

**STUDIES ON FOLIAR SPRAY OF ZINC METALOSATE
AND BORON METALOSATE ON GROWTH, YIELD AND
QUALITY OF GRAPES (*Vitis vinifera* L.) AND
POMEGRANATE (*Punica granatum* L.)**

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**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU
2017**

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RAMYA, S.H.

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Thesis submitted to the

University of Agricultural Sciences, Bengaluru

in partial fulfillment of the requirements

for the award of the degree of

Doctor of Philosophy

in

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

BENGALURU

DECEMBER, 2017



*Affectionately Dedicated
To My Beloved Parents*

*Shri. Hanumegowda
Smt. Manjula*

&

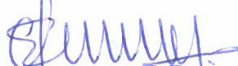
*Lovely Brother
Ranjith Kumar*

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CERTIFICATE

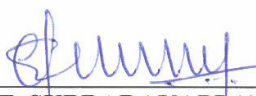
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BENGALURU
DECEMBER, 2017


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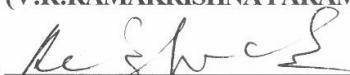
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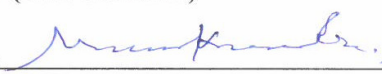
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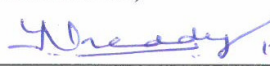
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ACKNOWLEDGEMENT

*At the very outset, I wish to express my profound indebtedness and deep sense of gratitude to **Dr.C. T, Subbarayappa** Professor, Department of Soil Science and Agricultural Chemistry, UAS, GKVK, BENGALURU and the esteemed chairman of my Advisory Committee, without whose valuable advice and constant encouragement, this task would not have been accomplished. I owe my heartfelt thanks for his wonderful guidance, extreme patience and efforts for providing me the facilities that I needed for completing this work successfully.*

*I would like to express my profound gratitude to **Dr. T.C.Chame gowda**, Professor & Head, Department of Soil Science and Agricultural Chemistry for his support and motivation throughout the course of my research work.*

*I owe my heartfelt thanks to **Dr. R. C. Gowda**, Professor & University Head, Department of Soil Science and Agricultural Chemistry and member of my advisory committee for his critical analysis and unceasing interest shown during the course of my research work.*

*My sincere thanks to **Dr.V. R. Ramakrishna Parama**, Professor, Department of Soil Science and Agricultural Chemistry, UAS, BENGALURU for their helpful suggestions rendered during the course of research work and preparation of this thesis.*

*I extend my sincere thanks to **Dr. G. K. Mukunda**, Professor, Department of Horticulture, UAS, BENGALURU for their helpful suggestions rendered during the course of research work and preparation of this thesis.*

*My sincere thanks to **Dr. Y. A. Nanja Reddy**, Professor, Department of Crop Physiology, UAS, GKVK, BENGALURU, for his constant encouragement and constructive criticism during my research work. I extend my sincere thanks to **Dr. V. Ramamurthy**, Principal Scientist, NBSS & LUP, Hebbal, their valuable suggestions rendered during the course of research work.*

*I am indebted to all my teachers, **Dr. H. C. Prakasha, Dr. N. B. Prakash, Dr. J. Sarala kumara, Dr. Harish, Dr. T. Chikkaramappa** and **Dr. A.Sathish** for being the lighthouses in this hard journey. I pay tributes to all my teachers both past and present who taught me all I know and made me what I am today.*

I cannot acknowledge in words the kindness, help, love and affection showed on me by my farmer Channakrishnappa and his family members Thippamma, Narayanamma, Devanna and Sumithra, Naganna and Premamma, Uday, Vidya, Akil and Theja.

I also extend my sincere thanks to Mr. D. Shrinivasmurthy, Senior Lab Assistant, and Mr. Manjunath, Lab Assistant, Department of Soil Science and Agricultural Chemistry, UAS, GKVK, BENGALURU.

My indebtedness to my best friend and well wisher Mr. Ravindra for his help, concern, moral support, unbroken inspiration and affection shown to me is beyond words. Still I wish to express my heartfelt special thanks to him.

The acknowledgement loses its value without thanking my classmets and friends for their continuous support and help Harsitha, Eresh, Shruthi, Prashanth, Sabyasachi majumdar and Jayanthi. Very sincere and heartfelt thanks to my best juniors Chandrakanth, Siva Prasad, Raghavendra Reddy, Vidhathri, Altaf, Anand, Ranjitha, Mahesh, Narayanareddy and Pavithra for their constant encouragement and untiring help throughout the course of time. It is wise to remain indebted to their rather than to go in search of words, which only inadequately express my thankfulness.

I avail this opportunity to thank my parents who are the almighty's most treasured gift to me. I feel scanty of words to magnitute the boundless love and tireless sacrifice and affection showed on me by my father Shri., Hanume gowda my mother Smt. Manjula loving brother Ranjith Kumar and all my family members whom I wish to idolize throughout my life for making me what I am today.

I am very much thankful to Indofil Industries Limited for financial support and Dr. A. K. Shukla for technical support.

I wish to extend my sincere thanks to Laxmipathi, Amrutha and Bindu for their constant help throughout my study period. I avail this opportunity to thank seniors and all others who have given their love and support during the course of this journey. I am profoundly thankful to junior friends and non-teaching staff of our department for their kind cooperation and help during my investigation. Finally, I thank the eternal love of the great Almighty for gracing the peaceful atmosphere during the course of my study. Any omission in this brief acknowledgement does not mean lack of gratitude.

BENGALURU
December, 2017

(RAMYA, S. H.)

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METALOSATE ON GROWTH, YIELD AND QUALITY OF GRAPES
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RAMYA S.H.

THESIS ABSTRACT

Field experiments were conducted to study the effect of sources and levels of zinc and boron as foliar spray on growth, yield and quality of grapes and pomegranate during 2015-16 and 2016-17 in the farmer's field at Chikkaballapur district in a Randomized Block Design. The experimental results indicated that significantly higher growth, yield, quality parameters, zinc content in the index tissue, fruit nutrient content except phosphorus was recorded in the treatment T₁₃ (NPK+ Foliar spray of zinc @ 0.150 % as zinc metalosate) which is on par with the treatment T₁₈ (NPK+ Foliar spray of zinc @ 0.150 % as Zn-EDTA) as compared to control (T₃: NPK + FYM) and other treatments in both grapes and pomegranate. Combined application of boron and zinc @ 0.017 and 0.050 per cent through boron and zinc metalosate along with recommended dose of NPK increased significantly cane length, cane girth, internodal length, number of bunches plant⁻¹, number of berries bunch⁻¹, mean weight of berries bunch⁻¹, weight of bunch, yield, TSS, total sugars, boron content in index tissue, fruit N, P, K, S and B content. Significant increase in plant growth, yield parameters, physical parameters, quality and nutrient content in pomegranate fruit was recorded due to combined application of boron @ 0.017 % as boron metalosate + zinc @ 0.050 % as zinc metalosate along with recommended NPK. Significantly higher soil available nitrogen, phosphorus, potassium, sulphur, zinc and boron content after harvest of the crops was recorded in the control (T₃: NPK+ FYM) compared to other treatments.

2017

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ಸತು ಮತ್ತು ಬೋರಾನ್ ಮೆಟಲೋಸೆಟ್‌ಗಳ ಮೂಲಕ ಸಿಂಪರಣೆ ಮಾಡಿದಾಗ ದ್ರಾಕ್ಷಿ ಮತ್ತು
ದಾಳಿಂಬೆಯ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಮತ್ತು ಗುಣಮಟ್ಟದ ಮೇಲಾಗುವ ಪರಿಣಾಮದ ಕುರಿತು
ಅಧ್ಯಯನ

ರಮ್ಯಾ ಎಸ್. ಹೆಚ್.

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಈ ಕ್ಷೇತ್ರ ಪ್ರಯೋಗವನ್ನು ೨೦೧೫-೧೬ ಮತ್ತು ೨೦೧೬-೧೭ ನೇ ಸಾಲಿನಲ್ಲಿ ಚಿಕ್ಕಬಳ್ಳಾಪುರ ಜಿಲ್ಲೆಯ
ರೈತರ ತೋಟದಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಗಿದೆ. ಈ ಪ್ರಯೋಗವನ್ನು ವಿವಿಧ ಮೂಲಗಳ ಮತ್ತು ವಿವಿಧ ಹಂತದ
ಮೂಲಕ ಸತು ಮತ್ತು ಬೋರಾನ್ ಸಿಂಪರಣೆಯನ್ನು ಯಾದೃಚ್ಛಿಕ (ಆರ್. ಬಿ. ಡಿ) ವಿನ್ಯಾಸದಲ್ಲಿ
ಮೂರು ಬಾರಿ ಪುನರಾವರ್ತನೆಗೊಳಿಸಲಾಗಿತ್ತು. ಈ ಸಂಶೋಧನೆಯಿಂದ ತಿಳಿದುಬಂದ ಅಂಶವೆಂದರೆ
ಗಮನಾರ್ಹವಾಗಿ ಅಧಿಕ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ, ಗುಣಮಟ್ಟ, ಸೂಚ್ಯಂಕ ಅಂಗಾಂಶದಲ್ಲಿ ಸತುವಿನ ಅಂಶ
ಮತ್ತು ಹಣ್ಣಿನ ಪೋಷಕಾಂಶಗಳ ಅಂಶವು ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ + ಸತುವಿನ ಸಿಂಪರಣೆ @
೦.೧೫೦ % ಸತುವಿನ ಮೆಟಲೋಸೆಟ್ ಮೂಲಕ ಸಿಂಪಡಿಸಿದಾಗ ಬೇರೆ ಉಪಚರಿಸಿದ ತಾಕುಗಳಿಗಿಂತ
ಹೆಚ್ಚಾಗಿ ಕಂಡುಬಂದಿದೆ. ಬೋರಾನ್ ಮತ್ತು ಸತು @ ೦.೦೧೭ % ಮತ್ತು ೦.೦೫೦ % ಸಂಯೋಜಿತವಾಗಿ
ಬೋರಾನ್ ಮತ್ತು ಸತು ಮೆಟಲೋಸೆಟ್ ಮೂಲಕ ಹಾಗೂ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ
ಒದಗಿಸಿದಾಗ ಕಡ್ಡಿಯ ಉದ್ದ, ಸುತ್ತಳತೆ, ಆಂತರಿಕ ಉದ್ದ, ಪ್ರತಿ ಗಿಡದ ಗೋಂಚಲುಗಳ ಸಂಖ್ಯೆ,
ಹಣ್ಣುಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಗೋಂಚಲುಗಳ ಸರಾಸರಿ ಹಣ್ಣಿನ ತೂಕ, ಗೋಂಚಲುಗಳ ತೂಕ, ಇಳುವರಿ,
ಟಿಎಸ್‌ಎಸ್ ಪ್ರಮಾಣ, ಒಟ್ಟು ಸಕ್ಕರೆಯ ಅಂಶ, ಸೂಚ್ಯಂಕ ಅಂಗಾಂಶದಲ್ಲಿ ಬೋರಾನ್ ಅಂಶ,
ಹಣ್ಣಿನಲ್ಲಿನ ಸಾರಜನಕ, ರಂಜಕ, ಪೋಟ್ಯಾಷ್, ಗಂಧಕ ಮತ್ತು ಬೋರಾನ್ ಅಂಶವು ಬೇರೆ
ಉಪಚರಿಸಿದ ತಾಕುಗಳಿಗೆ ಹೋಲಿಸಿದಾಗ ಗಮನಾರ್ಹವಾಗಿ ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಸಸ್ಯದ
ಬೆಳವಣಿಗೆ, ಇಳುವರಿ, ಭೌತಿಕ ನಿಯತಾಂಕಗಳು, ಗುಣಮಟ್ಟ ಮತ್ತು ಪೋಷಕಾಂಶಗಳ ಅಂಶವು
ಬೋರಾನ್ ಮತ್ತು ಸತು @ ೦.೦೧೭ % ಮತ್ತು ೦.೦೫೦ % ಬೋರಾನ್ ಮತ್ತು ಸತು ಮೆಟಲೋಸೆಟ್
ಸಂಯೋಜಿತವಾಗಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ ಮೂಲಕ ಒದಗಿಸಿದಾಗ ಗಮನಾರ್ಹವಾಗಿ ಬೇರೆ
ತಾಕುಗಳಿಗೆ ಹೋಲಿಸಿದಾಗ ಹೆಚ್ಚಾಗಿರುತ್ತದೆ. ಮಣ್ಣಿನಲ್ಲಿ ಲಭ್ಯವಿರುವ ಸಾರಜನಕ, ರಂಜಕ, ಪೋಟ್ಯಾಷ್,
ಗಂಧಕ, ಸತು ಮತ್ತು ಬೋರಾನ್ ಅಂಶವು ನಿಯಂತ್ರಣ ತಾಕಿನಲ್ಲಿ (ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ
+ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ) ಬೇರೆ ಉಪಚರಿಸಿದ ತಾಕುಗಳಿಗೆ ಹೋಲಿಸಿದಾಗ ಗಮನಾರ್ಹವಾಗಿ
ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ.

೨೦೧೭

ಮಣ್ಣು ವಿಜ್ಞಾನ ಮತ್ತು ಕೃಷಿ ರಸಾಯನಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ,
ಗಾಂಧಿ ಕೃಷಿ ವಿಜ್ಞಾನ ಕೇಂದ್ರ
ಬೆಂಗಳೂರು-೫೬೦ ೦೬೫

ಪ್ರಧಾನ ಸಲಹೆಗಾರರ ಸಹಿ
(ಸಿ. ಟಿ. ಸುಬ್ಬರಾಯಪ್ಪ)

CONTENTS

CHAPTER	TITLE	PAGE No.
I	INTRODUCTION	1-5
II	REVIEW OF LITERATURE	6-27
III	MATERIAL AND METHODS	28-52
IV	RESULTS AND DISCUSSION	53-203
V	SUMMARY	204-210
VI	REFERENCES	211-229
	PUBLICATIONS	230-238

LIST OF TABLES

Table No.	Title	Page No.
1	Initial physico - chemical properties of the soils of the experimental site	30
2	Quality of irrigation water used in the field experiments	31
3	Nutrient content of farm yard manure used in the field experiments	31
4	Methodology adopted for soil analysis	48
5	Methodology adopted for FYM analysis	51
6	Methodology adopted for water analysis	52
7	Methodology adopted for plant and fruit analysis	52
8	Effect of foliar spray on growth parameters of grapes as influenced by sources and levels of zinc	55
9	Effect of foliar spray on yield parameters of grapes as influenced by sources and levels of zinc	59
10	Effect of foliar spray on yield of grapes as influenced by sources and levels of zinc	62
11	Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of zinc	65
12	Effect of sources and levels of zinc on macro nutrient content (%) of index tissue of grapes before foliar spray	70
13	Effect of sources and levels of zinc on secondary nutrient content (%) of index tissue of grapes before foliar spray	71
14	Effect of sources and levels of zinc on micronutrient content (mg kg ⁻¹) of index tissue of grapes before foliar spray	72
15	Effect of foliar spray on zinc content (mg kg ⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of zinc	73
16	Effect of foliar spray on zinc content (mg kg ⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of zinc	74
17	Effect of foliar spray on macronutrient content (%) of grapes as influenced by sources and levels of zinc	76

18	Effect of foliar spray on secondary nutrient content (%) of grapes as influenced by sources and levels of zinc	78
19	Effect of foliar spray on micronutrient content (mg kg ⁻¹) of grapes as influenced by sources and levels of zinc	80
20	Effect of foliar spray on major nutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of zinc	82
21	Effect of foliar spray on secondary nutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of zinc	84
22	Effect of foliar spray on micronutrient content (mg kg ⁻¹) of index tissue of grapes at harvest as influenced by sources and levels of zinc	86
23	Effect of foliar spray on chemical properties of soil at harvest of grapes as influenced by sources and levels of zinc	88
24	Effect of foliar spray on major nutrient status (kg ha ⁻¹) of soil at harvest of grapes as influenced by sources and levels of zinc	89
25	Effect of foliar spray on secondary nutrient status of soil at harvest of grapes as influenced by sources and levels of zinc	91
26	Effect of foliar spray on micronutrient status (mg kg ⁻¹) of soil at harvest of grapes as influenced by sources and levels of zinc	93
27	Effect of foliar spray on growth and yield parameters of pomegranate as influenced by sources and levels of zinc	95
28	Effect of foliar spray on yield of pomegranate as influenced by sources and levels of zinc	98
29	Effect of foliar spray on physical parameters of pomegranate as influenced by sources and levels of zinc	100
30	Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of zinc	103
31	Effect of sources and levels of zinc on macronutrient content (%) of index leaf of pomegranate before foliar spray	108
32	Effect of sources and levels of zinc on secondary nutrient content (%) of index leaf of pomegranate before foliar spray	109
33	Effect of sources and levels of zinc on micronutrient content (mg kg ⁻¹) of index leaf of pomegranate before foliar spray	110

34	Effect of foliar spray on zinc content (mg kg ⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of zinc	111
35	Effect of foliar spray on zinc content (mg kg ⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of zinc	112
36	Effect of foliar spray on macro nutrient content (%) of pomegranate as influenced by sources and levels of zinc	114
37	Effect of foliar spray on secondary nutrient content (%) of pomegranate as influenced by sources and levels of zinc	116
38	Effect of foliar spray on micronutrient content (mg kg ⁻¹) of pomegranate as influenced by sources and levels of zinc	118
39	Effect of foliar spray on major nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of zinc	120
40	Effect of foliar spray on secondary nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of zinc	121
41	Effect of foliar spray on micronutrient content (mg kg ⁻¹) of index leaf of pomegranate at harvest as influenced by sources and levels of zinc	123
42	Effect of foliar spray on chemical properties of soil at harvest of pomegranate as influenced by sources and levels of zinc	125
43	Effect of foliar spray on major nutrient status (kg ha ⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of zinc	126
44	Effect of foliar spray on secondary nutrient status of soil at harvest of pomegranate as influenced by sources and levels of zinc	128
45	Effect of foliar spray on micronutrient status (mg kg ⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of zinc	129
46	Effect of foliar spray on growth parameters of grapes as influenced by sources and levels of boron and zinc metalosate	132
47	Effect of foliar spray on yield parameters of grapes as influenced by sources and levels of boron and zinc metalosate	136
48	Effect of foliar spray on yield of grapes as influenced by sources and levels of boron and zinc metalosate	138
49	Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of boron and zinc metalosate	141

50	Effect of sources and levels of boron and zinc metalosate on macronutrient content (%) of index tissue of grapes before foliar spray	143
51	Effect of sources and levels of boron and zinc metalosate on secondary nutrient content (%) of index tissue of grapes before foliar spray	144
52	Effect of sources and levels of boron and zinc metalosate on micro nutrient content (mg kg ⁻¹) of index tissue of grapes before foliar spray	145
53	Effect of foliar spray on boron content (mg kg ⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of boron and zinc metalosate	149
54	Effect of foliar spray on macronutrient content (%) of grapes as influenced by sources and levels of boron and zinc metalosate	151
55	Effect of foliar spray on secondary nutrient content (%) of grapes as influenced by sources and levels of boron and zinc metalosate	153
56	Effect of foliar spray on micronutrient content (mg kg ⁻¹) of grapes as influenced by sources and levels of boron and zinc metalosate	154
57	Effect of foliar spray on macronutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate	157
58	Effect of foliar spray on secondary nutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate	159
59	Effect of foliar spray on micronutrient content (mg kg ⁻¹) of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate	160
60	Effect of foliar spray on chemical properties of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate	162
61	Effect of foliar spray on major nutrient status (kg ha ⁻¹) of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate	163
62	Effect of foliar spray on secondary nutrient status of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate	165
63	Effect of foliar spray on micronutrient status (mg kg ⁻¹) of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate	167

64	Effect of foliar spray on growth and yield parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate	169
65	Effect of foliar spray on yield of pomegranate as influenced by sources and levels of boron and zinc metalosate	171
66	Effect of foliar spray on physical parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate	174
67	Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate	177
68	Effect of sources and levels of boron and zinc metalosate on macro nutrient content (%) of index leaf of pomegranate before foliar spray	179
69	Effect of sources and levels of boron and zinc metalosate on secondary nutrient content (%) of index leaf of pomegranate before foliar spray	180
70	Effect of sources and levels of boron and zinc metalosate on micronutrient content (mg kg ⁻¹) of index leaf of pomegranate before foliar spray	181
71	Effect of foliar spray on boron content (mg kg ⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of boron and zinc metalosate	182
72	Effect of foliar spray on macronutrient content (%) of pomegranate as influenced by sources and levels of boron and zinc metalosate	186
73	Effect of foliar spray on secondary nutrient content (%) of pomegranate as influenced by sources and levels of boron and zinc metalosate	188
74	Effect of foliar spray on micronutrient content (mg kg ⁻¹) of pomegranate as influenced by sources and levels of boron and zinc metalosate	190
75	Effect of foliar spray on major nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate	192
76	Effect of foliar spray on secondary nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate	194
77	Effect of foliar spray on micronutrient content (mg kg ⁻¹) of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate	195

78	Effect of foliar spray on chemical properties of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate	197
79	Effect of foliar spray on major nutrient status (kg ha^{-1}) of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate	198
80	Effect of foliar spray on secondary nutrient status of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate	201
81	Effect of foliar spray on micronutrient status (mg kg^{-1}) of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate	203

LIST OF FIGURES

Figure no.	Title	Between pages
1	Effect of foliar spray on yield of grapes as influenced by sources and levels of zinc	60-61
2	Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of zinc	60-61
3	Effect of foliar spray on zinc content (mg kg ⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of zinc	60-61
4	Effect of foliar spray on macronutrient content (%) of grapes as influenced by sources and levels of zinc	76-77
5	Effect of foliar spray on zinc content (mg kg ⁻¹) of grapes as influenced by sources and levels of zinc	76-77
6	Effect of foliar spray on yield of pomegranate as influenced by sources and levels of zinc	100-101
7	Effect of foliar spray on physical parameters of pomegranate as influenced by sources and levels of zinc	100-101
8	Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of zinc	100-101
9	Effect of foliar spray on zinc content (mg kg ⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of zinc	104-105
10	Effect of foliar spray on zinc content (mg kg ⁻¹) of pomegranate fruit as influenced by sources and levels of zinc	104-105
11	Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of boron and zinc metalosate	142-143
12	Effect of foliar spray on boron content (mg kg ⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of boron and zinc metalosate	142-143

13	Effect of foliar spray on boron content (mg kg^{-1}) of grapes as influenced by sources and levels of boron and zinc metalosate	158-159
14	Effect of foliar spray on major nutrient status (kg ha^{-1}) of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate	158-159
15	Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate	178-179
16	Effect of foliar spray on boron content (mg kg^{-1}) of index leaf of pomegranate at different intervals as influenced by sources and levels of boron and zinc metalosate	178-179
17	Effect of foliar spray on boron content (mg kg^{-1}) of pomegranate as influenced by sources and levels of boron and zinc metalosate	178-179

LIST OF PLATES

Plate no.	Title	Between pages
1	A view of the experimental site (Grapes)	32-33
2	A view of the experimental site (Grapes)	32-33
3	General view of the pomegranate experimental plot	35-36
4	General view of the pomegranate experimental plot	41-42
5	Effect of foliar spray on grape as influenced by sources and levels of zinc	62-63
6	Effect of foliar spray on pomegranate as influenced by sources and levels of zinc	98-99
7	Effect of foliar spray on pomegranate as influenced by sources and levels of boron and zinc metalosate	172-173

LIST OF ABBREVIATIONS

%	Per cent
@	At the rate
Ca	Calcium
⁰ C	degree celsius
CHO	Carbohydrate
cm	Centimeter
C mol (P ⁺) kg ⁻¹	Centimole proton per kilogram
Cu	Copper
dSm ⁻¹	Deci Siemens per meter
DTPA	DiethyleneTriaminePenta acetic acid
EC	Electrical conductivity
<i>et al.</i>	<i>et alii, and others</i>
<i>Etc.</i>	<i>et cetera, and other things</i>
Fe	Iron
Fig.	Figure
FYM	Farmyard manure
G	Gram
<i>i. e</i>	<i>id est, that is</i>
K ₂ O	Potassium
kg ha ⁻¹	Kilogram per hectare
Mn	Manganese
N	Nitrogen
NS	Non-significant
OC	Organic carbon
P ₂ O ₅	Phosphorous
pH	Power of Hydrogen
RDF	Recommended dose of fertilizers
S	Sulphur
S.Em±	Standard error of mean
t ha ⁻¹	Tonnes per hectare
<i>Viz.,</i>	<i>videlicet, Namely</i>
Zn	Zinc

I. INTRODUCTION

Micronutrients are essential for balanced crop nutrition. Lack of any one of the micronutrient in the soil can limit growth, even when all other nutrients are present in adequate amounts. Among different micronutrients, zinc and boron plays a major role in crop production.

Zinc plays a vital role in plant nutrition by profound influence on activation of enzymes like carbonic anhydrase, hydrogenase, stabilization of ribosomal functions and synthesis of cytochrome which in turn helps in starch and carbohydrate metabolism, maintenance of cellular membrane integrity, protein synthesis, regulating the auxin production and pollen formation (Marschner,1995). It is most important for the synthesis of tryptophan which is the precursor of indole acetic acid and for the integrity of cellular membranes to preserve structural orientation of macromolecules and ion transport system. The gene expression for the tolerance of environmental stresses in plants are zinc dependent. It plays a major role in chlorophyll synthesis, flower formation and normal fruit development.

Among micronutrients, zinc deficiency is wide spread followed by boron. About 30 per cent of the cultivable soils of the world contain low levels of plant available zinc. Zinc deficiency is wide spread and remained a major problem all over the country. It has increased from 44 to 48 per cent and expected to further increase upto 63 per cent by 2025 (Singh, 2010). In Karnataka, 72 per cent of soils were found deficient in zinc. Zinc deficiency found predominantly in coarse textured calcareous, alkaline and low organic carbon alluvial soils (Entisols and Inceptisols) of Indo- Gangetic alluvial plains of North India and fine textured calcareous black soils (Vertisols) of Deccan Plateau. Total zinc content in Indian soils is 47, 60, 61, 63, 44, 43, 30 and 72 mg kg⁻¹ in Entisols, Inceptisols, Aridisols, Vertisols, Alfisols, Ultisols, Mollisols and Oxisols respectively (Singh, 2006).

Boron plays an essential role in various physiological processes of plants. It helps in cell division, cell elongation, meristematic tissues development, maturation, carbohydrate, protein, nucleic acid, cytokinin, auxin and phenol metabolism. It is a component of membranes that regulate the passage of sugars and helps in translocation of

sugars in plant bodies. Pollination, flowering and fruit setting are induced by boron (Sims and Jhonson, 1991).

Boron deficiency has emerged as second most important micronutrient constraint in crops after zinc on global scale (Ahmad *et al.*, 2012) and in Indian agriculture (Sathya *et al.*, 2009). Deficiency of boron is reported in 80 countries and in 132 crops over last 60 years (Shorrocks, 1997). The boron content in Indian soils varies from 7 to 630 mg kg⁻¹ but only less than 5-10 mg kg⁻¹ is in available form to plants. About 33 per cent of boron deficiency was noticed in the soils of both India and Karnataka. Its deficiency is most common in sandy, calcareous, high pH, recently limed and highly leached soils. In Indian soils boron deficiency was increased from 2 per cent to 52 per cent and it was found predominantly in the calcareous soils of Bihar, Tamil Nadu, Uttar Pradesh, red lateritic soils of Orissa, Karnataka, Andhra Pradesh and Konkan region.

Grape (*Vitis vinifera* L.) is one of the important commercial fruit crop of temperate regions. However, it is also grown successfully in tropical and subtropical regions of the world. Grape is world's 3rd largest cultivated fruit crop after citrus and banana and it contributes 16 per cent of total fruit production. In world, it grown in an area of 7.50 lakh hectare with a production of 66 million tonnes (FAO, 2013). It is a refreshing fruit, rich source of sugars, acids, minerals, vitamins and tannins and it constitutes carbohydrate (15 %), minerals (0.2 - 0.6 %), organic acids (0.3-1.5 %), nitrogenous compounds (0.03-0.7 %), iron (0.003 - 0.017 %), calcium (0.004 - 0.025 %), potassium (0.15 - 0.25 %), vitamin A (1-80 microgram), vitamin B complex (391-636 mg 100 g⁻¹) and vitamin C (1-12.5 mg 100 g⁻¹). In India, it is cultivated in an area of 1.18 lakh hectares with an annual production of 25.85 lakh tonnes with productivity of 21.80 t ha⁻¹ during 2013-14 (Horticultural statistics at glance, 2015). Its cultivation in India had greater significance due to its higher productivity as compared to other grape producing countries. A record yield of 150 tonnes per hectare has been harvested at Hyderabad with Anab-e-Shahi cultivar which was termed as biological wonder by Olma (1970). Maharashtra, Karnataka, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Haryana and Punjab are the major grape cultivating states of India.

Pomegranate (*Punica granatum* L.) is one of the oldest fruit crop which dates back to antiquity and it predominantly grown in arid and semi arid regions of the world. Being, highly remunerative crop, it helps in replacing subsistence farming and alleviate poverty. It has high nutritional value better than grapes, mango, orange and papaya. It is richest source of riboflavin and polyphenols like ellagic acid and punicalgins which acts as antioxidants. Fruit also contains good amount of CHO (14.50 %), protein (1.60 %), calcium (10 mg 100g⁻¹), phosphorus (70 mg 100 g⁻¹), iron (0.3 mg 100 g⁻¹) and vitamin C (65 mg 100 g⁻¹) besides its calorific value of 65 kcal 100 g⁻¹. Therefore, pomegranate fruit is referred as ‘Elixir of life’ (Patil and Manjunath, 2014). India is one of the largest producers of pomegranate in the world and contributes about 50 per cent towards the world’s production. In India, area under cultivation has increased from 96.90 (2003-04) to 131.00 (2013-14) thousand hectare with an annual production of 13.46 lakh tonnes and productivity of 10.27 tonnes per hectare. Among states, Maharashtra is the leading pomegranate producer followed by Karnataka with an area 19.04 (000 ha), production 204.64(000 t) and productivity 10.75 t ha⁻¹ during 2014-15 (Horticultural statistics at glance, 2015). Other pomegranate growing states in India are Gujarat, Telangana and Tamil Nadu. In Karnataka, pomegranate is commercially cultivated in Vijayapur, Belgaum, Koppal, Chitradurga, Bagalkot and Tumkur districts.

Fruit crop production is governed by several factors like climate, soil, irrigation status, varieties, pests, diseases and nutritional status of soil as well as plant. Deficiency of various nutrients causes drastic reduction in growth, yield and quality of fruits. Among the nutrients, micronutrients though required in small quantities their importance in growth, yield and quality of fruit crops is quite essential (Raja, 2009).

Deficiency of zinc is characterized by abnormal development of internodes, interveinal chlorosis in early summer and small leaves, shot berries and poor fruit setting (Gowda *et al.*, 2008) whereas, the boron deficiency leads to reduced root tip elongation, inhibition of RNA and DNA synthesis in younger leaves, formation of abnormal berries, poor fruit setting and fruit cracking (Christensen *et al.*, 2006).

Zinc and boron availability to the plant from soil is limited and it depends on factors like dynamic soil properties, organic matter, texture, cultivation, drought and microbial activity (Mengel and Kirkby, 2001). Hence, plant roots are unable to absorb these micronutrients adequately from the dry top soil therefore foliar application for better results deserves attention.

Foliar sprays are widely used as their application rates are much lower than the rates required for soil application. Uniform application is easily obtained, 6 to 20 times more effective and helps in rapid uptake and plant response (Anees *et al.*, 2011). Hence, the nutrient deficiencies can be corrected during the growing season. It is also beneficial in correcting nutritional and physiological disorders in fruit trees thereby helps in improving fruit setting, quality and productivity of fruit crops.

Zinc metalosate is an amino acid chelated zinc fertilizer contains 6.8 per cent of zinc, liquid in nature, 100 per cent water soluble, neutral in charge and brown in colour. Boron metalosate is also amino acid chelated liquid boron fertilizer, contains 5.0 per cent of boron, neutral in charge, light yellow in colour and 100 per cent soluble in water.

Several research workers have reported that foliar spray of zinc and boron individually and in combination by using zinc sulphate and boric acid as sources of zinc and boron, respectively improved significantly yield and quality of fruits (Kumar and Verma, 2004 and Dinesh *et al.*, 2007). However, information on effects of different sources of zinc and boron on crop productivity and quality in grapes and pomegranate is lacking. Hence, there is a need to elucidate the beneficial effects of different sources of zinc *viz.*, zinc metalosate, Zn-EDTA, ZnSO₄ and boron *viz.*, boron metalosate and boric acid individually and in combination on growth, yield, quality and nutrient content of grapes and pomegranate. Keeping in view of the above facts a field experiment entitled “Studies on foliar spray of zinc metalosate and boron metalosate on growth, yield and quality of grapes (*Vitis vinifera* L.) and pomegranate (*Punica granatum* L.) was conducted in farmer fields with the following objectives

1. To study the effect of zinc metalosate and boron metalosate on growth and yield of grapes and pomegranate.
2. To study the effect of zinc metalosate and boron metalosate on quality of grapes and pomegranate.
3. To determine nutrient concentration in grapes and pomegranate fruits.

II. REVIEW OF LITERATURE

Micronutrients are essentially as important as macronutrients in horticultural crop production because of their ability to improve quality, input use efficiency, disease resistance, post harvest shelf life and their by increase in marketable fruit yield. The micronutrient deficiencies in fruit crops has increased markedly in recent years due to intensive cropping system, soil erosion and use of marginal lands for crop production. Among different micronutrients, zinc deficiency is most wide spread followed by boron in horticultural crops there by limiting the growth and yield of fruit crops.

About 30 per cent of the cultivable soils of the world contain low levels of plant available zinc. Zinc deficiency is wide spread and remained a major problem all over country. It has increased from 44 to 48 per cent and expected to further increase upto 63 per cent by 2025. In Karnataka 72 per cent of soils were found deficient in zinc. The boron content in Indian soils varies from 7 to 630 mg kg⁻¹ but only less than 5-10 per cent is in available form to plants. About 33 per cent of boron deficiency was noticed in the soils of India and Karnataka.

Supplementing zinc and boron through foliar application helps in maintaining optimum concentration by quick and efficient absorption as compared to soil application, there by helps to minimize the deficiency symptoms which results in good growth, yield and quality of fruit crops. Extensive research work has been reported on use of zinc sulphate and boric acid as sources of zinc and boron for foliar spray in fruit crops but the experimental work concerning to the use of zinc metalosate, Zn-EDTA and boron metalosate as zinc and boron sources respectively has not reported. Hence, an attempt has been made in this chapter to review the research work carried out by scientists on individual and combined application of zinc and boron as foliar spray on growth, yield, quality and nutrient content in index tissues and fruits of grapes, pomegranate and other fruit crops under the following headings.

- 2.1. Effect of foliar spray of different sources and levels of zinc and boron on growth parameters of horticultural crops
- 2.2. Effect of foliar spray of different sources and levels of zinc and boron on yield parameters and physical characteristics of fruits of horticultural crops
- 2.3. Effect of foliar spray of different sources and levels of zinc and boron on quality of fruits of horticultural crops
- 2.4. Effect of foliar spray of different sources and levels of zinc and boron on nutrient content in index tissue and fruit of horticultural crops
- 2.5. Effect of foliar spray of different sources and levels of zinc and boron on nutrient content of soil at harvest of horticultural crops

2.1 Effect of foliar spray of different sources and levels of zinc and boron on growth parameters of horticultural crops

Asha (2006) conducted field experiment, in order to know the effect of zinc on growth, yield and quality of Bangalore Blue grapes. The results revealed that foliar spray of zinc @ 0.30 per cent along with RDF (1000 g urea: 250 g phosphorus: 1500 g potassium) at 30 days after pruning improved the cane length (105.02 cm), cane girth (0.59 cm) and internodal length (7.29 cm) of grapes as compared to other levels and control.

Mostofa *et al.* (2006) reported that foliar nutrition of grapes with boron @ 0.5 per cent through boric acid *i.e.* four times at three weeks intervals significantly improved cane length (158 cm) of grape var. Bez El Anza as compared to single application (141 cm).

Afria *et al.* (1999) noticed significantly higher plant height in pomegranate due to foliar application of zinc @ 0.5 per cent through zinc sulphate.

Combined spray of zinc (0.4 %), boron (0.4 %) and iron (0.2 %) increased the plant height (11.52 %) in Sindhuri variety of pomegranate (Yadva *et al.*, 2014). Maximum shoot length of 37.67 and 50.33 cm in pomegranate cv. Bhagwa at 30 and 60 days after

first spray, respectively, with the foliar application of borax (0.1 %) +manganese (0.25%) + zinc (0.5%) + iron (0.5%) + molybdenum (0.1%) (Santhosh, 2015).

Foliar application of ZnSO_4 @ 1 per cent along with urea @ 2 per cent significantly recorded higher plant growth in terms of plant height, plant spread and shoot length in ber cv. Umrani (Singh and Ahlawat, 1995). Significant increase was observed in vegetative growth of the plant as indicated by plant height, plant spread and trunk girth as compared to control at all levels of zinc sulphate spray @ 0.1, 0.2 and 0.4 per cent in six years old mango cv. Fazil was recorded (Banik and Sen, 1997). Bhadur *et al.* (1998) noticed an improvement in the stem girth in twenty six year old mango cv. Dusheri with foliar spray of ZnSO_4 @ 1 per cent at flower bud differentiation stage.

EI-Sherif *et al.* (2000) reported that foliar application of zinc sulphate (0.5 and 1.0 %) and potassium sulphate (1.0 and 2.0 %) at full bloom stage significantly increased the shoot length in guava. Ram and Bose (2000) concluded that foliar application of zinc @ 0.50 per cent as zinc sulphate significantly increased the plant height in mandarin orange. Similarly, an increase in plant height was observed with foliar application of zinc in Washington Navel orange, Valencia orange mandarin (Dawood *et al.*, 2001). Increased plant height (34.45 per cent) and stem girth (18.63 per cent) with soil application of nitrogen @ 500 g along with foliar spray of urea @ 0.15 per cent and ZnSO_4 @ 0.5 per cent was observed in ber (Rathore and Chandra, 2002).

Saraswathy *et al.* (2004) concluded that foliar and soil application of ZnSO_4 (@ 0.5 % and 50 or 100 g plant⁻¹, respectively) and borax (@ 0.3 % and 25 or 50 g plant⁻¹, respectively) alone or in combination markedly improved the growth of sapota cv. PKM -1 compared to control.

Sarolia *et al.* (2007) in their study as the effect of foliar application of 0.3, 0.4 and 0.5 per cent zinc sulphate and ferrous sulphate with their possible combinations, maximum mean shoot length (26.05) and number of leaves (20.65) per shoot in guava recorded at 0.5 per cent ZnSO_4 spray.

Singh *et al.* (2010) opined that foliar application of borax (0.50 %) + zinc sulphate (0.25 %) at two months interval from transplanting resulted in maximum plant height

(171.62 cm), plant girth (39.74 cm) and number of leaves plant⁻¹(31.17) in papaya cv. Ranchi. Yadav *et al.* (2010) recorded maximum plant height (2.21 m) and plant girth (29.77 cm) under foliar spray of copper sulphate (0.25%) + manganese sulphate (0.25%) + borax (0.1%) in papaya cv. Washington, whereas minimum plant height and girth (1.86 m and 23.5 cm) were recorded in control.

An experiment was conducted by Pathak *et al.* (2011) revealed that combined foliar application of FeSO₄0.5 % + ZnSO₄0.5% along with RDF (250:500:300 g plant⁻¹) at 3, 5 and 7th month after planting of banana enhanced the plant growth in terms of plant height and pseudo stem girth.

Khan *et al.* (2012) investigated influence of foliar application of boron and zinc on the tree growth of *Citrus reticulata* cv. Feutrell's Early and reported that the combined application of boric acid (0.3%) and zinc sulphate (0.5%) at fruit set stage effectively improved the tree height (43.80 cm) and stem girth (4.28 cm) in Feutrell's Early madarin.

Modi *et al.* (2012) investigated the effect of foliar spray of various micronutrients on growth, yield and quality of papaya (*Carica papaya* L.) cv. Madhubindu and concluded that individual application of ZnSO₄ @ 0.5 per cent and borax @ 0.3 per cent exerted significant influence on plant height (169.87 and 175.69cm, respectively) and stem girth (42.18 and 44.36 cm, respectively).

Hada (2013) reported that combined spray of borax (0.4 %) + zinc sulphate (90.80%) during mid of August and mid of November 2012, significantly increased the vegetative growth in guava.

Razzaq *et al.*(2013) reported that foliar spray of zinc sulphate @ 0.6 per cent to nine year old Kinnow madarine at fruit set stage recorded the highest plant height (43.50 cm) as compared to control (35.75 cm).Vegetative characters like plant height, plant girth at 90 and 180 DAP were significantly higher with the foliar application of borax (0.50 %) + ZnSO₄ (0.25 %) (Lokesh, 2014).Urea solution of 1.5 per cent and zinc sulphate @ 0.6 per cent were effective for the augmentation of growth attributes of guava (Parmar *et al.*, 2014).

Arshad and Ali (2016) noticed an increase in the plant height of 3.11 m due to foliar application of zinc @ 0.50 per cent in guava. Highest shoot length (11.93 cm) was observed due to foliar spray of ZnSO₄ @ 0.4 per cent along with K₂SO₄ @2 per cent twice (at one month interval) on ten year old guava var. Gwalior-27 at Krishi Vigyan Kendra College of Agriculture, Gwalior (M.P.) (Pawar, 2016).

2.2 Effect of foliar spray of different sources and levels of zinc and boron on yield parameters and physical characteristics of fruits of horticultural crops

Daulta *et al.* (1983) conducted an experiment on ten year old Beauty Seedless grapes and concluded that foliar application of ZnSO₄ @ 0.6 per cent significantly increased the berry weight as compared to other zinc levels. Ravi kumar *et al.* (1988) reported that lower concentration of ZnSO₄@ 0.2 per cent influenced maximum berry set, length of bunch and reduced panicle drying in grapes cv. Gold. The treatments receiving 1.5 and 0.5 per cent urea and ZnSO₄ spray recorded maximum bunch weight and yield in the vines (Sindhu *et al.*, 1994).

Dhillon and Bindra (1995) revealed that foliar sprays of ZnSO₄ (0.2, 0.4 and 0.6 %), FeSO₄ (0.1 and 0.2 %) and boric acid (0.05 %) at full-bloom and fruit set stage in five year old Perlette grape vine significantly increased the berry weight (1.69 g), bunch weight (365g) and yield (22.40 kg vine⁻¹). Foliar application of macro and micronutrients significantly increased the mean weight of berries in Red Roumy grapes (Ahmed *et al.*, 1997).

Bacha *et al.* (1997) observed that spraying of chelated zinc on Thompson Seedless and Roomy Red grape vines caused a slight increase in yield of Thomson seedless but significant yield increase was seen in Roomy Red cultivar.

Usha and Singh (2002) recorded enhanced bunches plant⁻¹, berry weight and fruit yield plant⁻¹ as compared to control at 0.4 per cent boron spray. Combined application of ZnSO₄ (0.5 %) + borax (0.2 %) twice during vegetative (20 days after pruning) and full bloom stages excelled others with more yield of 6.3 kg vine⁻¹ (Prabu and Singaram, 2002). Significantly higher yield per plant was registered in Muscat variety of grape at 0.1 per cent boron (Janaki *et al.*, 2004).

Significant improvement in number of bunches vine⁻¹ (267), bunch weight (183.70 g, number of berries bunch⁻¹(42.20) and yield vine⁻¹ (47.75 kg) in Bangalore Blue grapes by the foliar spray of zinc @ 0.30 per cent along with RDF (1000 g urea: 250 g phosphorus: 1500 g potassium) at 30 days after pruning (Asha, 2006).

A field experiment was conducted by Mostofa *et al.* (2006) in order to correct boron deficiency in grape vine var. Bez El Anza through foliar application of boron at different intervals. The results indicated that foliar spray of boric acid @ 0.5 per cent at four times at three weeks intervals significantly improved number of bunches vine⁻¹ (26.30), berry set (9.91 %), weight of bunch (577 g) and vine yield (15.18 kg vine⁻¹) compared to three, two and one time spray. Recommended dose of N, P and K fertilizer along with ZnSO₄ (0.2%) + H₃BO₃ (0.2%) + FeSO₄ (0.2%) + MnSO₄ (0.2%) + MgSO₄ (0.2%) + CaCl₂ (0.5%) + KNO₃ (0.5%) + urea (1%) as foliar spray at blooming and fifteen days after blooming recorded significantly higher number of berries per bunch (238.00), fresh fruit weight (20.20 t ha⁻¹) and bunch weight (605.37g) in Thompson Seedless grapes (Subramoniam *et al.*, 2006).

Foliar application of 0.05 per cent Zn as ZnSO₄ significantly improved the yield parameters of grapes as compared to soil application (Aydin *et al.*, 2007). Er *et al.* (2009) reported that basal application of recommended dose of NPK (150: 50: 50 g NPK vine⁻¹) along with foliar application of Zn @ 2.5 g plant⁻¹ as zinc sulphate four times at fifteen days interval starting from before blossom significantly improved the yield (14.5 kg vine⁻¹) of Hespali grapes of 8-10 year old in sandy soils of turkey. Increased number of bunches per vine at 0.5 per cent of ZnSO₄ was observed in Perlette grapes (Sindhu *et al.*, 2000).

Bybordi *et al.* (2010) stated that foliar application of Zn @ 0.4 per cent at flower bud enlargement and three weeks after the flower petal drops significantly improved the yield of grapes as compared to control.

Er *et al.* (2011) observed that foliar spray of B @ 10 g vine⁻¹ stock through borax along with NPK significantly improved the yield of grape (17.60 kg vine⁻¹) of Black Dimrit grapes in Turkey.

Aroosa Khalil (2014) conducted study on twenty three year old grape vine var. Sahebi and found that FYM addition (50 kg vine⁻¹) + double the recommended dose NPK (1110 : 454: 940 g vine⁻¹) along with foliar spray of solubor @ 0.1 per cent at 128 buds vine⁻¹ recorded higher bunch weight (454.81 and 478.26 g), berry weight (10.33 and 10.47 g) and yield (22.98 and 26.89 kg vine⁻¹) in both the years (2011 and 2012), respectively.

Ashoori *et al.* (2013) stated that foliar spray of zinc sulphate @ 1.5 g l⁻¹ resulted in higher fruit set per plant (9.2 %) and number of fruits per plant (121.1) in var. Asgari of grapes. Combined application of Zn and boron @ 2 g lit⁻¹ significantly improved the yield attributing parameters of grapes viz., number of berries bunch⁻¹, weight of berries in Turkmenistan cultivars and Rotabizarghan local cultivars of Iran (Nikkhah *et al.*, 2013). Significant improvement in yield attributing characters of grapes viz., number of bunches vine⁻¹, weight of bunch, number of berries bunch⁻¹ and yield of grapes var. Karaerik was observed by the foliar application of boron @ 6.4 kg ha⁻¹ (Gunes *et al.*, 2015).

Foliar application of micronutrients viz., FeSO₄ (0.4%) + ZnSO₄(0.3%) in pomegranate resulted in highest number of fruits plant⁻¹ (103.83) over control (Bambal *et al.*, 1991). Foliar spray of zinc @ 0.4 % significantly reduced the unmarketable fruit yield of all commercial pomegranate cultivars (Togh Garden, Shahviar Dane Ghrmez, Malas Yazdi and Zagh Yazdi) which indicated possible role of zinc in improving the ability of pomegranate to resist unfavorable environmental factor and diseases (Khorsandi *et al.*, 2009).

Soil application of NPK (300: 225: 255 g tree⁻¹) and boron (20 g) along with foliar spray of zinc @ 1.0 per cent and iron @ 0.5per cent reduced the crack fruit percentage tree⁻¹ (6.96 %), improved the total number of fruits per tree (304) and finally fruit yield tree⁻¹ of pomegranate (154.58 kg tree⁻¹) as compared to control and NPK alone (Mohamad *et al.*, 2011). Similar results were observed by Sharma and Belsar (2011) who reported that foliar spray of boric acid @ 0.4 per cent to seven year old pomegranate cv.G-137 increased the physical parameters of fruits such as length (105.8 cm), diameter

(91.9 cm), weight (362.9 g) and yield (16.7 kg tree⁻¹) as compared to control (12.9 kg tree⁻¹).

Foliar spray of zinc @ 0.3 per cent along with Mn 0.6 per cent to six years old pomegranate tree at fifteen days before full bloom and one month after first application improved the number of fruits plant⁻¹, average weight of fruit and yield (Hasani *et al.*, 2012).

Pandey *et al.* (2012) noticed that during bud swell and fruit development stage combined foliar application of zinc (0.5%) and boron (0.2 %) was found to be most effective in minimizing flower drop, fruit cracking and increased fruit set, fruit size, fruit length, fruit breadth, fruit weight and yield of pomegranate var. Kandhari kabuli. Reduction in fruit cracking and increase in healthy fruit yield plant⁻¹ in pomegranate var. Ganesh due to foliar application of boric acid @ 0.2 per cent (Sheikh and manjula, 2012). Maximum fruit yield of pomegranate 48.51 kg tree⁻¹ was recorded due to nutrient combination of FeSO₄(0.2%)+ ZnSO₄(0.2%) (Mirzapour and Khoshgoftarmanesh, 2013).

Foliar application of zinc and boron @ 0.3 % along with 3 per cent calcium during two and eight weeks after full bloom significantly improved the fruit length (8.45 cm), diameter (8.00 cm), weight of fruit (340 and 352 g) and fruit yield tree⁻¹ (26.68 and 27.11 kg) during 2011 and 2012, respectively in Manfalouty cultivar of pomegranate (Khalil and Aly, 2013). Foliar application of zinc @ 3 per cent along with magnesium @ 60 mg l⁻¹ significantly enhanced the fruit set, fruit weight and yield of pomegranate var. Salemy (Obaid and Hadethi, 2013). Increased fruit set (54.17 %), number of fruits plant⁻¹ (23.67), fruit weight (213 g) and yield (5 kg plant⁻¹) in Sindhuri variety of pomegranate due to combined application of 0.4 % Zn, B and Fe (Yadav *et al.*, 2014).

Number of fruits plant⁻¹, fruit weight and yield of pomegranate were improved by the combined effect of boron and calcium @ 3 and 4 per cent, respectively (Korkmaz and Askin, 2015). Number of berries bunch⁻¹ (133.30), bunch weight (314.60 g) and yield (4.77 kg vine⁻¹) were higher in Seedless grape vine due to application of boron as foliar spray (Mohsen, 2015). Santhosh (2015) recorded maximum fruit weight (292.67 g), fruit volume (255 ml), fruit diameter (9.64 cm) in pomegranate var. Bhagwa due to foliar

spray of borax (0.1 %) + manganese (0.25 %) + zinc (0.5 %) + iron (0.5 %) + molybdenum (0.1 %) .

Hamouda *et al.* (2016) reported that foliar spray of zinc @ 2000 ppm three times viz., mid of March, April and June of 2011 and 2012 significantly improved the pomegranate yield shrub⁻¹ 12.50 and 16.16 kg shrub⁻¹) in both the seasons as compared to control. Zinc and boron application @ 0.4 per cent improved the fruiting percentage (67.80 %), weight of fruits (202.8 g), fruit yield plant⁻¹ (35.16 kg) and yield (7172 q ha⁻¹) as compared to individual application and control in pomegranate var. Ganesh (Tanuja *et al.*, 2016).

Perveen and Rehman (2000) concluded that foliar application of boron alone did not influence the fruit yield compared to combined application with zinc and manganese and also these nutrient combinations helps in correcting their deficiency in citrus crop.

Yadav and Chaturvedi (2005) observed that foliar application of 0.6 per cent zinc sulphate significantly increased the fruit weight (21.54 g) in ber plant. Babu *et al.* (2007) reported significant increase in number of fruits of kinnow mandarin with the foliar spray of 0.6 per cent of zinc sulphate.

Combined foliar application of zinc @ 0.05 per cent and boron @ 0.04 per cent before flower initiation and after fruit set, enhanced the yield tree⁻¹ (99.83 kg) as compared to control (71.17 kg) in sweet orange var. Blood Orange (Sajid *et al.*, 2010). Combined foliar application of boron 0.5 % and zinc sulphate 0.25 % in two months interval from transplanting resulted in maximum yield attributing parameters in papaya (Singh *et al.*, 2010). In papaya cv. Washington, copper sulphate (0.25 %) + manganese sulphate (0.25 %) + borax (0.1%) produced higher number of fruits plant⁻¹ (30.67), fruit weight (1.30 kg), yield (40.4 kg plant⁻¹ and 993.29 q ha⁻¹), fruit length (25.0 cm) and fruit width (13.17 cm) (Yadav *et al.*, 2010).

Dayal *et al.* (2010) studied the effect of nitrogen, phosphorus and zinc on growth and yield of ber cv. Gola under arid and semi arid conditions and noticed the maximum fruit length (3.13 cm), fruit diameter (3.18 cm), fruit weight (21.55 g) and fruit volume (20.67 ml) at 0.6 per cent zinc sulphate as compared to control.

Pathak *et al.* (2011) observed that foliar spray of ZnSO_4 (0.5 %) + FeSO_4 (0.5 %) along with RDF at 3, 5 and 7th month after planting of suckers improved the fingers bunch⁻¹ (129.20), fingers length (14.80 cm), fingers breadth (13.10 cm), bunch length (48.50 cm), bunch breadth (43.30 cm), bunch weight (16.30 kg) and yield (40.75 t ha⁻¹) in banana var. Martaman. Shukla (2011) reported that application of Ca+B @ 0.4 per cent had significantly reduced the incidence of fruit drop (32.6%) than control (2.8 and 79.2%, respectively) in Indian gooseberry. The maximum yield (158.6 kg tree⁻¹) was recorded with the application of calcium carbonate + borax @ 0.4%, while minimum was recorded under control (105.2 kg tree⁻¹).

Bhowmick *et al.* (2012) reported that foliar application of borax 0.25 per cent on mango cv. Amrapali resulted in maximum number of fruits plant⁻¹ (170), yield tree⁻¹ (36.00 kg), fruit length (10.33 cm) and breadth (6.33 cm).

Bhalerao and Patel (2012) observed that foliar application of calcium nitrate 1000 ppm + borax 30 ppm + zinc sulphate 200 ppm + ferrous sulphate 200 ppm at 60, 90 and 120 days after planting on papaya cv. Taiwan Red Lady recorded the highest fruit yield (80.76 t ha⁻¹). Khan *et al.* (2012) investigated the influence of foliar application of boron and zinc, on *Citrus reticulata* Blanco cv. Feutrell's Early at fruit set improved significantly fruit length, diameter, weight and yield tree⁻¹ with application of 0.3% boric acid + 0.5% zinc sulphate. Kumawat *et al.* (2012) found that foliar application of ZnSO_4 (0.5 %) + borax (0.2 %) + MnSO_4 (0.1 %) during August and October months resulted significantly highest fruit yield (12.63 kg plant⁻¹) in guava.

Rakesh Kumar (2012) reported combined spray of ZnSO_4 (0.8 %) + borax (0.4 %) + NAA (50 ppm) + GA₃ (100 ppm) twice at one month interval on six years old guava significantly enhanced the fruit setting percentage (80.98 %), number of fruit tree⁻¹ (235.83), average fruit weight (230 g), length (8.45 cm), diameter (5.90 cm) and fruit yield tree⁻¹ (49.88 kg) compared to individual application and control. Trivedi *et al.* (2012) evaluated the effect of zinc (Zn) and boron (B) fertilizers on the yield of guava and reported that foliar application of zinc sulphate (0.6%) and boric acid (0.5%) in combination after fruit set resulted in higher yield. Number of fruits plant⁻¹, weight of

fruit and fruit yield plant⁻¹ was increased in acid lime cv. Kagzi due to 0.5 per cent of zinc sulphate along with iron sulphate @ 0.5 per cent (Jagtap *et al.*, 2013).

Razzaq *et al.* (2013) reported that foliar application of 0.6 per cent zinc sulphate at fruit set stage significantly enhanced the fruit length (71.6 mm) and diameter (83.77 mm) in Kinnow mandrine.

Singh *et al.* (2013) recorded maximum fruit weight (165.6 g) and fruit yield (48.51 kg tree⁻¹) in mango cv. Dashehari with the foliar application of 0.02 per cent boric acid.

Hada (2013) reported that combined spray of borax (0.4 %) + Zinc Sulphate (0.80%) during mid of August and mid of November 2012, increased the fruit set percentage (78.57 %), number of fruit per tree (241.84), average weight of fruit (239.18 g) and yield per tree (57.84 kg) in guava cv. L-49 compared to control.

Girirajjat and kacha (2014) conducted an experiment on eighteen year old guava cv. Bhavnagar Red at fruit research station, Junagadh and observed that there was an increase in fruit length (7.95cm), breadth (7.72 cm) and yield attributing characters as compared to control under micronutrient application. Combined foliar application of zinc and boron @ 1 per cent resulted in higher fruit set, fruit retention (72.55 %) and fruit yield (135.10 kg tree⁻¹) of guava over control (Rajkumar *et al.*, 2014). Similar improvement in length and breadth of kinnow mandrine at zinc @ 500 ppm was observed (Kaure *et al.*, 2015).

Venu *et al.* (2014) reported that the recommended dose of fertilizers along with combined spray of ZnSO₄ (0.5 %) + Borax (0.4 %) + FeSO₄ (0.4 %) at full bloom and one month after first spray significantly recorded higher number of fruits plant⁻¹(925), fruit set percentage (49.33 %), weight of fruit (42.67 g) , length of fruit (4.80 cm), girth of fruit (13.20 cm) and yield plant⁻¹(27.07 kg plant⁻¹) in twenty year Kagzi lime. Foliar spray of boron @ 200 ppm in each time along with KNO₃ @ 2 per cent at monthly intervals on five year old Keitt mango recorded significantly higher number of fruits tree⁻¹, fruit weight and fruit yield tree⁻¹ compared to control (Baiea *et al.*, 2015).

Singh *et al.* (2015) conducted field experiment on twenty year old mango to study the effect of foliar nutrition of zinc @ 0.4 per cent on yield attributing characters. The results indicated that foliar spray at peanut stage led to increase fruit set, number of fruits shoot⁻¹ (7.00), fruit length (12.03 cm), fruit width (7.59 cm), weight of fruit (338.33 g) and yield (51 kg tree⁻¹) compared to control.

Field experiment was conducted at Krishi Vigyan Kendra, College of Agriculture, Gwalior (M.P.) by Pawar (2016) on ten year old guava var. Gwalior-27 in order to know the effect nutrient spray on fruit quality and yield. Highest number of fruits plant⁻¹ (262), length (6.21 cm), diameter (6.17 cm) weight of fruit (150.66 g) and yield plant⁻¹ (39.81 kg plant⁻¹) was obtained at ZnSO₄ @ 0.4 per cent along with K₂SO₄ @ 2 per cent twice (at one month interval). Application of micronutrients *viz.*, ZnSO₄ (0.5 %) + FeSO₄ (0.5 %) + Borax (0.2 %) along with RDF (750: 160: 750 NPK g tree⁻¹) at before flowering, full bloom stage and pea stage of mango var. Amrapali of ten year old significantly increased the number of fruits tree⁻¹ (353.20), fruit length (7.0 cm), fruit diameter (6.31 cm), fruit weight (177.14 g) and fruit yield tree⁻¹ (58.66 kg tree⁻¹) compared to other treatments and control (Sandipkumar, 2015).

Merwad *et al.* (2016) reported that foliar spray of 0.2 % Zn + 0.4 % Ca during flower bud emergence and full bloom stage reduced the malformed panicles and fruit drop and increased the fruit set in mango and there by enhanced the yield per tree by 445 and 435 per cent than the control in the first and second seasons, respectively followed by the treatment which includes NAA @ 25 ppm + Zn @ 0.2 % + Ca @ 0.4 % + B @ 200 ppm.

2.3 Effect of foliar spray of different sources and levels of zinc and boron on quality parameters of fruits of horticultural crops

Ruffiner *et al.* (1975) reported significant reduction in titratable acidity with foliar application of zinc sulphate @ 0.5 per cent in Thompson seedless grapes. Kumar and Bhushan (1980) observed that boron application increased TSS from 18.9 to 21.2 per cent in Thompson Seedless grapes. Spraying with zinc enhanced the total soluble solids (TSS) of berries (Aleksperov, 1985).

Boric acid spray @ 0.1 and 0.2 per cent increased the TSS from 11.8 to 12.2 and 12.7 per cent, respectively in grapes (Makhija *et al.*, 1988). Increase in TSS in Perlette grapes from 12.6 to 14.2 and 14.7 per cent by the application of boric acid @ 0.1 and 0.2 per cent, respectively as foliar spray (Makhija and Chandra 1992). Significant improvement in total soluble solids in Turkmenistan cultivars and Rotabizarghan local cultivars of Iran grapes were observed by Nikkhah *et al.* (2013) due to combined effect of zinc and boron.

Balakrishnan *et al.* (1996) found that the maximum total soluble solids was recorded with ZnSO₄ (0.4 %) + Boric acid (0.2 %), whereas minimum acidity was recorded with ZnSO₄ (0.5 %) spray in pomegranate fruit cv. Ganesh. In different commercial cultivars of pomegranate, total soluble solids were improved by the foliar spray of zinc @ 0.4 per cent through zinc sulphate (Khorsandi *et al.*, 2009). Significant improvement in TSS (15.40 %), total sugar (11.5 %) and titratable acidity (0.51 %) was observed when boric acid was sprayed @ 0.2 per cent to the seven year old pomegranate cv. G-137 during June 2008 (Sharma and Belsare, 2011).

Hasani *et al.* (2012) recorded higher TSS (15.73 °Brix) and lower titratable acidity (1.82 %) by the foliar spray of zinc @ 0.3 per cent along with Mn @ 0.6 per cent at fifteen days before full bloom and one month after first application in pomegranate. Improvement in total soluble solids, total sugars and reduction in titratable acidity was noticed in pomegranate by the foliar of zinc @ 2000 ppm during mid of March, April and June of 2011 and 2012 (Hamouda *et al.*, 2016).

Langthasa and Bhattacharyya (1991) reported the highest TSS (5.19%) in Assam lemon (*Citrus Limon* Brum) with 0.4 per cent chelated zinc.

Pant and Lavania (1998) observed that maximum level of total soluble solids and significantly high sugar and sugar acid ratio with foliar spray of boron @ 0.15 per cent in papaya. Awasthi and Lal (2009) sprayed different concentrations of calcium nitrate, boric acid and zinc sulphate on guava plant and recorded the highest value for total soluble solids at different concentration of boric acid spray. Application of borax @ 0.25 and 0.50 per cent and zinc sulphate @ 0.50 and 1.0 per cent twice at pea and marble stage

recorded significantly the highest TSS (20.88 ° Brix), total sugars (16.09 %) and the lowest acidity (0.456 %) in litchi cv. Bombai (Ghosh, 2009).

Kumari *et al.* (2009) reported that foliar spray of zinc 0.50 per cent along with iron @0.50 and copper @ 0.25 per cent twice at an interval of one month (june and july, 2007-2008) on six year old Kinnow mandarin increased the total soluble solids (13.25 ° Brix), total sugars (7.24 %) and reduced the titratable acidity (0.70 %) compared to individual application and control. A study by Thangaselvabai *et al.*, (2009) using foliar sprays of ZnSO₄(0.5 %), FeSO₄(0.2 %), CuSO₄ (0.2 %) and borax (0.1 %) at 3rd, 5th and 7th month after planting showed higher fruit quality in banana.

Rawat *et al.* (2010) carried out a field experiment during the rainy season of two successive years *i.e.*, 2005 and 2006 on guava cv. Lucknow-49 (Sardar Guava) to improve the quality of fruits by foliar application of micronutrients *i.e.* zinc, copper and boron at 0.2, 0.3 and 0.4 per cent alone and in combination of two and three, with control. Total soluble solids, total sugars and sugar-acid ratio were significantly improved whereas significant reduction in acidity was exhibited with the foliar application of zinc sulphate at 0.4 per cent concentration. Thus micronutrient spray with 0.4 per cent zinc sulphate and boric acid are beneficial for improvement of fruit quality in guava.

Anees *et al.* (2011) revealed that foliar application with ZnSO₄(0.8 %) along with FeSO₄ (0.4 %) and H₃BO₃ (0.8 %) before flowering and at full bloom stage recorded significantly maximum TSS, ascorbic acid, total sugar, reducing sugar and non-reducing sugar in mango cv. Dashehari. Foliar spraying of ZnSO₄, FeSO₄ and borax @ 1, 1 and 0.5 per cent, respectively at flowering initiation and at peanut stage significantly increased fruit quality *viz.*, TSS, total sugar, reducing sugar and non-reducing sugar as well as reduced acidity in mango cv. Kesar (Nehete *et al.*, 2011).Shukla (2011) examined the impact of pre-harvest foliar application of calcium and boron individually and in combination and they found that the higher TSS (16.50 ° Brix) at Ca+ B @ 0.4 per cent compared to control (15.10 ° Brix) in Indian gooseberry. Improved TSS (17.8 ° Brix) and sugar (17.93%) content in mango pulp was observed with at foliar application of borax @ 0.5 per cent (Bhatt *et al.*, 2012).

Kumawat *et al.* (2012) opined that foliar sprays of ZnSO_4 (0.5 %) + borax (0.2 %) + MnSO_4 (0.1%) twice in the months of August and October on rejuvenated guava plants recorded increased fruit yield ($12.63 \text{ kg plant}^{-1}$), fruit quality (TSS 13.20 %, total sugars 6.98 % and Vitamin – C content $239 \text{ mg } 100 \text{ g}^{-1}$ pulp).

Trivedi *et al.* (2012) evaluated the effect of zinc (Zn) and boron (B) fertilizers on the fruit quality of guava. Combined foliar application of zinc sulfate (0.6%) and boric acid (0.5%) before and after fruit set resulted in higher TSS, acidity, ascorbic acid and sugar acid ratio.

Sankar *et al.* (2013) conducted field experiment on nine year old mango cv. Alphonso in order to know the effect of foliar application of micronutrients and sorbital on fruit quality and leaf nutrient status of mango cv. Alphonso. The results revealed that foliar application of boric acid @ 0.02 per cent at fifty per cent bloom stage significantly improved the total soluble solids (21.81° Brix), total sugars (15.55 %) by reducing titratable acidity (0.28%) as compared to control. Improvement in total soluble solids by reducing titratable acidity was observed by the foliar spray of Zn and Mn on Kinnow mandarin at the end of April and mid of August, 2012 @ 1000ppm (Kaur *et al.*, 2015). The maximum reducing sugar, non-reducing sugar and total sugar were recorded with the application of 100% NPK + 0.1% Boron (Singroul, 2016) in mango cv. Amrapali.

2.4 Effect of foliar spray of different sources and levels of zinc and boron on nutrient content of index tissue and fruit of horticultural crops

Dhillon and Bindra (1995) reported that foliar spray of ZnSO_4 (0.6 %), FeSO_4 (0.2%) and boric acid (0.20 %)improved the major (N, P and K) and micro (Zn, Fe and B) concentrations in grape petiole cv. Perlette.

Kirkpatrick (2003) conducted study to know the effect of foliar spray of different sources of zinc on grape nutrition and found higher concentration of zinc in the xylem sap after 24 hours (21.4 mg kg^{-1}) and 48 hours (21.1 mg kg^{-1}) after spray under zinc metalosate source compared to zinc sulphate source.

Significant improvement in zinc concentration in petiole (188.15 mg kg⁻¹) and fruit pulp (6.95 mg kg⁻¹) was observed in fourteen year old Bangalore Blue grapes by foliar spray of zinc @ 0.30 per cent along with RDF (1000 g urea: 250g phosphorus: 1500 g potassium) at 30 days after pruning (Asha, 2006). Higher boron concentration (46.10 mg kg⁻¹) was observed at four times foliar spray of boron @ 0.5 per cent in three weeks intervals compared to one time application (20.80 mg kg⁻¹) in Bez El Anza grape of Egypt (Mostofa *et al.*, 2006).

Bybordi *et al.* (2010) conducted field experiment to evaluate the effect of foliar application with zinc (0, 0.2 and 0.4 % as ZnSO₄.7H₂O) along with magnesium (0, 0.4 and 0.8 % MgSO₄.H₂O) on three cultivars of grape (*Vitis vinifera* L.) namely 'Sahebi', 'Soltani' and 'Ghezel'. The results revealed that among different levels of zinc and magnesium, higher concentration of macro and micronutrients were recorded in both leaves and fruit samples at 0.40 per cent zinc sulphate and 0.80 per cent magnesium sulphate.

Aroosa Khalil (2014) concluded that foliar application of solubor @ 0.1 per cent along with three times higher recommended dose of NPK and 50 kg FYM vine⁻¹ significantly increased the leaf and fruit nitrogen. However, solubor @ 0.1 per cent along with double the recommended dose of NPK and 50 kg FYM vine⁻¹ significantly increased the leaf and fruit phosphorus, potassium and boron content.

Gunes *et al.* (2015) observed that foliar application of boron @ 0.2 per cent significantly increased the nitrogen (3.10 and 1.74 %), phosphorus (0.30 and 0.25 %), potassium (1.42 and 1.04 %), sulphur (0.23 and 0.13 %) and boron (97 and 24 mg kg⁻¹) concentration in leaves and berry tissue of grape, respectively when compared to soil application.

Sahu (2000) reported that, total nitrogen of 1.736 and 0.932 per cent and total potassium of 1.736 and 0.932 per cent at fifty-five days after fertigation and at harvest of pomegranate, respectively. In both years (2011 and 2012) zinc concentration in leaf samples of different commercial cultivars of pomegranate were improved by the foliar spray of zinc @ 0.4 per cent as compared to control (Khorsandi *et al.*, 2009). Significant

improvement in the macro (N, P and K) and micronutrients (Fe, Cu, Zn and Mn) concentration in pomegranate leaves was observed by foliar application of zinc @ 0.3 per cent at fifteen days before full bloom (Hasani *et al.*, 2012) stage.

Santhosh (2015) reported that zinc content in the pomegranate leaf was positively increased to 115.74 mg kg⁻¹ due to application of zinc @ 0.8 per cent through zinc sulphate. Davarpanah *et al.* (2016) observed that there was significant increase in pomegranate tree boron status (25.30 mg kg⁻¹) due to application of boron through boron nanofertilizers @ 6.5 mg l⁻¹ compared other treatments. Hamouda *et al.* (2016) studied the nutrient content of pomegranate leaves and fruit as influenced by zinc foliar spray and reported that zinc @ 2000 ppm is more effective in increasing macro and micro nutrients content in leaves, peel and seed of pomegranate.

Highest zinc concentration (80 mg kg⁻¹) in mango leaves was observed after 96 hours foliar spray of zinc sulphate @ 1.0 per cent at flower bud differentiation stage as compared to other levels and control. The treatment also improved the zinc content of mango pulp (54.16 mg kg⁻¹) (Bhadur *et al.*, 1998).

Anonymous (2001) concluded that foliar spray of zinc through zinc metalosate significantly increased the zinc concentration in leaves of apple (23.10 mg kg⁻¹), tart cherry (26.30 mg kg⁻¹) and peach (21.60 mg kg⁻¹) as compared to check (16.30, 19.50 and 15.60 mg kg⁻¹, respectively). Apple trees treated with zinc @ 0.5 per cent through zinc sulphate at four weeks after full bloom and eight weeks after full bloom recorded significantly higher zinc content of 160 mg kg⁻¹ (Rasouli *et al.*, 2002).

Yadav (2008) conducted a study on effect of zinc application on growth, yield and quality of sweet orange (*Citrus sinensis* Osbeck) cv. Jaffa with the soil and foliar application of zinc sulphate. The results revealed that soil application of 250 g zinc sulphate plant⁻¹ and foliar application of 0.75 per cent zinc sulphate significantly increased the leaf zinc content and also other nutrients like nitrogen, potassium, sulphur but decreased phosphorus content.

Kumari *et al.* (2009) reported that foliar spray of zinc and iron @ 0.50 per cent along with copper @ 0.25 per cent twice at an interval of one month (June and July,

2007-2008) on six year old Kinnow mandarin improved the nutrient concentrations in both leaves and fruits compared to individual application and control.

Khan *et al.* (2012) reported that application of boric acid (0.3%)+ zinc sulphate (0.5%) at fruit set stage effectively brought the zinc and boron levels of Feutrells early mandrine leaves from deficient to optimum range.

Rakesh Kumar (2012) reported combined spray of ZnSO_4 (0.8 %)+ borax (0.4 %) + NAA (50mg kg^{-1}) + GA_3 (100 ppm) twice at one month interval on six years old guava increased the nutrient content in fruit viz., Zn (12.10 mg kg^{-1}) and Fe (267.57 ppm). Foliar spray of zinc sulphate @ 0.2, 0.6 and 0.8 per cent at fruit set stage increased concentration of nutrients like (nitrogen, calcium and manganese), (phosphorus and iron) and (zinc and potassium) respectively in mandrine leaf (Razzaq *et al.*, 2013).

Sankar *et al.* (2013) conducted field experiment on nine year old mango cv. Alphonso in order to know the effect of foliar application of micronutrients and sorbital on fruit quality and leaf nutrient status of mango cv. Alphonso. The results revealed that foliar application of boric acid @ 0.02 % at fifty per cent bloom stage significantly improved the nitrogen (1.785 and 1.567 %), phosphorus (0.122 and 0.102 %), potassium (0.820 and 0.593 %) and boron (98.52 and 84.60 ppm) in leaf samples during flowering and harvesting, respectively.

Ullah *et al.*, (2012) studied the effect of foliar spray of different levels of boron on Kinnow mandrine and reported that among different levels, boric acid @ 0.4 per cent significantly increased the leaf boron (150 mg kg^{-1}). However, boric acid @ 0.3 per cent significantly increased the leaf nitrogen (2.20 %), phosphorus (0.11%), potassium (0.50 %) and zinc (30 mg kg^{-1}) concentration in the Kinnow mandrine.

Khan *et al.* (2015) studied the combined effect of boron and zinc on the leaf mineral status of 'Kinnow' mandarin (*Citrus nobilis* Lour $\times$ *Citrus deliciosa* Tenora) and reported that about 6.2fold increase in leaf boron content compared to control and suggested the potential benefits of exogenous application of boric acid and zinc sulphate in mandrine nutrition.

Sandipkumar (2015) indicated that combined spray of ZnSO_4 @ 0.5 % + FeSO_4 @ 0.5 % + Borax @ 0.2 % along with RDF (750: 160: 750 NPK g tree⁻¹) at before flowering, full bloom stage and pea stage of mango var. Amrapali of ten year old significantly improved leaf nutrient concentrations viz., zinc (176.67 mg kg⁻¹), iron (470.67 mg kg⁻¹) and boron (108.80 mg kg⁻¹). Similarly zinc (6.36 mg kg⁻¹) and boron (1.56 mg kg⁻¹) concentrations in mango fruit were also improved with the same treatment.

Baiea *et al.* (2015) concluded that spraying Keitt mango trees five times with 2 per cent potassium nitrate and 200 ppm zinc or 200 ppm boron during growing season showed increased major nutrients concentration in leaf. Concentration of nutrients like Zn (49.69 mg kg⁻¹), Mn (58.75 mg kg⁻¹) and Fe (218.38 mg kg⁻¹) in the leaves of Kinnow mandarin was improved by the individual application of Zn (1500 mg kg⁻¹) Mn (1500 mg kg⁻¹) and Fe (750 mg kg⁻¹) (Kaur *et al.*, 2015).

Gurel and Basar (2016) studied the effect of soil and foliar application of boron along with iron and zinc on the Pear trees. The results revealed that foliar application of boron is more effective in maintaining the sufficient levels of boron compared to soil application and its content was dramatically higher in the fruit parts (flesh and peel) than in the leaves due to translocation of B from treated leaves to the fruits.

Merwad *et al.* (2016) reported that foliar spray of NAA (25 ppm) + Zn (0.2 %) + Ca (0.4 %) + B (200 ppm) during flower bud emergency and full bloom stage, increased the nitrogen (2.54 and 2.49), phosphorus (0.190 and 0.188), potassium (1.88 and 1.78), calcium (1.83 and 1.92 %), iron (122.98 and 115.21 %), manganese (54.97 and 57.64 %) whereas Zn @ 0.2 % + B @ 200 ppm + NAA @ 25 ppm increased the zinc (42.74 and 48.52 %) and boron (22.27 and 26.88 %) during 2012 and 2013, respectively in leaves of mango var. Alphonso. Rajkumar *et al.* (2017) reported that boron content in leaves increased significantly with the increase in boron concentration during both the years of the study. Maximum boron content (116.85 and 118.35 ppm) was observed after ZnSO_4 (0.75%) + H_3BO_3 (1.0%) foliar spray. However, after harvesting of rainy season crop, boron content of leaves differed significantly with various levels of boron concentration. The maximum boron content (107.32 ppm) was observed in ZnSO_4 (1.0%) + H_3BO_3 (1.0%). These findings also indicated that ZnSO_4 (1.0%) + H_3BO_3 (1.0%)

significantly influenced the N, Zn and B concentrations in the leaves of guava cv. Pant Prabhat.

Thirupathaiah *et al.* (2017) noticed a higher boron concentration in the guava leaves by the soil application of 50 g ZnSO₄ + 40 g FeSO₄ + 25 g boron per tree along with foliar spray of zinc, iron and boron @ 0.5, 0.5 and 0.3 per cent, respectively.

2.5 Effect of foliar spray of different sources and levels of zinc and boron on nutrient content of soil after harvest of horticultural crops

Khan and Begum (2007) reported that addition of farm yard manure @ 50 kg per acid lime plant significantly increased the status of nitrogen, phosphorus, potassium and sulphur in soils after harvest compared to control. Higher available nitrogen content of 290.93 kg ha⁻¹ at harvest was observed by the Korwar *et al.* (2007) with the recommended dose of NPK in aonla orchard soils. Increase in available nitrogen, phosphorus, potassium, calcium and magnesium in aonla orchard soil was noticed due to 50 % NPK and FYM along with biofertilizers (Yadav *et al.*, 2007). Maximum improvement in the post harvest soil nutrients like nitrogen, phosphorus, potassium, calcium and magnesium under integrated nutrient management with the soil application of FYM + 100 % NPK + Azotobacter + PSB in both years of experimentation (Mahendra *et al.*, 2009).

Application of 50 kg tree⁻¹ FYM + 150 g Azotobacter + 100 g VAM + 500 g N: 250 g P₂O₅: 500 g K₂O tree⁻¹ year⁻¹ increased the residual soil nutrient status in litchi orchards cv. Bombai of alluvial zone of West Bengal (Dutta, 2010). Recommended dose of NPK (600:300:600 g plant⁻¹) along with farm yard manure (15 kg plant⁻¹) and neem cake (15 kg plant⁻¹) significantly increased the residual soil fertility status of available nitrogen and potassium (218 and 671 kg ha⁻¹, respectively) in acid lime orchard soils (Musmade *et al.*, 2010).

Pandey (2010) conducted an experiment on effect of N, K, Zn and B on growth, flowering and yield of pomegranate and concluded that the combined application of N at 750 g and K at 750 g per plant significantly enhanced the available nitrogen of orchard soil, while the low dose of N at 375 g and K at 450 g per plant significantly increased the

available phosphorus. Mir (2011) reported that conjunctive use of different organic resources and recommended dose of NPK have resulted in significant increase in available macro and micronutrient status of soil after harvest and highest increase was observed at vermicompost (20 kg tree⁻¹) + Biofertilizers (80 g tree⁻¹) + Farm yard manure (20 kg tree⁻¹) + Green manure (Sunnhemp) + recommended dose of NPK during both years of experimentation.

Higher available N, P and K content in soils at different growth stages of banana viz., vegetative, flowering and at harvest was higher in the treatment received 50 per cent RDF (110:30:110 g NPKplant⁻¹) through inorganic fertilizers + 25 kg FYM + 3 kg vermi compost + 1 kg neem cake + bio fertilizer followed by treatment which received 100 per cent of the recommended dose of fertilizer through chemical fertilizers (Selvamani *et al.*, 2011).

Singh *et al.* (2012) conducted a study in four year old aonla orchard at Central Horticultural Experiment Station (CIAH), Gujarat and concluded that recommended dose of NPK (400:200:300 g plant⁻¹) along with farm yard manure @ 60 kg plant⁻¹ significantly increased the available nitrogen (220.15 kg ha⁻¹), phosphorus (24.18 kg ha⁻¹) and potassium (124.15 kg ha⁻¹) content of post harvest soil.

Mustafa *et al.* (2013) conducted an experiment to know the effect of integrated nutrient management in aonla (*Embalica officinalis*) and revealed that foliar application of ZnSO₄ @ 0.5 % and CuSO₄ @ 0.4 % along with soil application of recommended dose of NPK (1000:400:400g RDF), iron sulphate (200g) and FYM (15 kg) significantly increased the available nitrogen, phosphorus and potassium of about 150.53, 10.09 and 324.30 kg ha⁻¹, respectively in post harvest soils.

Sharma *et al.* (2013) reported the effect of organic and inorganic sources of fertilizers on yield, quality and nutrient status of guava. The results revealed that highest available nitrogen (269.97 kg ha⁻¹), phosphorus (19.77 kg ha⁻¹), calcium (7.03 meq⁻¹ 100 g soil) and magnesium (2.76 meq⁻¹ 100 g soil) were recorded in the treatment comprising *Azotobacter* + 25% of N tree⁻¹ through FYM + 75% of N tree⁻¹ through inorganic fertilizer. whereas, the highest available soil potassium (148.23 kg ha⁻¹) was obtained

with the application of *Azotobacter* + 50% of N tree⁻¹ through FYM + 50% of N tree⁻¹ through inorganic fertilizer.

Verma and Chauhan (2014) reported that application of 1094 g 12:32:16 IFFCO mixture, 1237 g urea, 875 g MOP + 1.0 kg lime tree⁻¹ + farm yard manure (100 kg tree⁻¹) recorded higher available nitrogen (480.20 and 482.20), phosphorus (19.50 and 19.80) and potassium (278.40 and 280.40 kg ha⁻¹) in the apple orchard after harvest of the crop in both the years.

Integrated nutrient management had significant effect on the available soil nutrient status of plum orchard and the maximum soil available K (326.02 kg ha⁻¹) and Cu (2.27 ppm) were recorded with 50% NPK + biofertilizers (60g each tree basin⁻¹) + green manuring (Sunhemp @ 25 g seeds tree basin⁻¹) + FYM (40 kg) + vermicompost (11.5 kg). While the application of 75% NPK + biofertilizers (60 g each tree basin⁻¹) + Green manuring (Sunhemp @ 25 g seeds tree basin⁻¹) resulted in maximum soil available nitrogen and phosphorus (345.06 and 20.95 kg ha⁻¹, respectively) and maximum soil Mg (21.16 ppm) and Zn (2.10 ppm) were recorded with combination of biofertilizers (60 g tree basin⁻¹) + green manure (Sunhemp @ 25 g seed tree basin⁻¹) + FYM (40 kg) + vermicompost (24 kg) (Thakur,2013).

Mohanbhai (2014) studied the effect of integrated nutrient management in papaya (*carica papaya* L.) cv. Taiwan red lady and recorded higher available nitrogen (307.00 kg ha⁻¹), phosphorus (68.37 kg ha⁻¹) and potassium (415.67kg ha⁻¹) in post harvest soil when 50 per cent of recommended dose of fertilizer supplied through bio compost and castor cake and remaining 50 per cent through inorganic fertilizers as compared to control *i.e.* only RDF (249.83, 43.75 and 354.83 kg ha⁻¹, respectively).

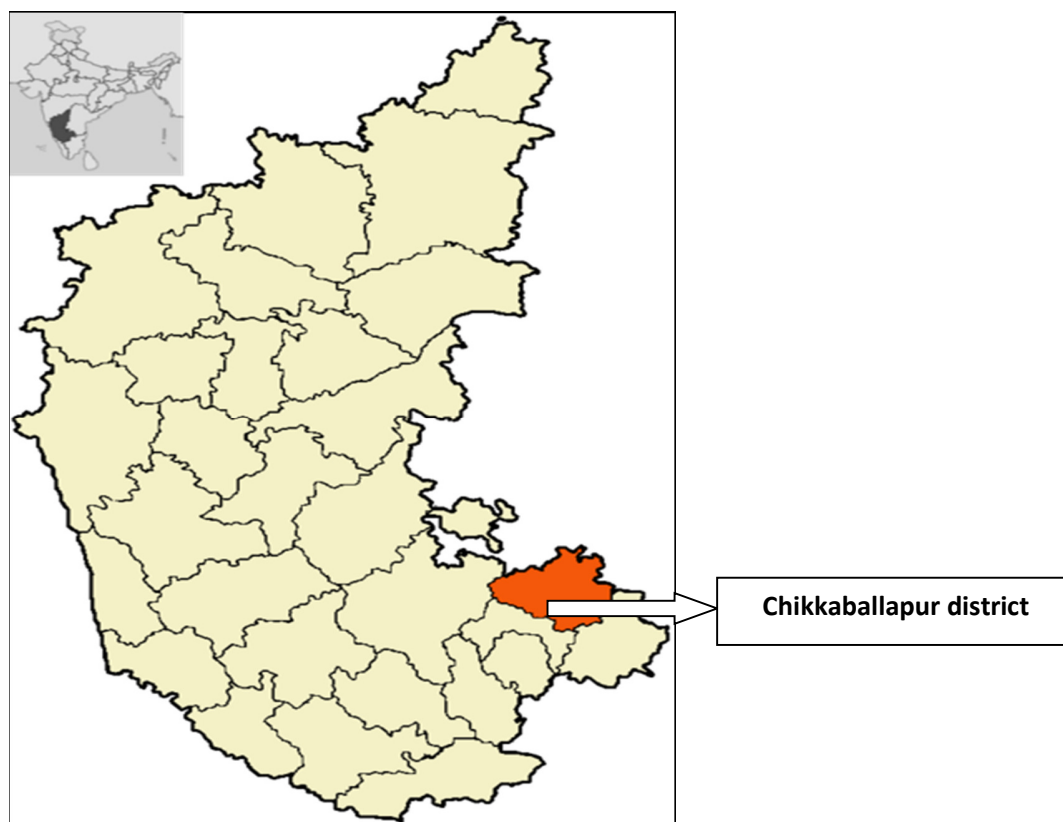
III. MATERIAL AND METHODS

An experiment titled “Studies on foliar spray of zinc metalosate and boron metalosate on growth, yield and quality of grapes (*Vitis vinifera* L.) and pomegranate (*Punica granatum* L.) was conducted in the farmer’s field. Details of the material used and methodology adopted during the investigation are detailed in this chapter.

3.1 Field experiments

3.1.1 Location of the experimental site

The field experiment was conducted at Marganahalli village, Chikkaballapur district during 2015-2016 and 2016-2017, which comes under Eastern Dry Zone of Karnataka (Zone 5) at 13° 52’ 29’’ N latitude and 77° 83’ 67’’ E longitude at an elevation of 835 m above mean sea level.



3.1.2 Soil properties of the experimental site

Prior to experimentation composite soil samples were drawn from 0-15 cm and analysed for sand, silt, clay, pH, EC (dS m^{-1}), organic carbon, available nitrogen, phosphorus, potassium, sulphur, exchangeable calcium and magnesium, DTPA extractable zinc, copper, iron, manganese and hot water soluble boron using standard procedures and are presented in Table 1.

3.1.3 Quality of irrigation water used in the studies

The irrigation water used for the field experiment was analysed for pH, EC (dS m^{-1}), calcium and magnesium, carbonates, bicarbonates, chlorides, sodium, zinc, copper, manganese, iron, sodium adsorption ratio, residual sodium carbonate using standard procedures and are presented in Table 2.

3.1.4 Properties of farm yard manure used in the studies

Farm yard manure used for the field experiments was analysed for pH, EC (dSm^{-1}), total carbon, nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, zinc, copper, iron and manganese using standard procedures and are presented in Table 3.

3.1.5 Sources of zinc and boron and its nutrient content

Zinc sources	Zinc content (%)
1.Zinc metalosate	6.8 %
2. Zn-EDTA	12.0 %
3. $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	21.0 %
Boron sources	Boron content (%)
1. Boron metalosate	5.0 %
2. Boric acid	17.0 %
3. Borax	11.0 %

Note: Zinc metalosate and boron metalosate are amino acid chelated, liquid and 100 % water soluble zinc and boron fertilizers. In zinc and boron metalosate N, P, K, S, Cd, Pb and F were not in detectable range.

Table 1: Initial physico - chemical properties of the soils of the experimental site

Sl. No	Parameters	Experiment No.1	Experiment No.2.	Experiment No.3	Experiment No.4
1	Sand (%)	68.00	66.90	67.00	65.25
2	Silt (%)	12.36	15.70	14.60	16.50
3	Clay (%)	19.63	17.30	18.10	17.95
4	Texture class	Sandy loam	Sandy loam	Sandy loam	Sandy loam
5	pH (1:2.5)	6.45	6.28	6.37	6.25
6	EC (dS m ⁻¹)	0.54	0.30	0.48	0.27
7	SOC (%)	0.68	0.52	0.65	0.50
8	Available N (kg ha ⁻¹)	286	292	281	296
9	Available P ₂ O ₅ (kg ha ⁻¹)	24	26	23	28
10	Available K ₂ O ₅ (kg ha ⁻¹)	175	169	180	170
11	Exchangeable Ca (C mol (p ⁺) kg ⁻¹)	4.50	4.35	4.40	4.30
12	Exchangeable Mg (C mol (p ⁺) kg ⁻¹)	1.90	1.98	1.86	2.00
13	Available S (mg kg ⁻¹)	11.61	11.51	11.47	13.21
14	Available Zn (mg kg ⁻¹)	0.55	0.49	0.53	0.52
15	Available Fe (mg kg ⁻¹)	39.00	40.06	38.45	37.22
16	Available Mn (mg kg ⁻¹)	27.00	27.51	26.20	22.06
17	Available Cu (mg kg ⁻¹)	0.35	0.35	0.30	0.37
18	Available B (mg kg ⁻¹)	0.45	0.46	0.47	0.44

Table 2 : Quality of irrigation water used in the field experiments

Parameters	content
pH	6.40
EC(dSm ⁻¹)	0.60
Ca ²⁺ (meq l ⁻¹)	8.00
Mg ²⁺ (meq l ⁻¹)	1.60
CO ₃ ⁼ (meq l ⁻¹)	Nil
HCO ₃ ⁻ (meq l ⁻¹)	2.00
Cl ⁻ (meq l ⁻¹)	4.00
Na ⁺ (meq l ⁻¹)	1.40
Zn (mg l ⁻¹)	ND
Cu (mg l ⁻¹)	ND
Mn (mg l ⁻¹)	ND
Fe(mg l ⁻¹)	0.23
SAR	0.64
RSC	-

Table 3: Nutrient content of farm yard manure used in the field experiment

Parameters	Composition
pH	7.64
EC (dS m ⁻¹)	0.11
O.C (%)	28.00
N (%)	1.06
P (%)	0.41
K (%)	0.57
S (%)	0.32
Ca (%)	0.20
Mg (%)	0.12
Fe (mg kg ⁻¹)	4536
Mn (mg kg ⁻¹)	246
Zn (mg kg ⁻¹)	109
Cu (mg kg ⁻¹)	34

3.1.6 Details of the experiments

To study the foliar spray of zinc metalosate and boron metalosate on growth, yield and quality of grapes (*Vitis vinifera* L.) and pomegranate (*Punica granatum* L.) four field experiments were conducted during 2015-16 and 2016-17. The details of the field experiments are given below.

3.1.6.1 Experiment No.1: Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of zinc

3.1.6.2 Experiment No.2: Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of zinc

3.1.6.3 Experiment No.3: Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of boron and zinc metalosate

3.1.6.4 Experiment No.4: Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of boron and zinc metalosate

3.1.6.1 Experiment No.1: Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of zinc

Three year old grape garden was selected for the experiment (Plate1 and 2). The experiment was conducted in a Randomized Block Design (RBD) with twenty treatments and three replications. The recommended dose of NPK and farm yard manure were applied as per package of practices. Cultural practices like irrigation, weed management and plant protection measures were followed throughout the course of investigation. Foliar spray of zinc was carried out at critical growth stages viz., vegetative stage, before flowering and after fruit set.

Variety : Dilkush

Design : RBD

Number of treatments	: 20
Replications	: 3
No.of plants per treatment	: 2
Spacing	: 11x 22 ft
Number of sprays	: 3 (Vegetative stage, before flowering and after fruit set)
Source of zinc	: Zinc metalosate, Zn-EDTA and Zinc sulphate
RDF (kg ha ⁻¹)	: 500:125: 750 N: P ₂ O ₅ : K ₂ O
FYM	: 20 kg plant ⁻¹
Volume of spray	: 500 L ha ⁻¹

3.1.6.1.1 Treatment details of the Experiment 1

Sl.No	Treatment Details
T ₁	NPK
T ₂	NPK+ Soil application of Zn as ZnSO ₄
T ₃	NPK + FYM
T ₄	NPK + Foliar spray of 0.010 % Zn as ZnSO ₄
T ₅	NPK + Foliar spray of 0.025 % Zn as ZnSO ₄
T ₆	NPK + Foliar spray of 0.050 % Zn as ZnSO ₄
T ₇	NPK + Foliar spray of 0.100 % Zn as ZnSO ₄
T ₈	NPK + Foliar spray of 0.150 % Zn as ZnSO ₄
T ₉	NPK + Foliar spray of 0.010% Zn as zinc metalosate
T ₁₀	NPK + Foliar spray of 0.025 % Zn as zinc metalosate
T ₁₁	NPK + Foliar spray of 0.050 % Zn as zinc metalosate
T ₁₂	NPK + Foliar spray of 0.10 % Zn as zinc metalosate
T ₁₃	NPK + Foliar spray of 0.150% Zn as zinc metalosate
T ₁₄	NPK + Foliar spray of 0.010 % Zn as Zn-EDTA
T ₁₅	NPK + Foliar spray of 0.025 % Zn as Zn-EDTA
T ₁₆	NPK + Foliar spray of 0.050 % Zn as Zn-EDTA
T ₁₇	NPK + Foliar spray of 0.10 % Zn t as Zn-EDTA
T ₁₈	NPK + Foliar spray of 0.150 % Zn as Zn-EDTA
T ₁₉	T ₃ + Soil application of Zn as ZnSO ₄
T ₂₀	T ₃ + Foliar spray of 0.01 % Zn as ZnSO ₄

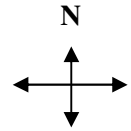


Plate 1: A view of the experimental site (Grapes)



Plate 2: A view of the experimental site (Grapes)

R - I	R - II	R - III
T ₁	T ₁₆	T ₃
T ₈	T ₅	T ₁₅
T ₁₂	T ₁₇	T ₁
T ₁₆	T ₂	T ₁₀
T ₁₉	T ₁₅	T ₄
T ₂	T ₆	T ₁₇
T ₅	T ₁₀	T ₂
T ₁₄	T ₁	T ₁₆
T ₃	T ₁₃	T ₂₀
T ₁₇	T ₈	T ₅
T ₁₁	T ₁₉	T ₁₂
T ₄	T ₉	T ₁₈
T ₂₀	T ₃	T ₇
T ₇	T ₁₁	T ₁₉
T ₁₅	T ₇	T ₉
T ₆	T ₄	T ₈
T ₉	T ₁₂	T ₁₄
T ₁₃	T ₁₈	T ₁₁
T ₁₀	T ₁₄	T ₆
T ₁₈	T ₂₀	T ₁₃



3.1.6.1.2 Design and layout of the Experiment1

3.1.6.2 Experiment No.2: Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of zinc

Experiment was conducted in Randomized Block Design (RBD) with twenty treatments and three replications. Four year old pomegranate garden was selected for the experiment (Plate 3). The recommended dose of NPK and FYM was applied as per the package of practice and other cultural practices were carried out throughout the course of experimentation. Foliar sprays were scheduled at critical growth stages of the pomegranate *i.e.* vegetative stage, fruit half lemon stage and fruit half grown stage.

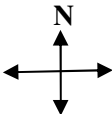
Variety	: Bhagwa
Design	: RBD
Number of treatments	: 20
Replications	: 3
No. of plants per treatment	: 2
Spacing	: 11 x 11 ft
Number of sprays	: 3 (Vegetative stage, half lemon stage of fruit and half grown stage of fruit)
Source of zinc	: Zinc metalosate, Zn-EDTA and Zinc sulphate
RDF (kg ha ⁻¹)	: 200:100: 100 N: P ₂ O ₅ : K ₂ O
FYM	: 12.5 t ha ⁻¹
Volume of spray	: 500 L ha ⁻¹



Plate 3: General view of the pomegranate experimental plot

3.1.6.2.1 Treatment details of the Experiment 2

Sl.No	Treatment Details
T ₁	NPK
T ₂	NPK+ Soil application of Zn as ZnSO ₄
T ₃	NPK + FYM
T ₄	NPK + Foliar spray of 0.010 % Zn as ZnSO ₄
T ₅	NPK + Foliar spray of 0.025 % Zn as ZnSO ₄
T ₆	NPK + Foliar spray of 0.050 % Zn as ZnSO ₄
T ₇	NPK + Foliar spray of 0.100 % Zn as ZnSO ₄
T ₈	NPK + Foliar spray of 0.150 % Zn as ZnSO ₄
T ₉	NPK + Foliar spray of 0.010% Zn as zinc metalosate
T ₁₀	NPK + Foliar spray of 0.025 % Zn as zinc metalosate
T ₁₁	NPK + Foliar spray of 0.050 % Zn as zinc metalosate
T ₁₂	NPK + Foliar spray of 0.10 % Zn as zinc metalosate
T ₁₃	NPK + Foliar spray of 0.150% Zn as zinc metalosate
T ₁₄	NPK + Foliar spray of 0.010 % Zn as Zn-EDTA
T ₁₅	NPK + Foliar spray of 0.025 % Zn as Zn-EDTA
T ₁₆	NPK + Foliar spray of 0.050 % Zn as Zn-EDTA
T ₁₇	NPK + Foliar spray of 0.10 % Zn as Zn-EDTA
T ₁₈	NPK + Foliar spray of 0.150 % Zn as Zn-EDTA
T ₁₉	T ₃ + Soil application of Zn as ZnSO ₄
T ₂₀	T ₃ + Foliar application of 0.01 % Zn through ZnSO ₄

R - I	R - II	R - III	
T ₁	T ₁₆	T ₃	
T ₈	T ₅	T ₁₅	
T ₁₂	T ₁₇	T ₁	
T ₁₆	T ₂	T ₁₀	
T ₁₉	T ₁₅	T ₄	
T ₂	T ₆	T ₁₇	
T ₅	T ₁₀	T ₂	
T ₁₄	T ₁	T ₁₆	
T ₃	T ₁₃	T ₂₀	
T ₁₇	T ₈	T ₅	
T ₁₁	T ₁₉	T ₁₂	
T ₄	T ₉	T ₁₈	
T ₂₀	T ₃	T ₇	
T ₇	T ₁₁	T ₁₉	
T ₁₅	T ₇	T ₉	
T ₆	T ₄	T ₈	
T ₉	T ₁₂	T ₁₄	
T ₁₃	T ₁₈	T ₁₁	
T ₁₀	T ₁₄	T ₆	
T ₁₈	T ₂₀	T ₁₃	

3.1.6.2.2 Design and layout of the Experiment 2

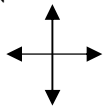
3.1.6.3 Experiment No.3: Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of boron and zinc metalosate

Three year old grape garden was selected for the experiment. The experiment was conducted with seventeen treatments and three replications in Randomized Block Design. The recommended dose of NPK and FYM were applied as per the package of practice and foliar spray was carried out at critical growth stages of the grapes *i.e.* flowering and fruit set stage. Cultural practices were carried out throughout the course of experimentation.

Variety	: Dilkush
Design	: RBD
Number of treatments	: 17
Replications	: 3
No.of plants per treatment	: 2
Spacing	: 11 x 22 ft
Number of sprays	: 2 (Flowering and fruit set stage)
Source of boron	: Boron metalosate, Boric acid and Borax
Source of zinc	: Zinc metalosate
RDF (kg ha ⁻¹)	: 500:125:750 N: P ₂ O ₅ :K ₂ O
FYM	: 20 kg plant ⁻¹ year ⁻¹
Volume of spray	: 500 L ha ⁻¹

3.1.6.3.1 Treatment details of the Experiment 3

Sl.No	Treatment Details
T ₁	NPK
T ₂	NPK+ Soil application of B as borax
T ₃	NPK + FYM
T ₄	NPK + Foliar spray of 0.0034 % B as boric acid
T ₅	NPK + Foliar spray of 0.0085 % B as boric acid
T ₆	NPK + Foliar spray of 0.017 % B as boric acid
T ₇	NPK + Foliar spray of 0.034 % B as boric acid
T ₈	NPK + Foliar spray of 0.051 % B as boric acid
T ₉	NPK + Foliar spray of 0.0034 % B as boron metalosate
T ₁₀	NPK + Foliar spray of 0.0085 % B as boron metalosate
T ₁₁	NPK + Foliar spray of 0.017 % B as boron metalosate
T ₁₂	NPK + Foliar spray of 0.034 % B as boron metalosate
T ₁₃	NPK + Foliar spray of 0.051 % B as boron metalosate
T ₁₄	T ₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate
T ₁₅	T ₁₁ + Foliar spray of 0.05 % Zn as zinc metalosate
T ₁₆	T ₃ + Soil application of B as borax
T ₁₇	T ₃ + Foliar spray of 0.005 % B as boric acid

			N 	
R - I	R - II	R - III		
T ₁₅	T ₁₄	T ₆		
T ₁₆	T ₂	T ₁₀		
T ₅	T ₁	T ₈		
T ₁₃	T ₁₆	T ₁₁		
T ₈	T ₃	T ₅		
T ₂	T ₁₀	T ₁₃		
T ₁₄	T ₁₁	T ₂		
T ₇	T ₁₅	T ₁₇		
T ₁₀	T ₄	T ₁		
T ₁₇	T ₆	T ₁₄		
T ₄	T ₁₂	T ₃		
T ₁	T ₈	T ₁₂		
T ₁₁	T ₉	T ₁₆		
T ₃	T ₅	T ₇		
T ₁₂	T ₇	T ₉		
T ₉	T ₁₃	T ₁₅		
T ₆	T ₁₇	T ₄		

3.1.6.3.2 Design and layout of the Experiment 3

3.1.6.4 Experiment No.4: Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of boron and zinc metalosate

The field experiment was conducted in a four year old pomegranate garden (Plate 4). The experiment was conducted in a Randomized Block Design (RBD) with seventeen treatments and three replications. Recommended dose of NPK and FYM were applied as per package of practice and other management practices were carried out till the harvest of the crop. Foliar spray was carried out at critical growth stages of the pomegranate *i.e.* vegetative growth and fruit lemon stage.

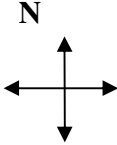
Variety	: Bhagwa
Design	: RBD
Number of treatments	: 17
Replications	: 3
No.of plants per treatment	: 2
Number of sprays	: 2 (Vegetative growth stage and fruit lemon stage)
Source of boron	: Boron metalosate, Boric acid and Borax
Source of zinc	: Zinc metalosate
RDF (kg ha ⁻¹)	: 200:100:100 N: P ₂ O ₅ : K ₂ O
FYM	: 12.5 t ha ⁻¹
Volume of spray	: 500 L ha ⁻¹



Plate 4 :General view of the pomegranate experimental plot

3.1.6.4.1 Treatment details of Experiment 4

Sl. No	Treatment Details
T ₁	NPK
T ₂	NPK+ Soil application of Boron as borax
T ₃	NPK + FYM
T ₄	NPK + Foliar spray of 0.0034 % B as boric acid
T ₅	NPK + Foliar spray of 0.0085 % B as boric acid
T ₆	NPK + Foliar spray of 0.017 % B as boric acid
T ₇	NPK + Foliar spray of 0.034 % B as boric acid
T ₈	NPK + Foliar spray of 0.051 % B as boric acid
T ₉	NPK + Foliar spray of 0.0034 % B as boron metalosate
T ₁₀	NPK + Foliar spray of 0.0085 % B as boron metalosate
T ₁₁	NPK + Foliar spray of 0.017 % B as boron metalosate
T ₁₂	NPK + Foliar spray of 0.034 % B as boron metalosate
T ₁₃	NPK + Foliar spray of 0.051 % B as boron metalosate
T ₁₄	T ₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate
T ₁₅	T ₁₁ + Foliar spray of 0.05 % Zn as zinc metalosate
T ₁₆	T ₃ + Soil application of Boron as borax
T ₁₇	T ₃ + Foliar spray of 0.005 % B as boric acid

R - I	R- II	R- III	
T₁₅	T₁₄	T₆	
T₁₆	T₂	T₁₀	
T₅	T₁	T₈	
T₁₃	T₁₆	T₁₁	
T₈	T₁₃	T₅	
T₂	T₁₀	T₁₃	
T₁₄	T₁₁	T₂	
T₇	T₁₅	T₁₇	
T₁₀	T₄	T₁	
T₁₇	T₆	T₁₄	
T₄	T₁₂	T₃	
T₁	T₈	T₁₂	
T₁₁	T₉	T₁₆	
T₃	T₅	T₇	
T₁₂	T₇	T₉	
T₉	T₁₃	T₁₅	
T₆	T₁₇	T₄	

3.1.6.4.2 Design and layout of the Experiment 4

3.2 Biometric observations

3.2.1 Grapes

The following growth parameters and yield attributes were recorded during the experimentation.

3.2.1.1 Growth parameters

3.2.1.1.1 Cane Length (cm)

The cane length was recorded by measuring length from the cane joint to tip of the cane at harvest grapes.

3.2.1.1.2 Cane girth (cm)

The cane girth was measured in between fifth and sixth internodes at central position of the cane using vernier calipers at harvest of grapes.

3.2.1.1.3 Intermodal length (cm)

The intermodal length was measured in between the fifth and sixth internodes using measuring scale at harvest and expressed in centimeters.

3.2.1.2 Yield parameters

The following yield attributing parameters were recorded as detailed below

3.2.1.2.1 Number of bunches per vine

The number of bunches on each vine of the plant was recorded and was expressed as number of bunches per vine. Thirty bunches per treatment vine were randomly selected and following bunch characters were recorded.

3.2.1.2.2 Bunch Weight (g)

From the labeled canes bunches were harvested and bunch weight was recorded by using top pan electronic balance and expressed in grams.

3.2.1.2.3 Number of berries per bunch

The number of berries were counted out of the selected thirty bunches in each treatment and expressed as number of berries per bunch.

3.2.1.2.4 Mean weight of berries per bunch (g)

From the thirty selected bunches berries were separated from rachis and mean weight of berries per bunch was recorded using electronic balance.

3.2.1.2.5 Yield per plant (kg)

Yield per plant was computed by adding the total weight of individual bunches per plant.

3.2.1.2.6 Yield (t ha^{-1})

Yield per hectare was computed by multiplying yield per plant with plant population per hectare.

3.2.2 Pomegranate

3.2.2.1 Growth parameter

3.2.2.1.1 Plant height (cm)

The plant height was measured from the base of the plant to the tip using a tape at the time of harvest.

3.2.2.2 Yield parameters

3.2.2.2.1 Number of fruits harvested per shoot

An average of thirty shoots were selected from each plant and number of fruits on each shoot were counted manually.

3.2.2.2.2 Total weight of fruits per shoot (g)

From the thirty selected shoots of each treatment total weight of fruits per shoot was recorded with the help of electronic balance.

3.2.2.2.3 Number of fruits per plant

The number of fruits formed on each plant was recorded manually by counting.

3.2.2.2.4 Yield (kg plant⁻¹)

Yield was recorded with the help of electronic balance by recording the weight of all the fruits per plant.

3.2.2.2.5 Yield hectare⁻¹(t)

Yield per hectare was calculated by multiplying yield per plant with plant population per hectare.

3.2.2.3 Physical parameters of fruits

3.2.2.3.1 Length of fruit (cm)

Thirty fruits were selected randomly from each treatment and length of fruits was measured using a scale.

3.2.2.3.2 Breadth of fruit (cm)

Breadth of thirty selected fruits was measured using scale.

3.2.2.3.3 Weight of fruit (g)

Thirty matured fruits were selected randomly from each treatment and recorded the weight of fruits using electronic balance.

3.3 Biochemical parameters

The juice of the fruits was subjected to quality analysis.

3.3.1 Total Soluble Solids (° Brix)

Total soluble solids content of juice was determined using hand refractrometer having a scale of 0-30 ° Brix and expressed as degree brix.

3.3.2 Titratable Acidity (%)

The titratable acidity of juice was determined by titrating with 0.1 *N* sodium hydroxide (NaOH) solution using phenolphthalein indicator. Titratable acidity was calculated and expressed in terms of grams of tartaric acid equivalent in 100 ml of juice.

$$\text{Titratable Acidity (\%)} = \frac{\text{TV} \times 0.1 \text{ N NaOH} \times \text{Vol. made up} \times \text{eq. wt. citric acid} \times 100}{\text{Vol. of sample taken for titration} \times \text{Wt. of the sample} \times 1000}$$

3.3.3 Total sugars (%)

The percentage of total sugars was estimated by A. O. A. C. method (1980). 20 ml of juice was taken into 100 ml conical flask and 20 ml of distilled water was added and to this 5 ml of 6 *N* HCl was added and kept on a hot water bath for eight minutes. The flask was removed from water bath and cooled to room temperature. The excess acidity was neutralized by adding 40 per cent sodium hydroxide using phenolphthalein indicator. This was indicated by the formation of pink colour. The solution was made up to the mark in a 100ml volumetric flask by adding distilled water.

This solution was taken into a burette and was titrated against 10 ml of Fehlings solution (A & B) in hot condition, using methylene blue as indicator till the brick red coloured precipitate is formed. The percentage of total sugars was estimated using the factor 10 ml of Fehling solution = 0.05g glucose.

$$\text{Total Sugars (\%)} = \frac{0.05 \times 100 \times 100}{\text{Titre Value} \times 20}$$

3.4 Analysis of soil, irrigation water, farm yard manure, plant samples (index tissue) and fruit samples

Soil samples, irrigation water, farm yard manure, plant samples (index tissues) and fruit samples were analysed for various parameters.

3.4.1 Soil Analysis

Soil samples after harvest were collected from each experimental plots and analysed for pH, EC, organic carbon, available nitrogen, phosphorus, potassium, sulphur, exchangeable calcium, magnesium, DTPA extractable zinc, iron, copper, manganese and hot water soluble boron using standard procedures (Table .4)

Table 4: Methodology adopted for soil analysis

Sl. No.	Parameter	Method	Reference
1.	Sand (%)	International pipette method	Piper (1966)
2.	Silt (%)		
3.	Clay (%)		
4.	Soil reaction (pH) (1:2.5 soil : water suspension)	Potentiometry	Jackson (1973)
5.	Electrical conductivity (1:2.5 soil: water suspension)	Conductometry	Jackson (1973)
6.	Organic carbon (%)	Wet oxidation	Walkley and Black (1934)
7.	Available Nitrogen (kg ha ⁻¹)	Macrokjeldahl distillation	Subbiah and Asija (1956)
8.	Available Phosphorus [Bray's-P] (kg ha ⁻¹)	Spectrophotometry	Jackson (1973)
9.	Available Potassium (kg ha ⁻¹)	Flame photometry	Jackson (1973)
10.	Exchangeable Ca and Mg (C mol (p ⁺) kg ⁻¹)	Versenate titrimetry	Jackson (1973)
11.	Available sulphur (mg kg ⁻¹)	Turbidometry	Jackson (1973)
12.	DTPA extractable Fe (mg kg ⁻¹)	Atomic Absorption Spectrophotometry	Lindsay and Norwell, (1978)
13.	DTPA extractable Mn (mg kg ⁻¹)		
14.	DTPA extractable Zn (mg kg ⁻¹)		
15.	DTPA extractable Cu (mg kg ⁻¹)		
16.	Hot water soluble boron (mg kg ⁻¹)	Azomethane –H method	Jones and Case (1990)

3.4.2 Plant (Index tissue) and fruit analysis

3.4.2.1 Collection and preparation of plant samples (Index tissues)

The index tissue *i.e.* 5th petiole for grapes and 8th leaf for pomegranate were collected one day before each spray and one week after each spray according to the method described by (Chapman, 1964). Then samples were decontaminated using two per cent teepol solution and 0.1 N HCl followed by washing with distilled water. Samples were dried under shade for six hours and in hot air oven at $70 \pm 1^{\circ}\text{C}$ until constant weight was reached. After drying, the samples were ground in Willey mill having stainless steel blades and stored in polythene bottles for further analysis.

3.4.2.2 Collection and preparation of fruit samples

At the time of harvest both grapes and pomegranate samples were collected from each treatment and washed with distilled water. After washing, the fruit samples were sliced, air dried and later oven dried at 68°C till a constant weight was obtained. Then the dried fruit samples were grounded in steel Willey mill and then kept in butter paper bags for nutrient analysis. The procedures adopted for different macro, secondary and micro-nutrient analysis are given below.

3.4.2.3 Estimation of nitrogen in leaf and fruits

Digestion: One gram of powdered leaf and fruit sample was taken into the digestion tube along with 5-8 grams of digestion mixture containing potassium sulphate, copper sulphate and selenium in the ratio of 100:20:1 followed by adding 10 ml of concentrated sulphuric acid and kept aside overnight. Later the tube was heated incrementally to 350°C till a clear green digest was obtained in digestive chamber.

3.4.2.3.1 Estimation of nitrogen (%)

Distillation and titration: Total nitrogen was determined by Micro-Kjeldahl's method (Jackson, 1973). About 10 - 15 ml of distilled water was added to the cooled Micro-kjedhal tube containing digested material. After cooling 40 per cent NaOH was added and the distillation was carried out. The liberated ammonia was collected in a 250 ml conical flask containing 20ml of H_3BO_3 (1%) and mixed indicator. The distillation was

continued for 12-18 minutes till more than 150 ml of distillate was collected. The distillate was titrated against 0.1 N H₂SO₄. Simultaneously, a blank titration was also conducted.

3.4.2.3.2 Analysis of leaf and fruit phosphorus, potassium, sulphur, calcium, magnesium, zinc, iron, copper and manganese

Digestion of sample: Half a gram powdered leaf and fruit samples were wet digested with 10 ml di acid mixture consisting of nitric acid and perchloric acid (9:4 ratio) in 100 ml flask. The flask was kept over-night for pre-digestion and next day placed on hot plate at 115-118 °C for complete digestion. The digested material was diluted with double distilled water to make a volume of 50 ml and filtered through whatman no.1 filter paper. The filtrate was used for the determination of macronutrients (P and K), secondary nutrients (Ca, Mg and S) and micronutrients (Zn, Fe, Cu and Mn).

3.4.2.3.2.1 Estimation of phosphorus (%)

Phosphorus was estimated by vanadomolybdo phosphoric yellow colour method (Piper, 1966). The colour intensity was measured at 420 nm with the help of the spectrophotometer.

3.4.2.3.2.2 Estimation of potassium (%)

Potassium content in leaf and fruit samples was determined using flame photometer as outlined by Piper (1966).

3.4.2.3.2.3 Estimation of calcium and magnesium (%)

The calcium and magnesium in the digested material was determined by versenate titration method as outlined by Piper (1966).

3.4.2.3.2.4 Estimation of sulphur (%)

The sulphur content in index tissue and fruit samples was determined turbidometrically. The intensity of turbidity was measured using spectrophotometer at 420 nm.

3.4.2.3.2.5 Estimation of micronutrients: zinc, iron, copper and manganese (mg kg^{-1})

After making suitable dilution of di-acid extract, the samples were fed to the atomic absorption spectrophotometer using appropriate hollow cathode lamps.

3.4.2.3.2.6 Estimation of boron (mg kg^{-1})

The samples were ashed by using muffle furnace at 550°C and the ash was taken in 10ml of 6.5 N HCl. Boron was determined by azomethine H- method (Jones and Case, 1990).

3.5 Statistical analysis

The experimental data was subjected to statistical analysis using the Fishers method of analysis and variance technique as given by Gomez and Gomez (1984). The level of significance used in 'F' and 't' test was 5 % probability and wherever 'F' test was found significant, the 't' test was performed to estimate critical difference values for comparing various treatments. The results have been interpreted and discussed based on the pooled data of two years (2015-16 and 2016-17).

Table 5 : Methodology adopted for FYM analysis

Sl. No	Parameter	Method	Reference
1.	Soil reaction (pH) (1:10 manure : water suspension)	Potentiometry	Jackson (1973)
2.	Electrical conductivity (dSm^{-1}) (1:10 manure : water suspension)	Conductometry	Jackson (1973)
3.	Total Nitrogen (%)	Microkjeldahl digestion and distillation	Jackson (1973)
4.	Total Phosphorus (%)	Di-acid digestion and spectrophotometry	Jackson (1973)
5.	Total Potassium (%)	Di-acid digestion and Flame photometry	Piper (1966)
6.	Total Calcium and Magnesium (%)	Di-acid digestion and Versenate titrimetry	Piper (1966)
7.	Total Sulphur (%)	Di-acid digestion and Turbidometry	Jackson(1973)
8.	Fe (mg kg^{-1})	Di-acid digestion and Atomic Absorption Spectrophotometry	Jackson (1973)
9.	Mn (mg kg^{-1})		
10.	Zn (mg kg^{-1})		
11.	Cu (mg kg^{-1})		

Table 6: Methodology adopted for irrigation water analysis

Sl.No	Parameter	Method	Reference
1.	Soil reaction (pH)	Potentiometry method	Manivasakam, 1987
2.	Electrical conductivity (dS m ⁻¹)	Conductometry method	Manivasakam, 1987
3.	Exchangeable Ca and Mg	Titration method	Manivasakam, 1987
4.	Carbonates (mg l ⁻¹)	Titrimetry using phenolphthalein indicator	Manivasakam, 1987
5.	Bicarbonates (mg l ⁻¹)	Titrimetry using methyl orange indicator	Manivasakam, 1987
6.	Fe (mg l ⁻¹)	Atomic absorption spectrophotometry	Manivasakam, 1987
7.	Mn(mg l ⁻¹)		
8.	Zn(mg l ⁻¹)		
9.	Cu (mg l ⁻¹)		
10.	SAR and RSC	Mathematical computation	Richards, 1954

Table 7: Methodology adopted for plant and fruit analysis

Sl.No	Parameter	Method	Reference
1.	Total Nitrogen (%)	Microkjeldahl digestion and distillation	Piper (1966)
2.	Total Phosphorus (%)	Di-acid digestion and spectrophotometry	Piper (1966)
3.	Total Potassium (%)	Di-acid digestion and Flame photometry	Piper (1966)
4.	Total Calcium and Magnesium (%)	Di-acid digestion and Versenate titrimetry	Piper (1966)
5.	Total Sulphur (%)	Di-acid digestion and Turbidometry	Piper (1966)
6.	Total Fe (mg kg ⁻¹)	Di-acid digestion and Atomic Absorption Spectrophotometry	Piper (1966))
7.	Total Mn (mg kg ⁻¹)		
8.	Total Zn (mg kg ⁻¹)		
9.	Total Cu (mg kg ⁻¹)		
10.	Total B (mg kg ⁻¹)	Di-acid digestion and colorimetry using Azomethane –H	Jones and Case (1990)

IV. RESULTS AND DISCUSSION

Field experiment on “Studies on foliar spray of zinc metalosate and boron metalosate on growth, yield and quality of grapes (*Vitis vinifera* L.) and pomegranate (*Punica granatum* L.)” was carried out in the farmer’s fields at Marganahalli village, Chikkaballapur district located in eastern dry zone of Karnataka during 2015-2016 and 2016-2017 and results of the experiments are presented and discussed in this chapter.

4.1 Experiment No.1. Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of zinc

4.1.1 Effect of foliar spray on growth parameters of grapes as influenced by sources and levels of zinc

The growth parameters of grapes such as cane length (cm), cane girth (cm) and internodal length (cm) as influenced by sources and levels of zinc are presented in Table 8.

4.1.1.1 Cane length (cm)

Significantly higher cane length of 119.39 cm was recorded in the treatment T₁₃ which received zinc @ 0.150 per cent through zinc metalosate along with NPK and it was on par with treatment T₁₈ (118.60 cm) which consists of 0.150 per cent zinc through Zn-EDTA. Cane length of 109.89 cm (T₁₂) recorded by spraying zinc @ 0.10 per cent through zinc metalosate was on par with 0.10 (T₁₇: 109.32 cm) and 0.150 (T₈: 108.85 cm) per cent zinc through Zn-EDTA and ZnSO₄, respectively. Among the different sources and levels of zinc, zinc @ 0.010 and 0.025 per cent did not influence the cane length significantly as compared to control (T₃: 93.14 cm). Lower cane length was recorded in the treatment T₁ (84.78 cm) which received only recommended NPK.

4.1.1.2 Cane girth (cm)

Cane girth was significantly enhanced by higher levels of zinc as compared to lower levels (0.010 and 0.025 % of Zn). Among the treatments higher cane girth was recorded in treatment T₁₃ (1.00 cm) which received 0.150 per cent zinc through zinc metalosate and was on par with T₁₈ treatment (0.99 cm) which received 0.150 per cent zinc through Zn-EDTA. Cane girth was enhanced by the application of zinc @ 0.150 per

cent through zinc sulphate (T₈: 0.83 cm) was on par with treatment T₁₂ (0.86 cm) and T₁₇ (0.84 cm) which received zinc @ 0.100 per cent through zinc metalosate and Zn-EDTA, respectively. Soil application of zinc sulphate along with recommended dose of NPK and Farm yard manure (T₁₉) significantly enhanced the cane girth compared to recommended dose of fertilizer along with farm yard manure application (T₂).

4.1.1.3 Internodal length (cm)

Among the different sources and levels of zinc, internodal length was recorded significantly higher in treatment which consists of zinc @ 0.150 per cent as zinc metalosate (T₁₃: 10.84 cm) and it was on par with the treatment T₁₈ (10.72 cm) which received zinc @ 0.150 per cent Zn-EDTA as foliar spray. Internodal length recorded in the treatment T₁₂ (9.81 cm) which consists of zinc @ 0.10 per cent was on par with treatment T₁₇ (9.74 cm) and T₈ (9.61 cm) which received zinc @ 0.10 and 0.150 per cent through Zn-EDTA and ZnSO₄, respectively. Least increase in internodal length was recorded in the treatment T₁ which received only recommended NPK (T₁: 7.03 cm).

Enhanced growth parameters of grapes *viz.*, cane length, cane girth and internodal length in the treatment T₁₃ and T₁₈ which received zinc @ 0.150 per cent through zinc metalosate and Zn-EDTA, respectively may be attributed to their maintaining optimum zinc concentration in plant which is required for various metabolic activities of plant, which inturn contributed for enhancement in growth parameters of grapes. Zinc metalosate is an amino acid chelated liquid zinc fertilizer which easily slide through the leaf pores due its smaller size, neutral charge, hundred per cent solubility in water, hence it is neither attracted to nor repulsed from negatively charged surfaces of the leaf, hence entire amino acid chelated zinc can easily and quickly pass through the cuticular layer of leaf very rapidly and efficiently their by help in increasing zinc content in the xylem sap without adverse interactions with other materials on the leaf surface (Sekhon, 2003). Similarly, Zn-EDTA is also chelated zinc fertilizer, during chelation positive charge of the metal ion convert to neutral charge their by easily translocate through the cuticular layer of the leaf and provided sufficient amount of zinc to meet the crop requirement. Nutrient translocation within the plant was much greater with chelates (Mireille and Andre, 1988).

Table 8: Effect of foliar spray on growth parameters of grapes as influenced by sources and levels of zinc

Treatments	Cane length (cm)			Cane girth (cm)			Internodal length (cm)		
	Season I	Season II	Pooled Mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	83.13	86.43	84.78	0.46	0.48	0.47	7.00	7.05	7.03
2	83.67	87.72	85.70	0.47	0.50	0.49	7.13	7.22	7.18
3	91.10	95.17	93.14	0.56	0.58	0.57	7.75	8.09	7.92
4	83.22	86.90	85.06	0.46	0.49	0.47	7.05	7.11	7.08
5	84.40	88.03	86.21	0.47	0.51	0.49	7.14	7.25	7.20
6	90.15	94.71	92.43	0.55	0.58	0.57	7.69	7.88	7.79
7	98.20	102.52	100.36	0.67	0.71	0.69	8.40	8.91	8.66
8	106.78	110.91	108.85	0.80	0.85	0.83	9.19	10.03	9.61
9	83.60	87.79	85.70	0.46	0.50	0.48	7.11	7.19	7.15
10	90.88	94.90	92.89	0.55	0.59	0.57	7.75	8.03	7.89
11	99.13	103.07	101.10	0.69	0.71	0.70	8.47	9.11	8.79
12	107.85	111.93	109.89	0.83	0.88	0.86	9.39	10.23	9.81
13	117.03	121.75	119.39	0.95	1.05	1.00	10.31	11.37	10.84
14	83.45	87.66	85.56	0.46	0.49	0.48	7.08	7.15	7.12
15	90.59	94.78	92.69	0.55	0.58	0.57	7.72	7.96	7.84
16	98.84	102.83	100.84	0.68	0.70	0.69	8.43	9.05	8.74
17	107.23	111.40	109.32	0.82	0.86	0.84	9.31	10.17	9.74
18	116.27	120.92	118.60	0.95	1.03	0.99	10.20	11.23	10.72
19	91.63	95.29	93.46	0.57	0.60	0.59	7.76	8.11	7.94
20	92.05	95.72	93.89	0.59	0.63	0.61	7.81	8.19	8.00
SEm ±	1.97	2.29	2.07	0.02	0.02	0.02	0.18	0.20	0.19
CD @ 5 %	5.63	6.55	5.92	0.06	0.06	0.06	0.512	0.58	0.54

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Zinc is precursor for IAA biosynthesis their by helps in active synthesis of the growth hormone auxin, which is necessary for active cell division, cell differentiation, elongation and chlorophyll synthesis. It also helps in activation of large number of enzymes like dehydrogenases, aldolases, isomerases, transphosphorylases, RNA and DNA polymerases which are involved in chlorophyll, starch, carbohydrate and protein metabolism in plant, which in turn provided sufficient amount of photosynthates for enhancement of growth and development of plant. Asha (2006) reported significant improvement in the cane length (105.02 cm), cane girth (0.59 cm) and intermodal length (7.29 cm) due to rapid uptake, translocation and assimilation of zinc by the plant on addition of zinc @ 0.30 per cent foliar spray in Bangalore blue grapes. Similarly, an improvement in the growth parameters of the plant due to foliar application of zinc was recorded by Singh and Ahlawat (1995), Bhadur *et al.* (1998), Sarolia *et al.* (2007) and Pathak *et al.* (2011).

4.1.2 Effect of foliar spray on yield parameters of grapes as influenced by sources and levels of zinc

The data pertaining to yield parameters of grapes *viz.*, number of bunches plant⁻¹, number of berries bunch⁻¹, mean weight of berries bunch⁻¹ and weight of bunch as influenced by sources and levels of zinc are presented in Table 9.

4.1.2.1 Number of bunches plant⁻¹

Maximum number of bunches plant⁻¹ (68.50) was recorded on spraying zinc @ 0.150 per cent through zinc metalosate along with recommended dose of NPK compared to other treatments and was on par with T₁₈ *i.e.* NPK+ zinc @ 0.150 per cent through Zn-EDTA. Number of bunches per plant recorded in the treatment T₁₂ (64.60) and T₁₇ (64.28) which received 0.100 per cent zinc as zinc metalosate and Zn-EDTA along with recommended dose of NPK was on par with treatment T₈ (63.96) which received 0.150 per cent zinc as zinc sulphate. Zinc sprayed at lower doses *i.e.* 0.025 and 0.010 per cent as zinc metalosate, Zn-EDTA and zinc sulphate did not influence in increasing the number of bunches plant⁻¹ over control (NPK+ FYM: T₃).

4.1.2.2 Number of berries bunch⁻¹

Higher number of berries bunch⁻¹ was recorded in treatment T₁₃ (107.14) which received zinc @ 0.150 % as zinc metalosate along with recommended dose of NPK compared to all other treatments and was on par with treatment T₁₈ (105.09) which consists of 0.150 per cent zinc as Zn-EDTA. Treatment T₁₂ was on par with treatment T₁₇ and T₈ which received 0.10 and 0.150 per cent zinc as metalosate and EDTA and increased number of berries bunch⁻¹. Zinc metalosate, Zn-EDTA and ZnSO₄ sources did not show any effect in increasing number of berries bunch⁻¹ at 0.010 (66.96, 65.80 and 63.25, respectively) and 0.025 (75.46, 74.10 and 67.76, respectively) per cent level compared to control (T₃: 75.72). Least number of berries bunch⁻¹ of 60.29 was recorded in treatment T₁ which received only recommended dose of NPK.

4.1.2.3 Mean weight of berries bunch⁻¹

Foliar spray of zinc at higher levels of 0.150, 0.10, 0.050 per cent recorded significantly higher mean weight of berries per bunch compared to lower levels of 0.025 and 0.010 per cent, respectively in all the sources compared to control (NPK+ FYM: T₃). Out of twenty treatments higher mean weight of berries bunch⁻¹ was recorded due to foliar spray of zinc @ 0.150 per cent (580.96 g: T₁₃) as zinc metalosate followed by Zn-EDTA @ 0.150 % Zn (T₁₈: 579.71g) over control (NPK and FYM : T₃). Treatment T₁ recorded low mean weight of berries bunch⁻¹ (474.53 g).

4.1.2.4 Weight of bunch (g)

Data on weight of bunch revealed that among three sources of zinc, higher fruit weight was recorded due to zinc metalosate followed by Zn-EDTA and Zinc sulphate. Treatment T₁₃ (591.17g) which received 0.150 per cent zinc metalosate recorded significantly higher bunch weight compared to other treatments and was on par with treatment T₁₈ (589.78 g) which received zinc @ 0.150 per cent as Zn-EDTA. Weight of bunch recorded as spraying zinc @ 0.10 per cent as Zn-EDTA (T₁₂: 557.03 g) was on par with treatment T₁₇ (556.03 g) and T₈ (555.06 g) which received zinc @ 0.10 and 0.150 per cent as zinc metalosate and Zn-EDTA, respectively. The treatment which received only recommended dose of NPK recorded least fruit weight.

Increase in number of bunches plant⁻¹ may be attributed to zinc directly or indirectly being involved in fruit setting, retention and improved formation of bunches per plant. Zinc is also associated with photosynthesis, hormone metabolism which promotes synthesis of auxin, which is necessary for fruit set and fruit growth. Similar results were also reported by Sindhu *et al.* (1994) who noticed increased number of bunches plant⁻¹ in Perlette grapes due to foliar spray of ZnSO₄ @ 0.5 per cent. Foliar application of ZnSO₄ @ 0.30 per cent along with recommended dose of fertilizer significantly increased the number of bunches plant⁻¹ in Bangalore blue grapes (Asha, 2006).

More number of berries bunch⁻¹ might be attributed to higher photosynthetic activity, biomass production in the vine, which might have resulted in the accumulation of more metabolites in the vine. As the growth and development of the berries advanced large amount of water and other metabolites move into the berries, there by the development of berries. The findings are in agreement with Ravi kumar *et al.* (1988), Asha (2006) and Aydin *et al.* (2007).

Increase in the mean weight of berries might be due to cell division in the initial stages and later cell expansion associated with the movement of water and other metabolites into the cell causing increase in overall weight of the berry (Ahmed *et al.*, 1997). The results are in agreement with the findings of Daulta *et al.* (1983) in beauty seedless grapes, Dhillon and Bindra (1995) in Perlette grapes and Ashoori *et al.* (2013).

The increase in weight of bunch by spraying of zinc along with recommended dose of NPK may be due to, role of zinc in photosynthetic activity, starch formation and carbohydrate metabolism in the vine and faster loading and mobilization of photo assimilates in fruits and involvement in cell division and cell expansion which ultimately reflected in more weight of fruit. Zinc involve in hormonal metabolism, increase in cell division and expansion of cell wall and it also helps in regulating the semi permeability of cell walls, thus mobilizing more water into fruits resulting in increase of fruit weight (Singh *et al.*, 2010). Similar results were observed by Sindhu *et al.* (1994); Dhillon and Bindra (1995); Bacha *et al.* (1997); Asha (2006); Er *et al.* (2009); Bybordi *et al.* (2010) and Jagtap *et al.* (2013).

Table 9: Effect of foliar spray on yield parameters of grapes as influenced by sources and levels of zinc

Treatments	Number of bunches plant ⁻¹			Number of berries bunch ⁻¹			Mean weight of berries bunch ⁻¹ (g)			Weight of bunch (g)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	52.78	55.09	53.94	56.93	63.64	60.29	469.24	479.82	474.53	481.33	490.16	485.75
2	53.95	56.48	55.22	63.70	70.59	67.15	469.86	480.23	475.05	482.05	491.10	486.58
3	55.87	58.61	57.24	71.78	79.65	75.72	487.55	500.39	493.97	499.77	510.45	505.11
4	52.83	55.23	54.03	59.89	66.61	63.25	469.37	479.94	474.66	481.52	490.51	486.02
5	53.24	56.08	54.66	64.08	71.43	67.76	470.54	481.03	475.79	482.71	492.00	487.36
6	55.69	58.79	57.24	69.73	77.71	73.72	486.63	499.11	492.87	499.05	509.73	504.39
7	58.71	62.05	60.38	77.90	87.25	82.58	508.54	522.23	515.39	520.30	533.07	526.69
8	62.04	65.87	63.96	86.71	98.80	92.76	537.68	551.05	544.37	547.43	562.69	555.06
9	52.91	55.51	54.21	63.38	70.53	66.96	469.50	480.19	474.85	481.72	490.90	486.31
10	55.80	59.14	57.47	71.31	79.60	75.46	487.14	500.07	493.61	499.37	510.45	504.91
11	58.95	62.95	60.95	79.59	89.91	84.75	509.31	523.23	516.27	521.25	534.77	528.01
12	62.30	66.90	64.60	88.72	102.40	95.56	538.50	551.78	545.14	548.86	565.19	557.03
13	65.93	71.07	68.50	98.05	116.23	107.14	574.39	587.53	580.96	582.03	600.30	591.17
14	52.89	55.40	54.15	62.21	69.39	65.80	469.48	480.11	474.80	481.67	490.75	486.21
15	55.72	58.93	57.33	69.95	78.25	74.10	486.89	499.27	493.08	499.13	510.13	504.63
16	58.83	62.57	60.70	78.14	88.33	83.24	508.95	522.69	515.82	520.72	533.86	527.29
17	62.17	66.39	64.28	87.03	100.52	93.78	537.84	551.33	544.59	548.10	563.95	556.03
18	65.70	70.40	68.05	96.12	114.05	105.09	573.14	586.28	579.71	580.89	598.67	589.78
19	55.91	58.85	57.38	72.33	79.73	76.03	488.27	500.51	494.39	501.05	512.04	506.55
20	56.05	59.20	57.63	73.09	80.58	76.84	489.06	501.04	495.05	501.93	513.83	507.88
SEm ±	0.81	0.89	0.79	1.91	2.12	1.98	5.46	6.181	4.75	5.56	6.09	5.63
CD @ 5 %	2.31	2.55	2.26	5.47	6.07	5.66	15.62	17.69	13.59	15.9	17.43	16.12

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.1.3 Effect of foliar spray on yield of grapes as influenced by sources and levels of zinc

The data pertaining to fruit yield of grapes as influenced by the spraying of different sources and levels of zinc along with recommended dose of NPK are presented in Table 10.

4.1.3.1 Yield (kg plant⁻¹)

Grape yield was significantly higher in treatment T₁₃ (38.87 kg plant⁻¹) which received zinc @ 0.150 per cent as zinc metalosate compared to all other treatments and was on par with treatment T₁₈ which received 0.150 per cent of zinc through Zn-EDTA. Fruit yield recorded at 0.10 per cent zinc through zinc metalosate and Zn-EDTA was on par with 0.150 per cent zinc as zinc sulphate. Non significant difference was recorded between treatment T₁₁ (0.50 per cent Zn through zinc metalosate) T₁₆ (0.50 per cent zinc through Zn-EDTA) and T₇ (0.10 per cent Zn through zinc sulphate). Zinc spray @ 0.010, 0.025 and 0.50 per cent as zinc sulphate and 0.010 and 0.250 per cent as zinc metalosate and Zn-EDTA recorded lesser yield compared to control (T₃). Soil application of zinc sulphate along with FYM recorded significantly higher fruit yield compared to without FYM application. The least fruit yield was recorded in treatment T₁ which received only NPK compared to all treatments (Figure 1).

4.1.3.2 Yield (t ha⁻¹)

Foliar application of zinc as zinc metalosate, Zn-EDTA and ZnSO₄ significantly increased the grapes yield ha⁻¹. Significantly higher yield was recorded in treatment T₁₃ (17.77 t ha⁻¹) which received 0.15 per cent zinc as zinc metalosate along with recommended NPK and was on par with treatment T₁₈ (17.35 t ha⁻¹) which received zinc @ 0.150 per cent as Zn-EDTA. Lower yield ha⁻¹ was recorded in treatment T₁ (11.93 t ha⁻¹).

The improvement in yield may be due to significant effect of the different sources of zinc on growth and yield parameters of grapes. Zinc metalosate is an amino acid chelated liquid zinc fertilizer it has smaller particle size, neutral charge and 100 per cent water soluble, hence it can slide through the cuticular pores without any barriers and once

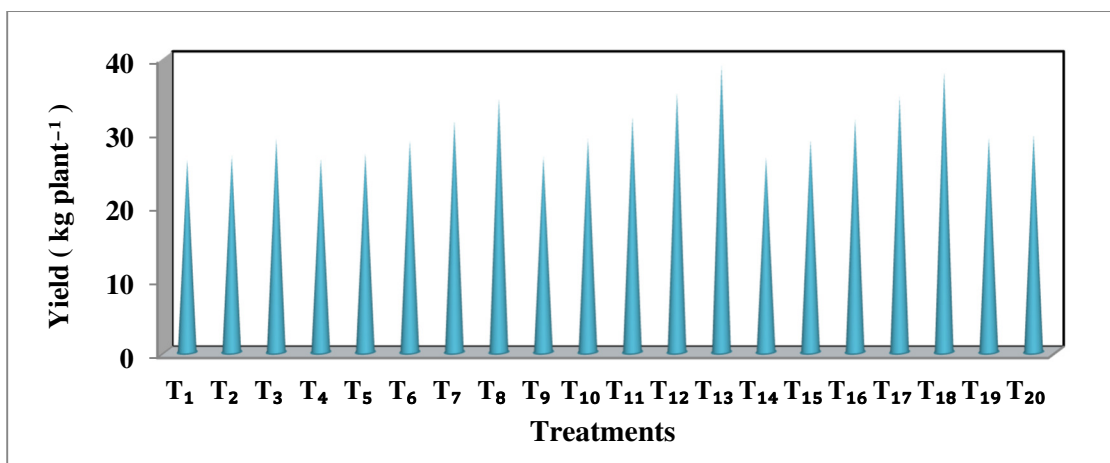


Fig.1: Effect of foliar spray on yield of grapes as influenced by sources and levels of zinc

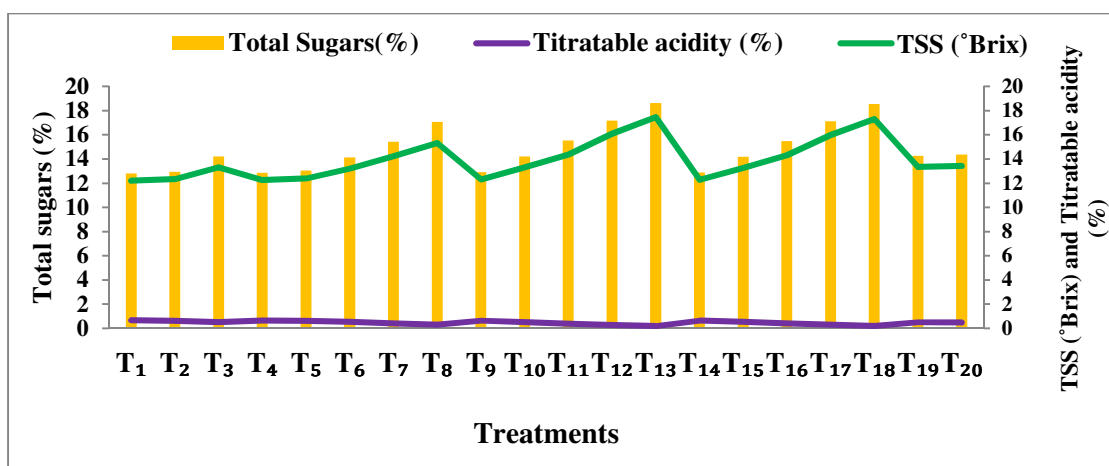


Fig.2: Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of zinc

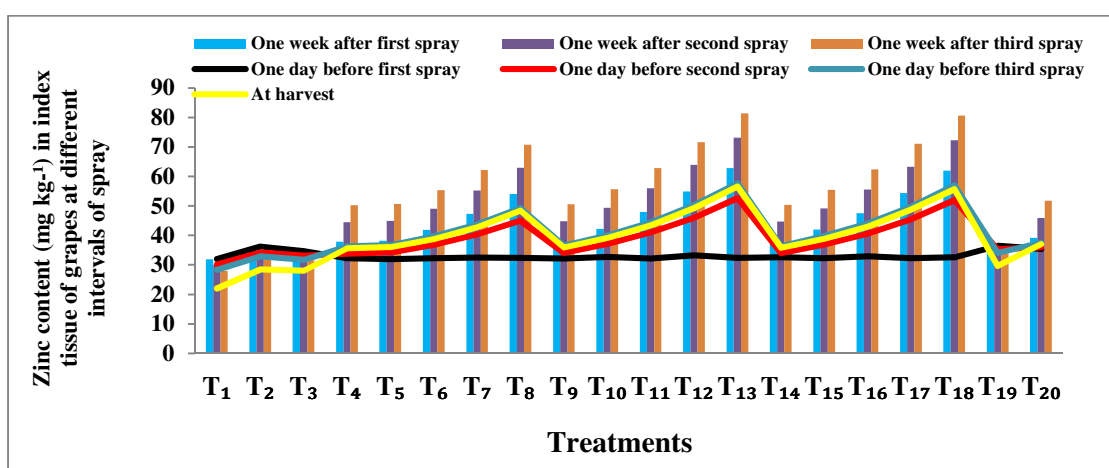


Fig. 3: Effect of foliar spray on zinc content (mg kg⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of zinc

this zinc enters, it is protected from adverse interactions on leaf surface by the amino acid ligands, hence it enhanced the nutrient availability for plant absorption and they are translocated within the plant similar to other small nitrogen containing molecules. When the chelated amino acid reaches the cell membrane, they are recognized by the mechanisms of absorption as a source of organic N. As a result, entire amino acid chelate is taken into the cell very rapidly and efficiently (Anonymous, 2000); Sekhon (2003). Similarly, Zn-EDTA is also chelated zinc fertilizer during chelation, positive charge of the metal ion is converted to neutral charge there by can also easily slide through the pores on the leaf surface rapidly. Chelates are more easily translocated within the plant as their action is partly systemic and are easily assimilated within the plant system which help in maintaining optimum level of zinc in plant system (Sekhon,2003). Nutrient translocation within the plant was much greater with chelates (Mireille and Andre, 1988). In zinc sulphate, due to its positive charge and higher ionic size it has some hinderence in moving to cuticular layers of the leaf hence it maintained lesser levels of zinc in plant compared to zinc metalosate and Zn-EDTA. Therefore the variations in these three sources in increasing the yield parameters and yield of grapes was observed. The enhanced zinc from these sources played vital role in activation of enzymes like dehydrogeneases, aldolases, isomerases, transphosphorylases, RNA and DNA polymerases and which are necessary for carbohydrate metabolism, protein synthesis and starch metabolism their by helped in production of photosynthates and mobilization of water and metabolities for fruit setting and helps in increasing number of berries and weight of bunch which in turn contributed for higher yield. Similar results were reported by Prabhu and Singaram (2002) in Muscat grapes, Sindhu *et al.* (1994) in Perlette grapes, Bacha *et al.* (1997) in Thompson seedless and Roomy Red grape, Ahmed *et al.* (1997) in red Roumy grapes, Sindhu *et al.* (2000), Asha (2006) in Bangalore blue grapes, Aydin *et al.* (2007) and Bybordi *et al.* (2010).

Table 10: Effect of foliar spray on yield of grapes as influenced by sources and levels of zinc

Treatments	Yield (kg plant ⁻¹)			Yield (t ha ⁻¹)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	25.37	26.85	26.11	11.59	12.27	11.93
2	25.90	27.46	26.68	11.84	12.55	12.20
3	28.08	29.83	28.96	12.83	13.63	13.23
4	25.52	27.05	26.29	11.66	12.36	12.01
5	26.11	27.76	26.94	11.93	12.69	12.31
6	27.83	29.59	28.71	12.72	13.52	13.12
7	30.45	32.45	31.45	13.92	14.83	14.38
8	33.29	35.50	34.40	15.21	16.22	15.72
9	25.74	27.36	26.55	11.76	12.50	12.13
10	28.02	29.91	28.97	12.81	13.67	13.24
11	30.79	33.04	31.92	14.07	15.10	14.59
12	33.83	36.55	35.19	15.46	16.70	16.08
13	37.30	40.43	38.87	17.05	18.48	17.77
14	25.65	27.23	26.44	11.72	12.44	12.08
15	27.90	29.71	28.81	12.75	13.58	13.17
16	30.63	32.65	31.64	14.00	14.92	14.46
17	33.55	35.84	34.70	15.33	16.38	15.86
18	36.72	39.20	37.96	16.78	17.91	17.35
19	28.23	30.07	29.15	12.90	13.74	13.32
20	28.61	30.52	29.57	13.07	13.95	13.51
SEm ±	0.55	0.59	0.55	0.27	0.28	0.27
CD @ 5 %	1.57	1.71	1.58	0.78	0.80	0.78

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

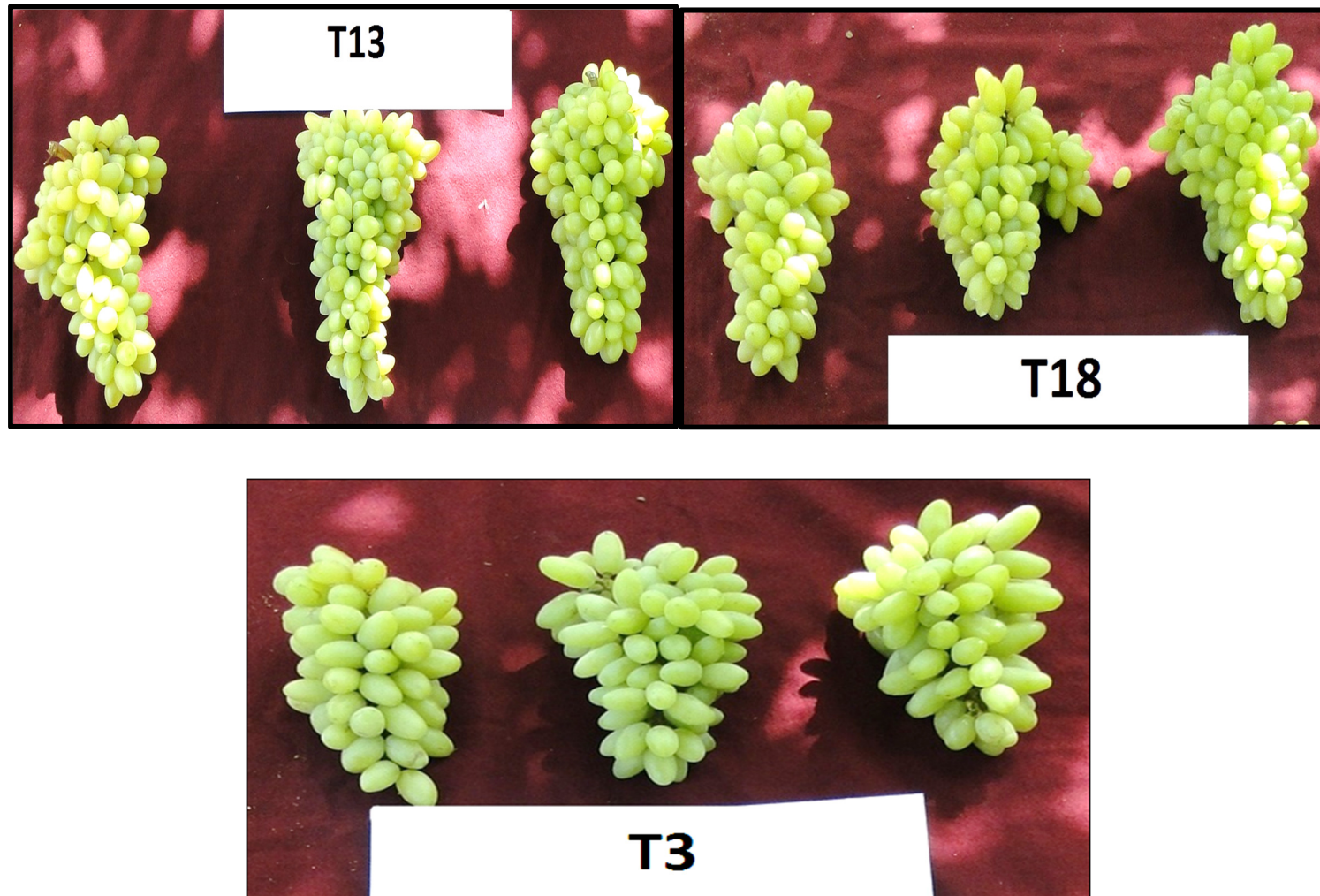


Plate 5: Effect of foliar spray on grape as influenced by sources and levels of zinc

4.1.4 Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of zinc

The data in respect of quality parameters of grapes *viz.*, total soluble solids, total sugars and titratable acidity as influenced by sources and levels of zinc is presented in Table 11 and Figure 2.

4.1.4.1 Total Soluble Solids (TSS)

Foliar application of zinc at higher levels *i.e.* 0.50(T₁₁: 14.39 ° Brix), 0.10 (T₁₂: 16.11° Brix) and 0.150 (T₁₃: 17.49° Brix) per cent through zinc metalosate significantly increased the total soluble solids compared to lower levels *viz.*, 0.010 (T₉: 12.33° Brix) and 0.025 (T₁₀ : 13.32 ° Brix) per cent over control (T₃: 13.33 ° Brix). Foliar spray of Zn-EDTA at lower levels *i.e.* 0.010 (12.29° Brix) and 0.025(13.26° Brix) per cent did not show any significant effect in increasing the TSS but at higher levels *viz.*, 0.05 (14.32° Brix) 0.10 (15.99° Brix) and 0.150 (17.32° Brix) per cent significantly enhanced the total soluble solids over control (T₃: 13.33 ° Brix).Application of Zinc @ 0.10 (14.24 ° Brix) and 0.150 (15.34 ° Brix) per cent as ZnSO₄ significantly increased TSS but was not at 0.010(12.26 ° Brix), 0.025(12.39 ° Brix) and 0.050(13.22 ° Brix) per cent level zinc as ZnSO₄. Among these treatments higher TSS was recorded in treatment T₁₃ (17.49 ° Brix) which received zinc @ 0.150 per cent zinc as metalosate and was on par with treatment T₁₈ (17.32 ° Brix) which received 0.150 per cent zinc as Zn-EDTA. Lower TSS was observed in treatment T₁ which received only NPK.

4.1.4.2 Total Sugars (%)

Total sugar content of grapes showed significant difference among treatments. Higher total sugar percentage was recorded in T₁₃ *i.e.* 0.150 per cent Zn which was supplied as zinc through zinc metalosate and was superior compared to all the treatments except treatment T₁₈ (Zn @ 0.150 % Zn through Zn-EDTA). The increased total sugar percentage in treatments T₁₂ (17.18 %) and T₁₇ (17.13 %) which received zinc @ 0.10 per cent as zinc metalosate and Zn-EDTA was on par with treatment T₈ (17.07 %) which consists of zinc @ 0.150 per cent through zinc sulphate.

4.1.4.3 Titratable Acidity (%)

Significant reduction in titratable acidity was recorded in treatment T₁₃ (0.19 %) which received zinc @ 0.150 per cent through zinc metalosate and was on par with treatment T₁₈ (0.20 %) which received zinc from Zn-EDTA @ 0.150 per cent. Titratable acidity recorded due to foliar spray of zinc @ 0.10 per cent as zinc metalosate was on par with zinc @ 0.150 per cent foliar spray as zinc sulphate. These three zinc sources viz., zinc metalosate, Zn-EDTA and ZnSO₄ were not effective in reducing titratable acidity at 0.010 and 0.025 per cent level compared to control (T₃: 0.52 %). Higher titratable acidity in grapes was noticed in treatment T₁(0.68 %) which received recommended dose of NPK.

Zinc is involved in synthesis of tryptophan that is a precursor of auxin, auxins help in mobilization of carbohydrate from source to sink which inturn increase TSS. Also zinc helps in increasing photosynthetic activity, accumulation of oligosaccharides and polysaccharides in higher amount in vine. Besides, this it also regulates the enzymatic activity and the enzymes that metabolize the carbohydrates into simple sugars (Kumar and Bhusan, 1980). Zinc is a component of molecular structure of enzymes carbonic anhydridease which involves in photosynthesis and cause increase in the level of soluble solids (TSS) (Marschner, 1995). Application of micronutrients may increase the mobilization of carbohydrates from source to sink. An association of zinc with synthesis of auxins in plants played a vital role in increasing enzymatic activities. This leads the biochemical reactions including conversion of complex food *i.e.* starch into simple sugars. The decrease in acidity may be due to increase in the total soluble solids and total sugars and it is also because of zinc which might have either involved in fast conversion of metabolitites into sugars and their derivatives by the reaction involving reversal of glycolytic pathway (Ruffiner *et al.*, 1975). These findings are supported by Alekperov (1985); Langthasa and Bhattacharyya (1991) and Kumari *et al.* (2009).

Table 11: Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of zinc

Treatments	TSS (° Brix)			Total Sugars (%)			Titratable Acidity (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	12.17	12.23	12.20	12.80	12.85	12.82	0.69	0.66	0.68
2	12.28	12.42	12.35	12.89	13.01	12.95	0.64	0.62	0.63
3	13.13	13.53	13.33	14.18	14.25	14.22	0.53	0.51	0.52
4	12.20	12.31	12.26	12.83	12.89	12.86	0.67	0.64	0.66
5	12.29	12.49	12.39	13.04	13.05	13.05	0.63	0.61	0.62
6	13.06	13.38	13.22	14.11	14.15	14.13	0.57	0.54	0.55
7	13.95	14.53	14.24	15.36	15.52	15.44	0.44	0.40	0.42
8	14.88	15.80	15.34	17.03	17.10	17.07	0.31	0.28	0.30
9	12.27	12.39	12.33	12.88	12.95	12.92	0.65	0.63	0.64
10	13.13	13.50	13.32	14.19	14.22	14.21	0.53	0.51	0.52
11	14.05	14.72	14.39	15.45	15.63	15.54	0.38	0.35	0.37
12	15.98	16.23	16.11	17.14	17.22	17.18	0.29	0.26	0.28
13	17.12	17.85	17.49	18.40	18.89	18.64	0.20	0.18	0.19
14	12.23	12.35	12.29	12.87	12.93	12.90	0.66	0.63	0.65
15	13.10	13.42	13.26	14.16	14.19	14.18	0.55	0.52	0.54
16	14.02	14.61	14.32	15.41	15.57	15.49	0.41	0.38	0.40
17	15.93	16.05	15.99	17.10	17.15	17.13	0.30	0.27	0.29
18	17.05	17.58	17.32	18.33	18.78	18.56	0.21	0.19	0.20
19	13.15	13.57	13.36	14.21	14.30	14.26	0.52	0.49	0.51
20	13.17	13.66	13.42	14.30	14.42	14.36	0.50	0.46	0.48
SEm ±	0.26	0.28	0.26	0.33	0.34	0.32	0.02	0.02	0.02
CD @ 5 %	0.74	0.80	0.76	0.93	0.98	0.91	0.05	0.06	0.05

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.1.5 Effect of sources and levels of zinc on nutrient content of index tissue of grapes before foliar spray

The data on macro, secondary and micronutrient content in the index tissue (*i.e.* 5th petiole) before spray of zinc are presented in the Table 12, 13 and 14.

It was found that there was a non significant difference among the treatments. The total nitrogen, phosphorus and potassium content recorded in the index tissue *i.e.* 5th petiole varied from 1.57 to 1.76, 0.61 to 0.72 and 2.07 to 2.26 per cent, respectively. Whereas the secondary nutrients calcium, magnesium and sulphur content were recorded in the range of 1.33 to 1.46, 0.52 to 0.61 and 0.47 to 0.60 per cent, respectively. Micronutrients recorded 120.21 to 132.58 mg kg⁻¹ iron, 11.19 to 12.19 mg kg⁻¹ copper, 81.04 to 86.61 mg kg⁻¹ manganese and 20.51 to 24.22 mg kg⁻¹ boron in index tissue.

4.1.6 Effect of foliar spray on zinc content (mg kg⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of zinc

The results of zinc content in the index tissue as influenced by different sources and levels of zinc foliar spray at critical growth stages of grapes is presented in Table 15,16 and Figure 3.

4.1.6.1 One day before first spray

Zinc content in the index tissue one day before first spray ranged from 31.91 to 36.53 mg kg⁻¹. Treatment T₁₉ which consists of soil application of zinc sulphate and farm yard manure recorded numerically higher zinc content in index tissue (36.53 mg kg⁻¹) and no statistical significance among the treatments was observed.

4.1.6.2 One week after first spray

Significant improvement in the zinc content in the index tissue was recorded due to foliar application of zinc as zinc metalosate, Zn-EDTA and ZnSO₄, the zinc content ranged from 31.91 to 62.79 mg kg⁻¹. Significantly, higher zinc content in index tissue was recorded in treatment T₁₃ (62.79 mg kg⁻¹) which received zinc @ 0.150 per cent as zinc metalosate as compared to other treatments and was on par with T₁₈ treatment (61.92 mg kg⁻¹). Zinc content in the index tissue in treatment T₁₂ which received zinc @ 0.10 per cent as zinc metalosate foliar spray was on par with treatment T₁₇ (54.31 mg kg⁻¹) and T₈

(53.98 mg kg⁻¹) which received zinc @ 0.10 and 0.150 per cent as Zn-EDTA and ZnSO₄, respectively. Similarly, the zinc content recorded in treatment T₁₁ which consists of zinc @ 0.050 per cent as zinc metalosate was on par with treatment T₁₆ (47.55 mg kg⁻¹) and T₇ (47.34 mg kg⁻¹) which received 0.050 and 0.10 per cent zinc as Zn-EDTA and ZnSO₄, respectively. Lower zinc content of 31.91 mg kg⁻¹(T₁) was recorded in treatment where zinc was not applied.

4.1.6.3 One day before second spray

One day before second spray significant reduction in the zinc content in the index was recorded compared to one week after first spray but values were more than at one day before first spray. Significantly higher content of zinc in the index tissue was noticed in the treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate and was on par with treatment T₁₈ which received zinc @ 0.150 per cent as Zn-EDTA followed by treatment T₁₂ which consisted of zinc @ 0.10 per cent as zinc metalosate which was on par with treatment T₁₇ (45.49 mg kg⁻¹) and T₈ (45.08 mg kg⁻¹) which received foliar spray of zinc through Zn-EDTA and ZnSO₄ @ 0.10 and 0.150 per cent. In treatment T₁ which consists of only recommended dose of NPK, less zinc was observed in the index tissue (T₁: 30.24 mg kg⁻¹).

4.1.6.4 One week after second spray

Foliar application of zinc as zinc metalosate, Zn-EDTA and ZnSO₄ sources significantly increased the zinc content in index tissue one week after second spray and it ranged from 30.04 to 73.14 mg kg⁻¹. Among different treatments, treatment T₁₃ which received 0.150 per cent zinc as zinc metalosate recorded significantly higher zinc content (73.14 mg kg⁻¹) but was on par with treatments which received zinc @ 0.150 per cent as Zn-EDTA (72.29 mg kg⁻¹). Zinc content in treatment T₁₂ which received zinc @ 0.10 per cent was on par with treatment T₁₇ (63.28 mg kg⁻¹) and T₈ (62.90 mg kg⁻¹) which received zinc @ 0.10 and 0.150 per cent as Zn-EDTA and ZnSO₄, respectively. Foliar addition of zinc @ 0.010 and 0.025 per cent did not influence zinc content in the index tissue, compared to other zinc sources (Zinc metalosate, Zn-EDTA and ZnSO₄) at different levels.

4.1.6.5 One day before third spray

One day before third spray zinc content in the index tissue recorded in the range of 28.32 to 57.76 mg kg⁻¹. Among the treatments significantly higher zinc content was recorded in the index tissue at one day before third spray in treatment T₁₃ (57.76 mg kg⁻¹) which consists of zinc @ 0.150 per cent as zinc metalosate and was on par with 0.150 per cent Zn-EDTA was followed by the treatment which had zinc @ 0.10 per cent as zinc metalosate, which was on par with 0.10 (T₁₇: 49.78 mg kg⁻¹) and 0.150 (T₈: 49.33 mg kg⁻¹) per cent zinc as Zn-EDTA and zinc sulphate. Lower zinc content of about 28.32 mg kg⁻¹ was recorded in treatment T₁.

4.1.6.6 One week after third spray

One week after third spray about 27.99 to 81.42 mg kg⁻¹ of zinc was recorded in the index tissue and its content was maximum in treatment T₁₃ (81.42 mg kg⁻¹) compared to other treatments and was on par with T₁₈ treatment (80.60 mg kg⁻¹) which received zinc @ 0.150 per cent as Zn-EDTA followed by treatment T₁₂ which consists of 0.10 per cent zinc metalosate which is on par with treatment T₁₇ (71.03 mg kg⁻¹) and T₈ (70.75 mg kg⁻¹) Zn-EDTA and ZnSO₄ @ 0.10 and 0.150 per cent. Lower zinc was recorded in T₁ treatment (27.99 mg kg⁻¹) where, zinc was not applied.

4.1.6.7 At harvest

At harvest stage significant reduction in zinc content in index tissue was observed and minimum zinc content was recorded in treatment T₁ (22.07 mg kg⁻¹) which did not receive any zinc. Higher zinc content of 56.54 mg kg⁻¹ was recorded in treatment T₁₃ which received the zinc @ 0.150 per cent zinc as zinc metalosate and was on par with treatment T₁₈ (55.69 mg kg⁻¹) which received zinc @ 0.150 per cent zinc as Zn-EDTA. Zinc content in the index tissue was numerically higher in soil application of ZnSO₄ + FYM compared to soil application of zinc sulphate alone.

Significant increase in zinc content in index tissue one week after first spray, second spray and third spray may be due to continuous supply of the zinc to the plant through foliar spray from zinc metalosate, Zn-EDTA and ZnSO₄ sources. Among treatments higher zinc content in index tissue in T₁₃ and T₁₈ treatments which received zinc @ 0.150 per cent as zinc metalosate and Zn-EDTA, respectively might be due to

zinc metalosate is being an amino acid chelate, which contains 6.8 per cent zinc and is hundred per cent soluble in water, it has smaller particle size and neutral charge, hence it is neither attracted nor repulsed from negatively charged surfaces of the leaf, hence entire amino acid chelated zinc can easily and quickly pass through the cuticular layer of leaf very rapidly and efficiently. Hence, zinc metalosate play vital role in maintaining optimum level of zinc in the plant throughout the growing period of crop (Sekhon, 2003). Metalosate zinc was able to move through the leaves and into xylem of the grape vine very quickly and efficiently and thereby its translocation to the desired areas of the plant without causing phytotoxicity (Kirkpatrick, 2003). Similarly, in apple, cherry and peaches a significant increase in the zinc concentration in leaf was observed due to zinc metalosate spray compared to zinc sulphate spray (Anonymous, 2001).

Similarly, Zn-EDTA is also chelated zinc, chelation process removes the positive charge from the micronutrients allowing the neutral or slightly negatively charged chelates to pass through the pores of the leaf more rapidly. Chelates are more easily translocated within the plants as their action is partly systemic and easily assimilated within the plant system, the chances of scorching is less because they are organic substances and are compatible with a wide variety of pesticide and donot react with their components (Sekhon, 2003). Zinc sulphate also played major role in increasing the zinc content in the petiole but its efficiency was lesser than zinc metalosate and Zn-EDTA because zinc sulphate is a positively charged inorganic salt, since the pores of leaf are negatively charged, positively charged micronutrients would normally be fixed at the pore entrance and would be difficult to be assimilated by plants (Sekhon, 2003). Hence variations were observed among these sources of zinc.

Similarly an increase in leaf zinc concentration due to foliar application of zinc was observed by Dhillon and Bindra (1995), Asha (2006) in grapes, Yadav (2008) in sweet orange cv.Jaffa and Rasouli *et al.* (2002) in apple.

However, one day before second and third spray and at harvest there was a significant reduction in the zinc content in the index tissue compared to one week after first, second and third spray, this might be due to active utilization of increased concentrations of zinc for various metabolic activities of the plant for proper growth and development of plant which intern helped to produce good crop yield and quality.

Table 12: Effect of sources and levels of zinc on macro nutrient content (%) of index tissue of grapes before foliar spray

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.55	1.60	1.58	0.62	0.63	0.63	2.05	2.11	2.08
2	1.58	1.61	1.59	0.65	0.64	0.65	2.10	2.14	2.12
3	1.65	1.78	1.71	0.69	0.75	0.72	2.14	2.31	2.22
4	1.58	1.60	1.59	0.61	0.72	0.67	2.05	2.13	2.09
5	1.55	1.62	1.59	0.58	0.74	0.66	2.04	2.15	2.09
6	1.54	1.65	1.60	0.59	0.67	0.63	2.01	2.18	2.10
7	1.55	1.68	1.62	0.57	0.69	0.63	2.07	2.21	2.14
8	1.56	1.72	1.64	0.58	0.72	0.65	2.03	2.25	2.14
9	1.53	1.61	1.57	0.57	0.74	0.66	2.05	2.14	2.10
10	1.55	1.66	1.61	0.59	0.67	0.63	2.06	2.18	2.12
11	1.57	1.70	1.64	0.61	0.70	0.66	2.00	2.23	2.12
12	1.55	1.73	1.64	0.58	0.64	0.61	2.03	2.26	2.15
13	1.57	1.76	1.67	0.62	0.65	0.64	2.07	2.29	2.18
14	1.53	1.60	1.57	0.59	0.64	0.62	2.01	2.13	2.07
15	1.55	1.66	1.61	0.61	0.67	0.64	2.00	2.18	2.09
16	1.54	1.69	1.62	0.60	0.69	0.65	2.04	2.22	2.13
17	1.56	1.72	1.64	0.58	0.71	0.65	2.05	2.25	2.15
18	1.58	1.75	1.67	0.61	0.64	0.63	2.07	2.28	2.18
19	1.69	1.83	1.76	0.65	0.77	0.71	2.19	2.33	2.26
20	1.64	1.80	1.72	0.62	0.75	0.69	2.15	2.30	2.23
SEm ±	0.06	0.09	0.06	0.05	0.05	0.04	0.07	0.08	0.07
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 13: Effect of sources and levels of zinc on secondary nutrient content (%) of index tissue of grapes before foliar spray

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.34	1.35	1.34	0.53	0.50	0.52	0.46	0.47	0.47
2	1.39	1.40	1.40	0.56	0.57	0.56	0.55	0.48	0.51
3	1.44	1.45	1.44	0.59	0.60	0.60	0.53	0.60	0.57
4	1.35	1.36	1.35	0.50	0.54	0.52	0.47	0.47	0.47
5	1.30	1.40	1.35	0.52	0.57	0.55	0.48	0.48	0.48
6	1.32	1.42	1.37	0.50	0.58	0.54	0.51	0.50	0.51
7	1.33	1.45	1.39	0.54	0.61	0.58	0.46	0.52	0.49
8	1.31	1.47	1.39	0.53	0.63	0.58	0.50	0.56	0.53
9	1.34	1.35	1.34	0.50	0.55	0.53	0.46	0.47	0.47
10	1.30	1.43	1.37	0.54	0.59	0.57	0.47	0.50	0.49
11	1.31	1.47	1.39	0.52	0.62	0.57	0.49	0.54	0.52
12	1.30	1.49	1.40	0.54	0.64	0.59	0.48	0.57	0.53
13	1.32	1.51	1.41	0.50	0.66	0.58	0.51	0.60	0.56
14	1.30	1.36	1.33	0.53	0.54	0.54	0.47	0.47	0.47
15	1.31	1.42	1.37	0.51	0.58	0.55	0.46	0.50	0.48
16	1.34	1.46	1.40	0.50	0.62	0.56	0.49	0.53	0.51
17	1.32	1.48	1.40	0.52	0.63	0.58	0.48	0.57	0.53
18	1.30	1.51	1.41	0.54	0.65	0.60	0.51	0.59	0.55
19	1.45	1.46	1.46	0.61	0.61	0.61	0.56	0.64	0.60
20	1.43	1.48	1.46	0.60	0.62	0.61	0.53	0.61	0.57
SEm ±	0.06	0.06	0.06	0.04	0.06	0.04	0.04	0.06	0.05
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 14: Effect of sources and levels of zinc on micronutrient content (mg kg⁻¹) of index tissue of grapes before foliar spray

Treatments	Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	122.02	121.90	121.96	11.22	11.15	11.19	81.25	81.17	81.21	20.56	20.47	20.51
2	124.47	123.10	123.79	11.31	11.47	11.39	82.67	81.90	82.29	23.37	22.04	22.70
3	128.54	133.55	131.04	11.04	12.06	11.55	84.80	86.55	85.68	23.99	23.95	23.97
4	121.62	123.03	122.33	11.29	11.42	11.36	81.81	81.86	81.84	21.27	21.39	21.33
5	119.84	123.36	121.60	11.32	11.61	11.47	80.26	82.03	81.15	20.55	22.10	21.33
6	116.67	123.75	120.21	11.40	11.75	11.58	80.79	82.37	81.58	22.21	22.47	22.34
7	120.34	124.63	122.49	11.45	12.06	11.76	80.87	82.92	81.90	21.24	22.82	22.03
8	119.80	126.07	122.94	11.37	12.47	11.92	80.15	83.60	81.88	20.96	23.13	22.05
9	120.33	123.25	121.79	11.31	11.55	11.43	80.03	82.05	81.04	21.35	21.72	21.54
10	117.66	124.06	120.86	11.35	11.96	11.66	80.68	82.66	81.67	20.87	22.65	21.76
11	119.28	125.19	122.24	11.20	12.27	11.74	80.26	83.23	81.75	21.94	23.04	22.49
12	120.40	126.30	123.35	11.39	12.76	12.08	81.13	83.90	82.52	21.63	23.42	22.53
13	123.94	127.43	125.69	11.27	13.14	12.21	82.22	84.21	83.22	21.52	23.57	22.55
14	120.57	123.14	121.86	11.30	11.49	11.40	80.71	81.97	81.34	21.49	21.61	21.55
15	122.81	123.89	123.35	11.33	11.84	11.59	81.15	82.53	81.84	20.37	22.50	21.44
16	120.92	125.05	122.99	11.28	12.15	11.72	82.26	83.04	82.65	21.20	22.91	22.06
17	123.28	126.67	124.98	11.37	12.61	11.99	81.48	83.71	82.60	22.64	23.28	22.96
18	120.10	127.12	123.61	11.35	13.03	12.19	80.59	84.10	82.35	22.10	23.43	22.77
19	129.37	135.78	132.58	11.05	12.44	11.75	85.95	87.27	86.61	24.18	24.26	24.22
20	128.22	133.91	131.07	11.09	12.25	11.67	83.87	86.90	85.39	23.91	24.07	23.99
SEm ±	4.75	4.76	3.53	0.24	0.70	0.43	2.16	2.20	1.94	1.32	1.35	1.05
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 15: Effect of foliar spray on zinc content (mg kg⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of zinc

Treatments	One day before first spray			One week after first spray			One day before second spray			One week after second spray		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	32.61	31.54	32.07	32.55	31.27	31.91	30.37	30.10	30.24	30.12	29.95	30.04
2	36.18	36.42	36.30	35.83	36.11	35.97	32.78	35.78	34.28	32.65	35.69	34.17
3	34.47	35.13	34.80	34.20	34.00	34.10	32.56	33.81	33.19	32.49	33.74	33.12
4	31.50	33.09	32.30	36.07	39.68	37.88	32.41	35.29	33.85	42.79	46.27	44.53
5	30.54	33.28	31.91	36.35	40.03	38.19	32.78	35.73	34.26	43.17	46.73	44.95
6	31.12	33.41	32.27	39.76	43.97	41.87	35.13	38.57	36.85	47.11	50.92	49.02
7	31.29	33.60	32.45	44.79	49.88	47.34	38.15	42.61	40.38	53.04	57.50	55.27
8	30.98	33.83	32.40	51.03	56.93	53.98	42.29	47.87	45.08	60.13	65.67	62.90
9	31.10	33.20	32.15	36.27	39.97	38.12	32.67	35.55	34.11	43.05	46.53	44.79
10	31.89	33.51	32.70	40.08	44.31	42.20	35.51	38.89	37.20	47.41	51.34	49.38
11	30.55	33.75	32.15	45.30	50.69	48.00	38.75	43.31	41.03	53.62	58.25	55.94
12	32.46	33.98	33.22	51.84	58.03	54.94	43.22	48.85	46.04	61.03	66.70	63.87
13	30.79	34.05	32.42	59.23	66.35	62.79	49.34	56.07	52.71	70.00	76.27	73.14
14	32.18	33.12	32.65	36.15	39.80	37.98	32.55	35.42	33.99	42.91	46.40	44.66
15	31.20	33.45	32.33	39.87	44.00	41.94	35.27	38.67	36.97	47.16	51.05	49.11
16	32.22	33.68	32.95	44.96	50.13	47.55	38.40	42.88	40.64	53.23	57.78	55.51
17	30.64	33.91	32.28	51.29	57.32	54.31	42.71	48.27	45.49	60.48	66.07	63.28
18	31.18	34.12	32.65	58.42	65.41	61.92	48.67	55.35	52.01	69.09	75.48	72.29
19	36.21	36.85	36.53	36.19	36.69	36.44	34.59	36.02	35.31	34.47	35.90	35.19
20	35.23	35.64	35.44	37.06	41.25	39.16	35.00	36.98	35.99	44.56	47.13	45.85
SEm ±	1.44	0.89	1.07	1.17	1.36	1.21	0.81	0.98	0.84	1.36	1.43	1.31
CD @ 5 %	NS	NS	NS	3.35	3.90	3.48	2.31	2.79	2.42	3.89	4.10	3.75

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 16: Effect of foliar spray on zinc content (mg kg⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of zinc

Treatments	One day before third spray			One week after third spray			Harvest		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	28.73	27.90	28.32	28.10	27.87	27.99	24.03	20.10	22.07
2	30.81	35.05	32.93	30.74	34.96	32.85	27.75	29.31	28.53
3	30.62	32.96	31.79	30.25	32.90	31.58	27.09	28.97	28.03
4	34.89	37.71	36.30	49.33	51.04	50.19	33.30	38.03	35.67
5	35.30	38.20	36.75	49.79	51.60	50.70	33.71	38.52	36.12
6	38.21	41.37	39.79	53.90	56.79	55.35	36.19	41.49	38.84
7	42.00	45.51	43.76	60.03	64.25	62.14	39.73	45.97	42.85
8	47.05	51.60	49.33	68.15	73.34	70.75	44.78	52.09	48.44
9	35.18	37.96	36.57	49.66	51.41	50.54	33.59	38.33	35.96
10	38.55	41.73	40.14	54.29	57.12	55.71	36.50	41.94	39.22
11	42.73	46.19	44.46	60.62	64.93	62.78	40.26	46.70	43.48
12	48.09	52.50	50.30	68.97	74.25	71.61	45.51	53.09	49.30
13	55.38	60.13	57.76	78.23	84.60	81.42	51.88	61.19	56.54
14	35.05	37.84	36.45	49.49	51.23	50.36	33.47	38.15	35.81
15	38.34	41.47	39.91	54.00	56.81	55.41	36.30	41.60	38.95
16	42.40	45.79	44.10	60.21	64.48	62.35	39.91	46.23	43.07
17	47.59	51.96	49.78	68.40	73.65	71.03	44.96	52.49	48.73
18	54.71	59.41	57.06	77.46	83.74	80.60	51.12	60.26	55.69
19	33.18	35.12	34.15	32.97	34.95	33.96	29.25	30.03	29.64
20	36.25	39.03	37.64	51.23	52.27	51.75	35.10	39.10	37.10
SEm ±	1.00	1.07	0.99	1.39	1.74	1.52	0.85	1.03	0.93
CD @ 5 %	2.85	3.06	2.85	3.99	4.97	4.35	2.44	2.95	2.65

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.1.7 Effect of foliar spray on nutrient content of grapes as influenced by sources and levels of zinc

Data pertaining to nutrients content of grape as affected by foliar application of different levels and sources of zinc has been presented in Table 17, 18 and 19.

4.1.7.1 Effect of foliar spray on macronutrient content (%) of grapes as influenced by sources and levels of zinc

The macro nutrient content in grapes as influenced by foliar spray of different sources and levels of zinc (Table. 17 and Figure 4).

The content of nitrogen in grapes varied from 1.00 to 1.74 per cent and the phosphorus content varied from 0.11 to 0.26 per cent whereas potassium ranged from 1.14 to 1.89 percent. Among the treatments both zinc metalosate and Zn-EDTA showed similar effect in increasing the nitrogen content in fruit compared to zinc sulphate. Significantly higher fruit nitrogen content was recorded in treatment T₁₃ (1.74 %) which received zinc @ 0.150 per cent as zinc metalosate compared to other treatments and it was on par with treatment T₁₈ (1.68 %) which received 0.150 per cent zinc through Zn-EDTA. The least nitrogen content in grapes was recorded in T₁ (1.00 %).

Foliar spray of different levels of zinc as different sources, did not show any significant effect in increasing fruit phosphorus content, with increasing zinc levels there was a decrease in phosphorus concentration in grapes. Among the treatments significant improvement in phosphorus content of grapes was observed in treatment T₃ (0.26 %) which received recommended dose of NPK along with farm yard manure.

Potassium content in grapes varied from 1.14 to 1.89 per cent and significantly higher potassium was recorded in treatment T₁₃ (1.89 %) which received zinc @ 0.150 per cent as zinc metalosate along with recommended NPK which was on par with the treatment which received 0.150 per cent zinc as Zn-EDTA (T₁₈: 1.84 %). In treatment T₁ (1.14 %) which received recommended dose of NPK, least potassium content was recorded in grapes.

Table 17: Effect of foliar spray on macronutrient content (%) of grapes as influenced by sources and levels of zinc

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.98	1.02	1.00	0.22	0.23	0.23	1.10	1.17	1.14
2	1.00	1.07	1.04	0.21	0.22	0.22	1.12	1.19	1.16
3	1.11	1.18	1.15	0.25	0.27	0.26	1.23	1.30	1.27
4	0.98	1.02	1.00	0.21	0.22	0.22	1.11	1.18	1.14
5	1.03	1.09	1.06	0.19	0.21	0.20	1.14	1.23	1.18
6	1.12	1.20	1.16	0.18	0.19	0.19	1.25	1.36	1.31
7	1.24	1.37	1.31	0.15	0.17	0.16	1.39	1.51	1.45
8	1.39	1.58	1.48	0.12	0.14	0.13	1.55	1.67	1.61
9	1.00	1.06	1.03	0.17	0.20	0.19	1.12	1.19	1.16
10	1.11	1.18	1.15	0.16	0.18	0.17	1.24	1.32	1.28
11	1.27	1.41	1.34	0.15	0.17	0.16	1.43	1.49	1.46
12	1.46	1.65	1.56	0.12	0.14	0.13	1.63	1.72	1.68
13	1.63	1.84	1.74	0.10	0.11	0.11	1.81	1.97	1.89
14	0.99	1.05	1.02	0.19	0.21	0.20	1.12	1.18	1.15
15	1.10	1.16	1.13	0.18	0.20	0.19	1.23	1.31	1.27
16	1.25	1.38	1.32	0.16	0.18	0.17	1.40	1.47	1.44
17	1.42	1.61	1.52	0.13	0.15	0.14	1.59	1.68	1.64
18	1.58	1.78	1.68	0.11	0.12	0.12	1.76	1.91	1.84
19	1.13	1.20	1.17	0.24	0.26	0.25	1.24	1.32	1.28
20	1.16	1.25	1.21	0.22	0.24	0.23	1.27	1.37	1.32
SEm ±	0.03	0.04	0.03	0.01	0.01	0.01	0.03	0.04	0.04
CD @ 5 %	0.09	0.11	0.10	0.02	0.03	0.23	0.10	0.13	0.11

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Foliar application of different sources of zinc along with recommended dose of NPK helped in increasing nitrogen and potassium concentration in index tissue due to synergistic effect between the zinc, nitrogen and potassium, which helped in better uptake, translocation, assimilation and accumulation of nutrients in the economic part of the plant (Dhillon and Bindra, 1995). Similar supportive results were obtained by Bybordi *et al.* (2010) and Hamouda *et al.* (2016).

Due to antagonistic effect between zinc and phosphorus, zinc did not increase the phosphorus content in fruit. But application of FYM along with recommended dose of NPK significantly increased phosphorous content of grapes which may be due to increased availability of phosphorus for plant uptake because organic acids released during decomposition of FYM have leads to release of phosphorus in soil, hence contributed to increase phosphorus content of grapes. These observations conform to those of Bybordi *et al.* (2010).

4.1.7.2 Effect of foliar spray on secondary nutrient content (%) of grapes as influenced by sources and levels of zinc

The data on Ca, Mg and S content of grapes as influenced by sources and levels of zinc are presented in Table 18.

Sulphur content in grapes increased with foliar spray of zinc and recorded significantly higher zinc in treatment T₁₃ (0.52 %) which received zinc @ 0.150 per cent as zinc metalosate followed by treatment T₁₈ (0.47 %) which received zinc @ 0.150 per cent as Zn-EDTA. The treatment T₁ which received recommended NPK recorded lower sulphur content (0.13 %) in grapes. Soil application of zinc sulphate along with farm yard manure (T₁₉) recorded significantly higher sulphur (0.20 %) compared to without farm yard manure application (T₂: 0.15 %). However, the treatments found to be non significant in increasing calcium and magnesium content in grapes but recorded numerically higher Ca and Mg in treatment T₁₃, which received zinc @ 0.150 per cent as zinc metalosate.

Table 18: Effect of foliar spray on secondary nutrient content (%) of grapes as influenced by sources and levels of zinc

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.57	0.62	0.59	0.42	0.40	0.41	0.12	0.14	0.13
2	0.59	0.63	0.61	0.44	0.45	0.45	0.13	0.16	0.15
3	0.62	0.66	0.64	0.47	0.48	0.47	0.16	0.22	0.19
4	0.57	0.63	0.60	0.43	0.45	0.44	0.13	0.15	0.14
5	0.59	0.65	0.62	0.45	0.47	0.46	0.14	0.16	0.15
6	0.61	0.67	0.64	0.47	0.51	0.49	0.18	0.21	0.20
7	0.66	0.74	0.70	0.53	0.55	0.54	0.25	0.29	0.27
8	0.73	0.82	0.78	0.60	0.61	0.61	0.34	0.38	0.36
9	0.58	0.63	0.60	0.44	0.46	0.45	0.13	0.16	0.15
10	0.61	0.66	0.64	0.47	0.49	0.48	0.18	0.21	0.20
11	0.67	0.72	0.70	0.52	0.55	0.54	0.25	0.30	0.28
12	0.76	0.81	0.79	0.61	0.63	0.62	0.36	0.43	0.40
13	0.87	0.93	0.90	0.69	0.72	0.71	0.46	0.57	0.52
14	0.57	0.63	0.60	0.43	0.46	0.45	0.13	0.15	0.14
15	0.60	0.65	0.62	0.45	0.48	0.46	0.17	0.20	0.19
16	0.65	0.70	0.68	0.50	0.53	0.52	0.23	0.28	0.26
17	0.74	0.78	0.76	0.58	0.60	0.59	0.32	0.39	0.36
18	0.84	0.89	0.87	0.65	0.68	0.67	0.42	0.52	0.47
19	0.63	0.65	0.64	0.48	0.49	0.49	0.17	0.23	0.20
20	0.66	0.69	0.68	0.51	0.52	0.52	0.19	0.25	0.22
SEm ±	0.10	0.10	0.09	0.09	0.10	0.08	0.01	0.02	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	0.04	0.05	0.03

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

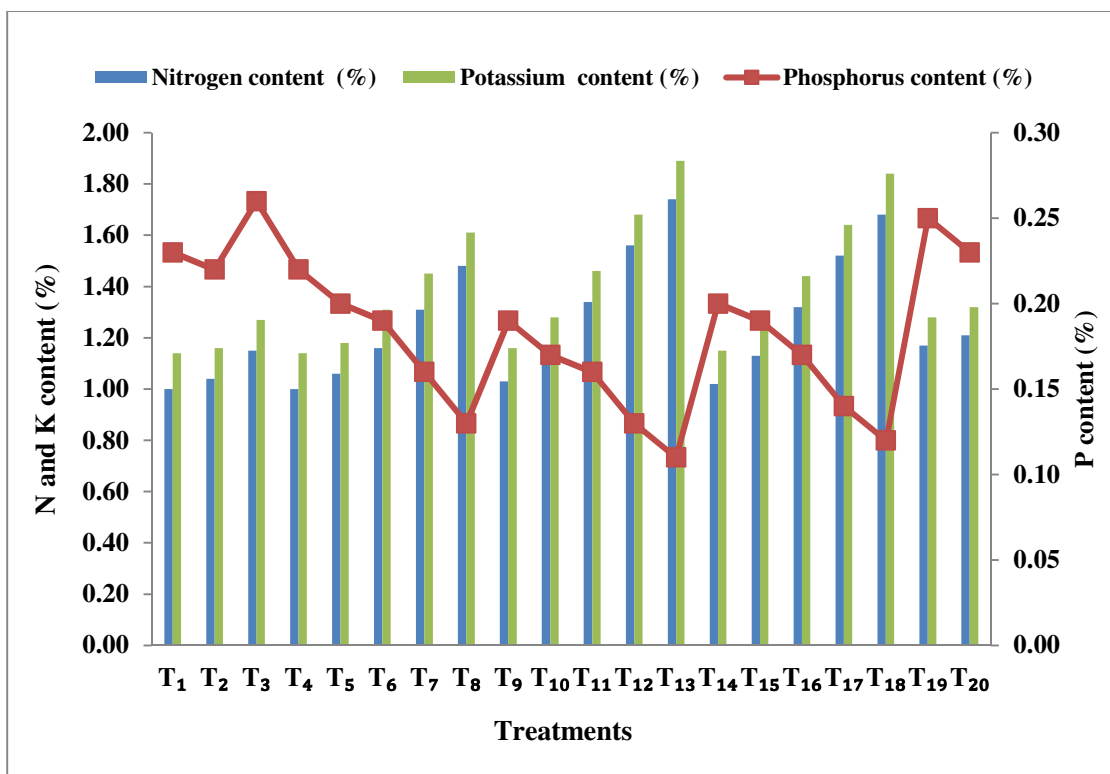


Fig.4: Effect of foliar spray on macronutrient content (%) of grapes as influenced by sources and levels of zinc

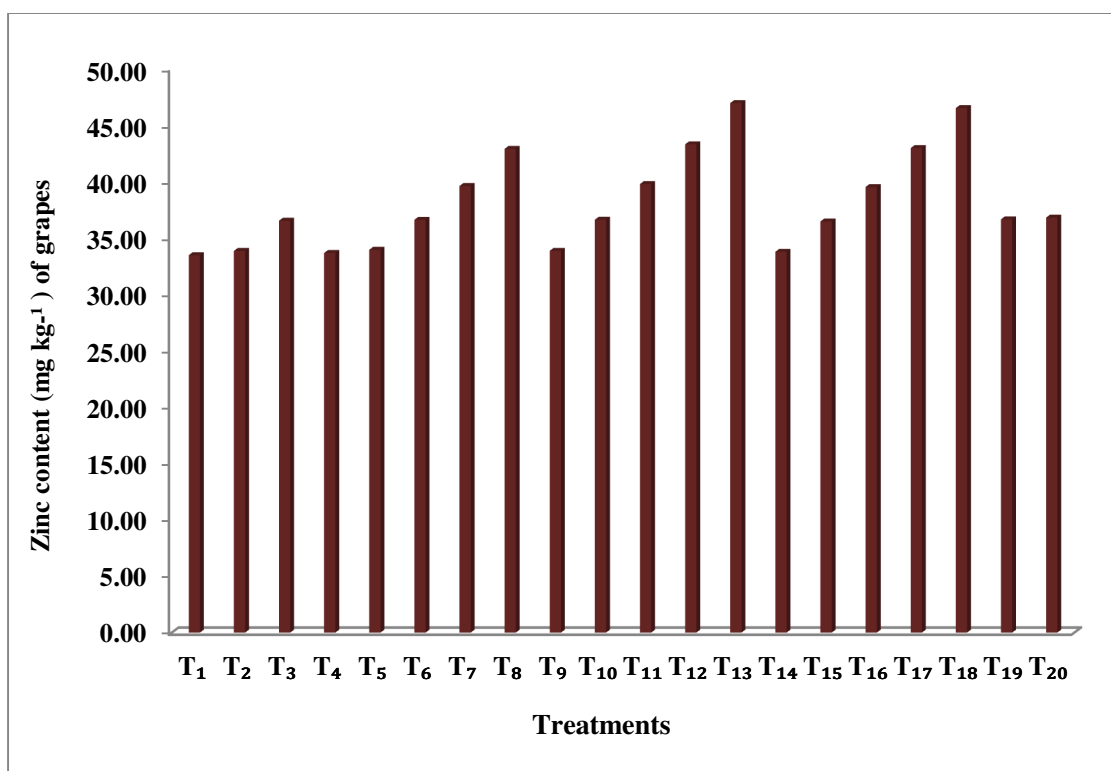


Fig .5: Effect of foliar spray on zinc content (mg kg⁻¹) of grapes as influenced by sources and levels of zinc

The zinc content increased in the plant tissue with recommended dose of NPK and enhanced sulphur content in grapes. These results are in conformation with the findings of Hamouda *et al.* (2016) and Bybordi *et al.* (2010).

4.1.7.3 Effect of foliar spray on micronutrient content (mg kg⁻¹) of grapes as influenced by sources and levels of zinc

The micronutrients content as influenced by sources and levels of zinc are presented in Table 19.

Zinc content varied significantly with different treatments. Among the different treatments, higher zinc content of 47 mg kg⁻¹ was recorded in T₁₃ which received 0.150 per cent zinc from zinc metalosate as foliar spray along with recommended NPK and it was on par with treatment T₁₈ (46.56 mg kg⁻¹) which received zinc @ 0.150 % as Zn-EDTA followed by treatment T₁₂ (43.35 mg kg⁻¹) which received zinc @ 0.10 per cent as zinc metalosate and it was on par with treatment T₁₇ (43.02 mg kg⁻¹) and T₈ (42.95 mg kg⁻¹) which received zinc @ 0.10 and 0.150 per cent as zinc metalosate and Zn-EDTA, respectively. Soil application of zinc sulphate along with farm yard manure numerically (T₁₉: 36.72 mg kg⁻¹) recorded higher zinc content in grapes compared to without farm yard manure (T₂: 33.93 mg kg⁻¹) (Figure 5).

Non significant difference was observed among the treatments with respect to iron, copper, manganese and boron content in grapes, ranging from 53.18 to 56.98, 5.21 to 6.73, 42.15 to 46.15 and 20.71 to 21.07 mg kg⁻¹. In treatment T₁₃ which received 0.150 per cent zinc as zinc metalosate numerically higher iron, copper, manganese and boron content was recorded.

Foliar application of zinc helps in increasing zinc concentration in the xylem sap through rapid and efficient absorption which in turn increased the translocation of nutrients from source to sink (Anonymous, 2001). Higher accumulation of zinc content in the pulp may be due to maintenance of higher concentration of zinc (Asha, 2006). Similar results were observed by Bhadur *et al.* (1998) in Mango, Kumari *et al.* (2009) and Hamouda *et al.* (2016) in pomegranate.

Table 19: Effect of foliar spray on micronutrient content (mg kg⁻¹) of grapes as influenced by sources and levels of zinc

Treatments	Zinc			Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	33.61	33.49	33.55	53.21	53.15	53.18	5.25	5.17	5.21	42.20	42.09	42.15	20.75	20.66	20.71
2	33.89	33.96	33.93	53.55	53.84	53.70	5.41	5.63	5.52	42.79	42.85	42.82	20.79	20.81	20.80
3	36.52	36.68	36.60	54.62	54.95	54.79	5.78	6.02	5.90	43.75	44.08	43.92	21.06	21.07	21.07
4	33.69	33.81	33.75	53.35	53.41	53.38	5.28	5.37	5.33	42.39	42.41	42.40	20.77	20.80	20.79
5	33.94	34.12	34.03	53.60	53.95	53.78	5.45	5.70	5.57	42.91	43.00	42.96	20.81	20.84	20.83
6	36.55	36.81	36.68	54.18	54.31	54.25	5.66	5.89	5.78	43.34	43.65	43.50	20.84	20.87	20.86
7	39.46	39.88	39.67	55.29	55.60	55.45	5.90	6.35	6.13	44.41	44.94	44.68	20.89	20.91	20.90
8	42.59	43.31	42.95	55.81	56.09	55.95	6.10	6.60	6.35	44.93	45.79	45.36	20.92	20.96	20.94
9	33.85	34.02	33.94	53.49	53.65	53.57	5.37	5.55	5.46	42.68	42.75	42.72	20.79	20.83	20.81
10	36.54	36.83	36.69	54.37	54.51	54.44	5.75	6.02	5.89	43.59	43.97	43.78	20.85	20.88	20.87
11	39.63	40.05	39.84	55.62	55.89	55.76	6.00	6.48	6.24	44.78	45.39	45.09	20.91	20.95	20.93
12	43.00	43.70	43.35	56.17	56.45	56.31	6.28	6.83	6.56	45.17	46.48	45.83	20.96	21.00	20.98
13	46.55	47.45	47.00	56.88	57.07	56.98	6.48	6.97	6.73	45.53	46.77	46.15	21.00	21.05	21.03
14	33.78	33.92	33.85	53.41	53.52	53.47	5.31	5.48	5.39	42.52	42.59	42.56	20.78	20.81	20.80
15	36.40	36.67	36.54	54.29	54.44	54.37	5.71	5.97	5.84	43.47	43.81	43.64	20.84	20.87	20.86
16	39.37	39.78	39.58	55.48	55.74	55.61	5.97	6.41	6.19	44.60	45.20	44.90	20.90	20.93	20.92
17	42.66	43.37	43.02	55.93	56.21	56.07	6.19	6.70	6.45	45.05	46.00	45.53	20.94	20.98	20.96
18	46.07	47.05	46.56	56.70	56.83	56.77	6.41	6.90	6.66	45.42	46.50	45.96	20.97	21.02	21.00
19	36.65	36.79	36.72	54.75	55.10	54.93	5.80	6.09	5.95	43.93	44.29	44.11	21.05	21.06	21.06
20	36.78	36.96	36.87	54.91	55.32	55.12	5.85	6.14	6.00	44.20	44.41	44.31	21.02	21.08	21.05
SEm ±	0.86	0.91	0.85	1.28	1.34	1.28	0.41	0.63	0.43	1.15	1.59	1.33	0.43	0.43	0.43
CD @ 5 %	2.47	2.60	2.45	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.1.8 Effect of foliar spray on nutrient content of index tissue of grapes at harvest as influenced by sources and levels of zinc

Results pertaining to nutrient content in the index tissue at harvest as influenced by different sources and levels of zinc are presented in Table 20, 21 and 22.

4.1.8.1 Effect of foliar spray on major nutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of zinc

The pooled data on major nutrient content in the index tissue as affected by different sources and levels of zinc at harvest are presented in the Table 20.

Higher nitrogen content in the index tissue at harvest was recorded in treatment T₁₃ (1.57 %) which received foliar spray of 0.150 per cent zinc as zinc metalosate along with recommended dose of fertilizers and it was on par with treatment T₁₈ (1.54 %) which received zinc @ 0.150 per cent as Zn-EDTA followed by treatment T₁₂ (1.42 %) which consists of 0.10 per cent zinc as zinc metalosate and was on par with treatment T₁₇ (1.40 %) which received same concentration of zinc as Zn-EDTA. Lower nitrogen content in the petiole was recorded in treatment T₁ (1.07 %) which received only NPK.

Significantly higher phosphorus content in index tissue at harvest was recorded in treatment T₃ (0.29 %) which received recommended dose of NPK along with farm yard manure. Foliar application of zinc at different levels as zinc metalosate, Zn-EDTA and ZnSO₄ recorded significantly lesser phosphorus content in index tissue compared to control (T₃). Lower phosphorus in index tissue was recorded in treatment T₁₃ (0.16 %) which received 0.150 per cent zinc through zinc metalosate.

Significantly higher potassium content in the index tissue at harvest was recorded in the treatment T₁₃ (1.97 %) which received 0.150 per cent zinc as zinc metalosate along with recommended dose of NPK and was on par with T₁₈ treatment (1.92 %) which received zinc foliar spray @ 0.150 per cent Zn-EDTA followed by treatment T₁₂ which received zinc @ 0.10 per cent as zinc metalosate. Treatment T₁₂ was on par with

Table 20: Effect of foliar spray on major nutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of zinc

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.04	1.09	1.07	0.25	0.26	0.26	1.20	1.27	1.24
2	1.06	1.12	1.09	0.22	0.24	0.23	1.28	1.29	1.29
3	1.12	1.19	1.16	0.28	0.30	0.29	1.37	1.38	1.37
4	1.05	1.10	1.08	0.24	0.26	0.25	1.23	1.28	1.26
5	1.06	1.13	1.09	0.23	0.25	0.24	1.30	1.30	1.30
6	1.11	1.19	1.15	0.22	0.24	0.23	1.38	1.40	1.39
7	1.20	1.31	1.26	0.20	0.22	0.21	1.50	1.55	1.53
8	1.30	1.44	1.37	0.17	0.19	0.18	1.67	1.72	1.70
9	1.06	1.11	1.08	0.22	0.24	0.23	1.28	1.29	1.29
10	1.12	1.20	1.16	0.20	0.23	0.22	1.40	1.42	1.41
11	1.23	1.34	1.29	0.19	0.21	0.20	1.56	1.59	1.57
12	1.35	1.50	1.42	0.17	0.19	0.18	1.74	1.78	1.76
13	1.48	1.67	1.57	0.15	0.16	0.16	1.95	1.99	1.97
14	1.05	1.10	1.08	0.22	0.24	0.23	1.25	1.28	1.27
15	1.11	1.19	1.15	0.21	0.23	0.22	1.39	1.41	1.40
16	1.21	1.32	1.26	0.20	0.22	0.21	1.54	1.57	1.55
17	1.32	1.47	1.40	0.18	0.19	0.19	1.71	1.74	1.73
18	1.44	1.63	1.54	0.15	0.17	0.16	1.90	1.93	1.92
19	1.13	1.21	1.17	0.27	0.29	0.28	1.38	1.40	1.39
20	1.16	1.24	1.20	0.25	0.27	0.26	1.41	1.44	1.43
SEm ±	0.02	0.02	0.01	0.01	0.01	0.01	0.03	0.03	0.03
CD @ 5 %	0.04	0.05	0.04	0.02	0.02	0.02	0.07	0.09	0.08

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Treatment T₁₇ (1.73 %) which consists of zinc @ 0.10 per cent as zinc metalosate and T₈ which received zinc @ 0.150 per cent as zinc sulphate (1.70 %). Treatment which received only NPK recorded lower potassium content in index tissue at harvest (T₁: 1.24 %).

Application of recommended dose of NPK along with foliar spray of zinc at critical growth stages significantly enhanced the macronutrient content (N and K) in the index tissue at different stages of grapes leading to accumulation, utilization and translocation from sources to sink, quantity of these macronutrients accumulated in the petiole at harvest of the crop. The results are in agreement with Dhillon and Bindra (1995) and Hamouda *et al.* (2016).

4.1.8.2 Effect of foliar spray on secondary nutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of zinc

The data on Ca, Mg and S content in the index tissue at harvest as influenced by sources and levels of zinc along with recommended NPK are presented in the Table 21.

Sulphur content in the index tissue at harvest of grapes recorded significantly higher content in T₁₃ treatment (0.49 %) which received zinc @ 0.150 per cent as zinc metalosate and was on par with zinc @ 0.150 per cent as Zn-EDTA (T₁₈: 0.45 %). Lower sulphur content in the index tissue at harvest was recorded in T₁ treatment (0.08 %). Treatment T₁₉ (0.16 %) which received soil application of zinc sulphate along with farm yard manure significantly recorded higher sulphur content than without application of FYM (T₂: 0.09 %). Foliar spray of zinc at different levels and sources did not significantly influence calcium and magnesium content in the index tissue at harvest and varied from 0.96 to 1.21 and 0.34 to 0.48 per cent, respectively.

The improvement in the sulphur content may be due to synergistic effect between the different levels of zinc supplied through various sources along with recommended dose of NPK. Similar, results were recorded by Hamouda *et.al.* (2016) in pomegranate with foliar application of zinc @ 2000 ppm.

Table 21: Effect of foliar spray on secondary nutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of zinc

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.95	0.98	0.96	0.35	0.33	0.34	0.07	0.08	0.08
2	0.97	1.00	0.99	0.36	0.37	0.37	0.08	0.10	0.09
3	1.03	1.04	1.03	0.38	0.39	0.38	0.13	0.16	0.16
4	0.95	0.98	0.96	0.35	0.36	0.35	0.07	0.09	0.08
5	0.97	1.00	0.98	0.36	0.37	0.37	0.08	0.11	0.10
6	0.99	1.02	1.01	0.38	0.39	0.39	0.12	0.16	0.14
7	1.07	1.09	1.08	0.41	0.42	0.42	0.19	0.25	0.22
8	1.13	1.15	1.14	0.43	0.45	0.44	0.27	0.36	0.32
9	0.96	0.99	0.98	0.35	0.36	0.36	0.08	0.10	0.09
10	1.03	1.05	1.04	0.37	0.39	0.38	0.14	0.17	0.16
11	1.10	1.11	1.10	0.41	0.43	0.42	0.22	0.28	0.25
12	1.17	1.19	1.18	0.44	0.46	0.45	0.33	0.40	0.37
13	1.20	1.22	1.21	0.46	0.49	0.48	0.46	0.51	0.49
14	0.96	0.99	0.98	0.35	0.36	0.36	0.07	0.09	0.08
15	1.02	1.05	1.04	0.37	0.39	0.38	0.13	0.16	0.15
16	1.09	1.10	1.10	0.40	0.42	0.41	0.20	0.26	0.23
17	1.15	1.17	1.16	0.43	0.46	0.45	0.30	0.37	0.33
18	1.18	1.20	1.19	0.45	0.48	0.47	0.41	0.49	0.45
19	1.03	1.04	1.04	0.38	0.40	0.39	0.14	0.17	0.16
20	1.05	1.06	1.06	0.40	0.41	0.41	0.16	0.19	0.18
SEm ±	0.09	0.08	0.07	0.04	0.06	0.04	0.01	0.01	0.02
CD @ 5 %	NS	NS	NS	NS	NS	NS	0.03	0.04	0.04

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.1.8.3 Effect of foliar spray on micronutrient content (mg kg⁻¹) of index tissue of grapes at harvest as influenced by sources and levels of zinc

The pooled data on micronutrient content in the index tissue at harvest as influenced by sources and levels of zinc are presented in Table 22.

Among the treatments significantly higher copper content in the index tissue at harvest was recorded in treatment T₁₃ (11.48 mg kg⁻¹) which received zinc @ 0.150 per cent as zinc metalosate along with recommended dose of NPK and was on par with treatment T₁₈ (11.05 mg kg⁻¹) which received 0.150 per cent zinc as Zn-EDTA. The copper content recorded in the treatment, which received 0.10 per cent zinc as zinc metalosate (T₁₂: 10.51 mg kg⁻¹) was on par with treatments T₁₇ (10.22 mg kg⁻¹) and T₈ (10.06 mg kg⁻¹) which received zinc @ 0.10 and 0.150 per cent from Zn-EDTA and zinc sulphate, respectively. Treatment T₁ which consists of recommended dose of NPK alone recorded lower copper content of 8.07 mg kg⁻¹ in the index tissue at harvest.

Foliar application of different sources and levels of zinc did not show significant iron, manganese and boron content in the index tissue at harvest and they recorded in the range of 90.10 to 97.74 mg kg⁻¹, 67.07 to 73.42 mg kg⁻¹ and 15.22 to 15.50 mg kg⁻¹, respectively.

Foliar spray of zinc at different growth stages like vegetative stage (first spray), flowering stage (second spray) and fruit set stage (third spray) with different sources along with recommended dose of NPK significantly increased the copper uptake from soil due to synergistic effect of zinc with copper. These findings are in line with Dhillon and Bindra (1995), Khan *et al.* (2012) and Hamouda *et al.* (2016).

Table 22: Effect of foliar spray on micronutrient content (mg kg⁻¹) of index tissue of grapes at harvest as influenced by sources and levels of zinc

Treatments	Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	90.13	90.07	90.10	8.09	8.05	8.07	67.09	67.05	67.07	15.23	15.20	15.22
2	90.40	90.57	90.49	8.20	8.39	8.30	67.37	67.71	67.54	15.28	15.33	15.31
3	91.73	91.84	91.79	8.57	9.08	8.83	68.26	68.40	68.33	15.50	15.55	15.53
4	90.26	90.31	90.29	8.13	8.35	8.24	67.15	67.69	67.42	15.25	15.29	15.27
5	90.63	90.63	90.63	8.32	8.63	8.48	67.44	67.95	67.70	15.30	15.33	15.32
6	91.57	91.70	91.64	8.60	8.98	8.79	68.07	68.28	68.18	15.32	15.36	15.34
7	92.79	93.05	92.92	9.05	9.67	9.36	69.13	69.33	69.23	15.37	15.40	15.39
8	94.22	94.50	94.36	9.63	10.48	10.06	70.44	70.79	70.62	15.42	15.46	15.44
9	90.59	90.55	90.57	8.26	8.55	8.41	67.35	67.88	67.62	15.28	15.31	15.30
10	92.03	92.10	92.07	8.75	9.20	8.97	68.52	68.91	68.72	15.33	15.38	15.36
11	93.66	93.79	93.73	9.34	10.03	9.68	69.86	70.07	69.97	15.41	15.44	15.43
12	95.51	95.70	95.61	10.07	10.94	10.51	71.43	71.76	71.60	15.44	15.48	15.46
13	97.66	97.82	97.74	10.92	12.03	11.48	73.19	73.65	73.42	15.48	15.52	15.50
14	90.37	90.43	90.40	8.19	8.46	8.32	67.26	67.79	67.53	15.26	15.30	15.28
15	91.74	91.90	91.82	8.64	9.06	8.85	68.35	68.57	68.46	15.33	15.37	15.35
16	93.25	93.35	93.30	9.17	9.81	9.49	69.58	69.79	69.69	15.39	15.42	15.41
17	94.97	95.09	95.03	9.81	10.63	10.22	71.03	71.34	71.19	15.43	15.46	15.45
18	97.03	97.18	97.11	10.56	11.54	11.05	72.67	73.09	72.88	15.46	15.51	15.49
19	91.88	91.95	91.92	8.71	9.18	8.95	68.39	68.53	68.46	15.48	15.54	15.51
20	92.51	92.66	92.59	8.86	9.39	9.13	68.80	68.98	68.89	15.49	15.52	15.51
SEm ±	2.45	2.54	2.48	0.07	0.11	0.08	2.00	2.18	2.04	0.32	0.32	0.31
CD @ 5 %	NS	NS	NS	0.21	0.30	0.22	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.1.9 Effect of foliar spray on chemical properties and nutrient status of soil at harvest of grapes as influenced by sources and levels of zinc

The pooled data on chemical properties and nutrient status of soil at harvest due to foliar spray of sources and levels of zinc are presented in Table 23, 24, 25 and 26.

4.1.9.1 Effect of foliar spray on chemical properties of soil at harvest of grapes as influenced by sources and levels of zinc

The pooled data on effect of foliar spray of different sources and levels of zinc on chemical properties of soils at harvest are presented in Table 23.

Non significant difference was observed among the treatments with respect pH, EC and organic carbon content of soil and recorded values between 6.37 to 6.42, 0.55 to 0.60 dSm⁻¹ and 0.67 to 0.73 per cent, respectively.

4.1.9.2 Effect of foliar spray on major nutrient status (kg ha⁻¹) of soil at harvest of grapes as influenced by sources and levels of zinc

The pooled data of major nutrients of soil at harvest are presented in Table 24.

Significant increase in major nutrients in soils at harvest was recorded in treatment with recommended dose of NPK compared to initial (Table 1). Available nitrogen content varied from 313.84 to 358.86 kg ha⁻¹ and recorded significantly higher content in treatment T₃(358.86 kg ha⁻¹) which received recommended dose of NPK along with farm yard manure. Lower available nitrogen content was recorded in treatment T₁₃(313.84 kg ha⁻¹) and T₁₈(314.08 kg ha⁻¹) which received zinc @ 0.150 per cent as zinc metalosate and Zn-EDTA along with recommended dose of NPK.

Available phosphorus content varied from 27.90 to 41.19 kg ha⁻¹ and recorded significantly higher content in treatments which received recommended dose of NPK along with farm yard manure (T₃: 41.19, T₂₀:41.05 and T₁₉: 40.92 kg ha⁻¹) and it recorded significantly lower content in treatments which received zinc @ 0.150 per cent as zinc metalosate and Zn-EDTA, respectively.

Table 23: Effect of foliar spray on chemical properties of soil at harvest of grapes as influenced by sources and levels of zinc

Treatments	pH			EC (dSm ⁻¹)			Organic carbon (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	6.41	6.40	6.40	0.55	0.56	0.55	0.67	0.68	0.67
2	6.42	6.40	6.41	0.54	0.56	0.55	0.69	0.69	0.69
3	6.39	6.37	6.38	0.58	0.60	0.59	0.70	0.74	0.72
4	6.40	6.39	6.40	0.55	0.57	0.56	0.69	0.69	0.69
5	6.42	6.40	6.41	0.56	0.56	0.56	0.69	0.70	0.70
6	6.42	6.42	6.42	0.56	0.57	0.56	0.67	0.68	0.68
7	6.41	6.39	6.40	0.55	0.57	0.56	0.67	0.68	0.68
8	6.43	6.41	6.42	0.56	0.58	0.57	0.66	0.67	0.67
9	6.40	6.39	6.39	0.57	0.58	0.57	0.69	0.71	0.70
10	6.40	6.38	6.39	0.55	0.56	0.56	0.66	0.67	0.67
11	6.42	6.40	6.41	0.56	0.57	0.56	0.69	0.71	0.70
12	6.41	6.39	6.40	0.55	0.56	0.55	0.68	0.69	0.69
13	6.40	6.39	6.39	0.55	0.56	0.56	0.68	0.70	0.69
14	6.40	6.38	6.39	0.56	0.58	0.57	0.69	0.70	0.69
15	6.43	6.41	6.42	0.57	0.58	0.57	0.67	0.69	0.68
16	6.41	6.39	6.40	0.55	0.56	0.55	0.69	0.70	0.69
17	6.41	6.40	6.40	0.57	0.59	0.58	0.68	0.70	0.69
18	6.42	6.40	6.41	0.56	0.57	0.56	0.68	0.70	0.69
19	6.40	6.38	6.39	0.58	0.61	0.60	0.72	0.73	0.73
20	6.38	6.37	6.37	0.59	0.61	0.60	0.71	0.72	0.72
SEm ±	0.14	0.14	0.14	0.01	0.02	0.01	0.03	0.04	0.02
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 24: Effect of foliar spray on major nutrient status (kg ha⁻¹) of soil at harvest of grapes as influenced by sources and levels of zinc

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	342.26	373.06	357.66	35.79	45.68	40.74	234.60	228.45	231.53
2	343.41	374.32	358.52	35.02	44.72	39.87	233.13	226.98	230.06
3	343.08	373.96	358.86	36.18	46.21	41.19	235.25	229.10	232.18
4	341.61	372.35	356.98	35.56	45.40	40.48	233.85	227.70	230.78
5	343.35	374.25	358.80	34.93	44.61	39.77	232.04	225.89	228.97
6	334.44	364.52	349.48	33.08	42.26	37.67	226.29	220.14	223.22
7	325.38	354.65	340.02	30.99	39.57	35.28	218.17	212.02	215.09
8	315.30	343.66	329.48	28.77	36.71	32.74	212.98	206.83	209.91
9	341.44	372.18	356.81	35.13	44.85	39.99	233.38	227.23	230.31
10	334.23	364.32	349.27	32.84	41.93	37.38	224.19	218.04	221.12
11	324.10	353.25	338.68	30.65	39.14	34.90	217.84	211.69	214.77
12	313.22	341.49	327.35	28.11	35.87	31.99	211.95	205.80	208.88
13	300.33	327.35	313.84	25.97	29.83	27.90	203.06	196.91	199.99
14	341.58	372.31	356.94	35.40	45.20	40.30	233.45	227.30	230.38
15	334.29	364.37	349.33	32.99	42.13	37.56	225.70	219.55	222.63
16	324.90	354.16	339.53	30.87	39.43	35.15	218.13	211.98	215.06
17	315.05	343.37	329.21	28.53	36.43	32.48	212.55	206.40	209.48
18	300.55	327.62	314.08	26.15	31.37	28.76	203.54	197.39	200.47
19	343.30	374.20	358.75	35.94	45.89	40.92	235.19	229.04	232.12
20	342.99	373.85	358.42	36.06	46.04	41.05	235.09	228.94	232.02
SEm ±	2.91	3.29	3.21	0.62	1.19	0.83	1.50	1.50	1.65
CD @ 5 %	8.32	9.42	9.20	1.78	3.39	2.37	4.29	4.29	4.72

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

About 199.99 to 232.18 kg ha⁻¹ available potassium was recorded in soil and recorded more in treatment T₃, T₁₉ and T₂₀ which received recommended dose of NPK along with farm yard manure. Lower available potassium content was recorded in treatment which received 0.150 per cent zinc as zinc metalosate and Zn-EDTA, *i.e* T₁₃ (199.99 kg ha⁻¹) and T₁₈ (200.47 kg ha⁻¹) respectively.

Higher available NPK content was recorded in treatments T₁₉ may be due to soil application of recommended dose of NPK and farm yard manure. Farm yard manure favoured mineralization of organic sources of nitrogen in the soil and also due to increased microbial activity which could have stimulated the nitrification process. Similarly increase in available phosphorus with FYM addition was due to release of more phosphorus from organic compounds, increase in microbial population as well as decomposition product of humic substances. Due to action of organic acids from organic matter complex available potassium was increased (Sharma *et al.*, 2013). Similarly, Singh *et al.* (2012) noticed that soil application of inorganic fertilizers and organic manures, significantly increased the available N, P, K status in the soil. Addition of farmyard manure improved the physical properties of soil there by creating favourable conditions for microbial activity resulting in increase in the nutrient availability in the soil. The increase in soil available K content might be due to release of fixed K due to action of organic acids from decomposed organic manure. Similar observations were recorded in different fruit crops by Korwar *et al.* (2007), Selvamani *et al.* (2011), Mohanbai (2014), Mustafa *et al.* (2013), Thakur (2013) and Verma and Chauhan *et al.* (2014).

4.1.9.3 Effect of foliar spray on secondary nutrient status of soil at harvest of grapes as influenced by sources and levels of zinc

The pooled data on secondary nutrient content of soil at harvest are presented in Table 25.

Significantly higher available sulphur content was recorded in treatment T₃ (19.91 mg kg⁻¹), T₁₉ (19.89 mg kg⁻¹) and T₂₀ (19.78 mg kg⁻¹) which received farm yard manure

Table 25: Effect of foliar spray on secondary nutrient status of soil at harvest of grapes as influenced by sources and levels of zinc

Treatments	Calcium (C mol (p ⁺) kg ⁻¹)			Magnesium (C mol (p ⁺) kg ⁻¹)			Sulphur (mg kg ⁻¹)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	4.80	4.88	4.84	1.89	1.87	1.88	16.93	22.35	19.64
2	4.70	4.78	4.74	1.87	1.85	1.86	16.45	21.70	19.07
3	4.95	5.03	4.99	1.95	1.96	1.95	17.08	22.75	19.91
4	4.78	4.86	4.82	1.85	1.84	1.84	16.89	22.29	19.59
5	4.81	4.89	4.85	1.89	1.87	1.88	16.15	21.32	18.73
6	4.83	4.91	4.87	1.87	1.85	1.86	15.33	20.24	17.78
7	4.79	4.87	4.83	1.85	1.83	1.84	14.37	19.96	17.16
8	4.88	4.96	4.92	1.88	1.86	1.87	13.32	17.59	15.46
9	4.81	4.89	4.85	1.87	1.85	1.86	16.71	22.06	19.39
10	4.85	4.93	4.89	1.85	1.83	1.84	15.18	20.02	17.60
11	4.83	4.91	4.87	1.89	1.87	1.88	14.15	19.34	16.75
12	4.84	4.92	4.88	1.87	1.85	1.86	13.20	18.09	15.65
13	4.87	4.95	4.91	1.89	1.87	1.88	12.33	15.27	13.80
14	4.71	4.78	4.75	1.85	1.83	1.84	16.77	22.13	19.45
15	4.79	4.87	4.83	1.88	1.86	1.87	15.22	20.10	17.66
16	4.82	4.90	4.86	1.84	1.82	1.83	14.30	19.74	17.02
17	4.85	4.93	4.89	1.89	1.87	1.88	13.25	17.49	15.37
18	4.83	4.91	4.87	1.86	1.84	1.85	12.40	16.38	14.39
19	4.98	5.06	5.02	1.97	1.99	1.98	17.23	22.55	19.89
20	4.97	5.06	5.01	1.96	1.97	1.97	17.05	22.51	19.78
SEm ±	0.10	0.14	0.11	0.04	0.05	0.04	0.26	0.48	0.38
CD @ 5 %	NS	NS	NS	NS	NS	NS	0.74	1.38	1.09

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

along with recommended dose of NPK. Treatments which received zinc @ 0.150 per cent zinc metalosate (T_{13} : 13.80 mg kg⁻¹) and Zn-EDTA (T_{18} : 14.39 mg kg⁻¹) recorded lower sulphur content in soil. Non significant difference was observed among treatments with respect to exchangeable calcium and magnesium content in soil. Available sulphur content was higher in soil due to addition of sulphur to the soil as single super phosphate.

4.1.9.4 Effect of foliar spray on micronutrient status (mg kg⁻¹) of soil at harvest of grapes as influenced by sources and levels of zinc

The pooled data on micronutrient content of soil is presented in Table 26.

Significantly higher zinc content in soil was recorded in treatment T_{19} (0.60 mg kg⁻¹) which received soil application of zinc sulphate along with farm yard manure and T_3 (0.60 mg kg⁻¹) which received farm yard manure followed by treatment T_{20} (0.59 mg kg⁻¹) which consists of farm yard manure. Among different sources and levels of zinc as zinc metalosate, Zn-EDTA and ZnSO₄, significantly higher zinc content in soil was recorded in treatment T_{18} (0.54 mg kg⁻¹) and T_{13} (0.53 mg kg⁻¹) which received 0.150 per cent zinc as Zn-EDTA and zinc metalosate respectively. Non significant difference was observed among the treatments with respect to DTPA extractable iron, copper, manganese and boron and which recorded in the range of 38.08 to 40.90, 0.31 to 0.35, 26.01 to 28.97 and 0.42 to 0.48 mg kg⁻¹, respectively.

The increase in zinc content of the soil may be due to application of farm yard manure to soil. Farm yard manure is a good source of all nutrients, during decomposition it releases organic acids which reduces the fixation and conversion to unavailable form, which in turn contributed to increasing available zinc in soil. Similar observations were also made by Thakur (2013) who stated that application of 75% NPK +biofertilizers (60 g tree basin⁻¹) + green manure (sunhemp @ 25 g seed/tree basin) + FYM (40 kg) + vermicompost (24 kg) resulted in available Zn of 2.10 mg kg⁻¹ in soils of plum orchards.

Table 26: Effect of foliar spray on micronutrient status (mg kg⁻¹) of soil at harvest of grapes as influenced by sources and levels of zinc

Treatments	Zinc			Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.46	0.44	0.45	38.63	38.23	38.43	0.35	0.34	0.35	26.50	26.22	26.36	0.44	0.43	0.43
2	0.47	0.45	0.46	38.48	38.10	38.29	0.35	0.33	0.34	26.35	26.09	26.22	0.44	0.43	0.43
3	0.58	0.61	0.60	40.44	41.36	40.90	0.34	0.32	0.33	28.31	28.68	28.50	0.47	0.49	0.48
4	0.46	0.44	0.45	38.58	38.19	38.38	0.35	0.34	0.34	26.45	26.18	26.32	0.43	0.43	0.43
5	0.47	0.45	0.46	38.45	38.05	38.25	0.35	0.34	0.34	26.32	26.05	26.18	0.43	0.42	0.43
6	0.48	0.46	0.47	38.44	38.04	38.24	0.35	0.35	0.35	26.31	26.03	26.17	0.44	0.41	0.42
7	0.50	0.48	0.49	38.38	38.00	38.19	0.34	0.33	0.34	26.25	25.99	26.12	0.43	0.43	0.43
8	0.52	0.50	0.51	38.32	37.95	38.13	0.34	0.34	0.34	26.19	25.94	26.06	0.44	0.43	0.43
9	0.46	0.44	0.45	38.51	38.13	38.32	0.35	0.34	0.34	26.38	26.12	26.25	0.44	0.42	0.43
10	0.49	0.47	0.48	38.40	38.02	38.21	0.34	0.33	0.34	26.27	26.01	26.14	0.44	0.42	0.43
11	0.51	0.49	0.50	38.34	37.98	38.16	0.34	0.34	0.34	26.21	25.97	26.09	0.43	0.43	0.43
12	0.53	0.51	0.52	38.28	37.97	38.13	0.34	0.32	0.33	26.15	25.96	26.06	0.43	0.42	0.43
13	0.54	0.52	0.53	38.23	37.92	38.08	0.34	0.34	0.34	26.10	25.91	26.01	0.43	0.43	0.43
14	0.46	0.44	0.45	38.53	38.14	38.33	0.35	0.35	0.35	26.40	26.13	26.26	0.43	0.44	0.44
15	0.49	0.47	0.48	38.43	38.06	38.25	0.35	0.35	0.35	26.30	26.05	26.18	0.43	0.43	0.43
16	0.51	0.49	0.50	38.36	38.00	38.18	0.34	0.34	0.34	26.23	25.99	26.11	0.43	0.43	0.43
17	0.53	0.50	0.52	38.30	37.91	38.10	0.34	0.34	0.34	26.17	25.90	26.03	0.43	0.42	0.43
18	0.54	0.53	0.54	38.25	37.86	38.06	0.34	0.33	0.33	26.12	25.85	25.99	0.44	0.43	0.43
19	0.59	0.61	0.60	40.74	41.01	40.87	0.33	0.32	0.32	28.61	29.33	28.97	0.46	0.49	0.48
20	0.58	0.60	0.59	40.63	40.95	40.79	0.32	0.30	0.31	28.50	29.03	28.77	0.47	0.47	0.47
SEm ±	0.01	0.02	0.01	1.24	1.59	1.26	0.01	0.02	0.01	1.10	1.25	1.13	0.02	0.03	0.02
CD @ 5 %	0.03	0.06	0.03	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.2. Experiment No.2. Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of zinc

The pooled results of the field experiment no. 2. entitled “Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of zinc” are discussed and furnished in this chapter.

4.2.1 Effect of foliar spray on growth and yield parameters of pomegranate as influenced by sources and levels of zinc

The data pertaining to the growth and yield parameters of pomegranate as influenced by different sources and levels of zinc are presented in Table 27.

4.2.1.1 Plant height (cm)

Significantly higher plant height was recorded in treatment T₁₃ (217.70 cm) which received zinc @ 0.150 per cent as zinc metalosate along with recommended dose of NPK and was on par with treatment T₁₈ (216.44 cm) which received 0.150 per cent zinc as Zn-EDTA and recommended NPK. Least plant height was recorded in treatment T₁ (204.66 cm) which received only recommended dose of NPK.

Zinc metalosate is a liquid amino acid chelated zinc fertilizer, due to its small particle size and neutral charge it can easily penetrate through the leaf pores. Similarly, Zn-EDTA is also a chelated zinc fertilizer. During chelation the positive charge is neutralizing and it can easily penetrate through the cuticular layer of the leaf. Hence, both zinc metalosate and Zn-EDTA enhanced zinc content and provided sufficient amount of zinc to the plant. Zinc is an essential constituent involved in the respiration and cellular mechanisms and plays a key role in chlorophyll, protein and DNA synthesis. Presence of zinc in chloroplast helps in increasing efficiency of various metabolic and physiological processes of plant. It plays a major role in increasing vegetative growth of plant. Improvement in growth characters resulted by foliar application of zinc may be due to the enhanced photosynthetic and other metabolic activity which lead to an increase in various plant metabolites responsible for cell division and elongation (Parmar *et al.*, 2014). Improvement in plant height was observed earlier with Zn by Razzaq *et al.* (2013) in Kinnow madarine, Banik and Sen (1997) in mango and Arshad and Ali (2016) in guava.

Table 27: Effect of foliar spray on growth and yield parameters of pomegranate as influenced by sources and levels of zinc

Treatments	Plant height (cm)			Number of fruits plant ⁻¹			Number of fruits harvested shoot ⁻¹			Total weight of fruits shoot ⁻¹ (g)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	183.45	225.87	204.66	75.81	78.53	77.17	3.70	3.80	3.75	838.05	879.21	858.63
2	183.94	227.13	205.54	76.10	78.80	77.45	3.90	4.00	3.95	915.76	958.44	937.10
3	185.21	230.76	207.99	78.03	81.25	79.64	4.10	4.30	4.20	1024.59	1115.39	1069.99
4	183.61	226.09	204.85	75.86	78.59	77.23	3.80	3.90	3.85	866.81	909.05	887.93
5	184.12	227.38	205.75	76.63	79.31	77.97	4.00	4.10	4.05	941.40	986.54	963.97
6	185.31	230.15	207.73	77.81	80.63	79.22	4.30	4.40	4.35	1069.93	1121.34	1095.63
7	186.63	233.80	210.22	79.92	82.90	81.41	4.60	4.80	4.70	1232.34	1308.25	1270.30
8	188.08	237.89	212.99	82.85	85.35	84.10	4.80	5.10	4.95	1391.21	1515.36	1453.29
9	183.93	227.05	205.49	75.94	78.76	77.35	3.90	4.00	3.95	909.09	952.48	930.79
10	185.27	230.71	207.99	78.11	80.97	79.54	4.20	4.30	4.25	1053.91	1106.52	1080.21
11	186.74	234.80	210.77	80.66	83.70	82.18	4.50	4.80	4.65	1226.07	1327.13	1276.60
12	188.33	239.75	214.04	83.93	86.75	85.34	4.80	5.10	4.95	1424.98	1569.71	1497.34
13	190.00	245.39	217.70	87.26	90.16	88.71	5.00	5.50	5.25	1625.25	1840.26	1752.76
14	183.88	226.85	205.37	75.89	78.71	77.30	3.90	4.00	3.95	901.84	945.00	923.42
15	185.09	230.25	207.67	77.93	80.85	79.39	4.10	4.30	4.20	1021.02	1097.75	1059.39
16	186.42	234.09	210.26	80.13	83.33	81.73	4.40	4.70	4.55	1182.15	1294.24	1238.20
17	187.85	238.44	213.15	83.12	86.26	84.69	4.70	5.00	4.85	1372.64	1507.05	1439.84
18	189.37	243.50	216.44	86.33	89.41	87.87	5.00	5.30	5.15	1585.51	1759.45	1677.48
19	185.23	230.90	208.07	78.06	81.46	79.76	4.00	4.40	4.20	1009.33	1126.62	1067.98
20	185.31	231.11	208.21	78.25	81.79	80.02	4.20	4.50	4.35	1050.46	1171.11	1110.78
SEm ±	3.92	4.82	4.25	1.56	1.79	1.65	0.30	0.42	0.33	40.31	44.81	40.04
CD @ 5 %	NS	NS	12.15	4.46	5.13	4.72	NS	NS	0.95	115.40	128.28	114.64

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.2.1.2 Number of fruits plant⁻¹

Significantly more number of fruits plant⁻¹ were recorded in treatment T₁₃ (88.71) which received 0.150 per cent zinc as zinc metalosate compared to other treatments but on par with treatment T₁₈ which consists of 0.150 per cent zinc as Zn-EDTA (T₁₈: 87.87). Less number of fruits plant⁻¹ was recorded in treatment T₁ (77.17) which received recommended dose of NPK.

4.2.1.3 Number of fruits harvested shoot⁻¹

Number of fruits per shoot was significantly higher in treatment T₁₃ (5.25) which received zinc @ 0.150 per cent as zinc metalosate and was on par with treatment T₁₈ (5.15) which consists of 0.150 per cent zinc as Zn-EDTA. Least number of fruits per shoot was recorded in T₁ treatment (3.75), which received recommended dose of NPK.

4.2.1.4 Total weight of fruits shoot⁻¹

Spraying of zinc @ 0.010 (T₉: 930.79g, T₁₄: 923.42 g) and 0.025 (T₁₀: 1080.21 g, T₁₅: 1059.39 g) per cent as zinc metalosate and Zn-EDTA and 0.010 (T₄: 887.93 g), 0.025 (T₅: 963.97 g) and 0.050 (T₆: 1095.63 g) per cent as zinc sulphate did not show significant effect in increasing total weight of fruit over control (T₃: 1069.99 g). Among the treatments higher total weight of fruits shoot⁻¹ was recorded in the treatment T₁₃ (1752.76 g) which received zinc @ 0.150 per cent as zinc metalosate and was on par with treatment T₁₈ (1677.48 g) which received zinc @ 0.150 per cent through Zn-EDTA. The total fruit weight recorded in treatments T₁₂ (1497.34 g), T₁₁ (1276.60 g) was on par with treatment T₁₇ (1439.84 g) and T₁₆ (1238.20 g) which received 0.10 and 0.050 per cent zinc as zinc metalosate and Zn-EDTA, respectively and were on par with 0.150 (T₈: 1453.29 g) and 0.10 (T₇: 1270.30 g) per cent zinc as zinc sulphate. Lower total weight of fruits shoot⁻¹ was recorded in treatment T₁ (858.63 g) which received only NPK.

Foliar application of zinc along with recommended dose of NPK significantly increased the yield parameters of pomegranate such as number of fruits shoot⁻¹, number of fruits plant⁻¹, total weight of fruit shoot⁻¹, yield (kg plant⁻¹) and yield (t ha⁻¹), this may be due to zinc being involved in balancing of auxin in plant and also regulates the fruits

drop or retention in plants by delaying the formation of abscission layer during early stages of fruit development. Zinc helps in hormonal metabolism, cell division, cell expansion, higher synthesis of metabolites, regulating the semi permeability of cell wall for enhanced mobilization of food and minerals from other parts of the plant towards developing fruits, resulting increase in fruit weight. Similar results were observed in pomegranate by Khorsandi *et al.* (2009), Mohamad *et al.* (2011), Hasani *et al.* (2012), Mirazapour and Khoshgoftarmanesh (2013), Obaid and Hadethi (2013) and Hamouda *et al.* (2016).

4.2.2 Effect of foliar spray on yield of pomegranate as influenced by sources and levels of zinc

The pooled data that related to effect of foliar spray on yield of pomegranate as influenced by sources and levels of zinc are presented in the Table 28.

4.2.2.1 Yield (kg plant⁻¹)

Among different sources and levels of zinc, both zinc metalosate and Zn-EDTA sources significantly increased the yield plant⁻¹ at 0.050, 0.10 and 0.150 per cent zinc compared to ZnSO₄ @ 0.10 and 0.150 per cent and control (T₃: NPK + FYM). Treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate recorded significantly higher yield per plant (27.38 kg plant⁻¹) compared to other treatments and was on par with treatment which received zinc @ 0.150 per cent Zn-EDTA (T₁₈: 26.79 kg plant⁻¹). Yield plant⁻¹ recorded in treatments T₁₂ (24.64 kg plant), T₁₇ (24.26) and T₈ (24.01) which was on par with each other. Lower yield plant⁻¹ (17.53 kg plant⁻¹) was noticed in treatment T₁ which received only recommended dose of NPK (Figure 6).

4.2.2.2 Yield (t ha⁻¹)

Foliar application of zinc @ 0.150 per cent as zinc metalosate significantly increased pomegranate yield ha⁻¹ (T₁₃: 25.05 t ha⁻¹) compared to other treatments but was

Table 28 : Effect of foliar spray on yield of pomegranate as influenced by sources and levels of zinc

Treatments	Yield (kg plant ⁻¹)			Yield (t ha ⁻¹)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	17.15	17.90	17.53	15.69	16.38	16.04
2	17.34	18.61	17.98	15.87	17.03	16.45
3	19.27	20.70	19.98	17.63	18.94	18.29
4	17.22	18.05	17.63	15.76	16.52	16.14
5	17.75	18.81	18.28	16.25	17.21	16.73
6	19.12	20.39	19.75	17.49	18.65	18.07
7	21.00	22.53	21.77	19.22	20.52	19.87
8	23.06	24.95	24.01	21.10	22.75	21.93
9	17.31	18.57	17.94	15.84	16.99	16.42
10	19.22	20.60	19.91	17.59	18.85	18.22
11	21.37	22.87	22.12	19.51	20.83	20.17
12	23.68	25.59	24.64	21.67	23.32	22.50
13	26.21	28.55	27.38	23.98	26.12	25.05
14	17.28	18.50	17.89	15.81	16.93	16.37
15	19.15	20.43	19.79	17.52	18.69	18.11
16	21.22	22.60	21.91	19.43	20.59	20.01
17	23.35	25.17	24.26	21.37	22.94	22.16
18	25.68	27.89	26.79	23.50	25.52	24.51
19	19.33	20.81	20.07	17.69	19.04	18.37
20	19.42	21.06	20.24	17.77	19.27	18.52
SEm ±	0.44	0.49	0.47	0.37	0.45	0.41
CD @ 5 %	1.26	1.41	1.33	1.07	1.30	1.18

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

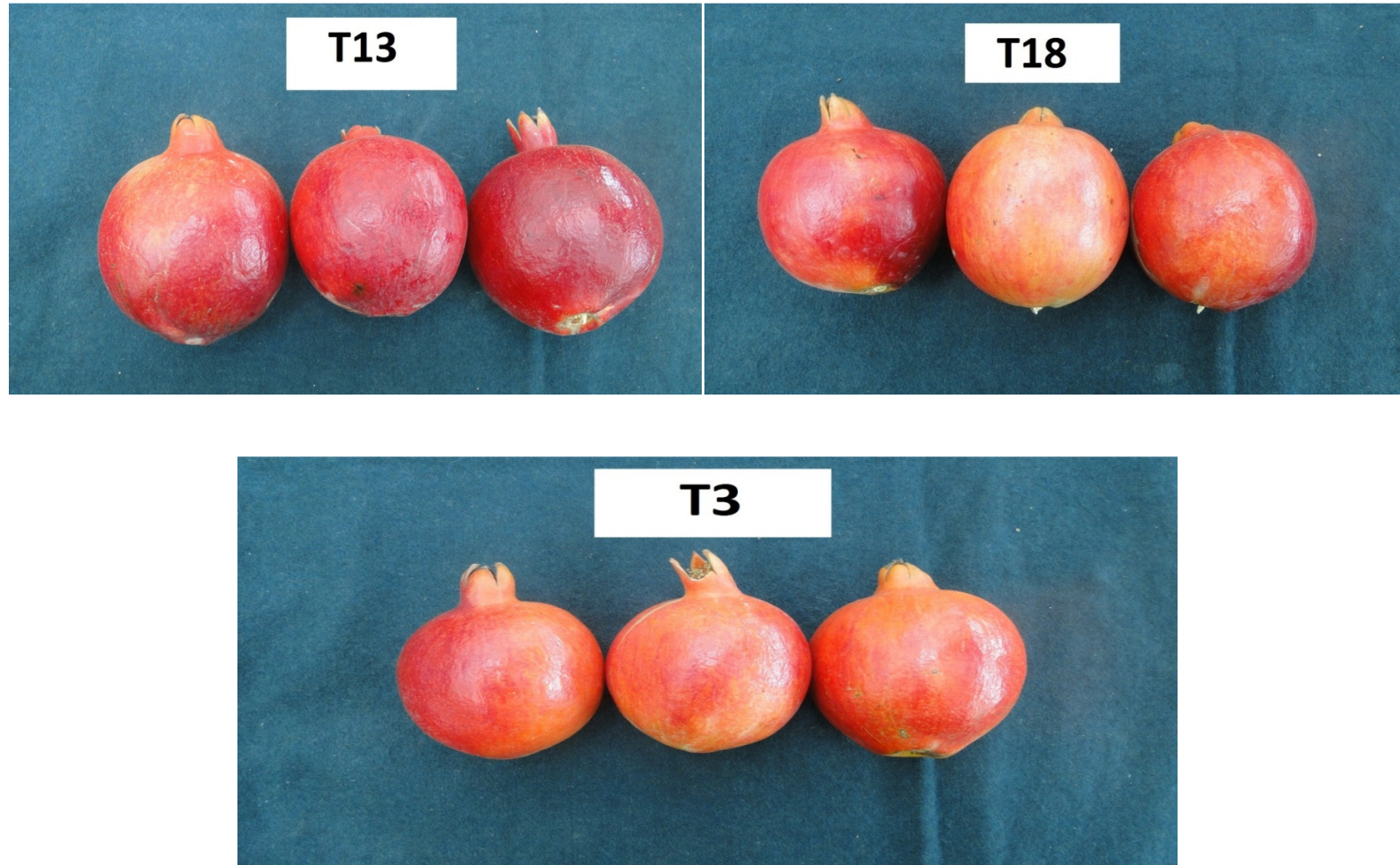


Plate 6: Effect of foliar spray on pomegranate as influenced by sources and levels of zinc

On par with treatment T₁₈ which received zinc @ 0.150 per cent as Zn-EDTA (24.51 t ha⁻¹). Fruit yield in treatments T₁₂, T₁₇ and T₈ recorded 22.50, 22.16 and 21.93 t ha⁻¹ respectively, which are at par with each other. Soil application of zinc sulphate along with farm yard manure recorded significantly higher yield of 18.37 t ha⁻¹ (T₁₉) over the treatment T₂ (16.45 t ha⁻¹) which received soil application of zinc sulphate without farm yard manure. Lower yield ha⁻¹ was recorded in treatment T₁ (16.04 t ha⁻¹) which received recommended dose of NPK.

Increase in yield of pomegranate may be due to increase in number of fruits and weight of fruits plant⁻¹. Similar results were reported by Khorsandi *et al.* (2009), Mohamad *et al.* (2011), Hasani *et al.* (2012), Mirazapour and Khoshgoftarmanesh (2013), Obaid and Hadethi (2013) and Hamouda *et al.* (2016).

4.2.3 Effect of foliar spray on physical parameters of pomegranate as influenced by sources and levels of zinc

The data related to effect of foliar spray on physical parameters of pomegranate as influenced by sources and zinc are presented in Table 29 and Figure 7.

4.2.3.1 Length of fruit (cm)

The fruit length as affected by different levels and sources of zinc varied from 9 cm to 12.14 cm. Among the sources of zinc, zinc sulphate did not bring any significant effect in increasing fruit length but zinc metalosate and Zn-EDTA at higher levels of zinc *i.e.* 0.150 per cent (T₁₃ and T₁₈) significantly increased the fruit length (12.14 and 11.71 cm, respectively) compared to control (T₃: 9.50 cm). Lower fruit length of 9.0 cm was recorded in treatment T₁ which did not receive zinc.

4.2.3.2 Breadth of fruit (cm)

Breadth of fruit in control (T₃) was 10.26 cm which increased significantly in treatment T₁₃ (13.84 cm), due to foliar application zinc @ 0.150 per cent as zinc metalosate along with recommended NPK. However, breadth of fruit in T₁₃ treatment was on par with treatment T₁₈ (13.51 cm). Increase in breadth of fruit in treatment T₁₂

Table 29: Effect of foliar spray on physical parameters of pomegranate as influenced by sources and levels of zinc

Treatments	Length of fruit (cm)			Breadth of fruit (cm)			Weight of fruit (g)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	8.95	9.04	9.00	9.30	9.47	9.39	226.50	231.37	228.93
2	9.04	9.21	9.13	9.37	9.63	9.50	234.81	239.61	237.21
3	9.35	9.65	9.50	10.06	10.45	10.26	249.90	254.73	252.32
4	8.96	9.10	9.03	9.32	9.51	9.42	228.13	233.09	230.61
5	9.09	9.27	9.18	9.42	9.67	9.55	235.35	240.62	237.99
6	9.27	9.53	9.40	10.00	10.29	10.15	248.82	254.85	251.84
7	9.57	9.90	9.74	10.79	11.33	11.06	267.90	274.66	271.28
8	10.24	10.51	10.38	11.70	12.45	12.08	289.85	297.13	293.49
9	8.99	9.17	9.08	9.35	9.60	9.48	233.10	238.12	235.61
10	9.30	9.61	9.45	10.09	10.45	10.27	250.93	257.33	254.13
11	9.81	10.19	10.00	10.95	11.55	11.25	272.46	278.61	275.54
12	10.65	10.95	10.80	12.10	12.82	12.46	296.87	304.06	300.47
13	11.93	12.34	12.14	13.41	14.26	13.84	325.05	333.32	329.19
14	8.98	9.19	9.09	9.34	9.55	9.45	231.24	236.25	233.75
15	9.20	9.57	9.39	10.05	10.36	10.21	249.03	255.29	252.16
16	9.63	10.03	9.83	10.85	11.42	11.14	268.66	275.37	272.02
17	10.35	10.71	10.53	11.87	12.63	12.25	292.05	299.21	295.63
18	11.50	11.92	11.71	13.10	13.91	13.51	317.12	325.18	321.15
19	9.40	9.57	9.49	10.08	10.52	10.30	250.11	256.05	253.08
20	9.45	9.65	9.55	10.18	10.65	10.42	252.35	258.69	255.52
SEm ±	0.64	0.75	0.65	0.18	0.20	0.19	4.66	4.89	4.34
CD @ 5 %	NS	NS	1.85	0.52	0.57	0.53	13.34	14.02	12.42

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

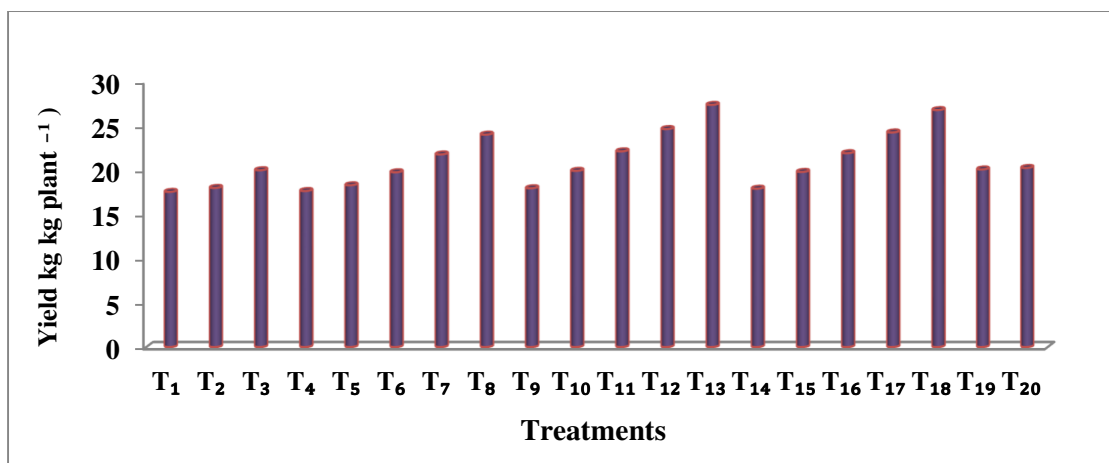


Fig.6: Effect of foliar spray on yield of pomegranate as influenced by sources and levels of zinc

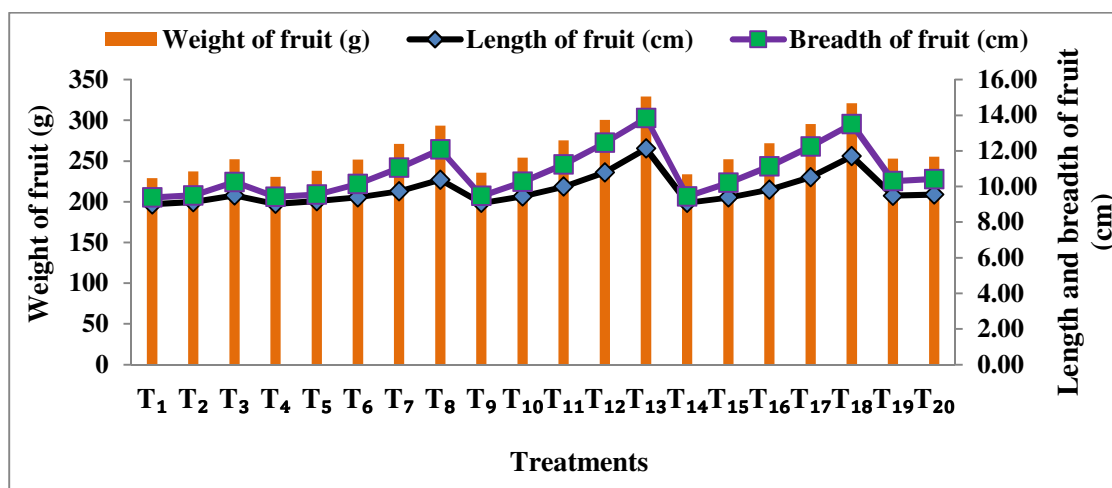


Fig.7: Effect of foliar spray on physical parameters of pomegranate as influenced by sources and levels of zinc

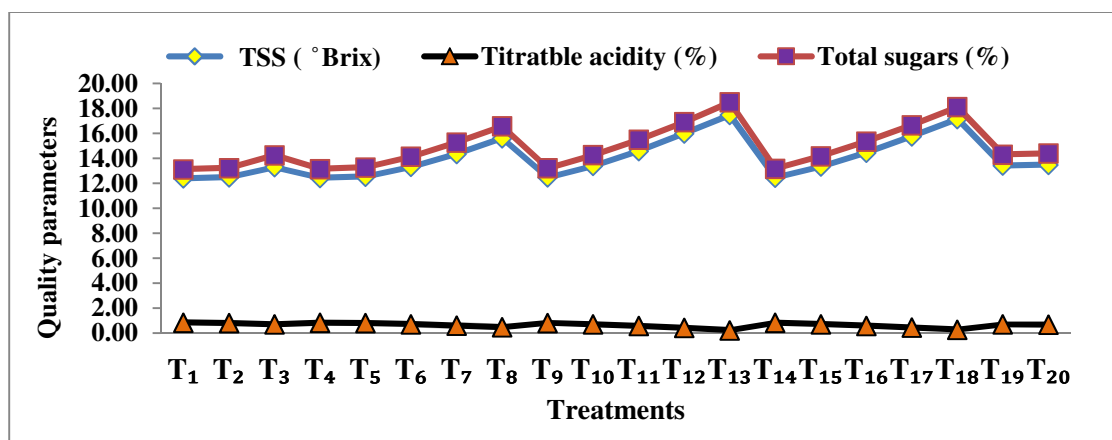


Fig.8: Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of zinc

which consists of zinc @ 0.10 per cent as zinc metalosate was on par with treatments T₁₇ (12.25 cm) and T₈ (12.08 cm) which received zinc @ 0.10 and 0.150 per cent as Zn-EDTA and ZnSO₄, respectively. Recommended dose of NPK (T₁: 9.39 cm) recorded lower breadth of fruit.

4.2.3.3 Weight of fruit (g)

Application of zinc @ 0.150 per cent significantly recorded higher fruit weight compared to other zinc levels and 0.010 and 0.025 per cent zinc levels were not effective in increasing the weight of fruit over control (T₃). Significantly higher fruit weight of 329.19 g was recorded in treatment (T₁₃), which received 0.150 per cent zinc as zinc metalosate and was on par with treatment T₁₈ (321.15 g) which received zinc as Zn-EDTA source @ 0.150 per cent. Fruit weight recorded at treatments T₁₂ (300.47 g) and T₁₁ (275.54 g) was on par with T₁₇ (295.63 g), T₈ (293.49 g) and T₁₆ (272.02 g) and T₇ (271.28 g), respectively. Combined application of zinc sulphate and FYM to soil recorded significantly higher fruit weight (T₁₉: 253.08 g) compared to soil application of zinc sulphate (T₂: 237.21 g) and lower fruit weight of 228.93 was recorded in treatment T₁ (NPK).

Improvement in physical parameters like length, breadth and weight of pomegranate fruit can be attributed to the involvement of zinc in cell division, cell expansion and increased volume of intercellular spaces in the mesocarpic cells. The application of zinc might have played a role in increasing the auxin level of fruits which, in turn, might have helped in the development of fruit components as there is direct correlation between auxin content and fruit growth. Zinc helps in regulating the cell wall permeability, thereby allowing more mobilization of water in fruits that contributed to the greater fruit length and breadth (Wali *et al.*, 2005). Increase in fruit weight may be attributed to the strengthening of middle lamella and consequently cell wall, which later may have increased the free passage of solutes to the fruits. This might have leads to more length and diameter of fruit and also larger weight of individual fruit. There was a positive and significant correlation between the length of fruit, breadth of fruit and weight of fruit. These results are in conformity with Razzaq *et al.*, (2013); Girirajjat and Kacha (2014); Kaur *et al.* (2015); Singh *et al.* (2015) and Pawar (2016).

4.2.4 Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of zinc

The pooled data relating to the quality parameters *viz.*, total soluble solids (TSS), total sugars and titratable acidity of pomegranate as influenced by sources and levels of zinc have been presented in Table 30 and Figure 8.

4.2.4.1 Total Soluble Solids (° Brix)

Significantly higher TSS content of 17.48 ° Brix was recorded in treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate compared to other treatments but was on par with T₁₈ treatment (17.16 ° Brix) which received zinc @ 0.150 per cent as Zn-EDTA. Total soluble solids (TSS) recorded in treatments T₁₂ (16.0 ° Brix), T₁₇ (15.77 ° Brix) and T₈ (15.62 ° Brix) was on par with each other. Least total soluble solids content was recorded in treatment T₁ (12.41 ° Brix) which received recommended dose of NPK.

4.2.4.2 Total Sugars (%)

An improvement in the total sugar content was recorded due to foliar spray of 0.150 per cent zinc as zinc metalosate (T₁₃: 18.51 %) over other treatments and was on par with treatment T₁₈ (18.12 %) which received zinc @ 0.150 per cent as Zn-EDTA. Total sugar content recorded as zinc application @ 0.10 per cent through zinc metalosate (T₁₂: 16.91 %) was on par with 0.10 per cent zinc as Zn-EDTA (T₁₇: 16.67 %) and 0.150 per cent zinc as zinc sulphate (T₈: 16.58 %). Lower total sugar content was recorded in treatment T₁ (13.13 %) only recommended NPK.

4.2.4.3 Titratable Acidity (%)

Application of zinc as different sources reduced the titratable acidity significantly and its content varied from 0.85 to 0.24 per cent. Lower per cent of titratable acidity (0.24 %) was recorded on spraying 0.150 per cent zinc as zinc metalosate (T₁₃) compared to other treatments and was on par with treatment T₁₈ (0.29 %) which received zinc @ 0.150 per cent as Zn-EDTA. Among the zinc sources *viz.*, zinc metalosate, Zn-EDTA and ZnSO₄, in ZnSO₄ source, a significant reduction in titratable acidity was noticed in 0.10 and 0.150 per cent of zinc. Least reduction in titratable acidity was recorded in T₁ (0.85 %) which did not receive zinc.

Table 30 : Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of zinc

Treatments	TSS (° Brix)			Total sugars (%)			Titratable acidity (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	12.37	12.45	12.41	13.10	13.17	13.13	0.86	0.84	0.85
2	12.42	12.58	12.50	13.15	13.33	13.24	0.83	0.81	0.82
3	13.17	13.42	13.30	14.05	14.48	14.26	0.73	0.69	0.71
4	12.38	12.49	12.44	13.12	13.20	13.16	0.85	0.83	0.84
5	12.44	12.63	12.54	13.20	13.37	13.29	0.81	0.80	0.81
6	13.15	13.50	13.33	14.01	14.29	14.15	0.73	0.71	0.72
7	14.06	14.67	14.36	15.09	15.50	15.29	0.63	0.59	0.61
8	15.30	15.93	15.62	16.35	16.82	16.58	0.50	0.46	0.48
9	12.41	12.55	12.48	13.15	13.29	13.22	0.84	0.82	0.83
10	13.22	13.57	13.40	14.13	14.42	14.28	0.72	0.70	0.71
11	14.34	14.86	14.60	15.26	15.73	15.50	0.59	0.56	0.58
12	15.70	16.30	16.00	16.67	17.16	16.91	0.44	0.41	0.43
13	17.13	17.83	17.48	18.24	18.77	18.51	0.25	0.23	0.24
14	12.40	12.53	12.47	13.13	13.25	13.19	0.85	0.82	0.84
15	13.17	13.52	13.35	14.04	14.34	14.19	0.73	0.71	0.72
16	14.18	14.75	14.47	15.13	15.59	15.36	0.62	0.58	0.60
17	15.45	16.09	15.77	16.44	16.91	16.67	0.48	0.44	0.46
18	16.81	17.50	17.16	17.87	18.37	18.12	0.31	0.27	0.29
19	13.19	13.67	13.43	14.08	14.53	14.31	0.73	0.68	0.71
20	13.23	13.74	13.49	14.17	14.65	14.41	0.71	0.66	0.69
SEm ±	0.24	0.28	0.25	0.27	0.30	0.28	0.02	0.03	0.02
CD @ 5 %	0.68	0.80	0.73	0.76	0.85	0.79	0.07	0.08	0.07

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

The increase in TSS of fruit on application of zinc might be due to increase in carbonic anhydrase and net photosynthesis which contributed to hydrolysis of complex polysaccharides into simple sugar, synthesis of metabolites and rapid translocation of photosynthesis products and minerals from other part of plants to developing fruits (Khorsandhi *et al.*, 2009). Increased concentration of zinc showed a positive effect in increasing the total sugar percentage in pomegranate which might be due to breakdown of complex polymers into simple substances by hydrolytic enzymes. Zinc acts as a catalyst in the oxidation- reduction processes and has great importance in sugar metabolism. It influences activities of dehydrogenase enzyme e.g. glucose-6, phosphate which decrease the acidity. These findings are supported by Hasani *et al.* (2012), Kaur *et al.* (2015), Santhosh (2015) and Hamoud *et al.* (2016).

4.2.5 Effect of sources and levels of zinc on nutrient content of index leaf of pomegranate before foliar spray

The pooled data on major, secondary and micronutrients content of index leaf due to different sources and levels of zinc are presented in Table 31, 32 and 33.

The macro nutrients like nitrogen, phosphorus and potassium were recorded in the range of 1.63 to 1.78, 0.43 to 0.55 and 1.34 to 1.49 per cent, respectively. Whereas secondary nutrients like calcium, magnesium and sulphur were recorded in the range of 1.13 to 1.27, 0.33 to 0.48 and 0.35 to 0.42 per cent, respectively. However, micronutrients were present in the range of 154.01 to 162.77, 13.22 to 15.96, 56.21 to 63.04 and 18.65 to 20.96 mg kg⁻¹ of iron, copper, manganese and boron respectively.

4.2.6 Effect of foliar spray on zinc content (mg kg⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of zinc

The pooled data in Table 34 and 35 indicate the effect of foliar application of different sources and levels of zinc on zinc content in index leaf of pomegranate at different spray intervals (Figure 9).

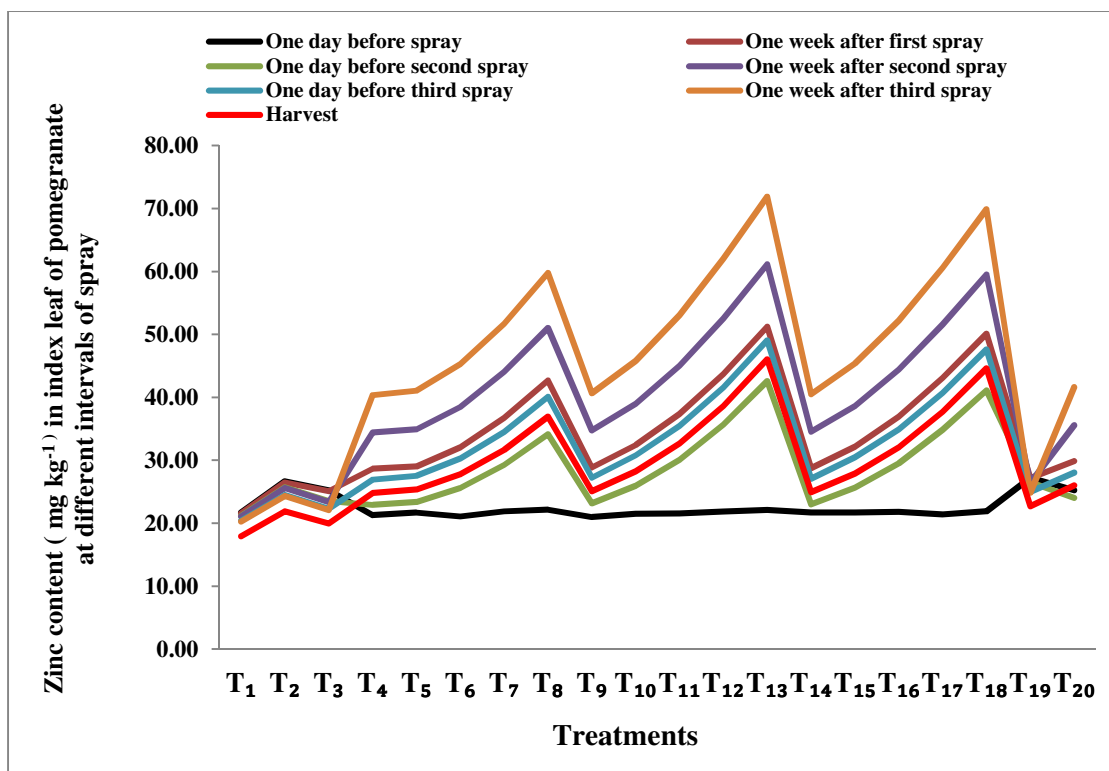


Fig.9 : Effect of foliar spray on zinc content (mg kg⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of zinc

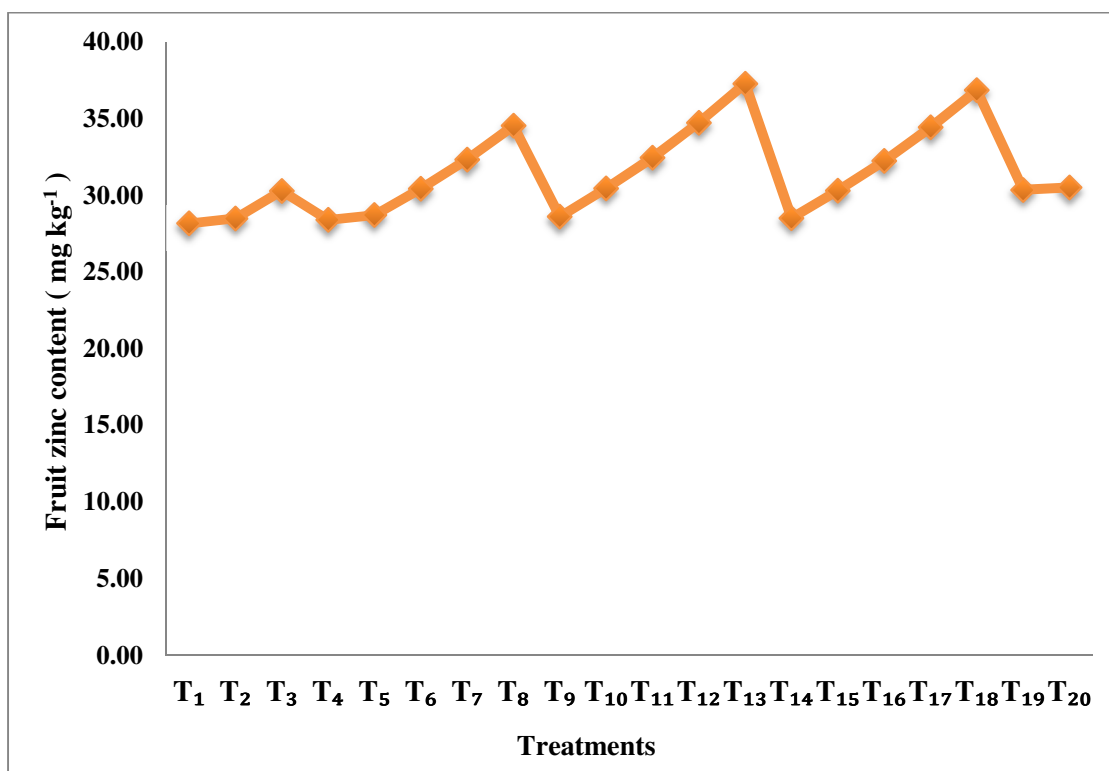


Fig.10: Effect of foliar spray on zinc content (mg kg⁻¹) of pomegranate fruit as influenced by sources and levels of zinc

4.2.6.1 One day before first spray

One day before first spray, non significant difference was observed among treatments with respect to zinc content in index leaf and ranged from 20.98 to 27.23 mg kg⁻¹ but was numerically higher in treatment T₁₉ (27.23 mg kg⁻¹) which consists of soil application of zinc sulphate along with farm yard manure.

4.2.6.2 One week after first spray

Foliar application of zinc as different sources of zinc, zinc metalosate, Zn-EDTA and ZnSO₄ along with recommended dose of NPK significantly increased zinc content in index leaf one week after first spray and ranged from 21.56 to 51.27 mg kg⁻¹. Treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate significantly increased zinc content in index leaf (51.27 mg kg⁻¹) but was on par with treatment T₁₈ which received 0.150 zinc as Zn-EDTA (50.15 mg kg⁻¹). Zinc content in treatment T₁₂ (43.74 mg kg⁻¹), T₁₇ (43.11 mg kg⁻¹) and T₈ (42.71 mg kg⁻¹) were on par with each other. Treatment which received only recommended dose of NPK recorded less zinc in index leaf (21.56 mg kg⁻¹).

4.2.6.3 One day before second spray

A significant reduction of zinc content in index leaf one day before second spray was observed compared to one week after first spray and recorded zinc in the range of 21.20 to 42.62 mg kg⁻¹. Among these treatments, significantly higher zinc in index leaf was recorded in treatment T₁₃ (42.62 mg kg⁻¹) which received 0.150 per cent zinc as zinc metalosate and was on par with treatment T₁₈ (41.15 mg kg⁻¹) which received zinc @ 0.150 per cent as Zn-EDTA. Lower zinc in index leaf was recorded in treatment T₁ (21.20 mg kg⁻¹) which received only recommended NPK.

4.2.6.4 One week after second spray

Zinc content of 21.09 to 61.18 mg kg⁻¹ was recorded in index leaf one week after second spray due to foliar application of zinc as zinc metalosate, Zn-EDTA and ZnSO₄ sources along with recommended dose of NPK. Among the treatments significantly higher zinc of 61.18 mg kg⁻¹ was recorded in treatment T₁₃ which received zinc @ 0.150

per cent as zinc metalosate but was on par with treatment which consists of 0.150 per cent zinc as Zn-EDTA (T₁₈: 59.54 mg kg⁻¹). Zinc content in treatment T₁₂ (52.55 mg kg⁻¹) which received zinc @ 0.10 per cent as zinc metalosate was on par with treatment T₁₇ (51.62 mg kg⁻¹) and T₈ (51.05 mg kg⁻¹) which received zinc @ 0.10 and 0.150 per cent as Zn-EDTA and ZnSO₄, respectively. Lower zinc of 21.09 mg kg⁻¹ was recorded in treatment T₁ which received only recommended NPK.

4.2.6.5 One day before third spray

One day before third spray the zinc content in index leaf reduced compared to one week after second spray and recorded zinc in the range of 20.44 to 49.08 mg kg⁻¹. Among the treatments significantly higher zinc content of 49.08 mg kg⁻¹ was recorded in T₁₃ treatment which received zinc as zinc metalosate @ 0.150 per cent and it was on par with treatment T₁₈ (47.65 mg kg⁻¹) which consists of zinc @ 0.150 per cent as Zn-EDTA. Significantly lower zinc content of 20.44 mg kg⁻¹ was recorded in treatment T₁ which received only recommended dose of NPK.

4.2.6.6 One week after third spray

Concentration of zinc recorded one week after third spray due to application of zinc as zinc metalosate, Zn-EDTA and zinc sulphate along with recommended NPK varied from 20.28 to 71.93 mg kg⁻¹ and was significantly higher in treatment T₁₃ (71.93 mg kg⁻¹) which received 0.150 per cent zinc as zinc metalosate compared to other treatments but was on par with treatment, which received zinc @ 0.150 per cent as Zn-EDTA (T₁₈: 69.93 mg kg⁻¹). Zinc content recorded at 0.10 per cent zinc as zinc metalosate (T₁₂: 62.05 mg kg⁻¹) was on par with 0.10 (T₁₇: 60.64 mg kg⁻¹) and 0.150 (T₈: 59.82 mg kg⁻¹) per cent foliar spray of zinc from Zn-EDTA and ZnSO₄, respectively. Similarly, zinc content recorded at treatment T₁₁ (53.08 mg kg⁻¹) which received zinc @ 0.050 per cent as zinc metalosate was on par with treatment T₁₆ (52.21 mg kg⁻¹) and T₇ (51.72 mg kg⁻¹) which received zinc @ 0.050 and 0.10 per cent as Zn-EDTA and zinc sulphate, respectively. In treatment T₁ which received only recommended NPK, lower content of zinc (20.28 mg kg⁻¹) was recorded.

4.2.6.7 At Harvest

Zinc content in index leaf at harvest varied from 17.93 to 46.05 mg kg⁻¹ and recorded significantly higher zinc in treatment T₁₃ which received 0.150 per cent zinc as zinc metalosate compared to other treatments and it was on par with treatment T₁₈, which received zinc @ 0.150 per cent as Zn-EDTA. Treatment T₁₂, T₁₇ and T₈ were on par with each other with respect to zinc content in index leaf at harvest. Least zinc content was recorded in T₁ treatment (17.93 mg kg⁻¹).

Significantly higher zinc content was recorded in index leaf *i.e.* one week after first, second and third spray at 0.150 per cent zinc as zinc metalosate and Zn-EDTA may be attributed to zinc in metalosate being in form of chelated amino acid, liquid, neutral in charge, small particle size and 100 per cent soluble in water, it can easily move through the cuticular layers of the leaf efficiently and effectively without causing any phytotoxicity, their by helps in increasing zinc concentration in xylem sap. Kirkpatrick (2003) reported that metalosate @ zinc was able to move through the leaves and into xylem very quickly and effectively where it is available for translocation without causing any phytotoxicity. Significant improvement in zinc concentration in leaves of apple, cherry and peaches due to foliar application of zinc as zinc metalosate was reported (Anonymous, 2001). Similarly, Zn-EDTA also increased the zinc concentration in pomegranate leaves one week after first, second and third spray. This may be due to Zn-EDTA being in chelated form, during chelation positive charges are neutralized, hence it easily penetrates through the cuticular layers of the leaf there by it increases the zinc concentration in the index leaf. Chelates are easily translocated within the plant as their action is partly systemic and are easily assimilated within the plant system, hence it helps in maintaining optimum level of zinc in plant system (Sekhon, 2003). Foliar application of zinc @ 0.4 per cent significantly increased the zinc concentration in different commercial cultivars of pomegranate (Khorsandi *et al.*, 2009). Santhosh (2015) reported that foliar spray of zinc @ 0.80 per cent as zinc sulphate recorded significantly higher zinc concentration *i.e.* 115.74 mg kg⁻¹ in pomegranate cv. Bhagwa. These findings are in agreement with Bhadur *et al.* (1998); Asha (2006); Yadav (2008); Pandey (2010) and Hasani *et al.* (2012).

Table 31: Effect of sources and levels of zinc on macronutrient content (%) of index leaf of pomegranate before foliar spray

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.60	1.65	1.63	0.40	0.45	0.43	1.31	1.37	1.34
2	1.62	1.67	1.65	0.43	0.46	0.45	1.32	1.39	1.36
3	1.68	1.85	1.77	0.47	0.59	0.53	1.37	1.56	1.47
4	1.62	1.66	1.64	0.44	0.46	0.45	1.35	1.38	1.36
5	1.61	1.67	1.64	0.40	0.57	0.49	1.30	1.40	1.35
6	1.59	1.69	1.64	0.42	0.46	0.44	1.35	1.41	1.38
7	1.60	1.72	1.66	0.41	0.54	0.48	1.30	1.43	1.36
8	1.62	1.76	1.69	0.43	0.56	0.49	1.31	1.46	1.39
9	1.60	1.67	1.64	0.45	0.46	0.46	1.34	1.39	1.37
10	1.61	1.71	1.66	0.44	0.50	0.47	1.31	1.41	1.36
11	1.59	1.73	1.66	0.40	0.52	0.46	1.33	1.45	1.39
12	1.63	1.78	1.71	0.42	0.55	0.49	1.30	1.48	1.39
13	1.62	1.81	1.72	0.41	0.47	0.44	1.32	1.53	1.43
14	1.60	1.66	1.63	0.43	0.48	0.46	1.35	1.38	1.37
15	1.62	1.70	1.66	0.42	0.49	0.46	1.30	1.41	1.36
16	1.61	1.73	1.67	0.44	0.52	0.48	1.33	1.44	1.39
17	1.59	1.77	1.68	0.43	0.51	0.47	1.32	1.47	1.40
18	1.61	1.80	1.71	0.45	0.54	0.50	1.34	1.51	1.43
19	1.69	1.86	1.78	0.49	0.60	0.55	1.39	1.58	1.49
20	1.67	1.84	1.76	0.48	0.58	0.53	1.36	1.56	1.46
SEm ±	0.04	0.08	0.04	0.04	0.06	0.04	0.04	0.08	0.04
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 32: Effect of sources and levels of zinc on secondary nutrient content (%) of index leaf of pomegranate before foliar spray

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.10	1.15	1.13	0.35	0.36	0.35	0.35	0.36	0.35
2	1.11	1.16	1.14	0.37	0.37	0.37	0.33	0.37	0.35
3	1.14	1.35	1.25	0.39	0.54	0.47	0.31	0.52	0.42
4	1.09	1.16	1.13	0.30	0.36	0.33	0.32	0.36	0.34
5	1.12	1.18	1.15	0.33	0.38	0.36	0.34	0.38	0.36
6	1.10	1.21	1.16	0.36	0.40	0.38	0.35	0.40	0.38
7	1.09	1.23	1.16	0.31	0.43	0.37	0.30	0.43	0.37
8	1.08	1.26	1.17	0.32	0.47	0.40	0.32	0.45	0.39
9	1.11	1.17	1.14	0.30	0.37	0.34	0.35	0.37	0.36
10	1.13	1.19	1.16	0.36	0.39	0.38	0.31	0.39	0.35
11	1.09	1.24	1.17	0.30	0.43	0.37	0.34	0.43	0.39
12	1.12	1.28	1.20	0.31	0.47	0.39	0.33	0.47	0.40
13	1.10	1.33	1.21	0.34	0.52	0.43	0.30	0.49	0.40
14	1.09	1.17	1.13	0.33	0.37	0.35	0.35	0.37	0.36
15	1.11	1.19	1.15	0.30	0.39	0.35	0.32	0.39	0.36
16	1.12	1.23	1.18	0.31	0.42	0.37	0.33	0.43	0.38
17	1.09	1.27	1.18	0.32	0.46	0.39	0.35	0.46	0.40
18	1.11	1.32	1.22	0.35	0.50	0.43	0.34	0.48	0.41
19	1.17	1.37	1.27	0.40	0.55	0.48	0.31	0.53	0.42
20	1.15	1.34	1.25	0.38	0.53	0.46	0.30	0.51	0.40
SEm ±	0.04	0.08	0.04	0.04	0.07	0.03	0.02	0.06	0.03
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010 % Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150 % Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 33: Effect of sources and levels of zinc on micronutrient content (mg kg⁻¹) of index leaf of pomegranate before foliar spray

Treatments	Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	155.35	155.30	155.32	13.24	13.19	13.22	56.25	56.17	56.21	18.68	18.62	18.65
2	159.48	155.71	157.60	12.97	13.87	13.42	57.42	58.11	57.77	20.09	20.12	20.11
3	161.91	162.39	162.15	13.05	14.25	13.65	61.98	63.15	62.57	20.25	21.10	20.68
4	157.39	155.63	156.51	13.47	13.81	13.64	56.38	58.03	57.21	19.20	19.25	19.23
5	156.95	155.85	156.40	14.10	14.19	14.15	58.11	58.25	58.18	19.11	20.15	19.63
6	155.27	156.14	155.71	13.41	14.73	14.07	57.84	58.58	58.21	18.92	20.27	19.60
7	154.11	156.51	155.31	13.22	15.37	14.30	58.08	59.07	58.58	19.15	20.59	19.87
8	155.08	156.96	156.02	13.35	16.13	14.74	56.66	59.63	58.15	18.72	20.83	19.78
9	151.90	155.79	148.84	14.10	13.96	14.03	58.21	58.16	58.19	18.80	19.29	19.05
10	154.19	156.33	155.26	13.12	14.43	13.78	59.00	58.41	58.71	19.21	20.33	19.77
11	152.37	156.96	154.67	14.25	15.04	14.65	57.98	58.93	58.46	18.69	20.72	19.71
12	151.13	157.68	154.41	15.01	15.89	15.45	58.10	59.86	58.98	18.87	20.91	19.89
13	155.49	158.31	156.90	14.97	16.95	15.96	57.44	60.90	59.17	18.30	21.03	19.67
14	152.30	155.72	154.01	15.21	13.87	14.54	56.25	58.07	57.16	19.00	19.27	19.14
15	153.08	156.19	154.64	15.07	14.30	14.69	59.18	58.29	58.74	18.85	20.29	19.57
16	151.99	156.75	154.37	15.26	14.85	15.06	56.94	58.78	57.86	18.34	20.67	19.51
17	152.86	157.39	155.13	14.98	15.59	15.29	59.03	59.65	59.34	18.80	20.88	19.84
18	155.28	157.96	156.62	15.00	16.50	15.75	57.62	60.57	59.10	18.59	20.98	19.79
19	162.39	163.15	162.77	13.09	14.37	13.73	62.18	63.89	63.04	20.77	21.15	20.96
20	161.27	162.88	162.08	12.93	14.60	13.77	62.09	63.50	62.80	20.30	21.09	20.70
SEm ±	4.34	2.82	3.29	0.85	1.39	0.64	2.19	2.78	1.37	0.95	0.99	0.51
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 34: Effect of foliar spray on zinc content (mg kg⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of zinc

Treatments	One day before first spray			One week after first spray			One day before second spray			One week after second spray		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	21.86	21.59	21.72	21.63	21.48	21.56	21.43	20.96	21.20	21.35	20.83	21.09
2	26.10	27.25	26.68	25.86	27.11	26.49	25.20	26.23	25.72	25.13	26.10	25.62
3	24.37	26.18	25.28	24.15	26.05	25.10	23.96	23.07	23.52	23.85	22.87	23.36
4	20.82	21.77	21.30	27.09	30.21	28.65	22.31	23.53	22.92	33.53	35.29	34.41
5	21.47	21.93	21.70	27.42	30.66	29.04	22.69	24.05	23.37	34.00	35.90	34.95
6	20.18	22.04	21.11	30.33	33.78	32.06	24.73	26.52	25.63	37.19	39.76	38.48
7	21.52	22.27	21.90	34.60	38.87	36.74	28.15	30.39	29.27	42.31	45.89	44.10
8	21.80	22.54	22.17	40.29	45.13	42.71	32.86	35.47	34.17	48.92	53.18	51.05
9	20.09	21.86	20.98	27.33	30.42	28.88	22.57	23.78	23.18	33.80	35.73	34.77
10	20.85	22.18	21.52	30.71	34.15	32.43	24.92	27.03	25.98	37.63	40.35	38.99
11	20.69	22.43	21.56	35.26	39.51	37.39	28.73	31.49	30.11	43.15	46.98	45.07
12	21.05	22.70	21.88	41.27	46.20	43.74	33.80	37.60	35.70	50.04	55.06	52.55
13	21.26	22.92	22.09	48.72	53.82	51.27	40.51	44.73	42.62	58.17	64.19	61.18
14	21.64	21.81	21.73	27.21	30.34	28.78	22.43	23.65	23.04	33.69	35.47	34.58
15	21.31	22.12	21.72	30.45	33.93	32.19	24.62	26.71	25.67	37.30	39.93	38.62
16	21.29	22.35	21.82	34.86	39.11	36.99	28.25	30.85	29.55	42.61	46.25	44.43
17	20.23	22.62	21.42	40.69	45.52	43.11	33.11	36.68	34.90	49.23	54.00	51.62
18	21.00	22.83	21.92	47.64	52.65	50.15	39.26	43.03	41.15	56.74	62.34	59.54
19	26.75	27.70	27.23	26.73	27.62	27.18	26.17	26.88	26.53	26.06	26.83	26.45
20	24.30	26.21	25.25	28.55	31.23	29.89	23.10	24.97	24.04	35.00	36.20	35.60
SEm ±	1.40	1.43	1.41	0.97	1.07	0.94	0.69	0.84	0.74	1.09	1.32	1.11
CD @ 5 %	NS	NS	NS	2.79	3.06	2.68	1.97	2.40	2.11	3.11	3.77	3.17

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 35: Effect of foliar spray on zinc content (mg kg⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of zinc

Treatments	One day before third spray			One week after third spray			Harvest		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	21.10	19.77	20.44	20.90	19.65	20.28	18.75	17.10	17.93
2	24.92	24.05	24.49	24.81	23.91	24.36	21.96	21.85	21.91
3	23.27	21.38	22.33	22.95	21.22	22.09	20.00	20.00	20.00
4	27.06	26.85	26.96	39.18	41.57	40.38	24.57	25.06	24.82
5	27.58	27.50	27.54	39.83	42.30	41.07	25.05	25.65	25.35
6	30.15	30.43	30.29	43.98	46.59	45.29	27.26	28.32	27.79
7	34.03	35.01	34.52	50.02	53.41	51.72	30.97	32.43	31.70
8	39.10	41.11	40.11	58.11	61.53	59.82	36.04	37.94	36.99
9	27.33	27.18	27.26	39.55	41.85	40.70	24.81	25.45	25.13
10	30.64	31.02	30.83	44.52	47.11	45.82	27.63	28.86	28.25
11	34.89	36.13	35.51	51.37	54.78	53.08	31.75	33.65	32.70
12	40.22	42.98	41.60	60.29	63.80	62.05	37.24	40.08	38.66
13	47.35	50.80	49.08	69.96	73.90	71.93	44.33	47.77	46.05
14	27.20	27.03	27.12	39.37	41.69	40.53	24.69	25.27	24.98
15	30.37	30.69	30.53	44.13	46.72	45.43	27.38	28.48	27.93
16	34.43	35.45	34.94	50.48	53.93	52.21	31.29	32.89	32.09
17	39.62	41.82	40.72	58.79	62.48	60.64	36.51	38.92	37.72
18	46.37	48.93	47.65	67.83	72.02	69.93	43.32	45.93	44.63
19	25.81	24.25	25.03	25.72	24.00	24.86	23.25	22.15	22.70
20	28.10	28.00	28.05	40.00	43.25	41.63	26.11	25.94	26.03
SEm ±	0.88	0.99	0.87	1.40	1.45	1.33	0.74	0.90	0.82
CD @ 5 %	2.53	2.83	2.49	4.01	4.14	3.81	2.13	2.58	2.35

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

One day before second and third spray and at harvest zinc content of zinc in index leaf recorded less zinc compared to one week after first, second and third spray. This may be due to effective utilization of zinc for various metabolic activities in plants *viz.*, activation of enzymes like oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases, which are necessary for phytohormone activity, protein synthesis, photosynthesis, carbohydrate metabolism, fertility, seed production, maintaining the integrity and function of cellular membranes by controlling the generation and detoxification of reactive oxygen species and defense against disease (Marschner, 1995).

4.2.7 Effect of foliar spray on nutrient content of pomegranate as influenced by sources and levels of zinc

The data pertaining to major, secondary and micronutrient content of pomegranate as influenced by different sources and levels of zinc are presented in Table 36, 37 and 38.

4.2.7.1 Effect of foliar spray on macro nutrient content (%) of pomegranate as influenced by sources and levels of zinc

The data presented in Table 36 indicated the content of macro nutrient in pomegranate as influenced by different sources and levels of zinc.

Foliar application of zinc as zinc metalosate, Zn-EDTA and ZnSO₄ along with recommended dose of NPK significantly increased the nitrogen content of fruits and recorded significantly higher values in treatment T₁₃ (2.64 %) which received 0.150 per cent zinc as zinc metalosate but was on par with treatment T₁₈ (2.55 %) which consists of zinc @ 0.150 per cent as Zn-EDTA. Lower fruit nitrogen content was recorded in treatment T₁ (1.63 %) which received only recommended dose of NPK.

Foliar application of zinc as zinc metalosate, Zn-EDTA and zinc sulphate did not show significant effect on fruit phosphorus content. With increasing levels of zinc through different zinc sources, there was a reduction in fruit phosphorus content. Recommended dose of NPK along with farm yard manure (T₃: 0.31 %) significantly increased fruit phosphorus content compared to other treatments and the lowest phosphorus content in fruit was recorded in treatment T₁₃ (0.16 %) which received 0.150 per cent zinc as zinc metalosate.

Table 36 : Effect of foliar spray on macro nutrient content (%) of pomegranate as influenced by sources and levels of zinc

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.60	1.65	1.63	0.25	0.28	0.27	1.05	1.09	1.07
2	1.62	1.67	1.65	0.24	0.26	0.25	1.08	1.12	1.10
3	1.73	1.82	1.78	0.29	0.32	0.31	1.19	1.25	1.22
4	1.61	1.66	1.64	0.25	0.28	0.27	1.07	1.10	1.09
5	1.64	1.68	1.66	0.24	0.27	0.26	1.10	1.14	1.12
6	1.75	1.83	1.79	0.23	0.26	0.25	1.21	1.26	1.24
7	1.90	2.03	1.97	0.20	0.23	0.22	1.36	1.47	1.42
8	2.08	2.29	2.19	0.18	0.20	0.19	1.57	1.71	1.64
9	1.62	1.67	1.65	0.23	0.24	0.24	1.09	1.12	1.11
10	1.74	1.82	1.78	0.22	0.23	0.23	1.21	1.26	1.24
11	1.91	2.03	1.97	0.20	0.21	0.21	1.42	1.53	1.48
12	2.15	2.42	2.29	0.17	0.19	0.18	1.67	1.84	1.76
13	2.45	2.83	2.64	0.15	0.16	0.16	1.95	2.19	2.07
14	1.61	1.66	1.64	0.24	0.25	0.25	1.09	1.12	1.11
15	1.73	1.81	1.77	0.22	0.23	0.23	1.20	1.25	1.23
16	1.88	1.98	1.93	0.20	0.22	0.21	1.39	1.46	1.43
17	2.10	2.34	2.22	0.18	0.20	0.19	1.61	1.75	1.68
18	2.37	2.73	2.55	0.16	0.17	0.17	1.86	2.06	1.96
19	1.77	1.85	1.81	0.28	0.30	0.29	1.23	1.29	1.26
20	1.82	1.90	1.86	0.27	0.28	0.28	1.26	1.34	1.30
SEm ±	0.04	0.05	0.04	0.01	0.01	0.01	0.04	0.04	0.04
CD @ 5 %	0.11	0.15	0.13	0.02	0.03	0.02	0.10	0.12	0.11

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Potassium content in fruit was significantly higher *i.e.* 2.07 per cent in treatment T₁₃ which received zinc through zinc metalosate @ 0.150 per cent compared to other treatments and was on par with treatment T₁₈ (1.96 %) which received 0.150 per cent zinc as Zn-EDTA. In treatment T₁, which received only NPK, lower potassium content in fruit was recorded (1.07 %).

Foliar application of zinc @ 0.150 per cent through zinc metalosate along with recommended dose of NPK significantly increased the fruit nitrogen and potassium content. This may be due to increased uptake of nitrogen and potassium by the pomegranate plant due to synergistic effect between zinc with nitrogen and potassium and also zinc helps in nitrogen and potassium metabolism in plant, hence increase nitrogen and potassium concentration in index leaf at different growth stages. The treatments also include NPK, which in turn contributed in increasing their concentration in fruit. Das (2003) reported that micronutrients help in the uptake of major nutrients and play an active role in plant metabolism starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity, hormone synthesis, nitrogen fixation and reduction. Hamouda *et al.* (2016) reported significantly higher nitrogen and potassium in pomegranate peel (2.20 and 1.28, respectively) and grain (2.67 and 1.20 %, respectively) zinc @ 1000 ppm as foliar spray. Farm yard manure application significantly enhanced the fruit phosphorus content which may be due to decomposition of FYM and release of organic acids. These organic acids increased the availability of phosphorus for plant uptake by reducing its fixation in soil, hence, fruit phosphorus content increased. Decrease in fruit phosphorus content with zinc application was mainly due to its dilution and their antagonistic effects in leaves (Bybordi *et al.*, 2010).

4.2.7.2 Effect of foliar spray on secondary nutrient content (%) of pomegranate as influenced by sources and levels of zinc

The data with respect to secondary nutrient content of pomegranate as influenced by different sources and levels of zinc are presented in Table 37.

Table 37: Effect of foliar spray on secondary nutrient content (%) of pomegranate as influenced by sources and levels of zinc

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.90	0.94	0.92	0.20	0.17	0.19	0.07	0.08	0.08
2	0.93	0.95	0.94	0.21	0.23	0.22	0.08	0.10	0.09
3	0.96	0.99	0.98	0.24	0.26	0.25	0.13	0.15	0.14
4	0.91	0.94	0.92	0.21	0.24	0.23	0.07	0.09	0.08
5	0.94	0.97	0.95	0.23	0.27	0.25	0.09	0.11	0.10
6	0.98	1.02	1.00	0.25	0.29	0.27	0.13	0.16	0.15
7	1.05	1.10	1.08	0.29	0.32	0.31	0.20	0.23	0.22
8	1.16	1.19	1.18	0.33	0.36	0.35	0.30	0.32	0.31
9	0.92	0.96	0.94	0.22	0.25	0.23	0.08	0.09	0.08
10	0.96	0.98	0.97	0.25	0.28	0.26	0.12	0.15	0.14
11	1.05	1.08	1.07	0.29	0.35	0.32	0.19	0.22	0.21
12	1.18	1.23	1.20	0.34	0.40	0.37	0.30	0.33	0.31
13	1.29	1.36	1.32	0.38	0.44	0.41	0.38	0.43	0.40
14	0.92	0.95	0.93	0.21	0.25	0.23	0.07	0.09	0.08
15	0.95	0.97	0.96	0.23	0.27	0.25	0.11	0.14	0.13
16	1.02	1.06	1.04	0.26	0.34	0.30	0.17	0.21	0.19
17	1.15	1.20	1.17	0.33	0.38	0.35	0.28	0.30	0.29
18	1.24	1.31	1.28	0.36	0.41	0.39	0.34	0.39	0.37
19	0.98	1.05	1.02	0.27	0.29	0.28	0.15	0.16	0.16
20	1.02	1.08	1.05	0.29	0.32	0.31	0.18	0.20	0.19
SEm ±	0.12	0.15	0.13	0.07	0.10	0.08	0.01	0.02	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	0.04	0.05	0.04

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Sulphur content in fruit increased significantly due to application of zinc in the form of different sources along with recommended dose of NPK and recorded significantly higher content (0.40 %) in treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate, but was on par with treatment which received 0.150 per cent Zn-EDTA (0.37 %). Less content of sulphur in fruit was recorded in treatment T₁ (0.08 %) which received only recommended NPK. Non significant differences were observed among treatments in case of fruit calcium and magnesium but recorded numerically higher content in treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate.

Improvement in the sulphur content in pomegranate may due to combined effect of recommended dose of NPK and foliar application of higher levels of zinc *i.e* 0.150 per cent as zinc metalosate.

4.2.7.3 Effect of foliar spray on micronutrient content (mg kg⁻¹) of pomegranate as influenced by sources and levels of zinc

Micronutrient content in pomegranate as affected by foliar spray of different sources and levels of zinc are presented in Table 38.

Zinc content in fruit significantly increased due to foliar application of zinc as different sources and recorded significantly higher zinc in T₁₃ treatment (37.29 mg kg⁻¹), which received zinc @ 0.150 per cent as zinc metalosate, however, zinc content in fruit recorded in T₁₃ was on par with treatment T₁₈ (36.86 mg kg⁻¹) which received zinc @ 0.150 per cent through Zn-EDTA. Lowest zinc content in fruit was recorded in treatment T₁ (28.18 mg kg⁻¹) which received recommended dose of NPK (Figure 10).

Non significant differences were observed among treatments in increasing micronutrient content of pomegranate fruit other than zinc. Numerically the content of iron (60.22 mg kg⁻¹), manganese (26.97 mg kg⁻¹), copper (6.32 mg kg⁻¹) and boron (20.04 mg kg⁻¹) were higher in treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate along with recommended dose of NPK.

Table 38: Effect of foliar spray on micronutrient content (mg kg⁻¹) of pomegranate as influenced by sources and levels of zinc

Treatments	Zinc			Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	28.25	28.11	28.18	58.23	57.97	58.10	5.53	5.45	5.49	25.09	24.94	25.02	19.51	19.48	19.49
2	28.44	28.56	28.50	58.59	58.65	58.62	5.62	5.74	5.68	25.20	25.31	25.26	19.56	19.96	19.76
3	30.19	30.39	30.29	59.03	59.17	59.10	5.60	5.61	5.61	25.41	25.55	25.48	19.86	20.29	20.08
4	28.37	28.45	28.41	58.39	58.47	58.43	5.55	5.59	5.57	25.13	25.20	25.17	19.53	19.94	19.74
5	28.65	28.78	28.72	58.64	58.71	58.68	5.68	5.77	5.72	25.28	25.42	25.35	19.57	19.99	19.78
6	30.34	30.53	30.44	58.79	58.87	58.83	5.77	5.82	5.79	25.41	25.59	25.50	19.60	20.05	19.83
7	32.19	32.48	32.34	59.33	59.45	59.39	5.88	6.05	5.97	25.62	25.85	25.74	19.65	20.13	19.89
8	34.30	34.77	34.54	59.80	59.99	59.90	6.10	6.22	6.16	25.95	26.20	26.08	19.70	20.20	19.95
9	28.57	28.65	28.61	58.51	58.60	58.56	5.59	5.70	5.65	25.23	25.34	25.29	19.56	19.96	19.76
10	30.38	30.54	30.46	58.95	59.10	59.03	5.82	5.93	5.88	25.42	25.58	25.50	19.61	20.10	19.86
11	32.33	32.60	32.47	59.57	59.70	59.64	6.04	6.13	6.09	25.69	25.91	25.80	19.67	20.16	19.92
12	34.56	34.91	34.74	59.92	60.15	60.04	6.15	6.30	6.23	26.21	26.49	26.35	19.75	20.22	19.99
13	37.07	37.50	37.29	60.10	60.34	60.22	6.23	6.40	6.32	26.80	27.13	26.97	19.81	20.27	20.04
14	28.49	28.55	28.52	58.45	58.54	58.50	5.57	5.66	5.62	25.17	25.29	25.23	19.54	19.95	19.75
15	30.25	30.39	30.32	58.87	58.93	58.90	5.80	5.89	5.85	25.35	25.50	25.43	19.59	20.07	19.83
16	32.14	32.35	32.25	59.45	59.51	59.48	5.95	6.10	6.03	25.57	25.81	25.69	19.65	20.15	19.90
17	34.29	34.58	34.44	59.89	60.07	59.98	6.13	6.27	6.20	26.04	26.32	26.18	19.73	20.21	19.97
18	36.67	37.05	36.86	60.05	60.25	60.15	6.20	6.36	6.28	26.56	26.91	26.74	19.79	20.25	20.02
19	30.28	30.44	30.36	59.08	59.25	59.17	5.62	5.64	5.63	25.45	25.61	25.53	19.85	20.30	20.08
20	30.41	30.61	30.51	59.15	59.31	59.23	5.67	5.70	5.69	25.50	25.68	25.59	19.87	20.32	20.10
SEm ±	0.57	0.60	0.57	1.25	1.25	1.25	0.25	0.34	0.22	0.71	0.82	0.76	0.40	0.42	0.40
CD @ 5 %	1.63	1.71	1.64	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Addition (Three sprays) of zinc as zinc metalosate @ 0.150 per cent foliar spray at different intervals significantly increased zinc content in the index leaf and helps in maintaining optimum zinc levels in plant, which in turn contributed to increased fruit zinc content. Similarly, an increase in zinc content in peel (25 mg kg⁻¹) and grain (50 mg kg⁻¹) of pomegranate fruit due to foliar application of zinc @ 1000 ppm was observed by Hamouda *et al.* (2016). Highest zinc content in mango pulp *i.e.* 54.16 mg kg⁻¹ was recorded by Bhadur *et al.* (1998) due to foliar application of zinc @ 1.0 per cent at flower bud differentiation stage. Similar, results were reported in grapes cv. Bangalore grapes by Asha (2006).

4.2.8 Effect of foliar spray on nutrient content of index leaf of pomegranate as influenced by sources and levels of zinc at harvest

Influence of different sources and levels of zinc on major, secondary and micronutrient content in index leaf at harvest are presented in Table 39, 40 and 41.

4.2.8.1 Effect of foliar spray on major nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of zinc

Effect of foliar spray of different sources and levels of zinc on major nutrient *viz.*, nitrogen, phosphorus and potassium content in index leaf at harvest of pomegranate is presented in Table 39.

Significantly higher nitrogen and potassium content in index leaf at harvest was recorded in treatment T₁₃ (1.57 and 1.25 %, respectively) which received zinc @ 0.150 per cent as zinc metalosate compared to other treatments but was on par with treatment T₁₈ which received 0.150 per cent zinc as Zn-EDTA (1.52 and 1.22 %, respectively). However, phosphorus content was higher in treatment, which received recommended dose of NPK and farm yard manure (T₂: 0.29 %) compared to other treatments.

4.2.8.2 Effect of foliar spray on secondary nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of zinc

Influence of foliar application of different sources and levels of zinc on secondary nutrient content in index leaf is presented in Table 40.

Table 39: Effect of foliar spray on major nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of zinc

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.01	1.07	1.04	0.23	0.24	0.24	0.80	0.86	0.83
2	1.03	1.09	1.06	0.22	0.23	0.23	0.82	0.88	0.85
3	1.08	1.21	1.15	0.27	0.30	0.29	0.87	0.95	0.91
4	1.02	1.08	1.05	0.23	0.24	0.24	0.81	0.86	0.84
5	1.04	1.10	1.07	0.22	0.23	0.23	0.83	0.88	0.86
6	1.10	1.18	1.14	0.21	0.22	0.22	0.88	0.94	0.91
7	1.17	1.31	1.24	0.18	0.20	0.19	0.96	1.03	1.00
8	1.26	1.45	1.36	0.15	0.17	0.16	1.03	1.14	1.09
9	1.03	1.09	1.06	0.19	0.22	0.21	0.82	0.87	0.85
10	1.12	1.21	1.16	0.17	0.21	0.19	0.88	0.94	0.91
11	1.21	1.35	1.28	0.16	0.19	0.18	0.98	1.04	1.01
12	1.33	1.50	1.42	0.14	0.16	0.15	1.08	1.14	1.11
13	1.47	1.66	1.57	0.12	0.13	0.13	1.20	1.29	1.25
14	1.02	1.08	1.05	0.20	0.23	0.22	0.81	0.87	0.84
15	1.11	1.19	1.15	0.18	0.21	0.20	0.88	0.93	0.91
16	1.19	1.32	1.26	0.17	0.20	0.19	0.97	1.03	1.00
17	1.30	1.46	1.38	0.15	0.17	0.16	1.06	1.14	1.10
18	1.43	1.61	1.52	0.12	0.15	0.14	1.17	1.27	1.22
19	1.09	1.23	1.16	0.25	0.26	0.26	0.88	0.96	0.92
20	1.11	1.26	1.19	0.26	0.28	0.27	0.90	0.98	0.94
SEm ±	0.02	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.02
CD @ 5 %	0.05	0.07	0.06	0.02	0.02	0.02	0.05	0.06	0.06

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 40: Effect of foliar spray on secondary nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of zinc

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.56	0.71	0.63	0.10	0.13	0.12	0.04	0.07	0.06
2	0.57	0.72	0.65	0.12	0.14	0.13	0.05	0.08	0.07
3	0.60	0.75	0.68	0.15	0.16	0.15	0.07	0.11	0.09
4	0.56	0.71	0.63	0.10	0.13	0.11	0.04	0.07	0.06
5	0.57	0.73	0.65	0.12	0.15	0.13	0.05	0.09	0.07
6	0.61	0.77	0.69	0.14	0.17	0.16	0.08	0.13	0.11
7	0.67	0.82	0.75	0.17	0.20	0.19	0.11	0.17	0.14
8	0.74	0.88	0.81	0.20	0.23	0.21	0.16	0.22	0.19
9	0.57	0.72	0.65	0.11	0.14	0.13	0.04	0.08	0.06
10	0.60	0.75	0.68	0.13	0.16	0.15	0.07	0.11	0.09
11	0.67	0.80	0.74	0.16	0.20	0.18	0.11	0.17	0.14
12	0.76	0.88	0.82	0.19	0.23	0.21	0.16	0.23	0.20
13	0.84	0.98	0.91	0.24	0.28	0.26	0.25	0.31	0.28
14	0.56	0.72	0.64	0.11	0.14	0.12	0.04	0.07	0.06
15	0.60	0.75	0.68	0.13	0.16	0.14	0.07	0.11	0.09
16	0.67	0.79	0.73	0.16	0.19	0.18	0.11	0.16	0.14
17	0.75	0.87	0.81	0.19	0.23	0.21	0.16	0.22	0.19
18	0.82	0.96	0.89	0.23	0.27	0.25	0.23	0.29	0.26
19	0.61	0.76	0.69	0.16	0.18	0.17	0.07	0.12	0.10
20	0.63	0.79	0.71	0.18	0.21	0.19	0.08	0.13	0.11
SEm ±	0.01	0.01	0.01	0.05	0.06	0.05	0.01	0.02	0.01
CD @ 5 %	0.03	0.04	0.03	NS	NS	NS	0.03	0.04	0.03

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Calcium and sulphur contents were significantly higher (0.91 and 0.28 %, respectively) in treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate but was on par with treatment T₁₈ which consists of zinc @ 0.150 per cent from Zn-EDTA (0.89 and 0.26 %, respectively). Lower concentration of calcium and sulphur was recorded in treatment T₁ (0.63 and 0.06 %) which received only recommended NPK. However, non significant difference was observed among treatments with respect to magnesium content in index leaf at harvest but numerically higher magnesium was recorded in treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate (0.26 %).

4.2.8.3 Effect of foliar spray on micronutrient content (mg kg⁻¹) of index leaf of pomegranate as influenced by sources and levels of zinc at harvest

Influence of foliar application of different sources and levels of zinc on micronutrient content in index leaf is presented in Table 41.

Significant differences were not seen among the treatments with respect to iron, copper, manganese and boron content in index leaf at harvest. Content of iron, copper, manganese and boron in index leaf varied from 109.79 to 113.40, 9.30 to 11.04, 40.02 to 43.33 and 15.93 to 16.21 mg kg⁻¹, respectively and they recorded numerically higher content in treatment T₁₃ which consists of zinc @ 0.150 per cent as zinc metalosate foliar spray along with recommended dose of NPK.

Significantly higher nitrogen, potassium, sulphur and calcium content in index leaf at harvest stage was recorded in treatment T₁₃ due to foliar application of zinc (0.150 % through zinc metalosate) and recommended dose of NPK. Due to synergistic effect between zinc and nitrogen, potassium, calcium and sulphur, zinc helped in uptake of N, K, Ca and S. However, due to addition of FYM, the availability of phosphorus to the plant was enhanced by reducing its fixation in soil, hence its content was recorded was higher under FYM application. Higher nitrogen (2.38 %), potassium (0.84 %) and calcium (4.25 %) concentration in index leaves was observed in pomegranate at foliar spray of zinc @ 2000 ppm (Hamouda *et al*, 2016). Sahu (2000) in pomegranate cv. Ganesha recorded leaf nitrogen and potassium of about 2.028, 1.736 and 1.163 to 0.932 per cent at 55 days and harvest of pomegranate, respectively due 100 per cent RDF through fertigation.

Table 41: Effect of foliar spray on micronutrient content (mg kg⁻¹) of index leaf of pomegranate at harvest as influenced by sources and levels of zinc

Treatments	Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	109.82	109.75	109.79	9.32	9.28	9.30	40.05	40.00	40.02	15.96	15.90	15.93
2	110.23	110.47	110.35	9.43	9.63	9.53	40.27	41.41	40.84	15.98	16.05	16.01
3	111.00	111.20	111.10	9.31	9.85	9.58	40.78	41.90	41.34	16.16	16.22	16.19
4	110.06	110.25	110.16	9.37	9.51	9.44	40.09	41.19	40.64	15.96	15.99	15.98
5	110.29	110.57	110.43	9.44	9.69	9.57	40.31	41.50	40.91	15.98	16.07	16.03
6	110.75	110.98	110.87	9.49	9.90	9.70	40.52	41.90	41.21	16.00	16.10	16.05
7	111.61	111.79	111.70	9.64	10.27	9.96	41.13	42.63	41.88	16.05	16.12	16.09
8	112.22	112.51	112.37	9.76	10.73	10.25	41.46	43.51	42.49	16.10	16.17	16.13
9	110.15	110.43	110.29	9.41	9.70	9.56	40.19	41.34	40.77	15.98	16.05	16.01
10	110.98	111.19	111.09	9.53	9.98	9.75	40.65	41.81	41.23	16.02	16.12	16.07
11	112.00	112.25	112.13	9.71	10.37	10.04	41.28	42.90	42.09	16.08	16.14	16.11
12	112.35	113.08	112.72	9.95	11.04	10.50	41.59	43.85	42.72	16.12	16.18	16.15
13	112.82	113.97	113.40	10.23	11.85	11.04	41.72	44.93	43.33	16.15	16.21	16.18
14	110.07	110.34	110.21	9.40	9.63	9.52	41.14	41.27	41.21	15.97	16.02	16.00
15	110.86	111.05	110.96	9.52	9.88	9.70	40.57	41.69	41.13	16.01	16.10	16.06
16	111.93	112.11	112.02	9.68	10.21	9.95	41.20	42.71	41.96	16.07	16.13	16.10
17	112.29	112.83	112.56	9.83	10.79	10.31	41.53	43.60	42.57	16.12	16.17	16.15
18	112.67	113.67	113.17	10.05	11.48	10.77	41.65	44.53	43.09	16.13	16.20	16.17
19	111.10	111.22	111.16	9.35	9.91	9.63	40.86	41.97	41.42	16.19	16.23	16.21
20	111.23	111.45	111.34	9.61	10.09	9.85	41.02	42.10	41.56	16.17	16.25	16.21
SEm ±	1.81	2.07	1.72	0.34	0.92	0.58	0.86	1.81	1.21	0.19	0.23	0.19
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.2.9 Effect of foliar spray on chemical properties and nutrient status of soil at harvest of pomegranate as influenced by sources and levels of zinc

The data pertaining to post harvest soil chemical properties and nutrient status as influenced by different sources and levels of zinc is presented in Table 42, 43, 44 and 45.

4. 2. 9.1 Effect of foliar spray on chemical properties of soil at harvest of pomegranate as influenced by sources and levels of zinc

The data presented in Table 42 indicates the effect of foliar spray of different sources and levels of zinc on chemical properties of soil at harvest of pomegranate.

The soil was acid, non saline and medium in organic carbon and recorded contents in the range in the range of 6.22 to 6.27, 0.29 to 0.33 and 0.53 to 0.59, respectively and was non significant between treatments but there was a slight increase in salt and organic carbon content compared to initial (0.30 dSm⁻¹ and 0.52 %, respectively) content. This may be due addition of salts through the recommended dose of NPK and increased organic carbon may be due to added FYM.

4.2.9.2 Effect of foliar spray on major nutrient status (kg ha⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of zinc

The pooled data related to effect of foliar spray of different sources and levels of zinc on major nutrient content (kg ha⁻¹) of soil at harvest is presented in Table 43.

Soil application of recommended dose of NPK, significantly increased the available nitrogen, phosphorus, potassium, calcium and sulphur content in soil compared to initial content (Table 1). Among different treatments, significantly higher NPK and S status of soil was observed in treatment T₃ which received recommended dose of NPK and FYM. Whereas in treatment T₁₃ and T₁₈ which received zinc @ 0.150 per cent as zinc metalosate and Zn-EDTA, along with recommended dose of NPK, significantly lower available NPK and S content of soil was observed compared to other treatments. Foliar application zinc @ 0.150 per cent as zinc metalosate at critical growth stages at three different intervals along with recommended NPK significantly increased nitrogen, potassium, sulphur and calcium uptake by the plant due to synergist effect. Soil application of recommended dose of NPK along with FYM recorded significantly higher available NPK and S in soil, because of lesser uptake of nutrient by plant from soil

Table 42: Effect of foliar spray on chemical properties of soil at harvest of pomegranate as influenced by sources and levels of zinc

Treatments	pH			EC (dSm ⁻¹)			Organic carbon (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	6.27	6.25	6.26	0.31	0.32	0.32	0.54	0.55	0.54
2	6.26	6.25	6.26	0.29	0.31	0.30	0.54	0.56	0.55
3	6.24	6.22	6.23	0.31	0.32	0.31	0.58	0.60	0.59
4	6.25	6.25	6.25	0.30	0.31	0.31	0.53	0.54	0.54
5	6.27	6.26	6.27	0.32	0.33	0.33	0.52	0.54	0.53
6	6.25	6.25	6.25	0.31	0.34	0.32	0.54	0.55	0.54
7	6.27	6.25	6.26	0.29	0.31	0.30	0.53	0.56	0.54
8	6.25	6.24	6.24	0.28	0.30	0.29	0.52	0.54	0.53
9	6.27	6.25	6.26	0.31	0.32	0.32	0.55	0.57	0.56
10	6.26	6.24	6.25	0.31	0.33	0.32	0.54	0.55	0.55
11	6.25	6.24	6.25	0.30	0.31	0.30	0.55	0.56	0.56
12	6.27	6.25	6.26	0.32	0.33	0.33	0.52	0.54	0.53
13	6.26	6.25	6.26	0.30	0.31	0.30	0.53	0.55	0.54
14	6.25	6.24	6.25	0.31	0.32	0.32	0.52	0.55	0.53
15	6.26	6.24	6.25	0.29	0.33	0.31	0.52	0.54	0.53
16	6.26	6.25	6.26	0.30	0.32	0.31	0.53	0.54	0.54
17	6.27	6.24	6.26	0.29	0.30	0.30	0.55	0.56	0.56
18	6.26	6.25	6.26	0.32	0.32	0.32	0.54	0.57	0.56
19	6.23	6.21	6.22	0.30	0.33	0.32	0.56	0.59	0.57
20	6.24	6.22	6.23	0.32	0.34	0.33	0.57	0.60	0.59
SEm ±	0.12	0.14	0.10	0.01	0.02	0.01	0.03	0.02	0.02
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 43: Effect of foliar spray on major nutrient status (kg ha⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of zinc

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	324.93	348.57	336.75	34.85	40.34	37.60	187.33	200.44	193.88
2	323.78	346.85	335.32	34.28	39.54	36.91	186.82	198.53	192.68
3	325.67	351.29	338.48	35.63	41.11	38.37	189.18	202.50	195.84
4	324.91	348.45	336.68	34.77	40.25	37.51	187.09	200.21	193.65
5	323.35	345.79	334.57	34.21	39.41	36.81	186.77	198.14	192.46
6	322.37	337.83	330.10	34.16	39.33	36.75	186.58	197.95	192.26
7	313.92	329.02	321.47	33.76	39.09	36.42	185.83	197.34	191.59
8	306.03	320.16	313.09	30.53	35.32	32.93	181.10	191.60	186.35
9	323.88	347.32	335.60	34.36	39.55	36.96	186.86	199.92	193.39
10	321.85	337.44	329.64	33.90	39.16	36.53	186.04	197.68	191.86
11	313.79	328.23	321.01	33.30	38.49	35.89	185.69	196.97	191.33
12	305.75	319.63	312.69	30.03	34.70	32.36	180.81	190.30	185.55
13	297.11	304.74	300.93	27.08	31.26	29.17	175.33	180.28	177.81
14	324.29	347.76	332.69	34.67	40.17	37.42	186.95	200.06	193.50
15	322.05	337.81	329.93	33.91	39.14	36.53	186.49	197.84	192.17
16	313.84	328.94	321.39	33.48	38.51	35.99	185.75	197.05	191.40
17	305.98	319.98	312.98	30.47	35.27	32.87	181.06	191.25	186.16
18	297.43	304.87	301.15	27.22	31.45	29.33	175.96	181.29	178.63
19	326.32	350.00	338.16	35.42	40.83	38.12	186.72	201.78	194.25
20	325.87	349.59	337.73	35.17	40.60	37.89	186.57	200.58	193.57
SEm ±	2.39	2.24	2.76	0.88	1.02	1.01	1.41	1.85	1.74
CD @ 5 %	6.84	6.40	7.90	2.51	2.93	2.89	4.05	5.29	4.98

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

compared to treatment T₁₃ and also FYM is a good source of nutrients, it helps in increasing available nutrient status of soil by reducing fixation and increasing microbial activities in soil, which are necessary for mineralization nutrients. Significant improvement in available nutrient status of pomegranate orchard due to application of recommended dose of NPK along with some organic resources was also reported by (Mir, 2011). Pandey (2010) reported that combined application of N at 750 g and K at 750 g per plant significantly enhanced the available nitrogen of pomegranate orchard soil, while the lowest dose of N at 375 g and K at 450 g per plant significantly increased the available phosphorus.

4.2.9.3 Effect of foliar spray on secondary nutrient status of soil at harvest of pomegranate as influenced by sources and levels of zinc

The data in the Table 44 indicates the effect of foliar spray of different sources and levels of zinc on secondary nutrient content of soil at harvest.

Among the treatments, higher available sulphur content in soil at harvest was recorded in the treatment T₁₉ (15.84 mg kg⁻¹) which received zinc sulphate, farm yard manure along with recommended dose of NPK. Least available sulphur content of 12.40 mg kg⁻¹ was recorded in treatment T₁₃ which consists of foliar application of zinc @ 0.150 per cent as zinc metalosate.

Significant difference was not observed among the treatments with respect to exchangeable calcium and magnesium content in soil and which recorded 4.44 to 4.62 and 1.89 to 2.03 C mol (p⁺) kg⁻¹, respectively.

4.2.9.4 Effect of foliar spray on micronutrient status (mg kg⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of zinc

The data in the Table 45 indicates the effect of foliar spray of different sources and levels of zinc on micronutrient status (mg kg⁻¹) of soil.

Significant difference was not observed among the treatments with respect to DTPA extractable micronutrients content in soil. The values at harvest are 0.42 to 0.52 mg kg⁻¹ Zn, 35.82 to 40.41 mg kg⁻¹ Fe, 0.26 to 0.32 mg kg⁻¹ Cu, 26.11 to 27.78 mg kg⁻¹ Mn and 0.40 to 0.50 mg kg⁻¹ B.

Table 44: Effect of foliar spray on secondary nutrient status of soil at harvest of pomegranate as influenced by sources and levels of zinc

Treatments	Calcium (C mol (p ⁺) kg ⁻¹)			Magnesium (C mol (p ⁺) kg ⁻¹)			Sulphur (mg kg ⁻¹)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	4.41	4.48	4.45	1.96	1.95	1.95	14.24	16.04	15.14
2	4.43	4.48	4.46	1.94	1.94	1.94	14.07	15.86	14.96
3	4.56	4.62	4.59	2.02	2.05	2.03	14.91	16.76	15.83
4	4.41	4.48	4.44	1.92	1.90	1.91	14.18	15.98	15.08
5	4.42	4.49	4.46	1.96	1.94	1.95	13.94	15.73	14.83
6	4.44	4.50	4.47	1.92	1.91	1.92	13.88	15.66	14.77
7	4.40	4.48	4.44	1.92	1.90	1.91	13.76	15.54	14.65
8	4.46	4.52	4.49	1.95	1.91	1.93	12.69	14.41	13.55
9	4.42	4.49	4.46	1.93	1.89	1.91	14.10	15.90	15.00
10	4.46	4.51	4.49	1.91	1.88	1.89	13.83	15.62	14.73
11	4.44	4.50	4.47	1.95	1.90	1.93	13.47	15.24	14.35
12	4.45	4.50	4.48	1.93	1.89	1.91	12.60	14.31	13.46
13	4.48	4.54	4.51	1.95	1.91	1.93	11.87	12.94	12.40
14	4.42	4.49	4.46	1.91	1.88	1.90	14.13	15.94	15.03
15	4.40	4.48	4.44	1.94	1.90	1.92	13.84	15.63	14.74
16	4.43	4.50	4.47	1.90	1.89	1.90	13.53	15.30	14.42
17	4.46	4.52	4.49	1.95	1.91	1.93	12.66	14.37	13.52
18	4.44	4.50	4.47	1.92	1.88	1.90	11.90	13.58	12.74
19	4.59	4.65	4.62	2.03	2.01	2.02	14.92	16.76	15.84
20	4.58	4.63	4.61	2.00	2.05	2.02	14.77	16.60	15.69
SEm ±	0.10	0.10	0.09	0.04	0.07	0.05	0.18	0.25	0.21
CD @ 5 %	NS	NS	NS	NS	NS	NS	0.59	0.71	0.61

T₁: NPKT₂: NPK+ Soil application of Zn as ZnSO₄T₃: NPK + FYMT₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosateT₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosateT₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosateT₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosateT₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosateT₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTAT₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTAT₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTAT₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTAT₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTAT₁₉: T₃+ Soil application of Zn as ZnSO₄T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

Table 45: Effect of foliar spray on micronutrient status (mg kg⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of zinc

Treatments	Zinc			Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.43	0.40	0.42	38.05	34.60	36.33	0.32	0.29	0.31	26.77	26.53	26.65	0.45	0.43	0.44
2	0.50	0.51	0.51	37.90	34.47	36.19	0.32	0.29	0.31	26.66	26.41	26.54	0.45	0.42	0.44
3	0.44	0.49	0.47	40.20	40.62	40.41	0.30	0.26	0.28	27.65	27.90	27.78	0.49	0.50	0.50
4	0.43	0.40	0.42	38.00	34.57	36.29	0.33	0.30	0.32	26.73	26.51	26.62	0.45	0.43	0.44
5	0.44	0.42	0.43	37.87	34.45	36.16	0.31	0.29	0.30	26.65	26.32	26.49	0.45	0.40	0.43
6	0.45	0.43	0.44	37.81	34.39	36.10	0.31	0.28	0.30	26.60	26.30	26.45	0.44	0.41	0.42
7	0.46	0.44	0.45	37.69	34.27	35.98	0.28	0.27	0.28	26.51	26.20	26.36	0.43	0.43	0.43
8	0.47	0.45	0.46	37.56	34.15	35.86	0.29	0.25	0.27	26.41	26.11	26.26	0.42	0.40	0.41
9	0.44	0.42	0.43	37.92	34.50	36.21	0.32	0.30	0.31	26.70	26.45	26.58	0.45	0.41	0.43
10	0.45	0.44	0.45	37.75	34.31	36.03	0.27	0.26	0.26	26.56	26.23	26.40	0.43	0.42	0.43
11	0.47	0.45	0.46	37.61	34.21	35.91	0.29	0.26	0.28	26.45	26.15	26.30	0.42	0.41	0.42
12	0.48	0.46	0.47	37.50	34.10	35.80	0.28	0.25	0.27	26.37	26.07	26.22	0.41	0.40	0.41
13	0.48	0.47	0.48	37.25	34.63	35.94	0.27	0.24	0.26	26.29	25.92	26.11	0.40	0.39	0.40
14	0.43	0.40	0.42	37.95	34.52	36.24	0.33	0.31	0.32	26.71	26.50	26.61	0.45	0.41	0.43
15	0.44	0.43	0.44	37.79	34.35	36.07	0.30	0.28	0.29	26.58	26.25	26.42	0.44	0.43	0.43
16	0.45	0.44	0.45	37.65	34.25	35.95	0.28	0.27	0.28	26.49	26.17	26.33	0.42	0.41	0.42
17	0.47	0.45	0.46	37.52	34.11	35.82	0.29	0.25	0.27	26.40	26.10	26.25	0.41	0.40	0.41
18	0.48	0.46	0.47	37.31	34.88	36.10	0.27	0.24	0.26	26.31	26.02	26.17	0.41	0.40	0.41
19	0.51	0.53	0.52	40.13	40.52	40.33	0.28	0.26	0.27	27.61	27.87	27.74	0.48	0.49	0.49
20	0.49	0.49	0.49	40.10	40.41	40.26	0.28	0.25	0.27	27.58	27.68	27.63	0.47	0.48	0.48
SEm ±	0.03	0.04	0.02	0.83	2.68	1.68	0.02	0.03	0.02	0.58	0.88	0.63	0.03	0.04	0.02
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of Zn as ZnSO₄

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.010 % Zn as ZnSO₄

T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄

T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄

T₇: NPK + Foliar spray of 0.100 % Zn as ZnSO₄

T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄

T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate

T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate

T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate

T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA

T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA

T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA

T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA

T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA

T₁₉: T₃+ Soil application of Zn as ZnSO₄

T₂₀: T₃+ Foliar application of 0.01 % Zn as ZnSO₄

4.3. Experiment No.3. Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of boron and zinc metalosate

The data related to the field experiment No. 3 on “Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of boron and zinc metalosate” and discussion on the pooled results are presented in this chapter.

4.3.1 Effect of foliar spray on growth parameters of grapes as influenced by sources and levels of boron and zinc metalosate

The data pertaining to growth parameters of grapes such as cane length (cm), cane girth (cm) and internodal length (cm) as influenced by different sources and levels of boron along with zinc metalosate are presented in Table 46.

4.3.1.1 Cane length (cm)

Maximum cane length of 112.43 cm was recorded in treatment T₁₅ which received micronutrients in combination of boron and zinc metalosate @ 0.017 and 0.050 per cent, respectively followed by the treatment T₁₄ (106.13 cm) which received boron @ 0.0085 and zinc @ 0.025 per cent, which was on par with treatment T₁₃ (105.70 cm) which received only boron @ 0.051 per cent. The treatment which received higher levels (0.051 %) of boron as boric acid (T₈: 99.94 cm) was on par with the treatment T₁₂ (99.38) which received boron @ 0.034 per cent with respect to cane length. The treatments T₁ (82.54 cm), T₄ (82.62 cm), T₉ (82.79 cm), T₅ (82.92 cm) , T₂(83.00 cm), T₁₀(87.87 cm) and T₆(88.00 cm) showed non significant effect in improving cane length over control (T₃: 88.10 cm).

4.3.1.2 Cane girth (cm)

Among the treatments significantly higher cane girth (0.89 cm) was recorded in the treatment T₁₅ which received boron @ 0.017 % + zinc @ 0.050 % as boron metalosate and zinc metalosate respectively, along with recommended dose of NPK followed by treatment T₁₄ (0.81 cm) which received the recommended dose of NPK along with boron and zinc @ 0.0085 and 0.025 per cent, which was on par with treatment T₁₃ (0.78 cm) which received higher levels of boron *i.e.* 0.051 per cent boron through

boron metalosate. Among different levels of boron, boron through boric acid recorded significantly higher cane girth at 0.051 per cent (T₈: 0.71 cm) and it was on par with T₁₂ (0.70 cm) which received boron @ 0.034 per cent as boron metalosate, compared to control (T₃: 0.55 cm) the least increase in the cane girth was recorded in T₁ (0.47 cm), T₄ (0.48 cm), T₉ (0.48 cm), T₅ (0.48 cm), T₂ (0.49 cm), T₁₀ (0.54 cm) and T₆ (0.54 cm).

4.3.1.3 Inter nodal length (cm)

Significant increase in internodal length of 9.60 cm was recorded when boron and zinc were applied in combination @ 0.017 and 0.050 per cent, respectively along with recommended dose of NPK (T₁₅) followed by application of recommended dose of NPK + 0.0085 % boron as boron metalosate + zinc @ 0.025 % as zinc metalosate (T₁₄: 9.18 cm) and was on par with treatment T₁₃ which received boron @ 0.0085 and zinc @ 0.025 per cent as boron metalosate and zinc metalosate, respectively. Application of boron @ 0.051 per cent as boric acid (T₈: 8.64 cm) along with recommended dose of NPK showed significant effect in increasing intermodal length but was on par with 0.034 per cent boron through boron metalosate (T₁₂: 8.53 cm) and least intermodal length was recorded in treatments T₁, T₄, T₉, T₅, T₂, T₁₀ and T₆ compared to control (T₃).

The increase in growth parameters might be due to combined application of boron and zinc as boron metalosate and zinc metalosate to the foliage. These are amino acid chelated boron and zinc liquid fertilizers they can pass through the cuticular pores due to their smaller particle size, neutral charge, hundred per cent solubility in water, hence it is neither attracted nor repulsed from negatively charged surfaces of the leaf, thereby in increasing boron and zinc content in the xylem sap without adverse interactions with other materials on the leaf surface (Sekhon, 2003). Nutrient translocation within the plant was much greater with chelates (Mireille and Andre, 1988). The enhanced boron and zinc played vital role in various metabolic activities of the plant, thus contributing to increasing vegetative growth and development of plant.

Table 46: Effect of foliar spray on growth parameters of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	Cane length (cm)			Cane girth (cm)			Internodal length (cm)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	82.23	82.85	82.54	0.46	0.47	0.47	7.03	7.06	7.05
2	82.92	83.08	83.00	0.48	0.49	0.49	7.21	7.25	7.23
3	87.81	88.39	88.10	0.54	0.55	0.55	7.55	7.69	7.62
4	82.35	82.90	82.62	0.47	0.48	0.48	7.07	7.10	7.09
5	82.80	83.05	82.92	0.48	0.49	0.48	7.19	7.21	7.20
6	87.74	88.27	88.00	0.53	0.55	0.54	7.52	7.66	7.59
7	93.10	94.33	93.72	0.62	0.64	0.63	7.95	8.23	8.09
8	99.37	100.51	99.94	0.70	0.72	0.71	8.44	8.84	8.64
9	82.61	82.97	82.79	0.47	0.48	0.48	7.11	7.15	7.13
10	87.63	88.10	87.87	0.53	0.54	0.54	7.50	7.60	7.55
11	93.00	94.19	93.60	0.60	0.61	0.60	7.91	8.12	8.02
12	98.30	100.45	99.38	0.69	0.71	0.70	8.34	8.72	8.53
13	104.59	106.81	105.70	0.77	0.80	0.78	8.79	9.35	9.07
14	105.15	107.10	106.13	0.79	0.82	0.81	8.90	9.47	9.18
15	111.23	113.63	112.43	0.86	0.91	0.89	9.33	9.86	9.60
16	87.92	88.47	88.20	0.55	0.56	0.56	7.59	7.73	7.66
17	93.17	94.40	93.79	0.61	0.63	0.62	8.03	8.26	8.15
SEm ±	1.61	1.70	1.67	0.01	0.01	0.01	0.09	0.10	0.10
CD @ 5 %	4.63	4.90	4.72	0.04	0.04	0.04	0.26	0.30	0.28

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

The increase in cane length, cane girth and internodal length might be due to improved photosynthetic activity and respiration of plants as influenced by zinc and boron. Zinc play important role in metabolism of nitrogen and synthesis of auxin in the plant and it was also involved in cell division and cell enlargement as well as enhancement of the plant growth and development (Modi *et al.*, 2012). Further, boron increases the phenolic compounds which regulated the polar auxin transport, cell division and cell elongation (Brawn and Amber, 1973). The higher vegetative growth due to combined application of zinc and boron may be attributed to their stimulatory effect on plant metabolism. These results are in line with Saraswathy *et.al.* (2004); Singh *et al.* (2010); Khan *et.al.* (2012); Hada *et al.* (2013); Lokesh (2014) and Yadav *et al.* (2014).

4.3.2 Effect of foliar spray on yield parameters of grapes as influenced by sources and levels of boron and zinc metalosate

Yield parameters of grapes *viz.*, number of bunches plant⁻¹, weight of bunch, number of berries bunch⁻¹, mean weight of berries bunch⁻¹ as influenced by sources and levels of boron and zinc metalosate are represented in the Table 47.

4.3.2.1 Number of bunches plant⁻¹

Significant increase in the number of bunches plant⁻¹ was recorded in the treatments T₁₁ (59.53), T₇ (59.71), T₁₂ (62.07), T₁₇ (60.21), T₈ (62.20), T₁₃ (64.14), T₁₄ (64.61), T₁₅ (66.42) compared to other treatments over control (T₃: 57.80). Among the treatments more number of bunches plant⁻¹ (66.42) was recorded in T₁₅ (NPK+ foliar application of boron @ 0.017 % as boron metalosate + zinc @ 0.050 % as zinc metalosate) followed by treatment T₁₄ (64.61) which received boron @ 0.0085 % + zinc @ 0.025 % as zinc and boron metalosate, respectively and was on par with treatment T₁₃. Among the levels of boron, significantly higher number of bunches were recorded at 0.051 per cent foliar spray of boron as boron metalosate compared to 0.051 per cent boron as boric acid which was on par with the treatment T₁₂ (62.07) which received boron @ 0.034 per cent as boron metalosate.

4.3.2.2 Number of berries bunch⁻¹

Number of berries bunch⁻¹ were significantly higher in the treatment T₁₅ (114.24) which received combination of boron (0.017 %) and zinc (0.050 %) along with recommended dose of NPK followed by treatment T₁₄ (103.68) which is on par with T₁₃ (boron @ 0.051 per cent through metalosate). Boron sprayed as boron metalosate @ 0.051 per cent recorded significantly higher number of berries compared 0.051 per cent of boron sprayed as boric acid which was on par with boron @ 0.034 per cent as boron metalosate and the least number of berries of 60.81 were recorded in treatment T₁.

4.3.2.3 Mean weight of berries bunch⁻¹

Mean weight of 441.50 g berries bunch⁻¹ of was recorded in T₁ which received recommended dose of NPK and was significantly superior to T₁₅ (542.06 g) which received recommended dose of NPK along with boron and zinc @ 0.017 and 0.050 per cent as boron and zinc metalosate, respectively followed by treatment T₁₄ (524.39 g) which was on par with T₁₃ (520.36 g). Among different sources of boron, 0.051 per cent foliar spray of boron as boron metalosate significantly recorded higher mean weight of berries compared to treatment T₈ which received the same concentration of boron as boric acid which was on par with 0.034 per cent foliar spray of boron as boron metalosate (T₁₂: 499.74 g).

4.3.2.4 Weight of bunch (g)

Weight of bunch differed significantly due to the application of different sources and levels of boron and it recorded significantly higher (563.69 g) in T₁₅ (T₁₁+ 0.050 % zinc as zinc metalosate) followed by T₁₄ (T₁₀+ 0.025 % zinc as zinc metalosate) which is on par with treatment T₁₃ (539.71 g) which consisted of 0.051 per cent boron as boron metalosate foliar spray. Among different sources of boron, treatment which received 0.051 per cent boron as boron metalosate recorded significantly higher fruit weight (T₁₃: 539.71 g) followed by treatment T₈ (519.40 g) which received boron @ 0.051 per cent as boric acid, which was on par with one which received 0.034 per cent of boron as boron metalosate (T₁₂: 517.69 g). The two different sources of boron Viz., boron metalosate and boric acid did not differ significantly in increasing fruit weight at 0.0034 and 0.0085 per cent boron compared to treatment which received recommended dose of NPK and farm yard manure (T₃: 479.58 g).

Foliar application of boron and zinc @ 0.017 and 0.050 per cent as boron and zinc metalosate along with recommended dose of NPK significantly enhanced the zinc and boron concentration in the plant and involved in various metabolic activities of plant. The beneficial effect of zinc and boron directly or indirectly are involved in fruit setting, retention and number of fruits per plant. These chemicals are also associated with photosynthesis, hormone metabolism which promotes synthesis of auxin, necessary for fruit set and fruit growth (Rajkumar *et al.*, 2014). The increase in number of fruits probably due to influence of boron which increases pollen grain germination, pollen tube elongation, reduces the fruit set deficiency and helps in fruit setting (Christensen *et al.*, 2006). These results are line with Usha and Singh (2002), Rakesh kumar (2012), Venu *et al.* (2014), Gunes *et al.* (2015) and Khan *et al.* (2015).

Combined application of zinc and boron along with recommended dose of fertilizers significantly increased number of berries bunch⁻¹ this may be attributed to boron which helps in pollen germination pollen tube growth and elongation and fruit setting (Wojcik and Wojcik, 2003) and zinc play a major role in the synthesis of tryptophan which is a precursor of indole acetic acid synthesis, starch metabolism, nucleic acid metabolism, protein biosynthesis and photosynthesis reaction which in turn helped in fruit setting and formation (Alloway, 2008). Similar results were also observed by Mostaofa *et al.* (2006), Subramoniam *et al.* (2006), Pandey *et al.* (2012), Nikkhah *et al.* (2013) and Gunes *et al.* (2015).

Significant improvement in mean weight of berries bunch⁻¹ may be due to strengthening of middle lamella, cell wall, which later facilitated free passage of solutes to the fruits. Zinc is essential for auxin and protein synthesis, seed production and proper maturity of fruits, while Boron has a key role in cell division and elongation and there by increased mean fruit weight. Singh *et al.* (2010) reported that foliar application of boron helps in increased accumulation of dry matter within in the fruit and zinc helps in regulating the semi permeability of cell walls, thus mobilizing more water into fruits, resulting increase in fruit size which intern increase the weight. Similar, results were obtained in grapes Prabhu and Singaram (2002), Asha (2006) and Nikkhah *et al.* (2013).

Table 47: Effect of foliar spray on yield parameters of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	Number of bunches plant ⁻¹			Number of berries bunch ⁻¹			Mean weight of berries bunch ⁻¹			Weight of bunch (g)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	54.60	56.31	55.45	57.49	64.12	60.81	435.53	447.47	441.50	452.56	462.23	457.39
2	55.11	56.98	56.05	58.86	65.75	62.31	439.46	452.18	445.82	456.10	466.39	461.24
3	56.82	58.77	57.80	66.91	74.05	70.48	457.45	470.59	464.02	474.15	485.00	479.58
4	54.79	56.58	55.69	57.52	64.30	60.91	435.91	448.05	441.98	452.79	462.71	457.75
5	55.06	56.93	56.00	58.60	65.71	62.16	438.75	451.78	445.27	455.92	466.10	461.01
6	56.62	58.75	57.69	65.59	73.84	69.72	453.76	467.81	460.79	471.06	481.97	476.52
7	58.51	60.90	59.71	74.61	85.09	79.85	474.45	490.49	482.47	491.88	505.04	498.46
8	60.98	63.41	62.20	84.40	98.93	91.67	491.02	514.23	502.63	508.70	530.10	519.40
9	54.85	56.67	55.76	57.55	64.55	61.05	437.99	450.55	444.27	455.10	465.29	460.19
10	56.53	58.55	57.54	65.43	73.17	69.50	452.79	465.93	459.36	470.05	480.82	475.44
11	58.35	60.71	59.53	74.32	84.10	79.21	473.51	487.77	480.64	491.00	503.51	497.26
12	60.84	63.30	62.07	83.17	98.05	90.61	489.57	509.90	499.74	507.14	528.24	517.69
13	62.68	65.60	64.14	92.36	112.33	102.35	506.63	534.08	520.36	524.33	555.09	539.71
14	63.15	66.07	64.61	93.89	113.47	103.68	512.92	535.85	524.39	530.81	556.83	543.82
15	64.90	67.93	66.42	102.22	126.25	114.24	527.20	556.92	542.06	545.20	582.17	563.69
16	56.88	58.97	57.92	67.52	75.00	71.26	459.63	473.09	466.36	476.58	487.51	482.05
17	59.13	61.28	60.21	74.95	85.32	80.14	475.34	490.74	483.04	492.35	505.10	498.73
SEm ±	0.46	0.51	0.49	2.23	2.65	2.42	4.46	4.59	4.48	4.78	4.90	4.79
CD @ 5 %	1.34	1.47	1.39	6.42	7.63	6.84	12.84	13.23	12.64	13.78	14.11	13.52

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Increased weight of bunch may be attributed to increased number of berries bunch⁻¹ by combined application of boron and zinc. Similarly, an improvement in the bunch weight due to combined application of zinc and boron was also reported by Prabu and Singaram (2002), Khan *et al.* (2012), Nikkhah *et al.* (2013), Gunes *et al.* (2015) and Mohsen (2015).

4.3.3 Effect of foliar spray on yield of grapes as influenced by sources and levels of boron and zinc metalosate

Fruit yield as influenced by sources and levels of boron and zinc metalosate have been compiled in Table 48.

4.3.3.1 Fruit yield (kg plant⁻¹)

Data reveals marked influence of different boron sources in combination with zinc metalosate along with recommended dose of fertilizers on fruit yield. The higher fruit yield of 36.79 kg plant⁻¹ was recorded on foliar application of 0.017 per cent boron and 0.050 per cent zinc as boron and zinc metalosate along with recommended dose of NPK (T₁₅) followed by treatment which consists of 0.0085 per cent boron as boron metalosate and 0.025 per cent zinc as zinc metalosate with recommended dose of NPK (T₁₄: 34.66 kg plant⁻¹) which is on par with treatment T₁₃ (34.08 kg plant⁻¹).

4.3.3.2 Fruit yield (tonnes ha⁻¹)

Higher fruit yield ha⁻¹ was noticed at 0.017 per cent boron and 0.050 per cent zinc applied as foliar spray of boron metalosate and zinc metalosate, respectively along with recommended dose of NPK (T₁₅: 16.81 t ha⁻¹) followed by treatment T₁₄ (15.84 t ha⁻¹) which received boron and zinc combinations *i.e.* boron @ 0.0085 % + zinc @ 0.025 % as boron and zinc metalosate along with recommended dose of NPK compared control (T₃:12.69 t ha⁻¹). Fruit yield recorded at 0.051 per cent boron as boron metalosate was significantly superior over 0.051 percent boron as boric acid, which was on par with boron @ 0.034 per cent as boron metalosate.

Table 48: Effect of foliar spray on yield of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	Yield (kg plant ⁻¹)			Yield (t ha ⁻¹)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	24.71	25.90	25.30	11.29	11.84	11.56
2	25.28	26.58	25.93	11.55	12.15	11.85
3	27.04	28.47	27.76	12.36	13.01	12.69
4	24.83	26.08	25.46	11.35	11.92	11.63
5	25.21	26.54	25.87	11.52	12.13	11.82
6	26.90	28.33	27.62	12.29	12.95	12.62
7	28.83	30.49	29.66	13.18	13.93	13.56
8	31.20	32.90	32.05	14.26	15.04	14.65
9	24.96	26.37	25.67	11.41	12.00	11.71
10	26.77	28.15	27.46	12.23	12.87	12.55
11	28.68	30.27	29.47	13.11	13.83	13.47
12	30.85	32.56	31.71	14.10	14.88	14.49
13	33.07	35.08	34.08	15.11	16.03	15.57
14	33.52	35.79	34.66	15.32	16.36	15.84
15	35.48	38.10	36.79	16.22	17.41	16.81
16	27.15	28.63	27.89	12.41	13.08	12.75
17	28.90	30.48	29.69	13.30	13.93	13.61
SEm ±	0.48	0.52	0.50	0.21	0.23	0.22
CD @ 5 %	1.38	1.50	1.40	0.61	0.66	0.63

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Zinc plays an important role in activation of enzymes which are necessary for growth hormone synthesis, photosynthesis, protein synthesis, carbohydrate metabolism, starch metabolism their by helped in enhancing yield of grapes. Similarly, boron also helps in cell division, cell elongation, pollination, fruit setting, fruit formation and translocation of sugars and other metabolites to the plant for the over growth and development. Hence combined application of zinc and boron as foliar spray as boron and zinc metalosate along with recommended dose NPK helped in enhancing yield by effect on increasing yield parameters like number of bunches plant⁻¹, number of berries bunch, mean weight of berries bunch⁻¹ and weight of bunch. These findings are supported by Dillon and Bindra (1995), Prabhu and Singaram (2002), Janaki *et al.* (2004), Subramoniam *et al.* (2006), Er *et al.* (2011), Nikkhah *et al.* (2013), Gunes *et al.* (2015) and Mohsen (2015).

4.3.4 Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of boron and zinc metalosate

Quality parameters such as total soluble solids (TSS), total sugars and titratable acidity as influenced by sources and levels boron and zinc metalosate are presented in the Table 49 and Figure 11.

4.3.4.1 Total soluble solids (° Brix)

Significantly higher total soluble solids (18.45 ° Brix) was recorded in treatment combination of T₁₁+ 0.050 % Zn as zinc metalosate followed by treatment T₁₄ (17.18 ° Brix) which consists of boron @ 0.0085 per cent and zinc @ 0.025 per cent foliar spray as boron and zinc metalosate, respectively which is on par with the treatment T₁₃ (16.96 ° Brix). Total soluble solids recorded under different levels of boron as boron metalosate source was higher than one which was recorded with boric acid.

4.3.4.2 Total sugar (%)

Significantly higher total sugar (20.74 %) was recorded in treatment which consists of combinations of boron and zinc @ 0.017 and 0.050 per cent foliar spray as boron and zinc metalosate along with recommended dose of NPK followed by treatment

0.0085 % B + 0.025 % Zn as boron and zinc metalosate (T₁₄: 19.28 %) which was on par with one which received higher level of boron as boron metalosate sources *i.e.* 0.051 % (T₁₃: 18.78 %). Total sugar content recorded in treatment T₁₃ (18.78 %) and T₈ (17.28 %) was on par with each other.

4.3.4.3 Titratable Acidity (%)

Foliar application of different sources and levels of boron in combination with zinc metalosate along with recommended dose of NPK played vital role in reducing titratable acidity per cent in the fruits. Among the nutrient sources and their combinations a significant reduction in titratable acidity was recorded in the treatment T₁₅ (0.19%) which received boron and zinc combination @ 0.017 and 0.050 per cent as boron and zinc metalosate as a foliar spray along with recommended dose of NPK *i.e.* T₁₅ (0.19 %) followed by T₁₄ which received boron @ 0.0085 % (boron metalosate) + zinc @ 0.025 % (zinc metalosate) as foliar spray + NPK (0.26 %) which was on par with treatment T₁₃ (0.28 %) *i.e.* boron @ 0.051 % through boric acid.

The increase in TSS may be due to catalytic action of zinc and boron and their combined synergistic effect. Boron increases the phloem carbohydrate and sugar movement, thereby by it helps in rapid translocation of sugars from leaves to developing fruits (Nikkhah, *et al.*, 2013). Zinc is a component of molecular structure of enzymes carbonic anhydrase which is involved in photosynthesis processes and cause increase in level of solids (Marschner, 1995).

Increased concentrations of boron and zinc in combination showed a positive effect in increasing the total sugars percentage in fruits might be due to breakdown of complex polymers into simple substances by hydrolytic enzymes. Increases in the levels of total sugars in treatments containing Zn may be attributed to its effects on the activities of aldolase enzyme, which is involved in the formation of sugars in fruits (Alloway, 2008).

The reduction of acid content in fruit with boron treatment might be due to hastening process of ripening during which degradation of acid might have occurred and helped in preventing excessive polymerization of sugar and accumulation of more sugar

Table 49: Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	TSS (° Brix)			Total Sugars (%)			Titratable Acidity (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	12.15	12.22	12.19	12.78	12.85	12.81	0.70	0.68	0.69
2	12.34	12.41	12.38	13.27	13.28	13.28	0.65	0.63	0.64
3	13.36	13.44	13.40	14.42	14.50	14.46	0.56	0.55	0.55
4	12.18	12.26	12.22	12.83	12.91	12.87	0.67	0.66	0.67
5	12.31	12.36	12.34	13.17	13.23	13.20	0.65	0.64	0.64
6	13.27	13.38	13.33	14.33	14.44	14.39	0.57	0.55	0.56
7	14.45	14.54	14.50	15.75	15.87	15.81	0.46	0.45	0.46
8	15.71	15.86	15.79	17.14	17.41	17.28	0.37	0.34	0.36
9	12.22	12.31	12.26	12.96	13.10	13.03	0.66	0.65	0.66
10	13.19	13.33	13.26	14.27	14.37	14.32	0.57	0.55	0.56
11	14.33	14.46	14.39	15.68	15.79	15.74	0.48	0.46	0.47
12	15.62	15.75	15.69	17.05	17.30	17.18	0.37	0.35	0.36
13	16.81	17.10	16.96	18.51	19.04	18.78	0.29	0.26	0.28
14	17.10	17.26	17.18	18.69	19.87	19.28	0.27	0.25	0.26
15	18.36	18.54	18.45	20.13	21.35	20.74	0.20	0.18	0.19
16	13.40	13.48	13.44	14.53	14.61	14.57	0.56	0.54	0.55
17	14.57	14.65	14.61	15.80	15.94	15.87	0.45	0.44	0.45
SEm ±	0.25	0.29	0.28	0.32	0.34	0.34	0.02	0.02	0.02
CD @ 5 %	0.73	0.85	0.79	0.91	0.97	0.95	0.05	0.06	0.05

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

in the cells of plant. It also appears that total soluble solids increase at the expense of acidity in tropical and subtropical fruit. The acid under the influence of borax might have converted into sugars and their derivatives by the reaction involving the reversal of glycolytic path way or might have been used in respiration (Trivedi *et al.*, 2012). Positive influence of boron and zinc in rapid conversion of acids into sugars and their derivatives by the reaction involving the reversal of glycolic pathway or might have been used as substrate in the respiration or both (Pandey *et al.*, 2008). The results were in close conformity with the findings of Makhija *et al.* (1988), Makhija and Chandra (1992), Prabhu and Singaram (2002), Aswathi and Lal (2009), Ghosh (2009), Thangaselvabai *et al.* (2009) and Rawat *et al.* (2010).

4.3.5 Effect of sources and levels of boron and zinc metalosate on nutrient content of index tissue of grapes before foliar spray

The major (N, P and K), secondary (Ca, Mg and S) and micronutrient (Zn, Cu, Fe, Mn) content in the index tissue (5th petiole) before application of boron and zinc metalosate are presented in the Table 50, 51 and 52.

The nitrogen, phosphorus and potassium content in the index tissue, which was collected one day before spray was, varied from 1.72 to 1.89, 0.61 to 0.74 and 2.28 to 2.48 per cent respectively. Whereas the secondary nutrients *Viz.*, calcium, magnesium and sulphur were in the range of 0.56 to 0.70, 0.45 to 0.55 and 0.48 to 0.61 per cent, respectively. With respect to micronutrients, about 31.25 to 35.34 mg kg⁻¹ Zn, 106.81 to 116.55 mg kg⁻¹ Fe, 10.04 to 10.86 mg kg⁻¹ Cu and 81.68 to 89.34 mg kg⁻¹ Mn was recorded in the index tissue.

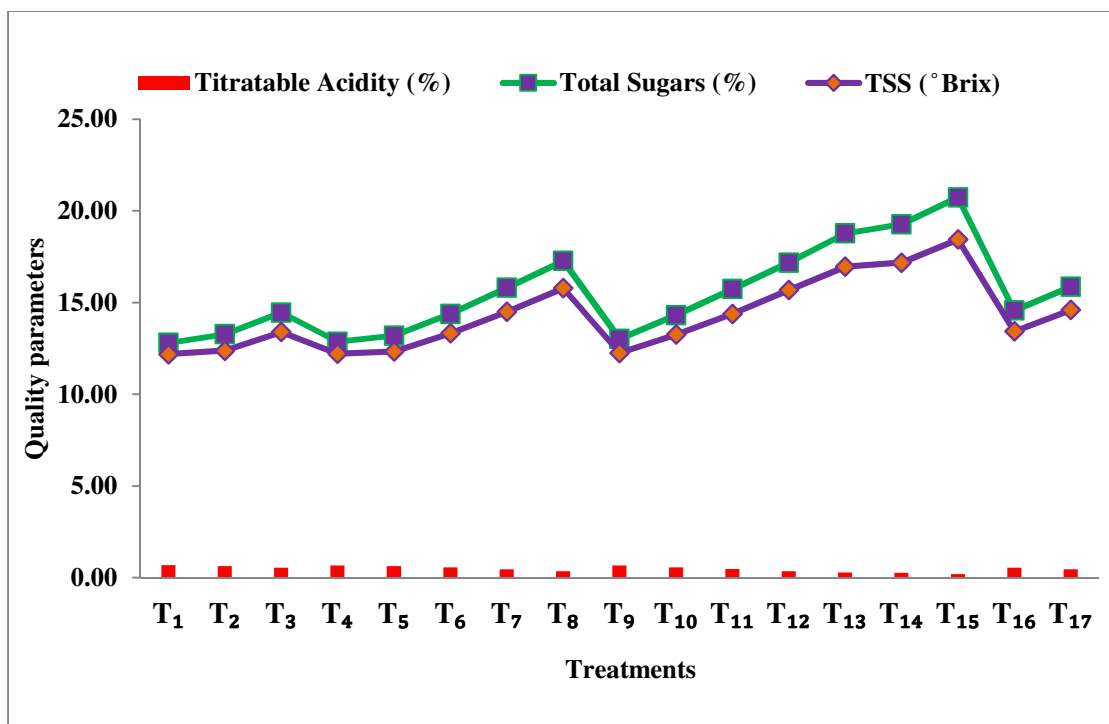


Fig.11: Effect of foliar spray on quality parameters of grapes as influenced by sources and levels of boron and zinc metalosate

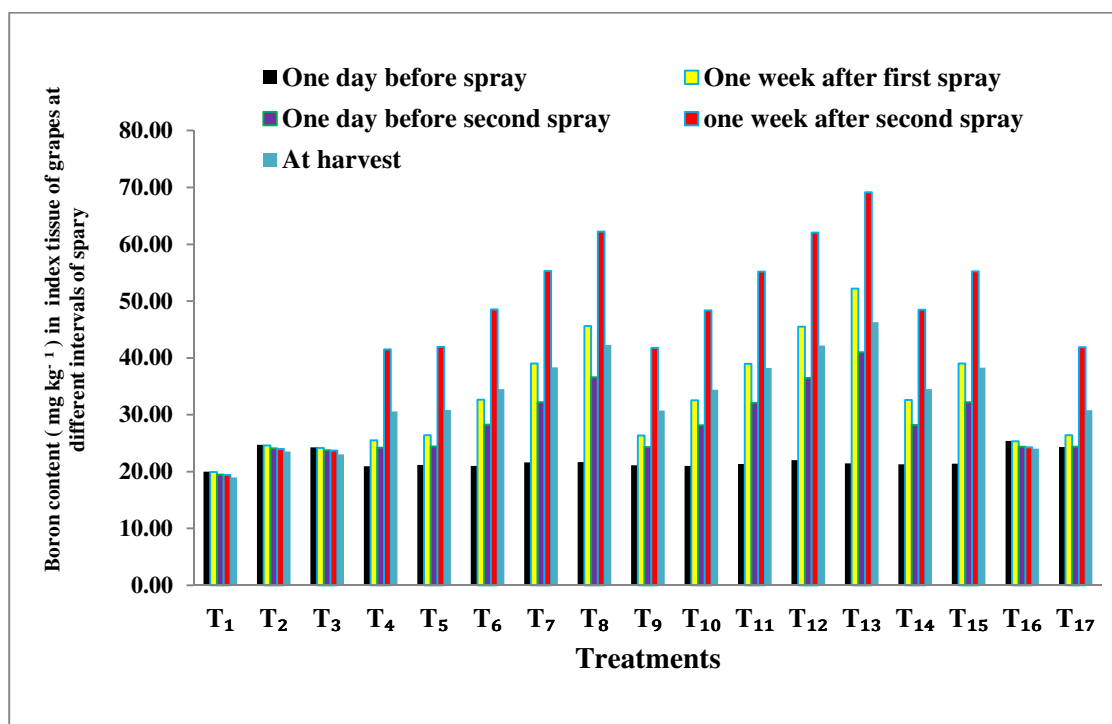


Fig.12: Effect of foliar spray on boron content (mg kg⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of boron and zinc metalosate

Table 50: Effect of sources and levels of boron and zinc metalosate on macronutrient content (%) of index tissue of grapes before foliar spray

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.69	1.74	1.72	0.60	0.62	0.61	2.20	2.37	2.28
2	1.71	1.75	1.73	0.63	0.64	0.64	2.28	2.40	2.34
3	1.81	1.92	1.87	0.67	0.76	0.71	2.31	2.57	2.44
4	1.70	1.74	1.72	0.61	0.62	0.62	2.19	2.38	2.29
5	1.69	1.76	1.73	0.62	0.64	0.63	2.20	2.40	2.30
6	1.73	1.78	1.76	0.64	0.66	0.65	2.17	2.43	2.30
7	1.75	1.81	1.78	0.61	0.68	0.64	2.22	2.45	2.34
8	1.72	1.84	1.78	0.63	0.70	0.67	2.19	2.48	2.34
9	1.70	1.75	1.73	0.62	0.63	0.63	2.21	2.39	2.30
10	1.71	1.77	1.74	0.65	0.66	0.66	2.20	2.41	2.30
11	1.69	1.80	1.75	0.61	0.67	0.64	2.18	2.44	2.31
12	1.74	1.83	1.79	0.64	0.69	0.67	2.20	2.47	2.34
13	1.70	1.86	1.78	0.60	0.71	0.66	2.22	2.50	2.36
14	1.72	1.87	1.80	0.63	0.72	0.68	2.19	2.52	2.36
15	1.71	1.90	1.81	0.61	0.74	0.68	2.21	2.55	2.38
16	1.83	1.94	1.89	0.68	0.79	0.74	2.35	2.61	2.48
17	1.80	1.92	1.86	0.66	0.77	0.72	2.30	2.58	2.44
SEm ±	0.04	0.07	0.06	0.02	0.07	0.05	0.07	0.09	0.11
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 51: Effect of sources and levels of boron and zinc metalosate on secondary nutrient content (%) of index tissue of grapes before foliar spray

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.53	0.61	0.57	0.45	0.46	0.46	0.47	0.48	0.48
2	0.52	0.62	0.57	0.47	0.48	0.48	0.50	0.51	0.51
3	0.60	0.74	0.67	0.51	0.56	0.54	0.56	0.61	0.59
4	0.50	0.61	0.56	0.45	0.46	0.46	0.51	0.48	0.49
5	0.53	0.62	0.58	0.46	0.47	0.46	0.50	0.52	0.51
6	0.51	0.64	0.58	0.45	0.48	0.47	0.52	0.53	0.53
7	0.49	0.65	0.57	0.44	0.50	0.47	0.48	0.54	0.51
8	0.52	0.68	0.60	0.46	0.53	0.50	0.49	0.56	0.53
9	0.53	0.62	0.58	0.44	0.46	0.45	0.51	0.52	0.52
10	0.49	0.63	0.56	0.45	0.47	0.46	0.48	0.52	0.50
11	0.50	0.65	0.58	0.44	0.49	0.47	0.50	0.54	0.52
12	0.52	0.67	0.60	0.46	0.50	0.48	0.51	0.55	0.53
13	0.49	0.70	0.59	0.45	0.52	0.49	0.52	0.57	0.55
14	0.51	0.72	0.62	0.44	0.53	0.49	0.49	0.58	0.54
15	0.53	0.74	0.63	0.46	0.53	0.50	0.52	0.60	0.56
16	0.63	0.77	0.70	0.52	0.57	0.55	0.57	0.64	0.61
17	0.61	0.75	0.68	0.50	0.55	0.53	0.55	0.62	0.59
SEm ±	0.05	0.05	0.07	0.03	0.04	0.04	0.02	0.06	0.04
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 52: Effect of sources and levels of boron and zinc metalosate on micro nutrient content (mg kg⁻¹) of index tissue of grapes before foliar spray

Treatments	Zinc			Iron			Copper			Manganese		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	31.58	31.47	31.53	107.04	106.57	106.81	10.35	10.27	10.31	84.10	83.34	83.72
2	32.78	32.85	32.82	107.99	107.32	107.66	10.34	10.20	10.27	85.07	84.79	84.93
3	34.15	35.06	34.61	113.24	114.45	113.85	10.22	10.05	10.14	88.25	89.07	88.66
4	32.38	32.55	32.46	107.97	107.66	107.82	10.25	10.13	10.19	84.22	83.94	84.08
5	31.94	32.64	32.29	107.22	106.97	107.09	10.20	10.05	10.13	83.78	83.53	83.66
6	31.73	31.96	31.85	108.13	107.38	107.75	10.21	9.96	10.09	83.92	83.65	83.78
7	31.42	32.11	31.77	107.78	106.93	107.36	10.18	9.90	10.04	81.89	81.46	81.68
8	32.55	32.65	32.60	109.24	108.81	109.03	10.27	10.09	10.18	84.02	83.59	83.81
9	31.41	31.57	31.49	110.79	110.28	110.54	10.94	10.78	10.86	84.98	84.74	84.86
10	30.67	31.82	31.25	109.07	108.65	108.86	10.83	10.69	10.76	84.02	83.65	83.84
11	31.18	32.05	31.62	110.47	109.96	110.22	10.84	10.58	10.71	83.97	83.71	83.84
12	31.37	32.23	31.80	109.79	109.32	109.56	10.45	10.21	10.33	83.55	82.98	83.26
13	31.50	32.78	32.14	110.94	110.25	110.60	10.94	10.66	10.80	85.42	85.09	85.26
14	31.03	32.95	31.99	108.12	113.13	110.63	10.73	10.85	10.79	83.17	86.87	85.02
15	30.98	33.07	32.03	107.88	114.25	111.07	10.65	10.76	10.71	83.75	87.21	85.48
16	35.23	35.44	35.34	115.94	117.16	116.55	10.25	10.03	10.14	89.75	88.92	89.34
17	34.18	35.63	34.91	114.54	116.05	115.30	10.39	10.14	10.27	88.51	88.75	88.63
SEm ±	1.62	1.45	1.52	3.14	3.72	3.49	0.27	0.36	0.33	2.77	2.64	2.67
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

4.3.6 Effect of foliar spray on boron content (mg kg^{-1}) of index tissue of grapes at different intervals as influenced by sources and levels of boron and zinc metalosate

The pooled data on effect of foliar spray of different sources and levels of boron in combination with zinc metalosate on boron content in index tissue at different intervals of spray are presented in Table 53 and Figure 12.

4.3.6.1 One day before first spray

Significant differences were not observed among the treatments with respect to boron content in the index tissue one day before first spray and its content ranged from 20.02 to 25.41 mg kg^{-1} . But higher boron content in index tissue one day before first spray was recorded in T₁₆ which consists of soil application of boron as borax along with farm yard manure and recommended dose of NPK (25.41 mg kg^{-1}).

4.3.6.2 One week after first spray

Foliar application of boron using different sources of boron in combination with zinc along with recommended dose of NPK significantly increased the boron content in index tissue one week after first spray and its content in index tissue ranged from 19.92 to 52.23 mg kg^{-1} . Among the different treatments higher content of boron *i.e.* 52.23 mg kg^{-1} was observed in treatment T₁₃, which consists of 0.051 per cent boron as boron metalosate foliar spray followed by treatment which received boron @ 0.051 per cent as boron acid foliar spray (T₈: 45.61 mg kg^{-1}) which was on par with treatment T₁₂ which consists of foliar application of boron @ 0.034 per cent as boron metalosate (45.52 mg kg^{-1}). Significantly higher boron content in index tissue was recorded in treatment T₇ (39.05 mg kg^{-1}) but was on par with treatment which received 0.017 per cent boron as boron metalosate and 0.050 per cent zinc as zinc metalosate (T₁₅: 39.01 mg kg^{-1}) and treatment T₁₁ (38.96 mg kg^{-1}) which received 0.017 per cent boron as boron metalosate. Lower boron content in index tissue was recorded where there was no application of boron either as soil or foliar application (T₁: 19.92 mg kg^{-1}).

4.3.6.3 One day before second spray

One day before second spray the boron content in index tissue reduced compared to one week after first spray and ranged from 19.49 to 40.99 mg kg⁻¹. Boron recorded higher content in treatment with higher boron *i.e.* T₁₃ (40.99 mg kg⁻¹) followed by the treatment T₈ (36.61 mg kg⁻¹) which received boron @ 0.051 per cent as boron metalosate which was on par with treatment T₁₂ (36.47 mg kg⁻¹). Boron content recorded in treatment T₇ (32.24 mg kg⁻¹) was on par with treatment T₁₅ (32.19 mg kg⁻¹) and T₁₁ (32.12 mg kg⁻¹). Lower content of boron *i.e.* 19.49 mg kg⁻¹ was recorded in treatment T₁ which received only recommended NPK.

4.3.6.4 One week after second spray

Higher boron content in the index tissue was recorded one week after second spray compared one week after first spray and ranged between 19.42 to 69.13 mg kg⁻¹. Treatment T₁₃ which received boron @ 0.051 as boron metalosate recorded 69.13 mg kg⁻¹ boron followed by treatment T₈ (62.23 mg kg⁻¹) which received boron @ 0.051 per cent as boron acid by foliar spray which was on par with treatment T₁₂ (62.08 mg kg⁻¹) which received 0.034 per cent boron as boron metalosate. Boron content in treatment T₇ (55.30 mg kg⁻¹) was on par with treatment which consists of T₁₁+ foliar spray of 0.050 per cent zinc as zinc metalosate (T₁₅: 55.25 mg kg⁻¹) and 0.017 per cent boron as boron metalosate (T₁₁: 55.18 mg kg⁻¹). Lower boron content in index tissue was recorded in treatment to which boron was not added (T₁: 19.42 mg kg⁻¹).

4.3.6.5 At harvest

Among the treatments, significantly higher boron content (46.27 mg kg⁻¹) was recorded in T₁₃ which received boron @ 0.051 per cent as boron metalosate followed by treatment T₈ (42.28 mg kg⁻¹) and T₁₂ (42.17 mg kg⁻¹). Boron content recorded in treatment T₇ was on par with treatment T₁₅ (38.28 mg kg⁻¹) and T₁₁ (38.23 mg kg⁻¹) which received boron and zinc @ 0.017 and 0.050 per cent as boron and zinc metalosate and 0.017 per cent boron as boron metalosate, respectively. Lower boron content in tissue was recorded in treatment T₁ which did not receive boron (T₁: 18.96 mg kg⁻¹).

Higher boron content in index tissue at one week after first spray and one week after second spray was recorded due to foliar application of higher content of boron *i.e.* 0.051 % as boron metalosate along with recommended NPK. Boron metalosate is an amino acid chelated boron liquid fertilizer, hundred per cent soluble in water, smaller particle size and neutral charge can easily translocate into the leaf through the cuticular layer thereby it helps in rapid absorption and effective utilization compared to other boron source like boric acid. Hence, this amino acid chelated boron metalosate, plays a vital role in increasing boron content in index tissue. Significant increase in leaf boron content upto 46.10 mg kg⁻¹ was due to foliar application of boron @ 0.5 per cent at three weeks intervals compared to one time application (20.80 mg kg⁻¹) to Bez El Anza grape in Egypt (Mostofa *et al.*, 2006). Effective increase in boron content of grape leaves was due to foliar application of boron @ 0.02 per cent compared to soil application (Gunes *et al.*, 2015). Also trees treated with combined application of boric acid and zinc sulphate at fruit set stage exhibited 6.2 fold increases in the leaf boron content as compared to untreated trees and suggested potential benefit of exogenous application of boric acid and zinc sulfate to Kinnow mandrine (Khan *et al.*, 2015). Foliar application of zinc and boron nanofertilizers increased the pomegranate leaf concentration, reflecting improvement in tree nutrient status (Davarpanah *et al.*, 2016). Similar, results were also reported by Dhillon and Bindra, (1995), Rajkumar *et al.* (2017) and Thirupathaiah *et al.* (2017).

One day before second spray and at harvest, index tissue of boron decreased compared to one week after first spray and one week after second spray which may be due effective and efficient utilization of boron to various metabolic activities of the plant such as cell division, cell elongation, cell differentiation, cell wall synthesis, root elongation, regulation of plant hormonal level, pollination, fruit setting, carbohydrate metabolism and sugar translocation (Marschner, 1995).

Table 53: Effect of foliar spray on boron content (mg kg⁻¹) of index tissue of grapes at different intervals as influenced by sources and levels of boron and zinc metalosate

Treatments	One day before first spray			One week after first spray			One day before second spray			One week after second spray			Harvest		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	20.10	19.93	20.02	20.03	19.81	19.92	19.87	19.10	19.49	19.80	19.03	19.42	19.07	18.85	18.96
2	24.13	25.26	24.70	24.05	25.19	24.62	23.81	24.36	24.09	23.73	24.29	24.01	23.31	23.75	23.53
3	23.45	25.05	24.25	23.40	24.96	24.18	23.25	24.27	23.76	23.19	24.18	23.69	22.90	23.13	23.02
4	20.79	21.13	20.96	24.83	26.23	25.53	23.95	24.50	24.23	38.94	44.03	41.49	27.58	33.55	30.57
5	21.10	21.30	21.20	25.70	27.17	26.44	24.17	24.69	24.43	39.15	44.74	41.95	27.85	33.87	30.86
6	20.55	21.50	21.03	31.41	33.92	32.67	27.42	29.13	28.28	45.69	51.39	48.54	31.50	37.58	34.54
7	21.22	22.08	21.65	37.20	40.90	39.05	30.76	33.71	32.24	52.31	58.29	55.30	35.23	41.42	38.33
8	21.00	22.35	21.68	43.16	48.05	45.61	34.55	38.66	36.61	59.10	65.35	62.23	39.04	45.51	42.28
9	20.97	21.23	21.10	25.62	27.13	26.38	24.08	24.57	24.33	39.03	44.58	41.81	27.73	33.78	30.76
10	20.62	21.38	21.00	31.29	33.79	32.54	27.29	29.04	28.17	45.55	51.25	48.40	31.39	37.47	34.43
11	21.03	21.61	21.32	37.10	40.82	38.96	30.63	33.61	32.12	52.19	58.16	55.18	35.14	41.31	38.23
12	21.85	22.23	22.04	43.07	47.97	45.52	34.36	38.58	36.47	58.95	65.20	62.08	38.95	45.39	42.17
13	20.35	22.50	21.43	49.15	55.30	52.23	38.27	43.70	40.99	65.87	72.38	69.13	42.90	49.63	46.27
14	21.22	21.38	21.30	31.38	33.81	32.60	27.38	29.09	28.24	45.62	51.29	48.46	31.45	37.54	34.50
15	20.75	22.06	21.41	37.16	40.85	39.01	30.70	33.67	32.19	52.28	58.22	55.25	35.19	41.37	38.28
16	24.93	25.89	25.41	24.85	25.78	25.32	24.32	24.41	24.37	24.25	24.33	24.29	23.96	24.10	24.03
17	23.52	25.13	24.33	25.67	27.15	26.41	24.13	24.62	24.38	39.10	44.65	41.88	27.78	33.86	30.82
SEm ±	1.09	1.29	1.34	1.84	2.24	2.02	1.03	1.47	1.30	2.16	2.22	2.20	1.14	1.24	1.26
CD @ 5 %	NS	NS	NS	5.31	6.45	5.71	2.96	4.23	3.68	6.23	6.39	6.22	3.30	3.57	3.57

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

4.3.7 Effect of foliar spray on nutrient content of grapes as influenced by sources and levels of boron and zinc metalosate

The macro, secondary and micronutrient content in grape as influenced by the foliar spray of different sources and levels of boron in combination with zinc metalosate are presented in Table 54, 55 and 56.

4.3.7.1 Effect foliar spray on macronutrient content (%) of grapes as influenced by sources and levels of boron and zinc metalosate

The data on nitrogen, phosphorus and potassium content in grapes varied significantly due to application of boron through various sources in combination with zinc metalosate along with recommended dose of NPK and are presented in Table 54.

Combined foliar application of boron and zinc @ 0.017 and 0.050 per cent as zinc and boron metalosate along with recommended dose of NPK (T₁₅) recorded significantly higher nitrogen content in grapes (1.83 %) followed by treatment T₁₄ (1.69 %) which consists of T₁₀ + foliar application of 0.025 % Zn as zinc metalosate which was on par with treatment T₁₃ (1.67 %). Least fruit nitrogen content was recorded in treatment T₁ (1.02 %) which consists of only recommended dose of NPK.

Phosphorus content (0.58 %) in the fruit was significantly higher in (T₁₁ + foliar application of 0.050 % Zn through zinc metalosate) followed by T₁₄ (T₁₀ + foliar spray of 0.025 % Zn through zinc metalosate) which was on par with T₁₃ (0.50 %) and the least phosphorus content was noticed in treatment T₁ (0.18 %).

Potassium content (2.23 %) of fruit was significantly higher in T₁₅ treatment which consists of T₁₁ + 0.050 % zinc as zinc metalosate as foliar spray followed by T₁₄ which received boron @ 0.0085 % through boron metalosate and zinc @ 0.025 % as zinc metalosate foliar spray along with recommended dose of NPK (T₁₄: 2.03 %) which was on par with one which received higher levels of boron *i.e.* 0.051 per cent as boron metalosate (T₁₃: 2.00 %). Significant increase of potassium content in the fruit was recorded at 0.017, 0.034 and 0.051 per cent boron level compared to control (1.42 %) and least fruit potassium content was recorded in T₁ (1.23 %).

Table 54: Effect foliar spray on macronutrient content (%) of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.01	1.03	1.02	0.17	0.18	0.18	1.20	1.25	1.23
2	1.09	1.11	1.10	0.20	0.22	0.21	1.23	1.29	1.26
3	1.21	1.27	1.24	0.27	0.29	0.28	1.39	1.45	1.42
4	1.03	1.05	1.04	0.19	0.20	0.20	1.21	1.26	1.24
5	1.07	1.10	1.09	0.20	0.22	0.21	1.23	1.28	1.25
6	1.21	1.27	1.24	0.25	0.28	0.27	1.39	1.45	1.42
7	1.35	1.42	1.39	0.35	0.37	0.36	1.57	1.64	1.61
8	1.49	1.58	1.53	0.40	0.47	0.44	1.76	1.85	1.81
9	1.05	1.07	1.06	0.19	0.21	0.20	1.21	1.27	1.24
10	1.20	1.25	1.23	0.25	0.28	0.27	1.37	1.45	1.41
11	1.34	1.41	1.38	0.34	0.37	0.35	1.55	1.64	1.60
12	1.47	1.56	1.52	0.39	0.46	0.43	1.74	1.83	1.79
13	1.61	1.73	1.67	0.46	0.54	0.50	1.94	2.05	2.00
14	1.64	1.75	1.69	0.48	0.56	0.52	1.97	2.09	2.03
15	1.76	1.90	1.83	0.54	0.63	0.58	2.15	2.31	2.23
16	1.23	1.27	1.25	0.29	0.31	0.30	1.41	1.47	1.44
17	1.35	1.42	1.39	0.33	0.39	0.36	1.59	1.64	1.62
SEm ±	0.03	0.05	0.04	0.02	0.02	0.02	0.05	0.05	0.05
CD @ 5 %	0.10	0.13	0.12	0.05	0.06	0.06	0.14	0.15	0.14

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Increase of NPK content in fruit might be due complementary effect of boron and zinc application as foliar spray as boron and zinc metalosate along with recommended NPK. Gunes *et al.* (2015) reported a significant improvement in nitrogen (1.74 %), phosphorus (0.25 %) and potassium (1.04 %) content in grapes due to foliar application of boron @ 12 kg ha⁻¹.

4.3.7.2 Effect foliar spray on secondary nutrient content (%) of grapes as influenced by sources and levels of boron and zinc metalosate

Data on secondary nutrients (Ca, Mg and S) content as affected by foliar spray of boron in combination with zinc metalosate through different sources and levels are presented in Table 55.

Significantly higher sulphur content of 0.46 per cent was recorded in grapes in treatment T₁₅ (T₁₁+ zinc @ 0.050 % through zinc metalosate) followed by treatment T₁₄ which received boron and zinc @ 0.0085 and 0.025 per cent as boron and zinc metalosate and treatment T₁ recorded least sulphur content (0.13 %). Non significant difference was observed between the treatments with respect to calcium and magnesium content in the fruit. Higher Ca and Mg content was recorded in treatment T₁₅ which consists of T₁₁+ zinc @ 0.050 % as zinc metalosate.

4.3.7.3 Effect foliar spray on micronutrient content (mg kg⁻¹) of grapes as influenced by sources and levels of boron and zinc metalosate

Data on fruit micronutrient content as affected by sources and levels of boron and zinc metalosate as a foliar spray is presented in Table 56.

Among different sources and levels of boron a significantly higher boron content in grapes was recorded in T₁₃ (45.74 mg kg⁻¹) which received 0.051 per cent boron as boron metalosate followed by T₈ (42.88 mg kg⁻¹) which consists of boron @ 0.051 per cent as boric acid which was on par with boron spray @ 0.034 per cent as foliar spray as boron metalosate (T₁₂: 42.72 mg kg⁻¹). Similarly, boron content of grapes recorded in treatment T₇ (40.03 mg kg⁻¹) which consist of 0.034 per cent boron as boric acid was on

Table 55: Effect foliar spray on secondary nutrient content (%) of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.53	0.55	0.54	0.39	0.37	0.38	0.12	0.14	0.13
2	0.57	0.60	0.58	0.40	0.44	0.42	0.13	0.16	0.15
3	0.62	0.64	0.63	0.44	0.47	0.45	0.18	0.22	0.20
4	0.55	0.57	0.56	0.39	0.43	0.41	0.12	0.15	0.13
5	0.58	0.60	0.59	0.41	0.45	0.43	0.13	0.16	0.14
6	0.61	0.64	0.63	0.43	0.48	0.46	0.17	0.21	0.19
7	0.66	0.70	0.68	0.49	0.53	0.51	0.24	0.29	0.27
8	0.70	0.75	0.73	0.54	0.60	0.57	0.29	0.36	0.33
9	0.57	0.60	0.58	0.40	0.43	0.42	0.12	0.15	0.14
10	0.59	0.63	0.61	0.42	0.47	0.45	0.17	0.21	0.19
11	0.64	0.68	0.66	0.47	0.51	0.49	0.23	0.28	0.26
12	0.68	0.74	0.71	0.51	0.56	0.54	0.28	0.34	0.31
13	0.75	0.80	0.77	0.56	0.63	0.60	0.34	0.41	0.38
14	0.77	0.83	0.80	0.58	0.66	0.62	0.36	0.44	0.40
15	0.83	0.88	0.86	0.63	0.70	0.66	0.41	0.50	0.46
16	0.64	0.67	0.66	0.45	0.48	0.47	0.19	0.23	0.21
17	0.67	0.70	0.69	0.48	0.51	0.50	0.23	0.28	0.26
SEm ±	0.09	0.12	0.11	0.09	0.12	0.10	0.01	0.02	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	0.04	0.05	0.04

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 56: Effect foliar spray on micronutrient content (mg kg⁻¹) of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	Zinc			Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	27.13	27.09	27.11	55.09	55.13	55.11	5.23	5.20	5.22	47.89	46.71	47.30	30.06	28.71	29.38
2	27.24	27.28	27.26	54.95	52.11	53.53	5.31	4.97	5.14	48.06	46.55	47.30	33.45	35.26	34.36
3	27.47	27.49	27.48	55.84	56.36	56.10	5.39	5.18	5.29	48.53	48.75	48.64	33.30	34.90	34.10
4	27.16	27.21	27.19	55.33	52.25	53.79	5.56	5.25	5.41	48.30	46.89	47.60	33.57	35.37	34.47
5	27.22	27.26	27.24	55.10	52.17	53.64	5.40	5.09	5.25	48.11	46.67	47.39	33.89	35.64	34.77
6	27.27	27.33	27.30	54.72	51.90	53.31	5.17	4.76	4.97	47.83	46.36	47.10	36.38	38.25	37.32
7	27.34	27.41	27.38	54.47	51.79	53.13	4.94	4.51	4.73	47.60	46.09	46.85	39.02	41.04	40.03
8	27.41	27.50	27.46	54.23	51.52	52.88	4.71	4.25	4.48	47.31	45.77	46.54	41.81	43.95	42.88
9	27.19	27.23	27.21	55.17	52.21	53.69	5.50	5.17	5.34	48.24	46.82	47.53	33.79	35.52	34.66
10	27.24	27.31	27.28	54.86	52.05	53.46	5.29	4.89	5.09	47.95	46.48	47.22	36.27	38.10	37.19
11	27.31	27.38	27.34	54.55	51.86	53.21	5.06	4.65	4.86	47.71	46.23	46.97	38.88	40.87	39.88
12	27.39	27.47	27.43	54.34	51.65	53.00	4.83	4.39	4.61	47.50	45.91	46.71	41.65	43.79	42.72
13	27.46	27.53	27.50	54.09	51.33	52.71	4.54	4.11	4.33	47.12	45.62	46.37	44.59	46.88	45.74
14	27.53	27.57	27.55	56.25	56.70	56.48	5.89	5.97	5.93	48.79	49.15	48.97	36.31	38.17	37.24
15	27.57	27.60	27.59	56.60	56.98	56.79	6.07	6.10	6.09	49.05	49.62	49.34	38.97	40.96	39.97
16	27.49	27.50	27.50	55.71	56.19	55.95	5.25	5.09	5.17	48.41	48.67	48.54	33.68	35.45	34.57
17	27.51	27.52	27.52	55.57	56.00	55.79	5.11	4.92	5.02	48.35	48.49	48.42	33.82	35.58	34.70
SEm ±	0.57	0.59	0.59	1.15	1.97	1.63	0.55	0.70	0.62	1.04	1.41	1.25	0.81	0.84	0.84
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.33	2.42	2.38

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

par with treatments T₁₅ (39.97 mg kg⁻¹) and T₁₁ (39.88 mg kg⁻¹) which consists of T₁₁ + foliar spray of zinc @ 0.050 per cent as zinc metalosate and foliar spray of boron @ 0.017 per cent as boron metalosate, respectively. Least boron content in grapes was recorded in treatment T₁ (29.38 mg kg⁻¹) (Figure 13).

The treatments did not show any significant influence in increasing zinc, iron, copper and manganese content in the fruit and they recorded numerically higher content in the treatment T₁₅ which consists of foliar application of boron and zinc @ 0.017 and 0.050 per cent as boron and zinc metalosate respectively along with recommended dose of NPK.

Increase in boron content in grape may be due to foliar spray of higher boron concentration as boron metalosate and its further translocation to grapes from leaves. Similarly, an improvement in boron content of grapes due to foliar spray of boron was recorded by Aroosa Khalil (2014) and Gunes *et al.* (2015).

4.3.8 Effect of foliar spray on nutrient content of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate

The pooled data containing major, secondary and micronutrient content in the index tissue as influenced by foliar spray of different sources and levels of boron in combination with zinc are presented in Table 57, 58 and 59.

4.3.8.1 Effect of foliar spray on macronutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate

The pooled data pertaining to nitrogen, phosphorus and potassium content in index tissue as affected by different source and levels of boron in combination with zinc is presented in Table 57.

Total nitrogen content in index tissue at harvest ranged from 1.13 to 1.64 per cent. In treatment T₁₅ which received boron and zinc @ 0.017 and 0.050 per cent as boron and zinc metalosate along with recommended dose of NPK, recorded significantly higher nitrogen content of 1.64 per cent followed by treatment T₁₄ which received 0.0085 and 0.025 per cent boron and zinc as boron and zinc metalosate (1.53 %) and NPK, which

was on par with treatment which received higher level of boron *i.e.* 0.051 per cent of boron through boron metalosate (T₁₃: 1.51 %). The total nitrogen content recorded at higher levels of boron from boric acid (T₈: 1.41 %) was on par with 0.034 per cent boron as boron metalosate (T₁₂: 1.39 %). Among the treatments, treatment T₁ recorded lower nitrogen content (1.13 %) in index tissue.

Significantly higher phosphorus content (0.57 %) in the index tissue at harvest was recorded in the treatment T₁₅ (T₁₁+ 0.050 % Zn through zinc metalosate) followed by treatment T₁₄ (0.51 %) which received 0.0085 % B + 0.025 % Zn as boron and zinc metalosate along with recommended NPK, this was (T₁₄) on par with treatment T₁₃ which received boron @ 0.051 per cent as boron metalosate (0.50 %). The treatment which received boron through boric acid (0.051 %) significantly recorded higher phosphorus content (T₈: 0.41 %) but was on par with 0.034 per cent boron as boron metalosate (T₁₂: 0.39 %). Least content of phosphorus in the index tissue at harvest was received in treatment T₁ (0.14 %).

Foliar application of boron and zinc through different sources along with recommended dose of NPK significantly increased the potassium content in index tissue and at harvest stage, it recorded 1.32 to 2.07 per cent. Among the treatments total potassium content was significantly higher in treatment T₁₅ which received boron and zinc @ 0.017 and 0.050 per cent as boron and zinc metalosate followed by treatment T₁₄ (1.93%) which consists of T₁₀ + foliar spray of 0.025 % Zn as zinc metalosate which was on par with the T₁₃ which received boron @ 0.051 per cent as boron metalosate (1.90 %). However, in treatment T₁, about 1.32 per cent of potassium was recorded in the index tissue at harvest.

Foliar spray of boron in combination with zinc as boron and zinc metalosate along with recommended dose of NPK at critical growth stages *viz.*, flowering (first spray) and fruit set stage (second spray) there was an enhancement of N, P and K contents in index tissue and at maturity, the entire metabolites move to economic part. Hence, small quantity of enhanced nitrogen, phosphorus and potassium content in

Table 57: Effect of foliar spray on macronutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.10	1.15	1.13	0.14	0.15	0.14	1.29	1.34	1.32
2	1.13	1.18	1.16	0.16	0.17	0.17	1.34	1.36	1.35
3	1.21	1.23	1.22	0.21	0.23	0.22	1.42	1.45	1.44
4	1.10	1.16	1.13	0.14	0.16	0.15	1.30	1.34	1.32
5	1.12	1.18	1.15	0.16	0.18	0.17	1.33	1.37	1.35
6	1.19	1.22	1.21	0.22	0.23	0.23	1.44	1.46	1.45
7	1.28	1.33	1.31	0.30	0.32	0.31	1.57	1.60	1.59
8	1.39	1.42	1.41	0.39	0.42	0.41	1.73	1.76	1.75
9	1.11	1.17	1.14	0.14	0.16	0.15	1.31	1.35	1.33
10	1.18	1.24	1.21	0.21	0.23	0.22	1.43	1.45	1.44
11	1.27	1.32	1.29	0.29	0.31	0.30	1.57	1.59	1.58
12	1.37	1.41	1.39	0.38	0.40	0.39	1.72	1.75	1.74
13	1.49	1.52	1.51	0.48	0.51	0.50	1.88	1.92	1.90
14	1.51	1.54	1.53	0.50	0.52	0.51	1.93	1.94	1.93
15	1.63	1.66	1.64	0.55	0.58	0.57	2.05	2.08	2.07
16	1.22	1.26	1.24	0.22	0.24	0.23	1.45	1.47	1.46
17	1.27	1.32	1.30	0.27	0.30	0.29	1.55	1.58	1.57
SEm ±	0.01	0.02	0.02	0.01	0.02	0.02	0.03	0.03	0.03
CD @ 5 %	0.04	0.05	0.05	0.04	0.05	0.05	0.08	0.09	0.09

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

index tissue was observed. Thirupathaiah *et al.* (2017), reported that the micronutrients like boron and zinc will enhance uptake of other nutrients NPK by nitrogen metabolism and optimum nitrogen enhances the absorption of other nutrients like P and K. The increase in the level of macronutrient was due to synergistic relationship between N, P and K with B and Zn (Khan *et al.*, 2015). Similar concord results were noticed by Sankar *et al.* (2013) and Baiea *et al.* (2015) in mango.

4.3.8.2 Effect of foliar spray on secondary nutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate

The data pertaining to secondary nutrient content in index tissue as influenced by different source and levels of boron in combination with zinc metalosate are presented in Table 58.

Total sulphur content was significantly higher in treatment T₁₅ (0.52 %) which consists of T₁₁+ foliar spray of 0.050 % Zn as zinc metalosate followed by treatment T₁₄ (0.45 %). lower content of sulphur in index tissue was recorded in treatment T₁ (0.09 %). However, non significant difference was observed among the treatments with respect to total calcium and magnesium content in index tissue at harvest and their concentration ranged from 0.30 to 0.42 and 0.20 to 0.39 mg kg⁻¹, respectively but numerically higher calcium and magnesium content was recorded in treatment T₁₅ followed by treatment T₁₄ which received boron and zinc @ 0.017 and 0.050 per cent and 0.0085 and 0.025 per cent through boron metalosate and zinc metalosate, respectively.

4.3.8.3 Effect of foliar spray on micronutrient content (mg kg⁻¹) of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate

The data pertaining to micronutrient content as influenced by different source and levels of boron in combination with zinc metalosate are presented in Table 59.

Non significant differences was recorded among the treatments with respect to zinc, iron, copper and manganese content in index tissue and they recorded in the range of 25.18 to 25.80, 85.03 to 90.07, 6.97 to 8.00 and 63.94 to 68.74 mg kg⁻¹ at harvest, respectively.

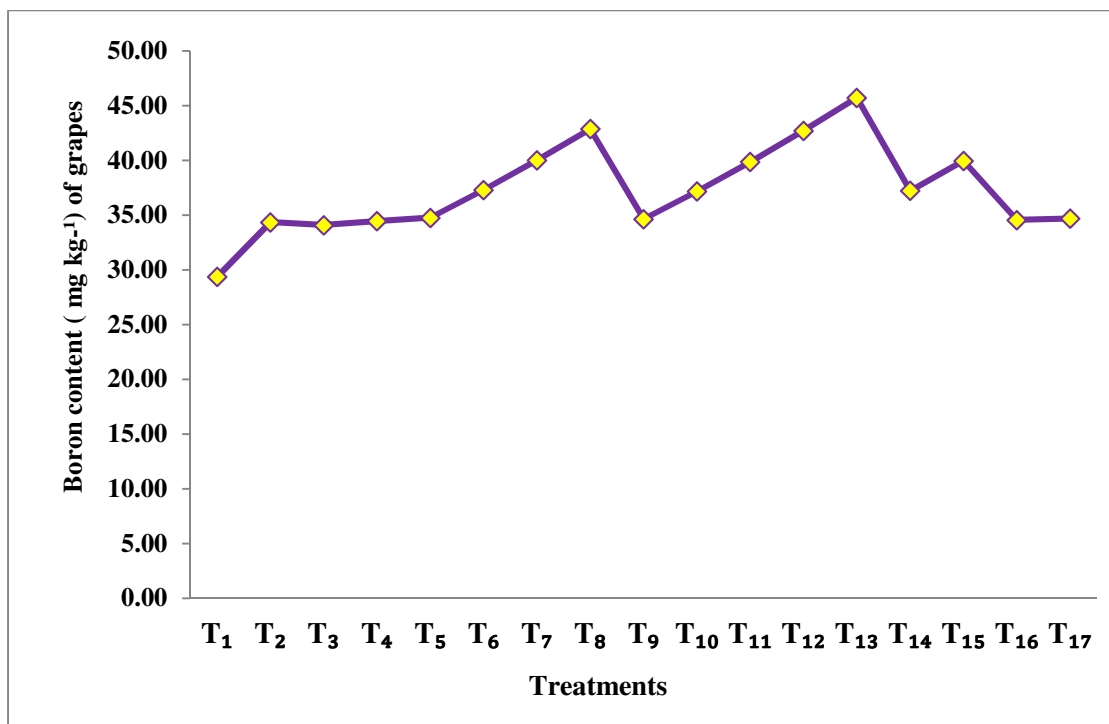


Fig.13: Effect of foliar spray on boron content (mg kg⁻¹) of grapes as influenced by sources and levels of boron and zinc metalosate

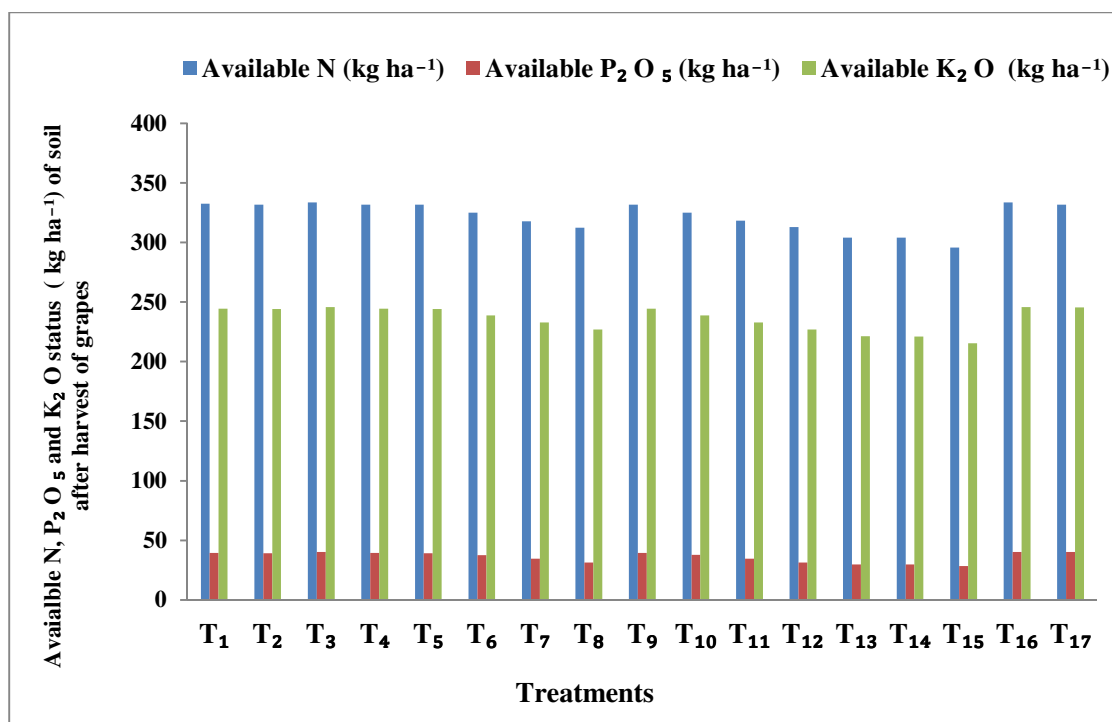


Fig.14: Effect of foliar spray on major nutrient status (kg ha⁻¹) of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

Table 58: Effect of foliar spray on secondary nutrient content (%) of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.28	0.32	0.30	0.21	0.18	0.20	0.08	0.09	0.09
2	0.29	0.33	0.31	0.23	0.25	0.24	0.10	0.12	0.11
3	0.31	0.36	0.34	0.25	0.28	0.27	0.14	0.16	0.15
4	0.28	0.32	0.30	0.22	0.25	0.24	0.08	0.10	0.09
5	0.30	0.33	0.32	0.24	0.27	0.26	0.10	0.12	0.11
6	0.31	0.35	0.33	0.26	0.30	0.28	0.15	0.16	0.16
7	0.33	0.37	0.35	0.29	0.32	0.31	0.23	0.25	0.24
8	0.36	0.40	0.38	0.31	0.35	0.33	0.32	0.35	0.34
9	0.29	0.33	0.31	0.22	0.26	0.24	0.09	0.10	0.10
10	0.30	0.34	0.32	0.25	0.28	0.26	0.15	0.16	0.16
11	0.32	0.36	0.34	0.27	0.31	0.29	0.22	0.23	0.23
12	0.35	0.38	0.37	0.30	0.33	0.31	0.31	0.33	0.32
13	0.37	0.41	0.39	0.32	0.36	0.34	0.42	0.44	0.43
14	0.38	0.42	0.40	0.34	0.38	0.36	0.44	0.46	0.45
15	0.40	0.44	0.42	0.36	0.41	0.39	0.53	0.51	0.52
16	0.32	0.35	0.34	0.26	0.29	0.28	0.15	0.17	0.16
17	0.35	0.38	0.37	0.28	0.32	0.30	0.21	0.23	0.22
SEm ±	0.04	0.05	0.04	0.04	0.08	0.06	0.01	0.01	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	0.04	0.04	0.04

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 59: Effect of foliar spray on micronutrient content (mg kg⁻¹) of index tissue of grapes at harvest as influenced by sources and levels of boron and zinc metalosate

Treatments	Zinc			Iron			Copper			Manganese		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	25.26	25.10	25.18	87.18	86.90	87.04	7.77	7.68	7.73	67.89	67.71	67.80
2	25.34	25.48	25.41	86.77	86.53	86.65	7.62	7.45	7.54	65.40	65.23	65.32
3	25.59	25.72	25.66	88.83	90.46	89.65	7.49	7.60	7.55	68.05	68.59	68.32
4	25.28	25.41	25.35	87.10	86.79	86.95	7.73	7.63	7.68	65.74	65.52	65.63
5	25.33	25.47	25.40	86.89	86.57	86.73	7.65	7.50	7.58	65.49	65.33	65.41
6	25.39	25.54	25.47	86.51	86.30	86.40	7.53	7.37	7.45	65.11	64.84	64.98
7	25.45	25.63	25.54	86.07	85.79	85.93	7.34	7.19	7.27	64.70	64.41	64.56
8	25.53	25.71	25.62	85.45	85.16	85.31	7.11	6.98	7.05	64.19	63.90	64.05
9	25.31	25.43	25.37	86.91	86.70	86.81	7.70	7.59	7.65	65.60	65.39	65.50
10	25.37	25.52	25.45	86.62	86.38	86.50	7.57	7.44	7.51	65.23	64.96	65.10
11	25.42	25.59	25.51	86.25	85.93	86.09	7.38	7.25	7.32	64.82	64.59	64.71
12	25.50	25.68	25.59	85.81	85.42	85.62	7.17	7.07	7.12	64.33	64.06	64.20
13	25.57	25.74	25.66	85.17	84.88	85.03	7.03	6.91	6.97	64.09	63.79	63.94
14	25.68	25.81	25.75	89.11	90.85	89.98	7.84	7.90	7.87	68.30	68.75	68.53
15	25.73	25.86	25.80	89.53	90.60	90.07	7.96	8.04	8.00	68.45	69.02	68.74
16	25.61	25.75	25.68	88.67	88.38	88.53	7.47	7.55	7.51	68.09	68.17	68.13
17	25.64	25.77	25.71	88.35	87.92	88.14	7.29	7.46	7.38	68.17	68.33	68.25
SEm ±	0.53	0.56	0.55	1.83	2.08	2.03	0.33	0.40	0.36	1.56	1.84	1.68
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

4.3.9 Effect of foliar spray on chemical properties and nutrient status of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

The data presented in the Table 60, 61, 62 and 63 indicates the effect of foliar spray of sources and levels of boron and zinc metalosate on chemical properties and nutrient status of soil at harvest of grapes

4.3.9.1 Effect of foliar spray on chemical properties of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

The data pertaining to chemical properties of soil by different source and levels of boron in combination with zinc metalosate are presented in Table 60.

The soil pH, EC (dSm^{-1}) and organic carbon content varies from 6.28 to 6.35, 0.50 to 0.57 dSm^{-1} and 0.66 to 0.75 per cent, respectively and non significant difference was observed among the treatments.

4.3.9.2 Effect of foliar spray on major nutrient status (kg ha^{-1}) of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

The data pertaining to major nutrient content in post harvest soil at harvest of grapes due to different source and levels of boron and zinc metalosate are presented in Table 61 and Figure 14.

Among different treatments, significantly higher available nitrogen in soil was recorded in treatment T_3 ($333.80 \text{ kg ha}^{-1}$) and T_{16} ($333.70 \text{ kg ha}^{-1}$) which received recommended dose of NPK along with farm yard manure and recommended NPK+ FYM+ soil application of ZnSO_4 , respectively. Least increase in available N content in soil was observed in treatment T_{15} ($295.74 \text{ kg ha}^{-1}$) and T_{14} ($304.02 \text{ kg ha}^{-1}$) which received boron and zinc as foliar spray @ 0.017 % + 0.050 % and 0.0085 % + 0.025 % as boron and zinc metalosate, respectively along with recommended dose of NPK.

Table 60: Effect of foliar spray on chemical properties of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	pH			EC (dSm ⁻¹)			Organic carbon (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	6.31	6.29	6.30	0.50	0.51	0.50	0.67	0.68	0.68
2	6.32	6.30	6.31	0.51	0.52	0.51	0.68	0.68	0.68
3	6.28	6.27	6.28	0.55	0.57	0.56	0.73	0.74	0.73
4	6.33	6.31	6.32	0.52	0.53	0.52	0.67	0.68	0.67
5	6.35	6.34	6.35	0.53	0.53	0.53	0.68	0.69	0.68
6	6.31	6.30	6.31	0.50	0.52	0.51	0.68	0.67	0.67
7	6.34	6.33	6.34	0.51	0.52	0.51	0.67	0.68	0.67
8	6.35	6.33	6.34	0.52	0.54	0.53	0.66	0.67	0.66
9	6.33	6.32	6.33	0.52	0.53	0.52	0.68	0.69	0.69
10	6.35	6.33	6.34	0.53	0.54	0.53	0.68	0.68	0.68
11	6.33	6.31	6.32	0.54	0.55	0.54	0.67	0.68	0.68
12	6.32	6.31	6.32	0.50	0.52	0.51	0.66	0.67	0.66
13	6.35	6.33	6.34	0.51	0.52	0.51	0.66	0.67	0.66
14	6.32	6.30	6.31	0.54	0.55	0.54	0.65	0.65	0.65
15	6.31	6.29	6.30	0.51	0.52	0.51	0.67	0.68	0.67
16	6.29	6.26	6.28	0.55	0.57	0.56	0.73	0.75	0.74
17	6.30	6.28	6.29	0.56	0.58	0.57	0.74	0.75	0.75
SEm ±	0.08	0.10	0.09	0.02	0.03	0.03	0.03	0.04	0.03
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 61: Effect of foliar spray on major nutrient status (kg ha⁻¹) of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	321.01	344.00	332.51	34.67	44.21	39.44	225.57	263.54	244.56
2	320.24	343.18	331.71	34.41	43.83	39.12	225.32	263.25	244.28
3	322.25	345.35	333.80	35.37	45.20	40.28	226.66	265.10	245.88
4	320.47	343.48	331.97	34.59	44.18	39.39	225.48	263.62	244.55
5	320.29	343.19	331.74	34.48	43.93	39.21	225.33	263.14	244.24
6	313.81	336.40	325.11	33.12	42.09	37.61	220.67	256.94	238.80
7	307.05	328.89	317.97	30.47	38.50	34.49	215.64	250.03	232.84
8	300.22	324.81	312.51	27.76	34.82	31.29	210.69	243.29	226.99
9	320.35	343.29	331.82	34.52	44.00	39.26	225.42	263.46	244.44
10	313.97	336.39	325.18	33.17	42.16	37.66	220.80	257.10	238.95
11	307.35	329.27	318.31	30.53	38.56	34.55	215.68	250.05	232.86
12	300.78	325.09	312.93	27.80	34.84	31.32	210.74	243.49	227.12
13	293.92	314.60	304.26	26.42	32.95	29.69	205.86	236.73	221.30
14	293.69	314.34	304.02	26.41	32.97	29.69	205.71	236.62	221.16
15	287.53	303.94	295.74	25.23	31.34	28.29	200.90	229.83	215.37
16	322.18	345.23	333.70	35.33	45.10	40.21	226.54	264.85	245.70
17	322.07	341.81	331.94	35.26	45.04	40.15	226.46	264.86	245.66
SEm ±	2.09	3.20	2.72	0.38	0.52	0.45	1.54	2.15	1.85
CD @ 5 %	6.03	9.21	7.67	1.10	1.49	1.28	4.42	6.21	5.22

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Increase in available nitrogen, phosphorus and potassium content of soil in treatments T₁₅ and T₁₄ may be due to combined application of boron and zinc as foliar spray along with soil application of recommended dose of NPK.

Higher available NPK content in T₃ and T₁₆ compared to other treatments may be due to lesser uptake of these nutrients by the crop compared to T₁₅ and T₁₄ treatments and also due to farm yard manure application. Combined application of inorganic fertilizers and organic manures will increase the available nutrients like NPK in soil because, application of farmyard manure improves physical properties of soil thereby creating favourable conditions for microbial activity resulting in increase in the nutrient availability in the soil. Also, organic acids produced during decomposition of FYM helps reduce fixation and conversion of unavailable forms of nutrients to available forms, hence helps in improving soil nutrient status (Singh *et al.*, 2012). These results are in line with Dutta *et al.* (2010), Musmade *et al.* (2010) and Mahendra *et al.* (2009) who reported that the application of different nutrients through chemical fertilizer and manures significantly increased the soil available nitrogen, phosphorus and potassium contents.

4.3.9.2 Effect of foliar spray on secondary nutrient status of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

The data pertaining to secondary nutrient content in post harvest soil by different source and levels of boron in combination with zinc are presented in Table 62.

Significant increase in available sulphur content in soil was recorded in treatment T₃ (18.66 mg kg⁻¹), T₁₆ (18.54 mg kg⁻¹) and T₁₇ (18.47 mg kg⁻¹) compared to other treatments. Lower available sulphur was recorded in treatment T₁₅ (T₁₁+ Foliar spray of 0.050 % Zn through zinc metalosate). Non significant difference was observed among the treatments with respect to exchangeable calcium and magnesium content of soil and recorded in the range of 4.53 to 4.57 and 1.81 to 1.88 C mol (p⁺) kg⁻¹.

Table 62: Effect of foliar spray on secondary nutrient status of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	Exch. Calcium (C mol (p ⁺) kg ⁻¹)			Exch. Magnesium (C mol (p ⁺) kg ⁻¹)			Sulphur (mg kg ⁻¹)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	4.51	4.59	4.55	1.84	1.82	1.83	16.99	19.53	18.26
2	4.50	4.57	4.54	1.83	1.81	1.82	16.89	19.30	18.09
3	4.54	4.61	4.57	1.87	1.89	1.88	17.10	20.22	18.66
4	4.52	4.56	4.54	1.83	1.82	1.83	16.97	19.39	18.18
5	4.50	4.57	4.54	1.84	1.83	1.83	16.92	19.32	18.12
6	4.50	4.58	4.54	1.84	1.84	1.84	15.91	18.23	17.07
7	4.51	4.55	4.53	1.83	1.82	1.83	14.89	17.14	16.02
8	4.50	4.57	4.53	1.81	1.81	1.81	13.90	16.83	15.36
9	4.51	4.55	4.53	1.82	1.81	1.82	16.94	19.34	18.14
10	4.50	4.55	4.53	1.84	1.84	1.84	15.94	18.26	17.10
11	4.51	4.56	4.53	1.82	1.81	1.82	14.91	17.15	16.03
12	4.52	4.57	4.54	1.82	1.81	1.82	13.94	16.81	15.37
13	4.50	4.56	4.53	1.82	1.81	1.82	13.01	15.61	14.31
14	4.52	4.57	4.55	1.84	1.84	1.84	12.99	15.50	14.25
15	4.51	4.55	4.53	1.83	1.82	1.83	12.15	14.16	13.15
16	4.53	4.60	4.56	1.87	1.89	1.88	17.08	19.99	18.54
17	4.54	4.59	4.57	1.87	1.88	1.87	17.05	19.89	18.47
SEm ±	0.10	0.10	0.10	0.03	0.03	0.03	0.27	0.42	0.36
CD @ 5 %	NS	NS	NS	NS	NS	NS	0.78	1.20	1.02

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Significant increase in available sulphur in soil in treatments T₃ and T₁₆ may be due to supply of sulphur from single super phosphate which was used to supply recommended dose of phosphorus along with N & K and farm yard manure. Farm yard manure is a good source of all the nutrients, hence its addition to the soil helps in increasing available sulphur content in soil. Application of FYM @ 50 kg plant⁻¹ significantly increased the available sulphur content in acid lime orchards in both years of the study over the control (Khan and Begum, 2007).

4.3.9.3 Effect of foliar spray on micronutrient status (mg kg⁻¹) of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

The data pertaining to micro nutrient content of soil due to different sources and levels of boron and zinc metalosate are presented in Table 63.

The treatment T₁₆ which received recommended dose of NPK along with soil application of boron and farm yard manure significantly recorded higher hot water soluble boron of 0.55 mg kg⁻¹ of soil followed by T₁₇ (0.51 mg kg⁻¹) and T₃ (0.51 mg kg⁻¹) compared to other treatments. About 0.45 to 0.56 mg kg⁻¹ zinc, 36.62 to 41.26 mg kg⁻¹ iron, 0.25 to 0.30 mg kg⁻¹ copper and 24.18 to 29.20 mg kg⁻¹ manganese were recorded in soil but the effect was non significant among treatments.

Significant increase in hot water soluble boron in treatments of T₁₇ and T₃ of soil may be due to addition of farm yard manure along with recommended dose of NPK. These results are in line with Thakur (2013) who reported significant improvement in the micronutrient content in soil due to addition of biofertilizers (60 g tree basin⁻¹) + green manure (Sunhemp@ 25 g seed/tree basin) + FYM (40 kg) + vermicompost (24 kg).

Table 63: Effect of foliar spray on micronutrient status (mg kg⁻¹) of soil at harvest of grapes as influenced by sources and levels of boron and zinc metalosate

Treatments	Zinc			Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.49	0.47	0.48	37.05	36.18	36.62	0.27	0.26	0.27	25.04	24.46	24.75	0.37	0.36	0.37
2	0.49	0.48	0.48	37.23	36.21	36.72	0.28	0.27	0.28	25.36	24.76	25.06	0.50	0.49	0.49
3	0.55	0.57	0.56	40.89	41.62	41.26	0.29	0.30	0.30	28.92	29.48	29.20	0.49	0.54	0.51
4	0.50	0.50	0.50	37.09	36.25	36.67	0.26	0.25	0.26	25.19	24.62	24.90	0.38	0.37	0.38
5	0.49	0.48	0.49	37.20	36.23	36.71	0.27	0.26	0.27	25.32	24.72	25.02	0.38	0.37	0.38
6	0.48	0.47	0.47	37.43	36.55	36.99	0.29	0.28	0.29	25.58	24.98	25.28	0.39	0.38	0.39
7	0.47	0.46	0.46	37.74	36.88	37.31	0.28	0.27	0.28	25.91	25.32	25.61	0.40	0.39	0.40
8	0.49	0.48	0.48	38.17	37.22	37.69	0.26	0.25	0.26	26.02	25.41	25.71	0.41	0.40	0.41
9	0.48	0.47	0.47	37.13	36.24	36.69	0.25	0.24	0.25	25.26	24.66	24.96	0.38	0.37	0.38
10	0.46	0.45	0.45	37.30	36.41	36.86	0.26	0.25	0.26	25.45	24.84	25.15	0.39	0.38	0.39
11	0.45	0.45	0.45	37.65	36.77	37.21	0.26	0.25	0.26	25.74	25.14	25.44	0.40	0.39	0.40
12	0.47	0.46	0.46	38.09	37.18	37.64	0.28	0.27	0.28	26.08	25.46	25.77	0.41	0.40	0.41
13	0.46	0.45	0.45	38.18	37.30	37.74	0.29	0.28	0.29	26.11	25.51	25.81	0.42	0.40	0.41
14	0.50	0.49	0.49	37.85	36.87	37.36	0.27	0.26	0.27	24.72	24.16	24.44	0.43	0.42	0.43
15	0.51	0.50	0.50	37.73	36.85	37.29	0.28	0.27	0.28	24.47	23.89	24.18	0.45	0.44	0.44
16	0.54	0.57	0.55	40.22	41.32	40.77	0.29	0.30	0.30	28.63	29.01	28.82	0.52	0.57	0.55
17	0.55	0.57	0.56	40.16	41.22	40.69	0.28	0.29	0.29	28.44	29.10	28.77	0.49	0.53	0.51
SEm ±	0.04	0.04	0.03	2.28	2.06	2.26	0.02	0.02	0.02	1.79	2.23	2.00	0.01	0.01	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.03	0.04	0.03

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

4.4. Experiment No. 4: Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of boron and zinc metalosate

4.4.1. Effect of foliar spray on growth and yield parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data on plant height and yield parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate are presented in Table 64.

4.4.1.1 Plant height (cm)

Among the treatments, significantly higher plant height of 218.95 cm was recorded in the treatment T₁₅ which received combination of boron and zinc metalosate @ 0.017 and 0.050 per cent as boron and zinc metalosate along with recommended dose of NPK compared to other treatments. Lower plant height of 199.62 cm was recorded in treatment T₁ which received only recommended dose of NPK.

The increase in plant height may be due to increased photosynthetic compounds in the plant tissue which might be involved in the synthesis of tryptophan which is a precursor of IAA on foliar application of micronutrients to the pomegranate cv Bhagwa (Santhosh, 2015). These results are in line with Ram and Bose (2000), Saraswathy *et al* (2004) in sapota, Singh *et al.* (2010) in papaya, Khan *et al.* (2012) in mandrine and Yadav *et al.* (2014) in pomegranate.

4.4.1.2 Number of fruits harvested shoot⁻¹

Significantly higher number of fruits shoot⁻¹ was recorded in the treatment T₁₅ (5.37) which received boron @ 0.017 and zinc @ 0.050 per cent as boron and zinc metalosate, respectively along with recommended dose of NPK compared to other treatments and least number of fruits shoot⁻¹ was noticed in treatment T₁(4.00).

4.4.1.3 Number of fruits plant⁻¹

The treatment T₁₅ which received T₁₁ + foliar spray of 0.050 % Zn through zinc metalosate recorded significantly more number of fruits plant⁻¹(90.82) and was on par

Table 64: Effect of foliar spray on growth and yield parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	Plant height (cm)			Number of fruits plant ⁻¹			Number of fruits harvested shoot ⁻¹			Total weight of fruits shoot ⁻¹		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	178.90	220.33	199.62	81.08	83.24	82.16	3.90	4.10	4.00	938.22	1042.59	990.41
2	179.78	221.45	200.62	81.79	84.17	82.98	4.00	4.20	4.10	987.00	1109.39	1048.19
3	182.11	224.16	203.14	82.68	85.28	83.98	4.30	4.50	4.40	1123.07	1255.32	1189.20
4	179.07	220.89	199.98	81.11	83.41	82.26	4.00	4.20	4.10	964.24	1081.51	1022.88
5	179.73	221.37	200.55	81.42	83.93	82.68	4.10	4.30	4.20	1009.51	1134.73	1072.12
6	181.95	224.04	203.00	82.63	85.29	83.96	4.20	4.40	4.30	1095.99	1226.37	1161.18
7	184.82	227.23	206.03	84.28	87.11	85.70	4.50	4.70	4.60	1257.12	1387.11	1322.12
8	188.21	231.41	209.81	86.05	89.06	87.56	4.80	5.00	4.90	1437.19	1564.00	1500.59
9	179.10	221.12	200.11	81.24	83.65	82.45	4.00	4.20	4.10	964.60	1107.46	1036.03
10	181.74	223.61	202.68	82.55	85.09	83.82	4.20	4.40	4.30	1095.49	1225.44	1160.47
11	184.31	226.85	205.58	83.96	86.77	85.37	4.40	4.70	4.55	1227.95	1385.37	1306.66
12	187.85	230.92	209.39	85.66	88.61	87.14	4.70	4.90	4.80	1405.07	1530.52	1467.79
13	191.72	235.47	213.60	87.41	90.56	88.99	4.90	5.20	5.05	1570.11	1727.34	1648.72
14	192.11	237.90	215.01	87.65	90.93	89.29	5.00	5.30	5.15	1604.05	1764.64	1684.34
15	196.76	241.14	218.95	89.10	92.55	90.82	5.20	5.50	5.37	1743.72	1934.35	1839.03
16	182.23	224.25	203.24	82.78	85.51	84.15	4.30	4.50	4.38	1099.25	1255.91	1177.58
17	184.90	227.36	206.13	84.37	87.23	85.80	4.50	4.70	4.60	1257.44	1387.49	1322.46
SEm ±	4.32	4.75	4.60	1.42	1.81	1.62	0.31	0.32	0.33	29.74	33.88	32.60
CD @ 5 %	NS	NS	12.98	4.08	5.22	4.56	NS	NS	0.93	85.66	97.59	92.03

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

with treatment, which received T₁₀ + foliar spray of 0.025 % Zn through zinc metalosate (T₁₄: 89.29) and lowest number of fruits plant⁻¹ was recorded in treatment T₁ (82.16).

4.4.1.4 Total weight of fruits shoot⁻¹

Significantly higher total weight of fruits shoots⁻¹ was recorded in treatment T₁₅ (1839.03 g) which received boron and zinc in combination @ 0.017 and 0.050 per cent as boron and zinc metalosate, respectively along with recommended dose of NPK followed by treatment T₁₄ (1684.34 g) which consists of T₁₀ + foliar application of 0.025 % Zn as zinc metalosate along with recommended dose of NPK, which was on par with the treatment T₁₃ (1648.72 g) which received boron as boron metalosate @ 0.051 per cent as foliar spray. Lower total weight of fruits shoot⁻¹ (T₁: 990.41 g) was recorded in the treatment T₁ which received recommended dose of NPK.

The increase in the yield parameters like number fruits harvested shoot⁻¹, number of fruits plant⁻¹ and total weight of fruits shoot⁻¹ may be due to boron and zinc metalosate in combination helps in pollination, fruit setting and fruit retention. Zinc stimulates the synthesis of endogenous auxins and auxin prevents the abscission and facilitated the ovary to remain attached with the shoot, resulting in lower fruit drop (Parmar *et al.*, 2014). Hence they showed stimulatory effect on the yield parameters of the pomegranate. The increase in the yield parameters of pomegranate cv. Bhagwa may also be due to the effect of foliar application of zinc and boron on cell division, cell elongation, photosynthesis and metabolites form leaf and other part of plants (Pandey, 2010). Similar results were noticed by Mohamad *et al.* (2011), Sharma and Belsar (2011), Pandey *et al.* (2012), Rakesh kumar (2012), Yadav *et al.* (2014), Tanuja *et al.* (2016), and Venu *et al.* (2014).

4.4.2. Effect of foliar spray on yield of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data of pomegranate yield, kg plant⁻¹ and t ha⁻¹ as influenced by source of boron and zinc along with recommended dose of NPK are presented in Table 65.

Table 65: Effect of foliar spray on yield of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	Yield (kg plant ⁻¹)			Yield (t ha ⁻¹)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	19.47	20.87	20.17	17.82	19.09	18.46
2	19.75	21.25	20.50	18.07	19.44	18.76
3	21.14	22.86	22.00	19.34	20.92	20.13
4	19.53	20.98	20.25	17.87	19.20	18.54
5	19.72	21.27	20.50	18.04	19.46	18.75
6	21.09	22.91	22.00	19.30	20.96	20.13
7	22.62	24.66	23.64	20.70	22.56	21.63
8	24.40	26.71	25.56	22.23	24.44	23.34
9	19.61	21.09	20.35	17.94	19.30	18.62
10	21.04	22.68	21.86	19.25	20.75	20.00
11	22.55	24.52	23.54	20.63	22.44	21.54
12	24.29	26.50	25.40	22.19	24.25	23.22
13	26.21	28.77	27.49	23.98	26.32	25.15
14	26.40	29.09	27.74	24.15	26.62	25.39
15	28.05	30.92	29.49	25.66	28.29	26.97
16	21.20	23.00	22.10	19.39	21.05	20.22
17	22.65	24.56	23.61	20.72	22.47	21.60
SEm ±	0.42	0.47	0.45	0.39	0.45	0.42
CD @ 5 %	1.22	1.35	1.28	1.14	1.29	1.18

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

4.4.2.1 Yield (kg plant⁻¹)

Significant increase in pomegranate yield was recorded due to foliar application of different sources and levels of boron in combination with zinc. Significantly higher yield per plant of 29.49 kg plant⁻¹ was recorded in the treatment T₁₅ which consists of T₁₁+ foliar spray of 0.050 per cent zinc as zinc metalosate followed by T₁₄ treatment (27.74 kg plant⁻¹) which consists of foliar application of boron and zinc as boron and zinc metalosate @ 0.0085 and 0.025 per cent, respectively which was on par with the treatment T₁₃ (27.49 kg plant⁻¹) which received boron @ 0.051 per cent through boron metalosate. Yield recorded at 0.051 per cent boron as boric acid (T₈: 25.56 kg plant⁻¹) was on par with treatment which consists of boron @ 0.034 per cent as boron metalosate compared to control (T₃: 22 kg plant⁻¹).

4.4.2.2 Yield (t ha⁻¹)

Foliar spray of boron and zinc in combination of 0.017 and 0.050 per cent as boron and zinc metalosate, respectively along with recommended dose of NPK significantly increased the fruit yield ha⁻¹ (T₁₅: 26.97 t ha⁻¹) followed by T₁₄ treatment (25.39 t ha⁻¹) which consists of foliar application of boron and zinc as boron and zinc metalosate @ 0.0085 and 0.025 per cent, respectively. In treatment T₁, lower fruit yield of 18.46 t ha⁻¹ was recorded.

Boron metalosate and zinc metalosate are the amino acid based liquid fertilizers, they are 100 % soluble in water and highly mobile, can easily pass through the physical and chemical barriers with high degree of efficiency, their by helps in increasing boron and zinc concentration in the leaf cells and may reach vascular system, which is used by the plants to transport photosynthates and other high value materials to growing parts of the plant (King, 2010). Boron helps in cell division and cell elongation and zinc in synthesis of growth hormone called auxin and chlorophyll synthesis and activation enzymes which are necessary for synthesis of metabolites which are required for the proper growth and development of plant, which in turn helps in increasing yield parameters like number of fruits shoot⁻¹, number of fruits plant⁻¹ and total weight of fruits shoot⁻¹ and finally yield. The increase in yield of pomegranate by the application of

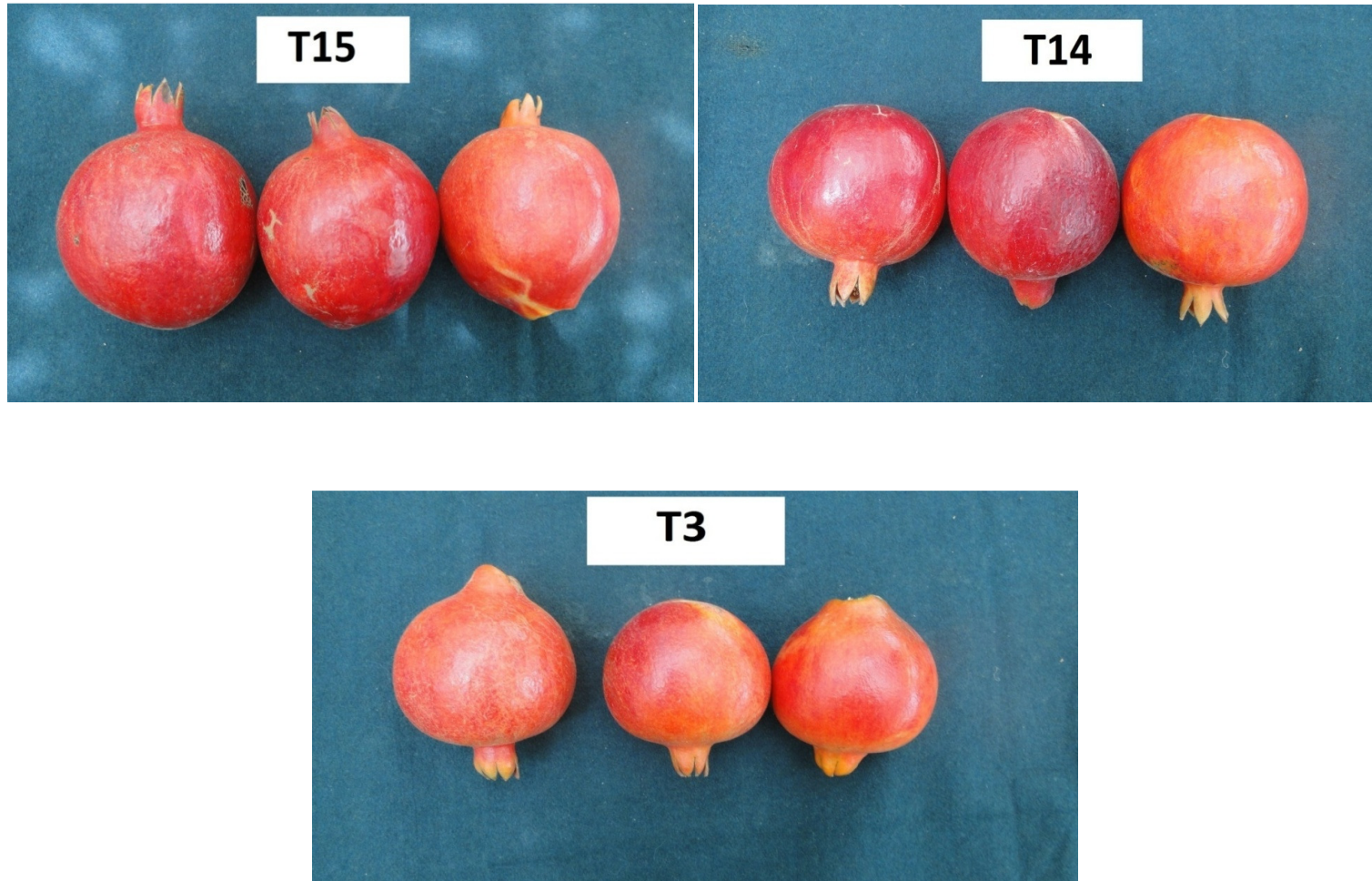


Plate 7: Effect of foliar spray on pomegranate as influenced by sources and levels of boron and zinc metalosate

micronutrient may be due its synergistic effect in yield contributing characters like size and weight of fruits, fruit set percent, fruit retention per cent (Yadav *et al.*, 2014). These results are in line with the findings of Sharma and Belsar (2011), Pandey *et al.* (2012), Sheikh and Manjula (2012), Trivedi *et al.*, (2012), Khalil and Aly, 2013), Yadav *et al.* (2014), Korkmoz and Askin (2015) and Tanuja *et al.* (2016).

4.4.3 Effect of foliar spray on physical parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate

Physical parameters of pomegranate *viz.*, length of fruit, breadth of fruit and weight of fruit as influenced by sources and levels of boron and zinc metalosate are presented in Table 66.

4.4.3.1 Length of fruit (cm)

Length of fruit as influenced by different sources and levels of boron in combination with zinc along with recommended dose of NPK varied from 8.25 to 10.54 cm and recorded significantly higher in treatment T₁₅ (10.54 cm), T₁₄(10.20 cm) and T₁₃(10.05 cm) compared to other treatments. The treatment T₁ which received recommended dose of NPK, recorded least fruit length (8.25 cm).

4.4.3.2 Breadth of fruit (cm)

Significant increase in breadth of fruit was noticed in T₁₅ treatment (13.51 cm) which consists of T₁₁+ foliar spray of 0.050 % Zn as zinc metalosate followed by treatment T₁₄ which consists of T₁₀+ foliar spray of 0.025 % Zn as zinc metalosate which was on par with treatment T₁₃ which received boron @ 0.051 per cent as boron metalosate along with recommended dose of NPK. Lower increase in breadth of fruit was noticed in treatment T₁ which received recommended dose of NPK (9.18 cm).

4.4.3.3 Weight of fruit (g)

Among different treatments significant increase in weight of fruit was recorded in treatment T₁₅ (350.71 g) when boron and zinc were applied in combination of 0.017 and 0.050 per cent as boron and zinc metalosate as foliar spray along with recommended dose

Table 66: Effect of foliar spray on physical parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	Length of fruits (cm)			Breadth of fruits (cm)			Weight of fruit (g)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	8.18	8.31	8.25	9.14	9.21	9.18	240.57	250.67	245.62
2	8.35	8.49	8.42	9.29	9.40	9.35	246.76	257.73	252.25
3	8.59	8.83	8.71	9.88	10.13	10.01	261.18	275.11	268.15
4	8.21	8.34	8.28	9.17	9.25	9.21	241.06	251.52	246.29
5	8.30	8.45	8.38	9.27	9.37	9.32	246.23	257.49	251.86
6	8.55	8.77	8.66	9.81	10.08	9.94	260.95	275.07	268.01
7	8.87	9.28	9.08	10.50	11.05	10.77	279.36	294.55	286.96
8	9.31	9.91	9.61	11.28	12.16	11.72	299.41	318.09	308.75
9	8.23	8.39	8.31	9.19	9.31	9.25	241.15	252.11	246.63
10	8.51	8.68	8.60	9.76	9.95	9.86	260.83	272.49	266.66
11	8.83	9.13	8.98	10.43	10.87	10.65	279.08	294.05	286.57
12	9.22	9.69	9.46	11.17	11.93	11.55	298.95	317.14	308.04
13	9.73	10.37	10.05	12.00	13.06	12.53	320.43	342.61	331.52
14	9.88	10.52	10.20	12.23	13.29	12.76	321.81	344.10	332.96
15	10.02	11.05	10.54	12.91	14.11	13.51	339.23	362.18	350.71
16	8.62	8.88	8.75	9.92	10.20	10.06	261.72	274.85	268.29
17	8.93	9.32	9.13	10.57	11.12	10.85	279.43	293.37	286.40
SEm ±	0.47	0.63	0.58	0.15	0.18	0.16	4.84	5.04	5.06
CD @ 5 %	NS	NS	1.65	0.44	0.51	0.47	13.95	14.51	14.30

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

of NPK followed by treatment T₁₄ (332.96 g) which received boron @ 0.0085% and zinc @ 0.025 % as boron and zinc metalosate, respectively along with recommended dose of NPK which was on par with treatment T₁₃ (331.52 g) which consists of boron @ 0.051 per cent through boron metalosate. Boron metalosate at 0.0034 (T₉: 246.63 g), 0.0085 (T₁₀: 266.66 g) and boric acid at 0.0034 (T₄: 246.29 g), 0.0085 (T₅: 251.86 g) and 0.017 (T₆: 268.01 g) per cent of boron did not record significant effect in increasing weight of fruit compared to control (T₃:268.15g). Lowest weight of fruit was recorded in the treatment T₁ which received recommended dose of NPK only (T₁: 245.62 g).

The increase in the length, breadth and weight of pomegranate fruit on application of boron and zinc may be due to their involvement in cell division, intercellular space enhancement in the mesocarpic cells and active mobilization of more photosynthates to fruit. Similar observation was also made by Yadav *et al.* (2013) who reported that the increase in the physical parameters of fruit like fruit length and volume might be due to increase in cell size and intercellular space. Dayal *et al.* (2010) reported that the foliar application of zinc sulphate which influences the fruit length, diameter, fruit volume and weight of fruit, yield might be due to the fact that zinc play an important role in nitrogen and phosphorus metabolism, synthesis of growth regulating substances, oxidation and metabolic activity in ber plants. Similar observations were also made by Khan *et al.* (2012), Santhosh (2015) and Hamouda, *et al.* (2016).

4.4.4 Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data on quality parameters of pomegranate *viz.*, total soluble solids, total sugars and titratable acidity as affected by sources and levels of boron and zinc are presented in Table 67 and Figure 15.

4.4.4.1 Total soluble solids (° Brix)

Significant increase in the TSS content of 17.46 ° brix was recorded by foliar application of boron and zinc in combination of 0.017 and 0.050 per cent as boron and zinc metalosate, respectively along with recommended dose of NPK (T₁₅) followed by treatment T₁₄ which consists of T₁₀ + foliar application of 0.025 % Zn as zinc metalosate (16.39 ° Brix) along with recommended dose of NPK which is on par with the treatment

T₁₃ (16.24 ° Brix). Whereas in treatment T₁ lower TSS content of 12.24 ° brix was recorded.

4.4.4.2 Total sugars (%)

Higher total sugar content of 19.11 per cent was recorded in treatment T₁₅ which consists of T₁₁+ foliar application of 0.050 per cent zinc as through zinc metalosate followed by treatment T₁₄ (17.89 %) which consists of T₁₀ + foliar application of 0.025 per cent zinc as zinc metalosate which is on par with the treatment T₁₃ (17.48 %) which consists of boron @ 0.051 per cent as boron metalosate. Total sugar content recorded in the treatments T₄ (12.96 %), T₉ (12.99 %), T₅ (13.05 %), T₁₀ (13.90 %) and T₆ (14.01 %) were lesser then control (T₃: 14.05 %). Lower total sugar of 12.89 per cent was recorded in treatment T₁ which received recommended dose of NPK.

4.4.4.3 Titratable Acidity (%)

Foliar application of boron @ 0.017 and zinc @ 0.050 per cent as boron and zinc metalosate along with recommended dose of NPK recorded significantly lesser titratable acidity of 0.24 per cent (T₁₅) followed by treatment T₁₄ (0.34 %) which consists of T₁₀+ foliar spray of 0.025 per cent zinc as zinc metalosate. Higher titratable acidity of 0.80 per cent was recorded in treatment T₁, which received only recommended dose of NPK.

The increase in TSS of fruit on the application of zinc and boron might be due to influence of zinc on helps auxin synthesis and sugar metabolism whereas boron helps in translocation of sugars. Hydrolysis of complex polysaccharides in to simple sugar, synthesis of metabolites and rapid translocation of photosynthesis products, sugars and minerals from other part of plants to developing fruits lead to increase in TSS content of fruit (Singroul, 2016).

Total sugar content in pomegranate fruit increased due to positive effect of boron and zinc in breakdown of complex polymerse into simple substances by hydrolytic enzymes. Alloway, (2008) reported that there was an increase in total sugar content due to foliar application of zinc, which is necessary for the activation of enzyme aldolase, required for the formation of sugars in fruits.

Table 67: Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	TSS (° Brix)			Total sugars (%)			Titratable acidity (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	12.20	12.27	12.24	12.82	12.95	12.89	0.81	0.78	0.80
2	12.41	12.48	12.45	12.97	13.21	13.09	0.78	0.76	0.77
3	13.20	13.31	13.26	13.83	14.27	14.05	0.70	0.67	0.69
4	12.25	12.32	12.29	12.85	13.06	12.96	0.80	0.78	0.79
5	12.36	12.43	12.40	12.93	13.17	13.05	0.79	0.76	0.78
6	13.14	13.24	13.19	13.79	14.23	14.01	0.71	0.68	0.70
7	14.05	14.31	14.18	14.76	15.52	15.14	0.60	0.58	0.59
8	15.10	15.45	15.28	15.91	16.87	16.39	0.49	0.45	0.47
9	12.27	12.37	12.32	12.87	13.11	12.99	0.80	0.77	0.79
10	13.09	13.19	13.14	13.74	14.05	13.90	0.71	0.69	0.70
11	13.96	14.15	14.05	14.70	15.30	15.00	0.62	0.59	0.61
12	14.93	15.29	15.11	15.72	16.65	16.19	0.51	0.46	0.49
13	15.98	16.50	16.24	16.88	18.08	17.48	0.39	0.33	0.36
14	16.07	16.71	16.39	16.94	18.83	17.89	0.37	0.31	0.34
15	17.10	17.82	17.46	18.07	20.14	19.11	0.26	0.22	0.24
16	13.24	13.37	13.31	13.87	14.37	14.12	0.70	0.67	0.69
17	14.13	14.42	14.28	14.80	15.58	15.19	0.61	0.58	0.60
SEm ±	0.22	0.24	0.23	0.25	0.27	0.26	0.02	0.02	0.02
CD @ 5 %	0.63	0.68	0.65	0.71	0.78	0.73	0.06	0.06	0.06

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Reduction in titratable acidity of fruit due to foliar application of boron and zinc might be attributed to excessive polymerization and accumulation of more sugars by hastening the process of ripening. Boron and zinc helps in rapid conversion of acids into sugars and their derivatives by the reaction involving the reversal of glycolic pathways or might have been used as substrate in the respiration (Pandey *et al.*, 2008 and Trivedi *et al.*, 2012). Similar results were observed by Balakrishna *et al.*, (1996), Pant and Lavania (1998), Sharma and Belsar (2011) and Kumawat *et al.* (2012).

4.4.5 Effect of sources and levels of boron and zinc metalosate on nutrient content of index leaf of pomegranate before foliar spray

The data pertaining to nutrient content in index leaf under different sources and levels of boron in combination with zinc are presented in Table 68, 69 and 70.

The total nitrogen, phosphorus and potassium content ranged from 1.65 to 1.80, 0.43 to 0.56 and 1.41 to 1.59 percent respectively. About 1.13 to 1.25 per cent calcium, 0.36 to 0.45 % magnesium and 0.33 to 0.46 % sulphur were recorded in the index leaf. However, total micronutrients like zinc, iron, copper and manganese were recorded between 25.34 to 27.40, 153.52 to 161.02 and 13.13 to 14.70 and 56.24 to 61.32 mg kg⁻¹, respectively.

4.4.6 Effect of foliar spray on boron content (mg kg⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of boron and zinc metalosate

Boron content in index leaf as influenced by sources and levels of boron and zinc metalosate are presented in Table 71 and Figure 16.

4.4. 6.1 One day before first spray

Non significant difference was observed among the treatments with respect to total boron content in index leaf one day before first spray and recorded 16.47 to 19.54 mg kg⁻¹.

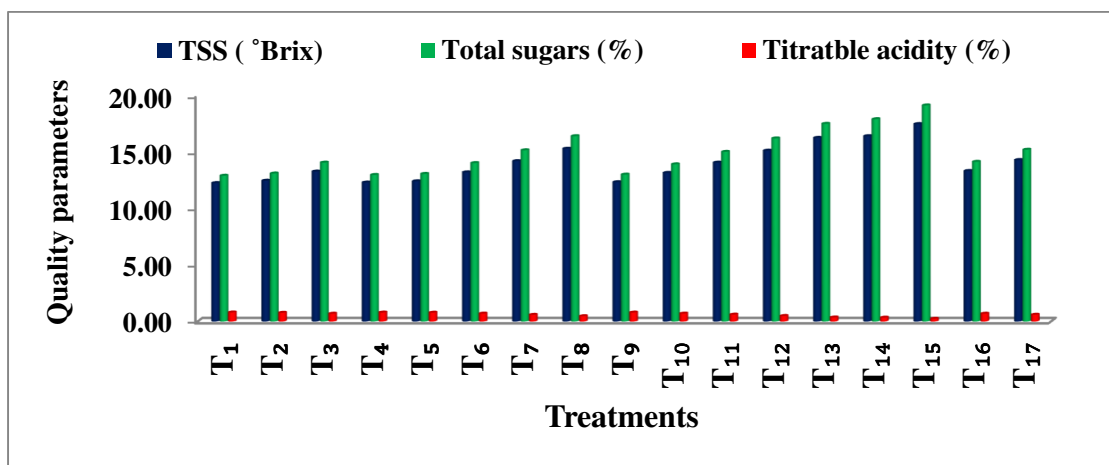


Fig.15: Effect of foliar spray on quality parameters of pomegranate as influenced by sources and levels of boron and zinc metalosate

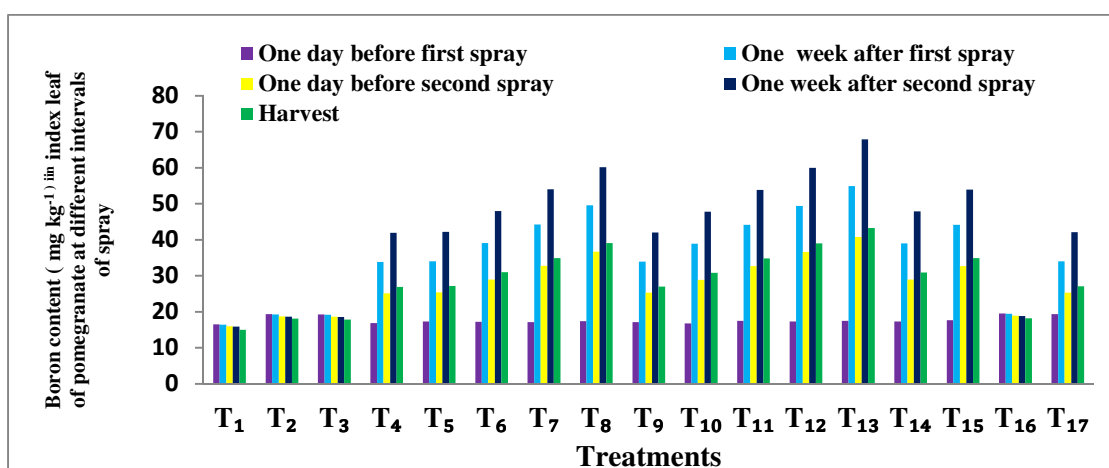


Fig.16: Effect of foliar spray on boron content (mg kg⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of boron and zinc metalosate

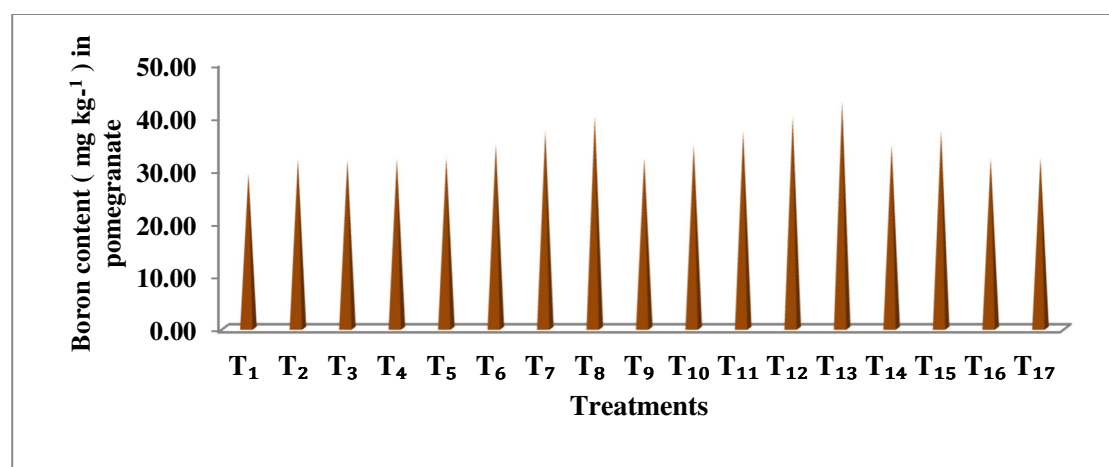


Fig.17: Effect of foliar spray on boron content (mg kg⁻¹) of pomegranate as influenced by sources and levels of boron and zinc metalosate

Table 68: Effect of sources and levels of boron and zinc metalosate on macro nutrient content (%) of index leaf of pomegranate before foliar spray

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.63	1.66	1.65	0.42	0.43	0.43	1.39	1.46	1.43
2	1.65	1.70	1.68	0.41	0.45	0.43	1.35	1.48	1.41
3	1.69	1.87	1.78	0.49	0.61	0.55	1.47	1.68	1.58
4	1.64	1.68	1.66	0.43	0.44	0.43	1.42	1.46	1.44
5	1.65	1.70	1.68	0.40	0.45	0.42	1.39	1.48	1.43
6	1.62	1.72	1.67	0.45	0.47	0.46	1.40	1.51	1.45
7	1.64	1.77	1.70	0.43	0.49	0.46	1.44	1.54	1.49
8	1.66	1.79	1.73	0.41	0.52	0.46	1.41	1.58	1.49
9	1.64	1.69	1.67	0.43	0.44	0.44	1.43	1.46	1.45
10	1.63	1.72	1.68	0.44	0.46	0.45	1.40	1.51	1.45
11	1.66	1.75	1.71	0.42	0.48	0.45	1.39	1.54	1.47
12	1.65	1.78	1.72	0.43	0.51	0.47	1.44	1.57	1.50
13	1.63	1.80	1.72	0.40	0.53	0.47	1.41	1.59	1.50
14	1.62	1.82	1.72	0.44	0.55	0.50	1.39	1.60	1.50
15	1.64	1.84	1.74	0.45	0.57	0.51	1.42	1.63	1.53
16	1.70	1.89	1.80	0.50	0.62	0.56	1.49	1.69	1.59
17	1.68	1.86	1.77	0.47	0.60	0.54	1.46	1.67	1.57
SEm ±	0.03	0.09	0.06	0.04	0.07	0.06	0.05	0.08	0.07
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 69: Effect of sources and levels of boron and zinc metalosate on secondary nutrient content (%) of index leaf of pomegranate before foliar spray

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.12	1.15	1.13	0.36	0.37	0.36	0.33	0.34	0.33
2	1.10	1.16	1.13	0.35	0.38	0.37	0.35	0.36	0.35
3	1.15	1.30	1.23	0.38	0.52	0.45	0.38	0.50	0.44
4	1.11	1.15	1.13	0.33	0.37	0.35	0.30	0.35	0.32
5	1.13	1.16	1.15	0.35	0.38	0.36	0.34	0.36	0.35
6	1.09	1.18	1.14	0.32	0.40	0.36	0.31	0.38	0.35
7	1.10	1.21	1.16	0.34	0.43	0.38	0.35	0.41	0.38
8	1.12	1.23	1.17	0.35	0.45	0.40	0.33	0.43	0.38
9	1.09	1.15	1.12	0.31	0.38	0.34	0.30	0.35	0.32
10	1.11	1.17	1.14	0.34	0.39	0.37	0.35	0.37	0.36
11	1.12	1.19	1.16	0.31	0.41	0.36	0.32	0.39	0.36
12	1.09	1.22	1.16	0.33	0.44	0.39	0.33	0.42	0.38
13	1.13	1.24	1.19	0.36	0.45	0.41	0.32	0.44	0.38
14	1.12	1.25	1.19	0.30	0.47	0.39	0.33	0.45	0.39
15	1.09	1.27	1.18	0.32	0.49	0.41	0.35	0.47	0.41
16	1.18	1.32	1.25	0.39	0.51	0.45	0.39	0.52	0.46
17	1.15	1.29	1.22	0.37	0.50	0.44	0.37	0.49	0.43
SEm ±	0.03	0.06	0.05	0.04	0.06	0.05	0.03	0.07	0.05
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil B through boraxT₃: NPK + FYMT₄: NPK + foliar spray of 0.0034 % boron through boric acidT₅: NPK + foliar spray of 0.0085 % boron through boric acidT₆: NPK + foliar spray of 0.017 % boron through boric acidT₇: NPK + foliar spray of 0.034 % boron through boric acidT₈: NPK + foliar spray of 0.051 % boron through boric acidT₉: NPK + foliar spray of 0.0034 % B through B MetalosateT₁₀: NPK + foliar spray of 0.0085 % B through B MetalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 70: Effect of sources and levels of boron and zinc metalosate on micronutrient content (mg kg⁻¹) of index leaf of pomegranate before foliar spray

Treatments	Zinc			Iron			Copper			Manganese		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	25.38	25.30	25.34	156.11	155.70	155.91	14.10	13.76	13.93	56.33	56.15	56.24
2	24.91	26.13	25.52	155.94	155.73	155.84	14.25	12.52	13.39	57.60	57.33	57.47
3	26.08	28.21	27.15	160.77	161.25	161.01	14.00	12.27	13.13	60.41	60.94	60.68
4	25.45	25.85	25.65	157.64	156.19	156.92	14.23	13.48	13.86	56.52	57.67	57.10
5	24.93	26.07	25.50	157.91	156.10	157.01	14.89	13.31	14.10	58.19	57.41	57.80
6	25.51	26.45	25.98	156.20	155.96	156.08	14.10	13.06	13.58	57.77	56.92	57.35
7	25.30	26.71	26.01	155.51	155.85	155.68	15.03	12.83	13.93	57.90	56.57	57.24
8	25.66	27.06	26.36	155.23	155.70	155.46	15.28	12.62	13.95	56.83	56.15	56.49
9	24.95	25.97	25.46	151.98	156.15	154.07	14.11	13.39	13.75	58.35	57.54	57.95
10	24.80	26.33	25.57	154.73	156.04	155.39	15.89	13.12	14.51	59.12	57.26	58.19
11	25.09	26.62	25.86	152.81	155.89	154.35	15.10	12.93	14.02	57.83	56.71	57.27
12	25.23	26.90	26.07	151.22	155.81	153.52	15.00	12.71	13.86	58.26	56.45	57.36
13	25.46	27.19	26.33	155.50	155.75	155.63	14.98	12.54	13.76	57.50	56.03	56.77
14	24.97	27.46	26.22	153.17	156.63	154.90	14.57	14.63	14.60	56.17	58.85	57.51
15	25.18	27.77	26.48	155.10	156.97	156.04	14.64	14.75	14.70	59.04	59.24	59.14
16	26.23	28.38	27.31	160.63	161.20	160.92	14.11	12.53	13.32	61.29	61.35	61.32
17	26.15	28.65	27.40	160.90	161.14	161.02	14.00	12.32	13.16	61.11	61.29	61.20
SEm ±	0.53	1.20	0.92	3.39	2.08	2.84	0.71	0.89	0.79	1.81	1.88	1.83
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 71: Effect of foliar spray on boron content (mg kg⁻¹) of index leaf of pomegranate at different intervals as influenced by sources and levels of boron and zinc metalosate

Treatments	One day before first spray			One week after first spray			One day before second spray			One week after second spray			Harvest		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	16.53	16.41	16.47	16.49	16.35	16.42	16.10	15.89	16.00	15.96	15.80	15.88	15.05	14.90	14.98
2	18.95	19.79	19.37	18.88	19.68	19.28	18.34	19.05	18.70	18.27	18.94	18.61	17.81	18.39	18.10
3	18.89	19.70	19.30	18.79	19.62	19.21	18.27	18.94	18.61	18.19	18.86	18.53	17.62	18.05	17.84
4	16.65	17.05	16.85	32.93	34.83	33.88	23.91	26.31	25.11	40.78	43.03	41.91	26.78	26.96	26.87
5	17.21	17.33	17.27	33.10	35.04	34.07	24.10	26.63	25.37	41.05	43.38	42.22	27.11	27.31	27.21
6	16.96	17.56	17.26	37.49	40.63	39.06	27.64	30.35	29.00	46.20	49.78	47.99	30.57	31.38	30.98
7	16.31	17.91	17.11	41.99	46.50	44.25	31.27	34.22	32.75	51.60	56.37	53.99	34.24	35.61	34.93
8	16.57	18.16	17.37	46.61	52.55	49.58	35.05	38.41	36.73	57.16	63.10	60.13	38.13	39.96	39.05
9	17.06	17.15	17.11	33.05	34.90	33.98	24.00	26.55	25.28	40.79	43.21	42.00	26.89	27.19	27.04
10	16.21	17.39	16.80	37.40	40.43	38.92	27.53	30.23	28.88	46.06	49.64	47.85	30.37	31.27	30.82
11	17.34	17.62	17.48	41.89	46.35	44.12	31.19	34.14	32.67	51.47	56.25	53.86	34.14	35.51	34.83
12	16.60	18.03	17.32	46.50	52.39	49.45	34.97	38.25	36.61	57.04	63.00	60.02	38.07	39.89	38.98
13	16.72	18.29	17.51	51.25	58.60	54.93	38.88	42.60	40.74	64.75	71.13	67.94	42.14	44.42	43.28
14	17.21	17.46	17.34	37.43	40.51	38.97	27.59	30.28	28.94	46.13	49.70	47.92	30.45	31.30	30.88
15	17.45	17.82	17.64	41.94	46.42	44.18	31.23	34.19	32.71	51.54	56.33	53.94	34.19	35.57	34.88
16	19.10	19.97	19.54	19.02	19.89	19.46	18.65	19.23	18.94	18.47	19.17	18.82	17.90	18.49	18.20
17	18.93	19.85	19.39	33.07	34.95	34.01	24.05	26.57	25.31	40.93	43.28	42.11	26.98	27.24	27.11
SEm ±	1.01	0.82	0.92	1.45	1.82	1.62	1.14	1.21	1.23	1.69	2.12	1.90	1.09	1.31	1.19
CD @ 5 %	NS	NS	NS	4.17	5.23	4.58	3.28	3.48	3.47	4.88	6.11	5.36	3.14	3.76	3.36

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

4.4.6.2 One week after first spray

One week after first spray significant increase in boron content of 16.42 to 54.93 mg kg⁻¹ in index leaf was recorded in the treatment T₁₃ which received boron @ 0.051 per cent as boron metalosate along with recommended dose of NPK followed by treatment T₈ which consists of foliar application of 0.051 % B through boric acid (49.58 mg kg⁻¹) and treatment T₁₂ (49.45 mg kg⁻¹) which consist of 0.034 per cent boron as boron metalosate. Treatment T₇ (44.25 mg kg⁻¹), T₁₅ (44.18 mg kg⁻¹) and T₁₁ (44.12 mg kg⁻¹) responded similarly in increasing boron content in the pomegranate leaf. Lower boron content of 16.42 mg kg⁻¹ was recorded in treatment T₁, which consists of recommended dose of NPK.

4.4. 6.3 One day before second spray

Significant reduction in boron content in index leaf one day before second spray was recorded compared to one week after first spray and it was recorded significantly higher in treatment T₁₃ (40.74 mg kg⁻¹) which consists of foliar application of boron @ 0.051 per cent as boron metalosate along with recommended dose of NPK followed by treatment T₈ which consists of 0.025 per cent boron as boric acid (36.73 mg kg⁻¹) which was on par with one which received 0.034 per cent boron as boron metalosate (T₁₂: 36.61 mg kg⁻¹). Lower boron content of 16.00 mg kg⁻¹ was recorded in treatment T₁.

4.4.6.4 One week after second spray

In treatment T₁ significant reduction in boron content in index leaf was observed compared to one day before second spray and it was increased significantly (67.94 mg kg⁻¹) due to foliar application of boron @ 0.051 per cent as boron metalosate sources along with recommended dose of NPK (T₁₃) followed by treatment T₈ which consists of foliar application of boron @ 0.051 % as boric acid (60.13 mg kg⁻¹) which was on par with T₁₂ treatment which consists of 0.034 per cent boron as boron metalosate (60.02 mg kg⁻¹).

4.4.6.5 At Harvest

At harvest boron content in index leaf ranged between 14.98 to 43.28 mg kg⁻¹ and was significantly higher in treatment which consists of boron @ 0.051 per cent as boron metalosate (T₁₃: 43.28 mg kg⁻¹) followed by treatment T₈ which consists of application of boron @ 0.051 % as boric acid along with recommended dose of NPK (39.05 mg kg⁻¹) which was on par with the treatment T₁₂ which received 0.034 per cent boron as boron metalosate (38.98 mg kg⁻¹). Among the treatments lower content of boron in index leaf was recorded in treatment T₁ (14.98 mg kg⁻¹) which received the recommended dose of NPK.

Significantly higher boron in index leaf one week after first spray and one week after second spray was recorded in treatment T₁₃ may be due to readily available nutrients and maximum absorption of boron @ 0.051 per cent as boron metalosate along with recommended dose of NPK. Boron metalosate are amino acid based liquid boron fertilizers, because of their neutral charge and higher mobility it can easily pass through cuticular layers of the leaf without any barriers for effective utilization of plants. Foliar application of boron @ 0.02 per cent at fifty per cent bloom stage significantly increased the leaf boron concentration of 98.52 mg kg⁻¹ in mango cv. Alphanso (Sankar *et al.*, 2013). Ullah *et al.* (2012) reported that the application of boron @ 0.4 per cent at fruit set stage as foliar spray in Kinnow mandrine increased significantly leaf boron content of 150 mg kg⁻¹. Application of zinc and boron to the plant through foliar spray significantly increased the leaf boron concentration their by helped in increasing pomegranate tree nutrient status (Davarpanah *et al.*, 2016). Combined application of boric acid and zinc sulphate at fruit set stage leads to 6.2fold increase in leaf boron concentration thereby suggested potential benefits of exogeneous application of boric acid and zinc sulphate in mandrine (Khan *et al.*, 2015). Similar results were also observed by Sandipkumar (2015) who reported foliar application of ZnSO₄@ 0.8 %+ FeSO₄ @ 0.5 %+ Borax @ 0.2 % along with recommended dose of NPK (750: 160:175 g tree⁻¹) before flowering, full bloom stage and peanut stage of mango significantly increased the leaf boron concentration of 108.80 mg kg⁻¹ in ten year old mango cv Amrapali.

However, at one day before second spray and harvest, boron concentration in the index leaf declined compared to one week after first and second spray may be due to utilization of boron for the various metabolic activities of the plant *viz.*, cell division, differentiation and elongation, pollination, fruit setting, carbohydrate and sugar metabolism (Yadav *et al.*, 2013).

4.4.7 Effect of foliar spray on nutrient content of pomegranate as influenced by sources and levels of boron and zinc metalosate

Major, secondary and micronutrient content in pomegranate as influenced by different sources and levels of boron in combination with zinc are presented in Table 72, 73 and 74.

4.4.7.1 Effect of foliar spray on macronutrient content (%) of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data of nitrogen, phosphorus and potassium content in pomegranate fruit as influenced by different sources and levels of boron in combination with zinc are presented in Table 72.

Among the treatments nitrogen content in pomegranate fruit varied from 1.51 to 2.40 per cent and recorded significantly higher content (2.40 %) in treatment T₁₅ which received boron @ 0.017 and zinc @ 0.050 % as boron and zinc metalosate along with recommended dose of NPK followed by treatment T₁₄ (2.27 %) which consists of boron and zinc @ 0.0085 and 0.025 % as boron and zinc metalosate, respectively along with recommended dose of NPK which was on par with treatment T₁₃ (2.21 %). Lower nitrogen content of 1.51 per cent was recorded in the treatment T₁ which received recommended dose of NPK alone.

About 0.13 to 0.64 per cent of phosphorus was recorded in pomegranate fruit and was significantly higher in the treatment which consists of T₁₁ + foliar application of zinc @ 0.050 % as zinc metalosate (T₁₅: 0.64 %) followed by T₁₀ + foliar application of zinc @ 0.025 % as zinc metalosate along with recommended dose of NPK (T₁₄: 0.55 %) which is on par with treatment T₁₃ which consists of 0.051 per cent boron as boron metalosate (0.52 %). Treatment T₁ which received recommended dose of NPK recorded lower phosphorus content of 0.13 per cent.

Table 72: Effect of foliar spray on macronutrient content (%) of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.49	1.53	1.51	0.10	0.16	0.13	0.93	0.98	0.95
2	1.54	1.59	1.57	0.12	0.19	0.15	0.97	1.04	1.00
3	1.65	1.71	1.68	0.18	0.27	0.22	1.05	1.14	1.09
4	1.52	1.55	1.54	0.11	0.16	0.14	0.95	1.00	0.98
5	1.58	1.63	1.61	0.13	0.19	0.16	1.00	1.06	1.03
6	1.69	1.75	1.72	0.19	0.28	0.24	1.06	1.16	1.11
7	1.83	1.91	1.87	0.26	0.39	0.32	1.18	1.28	1.23
8	2.00	2.10	2.05	0.35	0.50	0.43	1.32	1.42	1.37
9	1.55	1.60	1.58	0.11	0.17	0.14	0.97	1.03	1.00
10	1.65	1.72	1.69	0.18	0.27	0.22	1.06	1.14	1.10
11	1.79	1.87	1.83	0.25	0.38	0.32	1.17	1.26	1.22
12	1.96	2.05	2.01	0.34	0.48	0.41	1.29	1.40	1.35
13	2.15	2.27	2.21	0.44	0.60	0.52	1.44	1.56	1.50
14	2.21	2.33	2.27	0.47	0.63	0.55	1.47	1.60	1.54
15	2.33	2.47	2.40	0.55	0.72	0.64	1.58	1.71	1.64
16	1.67	1.73	1.70	0.19	0.29	0.24	1.08	1.16	1.12
17	1.77	1.86	1.82	0.25	0.37	0.31	1.16	1.27	1.22
SEm ±	0.04	0.04	0.04	0.02	0.03	0.02	0.03	0.03	0.03
CD @ 5 %	0.10	0.12	0.11	0.06	0.08	0.07	0.08	0.10	0.09

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Significant increase in potassium content was recorded in treatment T₁₅ (1.64 %) followed by T₁₄ (1.54 %) which consists of T₁₁+ foliar application of zinc @ 0.050 % and T₁₀ + foliar application of 0.025 % as zinc metalosate along with recommended dose of NPK, respectively. Lower potassium content of 0.95 per cent was recorded in treatment T₁ which received recommended dose of NPK.

Higher NPK content in the pomegranate was recorded due to synergistic effect between boron and zinc with NPK and their active involvement in NPK metabolism in plant, their by increased nitrogen, phosphorus and potassium content in the index leaf which was further translocated from leaves to fruit. Similar observations were also made by Gunes *et al.* (2015) who reported a significant improvement in the fruit nitrogen, phosphorus and potassium of about 1.74, 0.25 and 1.04 per cent respectively due to application of boron @ 12 kg ha⁻¹. These results are line with those of Aroosa Khalil (2014).

4.4.7.2 Effect of foliar spray on secondary nutrient content (%) of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data on secondary nutrient content in pomegranate as influenced by sources and levels of boron and zinc metalosate are presented in Table 73.

Foliar application of boron @ 0.017 and zinc @ 0.050 per cent as zinc and boron metalosate along with recommended dose of NPK, significantly increased the sulphur content of 0.54 per cent (T₁₅) followed by treatment T₁₄ which received T₁₀+ foliar application of zinc @ 0.025 % as zinc metalosate (0.46 %) but was on par with treatment T₁₃ which received boron as boron metalosate of 0.051 per cent. Sulphur content was low in treatment T₁ which received recommended dose of NPK alone (0.08 %).

Non significant differences were observed among the treatments with respect to calcium and magnesium content in the fruit and they were recorded in the range of 0.88 to 1.27 and 0.23 to 0.50 per cent, respectively.

Table 73: Effect of foliar spray on secondary nutrient content (%) of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.07	0.09	0.88	0.24	0.21	0.23	0.07	0.09	0.08
2	0.09	0.10	0.90	0.25	0.26	0.25	0.09	0.10	0.10
3	0.14	0.16	0.94	0.27	0.29	0.28	0.14	0.16	0.15
4	0.08	0.09	0.90	0.24	0.26	0.25	0.08	0.09	0.08
5	0.10	0.11	0.92	0.25	0.28	0.27	0.10	0.11	0.11
6	0.15	0.17	0.98	0.28	0.31	0.29	0.15	0.17	0.16
7	0.22	0.26	1.06	0.33	0.35	0.34	0.22	0.26	0.24
8	0.31	0.37	1.14	0.38	0.41	0.40	0.31	0.37	0.34
9	0.08	0.10	0.90	0.25	0.27	0.26	0.08	0.10	0.09
10	0.14	0.16	0.94	0.27	0.29	0.28	0.14	0.16	0.15
11	0.21	0.24	1.00	0.31	0.33	0.32	0.21	0.24	0.23
12	0.29	0.35	1.08	0.36	0.38	0.37	0.29	0.35	0.32
13	0.39	0.48	1.19	0.41	0.44	0.42	0.39	0.48	0.43
14	0.42	0.51	1.21	0.44	0.47	0.45	0.42	0.51	0.46
15	0.48	0.59	1.27	0.47	0.52	0.50	0.48	0.59	0.54
16	0.16	0.17	0.96	0.28	0.31	0.29	0.16	0.17	0.17
17	0.21	0.24	1.07	0.30	0.34	0.32	0.21	0.24	0.23
SEm ±	0.02	0.02	0.12	0.09	0.11	0.10	0.02	0.02	0.02
CD @ 5 %	0.05	0.06	NS	NS	NS	NS	0.05	0.06	0.05

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

The increase in the sulphur content in the fruit may be due to supply of sulphur through the recommended dose of NPK and also synergistic effect between zinc and boron with sulphur. Similar results were observed by Aroosa Khalil (2014).

4.4.7.3 Effect of foliar spray on micronutrient content (mg kg⁻¹) of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data on micronutrient content in pomegranate as influenced by sources and levels of boron zinc metalosate are presented in Table 74.

Among the treatments, the treatment T₁₃ which received boron @ 0.051 per cent as boron metalosate significantly increased the boron content in pomegranate (42.66 mg kg⁻¹) compared to other treatments followed by treatment T₈ (39.94 mg kg⁻¹) which received 0.051 per cent boron as boric acid which was on par with treatment T₁₂ (39.80 mg kg⁻¹) which consists of 0.034 per cent boron as boron metalosate. Boron content recorded in treatment T₇ (37.20 mg kg⁻¹) was on par with treatment T₁₅ (37.15 mg kg⁻¹) and T₁₁ (37.08 mg kg⁻¹). In treatment T₁, lower boron content of 29.21 mg kg⁻¹ was recorded (Figure 17).

Non significant difference was recorded among the treatments with respect to zinc, iron, copper and manganese content in the pomegranate and recorded in the range of 24.87 to 26.73, 58.32 to 61.22, 5.69 to 6.44 and 25.25 to 27.62 mg kg⁻¹, respectively.

Higher boron content in the pomegranate may be due to supply of boron from boron sources along with recommended dose of NPK. Higher boron content in flesh and peel of pear fruit was due to sufficient levels of boron and its translocation from treated leaves to fruit under foliar spray (Gurel and Basar, 2016). Similarly, fruit boron content of about 1.56 mg kg⁻¹ was recorded due to combined foliar spray of ZnSO₄ @ 0.5 % + FeSO₄ @ 0.5 % + borax @ 0.2 % along with RDF(750: 160: 750 NPK g tree⁻¹) before flowering, full bloom stage and pea stage of mango var. Amrapali of ten year old (Sandipkumar, 2015). These results are in line with Aroosa Khalil (2014) and Gunes *et al.* (2015).

Table 74: Effect of foliar spray on micronutrient content (mg kg⁻¹) of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	Zinc			Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	24.93	24.81	24.87	59.08	57.55	58.32	5.97	5.89	5.93	25.73	25.85	25.79	29.47	28.95	29.21
2	25.11	25.19	25.15	60.15	57.50	58.83	6.04	5.95	6.00	26.31	25.91	26.11	31.58	32.09	31.84
3	25.35	25.48	25.41	60.58	60.76	60.67	5.85	5.78	5.82	27.05	27.30	27.18	31.53	31.97	31.75
4	25.02	25.10	25.06	59.39	57.77	58.58	6.15	6.08	6.12	26.58	26.13	26.36	31.65	32.14	31.90
5	25.13	25.23	25.18	59.26	57.62	58.44	6.08	5.97	6.03	26.37	25.95	26.16	31.88	32.41	32.15
6	25.35	25.52	25.44	58.88	57.35	58.12	5.99	5.89	5.94	26.14	25.78	25.96	34.29	34.92	34.61
7	25.62	25.88	25.75	58.53	57.13	57.83	5.89	5.82	5.86	25.85	25.57	25.71	36.84	37.55	37.20
8	26.00	26.35	26.18	58.25	56.96	57.61	5.81	5.75	5.78	25.53	25.30	25.42	39.51	40.36	39.94
9	25.09	25.16	25.13	59.31	57.70	58.50	6.11	6.04	6.08	26.50	26.04	26.27	31.75	32.33	32.04
10	25.23	25.32	25.28	59.04	57.43	58.24	6.04	5.93	5.99	26.29	25.85	26.07	34.14	34.81	34.48
11	25.44	25.63	25.54	58.75	57.21	57.98	5.93	5.85	5.89	26.03	25.66	25.85	36.69	37.46	37.08
12	25.78	26.06	25.92	58.41	57.04	57.73	5.85	5.79	5.82	25.72	25.43	25.58	39.38	40.22	39.80
13	26.21	26.59	26.40	58.12	56.85	57.49	5.77	5.70	5.74	25.37	25.12	25.25	42.16	43.15	42.66
14	26.33	26.78	26.56	60.87	60.93	60.90	6.23	6.41	6.32	27.29	27.55	27.42	34.20	34.86	34.53
15	26.52	26.95	26.73	61.10	61.34	61.22	6.35	6.52	6.44	27.60	27.63	27.62	36.79	37.51	37.15
16	25.38	25.51	25.45	60.43	60.68	60.56	5.79	5.70	5.75	26.91	27.24	27.08	31.69	32.24	31.97
17	25.65	25.90	25.78	60.28	60.51	60.40	5.71	5.66	5.69	26.75	27.15	26.95	31.80	32.37	32.09
SEm ±	0.57	0.67	0.63	1.11	1.74	1.40	0.24	0.31	0.28	0.78	0.92	0.86	0.77	0.82	0.82
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.23	2.36	2.31

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

4.4.8 Effect of foliar spray on nutrient content of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate

The pooled data pertaining to major, secondary and micronutrient content in index leaf at harvest on foliar spray of different sources and levels of boron in combination with zinc are presented in the Table 75, 76 and 77.

4.4.8.1 Effect of foliar spray on major nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate

The pooled data presented in the Table 75 indicating the effect of foliar spray of different sources and levels of boron in combination with zinc metalosate on major nutrient content of index leaf at harvest.

Total nitrogen content in the index leaf at harvest ranged from 1.14 to 1.59 per cent and it was significantly higher in treatment T₁₅ (1.59 %) followed by T₁₄ (1.51 %) which consists of T₁₁+ foliar spray of zinc @ 0.050 % and T₁₀+ foliar spray of zinc @ 0.025 % as zinc metalosate, respectively compared to other treatments. The treatment which consists of recommended dose of NPK alone recorded lower nitrogen content of 1.14 per cent at harvest. Similarly, total phosphorus and potassium recorded among the treatments were varied from 0.09 to 0.41 and 0.98 to 1.40 per cent, respectively and they were recorded significantly higher in treatment T₁₅ (0.41 and 1.40 %, respectively) compared to other treatments.

Due to synergistic effect between zinc and boron with NPK, the nitrogen, phosphorus and potassium concentration in the index leaf increased when boron and zinc were sprayed @ 0.017 and 0.050 per cent as boron and zinc metalosate, respectively along with recommended dose of NPK at vegetative (First spray) and fruit lemon stage (second spray). When the crop attains maturity, NPK content was translocated and accumulated in the fruit. Therefore, some part of the increased nitrogen, phosphorus and potassium contents were observed in index leaf at harvest. Foliar application of micronutrients alone or in combination recorded higher N and K concentrations in mandrine leaves at different growth stages (Kumar *et al.*, 2017). Similar results were noticed by Thirupathaiah *et al.* (2017), Khan *et al.* (2015) and Baiea *et al.* (2015).

Table 75: Effect of foliar spray on major nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	1.09	1.19	1.14	0.08	0.10	0.09	0.89	1.07	0.98
2	1.11	1.21	1.16	0.10	0.12	0.11	0.93	1.09	1.01
3	1.17	1.28	1.23	0.15	0.17	0.16	0.99	1.16	1.08
4	1.09	1.20	1.15	0.08	0.11	0.10	0.90	1.07	0.99
5	1.11	1.22	1.17	0.10	0.12	0.11	0.94	1.08	1.01
6	1.18	1.29	1.24	0.14	0.18	0.16	1.00	1.15	1.08
7	1.24	1.38	1.31	0.20	0.24	0.22	1.07	1.23	1.15
8	1.32	1.49	1.41	0.25	0.31	0.28	1.16	1.32	1.24
9	1.09	1.20	1.14	0.08	0.12	0.10	0.92	1.08	1.00
10	1.17	1.28	1.22	0.14	0.17	0.16	0.99	1.16	1.08
11	1.24	1.37	1.31	0.19	0.23	0.21	1.05	1.23	1.14
12	1.31	1.46	1.38	0.24	0.29	0.26	1.15	1.30	1.23
13	1.39	1.57	1.48	0.30	0.36	0.33	1.24	1.38	1.31
14	1.42	1.59	1.51	0.32	0.38	0.35	1.27	1.40	1.34
15	1.49	1.68	1.59	0.37	0.44	0.41	1.33	1.47	1.40
16	1.18	1.30	1.24	0.16	0.18	0.17	1.01	1.17	1.09
17	1.25	1.37	1.31	0.20	0.23	0.22	1.08	1.24	1.16
SEm ±	0.02	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.02
CD @ 5 %	0.06	0.07	0.07	0.04	0.05	0.04	0.06	0.07	0.07

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

4.4.8.2 Effect of foliar spray on secondary nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate

The pooled data of secondary nutrient content in index leaf of pomegranate as influenced by sources and levels of boron and zinc metalosate are presented in Table 76.

Secondary nutrients like calcium (1.02 and 0.97 %, respectively) and sulphur (0.32 and 0.27 %, respectively) were significantly higher in treatment T₁₅ followed by treatment T₁₄ which consists of T₁₁+ foliar spray of zinc @ 0.050 and T₁₀+ foliar spray of zinc @ 0.025 % as zinc metalosate, respectively along with recommended dose of NPK and lower calcium and sulphur contents were recorded in the treatment T₁ (0.71 and 0.06 %, respectively) which received recommended dose of NPK.

Higher calcium and sulphur content in the index leaf at harvest stage in treatment T₁₅ may be due to combined application of boron and zinc as boron and zinc metalosate along with recommended dose of NPK and the synergistic effect between them. Similar results were observed by Gunes *et al.* (2015).

4.4.8.3 Effect of foliar spray on micronutrient content (mg kg⁻¹) of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate

The pooled data of micro nutrient contents in index leaf as influenced by sources and levels of boron and zinc metalosate are presented in Table 77.

Non significant differences was observed among the treatments with respect to total zinc, iron, copper and manganese content in the index leaf at harvest and they were recorded between the range of 21.02 to 23.65, 111.66 to 117.71, 10.03 to 12.45 and 42.23 to 46.78 mg kg⁻¹, respectively.

Table 76: Effect of foliar spray on secondary nutrient content (%) of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate

Treatments	Calcium			Magnesium			Sulphur		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.61	0.82	0.71	0.13	0.16	0.15	0.05	0.06	0.06
2	0.63	0.84	0.74	0.15	0.18	0.17	0.06	0.08	0.07
3	0.68	0.89	0.79	0.18	0.20	0.19	0.10	0.12	0.11
4	0.61	0.82	0.72	0.14	0.16	0.15	0.05	0.06	0.06
5	0.63	0.83	0.73	0.15	0.17	0.16	0.06	0.07	0.07
6	0.67	0.88	0.78	0.17	0.19	0.18	0.11	0.11	0.11
7	0.72	0.94	0.83	0.19	0.22	0.21	0.16	0.16	0.16
8	0.77	1.00	0.89	0.22	0.24	0.23	0.21	0.20	0.20
9	0.61	0.83	0.72	0.14	0.16	0.15	0.06	0.07	0.07
10	0.67	0.89	0.78	0.16	0.18	0.17	0.10	0.12	0.11
11	0.72	0.94	0.83	0.18	0.21	0.19	0.15	0.16	0.16
12	0.78	1.01	0.90	0.21	0.24	0.23	0.19	0.21	0.20
13	0.83	1.06	0.95	0.24	0.26	0.25	0.24	0.26	0.25
14	0.85	1.08	0.97	0.25	0.27	0.26	0.26	0.28	0.27
15	0.90	1.13	1.02	0.28	0.30	0.29	0.30	0.33	0.32
16	0.69	0.91	0.80	0.19	0.21	0.20	0.12	0.12	0.12
17	0.73	0.96	0.85	0.21	0.23	0.22	0.16	0.17	0.17
SEm ±	0.01	0.02	0.02	0.05	0.05	0.05	0.01	0.01	0.01
CD @ 5 %	0.04	0.05	0.05	NS	NS	NS	0.03	0.04	0.03

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 77: Effect of foliar spray on micronutrient content (mg kg⁻¹) of index leaf of pomegranate at harvest as influenced by sources and levels of boron and zinc metalosate

Treatments	Zinc			Iron			Copper			Manganese		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	21.09	20.95	21.02	113.07	110.25	111.66	10.73	10.09	10.41	42.71	41.75	42.23
2	21.32	22.69	22.00	114.10	113.04	113.57	10.89	10.77	10.83	43.15	42.60	42.88
3	21.50	22.88	22.19	116.00	116.95	116.47	10.40	10.32	10.36	44.40	44.73	44.57
4	21.13	22.45	21.79	114.39	113.23	113.81	11.84	10.97	11.41	44.46	42.85	43.66
5	21.25	22.62	21.94	114.21	113.12	113.67	11.63	10.86	11.24	44.21	42.73	43.47
6	21.47	22.91	22.19	113.89	112.75	113.32	11.41	10.63	11.02	43.90	42.42	43.16
7	21.82	23.25	22.54	113.62	112.43	113.03	11.12	10.37	10.75	43.41	42.14	42.78
8	22.27	23.70	22.99	113.33	112.05	112.69	10.93	10.22	10.58	43.15	41.93	42.54
9	21.20	22.53	21.87	114.27	113.15	113.71	11.72	10.93	11.33	44.38	42.80	43.59
10	21.43	22.80	22.12	114.03	112.92	113.48	11.55	10.70	11.12	44.04	42.52	43.28
11	21.75	23.11	22.43	113.70	112.57	113.14	11.24	10.51	10.88	43.53	42.27	42.90
12	22.16	23.49	22.83	113.41	112.23	112.82	11.03	10.29	10.66	43.21	42.05	42.63
13	22.67	23.93	23.30	113.12	112.09	112.61	10.85	10.14	10.50	43.06	41.88	42.47
14	22.80	24.05	23.43	117.09	117.73	117.41	12.19	12.31	12.25	46.11	46.47	46.29
15	22.98	24.31	23.65	117.44	117.98	117.71	12.37	12.52	12.45	46.62	46.93	46.78
16	21.57	22.97	22.27	115.75	116.41	116.08	10.26	10.17	10.22	44.73	45.00	44.86
17	21.70	23.32	22.51	115.37	115.85	115.61	10.09	9.96	10.03	44.39	44.97	44.68
SEm ±	0.69	1.19	0.98	1.82	2.70	2.28	0.81	0.91	0.86	1.38	1.84	1.66
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

4.4.9 Effect of foliar spray on chemical properties and nutrient status of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data on chemical properties, major, secondary and micronutrient content of the post harvest soil, by foliar spray of sources and levels of boron and zinc are represented in the Table 78, 79, 80 and 81.

4.4.9.1 Effect of foliar spray on chemical properties of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data on chemical properties of soil as influenced by foliar spray of different sources and levels of boron and zinc metalosate are represented in the Table 78.

Non significant differences were observed among the treatments regarding chemical properties of the soil like pH, EC and organic carbon content in soil at harvest and they were in the range of 6.19 to 6.23, 0.28 to 0.33 dSm⁻¹ and 0.51 to 0.57 per cent, respectively.

4.4.9.2 Effect of foliar spray on major nutrient status (kg ha⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate

The content of major nutrients in soil as affected by foliar spray of different sources and levels of boron in combination with zinc metalosate are presented in Table 79.

Significant increase in soil nutrient content was recorded compared to initial status (Table 1.). Among the treatments significantly higher nitrogen content in soil was observed in the treatments T₃ (326.78 kg ha⁻¹), T₁₆ (326.69 kg ha⁻¹) and T₁₇ (326.61 kg ha⁻¹) compared to other treatments. The treatment T₁₅ which consists of T₁₁+ foliar spray of zinc @ 0.050 % (299.19 kg ha⁻¹) and T₁₀+ foliar spray of zinc @ 0.025 % through zinc metalosate (T₁₄: 306.25 kg ha⁻¹), respectively recorded lower available nitrogen in the post harvest soil.

Table 78: Effect of foliar spray on chemical properties of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	pH			EC (dSm ⁻¹)			Organic carbon (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	6.21	6.19	6.20	0.30	0.32	0.31	0.51	0.53	0.52
2	6.22	6.20	6.21	0.29	0.30	0.30	0.50	0.55	0.53
3	6.20	6.17	6.19	0.31	0.35	0.33	0.55	0.59	0.57
4	6.23	6.20	6.22	0.28	0.31	0.30	0.52	0.51	0.52
5	6.22	6.21	6.22	0.29	0.32	0.31	0.50	0.53	0.52
6	6.21	6.18	6.20	0.30	0.31	0.30	0.53	0.55	0.54
7	6.24	6.22	6.23	0.28	0.30	0.29	0.51	0.53	0.52
8	6.25	6.21	6.23	0.27	0.29	0.28	0.54	0.54	0.54
9	6.23	6.20	6.22	0.30	0.30	0.30	0.50	0.52	0.51
10	6.22	6.19	6.21	0.29	0.32	0.31	0.51	0.55	0.53
11	6.21	6.17	6.19	0.27	0.28	0.28	0.50	0.54	0.52
12	6.24	6.20	6.22	0.29	0.30	0.30	0.52	0.56	0.54
13	6.22	6.19	6.21	0.30	0.33	0.32	0.51	0.52	0.52
14	6.23	6.20	6.22	0.28	0.30	0.29	0.54	0.54	0.54
15	6.24	6.21	6.23	0.30	0.31	0.31	0.51	0.55	0.53
16	6.20	6.18	6.19	0.31	0.34	0.32	0.54	0.58	0.56
17	6.20	6.17	6.19	0.31	0.35	0.33	0.53	0.57	0.55
SEm ±	0.14	0.14	0.14	0.01	0.03	0.02	0.02	0.03	0.02
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Table 79: Effect of foliar spray on major nutrient status (kg ha⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	315.01	334.81	324.91	36.44	42.65	39.54	186.53	197.98	192.26
2	314.37	333.90	324.13	36.06	42.87	39.47	185.95	197.10	191.52
3	317.25	336.30	326.78	37.17	43.49	40.33	186.62	198.49	192.55
4	314.80	334.69	324.75	36.39	43.54	39.97	186.44	197.63	192.04
5	314.62	334.21	324.42	36.15	42.98	39.56	186.09	197.25	191.67
6	313.48	333.62	323.55	35.92	42.37	39.14	184.63	195.68	190.16
7	312.05	333.13	322.59	34.94	41.90	38.42	184.27	195.33	189.80
8	307.22	321.63	314.43	32.56	38.12	35.34	183.65	188.35	186.00
9	314.68	334.53	324.61	36.32	43.12	39.72	186.38	197.57	191.98
10	313.97	333.85	323.91	35.97	42.57	39.27	185.76	196.91	191.34
11	312.68	333.46	323.07	35.33	42.10	38.72	184.31	195.37	189.84
12	307.78	322.89	315.34	32.60	38.17	35.39	184.10	188.49	186.30
13	302.59	311.40	306.99	30.55	34.77	32.66	178.49	182.53	180.51
14	302.02	310.47	306.25	30.21	34.35	32.28	177.67	182.37	180.02
15	297.59	300.79	299.19	28.03	30.07	29.05	172.53	176.20	174.36
16	317.18	336.21	326.69	37.13	43.45	40.29	186.84	198.22	192.53
17	317.07	336.16	326.61	37.06	43.35	40.20	186.56	198.08	192.32
SEm ±	1.47	3.30	2.32	0.69	1.03	0.94	1.58	1.73	1.91
CD @ 5 %	4.24	9.51	6.55	2.00	2.97	2.66	4.54	4.98	5.40

T₁: NPKT₂: NPK+ Soil application of B as boraxT₃: NPK + FYMT₄: NPK + Foliar spray of 0.0034 % boron as boric acidT₅: NPK + Foliar spray of 0.0085 % boron as boric acidT₆: NPK + Foliar spray of 0.017 % boron as boric acidT₇: NPK + Foliar spray of 0.034 % boron as boric acidT₈: NPK + Foliar spray of 0.051 % boron as boric acidT₉: NPK + Foliar spray of 0.0034 % B as boron metalosateT₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosateT₁₁: NPK + Foliar spray of 0.017 % B as boron metalosateT₁₂: NPK + Foliar spray of 0.034 % B as boron metalosateT₁₃: NPK + Foliar spray of 0.051 % B as boron metalosateT₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosateT₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosateT₁₆: T₃ + Soil application of B as boraxT₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

Available phosphorus content in post harvest soil was increased compared to initial value (Table 1.) and it was ranged from 29.05 to 40.33 kg ha⁻¹. The treatment which received 0.017 % boron and 0.050 % zinc from zinc and boron metalosate along with recommended dose of NPK recorded lower available phosphorus in post harvest soil compared to other treatments followed by treatment T₁₄ (32.28 kg ha⁻¹) which consists of T₁₀+ foliar spray of zinc @ 0.025 % through zinc metalosate (32.28 kg ha⁻¹). Significantly higher increase in available phosphorus content in the post harvest soil was recorded in the treatments T₃ (40.33 kg ha⁻¹), T₁₆ (40.29 kg ha⁻¹) and T₁₇ (40.20 kg ha⁻¹) which received FYM, FYM + soil application of boron and FYM + foliar spray of 0.005 per cent boron through borax, respectively along with recommended dose of NPK.

Compare to initial potassium content in soil (Table.1) a significant increase in available potassium content in post harvest soil was recorded and it was ranged from 174.36 to 192.55 kg ha⁻¹. Higher available potassium of 192.55, 192.53 and 192.32 kg ha⁻¹ was recorded in the treatments T₃ (FYM) T₁₆ (FYM+ soil application of boron) and T₁₇ (FYM + foliar spray of 0.005 per cent boron through borax) along with recommended dose of NPK. The treatment which consists of T₁₁+ foliar spray of 0.050 % zinc (T₁₅: 174.36 kg ha⁻¹) and T₁₀ + foliar spray of 0.025 % zinc through zinc metalosate (T₁₄: 180.02 kg ha⁻¹), respectively recorded lower available potassium content in soil.

Higher available nitrogen, phosphorus and potassium content was recorded in post harvest soil in the treatments T₃, T₁₆ and T₁₇ may be due to presence of farm yard manure along with recommended dose of NPK. The available nitrogen, phosphorus and potassium content in post harvest soil increased successively with increasing nitrogen levels along with farm yard manure may be attributed to significant effect of FYM in mineralization of organic sources and increased activity of microbes. The increase in available phosphorus with FYM addition may be due to release of more phosphorus from organic compounds, increase in microbial population as well as decomposition products of humic substances. Increase in availability of potassium was due to the action of organic acids from the organic matter complex (Sharma *et al.*, 2013). Increase in available N, P₂O₅ and K₂O content in soil was also reported by several authors as detailed below. Application of 75% NPK + Biofertilizers (60 g each/tree basin) + Green manuring

(Sunhemp @ 25 g seeds/tree basin) performed best for increasing soil N and P content in Plum orchard soil (Thakur *et al.*, 2013). There was a substantial increase in available nutrient content by FYM, urea and *Azotobacter* applied alone or in combination in strawberry. The highest available N, P and K viz., 256.4, 19.7 and 141.5 kg/ha were observed when 25% N was applied as FYM + 75% N through urea+ *Azotobacter*(Umar *et al.*, 2008). Musmade *et al.* (2010) reported in acid lime that significantly higher sustainable residual soil fertility was observed with the recommended dose of fertilizer (600:300:600 g NPK plant⁻¹) + farm yard manure (15 kg plant⁻¹) + neem cake (15 kg plant⁻¹) where available nitrogen and potash in soil was significantly highest overall other treatments (*i.e.* 218 and 671 kg ha⁻¹ respectively).

4.4.9.3 Effect of foliar spray on secondary nutrient status of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data on secondary nutrient content in soil at harvest on foliar spray of sources and levels of boron and zinc metalosate are presented in Table 80.

Available sulphur content in soil increased significantly in treatments T₃ (19.86 mg kg⁻¹), T₁₆ (19.82 mg kg⁻¹) and T₁₇ (19.76 mg kg⁻¹) which consists of FYM, FYM+ soil application of boron as borax and FYM + foliar spray of boron @ 0.005 per cent as borax, respectively along with recommended dose of NPK but it recorded less in treatment, which received T₁₁ + foliar spray of 0.050 % zinc through zinc metalosate (T₁₅: 14.57 mg kg⁻¹) followed by treatment T₁₄ which consisted of T₁₀ + foliar spray of 0.025 % zinc as zinc metalosate (T₁₄: 15.66 mg kg⁻¹). But, non significant difference was recorded among the treatments with respect to exchangeable calcium and magnesium content.

Significant increase in available sulphur in soil may be due to addition of sulphur to the soil in the form of single super phosphate. Recommended dose of NPK and farm yard manure was added as a nutrient source. FYM is a good source of all the essential

Table 80: Effect of foliar spray on secondary nutrient status of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	Calcium (C mol (p ⁺) kg ⁻¹)			Magnesium (C mol (p ⁺) kg ⁻¹)			Sulphur (mg kg ⁻¹)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	4.50	4.59	4.55	2.00	1.92	1.96	17.99	21.26	19.63
2	4.44	4.53	4.49	1.97	2.01	1.99	17.89	20.88	19.38
3	4.52	4.63	4.58	2.03	2.08	2.06	18.10	21.61	19.86
4	4.50	4.59	4.55	1.99	1.92	1.96	17.97	21.23	19.60
5	4.47	4.57	4.52	1.96	1.93	1.94	17.92	20.94	19.43
6	4.44	4.55	4.50	1.95	1.94	1.95	16.91	20.65	18.78
7	4.42	4.54	4.48	1.97	1.95	1.96	15.89	20.15	18.02
8	4.41	4.51	4.46	1.94	1.94	1.94	14.90	18.41	16.65
9	4.48	4.55	4.52	1.98	1.93	1.96	17.94	21.01	19.47
10	4.44	4.54	4.49	1.97	1.94	1.96	16.94	20.86	18.90
11	4.43	4.53	4.48	1.95	1.95	1.95	15.91	20.49	18.20
12	4.42	4.54	4.48	1.96	1.95	1.96	14.94	18.55	16.74
13	4.41	4.53	4.47	1.95	1.94	1.95	14.01	17.18	15.59
14	4.40	4.55	4.48	1.94	1.92	1.93	14.32	17.00	15.66
15	4.39	4.49	4.44	1.93	1.91	1.92	13.48	15.66	14.57
16	4.52	4.64	4.58	2.05	2.05	2.05	18.08	21.55	19.82
17	4.51	4.61	4.56	2.01	2.03	2.02	18.05	21.47	19.76
SEm ±	0.10	0.10	0.10	0.04	0.06	0.05	0.27	0.42	0.36
CD @ 5 %	NS	NS	NS	NS	NS	NS	0.78	1.21	1.03

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅:T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

nutrients, therefore its application to the soil helps in increasing available sulphur content in soil. Application of FYM @ 50 kg plant⁻¹ significantly increased the available sulphur content in acid lime orchards in both years of the study over the control was also reported by Khan and Begum (2007).

4.4.9.4 Effect of foliar spray on micronutrient status (mg kg⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate

The pooled data on micronutrient content in the post harvest soil on foliar spray of different sources and levels of boron in combination with zinc metalosate are presented in Table 81.

Significantly higher boron content in soil was recorded in treatment T₁₆ which received boron as borax and farm yard manure compared to other treatments and it recorded 0.38 mg kg⁻¹ in treatment T₁ which received recommended dose of NPK. However, the treatments showed non significant difference with respect zinc, iron, copper and manganese content in soil and recorded in the range of 0.44 to 0.57, 36.11 to 37.49, 0.30 to 0.37 and 20.42 to 22.62 mg kg⁻¹, respectively.

The significant increase in hot water soluble boron in soil may be due to addition of farm yard manure along with recommended dose of NPK. These results are in line with Thakur (2013) who reported significant improvement in the micronutrient content in soil due to addition of biofertilizers (60 g/ tree basin) + green manure (Sunhemp @ 25 g seed/tree basin) + farm yard manure (40 kg) + vermicompost (24 kg).

Table 81: Effect of foliar spray on micronutrient status (mg kg⁻¹) of soil at harvest of pomegranate as influenced by sources and levels of boron and zinc metalosate

Treatments	zinc			Iron			Copper			Manganese			Boron		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	0.45	0.43	0.44	36.85	36.07	36.46	0.32	0.31	0.31	21.27	20.75	21.01	0.38	0.37	0.38
2	0.47	0.46	0.47	36.45	36.10	36.28	0.32	0.32	0.32	21.20	20.35	20.78	0.45	0.46	0.46
3	0.51	0.53	0.52	37.45	37.52	37.49	0.31	0.31	0.31	22.53	22.70	22.62	0.43	0.44	0.44
4	0.45	0.44	0.44	36.40	35.96	36.18	0.31	0.30	0.31	20.95	20.00	20.48	0.38	0.37	0.38
5	0.46	0.45	0.46	36.49	36.05	36.27	0.32	0.31	0.32	21.05	20.11	20.58	0.39	0.37	0.38
6	0.48	0.47	0.48	36.59	36.10	36.35	0.33	0.32	0.32	21.10	20.17	20.64	0.40	0.41	0.41
7	0.49	0.47	0.48	36.68	36.18	36.43	0.35	0.34	0.34	21.15	20.23	20.69	0.41	0.39	0.40
8	0.50	0.48	0.49	36.81	36.20	36.51	0.37	0.37	0.37	21.20	20.30	20.75	0.42	0.40	0.41
9	0.45	0.44	0.45	36.45	35.98	36.22	0.31	0.31	0.31	20.98	20.05	20.52	0.39	0.37	0.38
10	0.47	0.43	0.45	36.54	36.07	36.31	0.33	0.31	0.32	21.06	20.13	20.60	0.40	0.38	0.39
11	0.48	0.44	0.46	36.63	36.12	36.38	0.34	0.33	0.33	21.10	20.20	20.65	0.40	0.40	0.40
12	0.49	0.51	0.50	36.75	36.18	36.47	0.36	0.34	0.35	21.17	20.27	20.72	0.41	0.39	0.40
13	0.50	0.48	0.49	36.87	36.21	36.54	0.36	0.35	0.35	21.22	20.31	20.77	0.42	0.40	0.41
14	0.49	0.47	0.48	36.35	35.95	36.15	0.32	0.31	0.32	20.93	19.97	20.45	0.42	0.41	0.42
15	0.50	0.47	0.48	36.30	35.91	36.11	0.31	0.30	0.31	20.89	19.95	20.42	0.43	0.42	0.43
16	0.53	0.60	0.57	37.39	37.45	37.42	0.31	0.29	0.30	22.30	22.65	22.48	0.47	0.48	0.48
17	0.52	0.55	0.54	37.32	37.49	37.41	0.32	0.32	0.32	22.41	22.57	22.49	0.42	0.43	0.42
SEm ±	0.03	0.04	0.04	0.82	0.81	0.81	0.02	0.03	0.03	0.91	0.96	0.93	0.01	0.04	0.04
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.03	0.09	0.06

T₁: NPK

T₂: NPK+ Soil application of B as borax

T₃: NPK + FYM

T₄: NPK + Foliar spray of 0.0034 % boron as boric acid

T₅: NPK + Foliar spray of 0.0085 % boron as boric acid

T₆: NPK + Foliar spray of 0.017 % boron as boric acid

T₇: NPK + Foliar spray of 0.034 % boron as boric acid

T₈: NPK + Foliar spray of 0.051 % boron as boric acid

T₉: NPK + Foliar spray of 0.0034 % B as boron metalosate

T₁₀: NPK + Foliar spray of 0.0085 % B as boron metalosate

T₁₁: NPK + Foliar spray of 0.017 % B as boron metalosate

T₁₂: NPK + Foliar spray of 0.034 % B as boron metalosate

T₁₃: NPK + Foliar spray of 0.051 % B as boron metalosate

T₁₄: T₁₀ + Foliar spray of 0.025 % Zn as zinc metalosate

T₁₅: T₁₁ + Foliar spray of 0.050 % Zn as zinc metalosate

T₁₆: T₃ + Soil application of B as borax

T₁₇: T₃ + Foliar spray of 0.005 % B as boric acid

V. SUMMARY

Field experiment entitled “Studies on foliar spray of zinc metalosate and boron metalosate on growth, yield and quality of grapes (*Vitis vinifera* L.) and pomegranate (*Punica granatum* L.) was carried out during 2015-16 and 2016-17 at Marganahalli village, Chickaballapur district with the following objectives: 1) To study the effect of zinc metalosate and boron metalosate on growth and yield of grapes and pomegranate 2) To study the effect of zinc metalosate and boron metalosate on quality of grapes and pomegranate 3) To determine the nutrient concentration in grapes and pomegranate fruits. To achieve the above objective of the research four experiments were carried out as detailed below

Experiment No.1: Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of zinc

Experiment No.2: Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of zinc

Experiment No.3: Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of boron and zinc metalosate

Experiment No.4: Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of boron and zinc metalosate

The results of the research was summarized as detailed below.

Experiment No.1: Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of zinc

1. Growth parameters *viz.*, cane length (cm), cane girth (cm) and internodal length (cm) was recorded higher on foliar application of 0.150 per cent zinc as zinc metalosate along with recommended dose of NPK (T₁₃) and it was on par with the treatment T₁₈.
2. Significantly higher yield parameters *viz.*, number of bunches per plant (68.50), number of berries per bunch (107.14), mean weight of berries per bunch (580.96

g), weight of bunch (591.17 g), yield per plant (38.87 kg plant⁻¹) and yield per hectare (17.77 t ha⁻¹) was recorded in treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate with recommended dose of NPK and it was on par with treatment T₁₈ (NPK+ Foliar spray of 0.150 % Zn as Zn-EDTA).

3. Treatment T₁₃ which received zinc @ 0.150 per cent as zinc metalosate foliar spray along with soil application of recommended dose of NPK recorded significantly higher TSS (17.85 ° Brix) and total sugars (17.49 %). However, titratable acidity was higher in treatment T₁ which received recommended dose of NPK and it recorded lower in treatment T₁₃ and T₁₈ which received 0.150 per cent zinc as zinc metalosate and Zn-EDTA, respectively along with recommended dose of NPK.
4. One week after first, second and third spray significantly higher zinc content in the index tissue was recorded in treatment T₁₃ which consists of NPK + foliar spray of zinc @ 0.150 per cent as zinc metalosate and it was on par with treatment T₁₈.
5. Foliar application of zinc @ 0.150 per cent as zinc metalosate along with recommended dose of NPK increased the nitrogen (1.74 %), potassium (1.89 %), sulphur (0.52 %) and zinc (47 mg kg⁻¹) content in grapes compared to other nutrients but it was on par with treatment T₁₈.
6. At the time of harvest higher total nitrogen (1.57 %), potassium (1.97%) sulphur (0.49%) and copper (11.48 mg kg⁻¹) content in the index tissue was noticed on foliar spray of 0.150 per cent zinc as zinc metalosate and it was on par with 0.150 per cent zinc as Zn-EDTA.
7. At harvest higher available nitrogen (358.86 kg ha⁻¹), phosphorus (41.19kg ha⁻¹), potassium (232.18 kg ha⁻¹), sulphur (19.91 mg kg⁻¹) and zinc (0.60 mg kg⁻¹) was recorded in treatment, which consists of recommended dose of NPK along with farm yard manure (T₃)

Experiment No.2: Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of zinc

1. Foliar application of zinc @ 0.150 per cent as zinc metalosate along with recommended dose of NPK (T₁₃) significantly increased plant height (217.70 cm) compared to control (T₃: 204.66 cm) and it was on par with treatment T₁₈.
2. Treatment T₁₃ which received 0.150 per cent zinc as zinc metalosate along with recommended dose of NPK recorded significantly higher yield and yield attributing parameters like number of fruits harvested per shoot (5.25), number of fruits per plant (88.71) total weight of fruits per shoot (1752.76 g), yield per plant (27.38 kg plant⁻¹) and yield tonnes per hectare (25.05 t ha⁻¹) compared to control (NPK+ FYM: T₃) and it was on par with treatment T₁₈.
3. Physical parameters of fruits *viz.*, length of fruit (cm), breadth of fruit (cm) and weight of fruit (g) were significantly higher on foliar application of zinc *i.e.* 0.150 per cent through zinc metalosate along with recommended dose of NPK (T₁₃) and it was on par with treatment T₁₈.
4. Significant increase in TSS (17.48 ° Brix), total sugars (18.51%) and decrease in titratable acidity (0.24 %) was observed at 0.150 per cent zinc as zinc metalosate and recommended dose of NPK *i.e.* treatment T₁₃ and it was on par with treatment T₁₈.
5. Foliar spray of zinc significantly increased the zinc content in the pomegranate leaf one week after first, second and third spray and it recorded significantly higher content in the treatment T₁₃ which received 0.150 per cent zinc as zinc metalosate along with recommended dose of NPK. One day before second, third and at harvest zinc content reduced and recorded less in treatment T₁, to which recommended dose of NPK alone was added.
6. Significantly higher nitrogen (2.64 %), potassium (2.07%), sulphur (0.40 %) and zinc content (37.29 mg kg⁻¹) in pomegranate fruit was observed in treatment which received zinc @ 0.150 per cent as zinc metalosate and recommended dose of NPK and it was on par with treatment T₁₈.

7. At harvest higher total nitrogen (1.57 %), potassium (1.25 %), calcium (0.91 %) and sulphur (0.28 %) content in the pomegranate leaf was recorded in treatment T₁₃ which consisted of zinc @ 0.150 per cent as zinc metalosate and recommended dose of NPK and it was on par with treatment T₁₈.
8. Soil application of recommended dose of NPK along with farm yard manure significantly increased the available nitrogen (338.48 kg ha⁻¹), phosphorus (38.37 kg ha⁻¹) potassium (195.84 kg ha⁻¹) and sulphur (15.83 mg kg⁻¹) content in the soil at harvest compared to initial values.

Experiment No.3: Effect of foliar spray on growth, yield and quality of grapes as influenced by sources and levels of boron and zinc metalosate

1. Foliar spray of boron @ 0.017 per cent through boron metalosate and zinc @ 0.050 per cent as zinc metalosate along with recommended dose of NPK significantly increased the growth parameters of grapes viz., cane length (112.43 cm), cane girth (0.89 cm) and internodal length (9.60 cm) compared to other treatments.
2. Yield parameters of grapes like number of bunches per plant (66.42), weight of bunch (563.69 g), number of berries per bunch (114.24) and mean weight of berries per bunch (542.06 g) were significantly higher in treatment T₁₅ which consists of T₁₁+ foliar spray of 0.050 per cent zinc as zinc metalosate and recorded least in treatment T₁ which consists of recommended dose of NPK alone.
3. Significantly higher yield of 36.79 kg plant⁻¹ and 16.81 t ha⁻¹ was recorded in the treatment T₁₅ which received boron and zinc @ 0.017 and 0.050 per cent as boron and zinc metalosate respectively along with recommended dose of NPK.
4. Combined foliar application of boron @ 0.017 per cent and zinc @ 0.050 per cent as boron and zinc metalosate, respectively along with recommended dose of NPK increased significantly the TSS (18.45 °Brix) total sugars (20.74 %) and decreased the titratable acidity (0.19 %).

5. Treatment T₁₃ which received boron @ 0.051 per cent as boron metalosate recorded significantly higher boron content in the index tissue one week after first and second spray. One day before second spray and at harvest, boron content in the index tissue was reduced compared to one week after first and second spray and was least in treatment T₁ which received recommended dose of NPK alone.
6. Significantly higher nitrogen (1.83 %), phosphorus (0.58 %), potassium (2.23 %) and sulphur (0.46 %) content in the grape was recorded in treatment T₁₅ which consists of T₁₁+ foliar spray of zinc @ 0.050 per cent as zinc metalosate along with recommended dose of NPK
7. Foliar application of boron @ 0.051 per cent as boron metalosate significantly recorded higher boron content (T₁₃: 45.74 mg kg⁻¹) in grape compared to other treatments.
8. Among the treatments higher total nitrogen (1.64 %), phosphorus (0.57 %), potassium (2.07 %) and sulphur (0.52 %) content in the pomegranate leaf was recorded at harvest and recorded significantly higher in treatment T₁₅ which consists of T₁₁+ foliar application of zinc @ 0.050 per cent as zinc metalosate
9. Addition of recommended dose of NPK along with farm yard manure significantly increased the available N (333.80 kg ha⁻¹), P₂O₅ (40.28 kg ha⁻¹), K₂O (245.88 kg ha⁻¹) and S (18.66 mg kg⁻¹) content in the soil at harvest
10. Available boron content of 0.55 mg kg⁻¹ in soil at harvest was recorded in treatment T₁₆ which consists of T₃+ soil application of boron as borax.

Experiment No.4: Effect of foliar spray on growth, yield and quality of pomegranate as influenced by sources and levels of boron and zinc metalosate

1. Treatment T₁₅ which consists of T₁₁+ foliar application of zinc @ 0.050 per cent as zinc metalosate along with recommended dose of NPK recorded significantly higher plant height of 218.95 cm compared to control (T₃: NPK + FYM).

2. Significantly higher number of fruits per shoot (5.50), number of fruits per plant (90.82) and total weight of fruits per shoot (1839.03 g), yield per plant (29.49 kg plant⁻¹) and hectare (26.97 t ha⁻¹) was recorded in treatment T₁₅ which consists of T₁₁+ foliar spray of 0.050 % Zn through zinc metalosate + recommended dose of NPK.
3. Foliar application of boron @ 0.017 per cent along with zinc @ 0.050 per cent and recommended dose of NPK recorded significantly higher length (10.54 cm), breadth (13.51 cm) and weight (350.71 g) of fruit.
4. Treatment T₁₅ which consists of T₁₁+ foliar application of zinc @ 0.050 per cent as zinc metalosate significantly increased the TSS (17.46 °Brix), total sugars (19.11 %) and decreased the titratable acidity (0.24 %).
5. Boron content in the pomegranate leaf was significantly higher one week after first spray (54.93 mg kg⁻¹) and one week after second spray (67.94 mg kg⁻¹) in the treatment T₁₃ which received boron @ 0.051 per cent as boron metalosate along with recommended dose of NPK.
6. Foliar application of boron and zinc @ 0.017 and 0.050 per cent as boron metalosate and zinc metalosate, respectively along with recommended dose of NPK recorded significantly higher nitrogen (2.40 %), phosphorus (0.64 %) potassium (1.64 %) and sulphur (0.54 %) content in the pomegranate fruit.
7. Treatment which received higher doses of boron as boron metalosate significantly increased the fruit boron content compared other treatments (T₁₃: 42.66 mg kg⁻¹).
8. The treatment which received boron and zinc in combination @ 0.017 and 0.050 per cent as boron and zinc metalosate recorded significantly higher N, P, K, Ca and S content in the pomegranate leaf at harvest compared to other nutrients.
9. Significantly higher available NP₂O₅K₂O and S content in soil at harvest was observed in the treatment T₃ which consists of recommended dose of NPK and farm yard manure, however the least increase in available nutrients were recorded

in the treatment T₁₅ which consists of T₁₀+ foliar application of zinc @ 0.050 per cent as zinc metalosate

10. Treatment T₁₆ which received soil application of boron (1500 g ha⁻¹) as borax, farm yard manure (12.5 t ha⁻¹) and recommended dose of NPK (200: 100: 100 kg ha⁻¹) recorded higher available boron in the soil at harvest of crop compared to other treatments.

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Effect of Foliar Application of Zinc Metalosate on Yield and Quality of Grapes (*Vitis vinifera*)

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ABSTRACT

A field experiment was conducted to study the effect of foliar spray of zinc metalosate on yield and quality of grape var. Dilkush in the farmer's field at Marganahalli village, Chikkaballapur district. The experiment was conducted with twenty treatments and replicated thrice in Randomized Block Design. Soils of the experimental site were acidic in pH, normal in EC (dSm^{-1}), low in organic carbon and available nitrogen and high in available phosphorus and potassium. The results of the study indicated that NPK and foliar spray of Zn @ 0.150 per cent through zinc metalosate (T_{13}) significantly increased the yield attributing parameters viz., number of bunches plant⁻¹ (66.73), number of berries bunch⁻¹ (96.44), weight of bunch (661.88 g) and yield plant⁻¹ (39.38 kg) compared to control. Significant improvement in total soluble solids, total sugars and decrease in titratable acidity was observed at foliar spray of zinc @ 0.150 per cent of through zinc metalosate followed by zinc @ 0.150 per cent through Zn-EDTA.

Keywords : Foliar spray, zinc metalosate, grape, yield and quality parameters

GRAPE (*Vitis vinifera*) is considered as one of the important commercial fruit crop and is grown in an area of about 118 ha (000 ha) with an annual production of 2483 MT (000 MT) (Anon., 2014) in India. Grape cultivation in India acquires great significance due to its high productivity as compared to many other grape producing countries. The major grape growing states in the country are Maharashtra, Karnataka, Andhra Pradesh and Tamil nadu.

The role of micronutrients in grape nutrition is well known and they are most commonly applied as foliar spray. Zinc is the important constituent of several enzymes which regulate various metabolic reactions in the plant and also essential for auxin and protein synthesis. The zinc deficiency is characterized by the abnormal development of internodes, interveinal chlorosis, small leaves, short berries and poor fruit set (Gowda *et al.*, 2008).

MATERIAL AND METHODS

A field experiment was conducted in order to study the effect of foliar application of zinc metalosate on yield and quality of grape in randomized block design with twenty treatments and three replications during 2015-16 at farmer's field, Marganahalli village, Chikkaballapur district, Karnataka. The treatments

were T_1 = control (NPK), T_2 = NPK + Soil-Zn through ZnSO_4 , T_3 = NPK+FYM, T_4 = NPK + foliar spray of 0.010 per cent Zn through ZnSO_4 , T_5 = NPK+ foliar spray of 0.025 per cent Zn through ZnSO_4 , T_6 = NPK+ foliar spray of 0.050 per cent Zn through ZnSO_4 , T_7 = NPK+ foliar spray of 0.100 per cent Zn through ZnSO_4 , T_8 = NPK + foliar spray of 0.150 per cent Zn through ZnSO_4 , T_9 = NPK + foliar spray of 0.010 per cent Zn through zinc metalosate, T_{10} = NPK+ foliar spray of 0.025 per cent Zn through zinc metalosate, T_{11} = NPK + foliar spray of 0.050 per cent Zn through zinc metalosate, T_{12} = NPK + foliar spray of 0.10 per cent Zn through zinc metalosate, T_{13} = NPK + foliar spray of 0.150 per cent Zn through zinc metalosate, T_{14} = NPK + foliar spray of 0.010 per cent Zn through Zn-EDTA, T_{15} = NPK + foliar spray of 0.025 Per cent Zn through Zn-EDTA, T_{16} = NPK + foliar spray of 0.050 per cent Zn through Zn-EDTA, T_{17} = NPK + foliar spray of 0.10 per cent Zn through Zn-EDTA, T_{18} = NPK + foliar spray of 0.150 per cent Zn through Zn-EDTA, T_{19} = T_3 + Soil application of Zn through ZnSO_4 , T_{20} = T_3 + Foliar application of 0.01 per cent of Zn through ZnSO_4 . Foliar spray was done thrice at vegetative stage, before flowering and at after fruit set. Zinc metalosate, zinc sulphate and Zn-EDTA are used as zinc sources. Soil

and irrigation water were analysed for various parameters. Before spray, initial plant samples (5th petiole) were collected and analysed for zinc content. At the time of harvest yield attributing parameters viz., number of bunches plant⁻¹, weight of bunch (g), number of berries bunch⁻¹ and yield plant (kg) were recorded. After harvest of the crop the quality parameters like total soluble solids (° Brix), total sugars and titratable acidity were estimated by following standard procedures.

RESULTS AND DISCUSSION

Initial soil properties of the experimental site indicated that soils were acid (6.45), normal in EC (0.15 dS m⁻¹), low in organic carbon (0.29 per cent), low in available nitrogen (230.8 kg ha⁻¹) higher in available phosphorus (57.71 kg ha⁻¹) and potassium (375.2 kg ha⁻¹) and deficit in DTPA extractable zinc (0.54 mg kg⁻¹) (Table I).

TABLE I
Initial soil properties of the experimental site

Parameters	Values
pH (1:2.5)	6.45
EC (1:2.5) dS-m	0.15
SOC (%)	0.29
Available N (kg ha ⁻¹)	230.8
Available P ₂ O ₅ (kg ha ⁻¹)	57.71
Available K ₂ O (kg ha ⁻¹)	375.2
Available S (mg kg ⁻¹)	18.77
DTPA-Fe (mg kg ⁻¹)	16.94
DTPA-Mn (mg kg ⁻¹)	17.06
DTPA-Zn (mg kg ⁻¹)	0.54
DTPA-Cu (mg kg ⁻¹)	1.07
HWS-B (mg kg ⁻¹)	0.34

Analysis of the Irrigation water used for the experiment indicated, pH of 6.40, EC of 0.60 (dS m⁻¹) and zinc was not in detectable range (Table II).

Significantly higher number of bunches plant⁻¹ were recorded in T₁₃ (66.73), T₁₈ (65.58) followed by T₈ (62.34) compared to all other treatments (Table III). The more number of bunches plant⁻¹ were

TABLE II
Properties of the irrigation water used for the experiment

Parameters	Values
pH	6.40
EC (dS/m)	0.60
Ca ²⁺ (meq/L)	8.00
Mg ²⁺ (meq/L)	1.60
CO ₃ (meq/L)	Nil
HCO ₃ (meq/L)	2.00
Cl (meq/L)	4.00
Na ⁺ (meq/L)	1.40
Zn	ND
Cu	ND
Mn	ND
Fe (ppm)	0.23
SAR	0.64
RSC	-

recorded in metalosate treatment which may be due to complete solubility of zinc metalosate in water, better penetration and availability of nutrient for plant absorption (Anon., 2000). Increased number of bunches per vine at 0.5 per cent of ZnSO₄ was observed in Perlette grapes (Sindhu *et al.*, 2000). Foliar application of 0.05 per cent zinc through zinc sulphate significantly improved the yield attributing parameters in grapes (Aydin *et al.*, 2007).

Foliar application of zinc @ 0.150 per cent through zinc metalosate, Zn-EDTA and zinc sulphate significantly improved the weight of bunches compared to control (Table IV). Girirajjat and Kacha (2015) reported that foliar spray of ZnSO₄ @ 0.6 Per cent to eighteen year old guava cv Bhavnagar Red at flowering and at three weeks after flowering recorded higher yield attributing characters compared to control. Foliar spray of ZnSO₄ @ 0.4 Per cent at pea stage of fruit set increased the weight of fruit (338.33 g) compared to control (Singh *et al.*, 2015).

Among different sources and levels of zinc, zinc @ 0.150 per cent through zinc metalosate, Zn-EDTA and Zinc Sulphate along with NPK significantly

TABLE III
Effect of foliar application of zinc metalosate on yield parameters of grapes (*Vitis vinifera*)

Sl. No.	Treatment	No. of bunches / plant	Weight of bunch	No. of berries / bunch	Yield / plant (kg)
T ₁	NPK (500: 500: 1000 kg/ha)	52.78	480.36	56.97	26.62
T ₂	NPK+ Soil Zn through ZnSO ₄	56.20	526.16	63.58	29.57
T ₃	NPK + FYM @ 20 kg/plant	53.83	489.58	61.84	27.00
T ₄	NPK + foliar spray of 0.010 % Zn through ZnSO ₄	53.79	486.93	60.03	26.73
T ₅	NPK + foliar spray of 0.025 % Zn through ZnSO ₄	54.79	500.46	62.55	27.47
T ₆	NPK + foliar spray of 0.050 % Zn through ZnSO ₄	56.57	527.73	67.38	28.73
T ₇	NPK + foliar spray of 0.100 % Zn through ZnSO ₄	59.03	560.58	74.52	31.18
T ₈	NPK + foliar spray of 0.150 % Zn through ZnSO ₄	62.34	607.45	82.85	34.82
T ₉	NPK + foliar spray of 0.010% Zn through Zn Metalosate	54.69	502.73	64.18	27.33
T ₁₀	NPK + foliar spray of 0.025 % Zn through Zn Metalosate	56.42	520.81	68.42	28.47
T ₁₁	NPK + foliar spray of 0.050 % Zn through Zn Metalosate	58.85	553.33	75.72	31.12
T ₁₂	NPK + foliar spray of 0.100 % Zn through Zn Metalosate	62.27	605.54	85.75	34.78
T ₁₃	NPK + foliar spray of 0.150% Zn through Zn Metalosate	66.73	661.88	96.44	39.38
T ₁₄	NPK + foliar spray of 0.010 % Zn through Zn-EDTA	54.22	491.37	62.30	27.11
T ₁₅	NPK + foliar spray of 0.025 % Zn through Zn-EDTA	55.47	508.20	65.58	28.19
T ₁₆	NPK + foliar spray of 0.050 % Zn through Zn-EDTA	57.82	537.55	73.00	30.48
T ₁₇	NPK + foliar spray of 0.100 % Zn through Zn-EDTA	61.30	586.00	81.26	33.61
T ₁₈	NPK + foliar spray of 0.150 % Zn through Zn-EDTA	65.58	637.40	91.34	37.70
T ₁₉	T3+ Soil application of Zn through ZnSO ₄	57.23	529.15	68.88	30.12
T ₂₀	T3+ foliar application of 0.01 % (100 ppm) of 54.88 Zn through ZnSO ₄	498.67	63.23	27.69	
	SEM ±	0.77	8.84	1.90	0.82
	CD @ 5 %	2.21	25.33	5.44	2.35

improved the number of berries bunch⁻¹. Significant improvement in number of berries bunch⁻¹ (42.20) in Bangalore blue grapes was observed by the foliar spray of zinc @ 0.30 per cent along with RDF (1000 g urea: 250g phosphorus: 1500 g potassium) at 30 days after pruning (Asha, 2006).

Higher grape yield were recorded in T₁₃ treatment (39.38 kg plant⁻¹), T₁₈ (37.70 kg plant⁻¹) and

T₈ (34.82 kg plant⁻¹) treatments compared to other treatments. Increased number of bunches plant⁻¹, berries plant⁻¹ and weight of bunch contributed to increase in the yield. The yield increase in zinc metalosate treatment may be the fact that the zinc metalosate is amino acid based liquid fertilizer which has got higher solubility, penetration and hence better absorption by the crop. Zn-EDTA is also more soluble in water and provides good amount of nutrients for

TABLE IV

Effect of foliar application of zinc metalosate on quality parameters of grapes (Vitis vinifera)

Treatment		TSS (° Brix)	Total Sugars (%)	Titrateable Acidity (%)
T ₁	NPK (500: 500: 1000 kg/ha)	8.75	11.70	1.63
T ₂	NPK+ Soil Zn through ZnSO ₄	10.87	13.60	1.37
T ₃	NPK + FYM @ 20 kg/plant	9.75	12.50	1.51
T ₄	NPK + foliar spray of 0.010 % Zn through ZnSO ₄	9.30	12.20	1.58
T ₅	NPK + foliar spray of 0.025 % Zn through ZnSO ₄	10.16	12.70	1.49
T ₆	NPK + foliar spray of 0.050 % Zn through ZnSO ₄	11.28	13.40	1.36
T ₇	NPK + foliar spray of 0.100 % Zn through ZnSO ₄	13.42	15.10	1.14
T ₈	NPK + foliar spray of 0.150 % Zn through ZnSO ₄	16.13	17.20	0.87
T ₉	NPK + foliar spray of 0.010% Zn through Zn Metalosate	10.04	13.20	1.45
T ₁₀	NPK + foliar spray of 0.025 % Zn through Zn Metalosate	11.23	13.90	1.30
T ₁₁	NPK + foliar spray of 0.050 % Zn through Zn Metalosate	13.22	15.40	1.07
T ₁₂	NPK + foliar spray of 0.100 % Zn through Zn Metalosate	15.95	17.60	0.76
T ₁₃	NPK + foliar spray of 0.150% Zn through Zn Metalosate	19.13	20.30	0.39
T ₁₄	NPK + foliar spray of 0.010 % Zn through Zn-EDTA	9.80	12.90	1.50
T ₁₅	NPK + foliar spray of 0.025 % Zn through Zn-EDTA	10.85	13.50	1.38
T ₁₆	NPK + foliar spray of 0.050 % Zn through Zn-EDTA	12.58	14.80	1.18
T ₁₇	NPK + foliar spray of 0.100 % Zn through Zn-EDTA	15.10	16.60	0.89
T ₁₈	NPK + foliar spray of 0.150 % Zn through Zn-EDTA	18.00	19.10	0.55
T ₁₉	T3+ Soil application of Zn through ZnSO ₄	11.87	14.00	1.27
T ₂₀	T3+ foliar application of 0.01 % (100 ppm) of Zn through ZnSO ₄	10.23	12.60	1.45
SEM±		0.42	0.46	0.05
CD @ 5 %		1.20	1.32	0.17

the plant absorption. Basal dose of 150: 50: 50 g NPK vine⁻¹ along with each time foliar addition of Zn @ 2.5 g / plant through zinc sulphate for four times at fifteen days intervals starting from before blossom significantly improved the yield (14.5 kg / grape vine) of hespali grapes of 8-10 year old in sandy soils of Turkey (Er *et al.*, 2009). Foliar application of Zn @ 0.4 per cent at enlargement of flower bud and three weeks after the flower petal drops significantly improved the yield of grapes compared to control (Bybordi *et al.*, 2010). In ten year old guava *var* Gwalior-27 foliar application of zinc sulphate @ 0.4 per cent along with potassium sulphate

@ 2 per cent significantly improved the yield plant⁻¹ (39.81 kg / plant) at Krishi Vigyan Kendra College of Agriculture, Gwalior (M.P.) (Pawar, 2016). Hamouda *et al.* (2016) reported that foliar spray of zinc @ 2000 ppm three times *viz.*, mid of March, April and June of 2011 and 2012 significantly improved the pomegranate yield shrub⁻¹ (12.50 and 16.16 kg / shrub) in both the seasons compared to control.

Significant improvement in total soluble solids (19.13 °Brix), total sugars (20.30 Per cent) and decrease in titrateable acidity (0.39 Per cent) were observed at T₁₃ followed by T₁₈ treatment. Significant

improvement in TSS (15.10°Brix) and decrease in titratable acidity (5.13 %) was recorded by foliar spray of zinc sulphate @ 1.5 g / l in asgari variety of grapes (Ashoori *et al.*, 2013). Foliar spray of zinc 0.50 per cent along with iron @ 0.50 and copper @ 0.25 per cent twice at an interval of one month (June and July, 2007-2008) on six year old kinnow mandarin increased the total soluble solids (13.25°Brix), total sugars (7.24 per cent) and reduced the titratable acidity (0.70 per cent) compared to individual application and control (Kumari *et al.*, 2009). Positive response in fruit quality in terms of increase in TSS (20.75° Brix), total sugars (17.08 per cent) and decreased acidity (0.18 per cent) due to rapid conversion of metabolites into sugars and their derivatives was observed by the foliar application of $ZnSO_4$ @ 1.0 per cent in mango cv. (Bhowmick *et al.*, 2012).

Foliar spray of zinc @ 0.150 Per cent through zinc metalosate along with recommended dose of NPK (500: 500: 1000 kg/ha) significantly improved the yield attributing parameters viz., number of bunches plant⁻¹, weight of bunch (g), number of berries bunch⁻¹ and yield plant (kg plant⁻¹) and quality parameters like total soluble solids and total sugars in grapes cv Dilkush.

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(Received : May, 2017 Accepted : August, 2017)

Major and Micronutrient Content in Soils of Grape Orchard as Influenced by Different Sources and Levels of Zinc and NPK

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ABSTRACT

A field experiment was conducted in three year old grape orchard *var.* Dilkush in order to know the nutrient status as influenced by different sources and levels of zinc along with recommended dose of NPK during 2015-16 and 2016-17, in Randomized Block Design with twenty treatments and three replications. Foliar spray was carried out at critical growth stages of the grape *viz.*, vegetative stage, before flowering and after fruit set by using zinc metalosate, Zn-EDTA and zinc sulphate as zinc sources. Recommended dose of NPK and FYM were applied as per package of practice. Before experimentation soil samples were collected and analysed. The initial soils were slightly acidic, normal in EC, medium in organic carbon, available N, P_2O_5 , K_2O and deficit in available zinc. Among different treatments significantly higher available nitrogen, phosphorus and potassium content were recorded in the treatment T₃ (NPK+ FYM) and lowest was recorded in treatments T₁₃ and T₁₈ which consists of foliar application of zinc @ 0.150 per cent through zinc metalosate and Zn-EDTA along with recommended dose of NPK. Significantly higher available zinc was recorded in the treatments T₃, T₁₉ and T₂₀ compared to other treatments.

Key words Grape, Foliar Spray, Zinc, Nutrient content, Harvest stage

Fruit crop production is governed by several factors like climate, soil and irrigation status, varieties, pest and disease situation and nutritional status of soil as well as plant. Deficiency of various nutrients causes drastic reduction in growth, yield and quality of fruits. Among the nutrients, micronutrients though required in small quantities their importance in growth, yield and quality of fruit crops nutrition is quite essential (Raja, 2009). Zinc availability to the plant from soil is limited and it depends on factors like dynamic soil properties, organic matter, texture, cultivation, drought and microbial activity (Mengel and Kirkby, 2001). Hence, plant roots are unable to absorb these micronutrients adequately from the dry top soil therefore foliar application for better results deserves attention.

Grape (*Vitis vinifera* L.) is one of the important commercial fruit crop grown successfully in tropical and subtropical regions of the world. It is the third world's most widely cultivated fruit crop after citrus and banana and it contributes about 16 per cent towards the total fruit

production. In world, it grown in an area of 7.50 lakh hectare with a production of 66 million tonnes (F.A.O, 2013). In India, it is cultivated in an area of 1.18 lakh hectares with an annual production of 25.85 lakh tonnes with productivity of 21.80 t ha⁻¹ during 2013-14 (Horticultural statistics at glance, 2015). Its cultivation in India had greater significance due to its higher productivity as compared to other grape producing countries. Several research workers have reported the significant effect of foliar spray of zinc through different sources along with recommended dose of NPK on growth, yield and quality of grapes and other fruit crops but the information regarding available soil nutrient status after harvest of the crop is lacking. Hence, in order to know the available soil nutrient content after harvest of the crop, the present research work was undertaken by using grape as test crop.

MATERIAL AND METHODS

The experimental work was undertaken in three year old grape *var.* Dilkush with twenty treatments and three replications in Randomized Block Design during 2015-16 and 2016-17. Before experimentation surface soil samples were collected and analysed for various parameters. Experimental soils were acidic (6.45), normal in EC (0.54 dS m⁻¹), medium in organic carbon (0.68%), available N (285.60 kg/ha), P_2O_5 (23.97 kg/ha), K_2O (175.20 kg/ha) and deficit in available zinc (0.55 mg /kg). Details of the treatments imposed include T₁: NPK, T₂: NPK+ Soil application of Zn as ZnSO₄, T₃: NPK + FYM, T₄: NPK + Foliar spray of 0.01 % Zn as ZnSO₄, T₅: NPK + Foliar spray of 0.025 % Zn as ZnSO₄, T₆: NPK + Foliar spray of 0.050 % Zn as ZnSO₄, T₇:

NPK + Foliar spray of 0.100 % Zn as ZnSO₄, T₈: NPK + Foliar spray of 0.150 % Zn as ZnSO₄, T₉: NPK + Foliar spray of 0.010% Zn as zinc metalosate, T₁₀: NPK + Foliar spray of 0.025 % Zn as zinc metalosate, T₁₁: NPK + Foliar spray of 0.050 % Zn as zinc metalosate, T₁₂: NPK + Foliar spray of 0.10 % Zn as zinc metalosate, T₁₃: NPK + Foliar spray of 0.150% Zn as zinc metalosate, T₁₄: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA, T₁₅: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA, T₁₆: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA, T₁₇: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA, T₁₈: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA, T₁₉: T₃+ Soil application of Zn as ZnSO₄ and T₂₀: T₃+ Foliar spray of 0.01 % (100 ppm) of Zn as ZnSO₄. Foliar spray was carried out at critical growth stages of grape *viz.*, vegetative stage, before flowering and after fruit set by using zinc metalosate, Zn-EDTA and zinc sulphate

Table 1. Effect of foliar spray of different sources and levels of zinc on major nutrient content (kg ha⁻¹) of soil at harvest of grapes

Treatments	Nitrogen			Phosphorus			Potassium		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	342.26	373.06	357.66	35.79	45.68	40.74	234.60	228.45	231.53
2	343.41	374.32	358.52	35.02	44.72	39.87	233.13	226.98	230.06
3	343.08	373.96	358.86	36.18	46.21	41.19	235.25	229.10	232.18
4	341.61	372.35	356.98	35.56	45.40	40.48	233.85	227.70	230.78
5	343.35	374.25	358.80	34.93	44.61	39.77	232.04	225.89	228.97
6	334.44	364.52	349.48	33.08	42.26	37.67	226.29	220.14	223.22
7	325.38	354.65	340.02	30.99	39.57	35.28	218.17	212.02	215.09
8	315.30	343.66	329.48	28.77	36.71	32.74	212.98	206.83	209.91
9	341.44	372.18	356.81	35.13	44.85	39.99	233.38	227.23	230.31
10	334.23	364.32	349.27	32.84	41.93	37.38	224.19	218.04	221.12
11	324.10	353.25	338.68	30.65	39.14	34.90	217.84	211.69	214.77
12	313.22	341.49	327.35	28.11	35.87	31.99	211.95	205.80	208.88
13	300.33	327.35	313.84	25.97	29.83	27.90	203.06	196.91	199.99
14	341.58	372.31	356.94	35.40	45.20	40.30	233.45	227.30	230.38
15	334.29	364.37	349.33	32.99	42.13	37.56	225.70	219.55	222.63
16	324.90	354.16	339.53	30.87	39.43	35.15	218.13	211.98	215.06
17	315.05	343.37	329.21	28.53	36.43	32.48	212.55	206.40	209.48
18	300.55	327.62	314.08	26.15	31.37	28.76	203.54	197.39	200.47
19	343.30	374.20	358.75	35.94	45.89	40.92	235.19	229.04	232.12
20	342.99	373.85	358.42	36.06	46.04	41.05	235.09	228.94	232.02
SEm ±	2.91	3.29	3.21	0.62	1.19	0.83	1.50	1.50	1.65
CD @ 5 %	8.32	9.42	9.20	1.78	3.39	2.37	4.29	4.29	4.72

sources of zinc. Recommended dose of NPK (500:125: 750 N, P₂O₅, K₂O) and FYM (20 kg plant⁻¹) were applied as per package of practice. After harvest of each crop soil samples were collected treatment wise and analysed for major and micronutrient content.

RESULTS AND DISCUSSION

Pooled data presented in the Table 1 indicating that significant increase in major nutrient content in soil at harvest of crop compared to initial values. Available nitrogen content varied from 313.84 to 358.86 kg ha⁻¹ and recorded significantly higher in treatment T₃ (358.86 kg ha⁻¹) which received recommended dose of NPK along with farm yard manure. Lower available nitrogen content was recorded in treatment T₁₃ (313.84 kg ha⁻¹) and T₁₈ (314.08 kg ha⁻¹) which received zinc @ 0.150 per cent as zinc metalosate and Zn-EDTA along with recommended dose of NPK. Available phosphorus content varied from 27.90 to 41.19 kg ha⁻¹ and recorded significantly higher content in treatments which received recommended dose of NPK along with farm yard manure (T₃: 41.19, T₂₀:41.05 and T₁₉: 40.92 kg ha⁻¹) and it recorded significantly lower content in treatments which received zinc @ 0.150 per cent as zinc metalosate and Zn-

EDTA, respectively. About 199.99 to 232.18 kg ha⁻¹ available potassium was recorded in soil at harvest and recorded more in treatment T₃, T₁₉ and T₂₀ which received recommended dose of NPK along with farm yard manure. Lower available potassium content was recorded in treatment which received 0.150 per cent zinc as zinc metalosate and Zn-EDTA, respectively i.e T₁₃ (199.99 kg ha⁻¹) and T₁₈ (200.47 kg ha⁻¹).

Higher available NPK content was recorded in treatments T₃ may be due to soil application of recommended dose of NPK and farm yard manure. Farm yard manure favoured mineralization of organic sources of nitrogen in the soil and also due to increased microbial activity which could have stimulated the nitrification process. Similarly increase in available phosphorus with FYM addition was due to release of more phosphorus from organic compounds, increase in microbial population as well as decomposition product of humic substances. Due to action of organic acids from organic matter complex available potassium was increased (Sharma, 2013). Similarly, Singh *et al.* (2012) noticed that soil application of inorganic fertilizers and organic manures, significantly increased the available

Table 2. Effect of foliar spray of different sources and levels of zinc on micronutrient content (mg kg⁻¹) of soil at harvest of grapes

Treat- ments	Zinc			Iron			Copper			Manganese			Boron		
	Season	Season	Pooled	Season	Season	Pooled	Season	Season	Pooled	Season	Season	Pooled	Season	Season	Pooled
	I	II	mean	I	II	mean	I	II	mean	I	II	mean	I	II	mean
1	0.46	0.44	0.45	38.63	38.23	38.43	0.35	0.34	0.35	26.50	26.22	26.36	0.44	0.43	0.43
2	0.47	0.45	0.46	38.48	38.10	38.29	0.35	0.33	0.34	26.35	26.09	26.22	0.44	0.43	0.43
3	0.58	0.61	0.60	40.44	41.36	40.90	0.34	0.32	0.33	28.31	28.68	28.50	0.47	0.49	0.48
4	0.46	0.44	0.45	38.58	38.19	38.38	0.35	0.34	0.34	26.45	26.18	26.32	0.43	0.43	0.43
5	0.47	0.45	0.46	38.45	38.05	38.25	0.35	0.34	0.34	26.32	26.05	26.18	0.43	0.42	0.43
6	0.48	0.46	0.47	38.44	38.04	38.24	0.35	0.35	0.35	26.31	26.03	26.17	0.44	0.41	0.42
7	0.50	0.48	0.49	38.38	38.00	38.19	0.34	0.33	0.34	26.25	25.99	26.12	0.43	0.43	0.43
8	0.52	0.50	0.51	38.32	37.95	38.13	0.34	0.34	0.34	26.19	25.94	26.06	0.44	0.43	0.43
9	0.46	0.44	0.45	38.51	38.13	38.32	0.35	0.34	0.34	26.38	26.12	26.25	0.44	0.42	0.43
10	0.49	0.47	0.48	38.40	38.02	38.21	0.34	0.33	0.34	26.27	26.01	26.14	0.44	0.42	0.43
11	0.51	0.49	0.50	38.34	37.98	38.16	0.34	0.34	0.34	26.21	25.97	26.09	0.43	0.43	0.43
12	0.53	0.51	0.52	38.28	37.97	38.13	0.34	0.32	0.33	26.15	25.96	26.06	0.43	0.42	0.43
13	0.54	0.52	0.53	38.23	37.92	38.08	0.34	0.34	0.34	26.10	25.91	26.01	0.43	0.43	0.43
14	0.46	0.44	0.45	38.53	38.14	38.33	0.35	0.35	0.35	26.40	26.13	26.26	0.43	0.44	0.44
15	0.49	0.47	0.48	38.43	38.06	38.25	0.35	0.35	0.35	26.30	26.05	26.18	0.43	0.43	0.43
16	0.51	0.49	0.50	38.36	38.00	38.18	0.34	0.34	0.34	26.23	25.99	26.11	0.43	0.43	0.43
17	0.53	0.50	0.52	38.30	37.91	38.10	0.34	0.34	0.34	26.17	25.90	26.03	0.43	0.42	0.43
18	0.54	0.53	0.54	38.25	37.86	38.06	0.34	0.33	0.33	26.12	25.85	25.99	0.44	0.43	0.43
19	0.59	0.61	0.60	40.74	41.01	40.87	0.33	0.32	0.32	28.61	29.33	28.97	0.46	0.49	0.48
20	0.58	0.60	0.59	40.63	40.95	40.79	0.32	0.30	0.31	28.50	29.03	28.77	0.47	0.47	0.47
SEm ±	0.01	0.02	0.01	1.24	1.59	1.26	0.01	0.02	0.01	1.10	1.25	1.13	0.02	0.03	0.02
CD @ 5 %	0.03	0.06	0.03	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

N, P and K status in the soil. Addition of farmyard manure improved the physical properties of soil there by creating favourable conditions for microbial activity resulting in increase in the nutrient availability in the soil. The increase in soil available K content might be due to release of fixed K due to action of organic acids from decomposed organic manure. Similar observations were recorded in different fruit crops by Korwar *et al.* (2007), Selvamani *et al.* (2011), Mohanbai (2014), Mustafa *et al.* (2013), Thakur (2013) and Verma and Chauhan *et al.* (2014).

Significantly higher available zinc content in soil in treatment T₁₉ (0.60 mg kg⁻¹) which received soil application of zinc sulphate along with farm yard manure and T₃ (0.60 mg kg⁻¹) which received farm yard manure followed by treatment T₂₀ (0.59 mg kg⁻¹) which consists of farm yard manure. Among different sources and levels of zinc as zinc metalosate, Zn-EDTA and ZnSO₄, significantly higher zinc content in soil was recorded in treatment T₁₈ (0.54 mg kg⁻¹) and T₁₃ (0.53 mg kg⁻¹) which received 0.150 per cent zinc as Zn-EDTA and zinc metalosate, respectively. No significant difference was observed among the treatments with respect to DTPA extractable iron, copper, manganese and boron and which recorded in the range of 38.08 to 40.90, 0.31 to

0.35, 26.01 to 28.97 and 0.42 to 0.48 mg kg⁻¹, respectively (Table 2).

The increase in zinc content in the soil may be due to application of farm yard manure to soil. Farm yard manure is a good source of all nutrients, during decomposition it releases organic acids which reduces the fixation and conversion to unavailable form, which in turn contributed to increasing available zinc in soil. Similar findings were also made by Thakur (2013) who stated that application of 75% NPK + biofertilizers (60 g tree basin⁻¹) + green manure (Sunhemp @ 25 g seed/tree basin) + FYM (40 kg) + vermicompost (24 kg) resulted in available Zn of 2.10 mg kg⁻¹ in soils of plum orchards.

CONCLUSION

Soil application of recommended dose of NPK along with FYM manure played significant role in improving available nutrient content in soil after harvest of grapes compared to other treatments. Lower available nutrients content in soil was recorded in treatments T₁₃ and T₁₈ due to enhanced uptake of these nutrients by the crop due to foliar application of higher levels of zinc *i.e.* 0.150 % zinc through zinc metalosate and Zn-EDTA.

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Received on 01-12-2017 Accepted on 03-12-2017