000). Means were compared by the LSD test when the F test is significant (Jan *et al.*, 2009).

Results and Discussion

Leaf protein content (%)

Data regarding leaf protein content was significantly influenced by zinc concentration and application stages. However, the interaction was non-significant (Table 1) when zinc was sprayed at the rate of 1.6 kg ha⁻¹ maximum (6.58 %) leaf protein content was recorded. However, this increase was not significantly different with Zn level of 1.1 kg ha⁻¹. Minimum (4.79 %) leaf protein content was shown in control plants. Among the application stages of zinc, maximum (6.70 %) leaf protein content was observed when zinc was sprayed 15 days after fruit set. Minimum (6.18 %) leaf protein content was calculated when zinc was applied 45 days after the fruit set.

One of the good functions of zinc is its role in protein synthesis and its contribution to the structural integrity of many proteins. Due to impaired structural integrity of the ribosome (protein synthesis site) and the activity of enzymes involved in protein synthesis (such as RNA polymerase) is regulated by zinc (Marschner, 2012; Lacerda *et al.*, 2018). The reason for leaf protein synthesis zinc is required for the activity of various enzymes (including dehydrogenase, aldolase, isomerase, transphosphatase, RNA and DNA polymerase), and is also involved in tryptophan synthesis, cell division, membranes Structure maintenance and photosynthesis and plays a role in regulating cofactors in protein synthesis (Marschner, 2012; Lacerda *et al.*, 2018). Application of zinc increase leaf protein because the role of zinc in leaf protein biosynthesis is further demonstrated by the rapid reduction of amino acid and amide concentrations (Cakmak *et al.*, 2000). Zinc acts as a catalytic or structural cofactor in many enzymes and regulates leaf proteins content in plant leaves (Maret, 2009). Some previous results are also in line with our present study that Foliar application of zinc after fruit set can more effectively increase leaf protein which may significantly enhance the activities of nitrate reductase and glutamate synthase, and then affect the leaf protein content and protein composition in plants (Liu *et al.*, 2015).

Total number of fruits plant⁻¹

Statistical analysis of the data showed that zinc concentration and its application at various stages had significantly affected the total number of fruits plant⁻¹. Their interaction (zinc concentration × application stages) was also significant (Table 1).

Trees sprayed with foliar zinc @ 1.6 kg ha⁻¹ produced a maximum (922) total number of fruits plant⁻¹, which are not significantly different from plants sprayed with 1.1 kg Zn ha⁻¹. While the minimum (808) total number of fruits plant⁻¹ was recorded in the control plants. An inverse trend between Zn application stages and the total number of fruits plant⁻¹ was observed. Maximum (932) total number of fruits plant⁻¹ was recorded when zinc was sprayed 15 days after fruit set. There is no significant difference between zinc application stages of 15 and 30 days after the fruit set. Trees sprayed with zinc 45 days after fruit set gave a minimum (881) the total number of fruits plant⁻¹.

Interaction between zinc concentration and zinc application stage indicated that total no. of fruits plant⁻¹ decreased with application stage and increased with zinc concentration increased, however total no. of fruits plant⁻¹ was increased with zinc application up to 1.6 kg ha⁻¹. The maximum total no. of fruits plant⁻¹ was (974) when zinc was applied @ 1.6 kg ha⁻¹ 15 days after fruit set. While minimum total no. of fruits plant⁻¹ was recorded (829) when zinc was applied at 0.5 kg ha⁻¹ 45 days after fruit set (Figure 1).

Foliar application of zinc plays a vital role in plant growth it produces sugars and carbohydrates that are essential for fruit development. Zinc activates the enzyme system that regulates fruit growth which significantly increased the number of fruit plants⁻¹ the reason may be due to zinc application significantly affecting fruit weight which may lead to the increasing number of fruits plants⁻¹ (Cakmak, 2000). Zinc is required for the synthesis of tryptophan, and is the precursor of indole acetic acid synthesis which is involved in the growth and development of fruits and affects in fruits number (Swietlik, 1999). Zinc promotes growth hormone biosynthesis, maturation and starch development in plants which may be the reason for better fruits number (Brady and Weil, 2002). Zinc plays a key role in DNA polymerase activity, sugar and protein metabolism, and can also increase cell division, thereby increasing fruit numbers and weight significantly (Marschner, 2011). Foliar application of zinc increases the number of fruits as it helps the formation of stamens, pollen and fruit set (Nadergoli *et al.*, 2011). Zinc plays a role in the formation of flowering fruit buds (Usenik and Stampar, 2002), and synthesis of tryptophan, a precursor of auxin, and the transport of metabolites to the site of bud development which leads to increased fruits number in plants (Day, 1994).

Table 1: Leaf protein content (%) and total No. of fruits plant⁻¹ of plum fruit as affected by zinc levels at different stages.

Zinc levels (kg ha ⁻¹)	Parameters	
	Leaf protein content (%)	Total No. of fruits plant ⁻¹
0	4.79 c	808 c
0.5	6.18 b	883 b
1.1	6.53 a	916 a
1.6	6.58 a	922 a
LSD (P ≤ 0.05)	0.286	29.62
Zinc application stages (days after fruit set)		
15	6.70 a	932 a
30	6.41 b	908 ab
45	6.18 b	881 b
LSD (P ≤ 0.05)	0.285	29.71
Interactions (LSD at (P ≤ 0.05))		
Zn × Stage	---	Figure. 1
Significance	NS	*

Means followed by same letters in respective columns are not significantly different at 5% level of probability. NS = non-significant; * = Significant at 5% level of probability

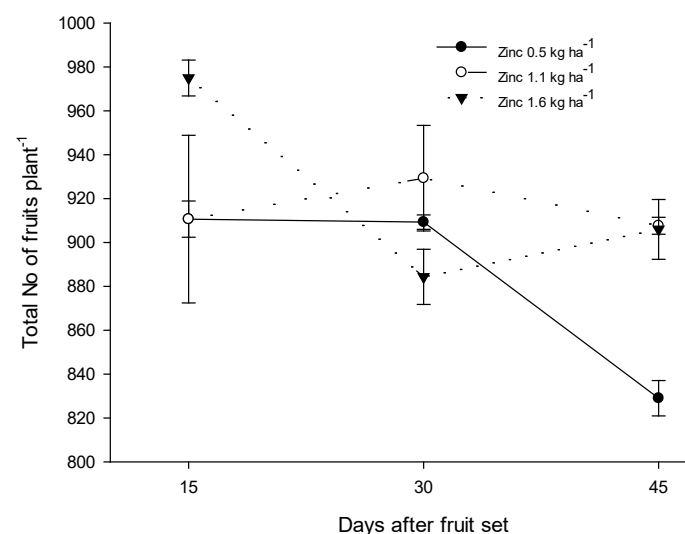


Figure 1: Interaction between zinc and days after fruit set for total no. of fruits plant⁻¹ of plum.

Weight loss (%)

Weight loss was significantly influenced by zinc concentration, zinc application stages and storage durations of plum fruit. All the interactions were significant except Storage × Zn × Stage (Table 2).

Results regarding weight loss in plum fruit showed that less weight loss (11.91%) was observed when zinc was applied @ 1.1 kg ha⁻¹. While more weight

loss (15.95%) was observed in control. Weight decreases when zinc levels increased. Minimum weight loss (12.75%) was observed when zinc was applied 15 days after fruit set. An increased in weight loss was observed with delaying application stages. Maximum weight loss was found (14.87%) when zinc was applied 45 days after the fruit set. In the case of storage durations minimum weight loss (9.66%) was found in fruit stored for 15 days. While weight loss was increased with storage duration, (22.18%) weight loss was observed in fruits stored for 75 days.

Table 2: Weight loss (%) and total soluble solids (°Brix) of plum as affected by zinc foliar application and stages during storage.

Zinc levels (kg ha ⁻¹)	Parameters	
	Weight loss (%)	Total Soluble Solids (°Brix)
0 (Control)	15.95a	16.19a
0.5	13.84b	15.00c
1.1	11.91d	13.76d
1.6	13.29c	15.66b
LSD (P ≤ 0.01)	0.488	0.243
zinc application stages (days after fruit set)		
15	12.75c	14.18c
30	13.63b	15.43b
45	14.87a	15.84a
LSD (P ≤ 0.01)	0.422	0.210
Storage durations (days)		
0	0.00f	8.99f
15	9.66e	12.25e
30	13.67d	14.27d
45	16.69c	16.37c
60	19.72b	18.46b
75	22.77a	20.56a
LSD (P ≤ 0.01)	0.60	0.30
Interactions (LSD at (P ≤ 0.01))		
Storage × Zn		
Significance	NS	NS
Storage × Stage		
Significance	NS	NS
Zn × Stage		
Significance	NS	Figure. 2
Storage × Zn × Stage		
Significance	NS	***

Means followed by same letters in respective columns are not significantly different at 5% level of probability. NS = non-significant; * = Significant at 5% level of probability

Weight loss is a vital problem of fruit quality deterioration during postharvest storage (Zhan *et al.*, 2012a, 2012b). The application of zinc can effectively reduce weight loss. The main reason for the weight loss of fruits is caused by water loss due to evapotranspiration during storage (Nasrin *et al.*, 2008). Foliar application of zinc during storage significantly affected weight loss this may be due to zinc regulate several chemical reactions, which can lead to slower respiration and evapotranspiration rates or internal decomposition and aging during storage and thus weight loss is reduced (Allan *et al.*, 2003). Zinc also regulates auxin synthesis in plants (Kramer and Clemens, 2006). Auxin promote some biochemical changes inside the fruit, which results in the retention of more water relative to the evaporation rate and is possible to increase the affinity for water due to changes in certain protein components in the cell by which less weight loss occurs (Mitchell, 2002). The effectiveness of zinc has been proven in many studies of guava (Chaitanya *et al.*, 1997), where pre-harvest application of zinc minimized weight loss of fruits is compared to other micronutrient after 20 days of storage. Ram *et al.*, (2001) also reported that zinc sulfate can effectively reduce weight loss in guava fruit.

Total soluble solids ($^{\circ}$ Brix)

Zinc concentration, zinc application stages, storage duration and Zn $\times$ Stage interaction significantly affected total soluble solids ($^{\circ}$ Brix) of plum fruits where all the other interactions were non-significant (Table 2).

TSS (13.76 $^{\circ}$ Brix) was found with foliar application of zinc @ 1.1 kg ha⁻¹. While maximum TSS (16.19 $^{\circ}$ Brix) was observed in control. Increased zinc application up to some level showed decreased in TSS of plum fruit. Minimum TSS (14.18 $^{\circ}$ Brix) was observed in plum fruit when zinc was applied 15 days after fruit set. An increased in TSS was observed with delaying zinc application stages. Maximum TSS (15.84 $^{\circ}$ Brix) was obtained when zinc was applied 45 days after fruit set. In case of storage durations minimum TSS (8.99 $^{\circ}$ Brix) was recorded at freshly harvested fruits. While TSS was increased with storage duration, (20.56 $^{\circ}$ Brix) was observed in fruits stored for 75 days.

Interaction between zinc concentration and zinc application stage indicated that total soluble solids

($^{\circ}$ Brix) increased with delayed zinc application stage and decreased with zinc concentration, however minimum TSS (11.96 $^{\circ}$ Brix) was observed when zinc applied @ 1.1 kg ha⁻¹ 15 days after fruit set. While maximum TSS (17.04 $^{\circ}$ Brix) was observed zinc was applied 45 days after fruit set (Figure 2).

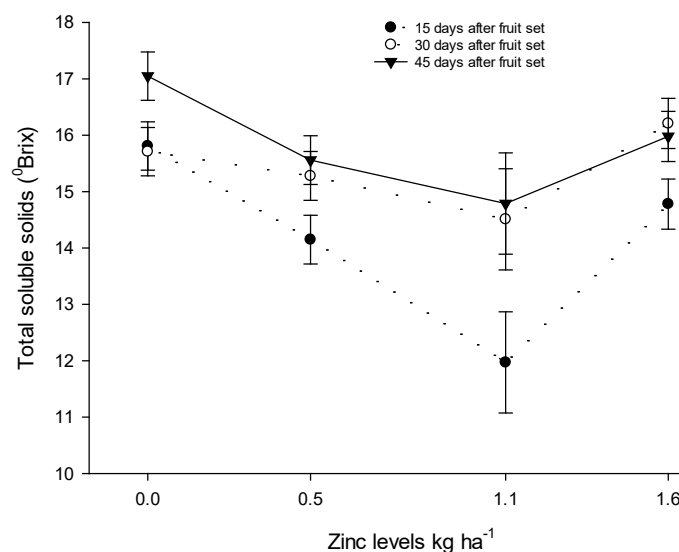


Figure 2: Interaction between zinc levels and stage (days after fruit set) for total soluble solids ($^{\circ}$ Brix) of plum.

The total soluble solid content in climacteric and non-climacteric fruits determines the ripeness index of the fruit. An increase in the total soluble solids (TSS) level in the fruit indicates an acceleration of the ripening process, while a decrease in the TSS content indicates a slower ripening of the fruit and extended shelf life (Gong *et al.*, 2015). During storage total soluble solids increases in fruits (Habib *et al.*, 2007) this may be attributed to the conversion of complex sugars to monosaccharides during storage and water loss (Hassan, 2000). With the application of zinc, the increase in total soluble solids may be due to more efficient transport of photosynthetic products to fruits and conversion of complex sugars to monosaccharides during storage (Osman, 1999). Zinc significantly increased TSS of fruits this can be attributed to the active role of zinc in photochemical reactions such as nucleic acid, starch metabolism, and the promotion of various enzyme activities in biochemical reactions (Alloway, 2004). Zinc also plays an important role in certain metabolic activities, such as sugar transport and carbohydrate metabolism (Jeyakumar *et al.*, 2001) and the rapid transfer of photosynthetic products which lead to increase TSS (Echeverria *et al.*, 1989). Zinc significantly affects the ripening characteristics of fruits are marked changes in physiology and biochemistry in the fruit, and significant effect

in total soluble solids (Brady *et al.*, 2002), leading to changes in carbohydrate composition (Asif *et al.*, 2004). Zinc has a significant positive effect on TSS. The lowest TSS was observed by foliar spraying zinc sulfate in pomegranates (Balakrishnan *et al.*, 1996). It is well understood from previous studies that the application of zinc increased the titratable acidity, it was reported that foliar application of zinc sulfate increases the titratable acidity, and decrease TSS in pomegranate fruits (El Khawaga, 2007). Another study has been approving our present study that application of zinc at fruit set stage significantly affect fruit quality such as TSS, titratable acidity and TSS: TA (Khan *et al.*, 2012). Zinc regulates free amino acids in plants which are effective in increasing total soluble solids (Rafie *et al.*, 2017).

Conclusions and Recommendations

Foliar application is a quick method that uses nutrients more effectively to remedy plant mineral nutrient deficiencies as compared to soil application. Therefore, the best treatment in this study was zinc 1.1 kg ha⁻¹ when it was applied 15 days after the fruit set which maximize leaf protein content, total number of fruits plant⁻¹ and retained weight loss and total soluble solids (°Brix) during storage.

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Novelty Statement

Novelty of this research is the appropriate source of Zinc and most responsive application stages of plum. The foliar application of zinc has been identified for the first time both for pre and post-harvest performance.

Author's Contribution

Mohammad Wasiullah Khan: Conducted research, field experiments and wrote draft of the MS as the main researcher.

Abdur Rab: Major supervisor, shared the conceptual idea of the research and provided technical guidelines.

Conflict of interest

The authors have declared no conflict of interest.

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