STUDIES ON THE EFFECT OF COMBINED FOLIAR APPLICATION OF B/Zn AND GROWTH REGULATORS ON THE GROWTH AND YIELD OF SOYBEAN (GLYCINE MAX. L (MERRIL))

By

SHAHID LIAQAT

Faculty of Biological Sciences
Quaid-i-Azam University
Islamabad Pakistan
2006

STUDIES ON THE EFFECT OF COMBINED FOLIAR APPLICATION OF B/Zn AND GROWTH REGULATORS ON THE GROWTH AND YIELD OF SOYBEAN (GLYCINE MAX.L (MERRIL))

By

SHAHID LIAQAT

Faculty of Biological Sciences
Quaid-i-Azam University
Islamabad Pakistan
2006

STUDIES ON THE EFFECT OF COMBINED FOLIAR APPLICATION OF B/Zn AND GROWTH REGULATORS ON THE GROWTH AND YIELD OF SOYBEAN (GLYCINE MAX.L (MERRIL))

A thesis submitted in the partial fulfillment of the requirements for the degree of Master of Philosophy

In

Plant Physiology

By

SHAHID LIAQAT

Faculty of Biological Sciences
Quaid-i-Azam University
Islamabad Pakistan
2006

DECLARATION

This thesis submitted by **Shahid Liaqat** is accepted in its present form by the Faculty of Biological Sciences, Quaid-i-Azam University Islamabad as fulfilling the thesis requirement for the degree of Master of Philosophy in Plant Physiology.

Supervisor:

(Prof. Dr. M. Fayyaz Chaudhary)

External Examiner:

(Prof. Dr. Ehsan Elahi)

Chairman:

(Prof. Dr. M. Fayyaz Chaudhary)

Dated: 06-03-2006

Dedicated

To My Parents,

My Wife and Daughter

List of Contents

List of Contents i
List of Tables vi
List of Figures ix
List of Abbreviations xiii
Acknowledgement xv
Abstract xvi
Chapter 1
Introduction 1
1.1 Soybean 1
1.1.1 Potential Areas 1
1.1.2 Proposed Cropping Pattern 2
1.1.3 Climatic Requirements 2
1.1.4 Soil and Fertilizer Requirements 3
1.1.5 Seed Inoculum 3
1.1.5.1 Method of Inoculation 4
1.1.6 Irrigation 4
1.1.7 Temperature 4
1.1.8 Nitrogen Fixation 5
1.2 Micronutrients 5
1.2.1 Boron (B) 6
1.2.2 Zinc (Zn) 7
1.3 Plant Growth Regulators 8
1.3.1 Auxins 8
1.3.1.1 Functions of Auxin 10
1.3.2 Cytokinins 11
1.3.2.1 Functions of Cytokinins 13
1.3.3 Gibberellins 14
1.3.3.1 Functions of Gibberellins 15

1.4 Foliar Application 15
1.5 Aims and Objective of Present Study 16
Chapter 2
Review of Literature 17
2.1 Foliar Application 17
2.2 Foliar Application of Micronutrients (Boron/Zinc) 17
2.3 Phytohormones 24
2.3.1 Effect of Auxin (IAA, NAA) on Growth and Yield in Plants 25
2.3.2 Effect of Cytokinins on Growth and Yield in Plants 26
2.3.3 Effect of Gibberellins on Growth and Yield in Plants 27
Chapter 3
Materials and Methods 36
3.1 Research Site and Materials Description 36
3.2 Soil Analysis 37
3.2.1 Physical Analysis 37
3.2.2 Chemical Analysis 37
3.3 Micronutrients Used 37
3.4 Micronutrients Concentrations Used 37
3.5 Hormonal Concentrations Used 38
3.6 Preparation of Stock Solutions 38
3.7 Micronutrients Solution Preparation 38
3.8 Strategy for Foliar Application 39
3.8.1 Preparation of Solution for Application 39
3.8.2 Amount of Solution applied per pot 39
3.8.3 Treatments Applied 39
3.9 Stages of Foliar Application 40
3.9.1 Vegetative Stage 40
3.9.2 Flowering Stage 40
3.9.3 Pod-Set Stage 40
3.10 Irrigation 41
3.11 Harvesting 41

3.12 Vegetative Stage 41
3.12.1 Parameters Studied at Vegetative Stage 41
3.13 Pod-Set Stage (50 DAT) 41
3.13.1 Parameters Studied at Pod-Set Stage 41
3.14 Harvest/Maturity Stage Observations 42
3.15 Strategy for Parameters Studied 42
3.15.1 Shoot Length and Root Length 42
3.15.2 Number of Branches 43
3.15.3 Number of Leaves 43
3.15.4 Middle Leaflet Length and width 43
3.15.5 Fresh Weight of Shoot and Root 43
3.15.6 Dry Weight of Shoot and Root 43
3.15.7 Number of pod-set per plant 44
3.15.8 Number of Pods per plant 44
3.15.9 Test weight of 1000 seeds 44
3.16 Statistical Analysis 44
Chapter 4 45
Results 45
4.1 Soil Analysis 45
4.2 Number of Branches 46
4.2.1 Number of Branches at 35 DAT 46
4.2.2 Number of Branches at 50 DAT 46
4.3 Number of Leaves 49
4.3.1 Number of Leaves per Plant at 35 DAT 49
4.3.2 Number of Leaves per Plant at 50 DAT 49
4.4 Middle Leaflet Length 52
4.4.1 Middle Leaflet Length at 35 DAT 52
4.4.2 Middle Leaflet Length at 50DAT 52
4.5 Middle Leaflet Width 55
4.5.1 Middle Leaflet Width at 35 DAT 55
4.5.2 Middle Leaflet Width at 50 DAT 55

4.6 Petiole Length 58
4.6.1 Petiole Length at 35 DAT 58
4.6.2 Petiole Length at 50 DAT 58
4.7 Shoot Length 61
4.7.1 Shoot Length at 35 DAT 61
4.7.2 Shoot Length at 50 DAT 61
4.7.3 Shoot Length at 90 DAT 61
4.8 Shoot Fresh Weight 64
4.8.1 Shoot Fresh Weight at 35 DAT 64
4.8.2 Shoot Fresh Weight at 50DAT 64
4.8.3 Shoot Fresh Weight at 90 DAT 64
4.9 Root Fresh Weight 67
4.9.1 Root Fresh Weight at 35 DAT 67
4.9.2 Root Fresh Weight at 50 DAT 67
4.9.3 Root Fresh Weight at 90 DAT 67
4.10 Root Length 70
4.10.1 Root Length at 35 DAT 70
4.10.2 Root Length at 50 DAT 70
4.10.3 Root Length at 90 DAT 70
4.11 Shoot Dry Weight 73
4.11.1 Shoot Dry Weight at 35 DAT 73
4.11.2 Shoot Dry Weight at 50 DAT 73
4.11.3 Shoot Dry Weight at 90 DAT 73
4.12 Root Dry Weight 76
4.12.1 Root Dry Weight at 35 DAT 76
4.12.2 Root Dry Weight at 50 DAT 76
4.12.3 Root Dry Weight at 90 DAT 76
4.13 Number of Pod Set at 50 DAT 79
4.14 Number of Pods per Plant at 90 DAT 81
4.15 Number of Empty Pods per Plant 83
4.16 Number of 3-Seeded Pods per Plant 85

4.17 Number of 1-Seeded Pods per Plant 87
4.18 Number of 2-Seeded Pods per Plant 89
4.19 1000-Seed Weight 91
Photographs of Soybean at Vegetative Stage (35 DAT) 93
Photographs of Soybean at Pod-Set Stage (50 DAT): 97
Photographs of Soybean at Harvest Stage (90 DAT) 101
Chapter 5 113
Discussion 113
Conclusions 123
References 124

List of Tables

Table 3.1: Phytohormone Used for Growth and yield of Soybean *Glycine max* L. 38
Table 3.2: Hormonal Combination and Concentrations Used with Micronutrients.....39
Table 3.3: Combinations and concentrations of B/Zn and IAA, BAP and GA_3..... 40
Table 4.1: Physical and chemical analysis of soil sample. 45
Table 4.2: Standard values of the macro and micronutrients..... 46
Table 4.3: ANOVA table for number of Branches at 35 DAT. 47
Table 4.4: ANOVA table for number of Branches at 50 DAT. 47
Table 4.5: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of branches at 35 and 50 DAT..... 48
Table 4.6: ANOVA table for number of Leaves at 35 DAT..... 50
Table 4.7: ANOVA table for number of Leaves at 50 DAT..... 50
Table 4.8: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on no. of leaves at 35 and 50 DAT. 51
Table 4.9: ANOVA table for middle leaflet length at 35 DAT. 53
Table 4.10: ANOVA table for middle leaflet length at 50 DAT. 53
Table 4.11: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on middle leaflet length at 35 and 50 DAT. 54
Table 4.12: ANOVA table for middle leaflet width at 35 DAT. 56
Table 4.13: ANOVA table for middle leaflet width at 50 DAT. 56
Table 4.14: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on middle leaflet width at 35 and 50 DAT.....57
Table 4.15: ANOVA table for petiole length at 35 DAT..... 59
Table 4.16: ANOVA table for petiole length at 50 DAT.....59
Table 4.17: Effect of foliar application of micronutrients (B/Zn) and growth regulators .(IAA, BAP and GA_3) on petiole length at 35 and 50 DAT.....
Table 4.18: ANOVA table for shoot length at 35 DAT..... 62
Table 4.19: ANOVA table for shoot length at 50 DAT..... 62
Table 4.20: ANOVA table for shoot length at 90 DAT..... 62

Table 4.21: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on shoot length at 35, 50 and 90 DAT. 63
Table 4.22: ANOVA table for shoot fresh weight at 35 DAT. 65
Table 4.23: ANOVA table for shoot fresh weight at 50 DAT. 65
Table 4.24: ANOVA table for shoot fresh weight at 90 DAT. 65
Table 4.25: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on shoot fresh weight at 35, 50 and 90 DAT. 66
Table 4.26: ANOVA table for root fresh weight at 35 DAT. 68
Table 4.27: ANOVA table for root fresh weight at 50 DAT. 68
Table 4.28: ANOVA table for root fresh weight at 90 DAT. 68
Table 4.29: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on root fresh weight at 35, 50 and 90 DAT. 69
Table 4.30: ANOVA table for root length at 35 DAT. 71
Table 4.31: ANOVA table for root length at 50 DAT. 71
Table 4.32: ANOVA table for root length at 90 DAT. 71
Table 4.33: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on root length at 35, 50 and 90 DAT. 74
Table 4.34: ANOVA table for shoot dry weight at 35 DAT. 74
Table 4.35: ANOVA table for shoot dry weight at 50 DAT. 74
Table 4.36: ANOVA table for shoot dry weight at 90 DAT. 75
Table 4.37: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on shoot dry weight at 35, 50 and 90 DAT. 75
Table 4.38: ANOVA table for root dry weight at 35 DAT. 77
Table 4.39: ANOVA table for root dry weight at 50 DAT. 77
Table 4.40: ANOVA table for root dry weight at 90 DAT. 77
Table 4.41: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on root dry weight at 35, 50 and 90 DAT. 78
Table 4.42: ANOVA table for pod sets at 50 DAT. 79
Table 4.43: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on pod sets at 50 DAT. 80

Table 4.44: ANOVA table for pods per plant at 90 DAT. 81
Table 4.45: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on no. of pods per plant at 90 DAT. 82
Table 4.46: ANOVA table for number of empty pods per plant at 90 DAT. 83
Table 4.47: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of empty pods per plant at 90 DAT. 84
Table 4.48: ANOVA table for number 3-Seeded pods per plant at 90 DAT. 85
Table 4.49: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of 3-seeded pods per plant at 90 DAT. 86
Table 4.50: ANOVA table for number of 1-Seeded pods per plant at 90 DAT. 87
Table 4.51: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of 1-seeded pods per plant at 90 DAT. 88
Table 4.52: ANOVA table for number of 2-Seeded pods per plant at 90 DAT. 89
Table 4.53: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of 2-seeded pods per plant at 90 DAT. 90
Table 4.54: ANOVA table for 1000-Seed Weight at 90 DAT. 91
Table 4.55: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on 1000-seed weight at 90 DAT. 92

List of Figures

Figure 1.1: Stuctural formula of IAA (Indole Acetic Acid) 9

Figure 1.2: Stuctural formula of Dichlorophenoxy Acetic Acid (2,4-D) 9

Figure 1.3: Stuctural formula of α-nephthalene Acetic Acid (NAA). 10

Figure 1.4: Stuctural formula of Zeatin. 12

Figure 1.5: Stuctural formula of Kinetin (Synthetic Cytokinin)..... 12

Figure 1.6: Stuctural formula of Benzylamino Purine (BAP) 12

Figure 1.7: Stuctural formula of gibberellin. 14

Figure 4.1: From L to R T_0(D.W), T_1(B50ppm + IAA10^{-3}M), ...93
T_2(B100ppm + IAA10^{-4}M)

Figure 4.2: From L to R T_0(D.W), T_3(Zn50ppm+IAA10^{-3}M), ...93
T_4(Zn100ppm+IAA10^{-4}M).

Figure 4.3: From L to R T_0(D.W), T_5(B50ppm +BAP10^{-3}M), ...93
T_6(B100ppm +BAP10^{4}M)

Figure 4.4: From L to R T_0(D.W), T_7(Zn50ppm+BAP10^{-3}M), ...94
T_8(Zn100ppm+BAP10^{-4}M)

Figure 4.5: From L to R T_0(D.W), T_9 (B50ppm +$GA_3 10^{-3}$M), ... 94
T_{10}(B100ppm +$GA_3 10^{-4}$M)

Figure 4.6: From L to R T_0(D.W),T_{11}(Zn50ppm+$GA_3 10^{-3}$M), ... 94
T_{12}(Zn100ppm+$GA_3 10^{-4}$M)

Figure 4.7: From L to R T_0(D.W), T_{13}(B50ppm +IAA10^{-3}M+BAP10^{-3}M), ...95
T_{14}(B50ppm +IAA10^{-3}M+$GA_3 10^{-3}$M)

Figure 4.8: From L to R T_0(D.W), T_{15}(B50ppm +BAP10^{-3}M+$GA_3 10^{-3}$M), ...95
T_{16}(Zn50ppm +IAA10^{-3}M.+BAP10^{-3}M)

Figure 4.9: From L to R T_0(D.W), T_{17}(Zn50ppm+IAA10^{-3}M+ $GA_3 10^{-3}$M),
T_{18}(Zn50ppm+BAP10^{-3}M+$GA_3 10^{-3}$M) 95

Figure 4.10: From L to R T_0(D.W), T_{19}(B50ppm +Zn50ppm+IAA10^{-3}M), T_{20}(B50ppm +Zn50ppm+BAP10^{-3}M)..... 96

Figure 4.11: From L to R T_0(D.W),T_{21}(B50ppm +Zn50ppm+$GA_3 10^{-3}$M) **96**

Figure 4.12: From L to R T_0(D.W), T_1(B50ppm + IAA10^{-3}M), T_2(B100ppm + IAA10^{-4}M) 96

Figure 4.13: From L to R T_0(D.W), T_3(Zn50ppm +IAA10^{-3}M), T_4(Zn100ppm +IAA10^{-4}M) 97

Figure 4.14: From L to R T_0(D.W), T_5(B50ppm+BAP10^{-3}M), T_6(B100ppm+BAP10^{-4}M) 98

Figure 4.15: From L to R T_0(D.W), T_7(Zn50ppm +BAP10^{-3}M), T_8(Zn100ppm +BAP10^{-4}M) 98

Figure 4.16: From L to R T_0(D.W), T_9(B50ppm+$GA_3$$10^{-3}$M), T_{10}(B100ppm+$GA_3$$10^{-4}$M) 98

Figure 4.17: From L to R T_0(D.W), T_{11}(Zn50ppm +$GA_3$$10^{-3}$M), T_{12}(Zn100ppm +$GA_3$$10^{-4}$M) 99

Figure 4.18: From L to R T_0(D.W), T_{13}(B50ppm +IAA10^{-3}M+BAP10^{-3}M), T_{14}(B50ppm +IAA10^{-3}M+$GA_3$$10^{-3}$M) 99

Figure 4.19: From L to R T_0(D.W), T_{15}(B50ppm+BAP10^{-3}M+$GA_3$$10^{-3}$M), T_{16}(Zn50ppm +IAA10^{-3}M.+BAP10^{-3}M) 99

Figure 4.20: From L to R T_0(D.W), T_{17}(Zn50ppm +IAA10^{-3}M+GA3$10^{-3}$M), T_{18}(Zn50ppm +BAP10^{-3}M+$GA_3$$10^{-3}$M) 100

Figure 4.21: From L to R T_0(D.W), T_{19}(B50ppm+Zn50ppm +IAA10^{-3}M), T_{20}(B50ppm +Zn50ppm +BAP10^{-3}M) 100

Figure 4.22 T_4(Zn100ppm....93.: From L to R T_0(D.W), T_{21}(B50ppm+Zn50ppm+$GA_3$$10^{-3}$M) 100

Figure4.23T_0(D.W) 101

Figure 4.24: From L to R T_1(B50ppm+IAA10^{-3}M), T_2(B100ppm +IAA10^{-4}M), T_3(Zn+IAA10^{-3}M) 101

Figure 4.25: From L to R T_4(Zn100ppm+IAA10^{-4}M), T_5(B50ppm +BAP10^{-3}M), T_6(B100ppm +BAP10^{-4}M) 101

Figure 4.26: From L to R T_7(Zn50ppm +BAP10^{-3}M), T_8(Zn100ppm +BAP10^{-4}M), T_9(B50ppm +$GA_3$$10^{-3}$M) 102

Figure 4.27: From L to R T_{10}(B100ppm+$GA_3$$10^{-4}$M), T_{11}(Zn50ppm+$GA_3$$10^{-3}$M), T_{12}(Zn100ppm +$GA_3$$10^{-4}$M) 102

Figure 4.28: From L to R T_{13}(B50ppm+IAA10^{-3}M+BAP10^{-3}M), T_{14}(B50ppm+IAA10^{-3}M+$GA_3 10^{-3}$M), T_{15}(B50ppm+BAP10^{-3}M+$GA_3 10^{-3}$M) 102

Figure 4.29: From L to R T_{16}(Zn50ppm+IAA10^{-3}M+BAP10^{-3}M), T_{17}(Zn50ppm+IAA 10^{-3}M+$GA_3 10^{-3}$M), T_{18}(Zn50ppm+BAP10^{-3}M+$GA_3 10^{-3}$M) 103

Figure 4.30: From L to R T_{19}(B50ppm +Zn50ppm+IAA10^{-3}M), T_{20}(B50ppm +Zn50ppm+BAP^{3}M),T_{21}(B50ppm+Zn50ppm+$GA_3 10^3$M..... 103

Figure 4.31: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of branches..... 104

Figure 4.32: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of leaves. 104

Figure 4.33: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on middle leaflet length. 105

Figure 4.34: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on middle leaflet width. 105

Figure 4.35: Effect of combined foliar application of micronutrients (B/Zn) and growth on Petiole length 106

Figure 4.36: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on shoot length. 106

Figure 4.37: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on shoot fresh weight. 107

Figure 4.38: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on root fresh weight. 107

Figure 4.39: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on root length 108

Figure 4.40: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on shoot dry weight. 108

Figure 4.41: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on root dry weight. 109

Figure 4.42: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of pod sets at 50 DAT 109

Figure 4.43: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of pods per plant at 90 DAT. 110

Figure 4.44: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of empty pods per plant at 90 DAT. . 110

Figure 4.45: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of 3-seeded pods per plant at 90 DAT. 111

Figure 4.46: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of 1-seeded pods per plant at 90 DAT. 111

Figure 4.47: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of 2-seeded pods per plant at 90 DAT. 112

Figure 4.48: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on 1000-seed weight at 90 DAT. 112

ABBERIVIATIONS

Abbreviations used in Text and Tables:

ANOVA	Analysis of Variance
BAP	6-Banzylaminopurine
°C	Degree Centigrade
cm	Centimeters
Combs.	Combinations
Cons.	Concentrations
df	Degree of freedom
2,4-D	2,4-Dichlorophenoxy acetic acid
DAS	Days after sowing
g	Gram
GA_3	Gibberellic acid
IAA	Indole-3-acetic acid
IBA	Indole-3-butyric acid
Kn	Kinetin (6-Furfurylaminopurine)
L to R	Left to Right
L.	Linneous
LSD	Least Significant Difference
M	Molar
mg/L	Milligram/litre
MS	Mean Square
N.S	Nutritional Status
NAA	Naphthlene acetic acid
ppm	Part per Million
SS	Sum of Squares
T	Treatments
T_0	Control
µM	Micro molar
W	Weeks

Wt	Weight
B	Boron
Zn	Zinc
Fe	Iron
Mn	Manganese
Cu	Copper
DAT	Days after Transplantation
Mo	Molybdenum
q	Quintal
ha	Hector
L^{-1}	Per litre
kg^{-1}	Per kg
wt	Weight
Fr	Fresh

ACKNOWLEDGMENTS

I bestow my humblest praise for Almighty Allah, the most Beneficial and Merciful for His countless blessings enabling me to pursue all endeavors of life. I offer special praise to His Last Messenger Hazrat Muhammad (SAW) who will forever remain a torch of wisdom and leadership for mankind.

I would like to express sincere appreciation and deep thanks to my worthy teacher and supervisor Prof. Dr. Muhammad Fayyaz Chaudhry, Department of biological sciences, Quaid-i-Azam University, Islamabad for his dynamic supervision, continuous guidance, polite nature, keen interest, encouraging behavior which enabled me to complete my research work.

My special thanks are due to Prof. Dr. Samina Jalali, Chairperson, Department of Biological sciences, Quaid-I-Azam University, Islamabad for providing me the necessary research facilities.

I wish to express my deep gratitude and respect to all my teachers whose knowledge and guidance enabled me to attain this target. I would like to thank Mr. Muhammad Javaid, phtographer and Mr. Muhammad Munawar, lab attendant for their valuable help and cooperation. I feel pleasure in acknowledging the nice company of me lab fellow Sabz Ali Khan, Muhammad Javed, Faran Durrani, Muhammad Fayyaz, Muhammad Ismail and Nazia Bibi.

I am deeply indebted to my Ph.D. senior Muhammad Zia in computer composing. I am really thankful to Dr. Zarrin Fatima Rizvi Post-Doctoral Research Fellow for her valuable help and guidance during my research work.

I offer profound and unlimited thanks to my beloved father, mother, sisters and my wife for their love, inspiration and moral support during my studies.

I feel pleasure in expressing appreciation for my friends and colleagues namely Dr. Athar Abbas, Akhtar Shehzad, Muhammad Azam, Prof. Saleem Anwar Raja, Prof. Shehzad Ahmed, Prof. Azhar Abbas, Prof. Ata M.Asif, Prof. Amjad Mehmood and Prof. Arshad Ali Khan for their valuable help and cooperation. I am deeply thankful to all those who wished me success. May Allah Almighty bless them with good health and prosperous long lives (Aameen).

Shahid Liaqat

ABSTRACT

This study was conducted to analyze the effect of B/Zn and growth regulators (IAA, BAP and GA_3) on growth and yield of soybean *Glycine max* L. (Merril) var. NARC-4 by foliar application. Two concentrations (C_1 (50ppm) and C_2 (100ppm)) of B, Zn, and (C_1 (10^{-3} M) and C_2 (10^{-4} M) of IAA, BAP and GA_3 were tested at three growth stages; vegetative, flowering and pod fill stage. Analysis of variation revealed that combined foliar application of B/Zn and IAA, BAP and GA_3 positively affected the growth and yield of soybean. T_{16} (ZnC_1 + $IAAC_1$ + $BAPC_1$) and T_{19} (BC_1 + ZnC_1 + $IAAC_1$) produced maximum number of branches at pod-set stage. Significant variations were observed for number of leaves per plant at vegetative and pod-set stage. T_{21} produced maximum number of branches at vegetative stage and pod-set stage, T_{18} (ZnC_1 + $BAPC_1$ + GA_3C_1) produced maximum number of leaves at pod-set stage. Middle leaflet length was maximum with foliar application of T_{21} at vegetative stage and pod-set stage. Middle leaflet width was maximum in T_5 (BC_1 + $BAPC_1$) at vegetative stage and in T_3 (ZnC_1 + $IAAC_1$) at pod-set stage. Maximum petiole length was recorded in T_{19} (BC_1 + ZnC_1 + $IAAC_1$) at vegetative stage and in T_{21} at pod-set stage. Combined foliar spray of B/Zn and growth regulators increased shoot length as compared to control. T_{21} produced maximum shoot length at vegetative stage, pod-set stage and harvest stage stage. T_7 (ZnC_1 + $BAPC_1$) produced maximum shoot fresh weight at vegetative stage, T_2 (BC_2 + $IAAC_2$) at pod-set stage, T_{12} (ZnC_2 + GA_3C_2) at harvest stage stage. Root maximum fresh weight was obtained in T_{21} at vegetative stage, T_2 at pod-set stage, and T_{19} at harvest stage stage. Root maximum length was recorded in T_7 at vegetative stage, T_{10} (BC_2 + GA_3C_2) at pod-set stage and in T_{17} (ZnC_1 + $IAAC_1$ + GA_3C_1) at harvest stage stage. Maximum dry weight was recorded in T_7 at vegetative stage, in T_{21} at pod-set stage and in T_{20} at harvest stage stage. Root maximum dry weight was recorded in T_{21} at vegetative stage, in T_{16} at pod-set stage and T_{21} at harvest stage stage. Maximum number of pods was set at pod-set stage in T_{18} and T_{19}. Maximum number of pods per plant at harvest stage stage was recorded in T_{19}. Maximum number of empty, 1-seeded, 2-seeded and 3-seeded pods were recorded in T_{21}, T_{20} (BC_1 + ZnC_1 + $BAPC_1$), T_1 (BC_1 + $IAAC_1$) and in T_{18} respectively. Maximum1000-seeded weight was in T_{16}.

Chapter 1

Introduction

1.1 Soybean:

Soybean belongs to family Papilionaceae and genus *Glycine* L. The cultivated form is *Glycine max* L. (Merril). Soybean in perhaps one of the oldest food crops of the world due to its good quality oil, protein contents and soil-enriching properties. The seed contains about 20% oil and 40% good quality protein, 23% carbohydrates, 5% minerals, 3% crude fiber, 9% moisture and reasonable amount of vitamins and minerals (Gandhi *et al.*, 1985). Soybean is especially a food for growing children, as it facilitates their growth and development. Soybean is also an excellent food for diabetics, heart patients, and persons suffering from skin diseases and mental fatigue.

Soybean is one of the most important crops in the world, Soybean is being grown from time immemorial in the hills of northern parts of Pakistan i.e. Hazara, Azad Kashmir, Swat, Dir and introducing new ones. At present, the United States of America has the largest area under its cultivation. Soybean is also grown in other parts of the World including Brazil, Peoples Republic of China, Argentina, Indonesia, Korea and Japan.

Generally, it is used in the food industry for flour, oil, margarine, cookies, biscuit, candy, milk, vegetable cheese, lecithin and many other products. In Pakistan soybean has suffered a setback and has therefore, not been able to attain a respectable position among the oilseed crops. Its cultivation remained limited to a very small acreage and showed declining trends.

1.1.1 Potential Areas:

Expansion of the area of soybean in those parts of the region which are idle or not used at certain seasons of the year could produce soybean in the country. Thus, there is a large scope to increase the area under this crop

- Dobari lands in Sindh and the area of Punjab, which often lie idle between two summer crops of rice from September/October to May every year for one or the other reason.

- Cotton fallow areas where no crop is grown between two crops of cotton from December to May.
- Riverine lands, which are flooded during, summer from June to September but are dry during the winter from November to May.
- Dry land (barani) areas, which are available in part of summer during the monsoon when moisture is abundant and most of the land is left fallow for wheat sowing in November. This land is available from June to October.
- Area under fall (September) and spring (March) planted sugarcane is available for intercropping of soybean because short season soybean grow without affecting slow growing sugarcane plants.

1.1.2 Proposed Cropping Pattern:

Soybean has a vast potential as spring (Rabi) and autumn (Kharif) crop cultivation. Throughout the country cotton and rice 8.4 and 2.10 million hectares, respectively and 30 percent of this area remains fallow after each crop which could be brought under soybean plantation. The results of past research revealed that soybean can give reasonable yield in Punjab, Sindh and high yield in the foothill areas of NWFP. In addition, soybean also improves the soil status for ensuring crops of cotton and rice in the irrigated areas of Punjab and Sindh. Soybean is a very successful crop both in irrigated and rain fed areas without clashing any major crop like rice, cotton and wheat. Thus, the area, which remains fallow, can be utilized effectively.

- Rice Soybean Rice
- Cotton Soybean Cotton
- Wheat Soybean Wheat
- Wheat-Sorghum / Millet-Fallow-Soybean-Wheat
- Intercropping soybeans with corn, sorghum, cotton, or sugarcane

1.1.3 Climatic Requirements:

Soybean can be grown successfully under a wide range of temperatures. The minimum and maximum soil temperatures for germination of soybean seeds are approximately 5°C and 40°C respectively. The optimum temperature for rapid vegetative growth rate is about 30°C whereas; temperature above 40°C has adverse effect on flower initiation and pod retention. Moisture availability is particularly critical during two

periods of soybean germination and pod filling. However, availability of adequate moisture during the pod filling period is critical. Water stress during floral initiation, pollination, and seed development may greatly reduce the seed yield significantly. Latitude and time of year (sun declination) are the determents of photoperiod and temperature. Soybean is short day plant (SDP) where flowering is promoted by day length shorter than a critical maximum varies among varieties. Actual controlling factor is the length of uninterrupted darkness or nyctoperiod. Photo periodically sensitive varieties of soybean are adapted to a narrow latitude range (200-250 km).

1.1.4 Soil and Fertilizer Requirements:

Soybean can be grown on almost all well-drained soils; however, crop is more productive on fertile loam soils. Soybean is not sensitive to acidic soils as many other legumes. Soil with pH 6-7 is suitable for crop growth. In this pH range, adequate calcium and magnesium are normally available. For efficient production, soil must be managed properly to allow optimum uptake of water and nutrients. Fertilizer application is important in the soybean production and has great effect on yield. Usually 25:50:50 (NPK) kg ha-1 at the time of sowing gives higher yields. Fertilizers are usually broadcasted during seed-bed preparation. Under conditions fertilizer dose may vary according to the soil fertility and status. Soybean in rotation with other crops (i.e. cotton, rice and wheat) often provides some nitrogen for the following crops and may reduce the need for pesticides by limiting certain disease or insect problems. Adding N fertilizer to soybeans usually decreases nodulation and results in smaller amounts of N being symbiotically fixed. Therefore, nitrogen is recommended only when adequate nodulation is not achieved. However, supplemental N should not be applied within 30 days of emergence but should be applied before flowering, which is usually early March to spring crop and late July to autumn crop depending on maturity group of a variety.

1.1.5 Seed Inoculum:

The nitrogen fixing bacteria (*Rhizobia*) that live on soybean roots in nodules are not native to most soils. The best way to introduce these bacteria is to inoculate the seed. Once, introduced, the *Rhizobia* population remains active in the soil for a long time. In the presence of the appropriate inoculant of *Rhizobium japonicum*, more nodules are formed on roots of soybean plant which can fix atmospheric nitrogen from the air that is

almost as effective as nitrogen applied as fertilizer to promote growth and development of the plant.

1.1.5.1 Method of Inoculation:

Inoculum is a black powder containing nitrogen fixing bacteria which are mixed with ground peat or some similar carrier and applied on seed just before planting time. Seeds are moistened with concentrated sugar solution; inoculant is applied @ 1250 gm per 100 kg seeds and then mixed thoroughly to have a uniform coating of inoculum on the seeds. This process should be done in shady place. The use of fungicide in case of seed treatment may interfere with inoculated seed and with symbioses of *Rhizobium*-soybean system. Thus, compatible fungicides (i.e. Benlate and Dithane Z-78 (Zineb) with no toxicity to *Rhizobia* should be used. Treat seed immediately before planting and use inoculum dose little higher than recommended.

1.1.6 Irrigation:

Number of irrigations varies with climatic conditions, management practices and length of growing season. Moisture stress during flowering, pod filling and seed development stages reduces yield. Usually 6-7 irrigations are required for spring soybean and 2-3 irrigations for autumn crop depending upon the rains. Therefore, irrigation must be given at the following stages:

- Three weeks after germination
- Initiation of flowering
- Pod filling stage
- Seed development stage

1.1.7 Temperature:

Vegetable soybean can be grown successfully under wide range of temperature conditions. The minimum and maximum soil temperature for germination of soybean seeds is approximately 5°C and 40°C, respectively. It takes about two weeks to germinate when minimum temperature averages 12°C. The optimum temperature for rapid vegetative growth rate is about 30°C. Temperature above 40°C has adverse effect on the rate of growth, flower initiation and retention.

1.1.8 Nitrogen Fixation:

Biological nitrogen fixation is the process whereby nitrogen from the air is converted to ammonia by the enzyme nitogenase. Each year biological nitrogen fixation adds about 139 million tons of nitrogen to the land surface of the earth; chemical nitrogen fertilizer contributes another 36 million tons (Soderland and Suensson, 1976).

1.2 Micronutrients:

Micronutrients are elements, which are essential for plant growth but they are required in much lesser amount than the primary nutrients i.e. nitrogen, phosphorous and potassium. The micronutrients include boron, copper, iron, manganese, molybdenum, zinc and chloride (Mauseth, 2003; Nyle, 1987).

In spite of the best efforts and intensive research in Pakistan, per crop yields are low with much gap to potential yield. There is need of balance fertilizer application and other measures to raise the production of crops to fill the yield gap. The soil and climatic conditions of Pakistan appear to be quite conducive to micronutrients deficiencies in the plants (Chaudry and Sharif, 1975).

Wide spread deficiency of micronutrients has been reported in various regions of county (Kausar *et al.*, 1976). The use of chemical fertilizers has mainly been confined to the application of macronutrients and little attention has been given to micronutrients (Askari *et al.*, 1995). Micronutrients play a vital role in the growth and development of plants. They carry out various metabolic processes by affecting enzyme activity, formation of hormones in the plant cells, electron transfer in oxidation-reduction reactions and in plant nutrition (Khattak *et al.*, 1983). These deficiencies may be attributed to intensive cultivation, introduction of high yield crop varieties, enhance use of different fertilizers and certain soil conditions like calcareous nature, fine texture, high pH and low organic matter. The liberal use of nitrogenous and phosphatic fertilizers along with increased cropping intensity and cultivation of high yield crop varieties have further aggravated the problem and intensified the depletion of various micronutrients from local soil reserves. Even the nature of phosphatic fertilizers is known to induce Zn deficiency in wheat. In Western Australia continuous use of diammonium phosphate (DAP) which is the major source of phosphorous has caused Zn deficiency (Bernnan, 1986).

Deficiencies of micronutrients have been increasing in some crops. Some reasons are: higher crops yield which increase plant nutrients demands, use of high NPK fertilizers containing lower quantities of micronutrients contents and decreased use of farmyard manure on many agricultural soil (Mortvedt *et al.*, 1972).

A brief discussion of micronutrient boron (B) and Zinc (Zn) functions and deficiency symptoms in plant and soil conditions affecting micronutrient availability is given below:

1.2.1 Boron (B):

It is the only non-metal among the micronutrients. Although precise function of boron in plant metabolism is unclear, evidence suggests that it plays roles in cell elongation, nucleic acid synthesis, hormone responses and membrane function (Shelp, 1973). Boron deficient plants may exhibit a wide variety of symptoms, depending upon the species and the age of plant. A characteristic symptom is black necrosis of the young leaves and terminal buds. The necrosis of young leaves occurs primarily at the base of leaf blade stems may be unusually stiff and brittle. Apical dominance may also be lost, causing the plant to become highly branched; however, the terminal apices of the branches soon become necrotic because of inhibition of cell division. Structures such as the fruit, fleshy roots and tubes may exhibit necrosis or abnormalities related to the bread down of internal tissues.

The total concentration of boron in the soil varies between 2-200 ppm. Less than 5% of the total soil boron is available to plants (Samuel *et al.*, 1993). Boron is important in the process like pollen germination, cell division, nitrogen metabolism, water movement, carbohydrate transport, active salt absorption, harmonic metabolism and fat metabolism (Agarwala *et al.*, 1981; Nason and McElroy, 1963; Ramah *et al.*, 1984). Boron deficiency is the most widespread micronutrient deficiency. In many countries deficiency of boron is common during dry period. Some severe symptoms are shortening of stem internodes, rosetting of terminal leaves and sometimes death of growing point. Boron is not a very mobile element. Boron deficiency is mainly found in acid sandy soils in regions of high rainfall and those with low organic matter. Borate ions are mobile in soil and can be leached from the root zone.

Studies on boron nutrition that the supply of boron required for seed and grain production is higher than that needed for vegetative growth only. Boron has both direct and indirect effects on fertilization. Indirect effects are probably related to the increase in amount and change in sugar composition on nectar, whereby the flower of species that rely on pollinating insects, become more attractive to the insects (Smith and Johnson, 1969; Erickson, 1979). Direct effects of boron are reflected by the close relationship between boron supply and pollen producing capacity of anther, as well as, the viability of pollen grains, pollen germination, pollen tube growth and fertilization (Agarwala *et al.*, 1981; Vaugn, 1977).

Keeping these ideas along with significance of foliar application in mind, the present investigation was undertaken.

1.2.2 Zinc (Zn):

In most plants normal range is between 20 to 100 ppm. Roots absorb zinc as Zn^{2+} and component of synthesis or natural organic complex absorb zinc. Zinc takes part in metabolism of plants as an activator of several enzymes such as dehydrogenases, proteinases, peptidases and phosphohydrolases. It also helps in seed and grain production and maturation (Ikhtiar *et al.*, 2000). Zinc may be involved in biosynthesis of indole-3-acetic acid (Skoog, 1940).

Soils of Punjab are alkaline and calcareous; they are especially conducive to Zinc deficiency (Chaudry *et al.*, 1973). They contain low organic matter content and receive heavy doses of nitrogen fertilizer for high yields. Zinc deficiency in plants is aggravated by nitrogen fertilizer (Lucas and Kneznk; Mortvedt *et al.*, 1972). Zinc is not mobile in plants. Zinc deficiencies are mainly found on sandy soils low organic matter. Uptake of Zinc decreases with increased soil pH. If the level of phosphorus and iron is high in soil, it adversely affects the uptake of Zinc by pants (Mortvedt *et al.*, 1972).

Zinc acts as an activator of large numbers of enzymes including alcohol dehydrogenase (ADH), which catalyzes the hydration of Carbon dioxide to bicarbonate and, along with copper, super oxide dismutase. However there is general agreement that disorder associated with Zinc deficiency reflect disturbances in the metabolism of the auxin hormone indole-3-acetic acid. The precise role of Zinc in auxin metabolism

remains obscure, but available evidence supports the view that Zinc is required for synthesis of the hormone precursor tryptophan (Marschner, 1986).

1.3 Plant Growth Regulators:

A plant hormone is an organic compound synthesized in one part of plant and translocated to another part where, in very low concentrations, it causes a physiological change/response. The response in the target organ need not be promotive, because processes such as growth or differentiation are sometimes inhibited by hormones, especially abscisic acid. The phytohormones have also been termed as growth hormones, growth substances, growth factors and growth regulators by various workers and defined accordingly. There are five groups of well accepted hormones. The five include; auxins, gibberellins and cytokinins, abscisic acid and ethylene (Salisbury and Ross, 1985).

Plant hormones most often regulate cell division, elongation and differentiation of cells, whereas animal hormones have very specific effects. Hormones are usually effective at very low concentrations. Plant hormones usually effective at internal concentrations of 1μM or less. Plant hormones affect membrane properties, control gene expression and affect enzyme activity. Plant hormones have multiple effects in plants. There are several classes of plant hormones, which include a number of recently "discovered" ones. Three classes of hormones used in present research work are discussed briefly.

1.3.1 Auxins:

Auxin (indole acetic acid) was the first hormone to be identified in plant. The term auxin was first used by Frits Went, who, as a graduate student in Holland in 1926, discussed that some unidentified compounds probably caused curvature of Oat coleoptiles towards light. As compound promoted the elongation of coleoptiles tissues, F. Kogel and other researchers named Went's compound auxin from the Greek word auxien, "to increase or to grow" (Taize and Zeiger, 1998).

It was later confirmed that indole-3-acetic acid (IAA) as the natural auxin. Many other chemical compounds, which are synthesized by chemists also cause many of the physiological responses similar to IAA and are generally considered to be auxins. Of these, naphthalene acetic acid (NAA), indole butyric acid (IBA), 2,4-dichlorophenoxy acetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2-methyl-4-

chlorophenoxy-acetic acid (MCPA) are the best known. Because they are not synthesized by plants, they are not hormones. They are classified as plant growth regulators (Salisbury and Ross, 1985).

2,4-dichlorophenoxy acetic acid (2,4-D) is an important plant growth regulator. It is yellow crystalline powder, noninflammable, soluble in 95% ethanol and in acetone. Precursor of auxin is tryptophan; as it is synthesized tryptophan. There are number of "synthetic auxins" too. Auxins promote growth in molar concentrations of 10^{-3} M to 10^{-8} M (Salisbury and Ross, 1985).

A primary site of auxin production is the apical shoot meristem. Auxin moves down the stem parenchyma cells by polar transport (auxin becomes negatively charged) using proton pumps, which is an ATP requiring process (Salisbury and Ross, 1985).

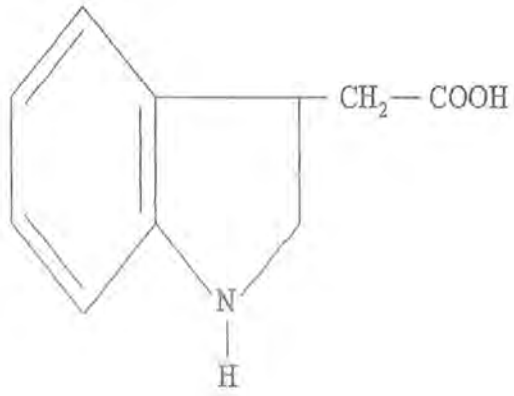

Figure 1.1: Structural formula of IAA (Indole Acetic Acid)

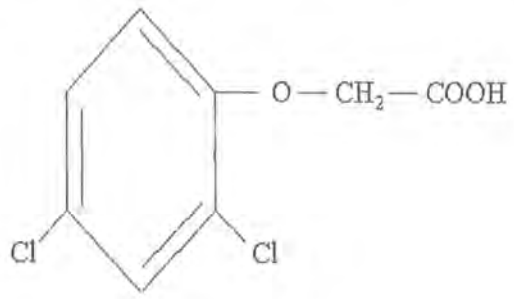

Figure 1.2: Structural formula of Dichlorophenoxy Acetic Acid (2,4-D)

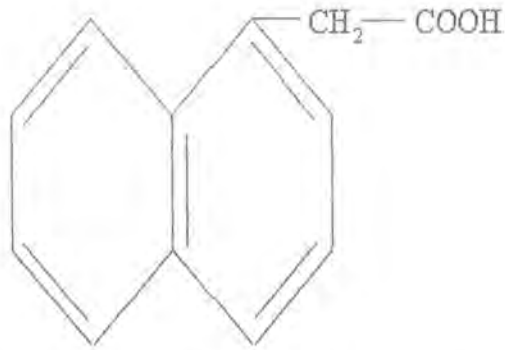

Figure 1.3: Structural formula of α-naphthalene Acetic Acid (NAA).

1.3.1.1 Functions of Auxin:

- It promotes elongation, cell enlargement and cell wall extensibility.
- Auxins are in tropic responses. They move away form a light source, which is the cause of uneven elongation of cells on the shaded side of a plant unevenly exposed to light.
- Auxins stimulate cambium cells to divide and secondary xylem to differentiate. Thus these stimulate secondary growth.
- Auxins have a role in apical dominance; a phenomenon in which apical bud dominated over the lateral buds and does not allow the later to grow. As distance increases form the tip, this effect is lessened. Removal of apical bud results in the rapid growth of lateral buds. Cytokinins which is another group of plant hormones acts the other way i.e. it counters the apical dominance effect of auxin (Taiz and Zeiger, 1998).
- In contrast to stem, higher concentration of auxin inhibits the elongation of root but the number of lateral branch roots is considerably increased. It also promotes adventitious root development.
- Auxins promote other hormone production especially ethylene when auxin concentration increases.
- Auxin can induce parthenocarpic fruits. In nature also, this phenomenon is not uncommon and in such cases the concentration of auxins in the ovaries of plants, which produce fruits only after fertilization.

- Besides all elongation, auxins may also be active in cell division. In fact in many tissue cultures where the callus growth is quite normal, the continued growth of such callus takes place only after the addition of auxin.
- Natural auxins have controlling influence on the abscission of leaves, fruits etc. Loss of auxin initiates leaf abscission.
- Auxins also promote flower initiation.
- Auxins are also required for fruit development; auxin in this case is produced by the developing seed (Salisbury and Ross, 1985; Taiz and Zeiger, 1998).

1.3.2 Cytokinins:

Cytokinins are N^6-substituted derivatives of the nitrogenous purine base adenine, characterized by their ability to stimulate cell division in tissue culture. Kinetin (N^6-furfurylamino purine) was the first cytokinins to be discovered. Kinetin does not occur naturally but was originally synthesized from herring sperm DNA (Miller *et al.*, 1956). In 1965, skoog *et al.*, proposed the term cytokinin. The most widely spread naturally occurring in higher plants is Zeatin. Miller 1960's, D.S. Letham 1960's, reported isolation of a purine with kinetin like properties from young, developing maiz seeds and plum friutlets. This substance was characterized as 6-(4-hroxy-3-methyl-Irams-2-butenylamino) purine, which was given the trivial name Zeatin. Since the discovery of Zeatin, a number of other naturally occurring cytokinins have been isolated and characterized.

The liquid endosperm of coconut (*Cocos nucifera*) often referred to as coconut milk has been found to contain some factors, which show kinetin like activity and can stimulate growth in many plant tissues in vitro. A number of purine compounds showing kinetin like properties have been isolated from coconut milk, but workers are failed to isolate and identify active ingredients of coconut milk.

Benzylamino purine is also a cytokinin. Benzylamino and kinetin are highly active, but which are probably not formed by plants (Salisbury and Ross, 1985). Zeatin riboside is relatively abundant cytokinin in many plants. All cytokinins have a side chain rich in carbon and hydrogen attached to the nitrogen protruding from the top of the purine ring. Each cytokinin can exist in the free-base form or as a nucleoside, in which ribose group is attached to the nitrogen atom of positon-9.

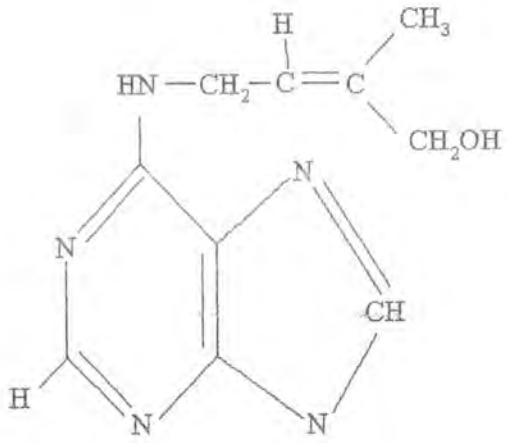

Figure 1.4: Structural formula of Zeatin.

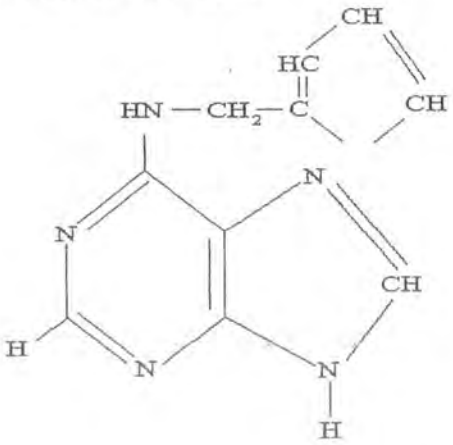

Figure 1.5: Structural formula of Kinetin (Synthetic Cytokinin).

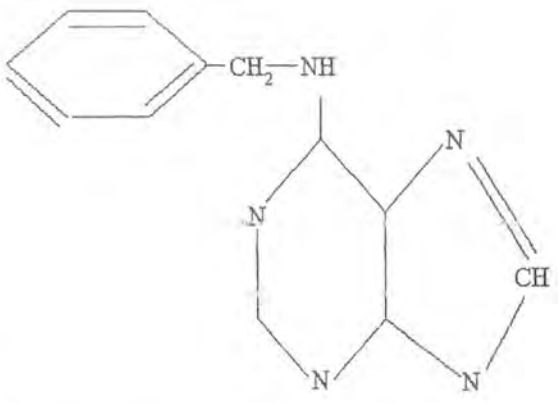

Figure 1.6: Structural formula of Benzylamino Purine (BAP)

1.3.2.1 Functions of Cytokinins:

- Cytokinesis: Cytokinins induce cytokinesis. Cytokinins are present in root meristems, embryos and fruits. They move/translocate from root to shoot of plants in xylem tissues.
- Inhibition of Apical Dominance: Cytokinins inhibit effect of auxin in apical bud and promote the axillary bud growth. Shoot tip auxins promote apical dominance thereby inhibiting lateral bud growth. Cytokinins produced in root meristems move/translocate upward in xylem and in higher concentration act against the inhibitory effect of auxins thereby activating lateral buds.
- Cytokinins Delay Senescence: Senescence is a phenomenon in which a mature leaf when detached from a plant, it undergoes; proteins breakdown, nucleic acids and other macromolecules breakdown take place, a loss of chlorophyll and accumulation of soluble nitrogen products such as amino acids. This in normal consequences of aging process. Delay in senescence by cytokinins is indicated by three kinds of evidence: Firstly exogenous application of cytokinins to the detached leaves delays the onset of senescence and maintains protein level and prevent chlorophyll breakdown. Application of cytokinin in intact leaves will also delay senescence. Secondly a correlation between endogenous level of cytokinins and senescence exist. Third evidence came from recombinant DNA technology.
- Cytokinins stimulate RNA and protein synthesis and delay the degradation of chlorophyll (Salisbury and Ross, 1985; Taiz and Zeiger, 1998).
- Cytokinins promote chloroplast development and chlorophyll synthesis.

⇒ High Auxin + Low Kinetin → Roots
⇒ Low Auxin + High Kinetin → Buds

- Cytokinins increase expansion of cell in Dicot cotyledons and in leaves (Salisbury and Ross, 1985).
- Cytokinins cause growth by cell enlargement not cell division (Salisbury and Ross, 1985).

- Cytokinins induce cell division in the presence of sufficient amount of auxin (IAA), especially in tobacco pith cells, carrot root tissues, soybean cotyledons and pea callus etc.
- Morphogenesis:
- Kinetin also has the ability to cause morphogenetic changes in an otherwise undifferentiated callus. For instance tobacco pith callus can be made to develop either buds or roots by changing the concentration of kinetin and auxin.
- Exogenous cytokinins can promote cell elongation in young leaves, cotyledons, wheat coleptiles and watermelon hypoctyles.

1.3.3 Gibberellins:

Ewiti Kurosawa discovered a fungus "Gibberella fujikuroi" was responsible for abnormal rice seedling growth called the "foolish seedling" disease. The fungus secreted a chemical that caused the rice plants to grow abnormally and long and then collapse from weakness. In 1926, he got a filtered extract of this fungus, which caused symptoms of foolish seedling disease. The name of gibberellins is after the name of this fungus. In 1935, Yabuta isolated the active substance and gave it the name gibberellin (Salisbury and Ross, 1985). Brain *et al.*, (1955) obtained pure sample of single gibberellin which was named "Gibberellic acid". Later on Cross *et al.*, (1961) established its structure.

Many seeds contain variety of gibberellins. Over 125 different gibberellins are known. Gibberellins are produced in roots and younger leaves of plants (Taiz and Zeiger, 2002).

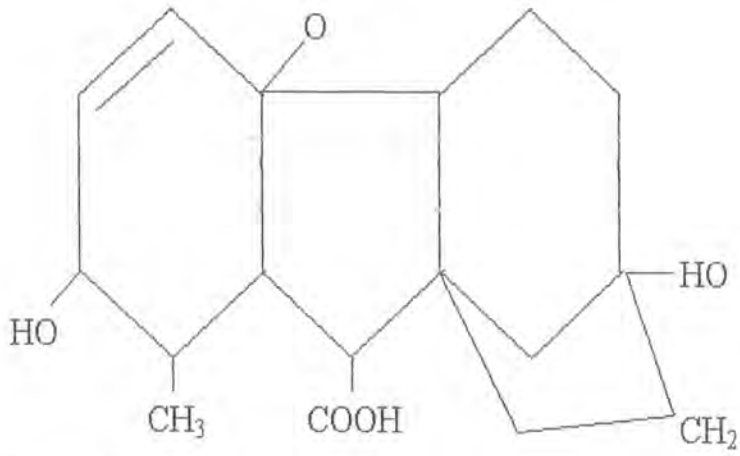

Figure 1.7: Structural formula of gibberellin.

1.3.3.1 Functions of Gibberellins:

- Dormancy of Buds: Dormancy of buds can be broken by gibberellin treatment. If we apply gibberellin to potatoes after harvest, it sprouts the eyes vigorously.
- Root Growth: Gibberellins have little or no effect on root growth. At higher concentrations in some plants, however, some inhibition of root growth may occur.
- Seed Germinatin: Certain light sensitive seeds e.g. Lettuce and tobacco show poor germination in dark, in light or red light germination starts vigorously. This requirement of light is overcome if seeds are treated with gibberellic acid in dark.
- Elongation of Internodes: Gibberellins bring about the elongation of internodes, so much so that in many plants such as dwarf pea, dwarf maize etc they overcome genetic dwarfism (Phinney, 1956; Brain and Hemming, 1955).
- Bolting and Flowering: Plants with rosette habit under short days and bolting (rapid elongation of stem with conversion into floral axis bearing flower primordia). This bolting can be induced under non-inductive short days by the application of gibberellin. In *Hyoscymus niger* (also a long day plant) gibberellin treatment causes bolting and flowering under non-inductive short days. While in long day plants gibberellin treatment results in early flower, and in short day plant variable effects of gibberellin are observed.
- Parthenocarpy: Seedless fruits can be induced by gibberellin treatment. Seedless and fleshy tomatoes and large sized grapes are produced by gibberellin treatment on commercial scale. In pome and stone fruits gibberellins have proven to be successful inducer of parthenocarpic fruits.
- Fruit enlargement: gibberellins stimulate some fruit enlargement (e.g. grapes with longer internodes) and may counter the effects of herbicides (Salisbury and Ross, 1985; Taiz and Zeiger, 1998).

1.4 Foliar Application:

In the last two decades, plant physiologists have developed the technique of foliar application i.e. spraying solutions of nutrients and chemical compounds (hormones) on the leaves of plants (Kochhar and Krishnamoorthy, 1988). In many cases, this foliar application method is preferred and gives quicker and better results than the soil

application. Under conditions when quick supply of substance is obviated or the soil conditions are not better for absorption, foliar application may be preferred (Jamal, 2001). Moreover, aerial spray is more economical and less wasteful than the soil application. Plant physiologists, agriculturists and horticulturists are very much interested in knowing the effect of exogenous application of growth hormones or growth regulators on yield and other growth parameters in the plants of economic importance (Salisbury and Ross, 1985).

1.5 Aims and Objective of Present Study:

Glycine max L. (Merrill) is one of the most important oilseed crops in the world. It contains 18 to 22 percent oil and is highly desirable in the diet and has 40 to 42 percent of good quality protein. Therefore, it is the best source of protein and oil and truly claims the title of the meat/oil that grows on plants. Considering its importance present research work was carried out to know the suitable combination of micronutrients and growth regulators for increasing growth and yield of soybean.

Combined foliar spray of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) were given to investigate their role in growth and yield parameters like number of branches per plant, number of leaves per plant, middle leaflet length, middle leaflet width, petiole length, shoot length, shoot fresh weight, root fresh weight, root length, shoot dry weight, root dry weight, number of pod-set per plant, number of pods per plant, number of empty pods per plant, 1-seeded pods per plant, 2-seded pods per plant, 3-seeded pods per plant and 1000-seed weight.

Chapter 2

Review of Literature

2.1 Foliar Application:

In the last two decades, plant physiologist has developed the technique of foliar application i.e. spraying solution of nutrients and chemical compounds on the leaves of plants (Kochar and Krishnamoorty, 1998; Noggle and George, 2002). Micronutrients are applied as spray on leaves. Similarly plant hormones or plant regulators are sprayed on foliage of plants to get greater growth and yield in plant. Plant growth regulators are chemical produced by plants that alter growth patterns and maintenance of the plant. They can be found in many cells and tissues, although plant hormones seem to be concentrated in meristems and buds.

2.2 Foliar Application of Micronutrients (Boron/Zinc):

Garg *et al.* observed that foliar application of boron (B) as boric acid at different concentrations in soybean (*Glycine max* L.(Merril)) grown in sandy loam soil revealed an increase in number of leaves, number of branches, leaf area per plant, 'a' and 'b' (mg/g fresh weight) at different growth stages. A sharp decline in flower drop was recorded through foliar application of boron at the rate of 50.0 mg/litre. However, a reduction in total leaf area per plant was noted at higher concentration (100mg/litre) of boron. Yield attributes like total dry matter production, flower drop percent, pod set per plant, length of pod, number of seeds per plant and test weight of 100 seeds were found to be maximum in case of plants applied with boron at 50 mg/litre.

Foliar application of zinc, manganese and boron alone and in various combinations were applied to sweet orange trees at 0.4, 0.2 and 0.04 kg in the presence 1.56 kg N (urea) and 0.4 kg surf/ha dissolved in 400 liters. The main effects and interactions of foliar spray of zinc, manganese and boron in factorial design/combinations were studied relative to micronutrients concentrations in citrus leaves and fruit yield of sweet orange. Zinc significantly increased leaf Zn contents and fruit yield as compared to trees where Zn was not included in foliar spray. The highest yield of 105.3 kg/tree was obtained from trees sprayed with Zn alone. Application of boron significantly increased total yield, but did not influence total leaf boron content. Mn application significantly

increased leaf Mn content; fruit yield intensified the red color of skin and juice (Sajida Parveen and Hafeez-ur-Rahman, 1998).

Zhu *et al.* (1996) worked on the characteristics of micronutrients uptake by rape plant and the method of boron and zinc uptake were greatest between flowering and maturation, accounting for 52 and 54.4% respectively of the total uptake. Mn uptake was evenly distributed for the production of 1000kg seed, the plant removed from the soil 8.8g B, 15.3g Zn, 19g Mn, 27g Cu and 185g Fe, Foliar application of boron at seedling and internode elongation stages gives better results than seed treatment or based application. Concentration of boron in the spray solution in the range of 0.1 to 0.25% increased seed yield significantly. 0.2% being the optimum concentration with a 17.8% yield increased over the control. Foliar application of boron and zinc in combination produced higher yield than the application of either element alone.

In a field experiment in 1991 irrigated sunflower were given 0-120 kg N/ha with or without dusting or spraying with B (0.4%). Seed yield increased with up to 80kg N. Seed yield from boron treatment were 1.23, 1.30 and 1.36 t/ha with no boron dusting or spraying respectively. Seed oil content was decreased by N application and was not affected by boron application (Rani and Reddy, 1993).

Foliar application of urea and zinc on many mungbeans resulted in increased number of branches per plant, pods per plant, tallest plant and highest seed yield per plant (Lateef *et al.*, 1998).

Porter, (1993) reported that application of boron results in 6.5% increase in the mean seed yields in canola. At the onset of flowering plants sprayed with boron had a 50% higher boron concentration than plants receiving no boron. Seed yield increased and peaked at 135 kg N decreased it higher N rates.

Bank (2004) reported effects of foliar application of zinc sulfate heptahydrate ($ZnSO_4.7H_2O$) on the yield component of six soybean varieties were studied at Trangie, New South Wales, on a zinc deficient soil, zinc was applied at 0.9kg/ha, four, six and both four and six weeks after sowing. Zinc deficiency symptoms appeared in unsprayed pots of Forrest, Dare, Dodds and Bragg from five weeks after sowing and zinc application increased yields and foliar zinc concentrations in all these varieties. Lee and Ruse did not show deficiency symptoms and did not respond to zinc treatments. The

single zinc application six weeks after sowing was slightly more effective than that at four weeks and double spray gave additional benefits to Forrest, Dare and Dodds. Forrest was most responsive variety with zinc application increasing yields from 920 to 3220 kg/ha through in pods/m^2, seeds per pod and seed weight. Yield of Dodds increased from 1835 to 2699 kg/ha in response to zinc by production of more pods/m^2, more seeds per pod while yield response of Dare (1783 to 2934 kg/ha) and Bragg (1801 to 2292 kg/ha) were due to increase in pods/m^2 alone.

Askari *et al.* (1995) reported that fruiting and flowering took place twenty days earlier in *Solanum melongena* L. (egg plant) and *Capsicum annuum* L. (Chilli pepper) by foliar application of essential trace elements. Treated plants bore more fruits and their sizes were bigger than those of the control series. Analysis of variance means revealed that in treated sets the growth factors were significantly different as compared with the control.

Dariusz and Joe (1991) studied benefits of $ZnSO_4$ and $MnSO_4$ foliar sprays for four years in one 'Valencia' orange and two ruby red grape fruit applying 216 and 168ppm metallic Zn and Mn, respectively. Zinc foliar sprays were effective in correcting deficiency symptoms and in elevating leaf Zn content to an optimum range. However, both the orange and grape fruit trees failed to respond to Zn sprays in terms of yield fruit number, average fruit weight and canopy height and width. In all experiments leaf Mn of the control trees ranged from 25 to 39ppm and in neither experiment was Mn deficiency patterns observed. Mn sprays produced no benefits even though they increased leaf Mn content. In some years, Zn and Mn were translocated from sprayed to new leaves to increase their concentration by 2-5ppm.

Plants of two tomato cultivars were grown in sand culture in a glass house at Zn concentrations of 0.15 and 7.70 µmole/liter in the nutrient solution. Foliar treatments entailed Zn as 0, 0.35 or 3.5 µmol $ZnSO_4.7H_2O$/litre to the tops of plants grown at low Zn (0.15 µmole/liter) in nutrient solution twice a week. Plants treated with 0.15 µmole Zn/liter in the nutrient solution and high levels of Zn (3.5 µmole/liter) applied as a foliar spray showed a significant decrease in the production of dry matter, chlorophyll and green fruit yield compared with those grown both at 7.70 µmole/liter in the nutrient solution and at 0.15 µmole Zn/liter in the nutrient solution with 3.5 µmole Zn/litre

applied as foliar spray. The concentration of Fe and P were significantly higher in leaves of plants grown in low (0.15 µmole/liter) root zone zinc treatment, and P was also higher in both the leaves and fruits of plants receiving foliar application of 3.5 µmole Zn/liter. In the roots, concentration of Zn, Fe, P and K increased with increasing Zn concentration in the nutrient solution and also as a foliar spray. These results clearly indicate that foliar application of Zn can overcome the negative effects of zinc deficiency on plant growth when it is applied at an optimum range (Kaya and Higgs, 2002).

El-Fouly *et al.* (2002) conducted a pod experiment to study the effect of micronutrient foliar application on salt tolerance of tomato. Seedlings were sprayed with micronutrient mixture (Wauxal 1.5ml/l) containing Fe, Mn and Zn and were irrigated with saline water containing different NaCl concentrations. Salinity adversely affected growth as dry weight and nutrient uptake. Spraying micronutrients could restore negative effect of salinity on dry weight. Effect of salinity on nutrient uptake could also be partially counteracted by spraying micronutrients.

The effect of foliar application of micronutrients (Zn, Mn, Fe and/or B), applied 30 and 60 days after transplanting, on growth, yield and quality of tomato cv. *Pusa Ruby* was investigated by Bose and Tripathi (1996). The best growth (plant height of 81.56cm), highest number of branches per plant (19), highest number of fruits per plant (319) and highest yield per plant (1.407kg) was observed after combined application of micronutrients. This treatment reduced fruit cracking from 16.5% (control) to 4.76% low fruit cracking (5.3%) was also observed in plants sprayed with boron alone.

Foliar application of zinc can increase the Ca content of apple fruits and thus reduce the incidence of bitter pit. A working hypothesis has been advanced as a possible physiological basis to account for this observation: Supplying Zn to the plant should improve Zn nutritional status and thereby enhance IAA biosynthesis and increase IAA concentration in shoot apices as in small fruits. As a consequence of these report on apple, the results presented do not support the hypothesis that increased Zn nutrition improves Ca inflow into young tomato fruits (Rahayu et *al.* 2001).

Yadav *et al.* (2001) conducted to evaluate the effect of different concentrations of zinc and boron on the vegetative growth, flowering and fruiting of tomato. The treatments comprised five levels of zinc (0, 2.5, 5.0, 7.5 and 1.0ppm) and four levels of

boron (0, 0.50, 0.75 and 10.0ppm) as soil application, as well as 0.5% zinc and 0.3% boron as foliar application. The highest value of secondary branches, leaf area, total chlorophyll content, fresh weight, fruit length, fruit breadth and fruit number was obtained with the application of 7.5ppm zinc and 1.0ppm boron.

Prasad *et al.* 1997 conducted a field experiment on an acidic red loam soil at Ranchi, India. Tomato plants were given a soil boron application (0.00, 4.54, 9.09, 13.63 or 18.18 kg Borax/ha) at final field preparation or as foliar boron application (0.0, 1.0, 1.5, 2.0 or 2.5 kg Borax/ha) at 25 days after transplanting. Boron application significantly increased tomato yield compared to the control treatment, with the 152.61 and 227.67 q/ha). Foliar application of borax also gave the highest average yield (143.06 q/ha).

Ranganthan *et al.* 1996 compared the yield of tomato in pot experiments using inceptisol or alfisol soil. Trace elements were applied as straight micronutrients or stanes micro food to the soil or leaves. The effects of applying composted coir pith (CCP) 25t/hac and/or *Azospirillum* (2kg/ha) with NPK (100:50:30 kg/ha) were examined. With NPK, composted coir pith, *Azospirillum* and foliar application of stanes micro food. In the alfisol the highest fruit yield was obtained by the same treatment except for stanes micro food being applied to the soil.

Tomato cultivars Naveen and Co3 were planted in pots with boron deficient calcareous soil. Boron was applied as Borax at 10, 20 and 30 kg/ha, 0.1, 0.2 and 0.3% foliar sprays or boronated super phosphate. Soil treatment with 30 kg Borax/ha resulted in the highest N content in roots and shoots. The 0.3% foliar spray resulted in highest P, Mg and K contents. Ca content increased with increasing boron levels (Prabha *et al.* 1996).

Hamsaveni *et al.* (2003) conducted a field experiment involving foliar spraying of 3 levels of boron (0, 0.1 and 0.5%) at 50% flowering stage of tomato. Foliar spray of boron at 0.5% was found beneficial in increasing plant height, fruit size, fruit weight, number of fruits per plant, fruit yield (3182 t/ha), number of seeds per fruit (14283) and seed yield (241.00 kg/ha). The interaction effect of gypsum and boron was significant only on plant height and days to 50% flowering, which were favored by application of 50 kg gypsum,/ha and 0.5% boron.

Davis *et al.* (2003) reported that boron deficiency in fresh market tomatoes (*Lycopersicum esculentum*) is a widespread problem. Regardless of the application boron was associated with increased tomato growth and the concentration of K, Ca and boron in plant tissues. Boron application was associated with increased N uptake by tomato in field culture, but not under hydroponic culture. In the field culture, foliar and/or soil applied boron similarly increased fresh market tomato plant and root dry weight, uptake and tissue concentrations of N, Ca, K and boron and improved fruit set, total yields, marketable yields, fruit shelf life and fruit firmness. The similer growth and yield responses of tomato to foliar and root boron application suggest that boron is translocated in the phloem in tomatoes. Fruits which received boron as foliar or root-applied boron contained more boron and K than fruits from plants not receiving boron, indicating that boron was translocated from leaves to fruits and is important factor in the management of K nutrition in tomato.

Rodriguez *et al.* (2000) studied the effects of foliar chemical treatments on the productivity recovery of greenhouse-grown sweet pepper at low temperature. The treatments evaluated were control (without treatment); SN (nutrient solution of N, P, K, Zn, Co, Mn, B, Mo and NAA); SNS (SN + sucrose) and SNSL (SNS + commercial beer yeast). SNSL exhibited the highest productivity of sweet pepper, which allowed a relative increase of 19% in fresh fruit weight and 45% in total fruit number.

Patnaik *et al.* (2002) conducted field experiments to determine the effect of Zn and Fe on yield and quality of tomato cv. *Marutham* soil application of 12.5 kg $ZnSO_4$/ha, followed by foliar sprays of 0.2% $FeSO_4$ and thrice at weekly interval resulted in highest fruit yield of 39.88 t/ha with a maximum yield response of 39%. The Zn and Fe contents in index leaves of tomato were in the range of 18.5-27.3 mg/kg and 116-160 mg/kg, respectively. The nutrients in index leaves were higher in the treatment where Zn and Fe were applied either through soil or through foliar spray. A similar trend was observed in fruits when Zn and Fe were sprayed along with soil application. Fe and Zn contents in fruits were less in fruits (14.1-17.6 mg/kg) compared to leaves (37.2 to 72.7 mg/kg). The highest uptake of Zn and Fe were recorded with 12.5 kg $ZnSO_4$ soil application along with 0.2% $ZnSO_4$ and 0.5% $FeSO_4$ sprays.

Segura *et al.* (1996) observed that tomato plants growing in a sandy soil in greenhouse trials, spaced at 2 plants/m and irrigated by drip irrigation, showed significantly higher marketable yields with foliar application of Almeria manure (100000 kg/ha) + Auxym (5 cm^3/litre applied at transplanting and 10 applications totaling 7.21 cm^3/litre, applied during flowering and fruiting) 19.75 kg/m^2 than with Almeria manure (applied at 100000 kg/ha) 16.93 kg/m^2 and with Organic fertilizers Italpollina + Phemix (3000+1500 kg/ha). Auxym is composed of natural plant extracts containing amino acids, vitamins, auxins, cytokinins, macro and micronutrients, phytochelates, enzymes and humic substances. Yield corresponded to 117.8, 103.6 and 106.5 marketable fruit/m^2 for 3 treatments respectively.

A greenhouse study carried out by Oliveira *et al.* (1995) in Espirito Santo do Pinhal, SP, Brazil. Tomato plants (cv. *Angela Hiper*) were supplied with various combinations of NPK (4-14.5 t/ha), dolomite (1.8 t/ha), boron (2 kg Borax or foliar application of 0.2% boric acid) or calcium (foliar application of 0.6% calcium chloride). Yields were highest in plants supplied with NPK + dolomite or NPK + dolomite + calcium. Calcium and dolomite application both reduced the percentage of fruits with stylar decay whereas boron appliation reduced yields and increased percentage of fruits with stylar decay.

Shehata (1994) tested the response of seeded balady lime trees, cultiver (*citrus aurontifolia* L.) grown on a sandy calcareous soil to different sources, rates and methods of iron applications. Iron was supplied to the soil or to the foliage as chelate or sulfates individually or together with Mn and Zn chelates in thirteen different treatments. The vegetative growth, gross-yield and fruit quality was improved under all investigated treatments as compared to the check Fe-EDDHA applied to the soil gave the highest reponse whereas foliar application of iron as chelates or sulfates were slightly inferior. Addition of Mn and Zn chelates together with Iron failed to give higher growth and yield response over the individual application of iron.

Naveed (2004) observed the response of tomato (*Lycopersicon esculentum* Mill) and chilli (*Capcium annum* L.). Three concentrations (C_1, C_2 and C_3) of each micronutrient (Fe, B, Zn, Cu, Mn and Mo) at three growth stages, t_1 (vegetative stage) C_1 of each micronutrient was applied at 30days AT and repeated 5 times after 15 days

interval; t_2 (flowering stage) C_2 of each micronutrient 45 days after transplantation repeated 4 times after 15 days interval; t_3 (flowering plus fruit stage) 60 days after transplantation C_3 of each micronutrient applied with 3 repetition after 15 days interval; were applied. 500 ppm. Fe foliar spray at t_1 stage and foliar plus soil same concentration positively affected the growth and yield of tomato fruits, while in case of chilli iron iron foliar (1500ppm at t_3 stage) produced maximum fruits yield as compared to soil and control treatment. Boron foliar treatment (50ppm) at t_1 produced negative effect on number of fruits in tomato. Boron (50ppm) at t_1 foliar treatment, zinc (150ppm) at t_3 foliar, Copper foliar treatment (30ppm) at t_3, Molybdenum foliar (40 and 60ppm) at t_2 and t_3 stage, Manganese foliar treatment (150ppm) at t_3 produced maximum number of chilli fruits. Foliar plus soil treatment of zinc (150ppm) at t_3 produced maximum number of tomato fruits. Soil and foliar plus soil treatment of molybdenum negatively affected and produced minimum number of chilli fruits. Soil and foliar plus soil treatment of manganese produced minimum number of fruits. Mn application did not affect the number of tomato fruits.

2.3 Phytohormones:

Plant growth hormones or plant growth regulators are the chemicals, which influence the plant growth when applied in very minute quantity. They are reported to improve yield (Chatterjee *et al.* 1976; Ray and Choudhary, 1981). It is obvious that leaves are the main source of metabolites for plants. Thus manipulation of leaf physiological characters by a treatment with growth hormones might have influence on growth and yield (Thangraj *et al.* 1999).

Bruinama, (1982) reported that plant growth regulators are effective in the regulation of photosynthesis efficiency and chemical manipulation of internal distribution of photosynthesis to seeds. Gifford and Evans (1981) have also supported the hypothesis that assimilate distribution may be hormonally mediated. Gibberellins, cytokinins and ethylene all influence the stem and leaf elongation to varying degrees (Zeroni and Hall, 1984) and senescence is markedly effected by cyotokinins, gibberellins and abscisic acid (Leopold and Neodin, 1984; Dhindra *et al.* 1982).

2.3.1 Effect of Auxin (IAA, NAA) on Growth and Yield in Plants:

IAA increased leaf numbers and leaf area as predicted by Chaudhry and Zahur (1992), Tuomine *et al.* (1997) and Awan *et al.* (1999). IAA exerts influence on plant growth by enlarging leaves and increasing photosynthetic activities in plants. It also activates the translocation of carbohydrates during their synthesis (Awan *et al.* 1999; Ritenour *et al.* 1996). IAA also increased the dry weight of seeds (Kumar *et al.* 1981). Hye *et al.* (2002) reported that IAA at concentrations of 200ppm increase the number of leaves, leaf size, root size and weight and the yield in onion (*Alliam cepa*). Newaj *et al.* (2002) observed that effects of defferent concentrations of IAA on growth and yield of mungbean (*Vigna radiata* L.) at a concentration of 300, 600 and 900ppm. All growth and yield parameters showed an increase but 600ppm provided the best result. IAA at 600ppm significantly increased plant height, number of branches per plant, number or leaves per plant, leaf area, total dry matter, crop growth rate, number of seeds per plant, seed yield and 1000 seed weight. Elongation and increase in number of roots was also observed in garlic due to foliar spray of IAA treatments (Bareen *et al.* 1988).

Lallu and Dexit (1999) the effect of growth regulators i.e. IAA, GA_3 and Kn at 35 days after application of hormones on yield, yield attributes, oil content and harvest index in mustard (*Brassica juncea* L.). IAA (500 μM) proved to be best in increasing yield. Number of siliqua per plant, 1000 seed weight, oil content and harvest index increased under all treatments as compared to control (water spray). Oil content improvement was achieved by 10 μM Kn.

Naeem *et al.* (2001) observed that 2.85 mM (500 mg/liter) IAA showed a decrease in length of shoot and number of internodes. The increase in the diameter, area and number of leaves was also observed in Lentil (*Lens culinaris*). IAA induced branching with lush green color of leaves. The dose of IAA + kinetin (0.14 mM / 30 mg/liter) showed a decrease in length and number of internodes. However, expansion in main stem diameter and increase in number and area of leaves was also observed. Applied IAA caused late flowering and increased number of floral buds while IAA + kinetin promoted late flowering with noticeable increase in number of floral buds. Mixed dose of IAA with GA_3 produced early flowering, increase in length of shoot and internodes number as well as number of compound leaves.

Upadhyay (1994) sprayed chickpea (*cicer arietinum*) with 10, 20 and 30ppm NAA (Naphthalenc acetic acid) and Kn. Seed yield was increased by growth regulators and was highest with 20ppm NAA. Foliar application of NAA in *Vigna radiata* increased number of pods per plant, seeds per pod and 1000 seed weight (Alugukannan and Vijay Kumar, 1999). 30-days old mustard plants were sprayed with aquous solutions of indole-3-acetic acid (IAA), gibberellic acid (GA_3), kinetin (Kn) and abscisic acid (ABA). All the phytohormones with the exception of ABA improved the vegetative growth and seed yield at harvest compared to control. The order of response of various hormones to the plant was GA_3 > IAA > Kn > contol > ABA (Wang *et al.* 2001).

2.3.2 Effect of Cytokinins on Growth and Yield in Plants:

Cytokinins usually trigger proliferation, while in rapidly dividing meristematic cells, it retards division (Vant hof, 1968). Cytokinins enhanced the cell expansion in soybean (Makarova *et al.* 1988) and increased stem thickness while kinetin reduced shoot length but increased the fresh weight by increasing stem diameter in morning glory (Kaul and Farooq, 1994) and okra (Chaudhry and Khan, 2000). There are some reports, which indicate that kinetin in combination with GA_3 enhanced germination and seedling growth in chick pea (Kaur *et al.* 1998).

Hamberg (1972) reported that kinetin increases the auxin content of *Coleus blumel* though the major increase was in bound auxin. Cytokinins can increase endogenous GA content or prevent reduction in GA content normally associated with certain stages of development (Chin and Beevers, 1970; Loveys and Wareing, 1971; Reid and Railton, 1974). Bai and Kastori, (1990) observed that cytokinins increased plant height and leaf area in sunflower (*Helianthus annus* L) kinetin (0.14mM) i.e. 30mg/litre foliar spray on lens showed inhibition in length and in number of internodes. The increase in number and area of leaves and expansion of diameter of shoot (Naeem *et al.* 2001).

Kinetin increased the free auxin content of mungbean hypocotyl segments which were exposed to IAA both by enhancing IAA uptake and supporting the conversion of IAA to indolacetylaspartic acid (Lau and Yang, 1973).

Kinetin and other cytokinins have the ability to trigger cell division in the presence of auxin and also promote bud and root formation (Cleland, 1996). Chaudhry

and Qurat-ul-Ain (2003) observed the increasing effect of Kn. on number of leaf primordia, leaf area, leaf fresh and dry weights by applying 50ppm Kn.

Benzyl amino purine (BAP) promoted vegetative growth in apple (Arello *et al.* 1991). Bhat *et al.* (1992) noted that BAP increased shoot elongation in Citrus. Coldiz observed significantly increase in potato tubers with foliar spray of BAP at 50ppm/litre. Number of branches has been reported to increase by foliar application of BAP. Merlo *et al.* (1987) observed increase in number of branches per plant in soybean. Daimon and Mii (1991) reported that number of branches increased with foliar applied BAP *Podocarpous macrophyllus*. According to Bini and Giannoni (1985) fruit size and weight in olives increased with application of BAP. Marin and Sowers (1991) reported that BAP application increased leaf area and fruit weight in apple. Ulvskovp *et al.* (1992) reported that BAP increased leaf area in sweet pepper. BAP increased number of flower buds in apple (Mclauglin and Greene 1991), increased boll weight in cotton and 1000 seed weight in Phaseolus vulgaris (Uddin, 1985), increased yield in brassica and sugar beet (Yadav *et al.* 2001).

2.3.3 Effect of Gibberellins on Growth and Yield in Plants:

GA increases auxin level either by enhancement of auxin biosynthesis (Sastry and Munir, 1965; Jindal and Hemberg, 1976) or by retardation of auxin destruction (Kogl and Elema, 1960). GA can also stimulate elongation independently of auxin (Cleland *et al.* 1968; Kaufman *et al.* 1969; Kazama and Katsumi, 1974). In excised *Avena sativa* stem internodes, GA stimulates cell elongation (Kaufman *et al.* 1969).

Mostafa and Sharbeem (1982) recorded stimulative effect of GA_3 application on number and weight of tomato fruits. The micronutrients accumulation was found to be promoted by the treatments with GA_3 and CCC as reported by Ibrahim (1976) on maize and Abd-ul-Rahman (1983) on lemon grass.

Das and Priesty (1968) treated brinjal plants with different growth regulators and observed that GA at 100 ppm significantly affect number of fruits.

El-Tabbakh *et al.* (1982) sprayed plants of sunflower cv. *Ghiza* with 125ppm GA_3. The GA_3 decreased days to flowering and days from flowering to maturity, while GA_3 at 125 ppm increased 1000-seed weight.

Abd El-Fattah (1997) and Deotale *et al.* (1998) recorded that GA_3 promote the germination of various seeds, stimulates stem elongation. GA_3 either increase germination rates for instance in sweet orange (Burns and Coggins, 1969), Cleopatra mandarin and sour orange (Rawash *et al.* 1980) or final percentage germination as seen in papaya (*Carica papaya*) and *Solnum incanum* (Yashua, 1978; Yahiro and Oryoji, 1980). Rappoport and Wolf (1965) reported exogenous GA promoted sprouting of dormant potatoes.

Kausar (1976) treated the okra plant with GA_3 at a concentration of 100, 150 and 200 ppm. GA_3 increased significantly the length, leaf area, dry weight of the plant but increase in shoot to root ratio and dry weight of root was not significant. He reported that 150ppm produced more flowers and high number of fruits and yield.

Gibberellins promote cell elongation (Kaufman and Jones, 1974). GA promote cell elongation in either excised or intact internode tissue, while endogenous levels of GA correlate well in growth rates in certain dwarf (Phinney, 1965) and normal plants (Durley *et al.* 1976). In roots GA is usually either without effect or inhibitory to elongation, though there are a few reports of stimulation of root growth by GA (Scott, 1972; Low, 1975). Nash and Wilhelm, (1960) suggested that in nature gibberellins may be exuded in small amounts into the rhizosphere of young plants and play part in the germination of Orobanche crenata seeds. Boes *et al.* (1961) concluded that foliar application of GA_3 at 100, 250 and 500ppm applied on 12 weeks old tomato plants, resulted in increased cell size, stem height, stem thickness and number of leaves.

Lee *et al.* (1999) reported that GA_3 increased stem length and number of flowers per plant. Kabar (1990) found that GA_3 accelerated bud development and stem elongation but the best results can be achieved if GA_3 is applied in combination with kinetin. Naeem *et al.* (2001) reported that 1.5 mM (500 mg/liter) foliar spray of GA_3 on Lentil (*Lens culinaris medick*) showed a marked elongation in the length of shoot and increase in the number of internodes and compound leaves.

Singh (1966) sprayed the GA_3 at the rates of 50, 250 and 1000ppm to tomato plants. GA_3 increased the stem height and length of lateral shoots and the plants flowered seven days earlier than untreated plants.

Increase in number of leaves, stem height and ascorbic acid by application of 50 and 100ppm GA_3 to lettuce crop. Dose of 100ppm proved to be better than 50ppm (Singh and Sambhi, 1967). Spray of GA_3 on young plants of brussels sprout increased stem length, fresh weight and per unit leaf area. Among 25, 100 and 400ppm GA_3, largest difference was obtained by application of 100ppm GA_3 (Selman and Bora, 1968).

Hoque and Hoque (2002) studied the effect of GA_3 on growth and yield characters of mungbean (*Vigna radiata* L). Three concentrations used for foliar spray were 50, 100 and 200ppm GA_3. Foliar application of GA_3 at 200ppm had higher relative growth rate, while that of 100ppm had greater relative growth rate, while that of 100ppm had greater leaf area index, total dry matter, crop growth rate and net assimilation rate. Hye *et al.* (2002) investigated effects of 50, 100 and 200ppm. GA_3 increased the leaf numbers and size, root length and weight and yield in onion (*Allium cepa*).

Kanahama *et al.* (1989) reported that plant height and node number of the inflorescence on the main shoot of small fruited tomato plants were increased by high gibberellins concentrations (50-100).

Ross *et al.* (1990) concluded that gibberellins may be important for nodal elongation and leaf growth in sweet pea. GA_3 increases the vegetative growth, enhances flowering and shorten the time of both flowering and fruit formation.

Deosarkar *et al.* (2001) reported that an investigation was undertaken in Parbhani, Maharashtra, India, during kharif 1999-2000 to determine the effect of micronutrients on seed yield of soybean. The experimental material consisted of two cultivars of soybean (JS-335 and MAUS-2) and eight micronutrient treatments: recommended dose of fertilizer (25 kg N + 50 kg P/ha (control), T_1); T_1 + basal application of $ZnSO_4$ (10, 20 and 30 kg/ha, T_2, T_3 and T_4, respectively); T_1 + basal application of boron (2, 4 and 6 kg/ha, T_5, T_6 and T_7, respectively) and T_1 + sprays of hamaur at 30, 45, 60 and 75 days after sowing (T_8). Treatments T_4 and T_8 had highly significant increased raw seed yield over T_1. Raw seed yield increased with increasing rate of zinc fertilizer. Boron treatments T_5, T_6 and T_7 showed increased response for raw seed yield, but were not statistically significant. T_5 was best among the boron treatments for increasing raw seed yield. T8 recorded the highest raw seed yield among all treatments. JS-335 recorded a higher raw seed yield (25.55 q/ha) than MAUS-2 (21.72 q/ha). Interaction effects (treatment x

cultivar) were significant for raw seed yield. For graded seed yields, T_4, T_5 and T_8 recorded higher graded seed yield over T1. JS-335 recorded higher graded seed yield over MAUS-2. However, the interaction effects (treatment x cultivar) were non-significant for this character.

Bujak *et al.* (2004) reported that the effect of reduced tillage systems and foliar nutrition on soybean seed and straw yield in monoculture on lessive loess soil (good-wheat agricultural usefulness complex) was determined in Poland, during 1998-2003. Tillage treatments were conventional (I) and 3 kinds of reduced tillage: without postharvest cultivation (II); chisel + cultivator instead of ploughing and postharvest operations (III); direct drilling (diquat 600 g ha^{-1} in spring prior to seed drilling, IV). Foliar application with 2 litre Florosol U/ha (N (12%); P (1.745%); K (4.981%); Mg (0.12%); B (0.012%); Cu (0.015%); Fe (0.018%); Mn (0.016%); Mo (0.002%); Zn (0.01%)), was performed twice: at 3-4 true soybean leaf and just after flowering. The crop was cultivated under other agrotechnical measures adjusted to its need with elementary (NPK) fertilization. Weeds were controlled by soil herbicides: linuron (450 ml) + metribuzin (210 g ha^{-1}) and in isolated cases (in the 2002), foliar herbicide (fluazifop-P-butyl [fluazifop-P], 150 g/ha) was used against *Echinochloa* crus-galli. The highest seed soybean production (2.08 t ha^{-1}) was obtained on conventional tillage treatment (I), and a tendency to a slight yield decrease was observed only (4.8%) in the case of plough tillage before winter (II). However, chisel + cultivator (III) and direct sowing (IV) decreased the yield essentially, by about 10.1% and 26.9%, respectively, in comparison to I and II tillage system. The seed yield obtained under direct drilling (IV) was essentially lower by 23.3% and 18.7% than those obtained from II and III tillage treatments. Two-fold nutrition of soybeans by macronutrients and micronutrients substantially, by 10.2%, produced the yield higher. Tillage treatments did not influence substantially and clearly the yield of straw; however, the straw production was increased by foliar nutrition of soybean plants. The straw weight amounted to 1.80-2.05 t/ha in the consecutive years of research; only in sporadic cases it reached 1.12 t/ha in 2002. The seed and straw yields were modified by variable weather conditions in the research years.

Kothule *et al.* (2003) reported that a field experiment was conducted in Maharashtra, India during the kharif season of 2001 to investigate the effect of plant

growth regulators on the growth, biomass partitioning and yield of soybean cv. MAUS-32. The foliar spray treatments included gibberellic acid (GA) at 100 and 200 ppm; NAA at 100 and 200 ppm; CCC [chlormequat] at 100 and 200 ppm; AA (ascorbic acid) 100 and 200 ppm; SA (salicylic acid) at 100 and 200 ppm; and urea at 1 and 2%. All the growth regulators improved plant height, number of branches, leaf area and total dry mater; and reduced the number of days to 50% flowering. SA at 200 ppm was the most effective in increasing the number of branches, leaf area, total dry matter content, grain yield/plant (58.8 g/plant), grain yield per ha (26.15 q/ha) and harvest index (48.85%). GA at 200 ppm was the best for increasing plant height, while CCC at 200 ppm promoted earliness.

Kothule *et al.* (2003) reported that effects of GA [gibberellic acid], NAA, CCC [chlormequat], AA [abscisic acid], SA (salicylic acid) and urea on the yield and yield components of soybean (cv. *MAUS-32*) were studied in Parbhani, Maharashtra, India, during kharif 2001/02. The growth regulators were applied as foliar sprays at 35 days after sowing at 100 or 200 ppm each except urea (1 or 2%). SA at 200ppm was the most effective in increasing the number of pods per plant (59.0) and grains per pod (3.0), weight of grains per pod (0.479g), weight of straw per plant (17.98g), 100-seed weight (14.10g), seed yield per plant (58.80g) and per ha (26.15 quintal), and harvest index (48.85%).

Rahman *et al.* (2004) reported the effects of plant growth regulators on the dry matter production and growth attributes of soybean (cv. PB-1) were studied in Mymensingh, Bangladesh, in 2002. Plants were sprayed at 15 (T_1), 30 (T_2) and 45 (T_3) days after sowing (DAS) with gibberellic acid (GA_3) and maleic hydrazide (MH) at 100 or 200 ppm. The time of application had significant effects on dry matter production in roots, stems and leaves; total dry matter per plant; and growth attributes such as leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR). CGR and NAR increased up to 80 DAS then decreased due to maturity. LAI and RGR were greatest at 100 and 60 DAS, respectively. T_2 resulted in the greatest LAI, CGR, NAR, and root, stem, leaf and total dry matter, followed by T_3 and T_1. All growth regulators had positive effect on dry matter production and growth of soybean over the control. GA_3 was more effective than MH. However, 100 ppm GA_3 was the most

effective in the enhancement of root, stem, leaf and total dry matter, LAI, CGR, RGR and NAR, followed by 200 ppm GA_3. MH at 200 ppm was the least effective among the treatments. The combination T2/100 ppm GA_3 was the most effective in the improvement of dry matter production and growth of soybean.

Rahman *et al.* (2004) reported that a field experiment was conducted in Bangladesh from December 2001 to March 2003 to study the effects of plant growth regulators and their time of application on the morphology, yield and yield components of soybean cv. PB-1. Soybean plants were sprayed 3 times (T_1=spraying 15 days after sowing (DAS), T_2=spraying 30 DAS and T_3=spraying 45 DAS) with gibberellic acid (0, 100 and 200 ppm) and maleic hydrazide (MH; 0, 100 and 200 ppm). T_2 followed by T_3 produced the tallest plants with the highest number of branches, leaves, flowers, pods per plant, number of seeds per pod, seed yield per plant, 100-seed weight and seed yield. GA_3 was more effective than MH. GA_3 at 100 ppm followed by GA_3 at 200 ppm produced the highest number of branches, leaves, flowers, pods per plant, number of seeds per pod, seed yield per plant, 100-seed weight and seed yield, whereas 200 ppm MH produced the lowest values of the parameters measured. The present study clearly shows that almost all the plants treated with plant growth regulators performed better than the control. Interaction effects between the plant growth regulator and time of application showed that 100ppm GA_3 treated plants sprayed 30 DAS (T_2C_3) recorded the best performance.

Senthil *et al.* (2003) reported that a field experiment was conducted on the sandy loam soil of Tamil Nadu, India to investigate the effects of brassinosteroids (BR) at 0.5 ppm, salicylic acid (SA) at 50 ppm, NAA at 40 ppm, IAA at 100 ppm and kinetin at 50 ppm on some biochemical and physiological aspects (total chlorophyll, nitrate reductase activity, soluble protein content and peroxidase activity of soybean cv. CO-5). The bioregulators were supplied as foliar spray 35 and 60 days after sowing (DAS). The estimation of the biochemical constituents was done at 20, 40, 60 and 80 DAS. All bioregulator treatments increased the biochemical parameters of soybean. SA produced the highest soluble protein content and nitrate reductase (12.42 micro g/g/h) activity. IAA treatment resulted in the highest peroxidase activity (3.16 unit/g FW).

Kalpana *et al.* (2003) reported that a field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, during rabi (September-

December) of 1999 to study the effect of the foliar application of nutrients and growth hormones either alone or in combination on the seed yield of soybean (cv. *co1*). The nutrients, i.e. DAP [diammonium phosphate], KCl and boron, and NAA were applied at different rates and combinations. The results indicated that seed filling and, hence, seed yield were improved by the combined application of 2% DAP, 1% KCl, 0.2% boron and 40 ppm NAA through spraying at 50% flowering and a fortnight later.

Basole *et al.* (2003) reported that a field experiment was conducted at Nagpur, Maharashtra, India during kharif 2001/02 to evaluate the effects of hormones and nutrients on the biochemical characters and yield of soybean cv. JS-335. The treatments consisted of foliar application of NAA (50 ppm) and nutrients, $FeSO_4$, KNO_3, $ZnSO_4$ and $MgSO_4$ (0.5%). A recommended dose of NPK fertilizer (RDF, 30:75:30 kg ha^{-1}) was used as a control treatment. The contents of chlorophyll, N, P and K significantly increased in treatments 1/2 RDF+NAA+KNO_3 (T_8), 1/2 RDF+NAA+$ZnSO_4$ (T_9) and 1/2 RDF+NAA+$MgSO_4$ (T_{10}) over RDF (T_0) and other treatments. Protein and oil content in seed significantly increased in 1/2 RDF+NAA+$ZnSO_4$ (T_9) and 1/2 RDF+NAA+KNO_3 (T_8), respectively. Yield plant-1 significantly increased in 1/2 RDF+NAA+$ZnSO_4$ (T_9) and 1/2 RDF+NAA+KNO_3 (T_8) increased crop yield.

Haq and Mallarino(2005) reported that numerous studies investigated fertilization effects on soybean [*Glycine max* L.(Merril)] grain yield, but few focused on oil and protein concentrations. This study determined fertilization effects on soybean grain oil and protein concentrations in 112 field trials conducted in Iowa from 1994 to 2001. Forty-two trials evaluated foliar fertilization (N-P-K mixtures with or without S, B, Fe, and Zn) at V5-V8 growth stages. Seventy trials evaluated preplant broadcast and banded P or K fertilization (35 P trials and 35 K trials). Replicated, complete block designs were used. Foliar and soil P or K fertilization increased ($P<0.05$) yield in 20 trials. Foliar fertilization increased oil concentration in one trial (1 g kg^{-1}) and protein in one trial (5 g kg^{-1}) but decreased protein in two trials (6 g kg^{-1}). Phosphorus fertilization increased oil concentration in two trials (6 g kg^{-1}) and protein in five trials (5 g kg^{-1}) but decreased oil in five trials (4 g kg^{-1}) and protein in two trials (6 g kg^{-1}). Potassium fertilization increased oil in four trials (3 g kg^{-1}) and protein in two trials (9 g kg^{-1}) but decreased oil in two trials (4 g kg^{-1}) and protein in two trials (11 g kg^{-1}). Total oil and protein

production responses to fertilization tended to follow yield responses. Fertilization increased oil production in 20 trials and protein production in 13 trials. Fertilization that increases soybean yield has infrequent, inconsistent, and small effects on oil and protein concentrations but often increases total oil and protein production.

Kalpana *et al.* (2003) reported that a field experiment was conducted in Tamil Nadu, India during 1999-2000 to study the effects of different irrigation layouts viz. flat beds, flat ridges + furrows and ridges + furrows, as well as of foliar nutrition on the yield, quality and nutrient uptake of soybean. The foliar nutrition consisted of combined application of nutrients (diammonium phosphate (DAP), KCl and boron) and plant growth regulator (1-napthaleneacetic acid (NAA)). Grain yield was highest (1601 kg/ha) under ridges + furrows during 1999. Foliar spraying of 2% DAP, 1% KCl, 0.2% boron and 40 mg NAA/litre produced comparable results as that of foliar spraying of 2% DAP, 1% KCl and 0.2% boron during both seasons. The combined application of DAP, KCl, boron and NAA resulted in higher mean grain yield (1612 kg/ha) over application of 2% DAP (1423 kg/ha) and water spraying (1353 kg/ha). The irrigation layouts failed to produce any significant effects on seed quality and nutrient uptake of the crop. The protein content was significantly higher in plants receiving DAP sprayed alone or in combination with other foliar nutrients. The oil content increased due to foliar application of DAP and KCl with or without boron.

Macedo *et al.* (2002) reported that In a field study in Espirito Santo do Pinhal, Brazil, the effects of basal B fertilizer and foliar application of Ca and B on soybean production were investigated. Crop yield was not significantly affected by fertilizer treatment.

Phiv-ChinTheng *et al.* (2003) reported that Soil and foliar fertilizer applications offer possible means of increasing soybean (*Glycine max*) yield in Thailand. However, little is known of appropriate foliar fertilizer use to supplement soil fertilization. Field experiments were conducted during 2001-02, in Thailand, to determine the effects of soil NPK fertilizer application together with foliar fertilizers containing macronutrients and micronutrients on growth, yield and nutrient composition of soybean cultivars Sukhothai 1 and KUSL 20004. Three soil fertilizer application methods were control, 18 kg N/ha at 7 days after seeding (DAS), and 18 kg N/ha at 7 DAS+18-18-18 kg N-P_2O5-K_2O/ha at 30

DAS. Foliar fertilizer contained both macronutrients and micronutrients. The three methods of foliar application were control, 3 applications at 34, 42 and 49 DAS and 6 applications at 20, 27, 34, 42, 49 and 56 DAS. Throughout the studies, soil and foliar fertilizer applications did not significantly affect growth, yield and yield components of soybean. The concentrations of N, P, K, Fe and Zn in shoot at 68 DAS and N, P, K and Ca in leaves at 89 DAS were not consistently affected by soil and foliar applications. Significant effects of soil fertilizers on the concentrations of Ca, Mn and Cu in shoot, and Mg, Fe, Mn and Cu in leaves were observed. Foliar fertilizer applications increased Fe and Cu concentrations in leaves. The nutrient concentrations of soybean shoots and leaves were in sufficient ranges, which were agreeable with soil test results. The results indicated that the soil can provide sufficient nutrients for soybean growth and yield under this condition. Therefore, soil and foliar fertilizer applications are not economically feasible.

Meschede *et al.* (2004) reported that a study was conducted in Maringa, Parana, Brazil, during 2000-01 to investigate the effect of Mo and Co as foliar application and seed treatment on grain yield, seed protein content and agronomic traits (number of days to maturation, plant density, plant height, degree of plant layering and height of the first pod insertion) of soybean cv. BRS 133. The treatments consisted of combination of seed treatment with and without Mo and Co (Comol; 12% Mo and 2% Co) and foliar application at different stages of development with the following commercial products: Comol at V4 stage, Bas-Citrus (10% N, 4% Zn, 3.7% S, 3% Mn and 0.5% B) at V4 stage, Bas-Citrus+Fetrilon (4% Mn, 4% Fe, 1.5% Cu, 1.5% Zn and 1% Mo) at V4 stage, Bas-Citrus+Fetrilon at R4 stage. A control without Mo and Co application was included. The Mo and Co seed treatment and the foliar application of Comol at V4 stage of development promoted significant increases in grain yield. The seed treatment with Mo and Co increased the seed protein content. The foliar application with Bas-Citrus+Fertilon at V4 stage of development increased the plant height and degree of plant layering. The foliar application and seed treatment with Mo and Co had no effects on the rest of plant agronomic traits.

Chapter 3

Materials and Methods

3.1 Research Site and Materials Description

A series of experiments were designed and conducted at the Department of Biological science, Quaid-i-Azam University, Islamabad to observe and evaluate the effects of combined Foliar application of Boron/Zinc and phytohormones/growth regulators IAA, BAP and GA_3; in different combination; on growth and yield of *Glycine max* L.(Merril) Soybean variety NARC-4.

Ceritified seeds of Soybean (*Glycine max* L.(Merril)) variety NARC-4 were brought from Oil Seed Program National Agricultural Research Centre, Islamabad and grown in pots.

The chemicals and hormones (IAA, BAP and GA_3) used in this experimental work were of highest grade of purity purchased from Sigma Chemical Company, USA and E. Merck of Germany.

The experimental work was carried out in clay pots of 28cm height and 26cm diameter during the month of July, 2005. As a whole 70 pots were used in an open field in present experimental work.

Soil was collected from university campus. Soil used mixed with sand in ratio of 3:1. 10 kg of thoroughly mixed soil was filled in each pot. Representative sample was taken for physical and chemical analysis of soil.

Healthy seeds of Soybean variety NARC-4 with uniform size were randomly selected for soaking. Seeds were dipped in 0.1% Mercuric Chloride ($HgCl_2$) for 3-5 minutes for surface sterilization. Mercuric Chloride was prepared by dissolving 0.1g of $HgCl_2$ in 100ml distilled water. These surface sterilized seeds were placed on wet cotton in Petri dishes in an incubator at 20°C on 16th July, 2005. They were allowed to germinate for five days. Later on seedlings were transplanted to pots on 21st July, 2005. Initially 10 seedlings were transferred to each pot. After one week they were thinned to 3 plants per pot.

3.2 Soil Analysis:

Soil was analyzed at the Department of Soil Sciences, National Agricultural Research Centre (NARC), Islamabad. Physical and chemical nature of soil was analyzed. Chemical analysis of soil was conducted at Land Resources Research Lab., NARC.

3.2.1 Physical Analysis:

For physical analysis of soil texture method was used. Soil texture was determined by Buoycous hydrometer method (Bouycous, 1962).

3.2.2 Chemical Analysis:

Three major nutrients Nitrogen, Phosphorous and Potassium (NPK) were analyzed. From micronutrients Zinc (Zn), Boron (B), Iron (Fe), Copper (Cu), Manganese (Mn) and also Calcium Carbonate were analyzed. Ammonium bicarbonate-Diethylen triamin penta acetic acid (AB-DTPA) method was used to analyze phosphorus and potassium (Soltanpour, 1985). Concentration of micronutrients was determined on atomic absorption, employing DTPA extraction method. Soil pH, soil organic matter and electrical conductivity were also analyzed.

3.3 Micronutrients Used:

Two micronutrients that is Boron (B) and Zinc (Zn) were used during the present study along with growth regulators (IAA, BAP and GA_3). The micronutrients were used in the form of H_3BO_3 (17% B) and $ZnSO_4.7H_2O$ (36% Zn).

3.4 Micronutrients Concentrations Used:

Following micronutrients concentrations of Boron and Zinc were prepared and used (along with growth regulators) for foliar application to observe growth and yield in Soybean variety NARC-4.

- 1^{st} concentration of Boron (B) = 50ppm
- 2^{nd} concentration of Boron (B) = 100ppm
- 1^{st} concentration of Zinc (Zn) = 50ppm
- 2^{nd} concentration of Zinc (Zn) = 100ppm

These concentrations were used along with growth hormones.

3.5 Hormonal Concentrations Used:

The following concentrations of auxin (IAA), cytokinins (BAP) and gibberellin (GA_3) were prepared and used (along with either Boron or Zinc or both) for foliar application to observe the growth and yield in Soybean variety NARC-4.

- 1^{st} concentration = 10^{-3} M
- 2^{nd} concentration = 10^{-4} M

3.6 Preparation of Stock Solutions:

Different concentrations of auxin (IAA), Cytokinins (BAP) and Gibberellin (GA_3) were prepared by calculating the weight of each hormone by following formula:

$$\text{Weight Required} = \frac{\text{Molarity} \times \text{Molecular weight} \times \text{Volume Required}}{1000}$$

Calculated weight of each hormone was dissolved in dilute sodium hydroxide (NaOH) and stirred on magnetic stirrer and final volume was made up to volume required. First 10^{-3} M solution was prepared and solution of 10^{-4} M was prepared by dilution method.

Table 3.1: Phytohormone Used for Growth and yield of Soybean *Glycine max* L.

Hormonal Class	Name of Hormone	Abbreviation	Solution Preparation	Molecular weight (g)
Auxin	Indole-3-acetic acid	IAA	Dissolved in NaOH	175.2
Cytokinins	6-Benzylaminopurine	BAP	Dissolved in dilute NaOH	225.2
Gibberellin	Gibberellic Acid	GA_3	Freely dissolved in Water	346.4

3.7 Micronutrients Solution Preparation:

For micronutrients Stock solution preparation (50ppm Boron, 100ppm Boron, 50ppm Zinc and 100ppm Zinc) weight of corresponding compounds were calculated by unitary method to get required weights of micronutrients in mg. They were dissolved in distilled water to get required volume.

Table 3.2: Hormonal Combination and Concentrations Used with Micronutrients

Hormonal Class	Abbreviation	Concentration I	Concentration II
Auxin	IAA	10^{-3} M	10^{-4} M
Cytokinins	BAP	10^{-3} M	10^{-4} M
Gibberellin	GA_3	10^{-3} M	10^{-4} M

3.8 Strategy for Foliar Application:

3.8.1 Preparation of Solution for Application:

Stock solutions of micronutrients (Boron, Zinc) and phytohormones were mixed at the time of foliar spray. 30 ml of each treatment as a whole was sprayed. In treatments where only one hormone and one micronutrient was to be sprayed 15 ml of both were added in spray bottle. In treatments where either two hormones one micronutrient or two micronutrients one phytohormone were to be used 10 ml each was added in spray bottle.

3.8.2 Amount of Solution Applied per Pot:

30 ml of prepared mixture of micronutrient and phytohormone was sprayed per pot. Manual sprayer was used for this purpose.

3.8.3 Treatments Applied:

Control Treatment (T_0):

One set of plants in pots was kept as control and sprayed with 30ml of distilled water per pot.

Table 3.3: Combinations and concentrations of B/Zn and IAA, BAP and GA_3.

Treatment number	Combination	Concentration of Micronutrients and phytohormone		
T_0	Distilled water	--	--	--
T_1	B + IAA	50ppm	10^{-3} M	--
T_2	B + IAA	100ppm	10^{-4} M	--
T_3	Zn + IAA	50ppm	10^{-3} M	--
T_4	Zn + IAA	100ppm	10^{-4} M	--
T_5	B + BAP	50ppm	10^{-3} M	--
T_6	B + BAP	100ppm	10^{-4} M	--
T_7	Zn + BAP	50ppm	10^{-3} M	--
T_8	Zn + BAP	100ppm	10^{-4} M	--
T_9	B + GA_3	50ppm	10^{-3} M	--
T_{10}	B + GA_3	100ppm	10^{-4} M	--
T_{11}	Zn + GA_3	50ppm	10^{-3} M	--
T_{12}	Zn + GA_3	100ppm	10^{-4} M	--
T_{13}	B + IAA + BAP	50ppm	10^{-3} M	10^{-3} M
T_{14}	B + IAA + BAP	50ppm	10^{-3} M	10^{-3} M
T_{15}	B + BAP + GA_3	50ppm	10^{-3} M	10^{-3} M
T_{16}	Zn + IAA + BAP	50ppm	10^{-3} M	10^{-3} M
T_{17}	Zn + IAA + GA_3	50ppm	10^{-3} M	10^{-3} M
T_{18}	Zn + BAP + GA_3	50ppm	10^{-3} M	10^{-3} M
T_{19}	B + Zn + IAA	50ppm	50ppm	10^{-3} M
T_{20}	B + Zn + BAP	50ppm	50ppm	10^{-3} M
T_{21}	B + Zn + GA_3	50ppm	50ppm	10^{-3} M

3.9 Stages of Foliar Application:

Foliar application of micronutrients and phytohormones was carried out at three stages of life cycle of *Glycine max* L.(Merril) Soybean. These stages were:

3.9.1 Vegetative Stage:

First combined foliar application was carried out at 20 days after transplantation at vegetative stage.

3.9.2 Flowering Stage:

Second combined foliar application of micronutrients and phytohormones was carried out at 40 days after transplantation at flowering stage.

3.9.3 Pod-Set Stage:

Third combined foliar application of micronutrients and phytohormones was carried out at 65 days after transplantation at pod-set stage.

3.10 Irrigation:

The pots were irrigated regularly from 21st of July 2005 to 21st of October 2005, with tap water. Weeds were removed regularly to keep the pots free from weeds.

3.11 Harvesting:

Plants were harvested 90 days after transplantation and 95 days after germination at physiological maturity stage when 90 percent of pods were dry on 21st October 2005.

3.12 Vegetative Stage:

1st data was collected after 15 days of 1st combined foliar spray of micronutrient (Boron/Zinc) and growth regulators and 35 days after transplantation.

3.12.1 Parameters Studied at Vegetative Stage:

The data was recovered in accordance with following parameters:

- Number of branches per plant.
- Number of leaves per plant.
- Shoot length (cm)
- Root length (cm).
- Middle leaflet length (cm).
- Middle leaflet width(cm)
- Shoot fresh weight (g).
- Shoot dry weight (g).
- Root fresh weight (g).
- Root dry weight (g).

3.13 Pod-Set Stage (50 DAT):

Second data was collected at pod-set stage at 50 days after transplantation and 10 days after second combined foliar application of micronutrient (Boron/Zinc) and phytohormones (IAA, BAP, and GA_3).

3.13.1 Parameters Studied at Pod-Set Stage:

The data was recorded in accordance with following parameters:

- Shoot length (cm).
- Root length (cm).
- Number of branches per plant.

- Number of leaves per plant.
- Middle leaflet length (cm).
- Middle leaflet Width(cm)
- Shoot fresh weight (g).
- Shoot dry weight (g).
- Root fresh weight (g).
- Root dry weight (g).
- Number of pods set/plant.

3.14 Harvest/Maturity Stage Observations:

The data was recorded in accordance with following parameters:

- Shoot length (cm).
- Root length (cm).
- Number of pods/plant.
- Number of seedless pods/plants.
- Number of 1 seeded pods/plants.
- Number of 2 seeded pods/plants.
- Number of 3 seeded pods/plants.
- Shoot fresh weight (g).
- Shoot dry weight (g).
- Root fresh weight (g).
- Root dry weight (g).
- 1000 seed weight (g).

3.15 Strategy for Parameters Studied:

Different parameters were studied at three different stages (35, 50 and 90 days) of life cycle of *Glycine max* L. (Merril) Soybean variety NARC-4.

3.15.1 Shoot Length and Root Length:

Shoot length and root lengths were measured with graduated meter rod in centimeters. Data for shoot length and root length (height) was measured from three individual plants within a pot and their mean was taken, this was mean of single replicate. Then mean for each treatment was taken by taking mean of three replicates.

3.15.2 Number of Branches:

Number of branches per plant were counted and recorded. Mean of single replicate was taken after recording number of branches of three plants within one pot. Then mean of each treatment was taken by taking mean of three replicates.

3.15.3 Number of Leaves:

Number of leaves per plant were counted and recorded. Data for number of leaves was collected form three individual plants within a pot and their mean was taken, this was mean of single replicate, then mean for each treatment was taken by taking mean of three replicates.

3.15.4 Middle Leaflet Length and Width:

Middle leaflets lengths and widths were measured with scale and recorded. Data for middle leaflet length and width was collected from three individual plants within a pot and their mean was taken, this was mean of single replicate. Mean of each treatment was taken by taking mean of three replicates.

3.15.5 Fresh Weight of Shoot and Root:

Fresh weight was calculated by digging out plant from pot. Toot and shoot were separated. Root was thoroughly washed with water and put in bolting paper sheets to absorb excess water. Shoots of three individual plants were weighed on electrical weight balance. Then the mean of three weights was taken. This was mean of single replicate. Then mean for each treatment was taken by taking mean of three replicates. Similarly roots of three individual plants within a pot were weighed on electrical weight balance. Then mean of these weights was taken. This was mean of single replicate. Then mean for each treatment was taken by taking mean of three replicates.

3.15.6 Dry Weight of Shoot and Root:

After recording fresh weight, shoots and roots were kept in oven at 60°C for 72 hours to get dry weight. Dried weight was taken for shoot as whole including dried flowers and fruits (pods). Data for dry weight of shoot and root was taken for three individual plants within pot and their mean was taken, this was mean of single replicate. Then mean for each treatment was taken by taking mean of three replicates.

3.15.7 Number of Pod-Set per Plant:

Number of pod-set was recorded for three individual plants within a pot, then their mean was taken, this was mean of single replicate. Then mean for each treatment was taken by taking mean of three replicates.

3.15.8 Number of Pods per Plant:

After harvesting the crop total number of pods, number of empty pods, number of 1-seeded pods, number of 2-seeded pods and number of 3-seeded pods were counted and recorded. Data for number of pods (of all types) for three individual plants within a pot was taken and then their mean was taken, this was mean of single replicate. Then mean for each treatment was taken by taking mean of three replicates.

3.15.9 Test Weight of 1000 Seeds:

Weight of 100 seeds was recorded. It was multiplied with 10 to get 1000 seeds weight. Data for 1000 seeds weight was taken from three individual plants within a pot and their mean was taken, this was mean of single replicate. Then mean for each treatment was taken by taking mean of three replicates.

3.16 Statistical Analysis:

Experiment was conducted in randomized complete block design with three replicates per treatment. All the data was entered in Microsoft Excel and further tests were applied. The data for all parameters after compilation was subjected to analysis of variance (ANOVA) and mean values for all treatments were compared by applying the Least Significant Difference Test (LSD) by using the statistical software MSTATC version 2.0.

Chapter 4

Results

4.1 Soil Analysis:

Soil used was analyzed physically and chemically. Texture of soil was analyzed by using Bouyeous hydrometer method. The results of the physical analysis showed that soil used in present research work was sandy loam in texture. Soil sample was analyzed for major and micronutrients by ammonium bicarbonate diethylene triamine penta acetic acid. Results showed that sample was highly deficient in P, K, B, Zn and Fe while Cu, Mn and NO_3-N in medium range. The present work values were compared to the standard values (Soltanpour, 1985) for different soil nutrients soil pH value electrical conductivity (EC), concentration of $CaCO_3$ and soil organic matter was also recorded. The results showed that soil used in present research work was alkaline sandy loam in texture.

Table 4.1: Physical and chemical analysis of soil sample.

Determination	Value	Units
Sand	53	%
Silt	30	%
Clay	17	%
Texture class	Sandy loam	---
pH	7.7	---
Ece	0.32	ds/m
Organic matter	0.19	%
$CaCO_3$	1.97	%
N	11.3	mg/kg
P	0.72	mg/kg
K	44	mg/kg
Zn	0.25	mg/kg
B	0.10	mg/kg
Mn	0.79	mg/kg
Fe	0.97	mg/kg
Cu	0.47	mg/kg

Table 4.2: Standard values of the macro and micronutrients.

S. NO.	Element	Low	Medium	High
1	N	<=10.00	11--20	21--30
2	P	<3.00	04--07	08--11
3	K	<6.00	61--120	121--180
4	Zn	<=0.90	1.0--1.5	>1.5
5	Fe	<=3.30	3.1--5.0	>5.0
6	Cu	<=0.20	0.3--0.5	>0.5
7	Mn	<=0.50	0.6--1.0	>1.0

4.2 Number of Branches:

The mean value for number of branches with statistical analysis at two stages (35 DAT and 50 DAT) of *Glycine max* L. (Merril) is given in Table 4.5 and Figure 4.31. Analysis of variance (ANOVA) predicted that non-significant variations were found both at 35 DAT and 50 DAT for number of branches.

4.2.1 Number of Branches at 35 DAT:

Maximum number of branches were recorded for treatments T_{16} (1.33) and T_{19} (1.33) at 35 DAT. Minimum number of branches were recorded for T_0 (control) T_2 ($B.C_2$+$IAA.C_2$), T_6 ($B.C_2$+$BAP.C_2$), T_9 ($B.C_1$+$BAP.C_1$) and T_{10} ($B.C_2$+$GA_3.C_2$), (1.00). MS value number of branches at this stage (0.033). Most of treatments increased number of branches except T_2, T_6, T_9 and T_{10} as compared to control (1.0).

4.2.2 Number of Branches at 50 DAT:

Maximum number of branches were recorded for treatments T_{13} ($B.C_1$+$IAA.C_1$+$BAP.C_1$) (1.99) and minimum number of branches were observed for T_6 ($B.C_2$+$BAP.C_2$) at 50DAT. Mean square value for number of branches at 50DAT was 0.153. Some treatments increased number of branches. Number of branches ranged from 1.11 to 1.99 within treatments T_6 number of branches (1.11) as compared to control (1.22). T_1 and T_6 produced 1.77 numbers of branches, significantly different from control.

Table 4.3: ANOVA table for number of Branches at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.409	0.205	6.8168	0.0027
2	Factor A	21	0.700	0.033	1.1099	0.3755
3	Error	42	1.261	0.030		
	Total	65	2.369			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 15.33%

Table 4.4: ANOVA table for number of Branches at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.089	0.045	0.5115	
2	Factor A	21	3.212	0.153	1.7565	0.0596
3	Error	42	3.658	0.087		
	Total	65	6.959			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 20.77%

Table 4.5: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of branches at 35 and 50 DAT.

	35 DAT		50 DAT	
Treatments	**No. of Branches**	**Ranking**	**No. of Branches**	**Ranking**
T0	1.00	B	1.22	CD
T1	1.11	AB	1.77	AB
T2	1.00	B	1.55	ABCD
T3	1.22	AB	1.55	ABCD
T4	1.11	AB	1.33	BCD
T5	1.11	AB	1.33	BCD
T6	1.00	B	1.11	D
T7	1.11	AB	1.22	CD
T8	1.11	AB	1.22	CD
T9	1.00	B	1.22	CD
T10	1.00	B	1.33	BCD
T11	1.11	AB	1.44	BCD
T12	1.00	B	1.33	BCD
T13	1.22	AB	1.99	A
T14	1.22	AB	1.44	BCD
T15	1.11	AB	1.22	CD
T16	1.33	A	1.77	AB
T17	1.22	AB	1.55	ABCD
T18	1.11	AB	1.22	CD
T19	1.33	A	1.66	ABC
T20	1.22	AB	1.33	BCD
T21	1.22	AB	1.44	BCD
LSD Value	0.2854		0.4860	

Non-Significant at 0.05 level of probability.
Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.3 Number of Leaves:

Mean values with statistical analysis given in Table indicated that as compared to control, out of 21 treatments applied, most of treatments significantly increased number of leaves per plant. The statistical analysis of data showing the mean values for number of leaves per plant at 35 and 50 DAT has been presented in Table 4.8 and plotted in Figure 4.32.

Analysis of variance showed that significant variations were found for number of leaves at 35 and 50 DAT. Maximum number of leaves were observed at 50DAT (8.88), where Mean square value for treatment was 0.902 (Table 4.8).

4.3.1 Number of Leaves per Plant at 35 DAT:

One treatment decreased number of leaves as compared to T_0 (control) (5.22) and T_2 ($B.C_2$+$IAA.C_2$) (4.88). Most of the treatments differed significantly from control except T_1 ($B.C_1$+$Zn.C_1$), T_9 ($B.C_1$+$BAP.C_1$) and T_{10} ($B.C_2$+$GA_3.C_2$). Number of leaves ranged from 4.88-7.00, which was significantly differed from control, T_1, T_2 and T_{10}. This was followed by T_{15} ($B.C_1$+$BAP.C_1$+$GA_3.C_1$) (6.88) and T_3 ($Zn.C_1$+$IAA.C_1$) (6.88). Minimum number of leaves were recorded for T_2 ($B.C_2$+$IAA.C_2$)(4.88), which was significantly different form all other treatments including control.

4.3.2 Number of Leaves per Plant at 50 DAT:

Analysis of variance table for number of leaves at 50DAT showed significant effect of treatments at α-0.05. Maximum number of leaves was recorded for T_{18} and T_{21} (8.88) and minimum number of leaves was recorded for T_5 (7.22) and T_9 (7.22). T_{18} (8.88) and T_{21} significantly differed from all other treatments. T_2, T_3, T_5, T_9, T_{10}, T_{16} (7.77) and T_{20} (7.77) decreased number of leaves as compared to control.

Table 4.6: ANOVA table for number of Leaves at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.535	0.267	0.7595	
2	Factor A	21	16.504	0.786	2.2330	0.0132
3	Error	42	14.782	0.352		
	Total	65	31.821			

Significant at 0.05 level of probability.
Coefficient of Variation: 9.36%

Table 4.7: ANOVA table for number of Leaves at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.066	0.033	0.0846	
2	Factor A	21	18.944	0.902	2.3246	0.0099
3	Error	42	16.299	0.388		
	Total	65	35.308			

Significant at 0.05 level of probability.
Coefficient of Variation: 7.57%

Table 4.8: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on no. of leaves at 35 and 50 DAT.

	35 DAT		50 DAT	
Treatments	**No. of leaves**	**Ranking**	**No. of leaves**	**Ranking**
T0	5.22	DE	7.88	ABCDE
T1	5.77	CDE	8.44	ABCD
T2	4.88	E	7.44	DE
T3	6.88	AB	7.77	BCDE
T4	6.44	ABC	8.44	ABCD
T5	6.44	ABC	7.22	E
T6	6.66	ABC	8.77	AB
T7	6.66	ABC	8.77	AB
T8	6.55	ABC	8.77	AB
T9	5.99	BCD	7.22	E
T10	5.88	CD	7.66	CDE
T11	6.44	ABC	8.10	ABCDE
T12	6.51	ABC	8.55	ABC
T13	6.44	ABC	8.66	ABC
T14	6.44	ABC	8.55	ABC
T15	6.88	AB	8.22	ABCDE
T16	6.55	ABC	7.77	BCDE
T17	6.22	ABC	8.44	ABCD
T18	6.44	ABC	8.88	A
T19	6.44	ABC	8.77	AB
T20	6.55	ABC	7.77	BCDE
T21	7.00	A	8.88	A
LSD Value	*0.9776		*1.026	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.4 Middle Leaflet Length:

The middle leaflet length of *Glycine max* L. (Merril) parameter was studied at 35 DAT and 50 DAT. Data for means of middle leaflet length at different micronutrients and growth regulators treatments a both stages is given in Table 4.11 and plotted in Figure 4.33. ANOVA results indicated significant variations at 35 DAT and non-significant variations at 50 DAT. Mean square value for different treatments was maximum at 35 DAT, which was 0.819.

4.4.1 Middle Leaflet Length at 35 DAT:

All the treatments increased middle leaflet length at 35 DAT than control (T_0) except T_{20} (5.04 cm), which decreased the middle leaflet length. Middle leaflet length ranged from 5.04 to 6.88. Middle leaflet length was maximum for T_{21} (6.88) and minimum for T_{20} (5.04). Middle leaflet length for T_{21} (6.88) was significantly different from majority of treatments. T_8 also increased middle leaflet length significantly than control (6.58). T_6 also increased middle leaflet length (6.74) than control (T_0) (5.13). Overall every treatment except T_{20} increased middle leaflet length at this stage.

4.4.2 Middle Leaflet Length at 50DAT:

Results for middle leaflet length at 50 DAT showed non-significant variations for treatments at this stage. Five treatments recorded decrease in middle leaflet length than control; these were T_9, T_{12}, T_{13}, T_{14} and T_{16}. Values were T_0 (6.25), T_9 (5.98), T_{12} (6.21), T_{13} (6.12), T_{14} (5.53) and T_{16} (5.86). T_3 (6.97) and T_{21} (6.98) recorded maximum middle leaflet length at this stage. Minimum middle leaflet length was recorded at T_{14} (5.53). Middle leaflet length ranged from 5.53 to 6.98. Sixteen treatments increased middle leaflet length as compared to control.

Table 4.9: ANOVA table for middle leaflet length at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.114	0.057	0.1359	
2	Factor A	21	17.208	0.819	1.9541	0.0321
3	Error	42	17.613	0.419		
	Total	65	34.935			

Significant at 0.05 level of probability.
Coefficient of Variation: 10.94%

Table 4.10: ANOVA table for middle leaflet length at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.465	0.232	0.6237	
2	Factor A	21	7.751	0.369	0.9910	
3	Error	42	15.642	0.372		
	Total	65	23.857			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 9.55%

Table 4.11: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on middle leaflet length at 35 and 50 DAT.

	35 DAT		50 DAT	
Treatments	**Mid. Leaflet length (cm)**	**Ranking**	**Mid. Leaflet length (cm)**	**Ranking**
T0	5.13	E	6.25	ABC
T1	5.36	DE	6.32	ABC
T2	5.37	DE	6.52	ABC
T3	6.46	ABC	6.97	A
T4	6.50	AB	6.71	AB
T5	6.74	AB	6.78	AB
T6	5.76	BCDE	6.46	ABC
T7	6.23	ABCD	6.27	ABC
T8	6.58	AB	6.75	AB
T9	5.91	ABCDE	5.98	ABC
T10	5.83	ABCDE	6.64	AB
T11	5.71	BCDE	6.32	ABC
T12	5.69	BCDE	6.21	ABC
T13	5.74	BCDE	6.12	ABC
T14	5.43	CDE	5.53	C
T15	5.80	BCDE	6.40	ABC
T16	5.43	CDE	5.86	BC
T17	6.08	ABCDE	6.11	ABC
T18	6.45	ABC	6.51	ABC
T19	5.98	ABCDE	6.45	ABC
T20	5.04	E	6.98	A
T21	6.88	A	6.37	ABC
LSD Value	*1.067		1.005	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.5 Middle Leaflet Width:

The statistical analysis for middle leaflet width at 35 and 50 DAT is given in Table 4.14 and plotted in Figure 4.34. Analysis of variance showed that non-significant ($P<0.05$) variations were seen both at 35 and 50 DAT. Mean square for treatments at both stages is 0.300 and 0.250 respectively. It shows that treatments at 35 DAT increased middle leaflet width as compared to control as at 50 DAT.

4.5.1 Middle Leaflet Width at 35 DAT:

Analysis of variance (ANOVA) showed that non-significant variations were seen at 35 days in middle leaflet width of *Glycine max* L. (Merril). Middle leaflet length ranged from 3.31 to 4.78. Maximum middle leaflet width was recorded for T_5 (4.78) and minimum middle leaflet width was recorded for T_1 (3.31). Five treatments i.e. T_1 (3.31), T_9 (3.51), T_{10} (3.39), T_{17} (3.50) and T_{20} (3.36) decreased middle leaflet width as compared to control (T_0) (3.54). All other treatments recorded an increase in middle leaflet width. Effect of T_4, T_5, T_6, T_7, T_8 and T_{21} was most visible on middle leaflet width.

4.5.2 Middle Leaflet Width at 50 DAT:

Analysis of variance (ANOVA) showed that non-significant variation for middle leaflet width at 50 days. Middle leaflet width ranged from 3.20 to 4.45 at this stage. All the treatments at this stage increased middle leaflet width of Soybean than control. Maximum middle leaflet width was seen T_3 (4.45cm) while minimum middle leaflet width was seen in control (T_0). Some treatments showed a decrease in middle leaflet length as compared to treatments at 35 DAT. T_4 (4.45 cm), T_8 (4.10 cm), T_9 (4.06 cm), T_6 (4.02 cm) and T_{19} (4.06 cm) showed significant middle leaflet width as compared to other treatments.

Table 4.12: ANOVA table for middle leaflet width at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.261	0.131	0.4939	
2	Factor A	21	6.292	0.300	1.1331	0.3549
3	Error	42	11.107	0.264		
	Total	65	17.660			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 13.66%

Table 4.13: ANOVA table for middle leaflet width at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.526	0.263	1.4936	0.2362
2	Factor A	21	5.386	0.256	1.4574	0.1471
3	Error	42	7.392	0.176		
	Total	65	13.304			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 11.13%

Table 4.14: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on middle leaflet width at 35 and 50 DAT.

	At 35 DAT		At 50 DAT	
Treatments	**Mid leaflet width (cm)**	**Ranking**	**Mid leaflet width (cm)**	**Ranking**
T0	3.54	B	3.20	E
T1	3.31	B	3.87	ABCDE
T2	3.73	B	3.63	BCDE
T3	3.81	B	4.45	A
T4	4.08	AB	3.97	ABC
T5	4.78	A	3.35	CDE
T6	3.75	B	4.02	ABC
T7	3.85	B	3.76	ABCDE
T8	4.15	AB	4.10	AB
T9	3.51	B	4.06	AB
T10	3.39	B	3.90	ABCD
T11	3.80	B	3.79	ABCDE
T12	3.85	B	3.62	BCDE
T13	3.74	B	3.46	BCDE
T14	3.81	B	3.27	DE
T15	3.70	B	3.67	BCDE
T16	3.60	B	3.65	BCDE
T17	3.50	B	3.73	BCDE
T18	3.67	B	3.71	BCDE
T19	3.81	B	4.06	AB
T20	3.36	B	3.81	ABCDE
T21	4.00	AB	3.79	ABCDE.
LSD Value	0.8466		0.6913	

Non-Significant at 0.05 level of probability.
Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.6 Petiole Length:

The statistical analysis of data showing the mean values for petiole length of *Glycine max* L. (Merril) is given Table 4.17 and plotted in Figure 4.35. Analysis of variance showed that significant variations ($P<0.05$) were seen at 35 DAT and non-significant variations were seen at 50 DAT. ($P<0.05$) .Mean square for both stages was 9.814 and 3.670 respectively.

4.6.1 Petiole Length at 35 DAT:

Petiole length after 35 days after transplantation showed significant variations in treatments. Most of treatments increased petiole length of *Glycine max* L. (Merril) at 35 days except T_4, T_5, T_7 and T_{16}. T_4 (7.05 cm), T_5 (6.75 cm), T_9 (6.50 cm) and T_{16} (6.67 cm) showed a decrease in mean value for petiole length as compared to control. Petiole length ranged from 6.50 cm to 14.72cm. Maximum petiole length was recorded in T_{19} (14.72 cm) and minimum petiole length was recorded in T_7 (6.50 cm). T_{19} significantly increased petiole length than all other treatments.

4.6.2 Petiole Length at 50 DAT:

Non-significant variations were seen for petiole length at 50 days. Petiole length ranged from 7.31cm to 11.27cm. Maximum petiole length was recorded for T_{21} (11.27) and minimum petiole length was recorded in T_7 (7.31). T_{21} significantly increased petiole length as compared to control. Mean value for T_0 was 9.33 at this stage. T_6 (10.03 cm), T_3 (10.02 cm), T_{12} (10.76 cm), T_{13} (10.54 cm), T_{18} (10.26 cm), T_{19} (10.06 cm), T_{20} (10.38 cm) and T_{21} (11.27 cm) showed increased in petiole length as compared to control and other treatments.

Table 4.15: ANOVA table for petiole length at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	6.662	3.331	1.4804	0.2392
2	Factor A	21	206.092	9.814	4.3620	0.0000
3	Error	42	84.495	2.250		
	Total	65	307.249			

Significant at 0.05 level of probability.
Coefficient of Variation: 16.30%

Table 4.16: ANOVA table for petiole length at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	1.032	0.516	0.1367	
2	Factor A	21	77.063	3.670	0.9725	
3	Error	42	158.480	3773		
	Total	65	236.575			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 20.38%

Table 4.17: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on petiole length at 35 and 50 DAT.

	35 DAT		50 DAT	
Treatments	**Petiole Length (cm)**	**Ranking**	**Petiole Length (cm)**	**Ranking**
T0	8.40	CDE	9.33	ABC
T1	9.98	BC	8.63	ABC
T2	8.76	BCDE	8.58	ABC
T3	9.83	BC	10.02	ABC
T4	7.05	DE	8.58	ABC
T5	6.75	DE	9.84	ABC
T6	10.02	BC	10.03	ABC
T7	6.50	E	7.31	C
T8	8.80	BCDE	10.92	A
T9	11.00	B	9.23	ABC
T10	9.95	BC	10.59	AB
T11	8.23	CDE	9.61	ABC
T12	8.67	BCDE	10.76	A
T13	10.29	BC	10.54	AB
T14	10.91	B	9.61	ABC
T15	9.10	BCD	7.40	BC
T16	6.67	DE	8.52	ABC
T17	9.73	BC	8.18	ABC
T18	9.05	BCD	10.26	ABC
T19	14.72	A	10.06	ABC
T20	8.04	CDE	10.38	ABC
T21	9.95	BC	11.27	A
LSD Value	*2.472		3.201	

***Significant at 0.05 level of probability.**
Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.7 Shoot Length:

The statistical analysis of mean values for shoot length at 35, 50 and 90 days is given in Table 4.21 and plotted in Figure 4.36. Analysis of variance showed that significant ($P<0.05$) varieties were seen for shoot length of *Glycine max* L.(Merril) soybean var. NARC-4 at 35, 50 and 90 days after transplantation.

4.7.1 Shoot Length at 35 DAT:

Mean value data presented in Table indicated that as compared to control (T_0), all the treatments increased shoot length at 35 days after transplantation. Shoot length ranged from 22.62 cm to 40.12cm. Maximum shoot length was observed for T_{21} (40.12 cm), which was significantly different from all other treatments. Minimum shoot length was observed for T_0 (control) (22.62 cm), which was significantly different from all other treatments except T_3, T_4, T_5, T_7, and T_{20} ($P<0.05$).

4.7.2 Shoot Length at 50 DAT:

Mean value data presented in Table indicated that as compared to control, all the treatments increased shoot length of *Glycine max* L. (Merril) soybean var. NARC-4 at 50 days. Shoot length ranged from 27.86 cm to 41.92cm. Maximum shoot length was observed for T_{21} (41.92 cm), which was significantly different from other treatments except T_9 (41.41 cm), T_{11} (40.78 cm), T_{10} (41.64 cm) and T_{18} (40.33 cm), while minimum shoot length was observed in T_0 (Control) (27.86 cm). As compared to shoot length at 35 days T_{20} increased shoot length more than any other treatment.

4.7.3 Shoot Length at 90 DAT:

Mean value for shoot length of soybean plants at 90 days presented in Table indicating significant variations within treatments. As compared to control, all the treatments increased shoot length at 90 days. Shoot length ranged from 33.44 cm to 48.82cm. Maximum shoot length was observed in T_{21} (48.82cm) while minimum shoot length was observed in T_0. T_{21} differed significantly from many treatments except T_9 (42.20cm), T_{10} (44.49cm), T_{11} (41.44cm), T_{13} (40.32cm), T_{14} (45.14cm), T_{15} (42.38cm), T_{17} (46.67cm), T_{18} (43.78cm) and T_{20} (45.61cm).

Table 4.18: ANOVA table for shoot length at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	4.967	2.483	0.5145	
2	Factor A	21	1235.788	58.847	12.1915	0.0000
3	Error	42	202.729	4.827		
	Total	65	1443.484			

Significant at 0.05 level of probability.
Coefficient of Variation: 7.60%

Table 4.19: ANOVA table for shoot length at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	31.127	15.564	1.4518	0.2457
2	Factor A	21	1283.912	61.139	5.7031	0.0000
3	Error	42	450.251	10.720		
	Total	65	1765.290			

Significant at 0.05 level of probability.
Coefficient of Variation: 9.22%

Table 4.20: ANOVA table for shoot length at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	3.344	1.672	0.1059	
2	Factor A	21	1120.894	53.376	3.3822	0.0004
3	Error	42	662.818	15.781		
	Total	65	1787.056			

Significant at 0.05 level of probability.
Coefficient of Variation: 9.83%

Table 4.21: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on shoot length at 35, 50 and 90 DAT.

	35 DAT		50 DAT		90 DAT	
Treatments	**Shoot Length (cm)**	**Ranking**	**Shoot Length (cm)**	**Ranking**	**Shoot Length (cm)**	**Ranking**
T0	22.62	L	27.86	J	33.44	G
T1	27.10	FGHIJ	34.07	EFGH	39.54	CDEFG
T2	26.69	GHIJK	34.27	DEFGH	37.73	EFG
T3	25.33	HIJKL	28.50	IJ	38.27	DEFG
T4	24.12	JKL	31.36	FGHIJ	36.58	FG
T5	23.25	KL	29.18	HIJ	33.08	G
T6	29.36	DEFG	33.60	EFGHI	36.12	FG
T7	24.51	JKL	30.61	FGHIJ	39.45	CDEFG
T8	30.59	BCDEF	34.80	DEFG	36.12	FG
T9	33.08	BC	41.41	A	42.20	BCDEF
T10	33.81	BC	41.64	A	44.49	ABCD
T11	30.97	BCDE	40.78	AB	41.44	BCDEF
T12	30.25	CDEFG	35.87	BCDEF	37.03	FG
T13	24.44	JKL	30.17	GHIJ	40.32	BCDEF
T14	34.11	B	39.54	ABCD	45.14	ABC
T15	28.28	EFGHI	38.61	ABCDE	42.38	ABCDEF
T16	27.42	EFGHIJ	38.49	ABCDE	40.94	BCDEF
T17	28.78	EFGH	35.97	BCDEF	46.61	AB
T18	33.29	BC	40.33	ABC	43.78	ABCDE
T19	32.89	BCD	37.26	ABCDE	40.40	BCDEF
T20	24.90	IJKL	35.11	CDEFG	45.61	ABC
T21	40.12	A	41.92	A	48.82	A
LSD Value	*3.62		*5.395		*6.546	

***Significant at 0.05 level of probability.**
Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.8 Shoot Fresh Weight:

The statistical analysis for mean values of shoot fresh weight of *Glycine max* L. (Merril) soybean var. NARC-4 is given in the Table 4.25 and plotted in Figure 4.37.

Analysis of variance showed that significant ($P<0.05$) variations were seen at 35 days and non-significant variations were seed both at 50 days and 90 days after transplantation in *Glycine max.* L. (Merril) Soybean var. NARC-4. Mean square value for shoot fresh weight for this stage i.e. 35 days is 5.688g.

4.8.1 Shoot Fresh Weight at 35 DAT:

Mean values for shoot fresh weight of soybean plants at 35 days are presented in Table shows an increase in shoot fresh weight at 35 days except T_2, T_4, T_8 and T_{10}. Shoot fresh weight at 35 days ranged from 3.53g to 9.51g. Maximum shoot fresh weight was observed in T_7 (9.51g) at 35 days, which was significantly different from all other treatments. Minimum shoot fresh weight was seen for T_8 (3.53g), T_2 (3.69g), T_4 (4.06g), T_8 (3.53g) and T_{10} (3.98g) all showed decrease in shoot fresh weight as compared to control. All other treatments showed an increase in shoot fresh weight of soybean plant at 35 days.

4.8.2 Shoot Fresh Weight at 50DAT:

Mean values for shoot fresh weight at 50 days as presented in Table indicated that all the treatments showed an increase in shoot fresh weight of soybean plants at 50 days as compared to control (T_0). Shoot fresh weight ranged from 6.79g to 14.34g. Maximum shoot fresh weight was observed in T_{21} (14.34g), which was significantly different form most of the treatments except T_9 (11.35g), T_{10} (10.84g) and T_{18} (11.11g). Minimum shoot fresh weight was observed for control (6.79g).

4.8.3 Shoot Fresh Weight at 90 DAT:

Mean values for shoot fresh weight of soybean plants at 90 days as presented in Table indicated that most of the treatments increased shoot fresh weight at 90 days except T_1, T_2, T_4, T_7, T_9, T_{11}, T_{14} and T_{15}; these treatments showed a decrease in shoot fresh weight at 90 days. Shoot fresh weight ranged from 8.58g to 15.94g. Maximum shoot fresh weight was seen in T_{12} (15.94g) followed by T_{18} (15.19g) and T_{21} (14.40g). Minimum shoot fresh weight was seen in T_2 (8.58g).

Table 4.22: ANOVA table for shoot fresh weight at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	3.880	1.940	0.9389	
2	Factor A	21	119.439	5.688	2.7526	0.0026
3	Error	42	86.781	2.066		
	Total	65	210.100			

Significant at 0.05 level of probability.
Coefficient of Variation: 27.63%

Table 4.23: ANOVA table for shoot fresh weight at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	23.331	11.665	1.5007	0.2347
2	Factor A	21	166.524	7.930	1.0201	0.4624
3	Error	42	326.484	7.773		
	Total	65	516.338			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 29.55%

Table 4.24: ANOVA table for shoot fresh weight at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	59.946	29.973	3.3352	0.0453
2	Factor A	21	226.187	10.771	1.1985	0.3009
3	Error	42	377.450	8.987		
	Total	65	663.584			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 26.26%

Table 4.25: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on shoot fresh weight at 35, 50 and 90 DAT.

	35 DAT		50 DAT		90 DAT	
Treatments	**Shoot Fresh Weight (g)**	**Ranking**	**Shoot Fresh Weight (g)**	**Ranking**	**Shoot Fresh Weight (g)**	**Ranking**
T0	4.13	CDE	6.79	B	10.40	BCDE
T1	4.45	CDE	9.44	B	9.73	CDE
T2	3.69	DE	8.90	B	8.58	E
T3	4.44	CDE	7.71	B	11.68	ABCDE
T4	4.06	CDE	9.74	B	9.22	DE
T5	6.32	BC	8.27	B	10.83	BCDE
T6	7.54	AB	7.54	B	11.00	ABCDE
T7	9.51	A	9.64	B	10.36	BCDE
T8	3.53	E	9.81	AB	10.68	BCDE
T9	4.3	CDE	11.35	AB	10.39	BCDE
T10	3.98	CDE	10.84	AB	11.68	ABCDE
T11	5.06	CDE	8.42	B	10.38	BCDE
T12	5.13	CDE	8.98	B	15.94	A
T13	5.23	BCDE	10.27	AB	12.25	ABCDE
T14	5.38	BCDE	8.17	B	10.87	BCDE
T15	5.19	BCDE	8.36	B	9.86	CDE
T16	5.08	CDE	9.97	AB	11.42	ABCDE
T17	4.74	CDE	8.58	B	13.85	ABCD
T18	6.15	BC	11.11	AB	15.19	AB
T19	4.62	CDE	10.61	AB	10.40	BCDE
T20	5.95	BCD	8.72	B	12.00	ABCDE
T21	6.15	BC	14.34	A	14.40	ABC
LSD Value	*2.368		4.594		4.940	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.9 Root Fresh Weight:

The statistical analysis of data showing the mean values for root fresh weight of soybean plant at 35, 50 and 90 days is given in Table 4.29 and plotted in Figure 4.38.

Analysis of variance showed that significant variation ($P<0.05$) was seen at 35 days for root fresh weight of *Glycine max.* L. (Merril) soybean var. NARC-4 and non-significant variations were recorded at 50 and 90 days for soybean plants. Mean square value at 35 days was 0.224.

4.9.1 Root Fresh Weight at 35 DAT:

Mean values for root fresh weight of soybean at 35 days indicated that as compared to control all the treatments increased root fresh weight. Root fresh weight ranged from 0.726g to 1.75g. Maximum root fresh weight was recorded in T_{21} (1.75g), which was significantly different from most of treatments except T_{18} (1.64g) and T_{20} (1.56g). Minimum root fresh weight was seen in T_0 (0.726g), which was significantly different from most of the treatments except T_4 (0.796g).

4.9.2 Root Fresh Weight at 50 DAT:

Mean values for root fresh weight of soybean plant presented in Table showed that almost all treatments increased root fresh weight at 50 days but they were not significantly different ($P<0.05$) form each other. Root fresh weight of soybean plants ranged from 0.681g to 1.117g. Maximum root fresh weight was observed in T_2 (1.117g), which was different from other treatments except T_{21} (1.107g), T_{18} (1.103g), T_{16} (1.062g), T_{17} (1.067g), T_{18} (1.089g) and T_9 (1.084g). Minimum root fresh weight was observed in T_8 (0.681g) and T_0 (0.681g), which was different from other treatments.

4.9.3 Root Fresh Weight at 90 DAT:

Mean values for root fresh weight of soybean plants presented in Table showed that by comparing the control with treatments increased the root fresh weight at 90 days. Root fresh weight ranged from 1.23g to 6.61g. Maximum root fresh weight was observed in T_{19} (2.61g), which was significantly different from all other treatments. Minimum root fresh weight was observed for control (1.23g) and T_2 (1.23g). All treatments differed from each other but not significantly.

Table 4.26: ANOVA table for root fresh weight at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.104	0.052	0.6047	
2	Factor A	21	4.705	0.224	2.6055	0.0041
3	Error	42	3.612	0.086		
	Total	65	8.421			

Significant at 0.05 level of probability.
Coefficient of Variation: 24.75%

Table 4.27: ANOVA table for root fresh weight at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.348	0.174	2.0651	0.1395
2	Factor A	21	1.476	0.070	0.8344	
3	Error	42	3.537	0.084		
	Total	65	5.360			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 32.21%

Table 4.28: ANOVA table for root fresh weight at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	1.601	0.800	4.1906	0.0219
2	Factor A	21	5.195	0.247	1.2954	0.2326
3	Error	42	8.021	0.191		
	Total	65	14.816			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 28.90%

Table 4.29: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on root fresh weight at 35, 50 and 90 DAT.

	35 DAT		50 DAT		90 DAT	
Treatments	**Root Fresh Weight (g)**	**Ranking**	**Root Fresh Weight (g)**	**Ranking**	**Root Fresh Weight (g)**	**Ranking**
T0	0.726	H	0.681	A	1.23	B
T1	0.873	FGH	0.880	A	1.39	B
T2	0.920	EFGH	1.117	A	1.23	B
T3	1.03	DEFGH	0.937	A	1.37	B
T4	0.956	EFGH	0.695	A	1.48	B
T5	0.892	EFGH	0.782	A	1.61	B
T6	0.796	GH	0.746	A	1.37	B
T7	0.986	DEFGH	0.792	A	1.46	B
T8	1.19	BCDEFGH	0.681	A	1.46	B
T9	1.10	CDEFGH	1.084	A	1.37	B
T10	1.23	BCDEFG	0.948	A	1.45	B
T11	1.44	ABCD	0.755	A	1.32	B
T12	1.37	ABCDE	0.851	A	1.48	B
T13	1.23	BCDEFG	0.815	A	1.36	B
T14	1.29	ABCDEF	0.803	A	1.54	B
T15	1.22	BCDEFG	0.853	A	1.42	B
T16	1.24	BCDEFG	1.062	A	1.42	B
T17	1.22	BCDEFG	1.067	A	1.79	B
T18	1.64	AB	1.089	A	1.73	B
T19	1.34	ABCDEF	1.103	A	2.61	A
T20	1.56	ABC	0.965	A	1.37	B
T21	1.75	A	1.107	A	1.70	B
LSD Value	*0.4832		0.4776		0.7201	

***Significant at 0.05 level of probability.**
Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.10 Root Length:

The statistical analysis of data showing the mean values for root length of soybean plant at 35, 50 and 90 days is given in Table 4.33 and plotted in Figure 4.39. Analysis of variance showed that significant variations ($P<0.05$) were seen at 35,50 and 90 days. MS value at 35 days is 13.220cm, at 50 days is 17.513cm and at 90 days is 20.875cm.

4.10.1 Root Length at 35 DAT:

Mean values data presented in Table indicated that as compared to control all the treatments increased root length. Root length of soybean plants ranged from 20.61cm to 28.43cm. Maximum root length was observed for T_7 (28.43cm), which was significantly different form most of the treatments except T_{18} (25.63cm), T_{20} (24.63c,), T_{21} (26.44), T_6 (27.47cm) and T_5 (26.45cm). Minimum root length was observed for T_0 (20.61cm), which was significantly different form T_3, T_4, T_5, T_6, T_7, T_{13} T_{18}, T_{19}, T_{20} and T_{21}.

4.10.2 Root Length at 50 DAT:

Mean value for root length of soybean plants at 50 days as presented in Table indicated that as compared to control all the treatments increased root length. Root length ranged from 36.42cm to 44.84cm. Maximum root length was observed for T_{10} (44.84cm), which was significantly different from control and T_1, T_2, T_3, T_5, T_6, T_{13}-T_{16}, T_{18} and T_{20}. Minimum root length was observed in T_0 (36.42cm) at 50 days, which was significantly different from other treatments.

4.10.3 Root Length at 90 DAT:

Mean values for root length of soybean plants at 90 days indicated that as compared to control all the treatments increased root length. Root length at 90 days ranged from 64.47cm to 74.53cm. Maximum root length was observed for T_{17} (74.93cm), which was significantly different from most of treatments except T_{18} (72.53cm), T_{20} (70.57cm) and T_{21} (71.90cm). Minimum root length was observed in T_0 (64.47cm).

Table 4.30: ANOVA table for root length at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	12.623	6.311	3.9853	0.0260
2	Factor A	21	279.727	13.320	6.4111	0.0000
3	Error	42	66.513	1.584		
	Total	65	359.863			

Significant at 0.05 level of probability.
Coefficient of Variation: 5.32%

Table 4.31: ANOVA table for root length at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	41.923	20.961	2.6273	0.0841
2	Factor A	21	367.767	17.513	2.1950	0.0149
3	Error	42	335.089	7.978		
	Total	65	744.779			

Significant at 0.05 level of probability.
Coefficient of Variation: 6.88%

Table 4.32: ANOVA table for root length at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	17.232	8.616	0.9789	
2	Factor A	21	438.383	20.875	2.3717	0.0085
3	Error	42	369.683	8.802		
	Total	65	825.298			

Significant at 0.05 level of probability.
Coefficient of Variation: 4.35%

Table 4.33: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on root length at 35, 50 and 90 DAT.

	35 DAT		50 DAT		90 DAT	
Treatments	**Root Length (cm)**	**Ranking**	**Root Length (cm)**	**Ranking**	**Root Length (cm)**	**Ranking**
T0	20.61	I	36.42	F	64.47	F
T1	21.91	GHI	37.82	EF	64.90	EF
T2	21.67	HI	38.78	EF	64.80	EF
T3	23.63	DEFGH	39.11	DEF	68.96	BCDEF
T4	22.87	FGH	40.86	ABCDEF	68.48	BCDEF
T5	26.45	ABC	40.41	BCDEF	66.20	DEF
T6	27.47	AB	40.30	BCDEF	69.57	BCDE
T7	28.43	A	41.62	ABCDE	69.17	BCDEF
T8	22.21	GHI	41.41	ABCDE	67.70	BCDEF
T9	23.47	EFGH	43.44	ABCD	68.00	BCDEF
T10	22.38	GHI	44.84	AB	69.40	BCDE
T11	22.42	GHI	44.39	AB	66.20	DEF
T12	22.28	GHI	45.29	A	67.75	BCDEF
T13	25.45	BCDE	40.55	BCDEF	66.26	DEF
T14	22.38	GHI	40.32	BCDEF	65.25	EF
T15	22.38	GHI	40.21	BCDEF	68.45	BCDEF
T16	22.08	GHI	37.89	EF	67.53	CDEF
T17	22.13	GHI	43.46	ABCD	74.93	A
T18	25.63	BCD	39.47	CDEF	72.53	AB
T19	23.93	DEFG	42.46	ABCDE	68.07	BCDEF
T20	24.63	CDEF	40.41	BCDEF	70.57	ABCD
T21	26.44	ABC	44.03	ABC	71.90	ABC
LSD Value	*2.074		*4.654		*4.889	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.11 Shoot Dry Weight:

The statistical analysis of data showing the mean values for shoot dry weight of soybean plants is given in Table 4.37 and plotted in Figure 4.40.

Analysis of variance showed that shoot dry weight has significant variations ($P<0.05$) 35, 50 and 90 days. MS values for treatments at 35 days are 0.350g, 0.989g and 0.561g respectively.

4.11.1 Shoot Dry Weight at 35 DAT:

Mean values for shoot dry weight of soybean plants at 35 days indicated that as compared to control all treatments increased shoot dry weight except T_2 and T_8. T_2 and T_8 showed a decrease in shoot dry weight as compared to control. Shoot dry weight ranged from 1.10g to 2.27g. Maximum shoot dry weight was observed in T_7 (2.27g), which differed from all other treatments but not significantly ($P<0.05$). Minimum shoot dry weight at 35 days was observed in T_8 (1.16g), which differed from other treatments but not significantly ($P<0.05$).

4.11.2 Shoot Dry Weight at 50 DAT:

Mean values for shoot dry weight of soybean plants at 50 days indicated that compared to control all treatments increased shoot dry weight. Shoot dry weight at 50 days ranged from 1.45g to 3.79g. Maximum shoot dry weight was observed for T_{21} (3.79g), which was significantly different from most of other treatments except T_{19} (3.54g), T_{20} (3.31g) and T_{17} (3.34g). Minimum shoot dry weight at 50 days was observed in T_0 (1.45g), which was significantly different from other treatments except T_1 (1.85g).

4.11.3 Shoot Dry Weight at 90 DAT:

Mean values for shoot dry weight of soybean plants at 90 days as presented in Table indicated that as compared to control all the treatments increased shoot dry weight. Shoot dry weight at 90 days ranged from 3.50g to 4.97g. Maximum shoot dry weight was observed for T_{20} (4.97g), which was significantly different from most of treatments except T_{17} (4.94g), T_{18} (4.91g) and T_{21} (4.93g). Minimum shoot dry weight was observed for T_0 (control) (3.50g). Other treatments differed in shoot dry weight at 90 days.

Table 4.34: ANOVA table for shoot dry weight at 35 DAT

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.021	0.010	0.1880	
2	Factor A	21	7.358	0.350	6.3388	0.0000
3	Error	42	2.322	0.055		
	Total	65	9.701			

Significant at 0.05 level of probability.
Coefficient of Variation: 14.74%

Table 4.35: ANOVA table for shoot dry weight at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.694	0.347	1.5867	0.2166
2	Factor A	21	20.768	0.989	4.5218	0.0000
3	Error	42	9.186	0.219		
	Total	65	30.647			

Significant at 0.05 level of probability.
Coefficient of Variation: 17.02%

Table 4.36: ANOVA table for shoot dry weight at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.079	0.040	0.1355	
2	Factor A	21	11.775	0.561	1.9174	0.0360
3	Error	42	12.282	0.292		
	Total	65	24.136			

Significant at 0.05 level of probability.
Coefficient of Variation: 12.47%

Table 4.37: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on shoot dry weight at 35, 50 and 90 DAT.

	35 DAT		50 DAT		90 DAT	
Treatments	**Shoot Dry Weight (g)**	**Ranking**	**Shoot Dry Weight (g)**	**Ranking**	**Shoot Dry Weight (g)**	**Ranking**
T0	1.20	A	1.45	F	3.50	E
T1	1.25	A	1.85	EF	3.73	CDE
T2	1.10	A	3.00	BCD	4.30	ABCDE
T3	1.25	A	2.47	DE	4.57	ABC
T4	1.21	A	2.45	DE	4.36	ABCDE
T5	1.54	A	2.37	DE	4.44	ABCD
T6	2.24	A	2.26	DE	4.49	ABCD
T7	2.27	A	2.47	DE	3.85	BCDE
T8	1.16	A	2.77	CD	4.40	ABCD
T9	1.35	A	3.55	AB	4.11	ABCDE
T10	1.28	A	3.29	ABC	4.55	ABCD
T11	1.58	A	2.32	DE	4.43	ABCD
T12	1.67	A	2.32	DE	4.67	AB
T13	1.79	A	2.76	CD	4.13	ABCDE
T14	1.65	A	2.89	BCD	3.72	CDE
T15	1.68	A	2.74	CD	4.34	ABCDE
T16	1.58	A	2.81	BCD	4.28	ABCDE
T17	1.74	A	2.61	CDE	4.94	A
T18	1.85	A	3.34	ABC	4.91	A
T19	1.64	A	3.54	AB	3.66	DE
T20	1.96	A	3.31	ABC	4.97	A
T21	1.99	A	3.79	A	4.93	A
LSD Value	*2.074		*0.7711		*0.8904	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.12 Root Dry Weight:

The statistical analysis of data showing the mean values of root dry weight at 35, 50 and 90 days is given in Table 4.41 and plotted in Figure 4.41. Analysis of variance showed that root dry weight of soybean plants has significant variations ($P<0.05$) at 35 and 90 days and non-significant variations at 50 days. MS values for root dry weight at 35 and days were 0.004g and 0.018g respectively and at 50 days 0.007g.

4.12.1 Root Dry Weight at 35 DAT:

Mean values for root dry weight of *Glycine max.* L. (Merril) at 35 days showed that as compared to control all treatments increased root dry weight. Root dry weight ranged from 0.227g to 0.375g. Maximum root dry weight was observed for T_{21} (0.375g) at 35 days, which was significantly different from most of the treatments except T_{20} (0.339g), T_{19} (0.338g) and T_{18} (0.324g). Minimum root dry weight was observed for T_0 (control) (0.227g), which was significantly different from most of the treatments except T_{14} (0.232g). Other treatments also increased root dry weight at 35 days.

4.12.2 Root Dry Weight at 50 DAT:

Mean values for root dry weight at 50 days as presented in Table indicated that compared to control all the treatments increased root dry weight. Root dry weight ranged from 0.245g to 0.460g. Maximum root dry weight at 50 days was observed for T_{16} (0.460g), which was significantly different from most of the treatments except T_2 (0.41g), T_{21} (0.373g), T_3 (0.349g), T_4 (0.336g) and T_{10} (0.348g). Minimum root dry weight at 50 days was observed for T_0 (control) (0.245g), which was significantly different from other treatments except T_{11} (0.262g), T_{13} (0.267g), T_{14} (0.269g) and T_{15} (0.265g).

4.12.3 Root Dry Weight at 90 DAT:

Mean values for root dry weight of soybean plants at 90 days as presented in Table indicated that as compared to control most of the treatments increased root dry weight. Root dry weight ranged from 0.567g to 0.921g. Maximum root dry weight was observed for T_{21} (0.921g), which was significantly different from most of the treatments except T_{18} (0.832g), T_{17} (0.795g) and T_{12} (0.795g). Other treatments also significantly increased root dry weight. Minimum root dry weight was observed for T_0 (control) (0.567g), which was significantly different from most of the treatments except T_{20} (0.597g).

Table 4.38: ANOVA table for root dry weight at 35 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.002	0.001	1.0639	0.3542
2	Factor A	21	0.082	0.004	3.6017	0.0002
3	Error	42	0.045	0.001		
	Total	65	0.129			

Significant at 0.05 level of probability.
Coefficient of Variation: 11.58%

Table 4.39: ANOVA table for root dry weight at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.030	0.015	2.6465	0.0827
2	Factor A	21	0.157	0.007	1.3061	0.2259
3	Error	42	0.241	0.006		
	Total	65	0.428			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 23.85%

Table 4.40: ANOVA table for root dry weight at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.030	0.015	2.7680	0.0743
2	Factor A	21	0.370	0.018	3.2019	0.0007
3	Error	42	0.231	0.006		
	Total	65	0.632			

Significant at 0.05 level of probability.
Coefficient of Variation: 10.20%

Table 4.41: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on root dry weight at 35, 50 and 90 DAT.

	35 DAT		50 DAT		90 DAT	
Treatments	**Root Dry Weight (g)**	**Ranking**	**Root Dry Weight (g)**	**Ranking**	**Root Dry Weight (g)**	**Ranking**
T0	0.227	F	0.245	D	0.567	F
T1	0.310	BCD	0.293	BCD	0.772	BCD
T2	0.263	DEF	0.410	AB	0.708	BCDE
T3	0.276	CDEF	0.349	ABCD	0.783	BCD
T4	0.266	DEF	0.336	ABCD	0.707	BCDE
T5	0.261	DEF	0.297	BCD	0.665	DEF
T6	0.273	CDEF	0.318	BCD	0.736	BCD
T7	0.251	EF	0.296	BCD	0.757	BCD
T8	0.275	CDEF	0.307	BCD	0.753	BCD
T9	0.295	BCDE	0.295	BCD	0.719	BCDE
T10	0.256	EF	0.348	ABCD	0.697	CDE
T11	0.269	DEF	0.262	CD	0.669	CDEF
T12	0.268	DEF	0.330	BCD	0.795	ABC
T13	0.293	BCDE	0.267	CD	0.691	CDEF
T14	0.232	F	0.269	CD	0.744	BCD
T15	0.274	CDEF	0.265	CD	0.721	BCDE
T16	0.270	DEF	0.460	A	0.656	DEF
T17	0.302	BCDE	0.328	BCD	0.795	ABC
T18	0.324	ABC	0.307	BCD	0.832	AB
T19	0.338	AB	0.310	BCD	0.704	F
T20	0.339	AB	0.315	BCD	0.597	EF
T21	0.375	A	0.373	ABC	0.921	A
LSD Value	*0.05211		0.1276		*0.1276	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.13 Number of Pod Set at 50 DAT:

This parameter was studied at 50 days only for soybean plants. The statistical analysis of data showing mean values of number of pod set at 50 days is given in Table 4.43 and plotted in Figure 4.42.

Analysis of variance showed that number of pod set of soybean var. NARC-4 showed significant ($P<0.05$) variations at 50 days and MS value for number of pod set was 3.264.

Mean values for number of pod set at 50 days indicated that as compared to control most of the treatments increased number of pod set at 50 days except T_3 (4.22). Number of pod set for *Glycine max.* L. (Merril) ranged from 4.22 to 7.88. Maximum number of pod sets was seen for T_{18} and T_{19} (7.88), which was significantly different form most of the treatments except T_{21} (7.55), T_{20} (6.33), T_{10} (6.44), T_7 (6.44), T_6 (6.55) and T_1 (7.55). Minimum number of pods set was observed for T_3 (4.22) followed by control (T_0) (4.44).

Table 4.42: ANOVA table for pod sets at 50 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	2.752	1.376	1.4235	0.2522
2	Factor A	21	68.545	3.264	3.3770	0.0004
3	Error	42	40.596	0.967		
	Total	65	111.893			

Significant at 0.05 level of probability.
Coefficient of Variation: 16.50%

Table 4.43: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on pod sets at 50 DAT.

Treatments	No. of Pod sets at 50 DAT	Ranking
T0	4.44	E
T1	7.55	AB
T2	5.11	CDE
T3	4.22	E
T4	5.22	CDE
T5	5.55	CDE
T6	6.55	ABC
T7	6.44	ABCD
T8	5.77	CDE
T9	5.66	CDE
T10	6.44	ABCD
T11	5.33	CDE
T12	6.11	BCD
T13	5.22	CDE
T14	4.88	DE
T15	5.44	CDE
T16	5.77	CDE
T17	5.66	CDE
T18	7.88	A
T19	7.88	A
T20	6.33	ABCD
T21	7.55	AB
LSD Value	*1.620	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.14 Number of Pods per Plant at 90 DAT:

This parameter was studied at 90 days only for soybean plants. The statistical analysis of data showing mean values of number for pods per plant at 90 days is given in Table 4.45 and plotted in Figure 4.43.

Analysis of variance for number of pods per plant showed significant ($P<0.05$) variations within treatments at 90 days.

Mean values for number of pods per plant at 90 days as presented in Table indicated that as compared to control all treatments increased number of pods per plant. Number of pod per plant ranged from 7.38 to 14.11. Maximum number of pods per plant were seen for T_{19} (14.11), which was significantly different form other treatments except T_{20} (13.67). Minimum number of pods per plant was observed for control (T_0) (7.38), which were significantly different from other treatments.

Table 4.44: ANOVA table for pods per plant at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	13.457	6.729	2.1987	0.1236
2	Factor A	21	203.069	9.670	3.1599	0.0007
3	Error	42	128.530	3.060		
	Total	65	345.056			

Significant at 0.05 level of probability.
Coefficient of Variation: 17.51%

Table 4.45: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on no. of pods per plant at 90 DAT.

Treatments	No. of Pods per plant at 90 DAT	Ranking
T0	10.00	DEF
T1	9.00	DEF
T2	7.38	F
T3	8.00	EF
T4	10.17	DEF
T5	10.50	CDE
T6	8.66	DEF
T7	11.17	BCD
T8	8.88	DEF
T9	9.66	DEF
T10	10.56	CDE
T11	8.00	EF
T12	8.66	DEF
T13	8.00	EF
T14	9.77	DEF
T15	9.83	DEF
T16	9.66	DEF
T17	10.11	DEF
T18	13.11	ABC
T19	10.89	BCD
T20	13.67	AB
T21	14.11	A
LSD Value	*2.882	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.15 Number of Empty Pods per Plant:

This parameter was studied at 90 days. The statistical analysis of data showing mean values of number for empty pods per plant at 90 days is given in Table 4.47 and plotted in Figure 4.44.

Analysis of variance for number of empty pods per plant showed significant ($P<0.05$) variations at 90 days. MS value for number of empty pod per plant is 1.042.

Mean values for number of empty pods per plant at 90 days indicated that some treatments showed decrease in number of empty pods per plant. Number of empty pods per plant ranged from 0.444 to 2.55. Maximum number of empty pods per plant was observed in T_{21} (2.55), which was significantly different from all other treatments except T_{15} (2.33). Minimum number of empty pods per plant was observed in T_{18} (0.444).

Table 4.46: ANOVA table for number of empty pods per plant at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.354	0.177	1.0448	0.3607
2	Factor A	21	21.892	1.042	6.1474	0.0000
3	Error	42	7.122	0.170		
	Total	65	29.369			

Significant at 0.05 level of probability.
Coefficient of Variation: 38.41%

Table 4.47: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of empty pods per plant at 90 DAT.

Treatments	No. of empty pods per plant at 90 DAT	Ranking
T0	0.888	DEFGHI
T1	1.33	CDEF
T2	1.66	CDEFG
T3	0.66	FGHI
T4	0.592	GHI
T5	1.000	DEFGHI
T6	0.999	DEFGHI
T7	1.16	CDEFG
T8	0.555	GHI
T9	0.833	EFGHI
T10	1.55	CD
T11	1.50	CDE
T12	0.333	I
T13	0.333	I
T14	0.666	FGHI
T15	2.33	AB
T16	1.11	CDEFGH
T17	0.777	FGHI
T18	0.444	HI
T19	0.999	DEFGHI
T20	1.77	BC
T21	2.55	A
LSD Value	*0.6794	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.16 Number of 3-Seeded Pods per Plant:

This parameter was studied only at 90 days. The statistical analysis of data showing mean values for number of 3-seeded pods per plant at 90 days for *Glycine max.* L. (Merril) is given in Table 4.49 and plotted in Figure 4.45.

Analysis of variance results indicated non-significant ($P<0.05$) variations for number of 3-seeded pods per plant at 90 days. MS value for 3-seeded pods per plant was 0.324.

Mean value results presented in Table showed that some treatments increased, while some treatments decreased number of 3-seeded pods per plant at 90 days of *Glycine max.* L.(Merril). Number of 3-seede pods per plant ranged from 0.407 to 1.55. Maximum number of 3-seeded pods per plant was observed in T_1 (1.55), which was different from other treatments. Other significant treatments were T_{10} (1.33), T_{12} (1.33), T_{16} (1.33), T_{18} (1.44), T_{20} (1.44) and T_{21} (1.33). Number of 3-seeded pods per plant in control was 1.11, which was greater than T_2 (0.407), T_4 (0.861), T_5 (1.0), T_6 and T_7 (0.666), T_8 (0.777), T_{11} (0.999), T_{14} (0.777), and T_{15} (0.666). Other treatments showed increase in number of 3-seeded pods per plant. Minimum number of 3-seeded pods per plant was observed for T_9 (0.5).

Table 4.48: ANOVA table for number 3-Seeded pods per plant at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.098	0.049	0.1513	
2	Factor A	21	6.797	0.324	1.0029	0.4801
3	Error	42	13.555	0.323		
	Total	65	20.449			

Non-Significant at 0.05 level of probability.
Coefficient of Variation: 54.90%

Table 4.49: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of 3-seeded pods per plant at 90 DAT.

Treatments	No. of 3-seeded pods per plant at 90 DAT.	Ranking
T0	1.11	AB
T1	1.55	A
T2	0.407	B
T3	1.16	AB
T4	0.861	AB
T5	1.000	AB
T6	0.666	AB
T7	0.666	AB
T8	0.777	AB
T9	0.500	B
T10	1.33	AB
T11	0.999	AB
T12	1.33	AB
T13	1.16	AB
T14	0.777	AB
T15	0.666	AB
T16	1.33	AB
T17	1.11	AB
T18	1.44	A
T19	1.11	AB
T20	1.44	A
T21	1.33	AB
LSD Value	0.9365	

***Significant at 0.05 level of probability.**
Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.17 Number of 1-Seeded Pods per Plant:

Number of 1-seeded pods per plant was studied at 90 days only. The statistical analysis of data showing mean values for number of 1-seeded pods per plant is given in Table 4.51 and plotted in Figure 4.46.

Analysis of variance showed significant ($P<0.05$) variations for number of 1-seeded pods per plant. MS value for number of 1-seeded pods per plant was 1.029.

Results of mean for number of 1-seeded pods per plant as presented in Table indicated that most of the treatments increased number of 1-seeded pods per plant except T_1, T_2, T_3 and T_{12}. Number of 1-seeded pods per plant ranged from 1.66 to 4.11. Maximum number of 1-seeded pods per plant was observed forT_{20} (4.11), which was significantly different from other treatments except T_{18} (3.66) and T_{21} (3.55). Minimum number of 1-seeded pods per plant was observed in T_4 (1.66).

Table 4.50: ANOVA table for number of 1-Seeded pods per plant at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	0.216	0.108	0.1883	
2	Factor A	21	25.379	1.209	2.1066	0.0198
3	Error	42	24.095	0.574		
	Total	65	49.691			

Significant at 0.05 level of probability.
Coefficient of Variation: 27.94%

Table 4.51: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of 1-seeded pods per plant at 90 DAT.

Treatment	No. of 1-seeded pods per plant at 90 DAT	Ranking
T0	2.11	DE
T1	2.00	DE
T2	2.00	DE
T3	1.66	E
T4	3.22	ABCD
T5	2.50	BCDE
T6	2.55	BCDE
T7	3.00	ABCD
T8	2.77	BCDE
T9	2.41	CDE
T10	2.88	ABCDE
T11	2.16	DE
T12	2.00	DE
T13	1.99	DE
T14	2.66	BCDE
T15	3.00	ABCD
T16	3.11	ABCD
T17	3.11	ABCD
T18	3.66	AB
T19	3.11	ABCD
T20	4.11	A
T21	3.55	ABC
LSD Value	*1.248	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.18 Number of 2-Seeded Pods per Plant:

Number of 2-seeded pods per plant was studied at 90 days only. The statistical analysis of data showing mean values for number of 2-seeded pods per plant is given in Table 4.53 and plotted in Figure 4.47.

Analysis of variance showed significant ($P<0.05$) variations for number of 2-seeded pods per plant at 90 days of *Glycine max.* L. (Merril) soybean. MS value for number of 2-seeded pods per plant was 3.789.

Results of mean for number of 2-seeded pods per plant as presented in Table indicated that some treatments increased number of 2-seeded pods per plant while some treatments decreased number of 2-seeded pods per plant as compared to control. Number of 2-seeded pods per plant ranged from 3.13 to 7.00. Maximum number of 2-seede pods per plant was observed in T_{18} (7.00), which was significantly different from other treatments except T_{20} (6.77), T_{21} (6.77) and T_7 (6.83). Minimum number of 2-seede pods per plant was observed for T_4 (3.13), which differed significantly for other treatments except T_{11} (3.33).

Table 4.52: ANOVA table for number of 2-Seeded pods per plant at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	15.548	7.774	4.9400	0.0118
2	Factor A	21	79.564	3.789	2.4076	0.0076
3	Error	42	66.094	1.574		
	Total	65	161.205			

Significant at 0.05 level of probability.
Coefficient of Variation: 24.83%

Table 4.53: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on number of 2-seeded pods per plant at 90 DAT.

Treatments	No. of 2-seeded pods per plant at 90 DAT	Ranking
T0	5.88	AB
T1	5.22	ABC
T2	3.33	CD
T3	4.50	BCD
T4	3.13	D
T5	5.33	ABC
T6	4.44	BCD
T7	6.83	A
T8	4.66	BCD
T9	5.25	ABC
T10	5.11	ABCD
T11	3.33	CD
T12	4.66	BCD
T13	4.25	BCD
T14	5.55	AB
T15	4.16	BCD
T16	4.44	BCD
T17	5.00	ABCD
T18	7.00	A
T19	5.44	AB
T20	6.77	A
T21	6.77	A
LSD Value	*2.067	

***Significant at 0.05 level of probability.**

Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

4.19 1000-Seed Weight:

This parameter was studied at 90 days only. The statistical analysis of data showing means for test weight of 1000 seeds of *Glycine max.* L. (Merril) is given in Table 4.55 and plotted in Figure 4.48. Analysis of variance showed significant ($P<0.05$) variations for 1000-seed weight of *Glycine max.* L. (Merril) at 90 days. MS value for 1000-seed weight was 180.837g.

Results showing mean for 1000-seed weight of soybean plants at 90 days indicated that all treatments increased 1000-seed weight as compared to control. 1000-seed weight ranged from 130.8g to 164.4g. Maximum 1000-seed weight was recorded for T_{16} (164.4g), which was significantly different from all other treatments and placed singly. T_{15} (160.0g), T_{14} (157.1g), T_{13} (154.2g) and T_{12} (152.9g) also significantly increased 1000-seed weight as compared to control. Minimum 1000-seed weight was recorded for control (T_0).

Table 4.54: ANOVA table for 1000-Seed Weight at 90 DAT.

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Replication	2	36.621	18.310	4.1586	0.0225
2	Factor A	21	3797.579	180.837	41.0711	0.0000
3	Error	42	184.927	4.403		
	Total	65	4019.126			

Significant at 0.05 level of probability.
Coefficient of Variation: 1.42%

Table 4.55: Effect of foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) on 1000-seed weight at 90 DAT.

Treatments	1000-seed weight (g)	Ranking
T0	130.8	N
T1	138.0	M
T2	139.1	LM
T3	140.3	KLM
T4	142.3	JKL
T5	144.5	IJ
T6	145.7	HIJ
T7	146.3	GHI
T8	148.0	FGH
T9	148.4	FGH
T10	149.9	EF
T11	152.9	DE
T12	153.6	D
T13	154.2	CD
T14	157.1	BC
T15	160.0	B
T16	164.4	A
T17	142.7	JK
T18	149.4	FG
T19	149.5	EFG
T20	140.4	KLM
T21	146.9	FGHI
LSD Value	*3.458	

***Significant at 0.05 level of probability.**
Mean in a column followed by similar alphabets are not significantly different from each other at Alpha = 0.05

Photographs of Soybean at Vegetative Stage (35 DAT)

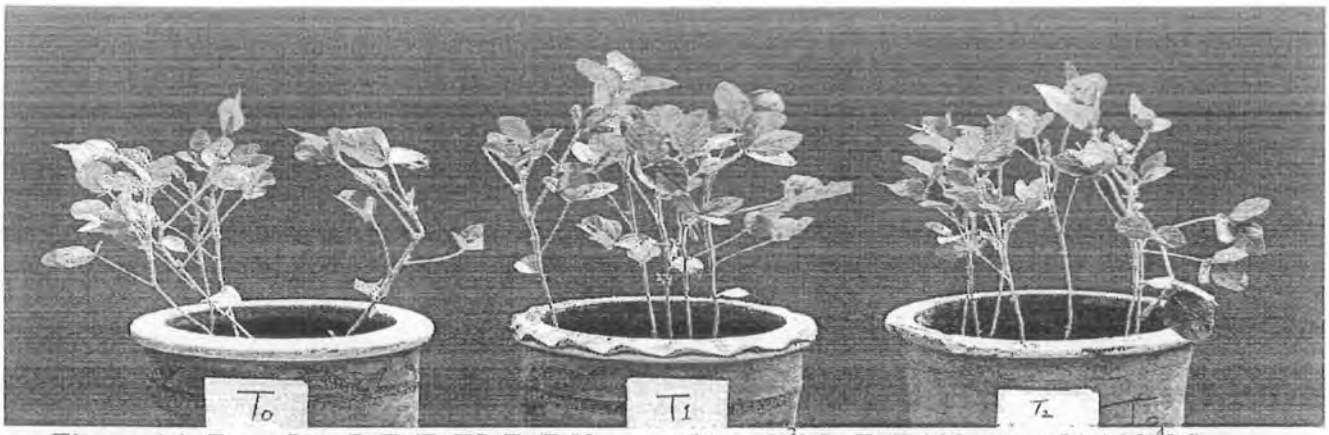

Figure 4.1: From L to R T_0(D.W),T_1(B50ppm + IAA10^{-3}M), T_2(B100ppm + IAA10^{-4}M)

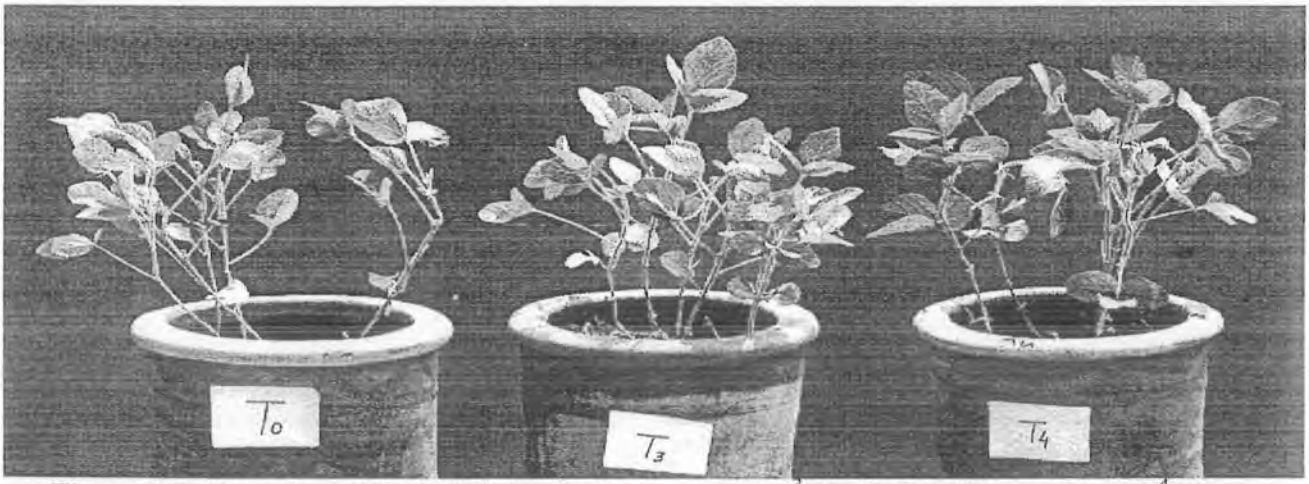

Figure 4.2: From L to R T_0(D.W), T_3(Zn50ppm+IAA10^{-3}M), T_4(Zn100ppm+IAA10^{-4}M)

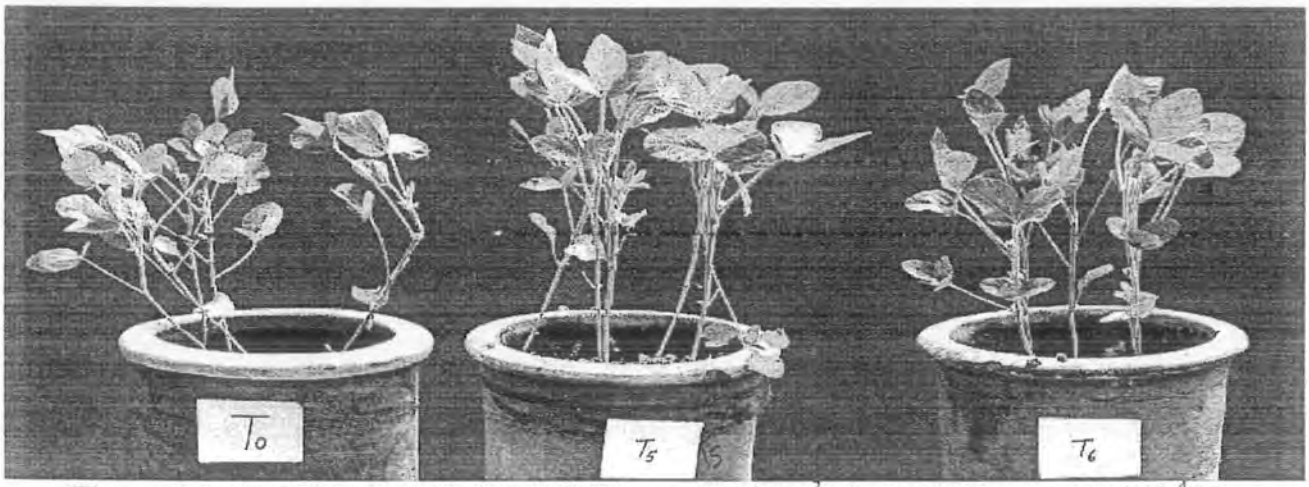

Figure 4.3: From L to R T_0(D.W), T_5(B50ppm +BAP10^{-3}M), T_6(B100ppm +BAP10^{-4}M)

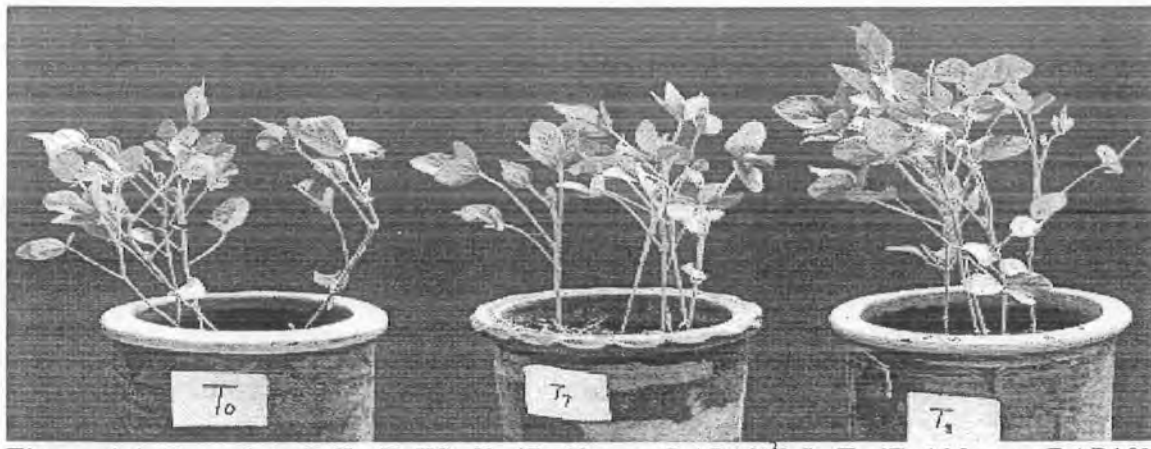

Figure 4.4: From L to R T_0 (D.W), T_7 (Zn50ppm+BAP10^{-3}M), T_8 (Zn100ppm+BAP10^{-4}M)

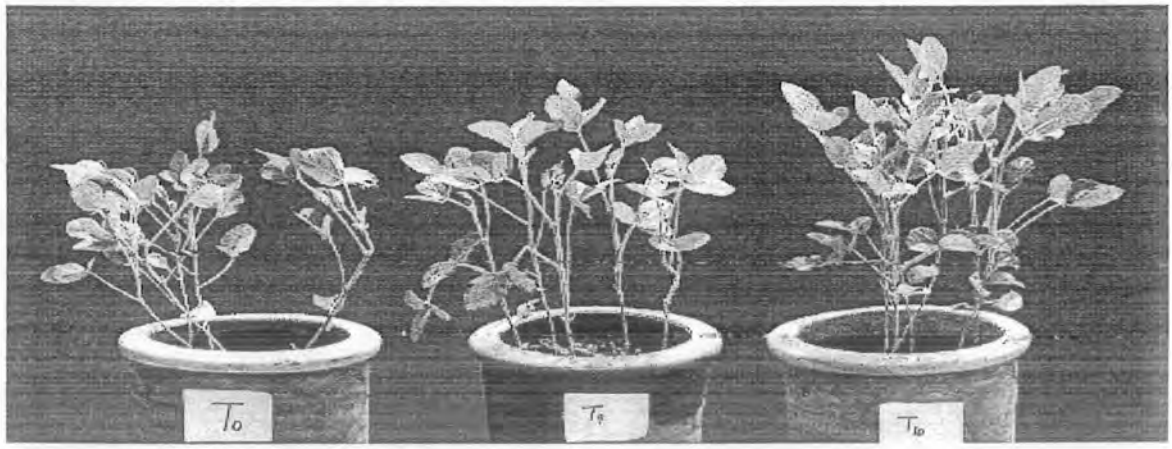

Figure 4.5: From L to R T_0 (D.W), T_9 (B50ppm +$GA_3 10^{-3}$M), T_{10} (B100ppm +$GA_3 10^{-4}$M)

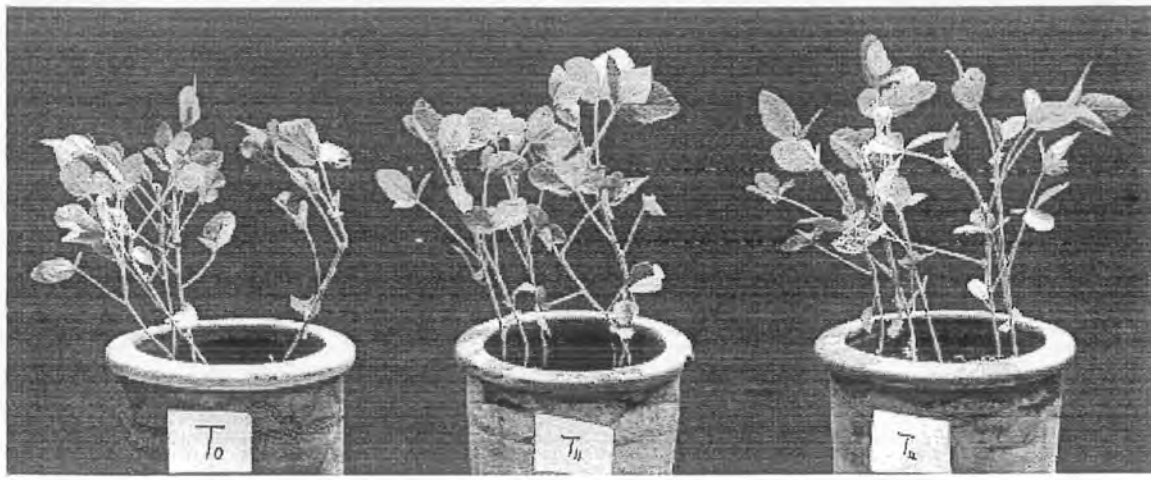

Figure 4.6: From L to R T_0 (D.W), T11 (Zn50ppm+$GA_3 10^{-3}$M), T12 (Zn100ppm+$GA_3 10^{-4}$M)

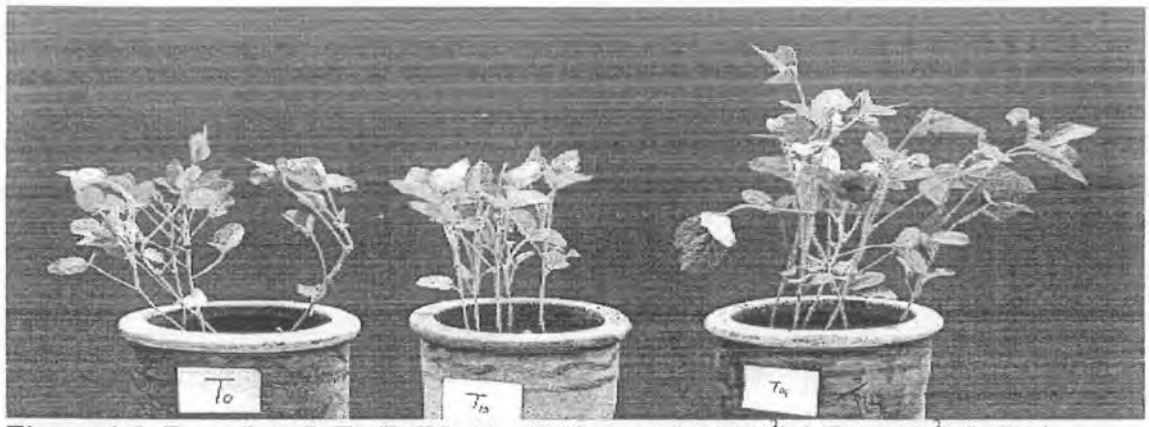

Figure 4.7: From L to R T_0 (D.W), T_{13} (B50ppm +IAA10^{-3}M+BAP10^{-3}M), T14 (B50ppm +IAA10^{-3}M+$GA_3 10^{-3}$M)

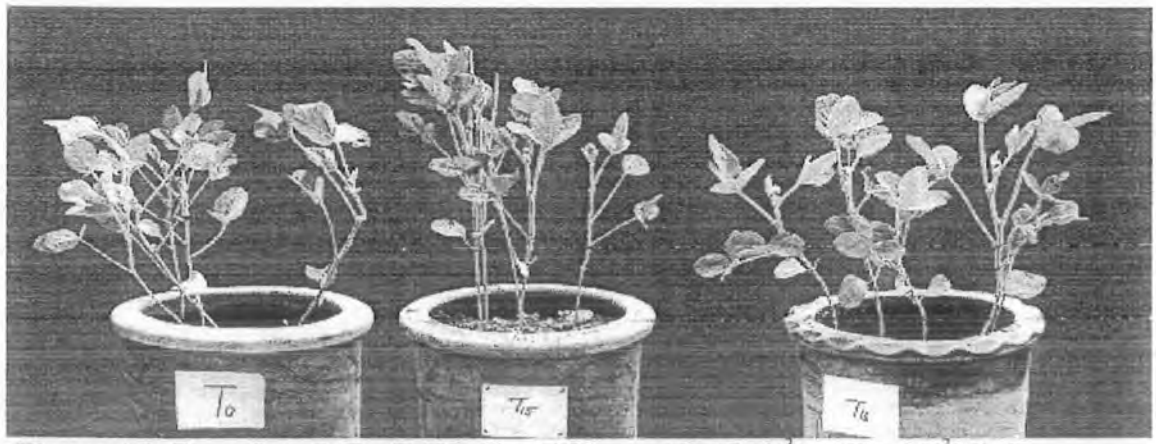

Figure 4.8: From L to R T_0 (D.W), T_{15} (B50ppm +BAP10^{-3}M+$GA_3 10^{-3}$M), T_{16} (Zn50ppm +IAA10^{-3}M +BAP10^{-3}M)

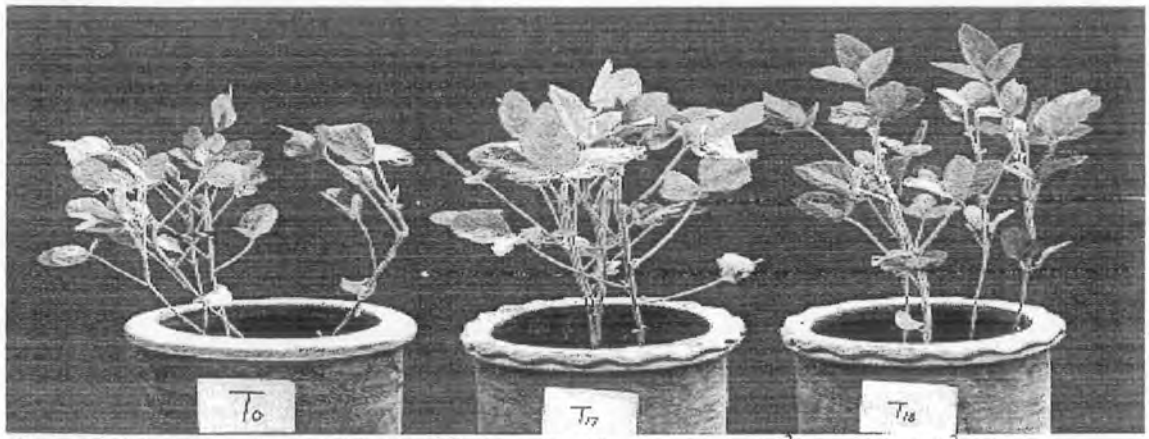

Figure 4.9: From L to R T_0 (D.W), T_{17} (Zn50ppm+IAA10^{-3}M+ $GA_3 10^{-3}$M), T_{18} (Zn50ppm+BAP10^{-3}M+$GA_3 10^{-3}$M)

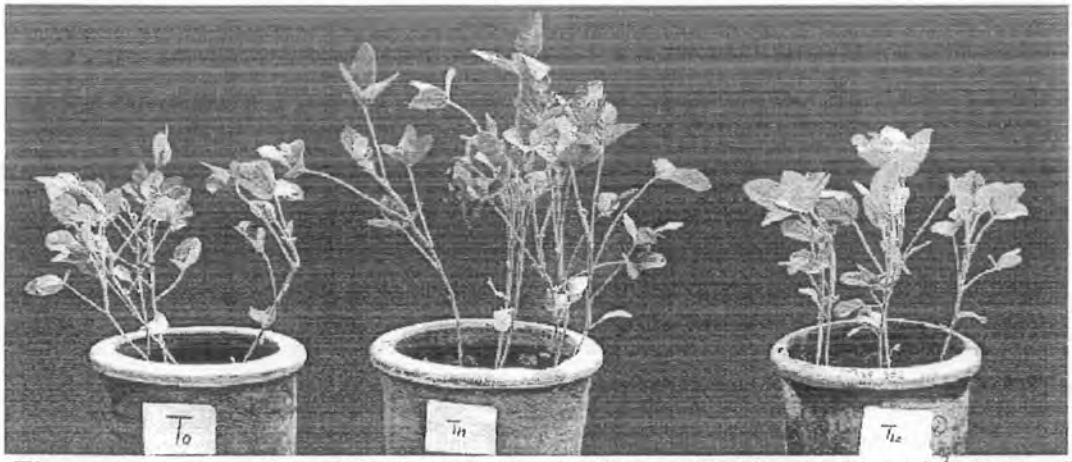

Figure 4.10: From L to R T_0 (D.W), T_{19} (B50ppm +Zn50ppm+IAA10^{-3}M), T_{20} (B50ppm +Zn50ppm+BAP10^{-3}M)

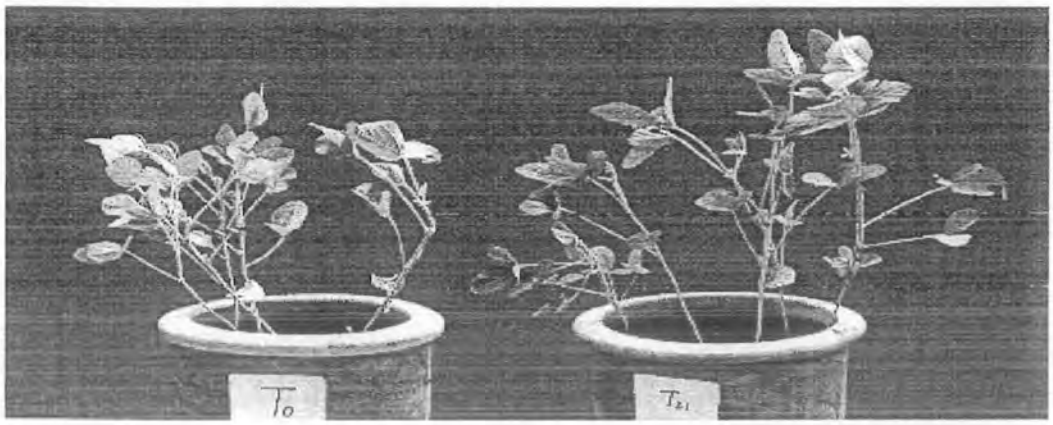

Figure 4.11: From L to R T_0 (D.W), T21 (B50ppm +Zn50ppm+$GA_3 10^{-3}$M)

Photographs of Soybean at Pod-Set Stage (50 DAT):

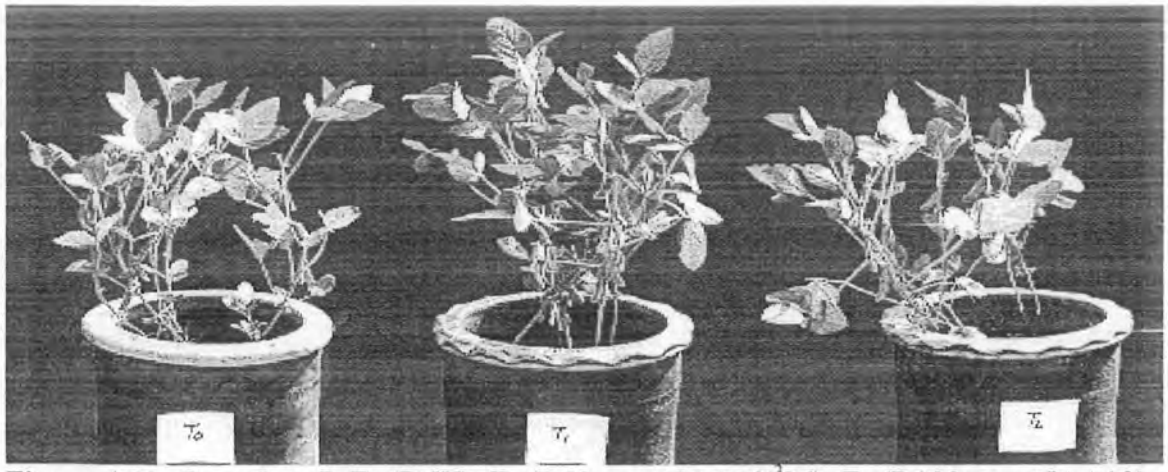

Figure 4.12: From L to R T_0 (D.W), T_1 (B50ppm +IAA10^{-3}M), T_2 (B100ppm +IAA10^{-4}M)

Figure 4.13: From L to R T_0 (D.W), T_3 (Zn50ppm +IAA10^{-3}M), T_4 (Zn100ppm +IAA10^{-4}M)

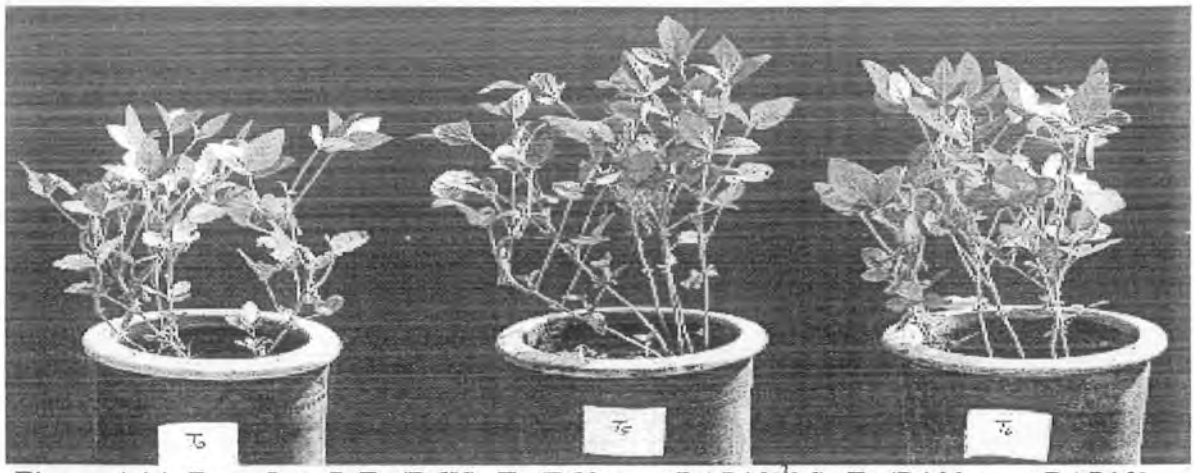

Figure 4.14: From L to R T_0 (D.W), T_5 (B50ppm+BAP10^{-3}M), T_6 (B100ppm+BAP10^{-4}M)

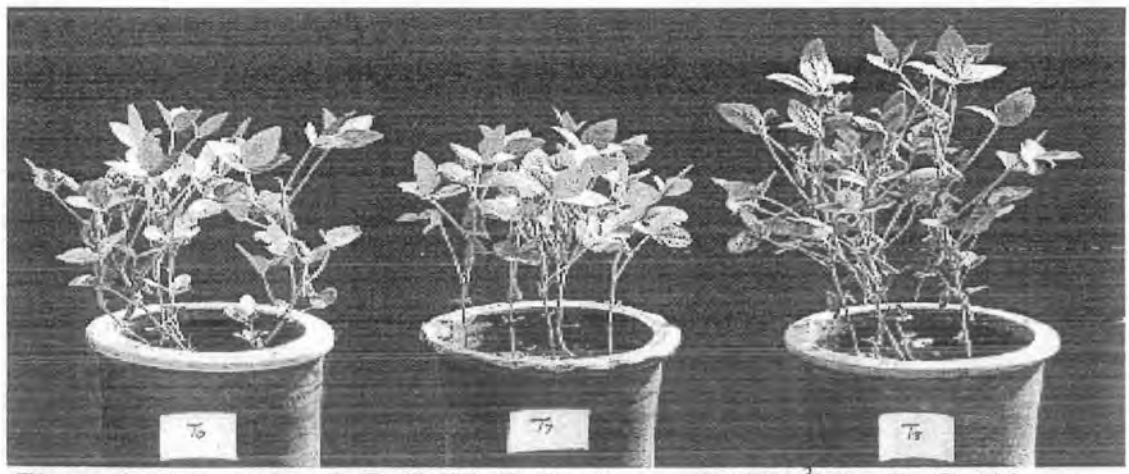

Figure 4.15: From L to R T_0 (D.W), T_7 (Zn50ppm +BAP10^{-3}M), T_8 (Zn100ppm +BAP10^{-4}M)

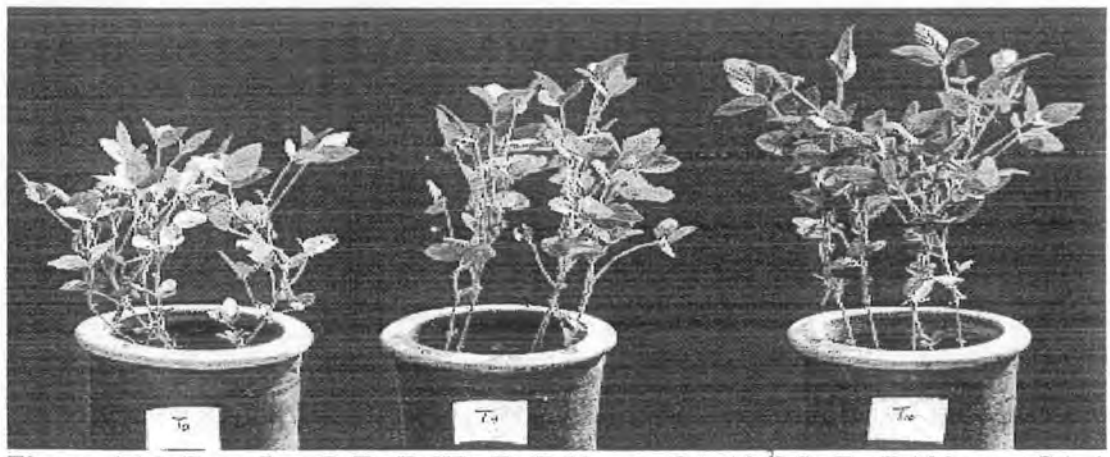

Figure 4.16: From L to R T_0 (D.W), T_9 (B50ppm+$GA_3$$10^{-3}$M), T_{10}(B100ppm+$GA_3$$10^{-4}$M)

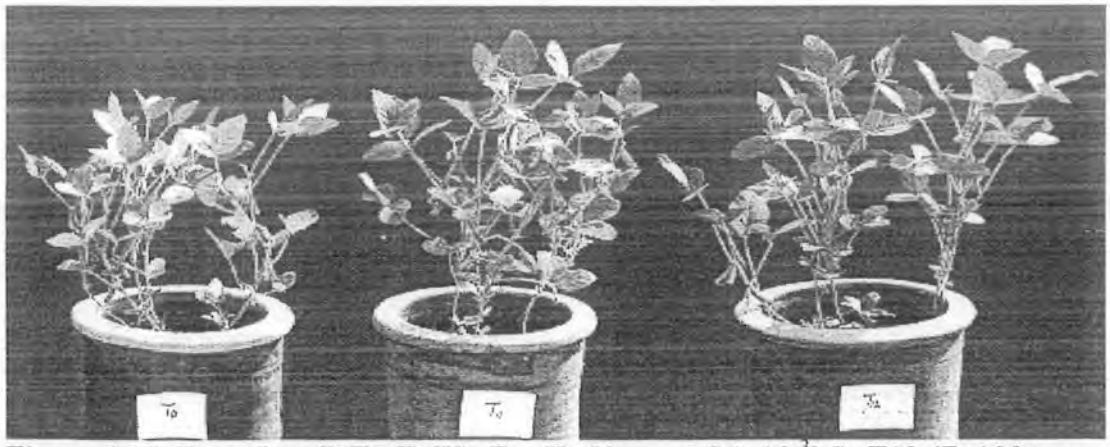

Figure 4.17: From L to R T_0 (D.W), T_{11} (Zn50ppm +$GA_3 10^{-3}$M), T12 (Zn100ppm +$GA_3 10^{-4}$M)

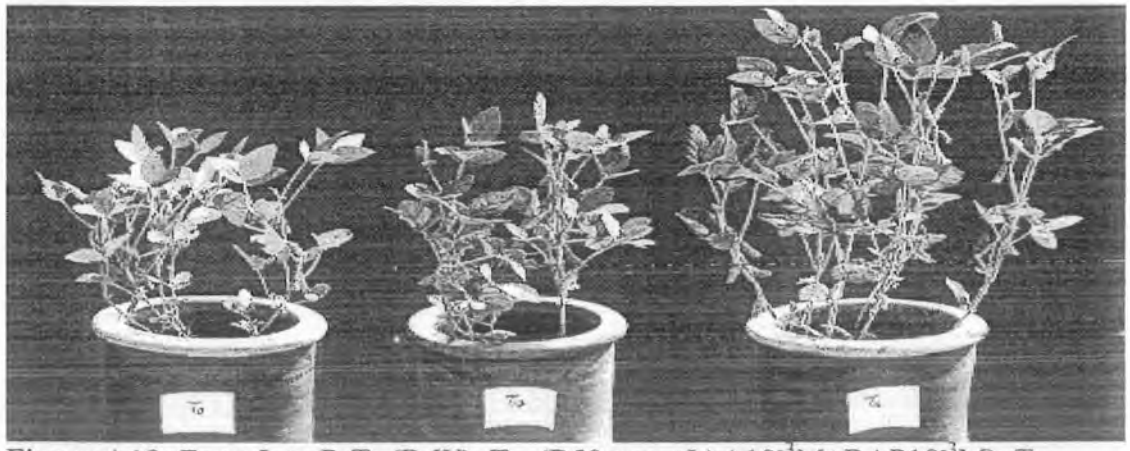

Figure 4.18: From L to R T_0 (D.W), T_{13} (B50ppm +$IAA10^{-3}$M+$BAP10^{-3}$M), T_{14} (B50ppm +$IAA10^{-3}$M+$GA_3 10^{-3}$M)

Figure 4.19: From L to R T_0 (D.W), T_{15} (B50ppm+$BAP10^{-3}$M+$GA_3 10^{-3}$M), T_{16} (Zn50ppm +$IAA10^{-3}$M+$BAP10^{-3}$M)

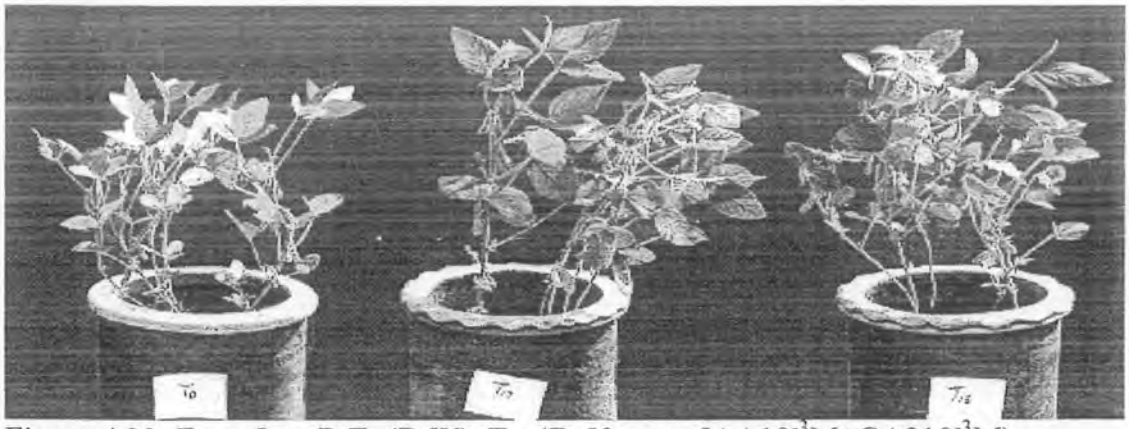

Figure 4.20: From L to R T_0 (D.W), T_{17} (Zn50ppm +IAA10^{-3}M+GA3$10^{-3}$M), T_{18}(Zn50ppm +BAP10^{-3}M+$GA_3$$10^{-3}$M)

Figure 4.21: From L to R T_0 (D.W), T_{19}(B50ppm+Zn50ppm +IAA10^{-3}M), T_{20}(B50ppm +Zn50ppm +BAP10^{-3}M)

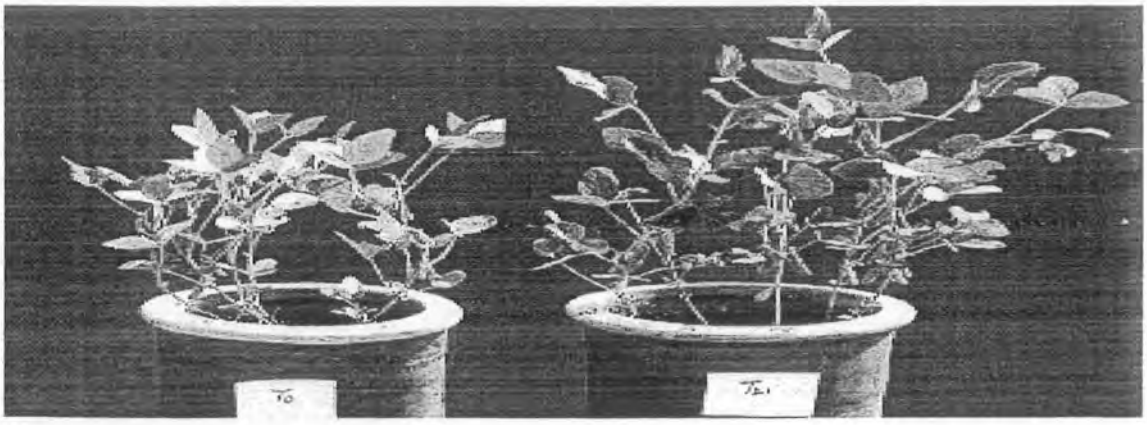

Figure 4.22: From L to R T_0 (D.W), T_{21} (B50ppm+Zn50ppm+$GA_3$$10^{-3}$M)

Photographs of Soybean at Harvest Stage (90 DAT)

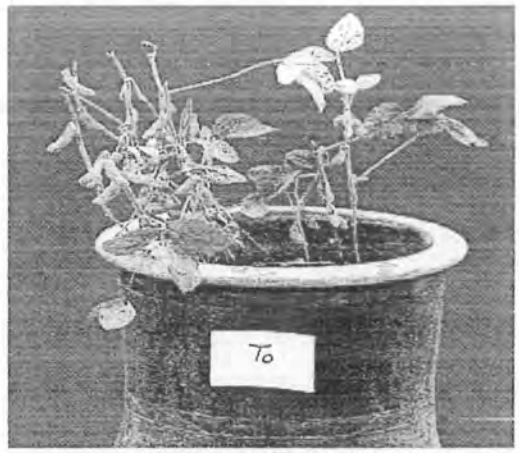

Figure 4.23: T_0 (D.W).

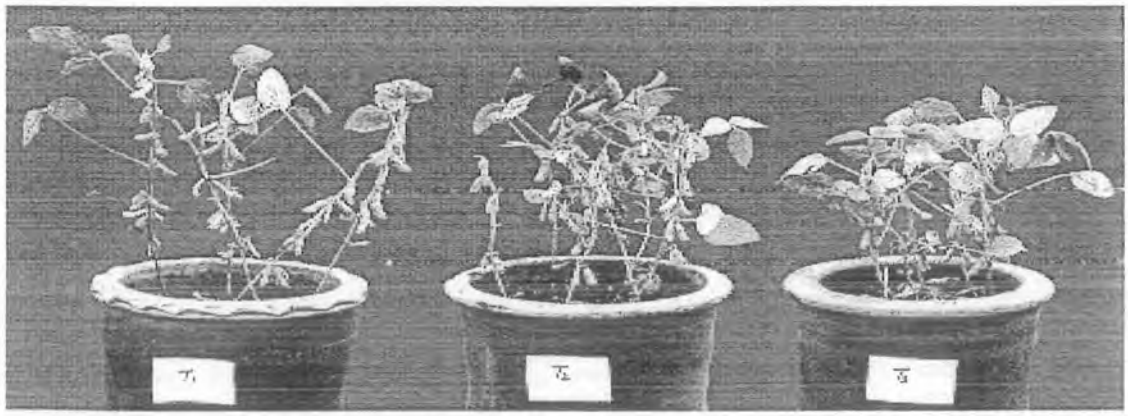

Figure 4.24: From L to R T_1 (B50ppm+IAA10^{-3}M), T_2(B100ppm +IAA10^{-4}M), T_3(Zn+IAA10^{-3}M)

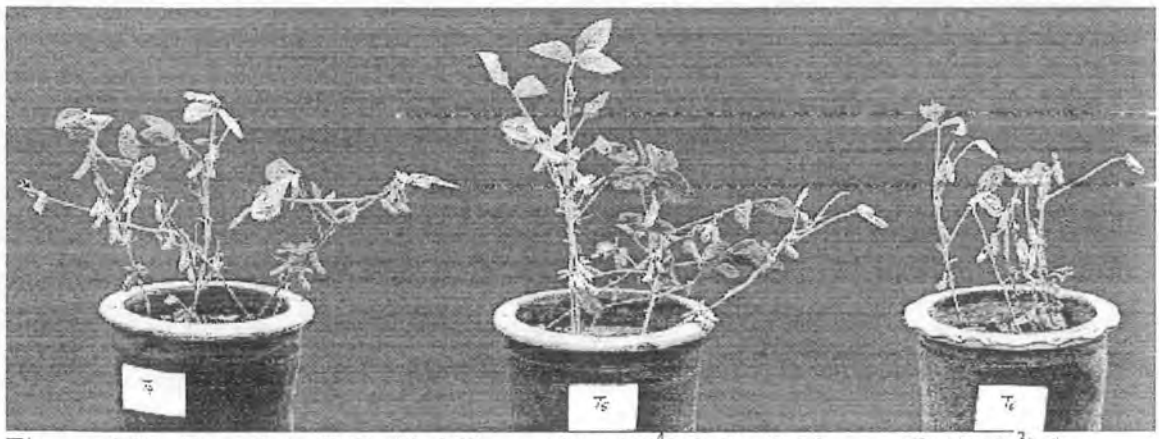

Figure 4.25: From L to R T_4 (Zn100ppm+IAA10^{-4}M), T_5 (B50ppm +BAP10^{-3}M), T_6(B100ppm +BAP10^{-4}M)

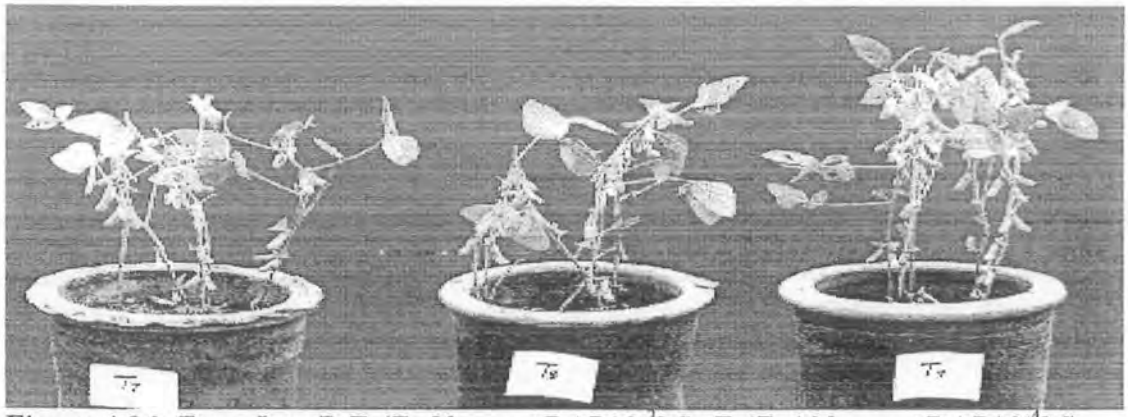

Figure 4.26: From L to R T_7(Zn50ppm +BAP10^{-3}M), T_8(Zn100ppm +BAP10^{-4}M), T_9(B50ppm +$GA_3 10^{-3}$M)

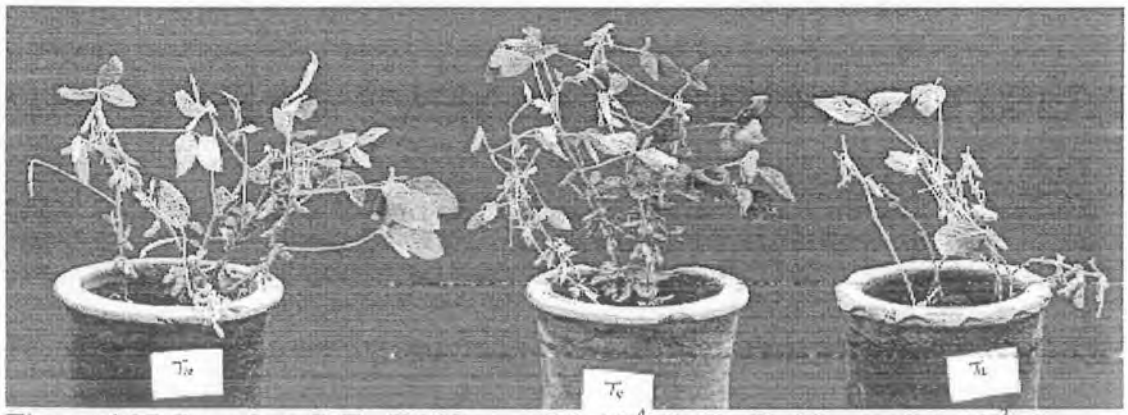

Figure 4.27: From L to R T_{10}(B100ppm+$GA_3 10^{-4}$M), T_{11}(Zn50ppm+$GA_3 10^{-3}$M), T_{12}(Zn100ppm +$GA_3 10^{-4}$M)

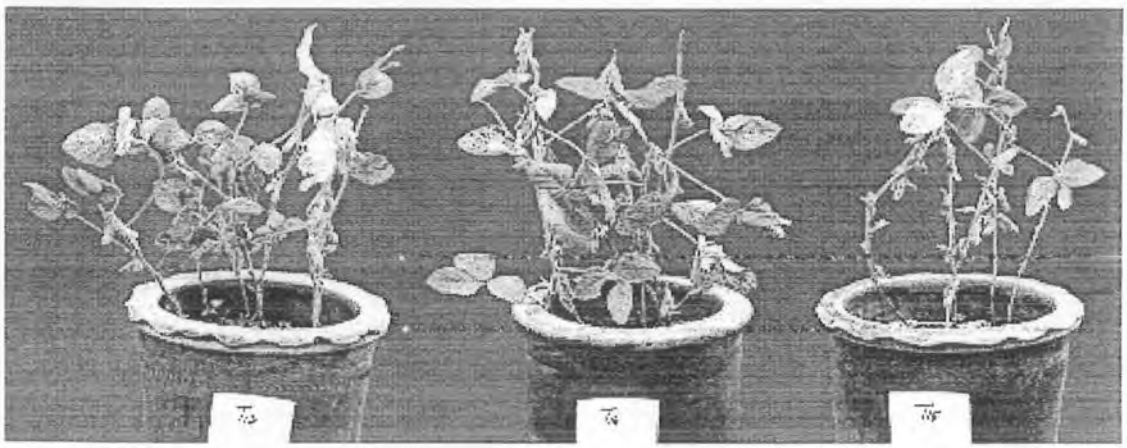

Figure 4.28: From L to R T_{13}(B50ppm+IAA10^{-3}M+BAP10^{-3}M), T_{14}(B50ppm+IAA10^{-3}M+$GA_3 10^{-3}$M), T_{15}(B50ppm+BAP10^{-3}M+$GA_3 10^{-3}$M)

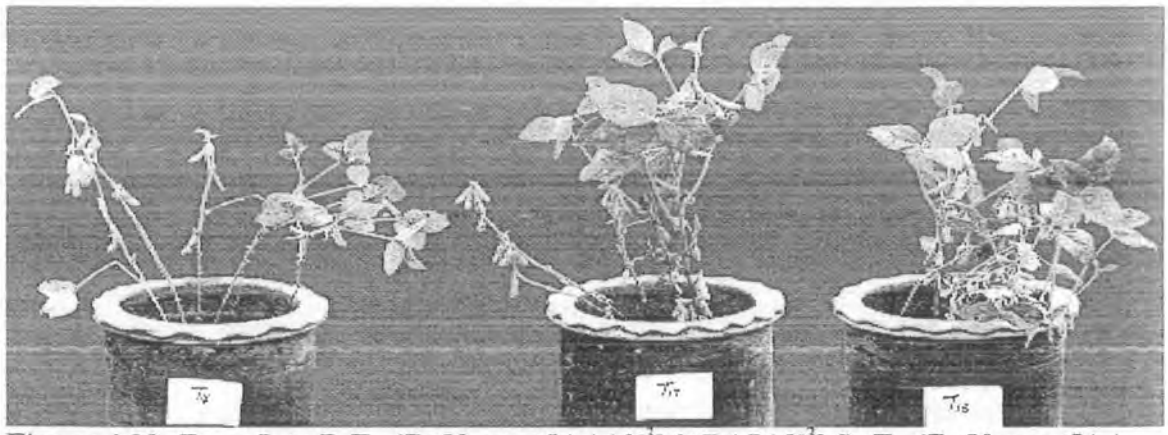

Figure 4.29: From L to R T_{16}(Zn50ppm+IAA10^{-3}M+BAP10^{-3}M), T_{17}(Zn50ppm+IAA 10^{-3}M+$GA_3$$10^{-3}$M), T_{18}(Zn50ppm+BAP10^{-3}M+$GA_3$$10^{-3}$M)

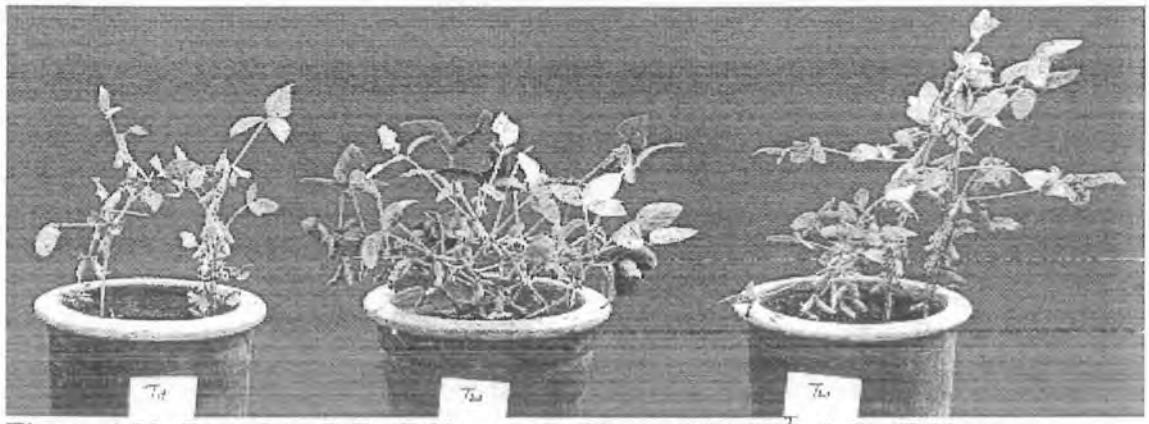

Figure 4.30: From L to R T_{19}(B50ppm +Zn50ppm+IAA10^{-3}M), T_{20}(B50ppm +Zn50ppm+BAP10^{-3}M), T_{21}(B50ppm+Zn50ppm+$GA_3$$10^{-3}$M)

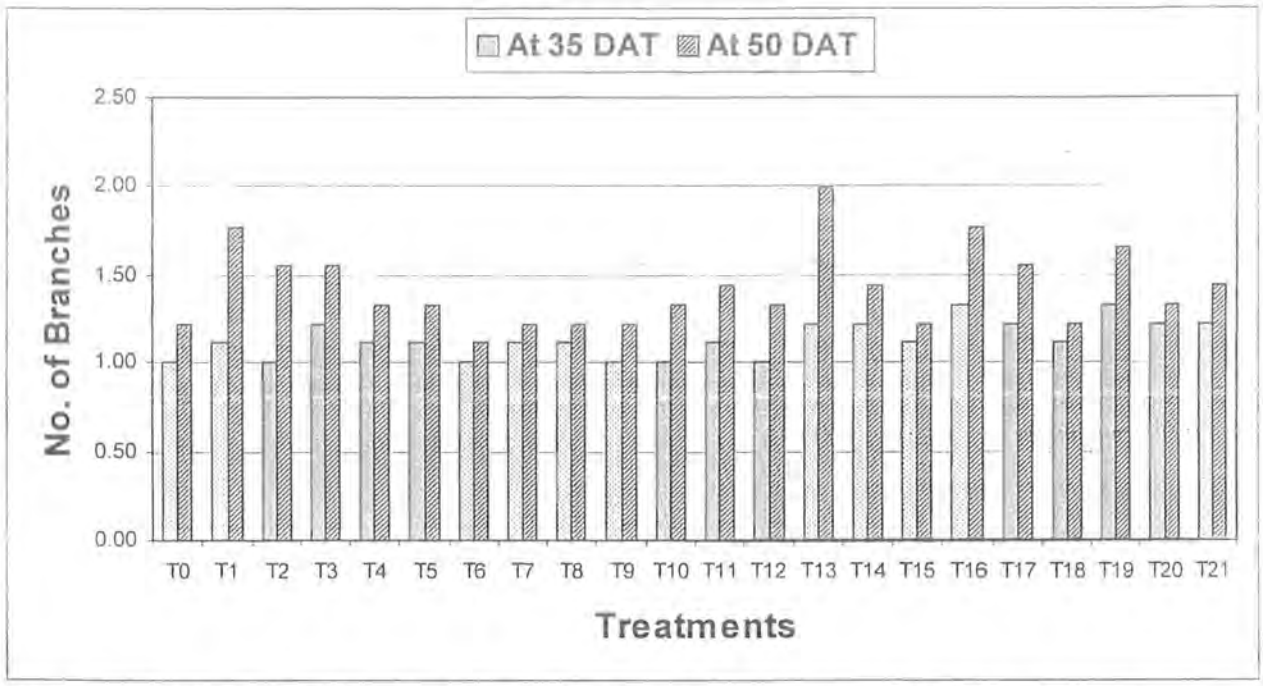

Figure 4.31: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of branches.

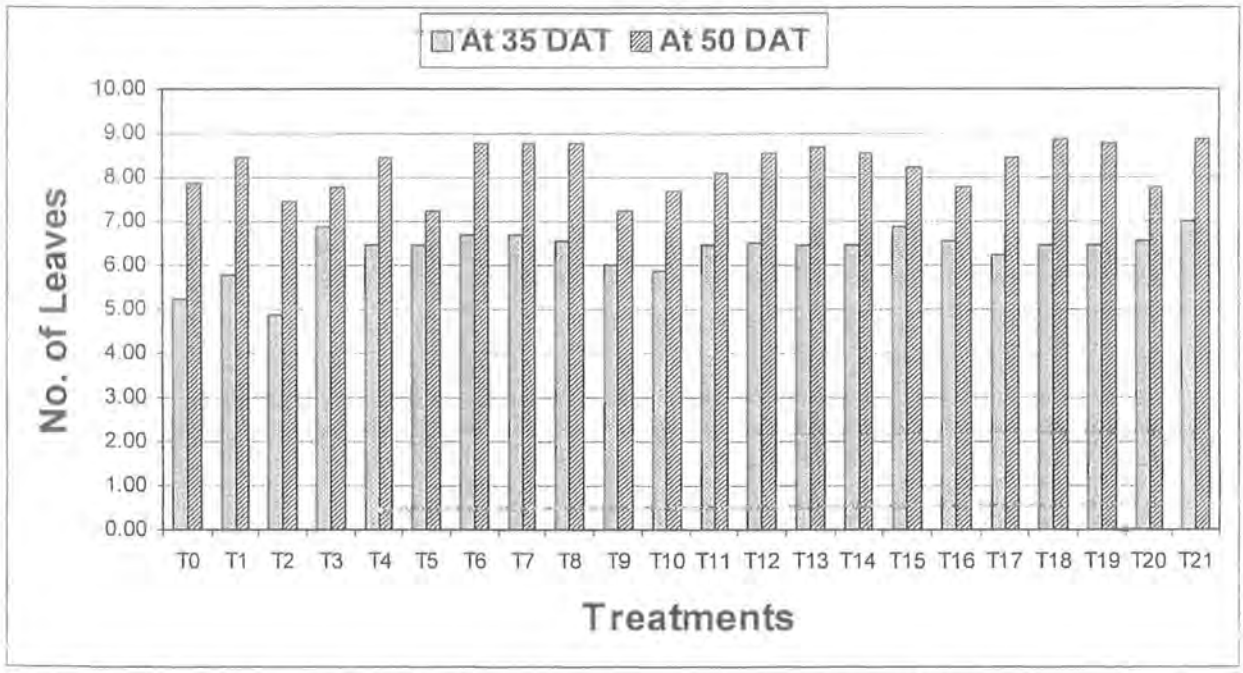

Figure 4.32: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of leaves.

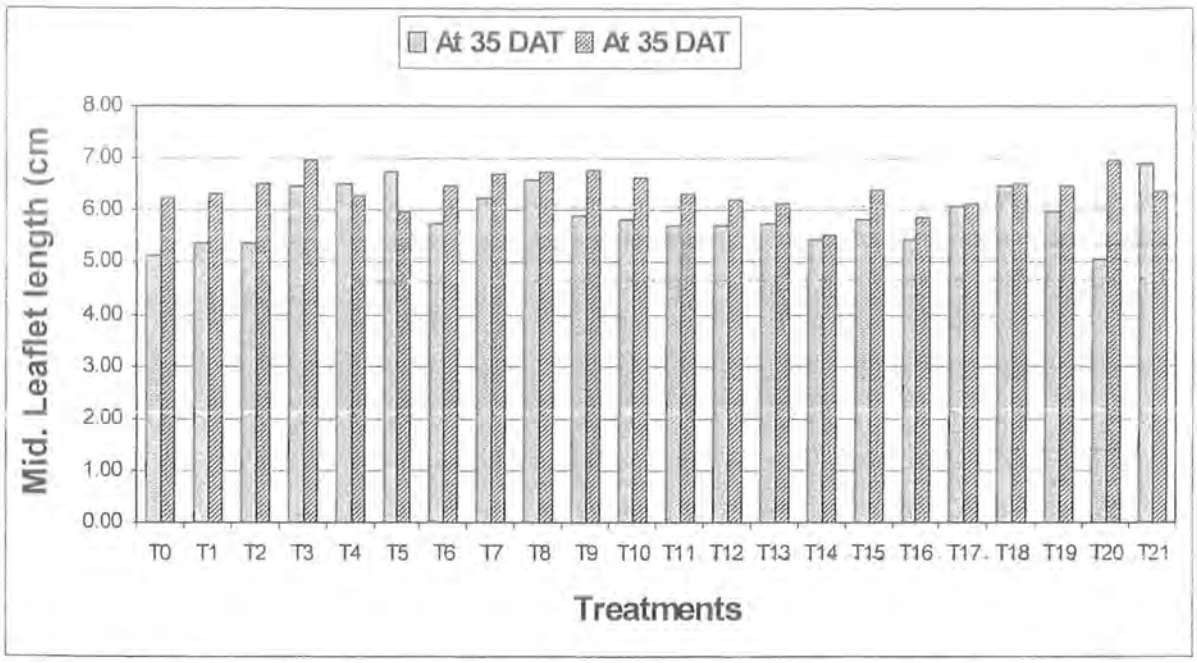

Figure 4.33: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on middle leaflet length.

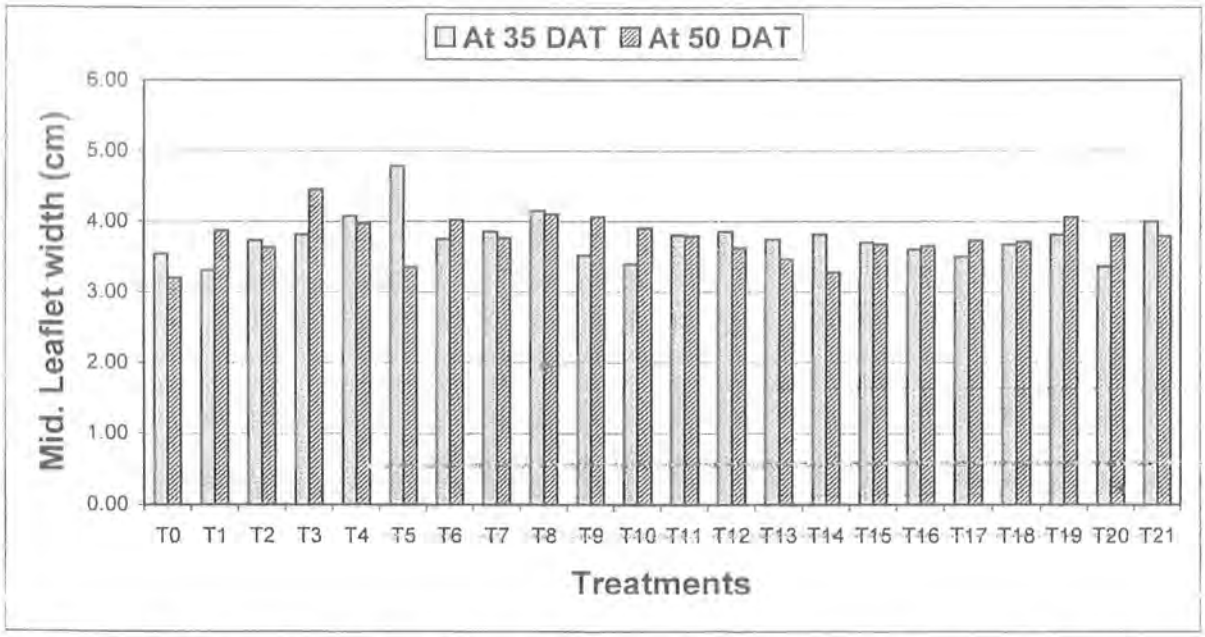

Figure 4.34: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on middle leaflet width.

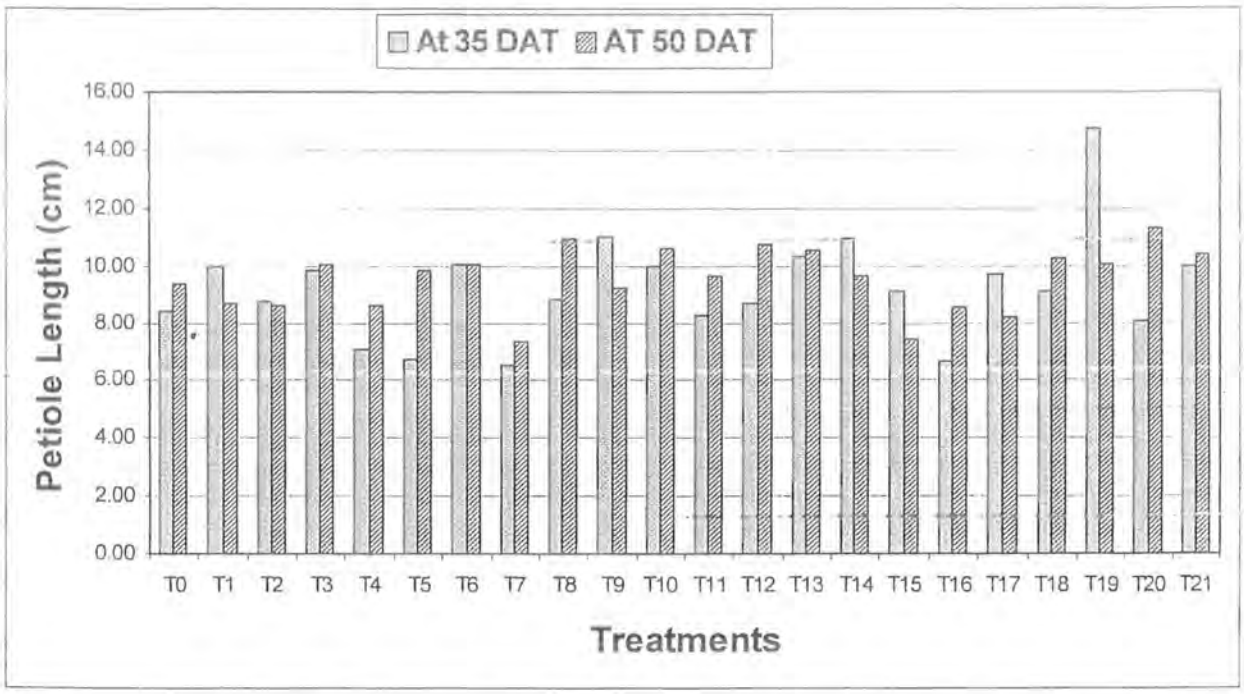

Figure 4.35: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on petiole length.

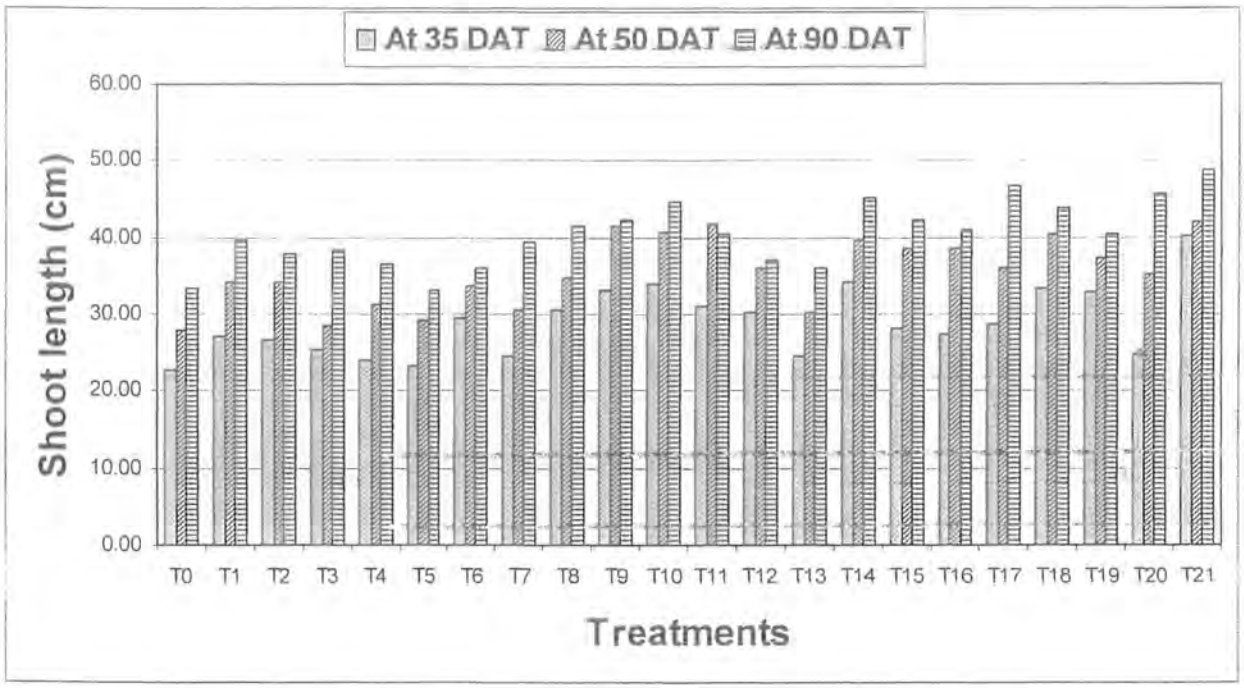

Figure 4.36: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on shoot length.

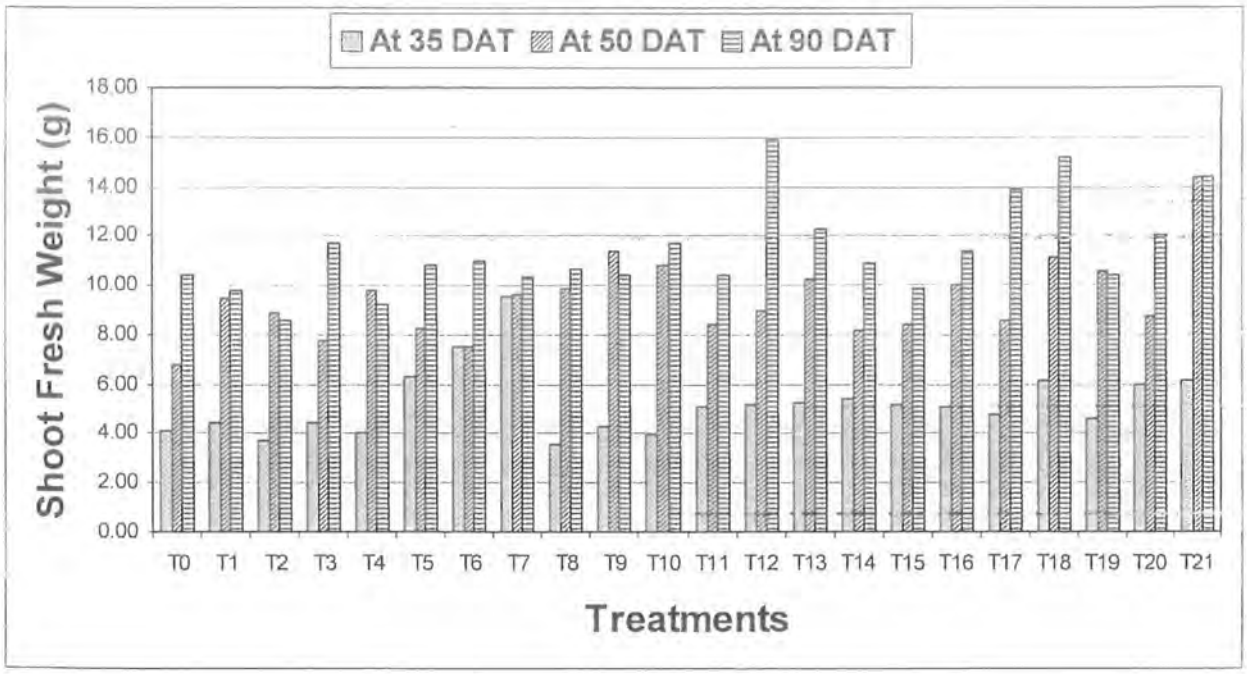

Figure 4.37: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on shoot fresh weight.

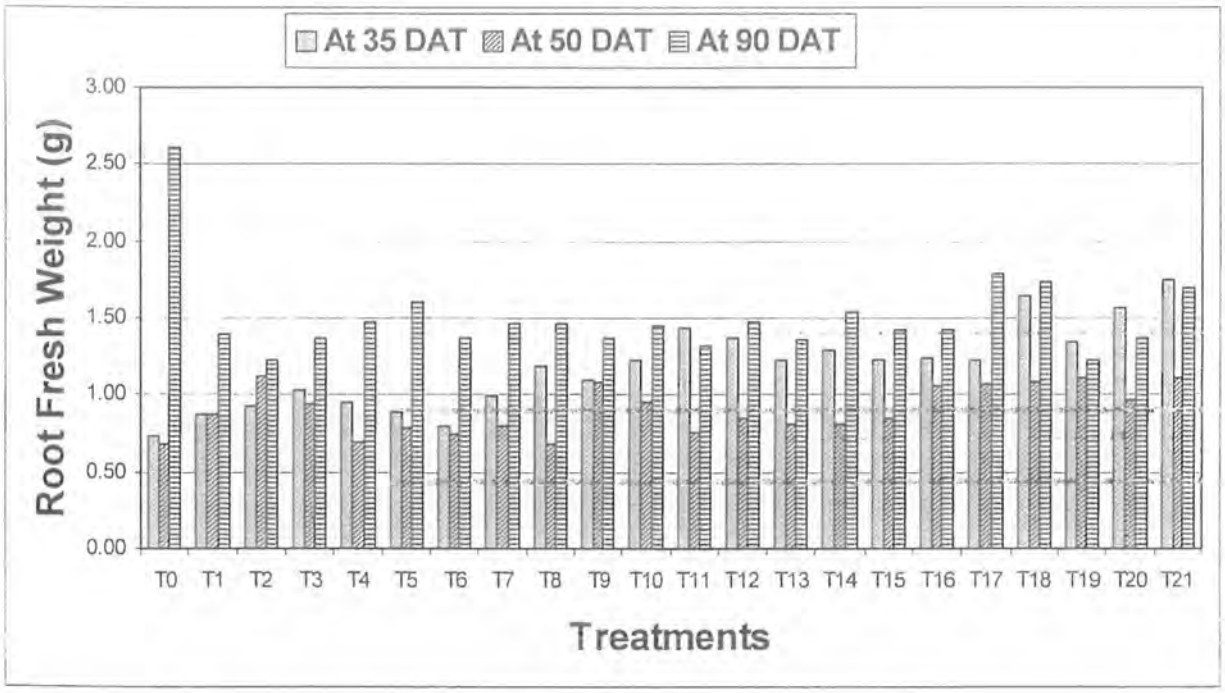

Figure 4.38: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on root fresh weight.

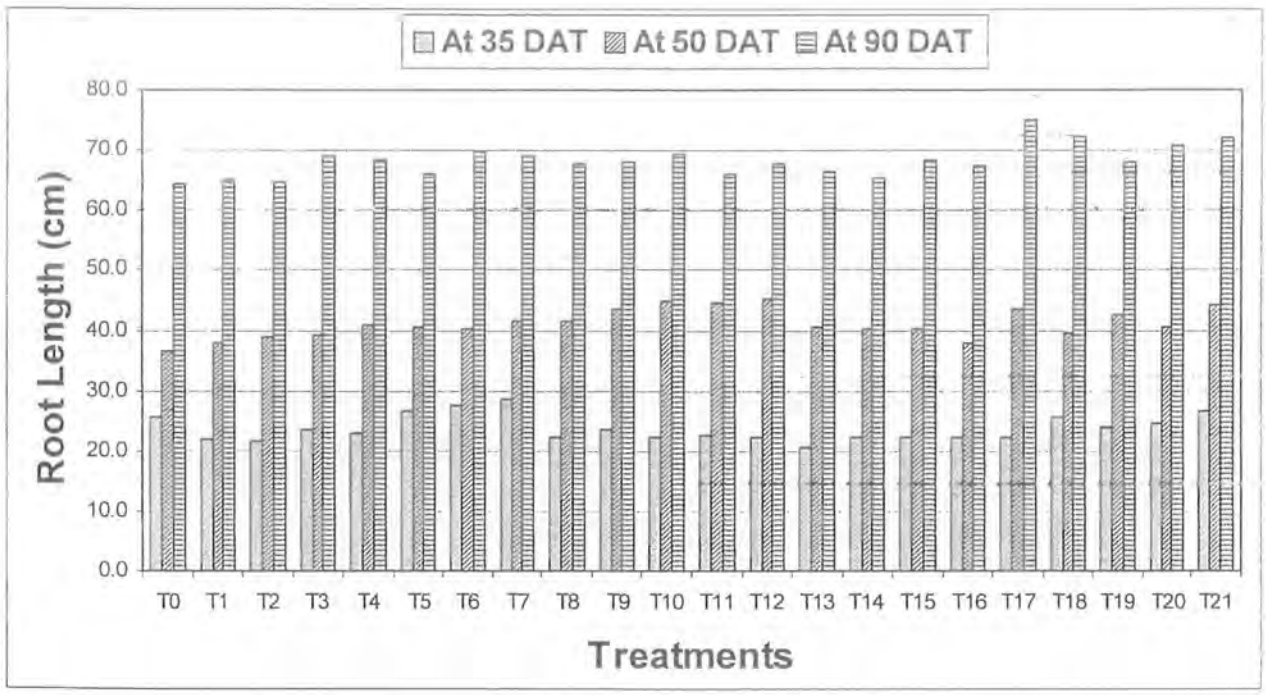

Figure 4.39: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on root length.

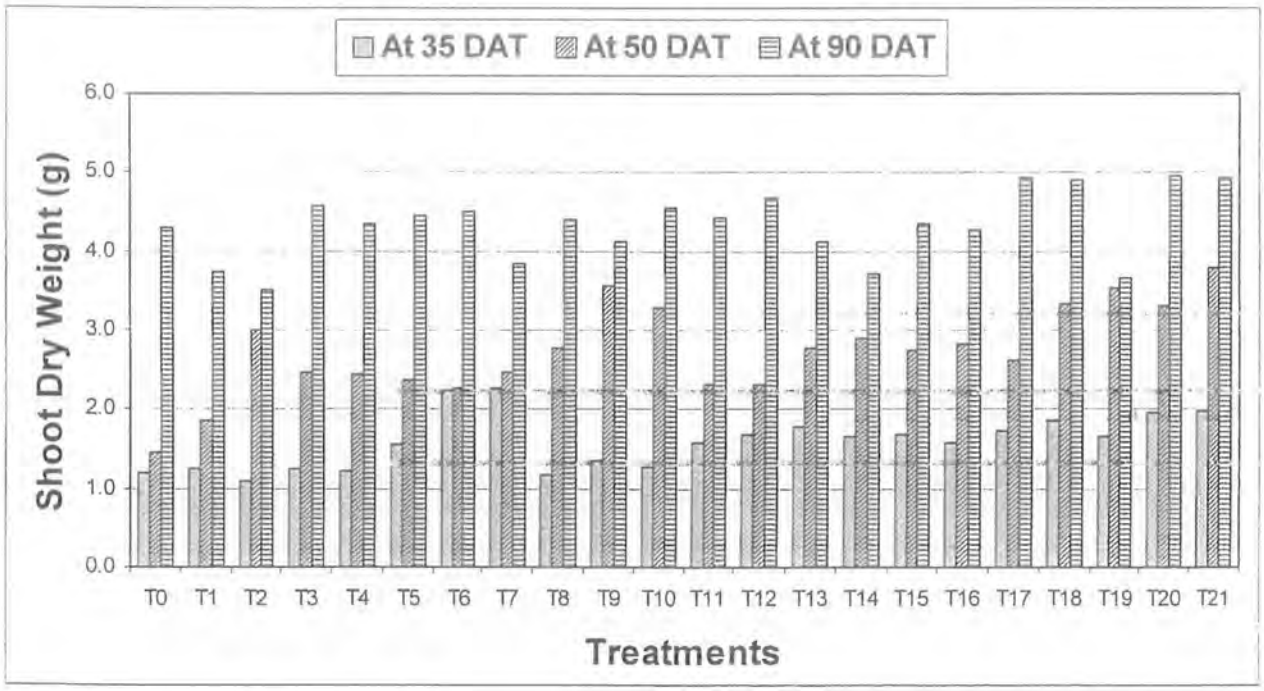

Figure 4.40: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on shoot dry weight.

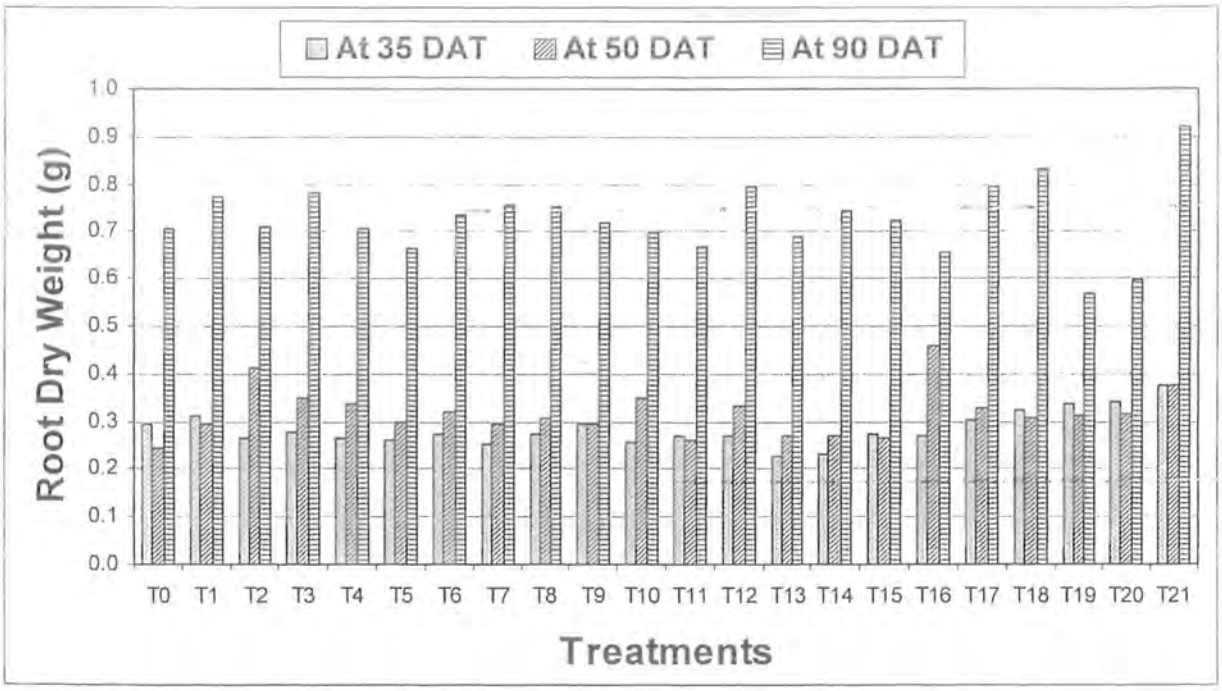

Figure 4.41: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on root dry weight.

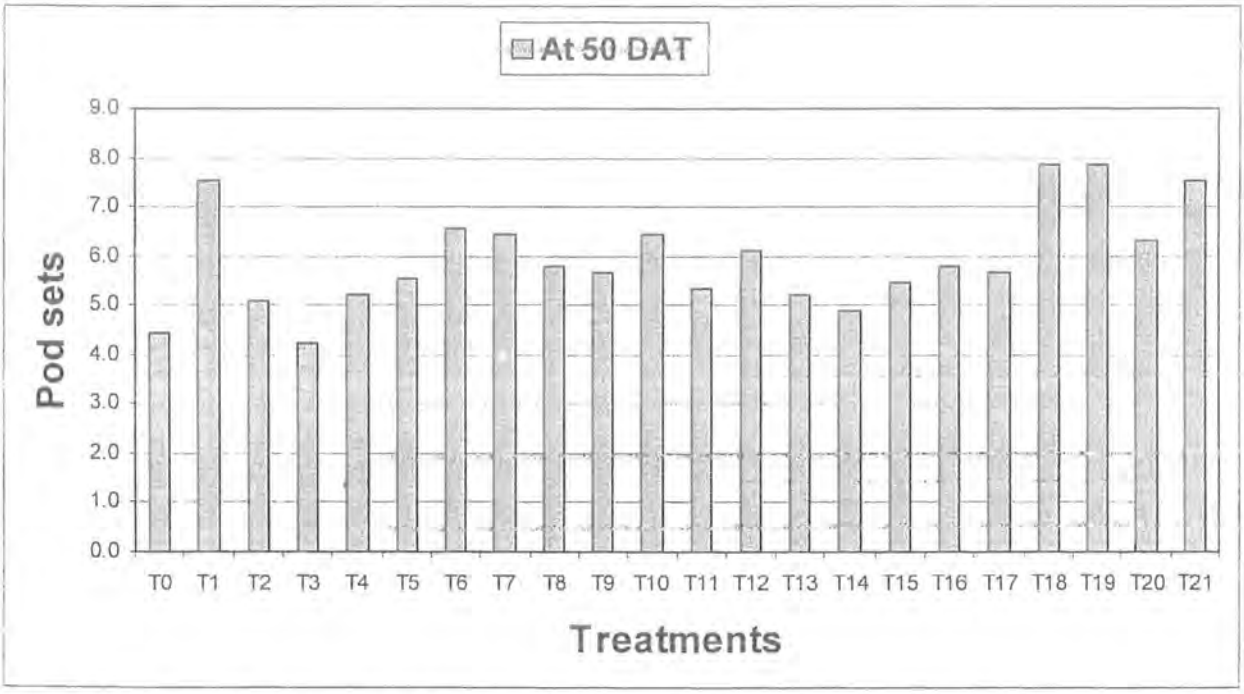

Figure 4.42: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of pod sets at 50 DAT.

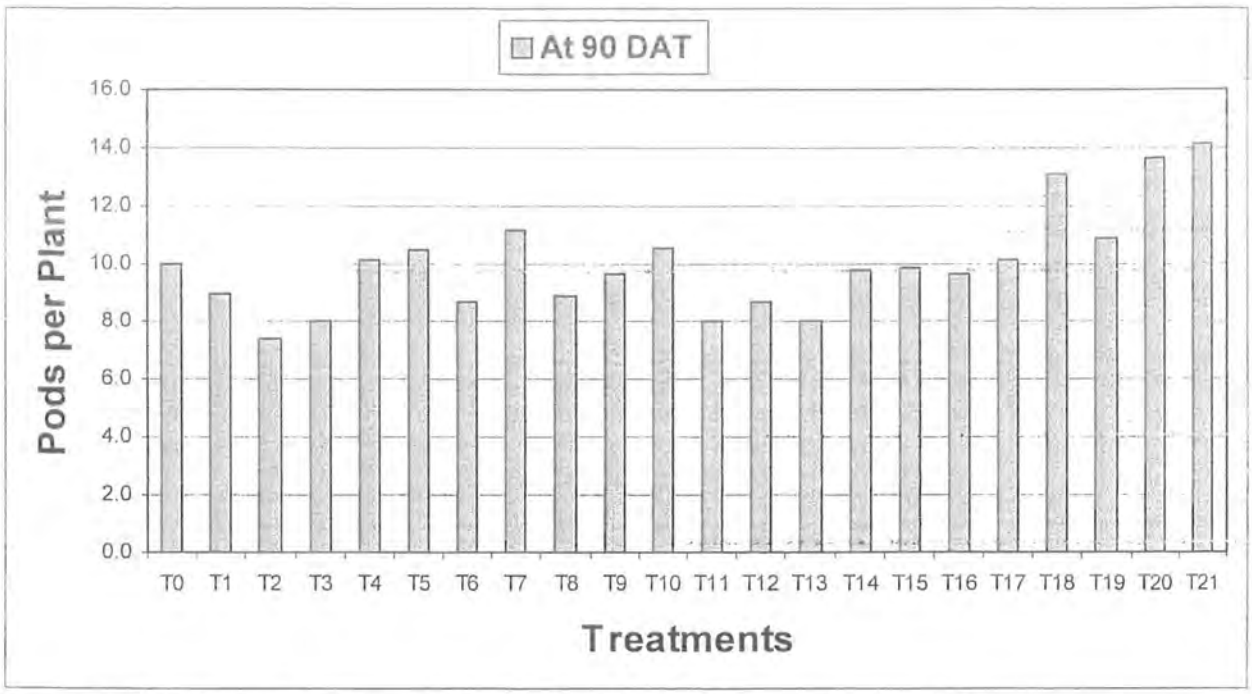

Figure 4.43: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of pods per plant at 90 DAT.

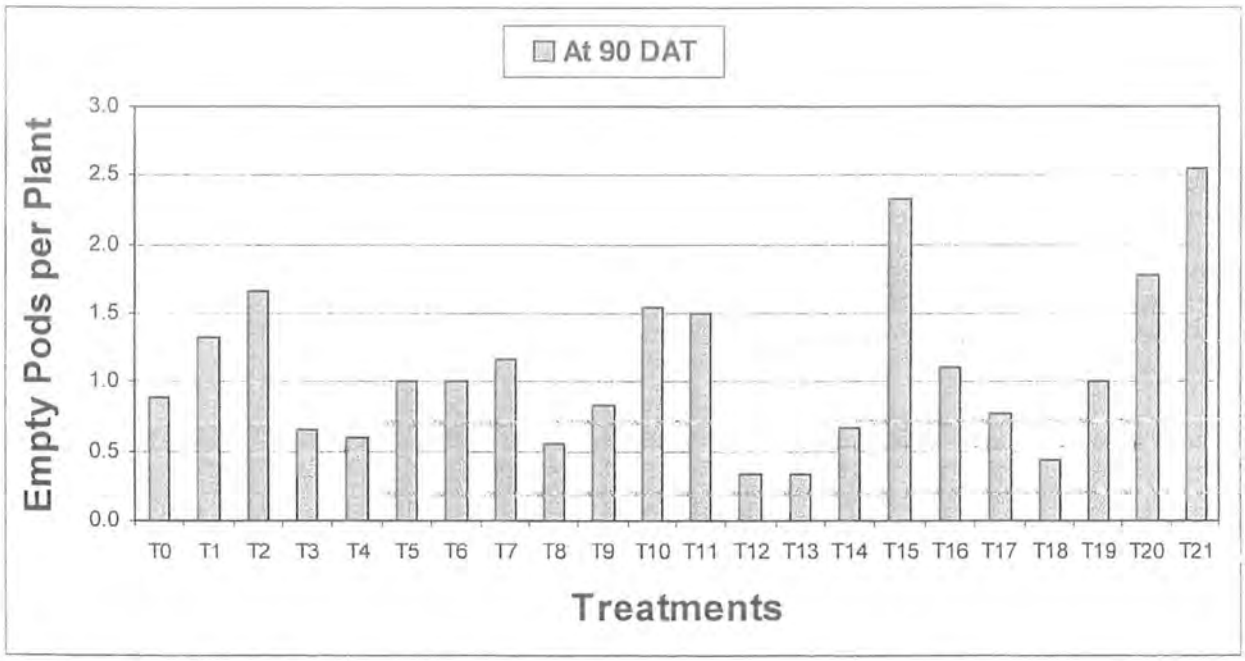

Figure 4.44: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of empty pods per plant at 90 DAT.

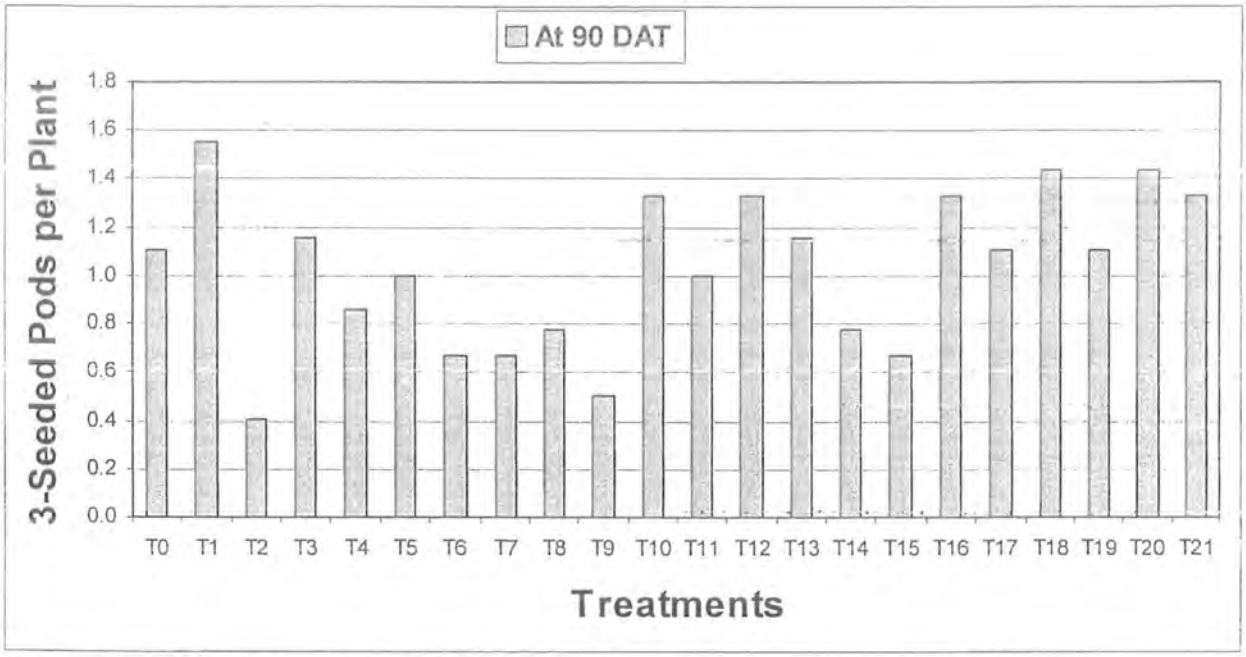

Figure 4.45: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of 3-seeded pods per plant at 90 DAT.

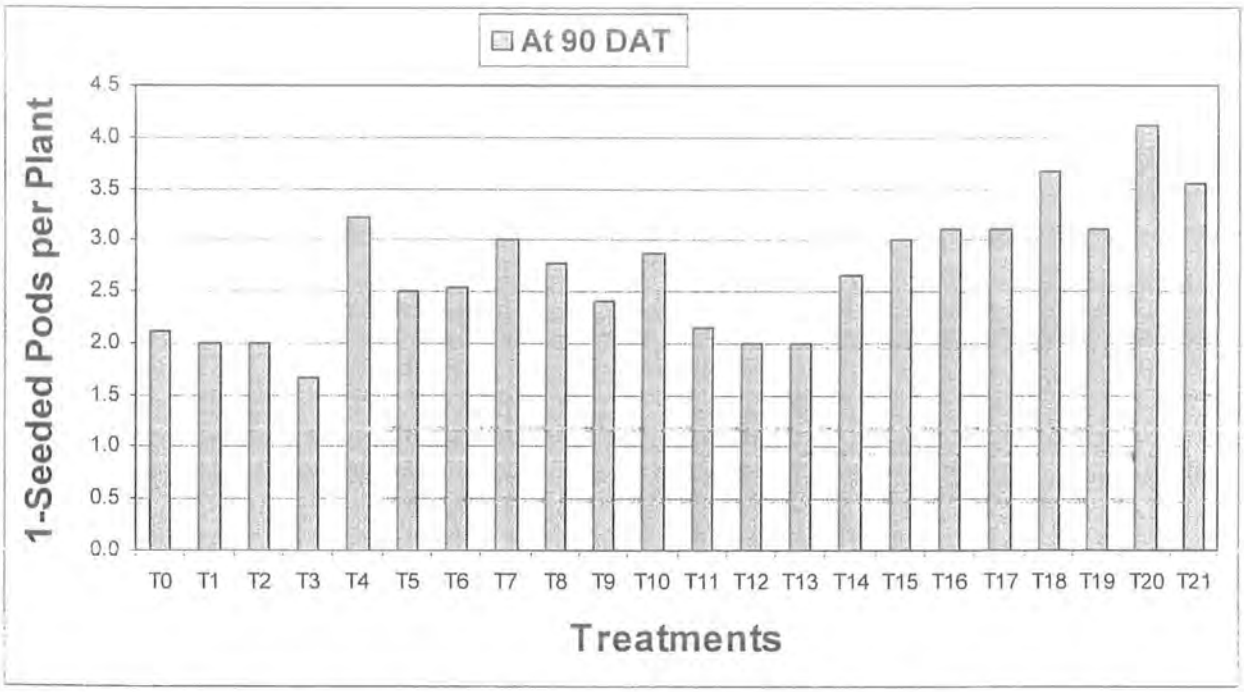

Figure 4.46: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of 1-seeded pods per plant at 90 DAT.

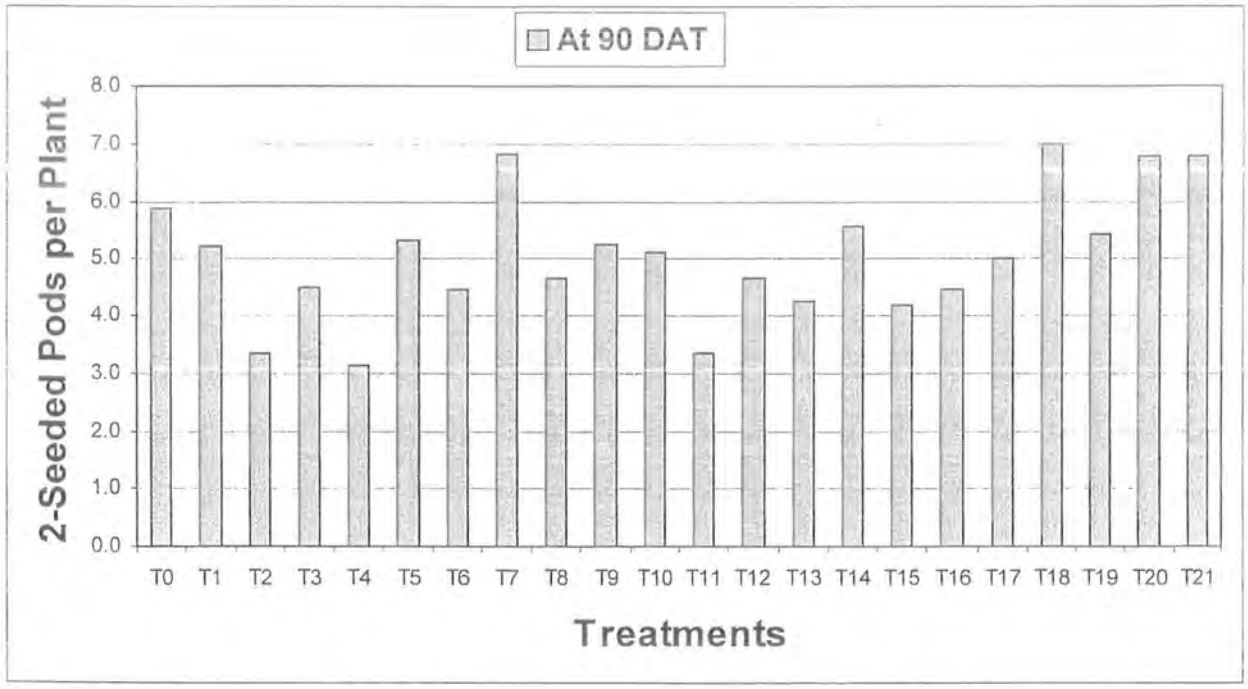

Figure 4.47: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on number of 2-seeded pods per plant at 90 DAT.

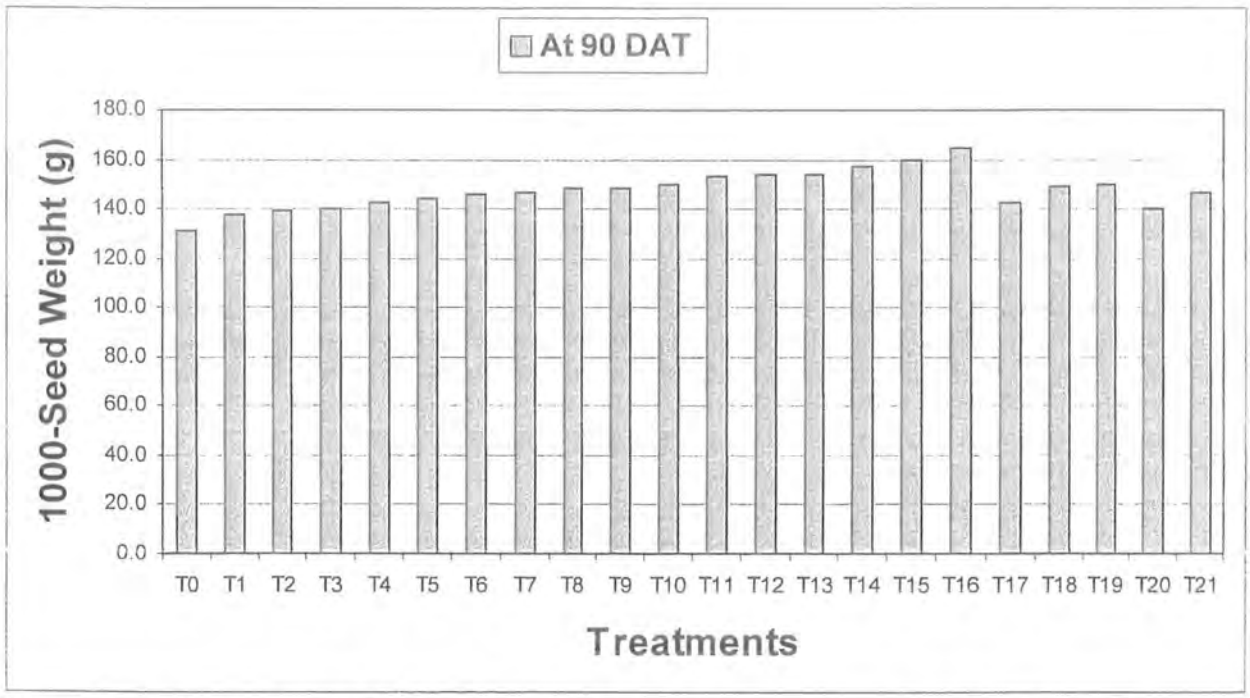

Figure 4.48: Effect of combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP, and GA_3) on 1000-seed weight at 90 DAT.

Chapter 5

Discussion

A set of pot experiment was conducted to know the effect of foliar application of different combinations of micronutrients (Boron and Zinc) and growth regulators (IAA, BAP and GA_3) on growth and yield of *Glycine max.* L. (Merril) soybean variety NARC-4 Most of combinations of B/Zn and growth regulators affected the growth and yield parameters of *Glycine max.* L. (Merril).

Number of branches of soybean plants was not significantly affected by micronutrients (B/Zn) and growth regulator combinations. T_{16} where Zn (50ppm), IAA (10^{-3} M) were used in combination, and T_{19} where B and Zn 50ppm each and IAA (10^{-3} M) were used in combination produced maximum number of branches (1.33) at 35 DAT. T_{13} where B (50ppm), IAA (10^{-3} M) and BAP (10^{-3} M) were used in combination produced maximum number of branches at 50 DAT for soybean plants. At 50 DAT most of the treatments increased number of branches except T_6 where B (100ppm) and BAP (10^{-4}M) were used in combination (1.11), T_7 where Zn (50ppm) and BAP (10^{-3} M), T_8 where Zn (100ppm) and BAP (10^{-4} M), T_9 where B (50ppm) and GA_3 (10^{-3} M) were used in combination decreased or had not affected number of branches.

No such combinations are found on previous work to compare the results. Boron application increased number of branches of soybean plants at 50ppm (Garg *et al.* 1999). Hatwar *et al.* (2003) reported that application of Zn, Fe and B at 0.1% was most effective, yielding number of branches, plant height, and diameter of stem and spread of plant.

Naveed (2004) reported that soil plus foliar application of Zn (50ppm) produced maximum number of secondary braches (4.00) in tomato; in case of chilli foliar spray of 150ppm Zn produced maximum number of secondary branches. Jadoon (2004) reported maximum number of branches (1.53) for foliar spray of NAA + Kn + GA_3 (10^{-5} M of each) at 60 days; 10^{-5} M NAA at 100 days (8.00) and BAP 10^{-3} M foliar spray at 100 days produced maximum branches (12.00) at 130 days after sowing in *Nigella sativa.* Merlo *et al.* (1987) increased number of branches in soybean plants by BAP application Daiman and Mii (1991) reported similar results with BAP application in *Podocapous macrophyllus* by spraying BAP. Present findings are also in conformity with these

findings. Results indicated that IAA and BAP alone or in combination has enhancing role in number of branches per plant with Boron or Zinc used in combination at low concentration (50ppm) Cytokinins (BAP and Kn.) are responsible for lateral bud and shoot development. Auxins inhibit lateral bud and shoot development but their effect was branched by BAP in T_{16} and T_{13} for number of branches at 35 and 50 DAT. Boron and zinc at 50ppm and IAA 10^{-3} M also increased number of branches. Sarkar *et al.* (2002) reported that GA_3 and IAA significantly increased number of branches per plant, especially at final stage of plant growth. IAA induced higher number of branches as reported by Chhipa and Lal (1988).

Mean value for number of leaves per plant indicated that most of the combined foliar treatments of B/Zn and growth regulators have increased number of leaves at 35 DAT but at 50 DAT some treatments decreased number of leaves per plant; with most increasing the number of leaves. Maximum number of leaves at 35 DAT is seen in T_{21} (7.00) where B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) were used in combination; same treatment produced with T_{18} where Zn (50ppm), IAA (10^{-3} M) and GA_3 (10^{-3} M) was used in combination produced maximum number of leaves per plant (8.88), T_6 B (100ppm) + BAP (10^{-4} M), T_7 Zn (50ppm) + BAP (10^{-3} M), T_8 Zn (100ppm) + BAP (10^{-4} M) results for number of leaves followed the maximum number of leaves (8.77). No such combinations were found for comparison. Garg *et al.* (1999) reported maximum number of leaves with 50ppm B concentration foliar spray in soybean plants. Naveed (2004) reported similar results with boron foliar spray for tomato and chilli plants; and zinc foliar (50ppm) and soil plus foliar treatment (50ppm) produced maximum number of leaves in tomato and with only foliar application of 50ppm zinc produced maximum number of branches in chilli. Similar results for zinc application were recorded by Yadav *et al.* (2001). Jadoon (2004) reported that 10^{-4} M of each NAA, Kn and GA_3 in combination produced maximum number of leaves per plant at 60 days in *Nigella sativa* and 10^{-3} M of both IAA and Kn produced maximum number of leaves in *Nigella sativa* at 100 days. Hye *et al.*(2002) got maximum number of leaves in *Allium cepa* by applying 200ppm IAA and 200ppm GA_3. Chaudhary and Qurat-ul-Ain. (2003) reported increased number of leaves in *Phaseolus vulgaris* using both IAA and Kn. in combinations. Shishido and Saito (1984) also reported increased number of leaves per plant by foliar

application of GA_3. In present case number of leaves increased with foliar application of GA_3 but in combination with IAA and zinc. Khurshid *et al.* (1992) reported decreased number of leaves per plant by foliar application of GA_3. In present study decreased number of leaves were observed for T_9 where B (50pm) and GA_3 (10^{-3} M), T_{10} where B (100ppm) and GA_3 (10^{-4} M), T_{16} where Zn (50pm) and IAA (10^{-3} M) + GA_3 (10^{-3} M) were used in combination. These results are according to the findings of Khurshid *et al.* (1992) at 50 DAT. But contradictory to them at 35 and 50 days GA_3 in combination with boron and zinc increased number of leaves. Zinc is known to induce auxin synthesis, synthesis of auxin might cause significant response along with exogenous IAA applied, zinc also takes part in metabolism as an activator so it can increase metabolism. Auxins in combination with cytokinin (IAA and BAP) increase number of leaves by rapid cell division and elongation.

Middle leaflet length of soybean plants was increased by micronutrients (B/Zn) phytohormonal combination at 35 days but at 50 days it was decreased by some combined foliar treatments. T_{21} where B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) was used in combination produced maximum middle leaflet length (6.88cm) followed by T_5 where B (50ppm) and BAP (10^{-3} M) (6.74cm) at 35 DAT. T_{21} also produced maximum middle leaflet length at 50 DAT followed by T_5 (6.78cm). Cytokinins are known to induce cell elongation, so they in combination with one B/Zn or two micronutrients (B and Zn) have increased middle leaflet length. No exact report for such combinations is available for comparison. Considering micronutrient (B/Zn) and growth regulators foliar sprays; Boron as 50ppm foliar spray on soybean plant increased leaf area (Garg *et al.*s 1999). Leaf area index of chilli plant was maximum with foliar spray of 50ppm boron as reported by Naveed (2004), also foliar spray of zinc (150ppm) produced maximum leaf area index in chilli plant. Yadav *et al.* (2001) also reported similar results for zinc. Here in this case boron and zinc at 50ppm in combination or separately with BAP increased middle leaflet length. Naeem *et al.* (2002) reported 500ppm Kn showed an increased in the area of first five leaves in Lentil plant, which was 14.72% after 30 days. Jadoon (2004) reported maximum leaf length for *Nigella sativa* for foliar treatment of 10^{-4} M of NAA + Kn + GA_3 each in combination at 60 days and 10^{-4} M IBA at 100 days. Hye *et al.* (2002) reported that 200ppm GA_3 produced largest leaves in *Allium cepa*. The increase in

leaf length due to application of GA_3 was also reported earlier (Singh *et al.* 1983; Saleh *et al.* 1989). Khan *et al.* (1996) reported maximum leaf length by 10^{-5} M GA_3 in *Brassica juncea*. Cytokinin (BAP) can induce cell division and cell enlargement, GA_3 helps in cell enlargement so both have increased middle leaflet length.

Middle leaflet width of soybean plants was increased by some combined foliar treatments and decreased by some other treatments at 35 days. But at 50 days most of the treatments increased middle leaflet width as compared to control. Middle leaflet width was maximum for T_5 (4.78cm) at 35 DAT. T_5 was composed of B (50ppm) and BAP (10^{-3} M). At 50 days T_3 Zn (50ppm) and IAA (10^{-3} M) produced maximum middle leaflet width (4.45cm). No exact reports are available to compare the results BAP is known to induce cell division. IAA, BAP with boron and zinc either alone produced maximum middle leaflet width. This is in accordance to above discussion.

Petiole length of soybean plants was studied. All the treatments at 35 days and most treatments at 50 days increased petiole length as compared to control. Maximum petiole length was observed at 35 days for T_{19} having B (50ppm), Zn (50ppm) and IAA (10^{-3} M), at 50 days T_{21} having B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) produced maximum petiole length (11.27cm). No exact reports for this parameter are available for combinations used in this research work. Boron and zinc foliar sprays increase metabolism and IAA and GA_3 increased cell division and cell enlargement thus increase petiole length.

Shoot length of *Glycine max.*L.(Merril) soybean plants were significantly affected by combined foliar treatments of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3). Maximum shoot length at 35 days was observed for T_{21} B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) (40.12cm) followed by T_{14} B (50ppm), IAA (10^{-3} M) and GA_3 (10^{-3} M) (34.11cm). At 50 days maximum shoot length was observed for T_{21} (41.92cm) followed by T_{10} B (100ppm) and GA_3 (10^{-4} M) (41.64cm) followed by T_9 B (50ppm) and GA_3 (10^{-3} M) (41.41cm). At 90 days maximum shoot length was observed for T_{21} followed by T_{17} Zn (50ppm), IAA (10^{-3} M) and GA_3 (10^{-3} M) followed by T_{20} B (50ppm), Zn (50ppm) and BAP (10^{-3} M) (45.01cm) followed by T_{14} B (50ppm), BAP (10^{-3} M) and GA_3 (10^{-3} M) (45.14cm). Shoot length at all three stages showed that all those treatment where GA_3 was present in combination with one or two micronutrients

and one growth regulator (IAA or BAP) increased shoot length significantly than other treatments. No exact report for such combinations as used in this research work is available to compare the results but keeping in view the foliar application of micronutrients and growth regulators it can be interpreted. Naveed (2004)reported maximum shoot length for tomato and chilli plants with foliar spray of 50ppm Zn and 150ppm Zn respectively,while 100ppm boron produced maximum shoot length in tomato and soil plus foliar spray of boron produced maximum shoot length. Hamsaveni *et al.* (2003) reported that foliar spray of boron at 0.5% was found beneficial in increasing plant height of tomato. Hatwar *et al.* (2003) reported that single spray of boric acid at 0.1% was effective in yielding plant length in chilli plant. However Garg *et al.* (1999) reported a decrease in soybean shoot length with foliar application of 50mg/litre and 100mg/litre boron. Hatwar *et al.* (2003) reported 0.1% Zn (zinc sulfate) to be most effective in yielding plant height. Jadoon (2004) reported that at 60 days maximum height of *Nigella sativa* plant was observed for 10^{-3} M concentration of NAA + Kn + GA_3 used in combination. At 100 and 130 days plant height was maximum for 10^{-3} M GA_3 sprayed singly. Deotale *et al.* (1998) in soybean and Abd-el-Fattah (1997) reported that GA_3 application caused a profound stem elongation. Singh (1966) sprayed GA_3 on tomato plants and observed that it increased the plant height at 250ppm and 100ppm. Sarkar *et al.* (2001) reported that GA_3 at 100ppm produced the tallest soybean plants at all growth stages. IAA at 100ppm was superior to 200ppm in producing taller plants,GA_3 was more efficient in stem elongation than IAA. Naeem *et al.* (2003) reported GA_3 + IAA seed soaking and later on application on hypocotyl induced significant shoot length. GA_3 induced higher plant height was reported earlier in okra (Kumar *et al.* 1996), sesame (Sontakey *et al.* 1991), rice (Awan and Alizai, 1989) and groundnut (Lee, 1990). Singh and Sambhi (1967) reported increase in plant height in Lettuce. Brussels spout (Selman and Bora, 1968) increase in stem height. Similar findings were reported by Kausar (1976) who treated okra plants with GA_3, which increased plant height significantly. GA_3 alone or in combination is responsible for (internodal) stem elongation. GA_3 is mostly used to increase height in dwarf plants. But present results also suggest that it can increase plant height or shoot length in normal plants. Present findings are mostly in accordance with above cited workers.

Shoot fresh weight was increased by most of the combined foliar treatments as compared to control at 35 DAT increased by all treatments at 50 DAT and increased by most and decreased by some treatments at 90 DAT as compare to control. Maximum shoot fresh weight was recorded for T_8 Zn (100pm) and BAP (10^{-4} M) (9.51g) at 35 DAT. At 50 DAT for T_{21} B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) (14.34g) and at 90 DAT for T_{12} Zn (100pm) and GA_3 (10^{-4} M) (15.94g). GA_3 increased plant height and cytokinin increased other parameters and total biomass of plant by cell division and elongation. No findings are available to compare the observation of present research work. Naveed (2004) reported maximum shoot fresh weight of tomato for foliar 50ppm boron, foliar + soil treatment of 50ppm zinc, soil +foliar 50ppm boron and 150ppm foliar spray of zinc in chilli produced maximum shoot fresh weight. The application of foliar fertilizer (B/Zn) + growth regulator during the periods enhanced nutrients demand could allow for increased growth rate and yield (Garcia and Han-Way, 1976). Yadav *et al.* (2001) found that 0.1% boron as foliar spray increased plant fresh weight.

Root fresh weight of soybean plants was increased by all treatments as compared to control. Maximum root fresh weight was observed at T_{21} B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) (1.75g). Increase in root fresh weight was more in treatments where two phytohormones and one micronutrients was used in combination for foliar spray and in treatments with GA_3 with one of the micronutrients. Root fresh weight at 50 DAT was maximum again for T_{21} (1.107g) root fresh weight showed a decreased as compared to first stage treatments. Maximum root fresh weight was observed for T_{19} B (50ppm), Zn (50ppm) and IAA (10^{-3} M) (2.61g) at 90 DAT. No previous report for such micronutrient and growth regulator combination is available for comparison. Considering micronutrients (B/Zn) foliar spray; Naveed (2004) reported maximum root fresh weight for 150ppm boron foliar and 50ppm zinc foliar for tomato, soil + foliar boron and 150ppm foliar treatment produced maximum root fresh weight in chilli plants.

Root length of soybean plants with all combined foliar treatments of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) as compared to control at 35, 50 and 90 DAT. T_7 Zn (50ppm) and BAP (10^{-3} M) produced maximum root length (28.43cm) followed by T_6 B (100ppm) and BAP (10^{-4} M) (27.47cm) at 35 DAT and T_{12} Zn (100ppm) and GA_3 (10^{-3} M) produced maximum root length (45.29cm) at 50

DAT and T_{17} Zn (50ppm), IAA (10^{-3} M) and GA_3 (10^{-3} M) (74.93cm) at 90 DAT followed by T_{18} Zn (50ppm), BAP (10^{-3} M) and GA_3 (10^{-3} M) (72.53cm) at 90 DAT . No exact report for root length for the sort of combinations used in present research work. Naveed (2004) reported foliar of 150ppm boron and soil + foliar treatment of 50ppm zinc produced maximum root length in tomato and 150ppm zinc foliar and soil + foliar boron produced maximum root length in chilli plants. Garg *et al.* (1999) reported reduction in root length of plants with boron at 50 and 100ppm. Jadoon (2004) reported maximum root length with 10^{-3} M of each NAA + Kn + GA_3 sprayed at 60 days and 10^{-3} M GA_3 produced maximum root length at 100 days and at 130 days. Hye *et al.* (2002) reported that 200ppm GA_3 increased root length in *Allium cepa*.

Shoot dry weight of soybean plant increased with all combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) combinations as compared to control. Maximum shoot dry weight was observed for T_7 Zn (50ppm) and BAP (10^{-3} M) (2.27g) followed by T_6 B (100ppm) and BAP (10^{-4}M) (2.24g) at 35 DAT. Maximum shoot dry weight was observed for T_{21} B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) (3.79g) at 50 DAT. Maximum shoot dry weight at 90 DAT was observed for T_{26} B (50ppm), Zn (50ppm) and BAP (10^{-3} M) (4.97g) followed by T_{17} Zn (50ppm), IAA (10^{-3} M) and GA_3 (10^{-3} M) (4.94g) and T_{21} B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) (4.93g) and T_{18} Zn (50ppm), IAA (10^{-3} M) and GA_3 (10^{-3} M) (4.91g) at 90 DAT. No exact report is available to compare the results as no such combination of micronutrients and growth regulators (IAA, BAP and GA_3) were used. Naveed (2004) reported that maximum shoot dry weight was obtained with 150ppm boron foliar and Zn 50ppm soil + foliar treatment in chilli plant. Rammah *et al.* (1998) reported that soil + foliar spray of boron increased dry matter yield of alfalfa. Bussler and Doring (1979) reported that the occurrence of significant concentrations of boron in chloroplasts and they suggested a role of boron in photosynthetic, which might have increased dry matter production. Kausar and Sharif reported that in case of maize plant dry matter increased remarkably due to applied Zn by all methods. Jadoon (2004) reported that maximum plant dry weight was obtained for 10^{-3} M of each NAA + Kn + GA_3 used in combination at 60, 100 and 130 days. These findings are in confirmation of present findings where BAP and GA_3 along with zinc produced maximum shoot dry weight.

Root dry weight of soybean plants was increased by all combined foliar treatments of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) as compared to control root dry weight was recorded for T_{21} B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) (0.375g) at 35 DAT, for T_{16} Zn (50ppm), IAA (10^{-3} M) and BAP (10^{-3} M) (0.460g) at 50 DAT and for T_{21} B (50ppm), Zn (50ppm) and GA_3 (10^{-3} M) at 90 DAT. At 35 DAT treatments in which either two micronutrients or two growth regulators were present with third micronutrient or growth regulator increased root dry weight. At 50 DAT treatments with IAA or GA_3 as one of its component increased root dry weight. No exact report regarding present combinations of micronutrients and growth regulators is available for comparison. Naveed (2004), reported maximum root dry weight for chilli plant with foliar + soil treatment of 50ppm B, 50ppm Zn foliar treatment in tomato and 150ppm Zn foliar treatment in case of chilli produced maximum root dry weight. Jadoon (2004) obtained maximum plant dry weight with 10^{-3} M of NAA + Kn + GA_3 each foliar treatment in *Nigella sativa*.

Number of pod set per plant at 50 DAT was increased by all the treatments in soybean plants as compared to control. Maximum number of pod set per plant at 50 DAT was observed in T_{18} Zn (50ppm) IAA (10^{-3} M) and GA_3 (10^{-3} M) and T_{19} B (50ppm) Zn (50ppm) and IAA (10^{-3} M) (7.88). T_{21} B (50ppm) Zn (50ppm) and GA_3 (10^{-3} M) also increased number of pod set per plant significantly as compared to control (7.55). No exact report is available for present combined foliar treatments of B/Zn and IAA BAP and GA_3. Garg *et al.* (1999) reported that 50ppm B and 100ppm B foliar application on soybean plants increased number of pod set per plant as compared to control. 50ppm B foliar spray produced maximum number of pod set per plant. Sarkar *et al.* (2002) reported increase in number of fruit (pod) set for soybean plant with 100ppm IAA and GA_3 spray.

Number of pods per plant at 90 DAT was increased by all treatments in soybean plants as compared to control. Maximum number of pods per plant was observed for T_{19} B (50ppm) Zn (50ppm) and IAA (10^{-3} M) (14.11) followed by T_{20} B (50ppm) Zn (50ppm) and BAP (10^{-3} M) (13.67). Zinc was associated with one or more growth regulator in combination to increase number of pods per plant. No exact report for present micronutrient and growth regulator combination is available for comparison.

Garg *et al.* (1999) observed that number of pods per plant was significantly increased by 50ppm boron foliar spray followed 100ppm boron foliar spray.

Number of seedless (empty) 3-seeded 1-seeded and 2-seeded pods per plant was also recorded for *Glycine max.* L.(Merril) soybean plants at 90 DAT. Maximum empty pods were observed in T_{21} B (50ppm) Zn (50ppm) and GA_3 (10^{-3} M). Some treatments increased some decreased number of empty pods per plant as compared to control. T_{12} and T_{13} (0.333) product minimum number of empty pods. Maximum number of 3-seeded pods per plant was observed for T_1 B (50ppm) and IAA (10^{-3} M) (1.55). Number of 1-seeded pods per plant was increased by most treatments except T_1 T_2 T_3 T_{12} and T_{13} which decreased number of 1-seeded pods per plant. Maximum number of 1-seeded pods per plant was observed in T_{20} B (50ppm) Zn (50ppm) and BAP (10^{-3} M) (4.11). Most of the treatments decreased number of 2-seeded pods per plant except T_7 (6.83) T_{18} (7.00) T_{20} and T_{21} (6.77 each). Maximum number of 2-seeded pods per plant was observed for T_{18} Zn (50ppm) IAA (10^{-3} M) and GA_3 (10^{-3} M) (7.00). No exact report for present treatment combinations is available for comparison. Garg *et al.* (1999) reported boron at 100mg/litre as boric acid was suitable for flowering to boron at 100mg/litre which might be due to its toxic effect at the higher level. Number of seeds per pod was increased by 50mg boron foliar spray and decreased by 100mg boron foliar spray showing its toxic nature. Boron (50ppm) in present study with IAA 10^{-3} M produced maximum number of 3-seeded pods per plant. Sarkar *et al.* (2002) reported highest number of seeds per plant with 100ppm GA_3, while 200ppm IAA produced lowest number of seeds per plant. They also reported that lower concentrations (100ppm) of IAA and GA_3 increased the number of pods per plant better than higher concentrations. 100ppm GA_3 produced maximum number of pods per plant and 200ppm IAA produced minimum number of pods. Increase in number of pods has been reported in groundnut, rice and gram by application of 100ppm IAA and GA_3 (Lee, 1990; Awan and Alizai, 1989; Mange, 1971). Naveed (2004) reported that soil + foliar 50ppm Zn spray and foliar 50ppm Zn spray produced maximum number of fruit per plant in tomato and chilli, foliar spray of 150ppm boron and 50ppm boron produced maximum number of fruits per plant in tomato and chilli plants. Foliar spray of boron at 0.5% was found beneficial in increasing fruit size and seed yield (Hamsaveni *et al.* 2003). Foliar and/or soil applied boron improved fruit set,

total yield, marketable yields, fruit shelf life and fruit firmness (Davis *et al.* 2003). Hatwar *et al.* (2003) reported that single spray of 0.1% boron improved number of fruits per plant, yield per plant of red ripe chilli. Prasad *et al.* (1997) reported that boron application significantly increased tomato yield compared to the control treatment. Kalita (1989) reported increase in number of pods of *Vigna radiata* by application of NAA. Some works increased fruit yield with application of single hormone. Jadoon (2004) reported an increase in number of fruits of *Nigella sativa* by phytohormonal combination. Maximum numbers of fruits (capsules) were observed for 10^{-3} M of NAA + Kn + GA_3 each in combination. Auxins and GA_3 have role in fruit development. Abd-El-Fattah (1996) noted that number of seed per Flax pod was increased by 10-5 M solution of IAA. Increased seed yield in mungbean (*Vigna radiata*) was also investigated by foliar application of 600ppm IA (Newaj *et al.* 200).

1000-seed weight of soybean was increased by all of the treatments as compared to control. Maximum 1000-seed weight for plant was observed in T_{16} Zn (50ppm), IAA (10^{-3} M) and BAP (10^{-3} M) (164.4g) followed by T_{15} B (50ppm), BAP (10^{-3} M) and GA_3 (10^{-3} M) (160.0g) followed by T_{14} B (50ppm), IAA (10^{-3} M) and GA_3 (10^{-3} M). No exact report for these sorts of combinations is available to compare the result. Sarkar *et al.* (2001) reported that foliar spray of 100ppm GA_3 produced maximum 1000-seed weight and 100ppm IAA produced lowest 1000-seed weight. Application of 100ppm GA_3 was reported to increase 100 seed weight in groundnut and sorghum (Lee 1990; Shinde *et al.* 1989). Garg *et al.* (1999) reported that 50ppm boron increased 100 seed weight while 100ppm boron foliar spray decreased 100 seed weight. This decrease may be attributed to low pollen fertilization as reported by Mishra and Patil (1987). Jadoon (2004) reported that most of treatments of phytohormones increased 1000-seed weight in *Nigella sativa*. 10^{-4} M of each IAA, Kn and GA_3 in combination. In present finding GA_3 either with IAA or with BAP in higher concentrations with one of the micronutrients showed increase in 1000-seed weight. Lallu and Dixit (1996) got maximum 1000-seed weight in *Brassica juncea* by applying 500ppm IAA. Singh and Kumar (1991) reported similar results with application of NA in Indian mustard. Similarly BAP increased 1000-seed weight in barley (Ehrenbergerory and Andonov 1985) and in *Phaseolus vulgaris* (Uddin, 1985).

Conclusions:

Non-significant results were observed for combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3) for following parameters: number of branches (at 35 and 50 DAT), middle leaflet width (at 35 and 50 DAT), shoot fresh weight (at 50 and 90 DAT), root fresh weight (at 50 and 90 DAT), shoot dry weight (at 50 DAT), root dry weight (at 50 DAT) and number of 3-seeded pods per plant (at 90 DAT). All other parameters like number of leaves, middle leaflet length, shoot fresh weight (at 35 DAT), shoot dry weight (at 35 and 90 DAT), root fresh weight (at 35 DAT), root dry weight (at 35 and 90 DAT), number of pod sets per plant (at 50 DAT), shoot length (at 35, 50 and 90 DAT), number of pods per plant (at 90 DAT), number of 1-seeded and 2-seeded pods per plant (at 90 DAT), and 1000-seed weight were significantly affected by combined foliar application of micronutrients (B/Zn) and growth regulators (IAA, BAP and GA_3). T_{21} (B50ppm + Zn50ppm + $GA_3 10^{-3}$M) proved to be most effective producing maximum: number of leaves per plant (at35 and 50 DAT), middle leaflet length (at 35 DAT), petiole length (at 50 DAT), shoot length (at 35, 50 and 90 DAT), root fresh weight (at 35 DAT), root dry weight (at 35 and 90 DAT), number of pods per plant (at 90 DAT), number of empty pods per plant (at 90 DAT). T_0 (control) was the least responsive with respect to growth and yield parameters. Most of treatments had positive effect on growth and yield parameters of soybean, but some treatments decreased growth and yield parameters depending upon concentration of constituent micronutrient and growth regulators. Treatments having GA_3 as one of its constituent had enhancing effect on shoot length.

References

Abdel, G.B.A., El-Shourbagy, M.N. and El-Naggar. 1996. Effect of IAA and GA_3 on flax (*Linum usitatissimum* L.) seed yield and their metabolic constitutes. Egyptian Journal of Botany, 35: 1-9.

Abd-El-Fattah, M.A. 1997. Effect of phosphorus, Boron, GA_3 and their interaction on growth, flowering, pod setting, abscission and both green pod and seed yield of broad bean (*Vicia faba* L.) plants. Alexandria Journal of Agricultural Research, 42: 311-332.

Agarwala, S.C., P.N. Sharma, C. Chatterjee and C.P. Sharma. 1981. Develpment and enzyme changes during pollen development in boron deficient maize plants. Journal of Plant Nutri., 3: 329-336

Agrawal,-S-C; Singh,-K-J; Tripathi,-A-K. 2003. Integrated pest management in pigeonpea (*Cajanus cajan*). Indian-Journal-of-Agricultural-Sciences, 73(5): 291-293.

Alagukannan, G. and Vijaykumar, M. 1999. Effect of plant growth substances n yield attributing parameters, yield and quality in fenugreek. South Indian Horticulture, 47(1-6): 130-133.

Alam, S.M., M. Sharif and A. Latif. 1989. Phosphorus-zinc interaction in flooded rice grown on some alkaline soils. Pak. J. of Soil Sci., R (3-4): 3-5.

Andrews, J. 1984. Peppers, the Doesticated Capsicums. University of Texas Press, Austin.

Anonymus. 2000. Fruit, Vegetable and Condiments. Govt. of Pakistan MINFAL. Islamabad, 11-19.

Askari A, I.H. Siddiqui, A. Yasmin, M. Qadiruddin, R. Jafri, S. A.H. Zaidi. 1995. Journal of Islamic Academy of Sciences, 8(1).

Awan, I. and Alizai, H. K. 1989. Effect of plant growth regulators on ripening, grain development and rice quality. Int. Rice Res. Newsletter, 149: 30-31.

Bai, B.Z. and Kastori, R. 1990. Physiological effects of the cytokinin BAP in sunflower. Plant Growth Regulation Abstract, 18(5): 2105 (1992).

Bank, L.W. 2004. Effects of timing of foliar zinc fertilization on yield components of soybean. Australian J. of Agriculture and animal husbandry, 22(116): 226-231.

Baren, F.E., Iqbal, S.H. and Abedin, Z. 1988. Effect of IAA and mYcorrhizal treatments on growth in Allium cepa L. Biologia, 34: 113-122.

Basole,-V-D; Deotale,-R-D; Ilmulwar,-S-R; Kadwe,-B-S; Raut,-S-S. 2003. Effect of hormone and nutrients on biochemical characters and yield of soybean. Botany Section, College of Agriculture, Nagpur, India. Journal-of-Soils-and-Crops, 13(2): 322-326

Bhardwaj, S.N. 1988. Effect of Benzyladenine on boll weight and fiber properties in Cotton. Indian Journal of Plant Physiology, 31(1): 111-113.

Bini, G. and Giannone, M. 1985. The effect of various exogenous plant growth regulators on branch, growth, fruiting, and fruit drop of Olives. Plant Growth Regulators Abstracts, 12(11): 1898 (1986).

Boes, P.C. and Hamher, C.L. 1961. Effect of various concentrations of gibberellins on growth, flowers, fruits, mineral uptake of potato plants. Journal of Indian Agricultural Science, 31: 216-225.

Bose, US. and SK-Tripathi, 1996. Effect of micronutrients on growth, yield and quality of tomato cv. Pusa Ruby in M. P. Crop-Research-Hisar., 12(1): 61-64.

Bouycous, G.J. 1962. Hydrometer method improved for making practical size analysis. Agran. J., 54: 464-465.

Bowszys, T. 1996. Response of winter rape to foliar application of boron fertilizers. 434(1): 71-76.

Brady, N.C. 1984. The nature of property of soil, 8th ed. MacMillan Publications Co., INC., New York, :456.

Brain, P.W. and Hemming, H.G. 1955. The effect of Gibberellic acid on shoot growth of pea seedlings. Plant Physiology, 8: 669-681.

Bruinama, J. 1982. Plant growth regulators in field crops. In: Chemical Manipulation of Crop Growth and Development. (Edit). Mclaren, J.S. Butterworths, T. London, pp: 3-12.

Bujak,-K; Jedruszczak,-M; Frant,-M. 2004. Reduced tillage and foliar nutrition by macro- and microelements and weed infestation of soybean growing in monoculture.Annales-Universitatis-Mariae-Curie-Skodowska-Sectio-E,-Agricultura, 59(2): 825-832.

Bujak,-K; Jedruszczak,-M; Frant,-M. 2004. The effect of reduced tillage and foliar nutrition by macro- and microelements on the yielding of soybean growing in monoculture.Annales-Universitatis-Mariae-Curie-Skodowska-Sectio-E,-Agricultura, 59(1): 139-147.

Bukvac, M.J. and S.H. Witter. 1957. Absorption and mobility of foliar applied nutrients. Plant Physiology, 32: 428-433.

Burns, R.M. and Coggins, J.C.W. 1969. Sweet orange germination and growth aided by water and gibberellin seed soak. Calif Agricultre, pp: 18-19.

Bussler, W. and Doring, H.W. 1979. Verterilung and Loslichkeit von Bor in *Helianthus annuus* in Abhangigkeit Vom Bor-Angebot. Z. Pflanzenern. Bodernkde, 142: 719-730.

Chamel, A. 1970. Some aspect of the foliar feeding of plant. Potash Rev., 16(51): 1-8.

Chatterjee, A., Mabdal, R.K. and Sircar, S.M. 1976. Changes in the levels of growth substances during grain filling in rice. Indian Journal of Plant Physiology, 19: 254-258.

Chaudhry, F.M., and M. Sharif. 1975. In isotope-aided micronutrient studies in rice production with special reference to zinc deficiency, proc. Combined panel. Res. Coordinating meeting, Vienna, 23-27, p.1.

Chaudhry, F.M., M. Sharif, A. Latif and R. H. Qureshi. 1973. Zinc copper antagonism in the nutrition of rice. Plant soil, 38: 573-580.

Chaudhry, N.Y. and Qurat-ul-Ain 2003. Effect of growth hormones i.e. IAA, kinetin and heavy metals (Lead Nitrate) on the internal morphology of leaf of *Phaseolus vulgaris* L. Pakistan Journal of Biological Sciences, 6(2): 157-163.

Chhipa, B. R. and Lal, P. 1988. Effect of pre-sowing seed treatment in wheat grown sodic soils. Indian J. of Plant Physiology, 31:183-185.

Chin, T.Y. and Beevers, L. 1970. Change in growth regulators in Nasturtium leaves during senescence. Planta., 92: 178-188.

Cladiz, D. 1996. Seed potato *(Solanum tuberosum* L.) yield and tuber number increase after foliar application of cytokinins and gibberellic acid under field and greenhouse conditions. Plant-Growth-Regulators, 20(3): 185-188.

Cleland, R., Thompson, M., Rayle, D.L. and Purves, W.K. 1968. Differences in effect of gibberellins and auxins on wall extensibility of cucumber hypocotyls. Nature, 219: 510-511.

Cleland, R.E. 1996. Growth substances. In units, symbols and terminology for plant physiology. Salisbury, F.B. (Edit.). Oxford University Press. New York, pp: 126-128.

Coke, L. and Whittington, W. S. 1968. The role of boron in the plant growth. IV. Inter-relationships between boron and indole-3-acetic acid in the metabolism of radicles J. Exp. Bot., 19: 295-308.

Csizinszky, AA. 1994. Yield response of tomato, cv. Agriset 761, to seaweed spray, micronutrient, and N and K rates. 107th Annual meeting of the Florida State horticultural Society, Orlando, Florida, USA. Proceedings-of-the-Florida-State-Horticultural-Society, 107: 139-142.

Dariusz, swietlik and Joe V. Ladoke. 1991. Productivity, growth and leaf mineral composition of orange and grape fruit trees foliar-spray with zinc and manganese. Journal of Plant Nutri., 14(2): 129-142.

Das, R.C. and Prustly, S.S. 1969. A study on the effect of growth regulators on brinjal (*Solanum melanogena* L.). Indian Journal of Horticulture Science, 17: 91-94.

Davis, JM., DC-Sandres, PV-Nelson, L-Lengnick, WJ-Sperry. 2003. Boron improves growth, yield, quality and nutrient content of tomato. Journal of American Society for Horticultural Sciences, 128(3): 441-446.

Deosarkar,-D-B; Patinge,-S-P; Bhosale,-A-M; Deshmukh,-S-B. 2001. Effect of micronutrients on seed yield of soybean. Annals-of-Plant-Physiology, 15(2): 163-166.

Deotale, R.D., Maske, V.G., Sorte, N.V., Chimurkar, B.S. and Yerne, A.Z. 1998. Effect of GA_3 and NAA on morpho-physiological parameters of Soybean. Journal of Soils and Crops., 8: 91-94.

Devlin, M. Robert and Francis H. Witham. 1986. Detection occurance and availability of essential elements. In: Plant Physiology 4th ed. PWS Publishers. Inc. Boston MA. 02116 USA, 95-112.

Devlin, M. Robert and Francis H. Witham. 1986. Function of essential mineral elements and symptoms of mineral deficiency. In: Plant Physiology 4th ed. PWS Publishers. Inc. Boston MA. 02116 USA, 139-153.

Dhindra, R.S., Dhindra, P.L. and Reid, D.M. 1982. Leaf senescence and leaf peroxidation: Effects of some phytohormones and scavengers of free radicals and singlet oxygen. Plant Physiology, 13: 105-125.

Dugger, W.M. 1983. Boron in plant metabolism. In: Encyclopedia of Plant Physiology. New Ser., Springer-Verlag. Berlin, New York, 15B: pp. 626-650.

Durley, R.C., Bewley, J.D., Railton, I.D. and Pharis, R.P. 1976. Effect of light, Abscisic acid and BA on the metabolism of gibberellin in seeds and seedlings of lettuce, cv. Grand Rapids. Plant Physiology, 57: 699-703.

Ehrenbergerova, J. and Andonov, I. (1985). Studies on the effect of exogenous growth regulators on some traits of spring barely. Plant Growth Regulators. Abstracts, 14(10): 1941 (1988).

El-Fouly, MM., ZM.Moubarak, ZA-Salama, U-Aksoy (ed.)., D-Anac (ed.)., S-Anac (ed.)., J-Beltrao (ed.)., J-Ben-Asher (ed.)., J-Cuartero (ed.)., TJ-Flowers (ed.)., S-Hepaksoy. (2002). Micronutrient foliar application increases salt tolerance of tomato seedlings. Proceedings of the International Symposium on Techniques to Control Salination for Horticultural Productivity, Antalya, Turkey. Acta-Horticulturac, 573: 467-474.

El-Tabbak, A.E., El-Habbal, M.S., El-Sayed, S.A. and Thabet, E.M.A. 1982. Effects of IAA and GA_3 on growth and yield of sunflower. Research Bulletin, Facuality of Agriculture, Ain Shams University, 1834, 11. Field crop Abstracts, 36(11): 9694 (1983).

El-Tahir, K.E., Ashour, M.M. and al Harbi, M.M. 1993. Gen. Pharmacol. 24(5):1123.

Garcia, L.R. and J.J. Hanway, 1976. Foliar fertiliztion of soybeans during the seed filling period. Agron. J., 68: 653-657.

Garg, O.K., A. Hemantaranjan, Mani Ram and A.K. Trivedi Growth and yield of *Glycine max* L. Merril as influenced by foliar application of boron., 1999. In Plant

Physiology for sustainable agriculture. Pointer publishers. Jaipur India, pp: 193-197.

Gifford, R.M. and Evans, L.T. 1981. Phtosynthesis, carbon partitioning and yield. Annual Revision of Plant Physiology, 32: 485-509.

Hamilton S. Pereira. and Simone C. Mello. 2002. Foliar fertilizer application on nutrition and yield of sweet pepper and tomato. Hortic. Bras., 20(4): 0102-0536.

Hamsaveni. MR., MB-Khudikeri, M-Shekhargouda, SD-Shashidhara, PR-Dharmatti. (2003). Effect of gypsum and boron on seed yield and quality on tomato cv. Megha. Karnataka Journal of Agri. Sci., 16(3): 457-459.

Haq,-M-U; Mallarino,-A-P. 2005. Response of soybean grain oil and protein concentrations to foliar and soil fertilization. Dep. of Agron., Iowa State Univ., Ames, IA 50011, USA. Agronomy-Journal, 97(3): 910-918.

Harlan, J.R. (1992). Crops and Man, 2nd ed. American Society of Agronomy, Crop Sciene Society of America, Madison, WI.

Hatwar, GP; SU-Gondane, SM-Ukrude, OV-Gahukar. 2003. Effect of micronutrients on growth and yield of chilli. Journal of Soils and Crops., 13(1): 123-125.

Hemberg, T. 1972. The effect of kinetin on the occurrence of acid auxin in Coleus blumei. Plant Physiology, 26: 98-103.

Hewitt, E.J. 1963. The essential nutrient elements requirements and interaction in plants. In F.C. Steward, ed. Plant Physiology, New York: Academic press.

Huang, L., Ye. Zheng, R.W. Bell and L.B. Huang. 1996. The importance of sampling immature leaves for the diagnosis of boron deficiency in oilseed rape, 183(2): 187-198.

Hye, Md.A., Haque, Md.S. and Karim, M.A. 2002. Influence of growth regulators and their time of application on yield of onion (*Allium cepa*). Pakistan Journal of Biological Sciences, 5(10): 1021-1023.

Ibrahim, M and N. Ahmed. 1973. Elements status and their relationship with soil pH, organic matter and clay content. Pak. Asso. for Adv. Of Sci. Lahore. J. Sci., 2: 50-55.

Ikhtiar Khan, Javed Akhtar, S.Z. Shah and M. Saleem Khan. 2000. Sci. Khyber, 13(2): 73-86.

Iqbal, J. and Mahmood, S. 1980. Germination and growth of *Capsicum annuum* L., seedling grown from Gibberellic acid treated with gamma-irradiated seeds. Biologia, 26: 173-181.

Iqbal, J. and Mahmood, S. 1980. Germination and growth of *Capsicum annum* L., seedling grown from Gibberellic acid treated with gamma-irradiated seeds. Bioligia, 26: 173-181.

Jadoon, F.N.K, 2004. Studies on the role of phytohormones in callus induction and growth and yield of *Nigella sativa*. M. Phil. Thesis, Department of Biological Sciences, Quaid-i-Azam University, Islamabad

Jaiswal, JP., SP-Bhattarai, PP-Subedi. 1997. Effect of Multiplex spray on tomato (var. *Monprecos* and CH-154) and plant density per hill on bean (var. Kentucky Wonder and S-9) for spring season planting. Working-Paper-Lumle-Agricultural-Research-Center, No. 97-59: 15.

Jamal, Z. 2001. Effects of soil and foliar application of different concentrations of NPK and foliar application of $(NH_4)_2SO_4$ on different growth parameters in wheat (*Triticum aestivum* L.). M. Phil Thesis. Department of Biological Sciences, Quaid-i-Azam University, Islamabad, Paksitan.

Jamro, G.H., B.R. Kazi, F.C. Oad, N.M. Jamali and N.L. Oad. 2002. Effect of Foliar application of micronutrients on the growth traits of sugarcane variety Cp-65/357. (Ratoon Crop). J. of plant Sci., 1(4): 462-463.

Jindal, K.K. and Hemburg, T. 1976. Influence of gibberellic acid on growth and endogenous auxin level in epicotyl and hypocotyl tissues of normal and dwarf bean plants. Plant Physiology, 38: 78-82.

Jobin, Lawler.F., K-Simard, A-Gosselin, AP-Papadopoulos, M-Dorais. 2000. The influence of solar radiation and boron-calcium fruit application on cuticle cracking of a winter tomato crop grown under supplemental lighting. Proceedings of the Fourth International ISHS Symposium on Artificial Lighting. Acta-Horticulturae, 580: 235-239.

Kalita, M.M. 1989. Effect of phosphate and growth regulators on green gram. Indian Journal of Agronomy, 34(2): 236-237.

Kalita, M.M.1989. Effect of phosphate and growth regulators on green gram. Indian journal of Agronomy, 34(2): 236-237.

Kalpana,-R; Krishnarajan,-J. 2003. Effects of combined application of nutrients and hormones on soybean yield. Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, India. Legume-Research, 26(2): 151-152.

Kalpana,-R; Subbian,-P; Selvi,-R-V. 2003. Effect of irrigation layouts and foliar nutrition on grain yield and quality of soybean. Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, India. Tropical-Agricultural-Research, 15: 20-26.

Kanahama, K., Qu, Y.H., Takagi, Y.Q.H. and Saito, I. 1989. Effect of growing conditions and plant growth regulators on the formation of double clusters in tomato plant. Bulletin of the Yamagata University. Agricultural Science, 10: 911-915.

Kannan, S. (1980). Mechanisms of foliar uptake of plant nutrients. Accomplishments and propects. Journal of Plant Nutri., 2: 717-735.

Katyal, J.C. and N.S. Randhawa. 1983. Micronutrient, F.A.O. Fertilizer and Plant Nutrition Bulletin 7. Indian Council of Agic. Res., New Delhi, India.

Kaufman, P. B. and Jones, R.A. 1974. Regulations of growth in Avena (oat) stem segments by gibberllic acid and Abscisic acid. Plant Physiology, 31: 39-43.

Kaufman, P. B., Petering, L.B. and Adam, P.A. 1969. Regulation of growth and cellular differentiation in developing Avena internodes by gibberellic acid and Indole-3-acetic acid. Journal of Botany, 56: 918-927.

Kausar, M.A., A. Hamid, M. Tahir and M. Aslam. 1989. Boron toxicity in wheat. Pak. J. Soil Sci., (3-4): 1.

Kausar, M.A., F.M. Chudhry, A. Rashid, A. Latif and S.M. Alam. 1976. Plant soil, 45:397.

Kauser, M. (1976). Effect of Gibberellic acid on growth and yield of *Hibiscus esculentus*. M.Sc. Botany Thesis. Agricultural University, Layallpur.

Kaya, C. and D-Higgs. 2002. Improvements in physiological and nutritional developments of tomato cultivars grown at high zinc by foliar application of phosphorus and iron. Journal of Plant Nutri., 25(9): 1881-1894.

Kays, S. J. 1991. Biotechnology - A horticulturist's perspective: Introduction to the colloquium. Horticulture Science, 26:1020-1021.

Kays, S. J. 1991. Biotechnology – A horticulturist's perspective: Introduction to the colloquium. Horticulture Science, 26:1020-1021.

Kazma, H. and Katsuri, M. 1974. Auxin-gibberellin relationship in their effects on hypocotyls elongation of light-grown cucumber seedlings. Effect of GA_3 pretreatment on IAA-induced elongation. Plant Cell Physiology, 15: 307-314.

Khalid, N.A. and R Khalifa. 1991. Response of lentil growth and yield to macro and micronutrients application. Bull. Fac. Agric. Univ. Cairo., 42(3): 701-712.

Khalil, A. 1994. Nutritional yield and protein quality of maize influenced by boron application. J. Sci. Tec., 18: 43-50.

Khan, M.M., Usman, M., Waseem, R. and Ali, M.A. 2002. Role of Gibberellic acid (GA_3) on citrus seed germination and study of some morphological characteristics. Pakistan Journal of Agricultural Sciences, 39(2): 113-118.

Khan, N.A., Ansari, H.R., Mobin, M. and Samiullah. 1996. Effect of gibberellic acid on morphology and yield of Mustard (Brassica juncea L.) grown with basal levels of nitrogen and phosphorus. Plant Physiology for Sustainable Agriculture. Pointer Publishers Jaipur India, pp: 214-224.

Khattak J. K., S. Parveen and A. Bhatti. 1983. Bull. S. I. Dept. of Soil Sci. N.W.F.P. Agri. Uni. Peshawar.

Khurshid, I., Jackson, D.I. and Rowe, R.N. 1992. Effect of plant growth regulators on flower development in grapevine (*Vitis vinifera*) cv. *Cabernet Sauvignon*. New Zealand. Journal of Crop and Horticultural Science, 20: 351-356.

Kim-SunLim; Son-YoungKoo; Hwang-JongJin; Kim-SungKuk; Hur-HanSun; Park-Cheolho. 2001. Development and utilization of buckwheat sprouts as functional vegetables. National Crop Experiment Station, RDA, Suwon 440-100, Korea Republic. Fagopyrum-, 18: 49-54.

Kochar, P.L. and H.N. Krishnamoorthy. 1988. A text book of plant physiology. Tata McGraw-Hill publication company Ltd. New Delhi, 214-245.

Kochhar, P.L. and Krishnamoorty, H. (1988). A text book of plant physiology, pp: 260.

Kogal, F. and Elema, J. (1960). Wirkungsbeziehungen zwischen Indole-3-Essigaure and gibberellinsaure. Naturwissenschaften, 47. pp:90.

Kothule,-V-G; Bhalerao,-R-K; Rathod,-T-H. 2003. Effect of growth regulators on yield attributes, yield and correlation coefficients in soybean. Annals-of-Plant-Physiology, 17(2): 140-142.

Kothule,-V-G; Bhalerao,-R-K; Sathe,-B-V. 2003. Effect of exogenous application of growth regulators on growth, biomass partitioning and yield in soybean. Annals-of-Plant-Physiology, 17(1): 95-99.

Krishnamoorty, H.N. 1981. Plant growth substances. Tata McGraw-Hill Publiction Company Limited. New Delhi, pp:214-245.

Kumar, P., Rao, A.D. and Baijal, B.D. 1981. Effects of some growth regulators on plant growth, tuber initiation, yield and chemical composition of potato *(Solanum tuberosum*). Pakistan Jouranl of Botany, 13: 69-75.

Kumer, S., Singh, P., Katiyar, R.P., Vaish, C.P. and Khan, A.A. 1996. Beneficial effect of some growth regulators on the aged seeds of okra (*Abelmoschus esculentus* L.) under field conditions. Seed Res., 24: 11-14.

Lallu and Dixit, R.K. 1996. Effect of growth regulators on yield and oil content in Indian mustard (*Brassica juncea* L.). Plant Physiology for Sustainable Agriculture. Pointer Publishers Jaipur, India, pp: 242-244.

Lau, O.L. and Yang, S.F. 1973. Mechanism of a synergistic effect of kinetin on auxin induced ethylene production. Plant Physiology, 51: 1011-1014.

Lee, H.S. 1990. Effects of pre-sowing seed treatments with GA_3 and IAA on flowering and yield components in groundnuts. Korean J. of Crop. Sci., 35: 1-9.

Leopold, A.C. and Nooden, L.D. 1984. Hormonal regulatory systems in plants. In: Scot, T.K. (Edit.). Hormonal regulation of development 11. Encyclopedia of Plant Physiology N.S. Vol., (10): 4-22.

Lewis, D.H. 1980. Are there inter-relations between the metabolic acid of boron, synthesis of phenolic phyto auxins and the germination of pollen. New Phytol., 84: 261-270.

Lima,-I-A-V; Miyada,-V-S. 2003. Organic and inorganic copper as growth promoters of weanling pigs. Revista-Brasileira-de-Zootecnia, 32(6, Supp.1): 1657-1662.

Lindsay, W.L. (1984). Soil and plant relationship associated with iron deficiency with emphasis on nutrient interaction. Journal of Plant Nutri., 7(15): 489-500.

Lindsay, W.L. 1972. Advance Agron., 24, 147

Lindsay, W.L. and W.A. Norvell. 1969. Agron Abstr., 69.

Lindsay, W.L., J. Hodgson Fe., and W.A. Vell. 1967. The physico chemical equilibrium of metal chelates in soils and their influence on the availability of metal cation. Trans. Comm. II. And IV. Int. Soc. Soil Sci., 305-316.

Loustalot, A.J., F.W. Burrows, S.G. Gilbert, and A. Nason. 1945. Effect of Copper and Zinc deficiencies on the photosynthesis activity of foliage of young tung trees. Plant physiol., 20: 283.

Low, V.H.K. 1975. Role of gibberellins in root and shoot growth. In: Krishnamoorty, H.N. (Edit.) Gibberllins and plant growth. Wiley and Sons, New York. pp: 101-114.

Macedo,-F-B; Teixeira,-N-T; Lima,-A-de-M; Bernardes,-C-R; Freitas,-D-J-B-de; Oliveira,-R-F. 2002. Boron applied at planting and calcium and boron in leaf fertilization of soybean production. Monitor de Nutricao de Plantas, Nucleo de Solos e Nutricao de Plantas, Curso de Engenharia Agronomica, CREUPI, Espirito Santo do Pinhal, SP, Brazil. Ecossistema-, 27(1/2): 87-88.

Macias, W., J-Sobolewshi, J-Robak. 1996. The possibility of chemical control of bacterial speck on tomato. Biuletyn-Warzywniczy, 45: 71-76.

Marini, R.P. and Sowers, D. 1991. Growth, yield and fruit weight of apple trees flowering spurpruning and BA plus GA applicaiton. Journal of American Society for Horticulture Science, 116(3): 454-459.

Masud Mahmood, Tariq, Amjid Hussain, K. Farooq and K.A. Bajwa. 2000. Effect of micronutrients on the growth and yield on potato crop by NARC. Annual Report, 239-243.

Mauseth James D. 2003. Soils and minerals nutrition. In: Botany, an introduction to plant biology. 3rd edition. Pub. Jones and Barlett, Canada, pp: 373-396.

Mawardi, A.E., A.Y. Gad, S.A. Chalt. 1977. Response of Alfalfa and Sudan grass to Boron. Agric: Res. Rev. Cairo, 55(5).

Mclaughin, J.M. and Greene, D.W. 1991. Fruit and hormone influence flowering of Apple. Journal of Americal Society for Horticulture Science, 116(3): 446-449.

Menser, H.A, 1985. Effect of zinc levels on phosphorous and zinc content in sand-cultured soybeans. J. of plant nutri., 8(1): 89-97.

Merlo, D., Soldati, A. and Keller, E.R. 1987. Influence of growth regulators on abscission of flowers and young pods of soybeans. Plant Growth Regulators Abstracts, 14(7): 1325 (1988).

Meschede,-D-K; Lucca-e-Braccini,-A-de; Braccini,-M-do-C-L; Scapim,-C-A; Schuab,-S-R-P. 2004. Grain yield, seed's protein content and plant agronomic traits of soybean in response to foliar fertilization and molybdenum and cobalt seed treatment. Universidade Estadual do Mato Grosso, Av. Sao Joao, s/n. 78200-000, Caceres, Mato Grosso, Brazil. Acta-Scientiarum-Agronomy, 26(2): 139-145.

Mishra, S.M. and BC. Patil, 1987. Effect of boron on seed yield in lucerne *(M. sativa* L.), J. Agron. Crop Sct., 158: 34-37.

Mortvedt, J.J., and F.R. Cox. 1985. Production, Marketing and use of calcium, magnesium, and micronutrient fertilizer, pp. 455-482. In O. P. Engelstad (Ed.), Fertilizer Technology and Use. Soil Science Society of America, Madison, Wisc.

Mortvedt, J.J.(Eds.) 1991. Micronutrients in Agriculture. N0. 4. Soil Science Society of America, Madison, Wisc.

Mortvedt, J.J., P.M. Giordano and W.L. Lindsay. 1972. Micronutrients in agriculture. Soil Sci. Soc. Amer J., 33, 521-528

Moussa,-H-R. 2004. Amelioration of salinity-induced metabolic changes in soybean by weed exudates. International-Journal-of-Agriculture-and-Biology, 6(3): 499-503.

Muhammad Iqbal Makhdum, Shabab-ud-din, Fiaz Ahmad and Fazal Ilahi Chaudhry. 2002. Zinc and boron fertilizer requirement for cotton grown in a calcaric cambisol. Baloc. J. Agri. Sci., 3(2): 11-14.

Muzafar, A., 1989. Boron effect on mineral nutrients of maize. Agron J., 81: 285-290.

Naeem, M., Bhatti, I., Ahmed, R.H. and Ashraf, Y.M. 2004. Effect of some growth regulators (GA_3, IAA and kinetin) on the morphology and early of delayed initiation of bud of lentil (*Lens culinaris medik*). Pak. J.of Bot., 36(4): 801-809.

Nash, S.M. and Whillem, S. 1960. Stimulation of Broomrape seed germination. Phytopathology, 50: 7672-7774.

Nason, A. and W.D. McElory. 1963. Modes of action of the essential mineral elements. In F.C. Steward, ed., Plant Physiology, New York Academic Press.

Nason, A., N.O. Kaplan and H.O. Oldewurtel. 1953. Further studies of nutritional conditions affecting enzymatic constituents in Neurospora. J. Biol. Chem., 201: 435.

Naveed, M. 2004. Studies on the effect of soil and foliar application of micronutrients on the gorwth and yield of *Lycopersicon esculentum* Mill and *Capsicum annuum* L. M. Phil. Thesis, Department of Biological Sciences, Quaid-i-Azam University, Islamabad.

Newaj, M.N., Halal Uddin, Md., Anam, M.K., Nazrul Islam, Md. and Asd-ud-doullah, Md. 2002. (1) Effect of Indoleacetic acid on growth of Mungbean (*Vigna radiata*L.). (2). Effect of Indoleacetic acid on yield of Mungbean (*Vigna radiata* L.). Pakistan Jouranl of Boilogical Sciences, 5(9): 891-899

Noggle Ray G. and Georg J. Fritz. 2002. Foliar nutrition, In: Introductory plant physiology. Pub. Prentice-Hall New Delhi, pp: 253-254.

Norrie, J., Med-Graham, J-Charbonneau, A-Gosselin. 1995. Impact of irrigation management of greenhouse tomato: yield, nutrition, and salinity of peat substance. Canadian-Journal-of-Plant-Science, 75: 2, 497-503; 29.

Nyle C.B. 1987. The nature and properties of soils, Macmillian Pub, Co. INC. New York, 8th Ed., 372. 474-489.

Parasi, B., Cella, R. and Ciferri, O. (Edit.). Elsevier, North Holland Biomedical Press. Netherlands, pp: 183-186.

Parveen S. and Hafeez-ur-Rahman. 2000. Effect of foliar application of zinc, manganese and boron in combination with urea on the yield of sweet orange. Pak. J. of Agric. Res., 16(2):135-141.

Patnaik, MC., GB-Raj, IP-Reddy. 2001. Response of tomato (*Lycopersicon esculentum*) to zinc and iron. Vegetable-Science, 28(1): 78-79.

Phinney, B.O. 1956. Growth response of single-gene dwarf mutants in maize to gibberellic acid. National Academy of Sciences, USA, 42. pp: 185-189.

Phiv-ChinTheng; Hongprayoon,-C; Srinives,-P; Kumlung,-A; Osotsapar,-Y. 2003. Soybean yield and nutrient composition as affected by soil and foliar fertilizations. Department Soil Science, Faculty of Agriculture, Kasetsart University, Kamphaeng Saen, Nakhon Pathom 73140, Thailand. Kasetsart-Journal,-Natural-Sciences, 37(1): 14-26.

Possingham, J.V. 1956. The effect of mineral nutrition on the content of three amino acids and amides in Tomato plant. I. A comparison of effects of deficiencies of copper, zinc, manganese, iron and molybdenum. Austalian Biol. Sci., 9:539.

Prabha, K. and P-Singaram. 1996. Effect of boron on the content and uptake of nutrients in tomato. Madras Agri. J., 83(11): 745-746.

Prasad, KK. BM-Chowdhary, Amrendra-Kumar; A-Kumar. 1997. Response of tomato to boron application in Chotanagpur region. J. of Res. Birsa Agri. Univercity, 9(2): 145-147.

Qureshi, R.A. and Chaudhry, M.N. 1988. Nigella sativa L. In: Pakistan Systematics, Bulletin of the Herbarium, Quaid-i-Azam University, Islamabad, Pakistan, 4(1-2): 32-33.

Radulovic, M. 1996. Soil and vegetable nutrients supply in the region of the Zeta-Montenegro. Review of research work at the faculty of agriculture, Belgrade, 41(1): 31-40.

Rahayu, YS., V-Romheld, F-Bangerth, D-Neilsen (ed.), B-Fallahi (ed.), G-Neilsen (ed.), F-Peryea. 2001. Does zinc nutrition affect calcium disorder of fruits? Proceedings of the fourth international symposium on mineral nutrition of deciduous fruit crops, penticton, British Columbia, Canada. Acta-Horticulturae, 564: 135-143.

Rahman, -M-S; Islam,-M-N; Abu-Tahar; Karim,-M-A. 2004. Influence of GA_3 and MH and their time of spray on morphology, yield contributing characters and yield of soybean. Asian-Journal-of-Plant-Sciences, 3(5): 602-609

Rahman,-M-S; Tahar,-N-I-M-A; Karim,-M-A. 2004. Influence of GA_3 and MH and their time of spray on dry matter accumulation and growth attributes of soybean. Pakistan-Journal-of-Biological-Sciences, 7(11): 1851-1857

Ram, M. and Jaffel, W.G. 1981. Nutritional improvement of food legumes by breeding. Proc. Symp. PAG. F.A.O. Rome, Italy, pp: 44.

Rammah. A.M., M.S. Khedr, M. Th-Hassan. 1984. Response of alfalfa to iron and boron in some Egyptian soils. J. of plant nutri., 7(1-5): 235-242.

Ranganthan, DS., Rani-Perumal, R-Perumal. 1996. Response of tomato to micronutrients in different soils. DS-Ranganthan, Rani-Perumal, R-Perumal. South Indian Horticulture, 44(1-2): 23-26.

Rani, P.L. and T. M. M. Reddy. 1993. Effect of nitrogen and boron on growth characters and dry matter production of sunflower. J. Res. APAU., 21(1-2): 107-108.

Rappoport, L. and Wolf, N. 1969. In: dormancy and survival. (Edit). Woolhouse, Cambridge University Press, pp: 366-378.

Rashid, A., N. Bughio and E. Rafique. 1994. Diagnosing zinc deficiency and rape seed and mustard by seed analysis, 25(9-28): 3405-3421.

Rashid, A., Rahmatullah, F. Hussain, A. Latif and M. Sharif. 1979. The extent and severity of Zn and Cu deficiency and their mutual interaction in Maize and soil of Punjab. Pak. J. Sci. Ind. Res., 23: 17-63.

Rawash, M.A., Montaser, S.S., Habib, S.E., Nabawy, A. and Mahmoud, N. 1980. Germination of citrus seeds as effected by soaking in growth regulators, water washing and sowing date. Research Faculty of Agriculture, Ain Shams University, pp: 1-10.

Ray, S. and Chaudhry, M.A. 1981. Effects of growth regulators on grain filling and yield of rice. Annual of Botany, 47: 755-758.

Reid, D.M. and Railton, I.D. 1974. The influence of benzyl-adenine on the growth and gibberellin content of shoots of Tomato plants. Plant Science Letters, 2: 151-156.

Riaz Baqar S. 2001. Capsicums. In Textbook of Economic Botany. Publ. Ferozsons Lahore Pakistan, pp: 563-567.

Riaz Baqar S. 2001. Tomato. In Textbook of Economic Botany. Publ. Ferozsons Lahore Pakistan, pp: 239-243.

Robertson, G.A, and Loughman, B.C. 1973. Rubidium uptake and boron deficiency in *Vicia faba* L. J. Exp. Bot., 24: 1046-1052.

Rodriguez-Rey-JA., ER-Romero, JL-Vidal, R-Budeguer, C-Rodriguez, 2000. Effectiveness of the foliar application of three chemical treatments on the

recovery of the productivity of sweet pepper (*Capsicum annuum*) grown in the greenhouse and affected by low temperatures. Revista-Industrial-y-Agricola-de-Tucuman, 77(2): 7-11.

Romero, L. 1988. A new statistical approach for the interpretation of nutrient interrelationship. III manganese / iron. J. of plant nutri., 11(6-11): 995-1004.

Romheld, V. and H. Marschner 1991. Function of micronutrients in plants. In: Micronutrients in Agriculture, pp 297-238. Soil Sci. Soc. Amer. Madson, U.S.A.

Ross, G.W., Davies, J. N. and long, M.I.E. 1990. Growth of sweet pea as affected by the application of growth regulators. Field Crop Abstracts, 30(11): 2345.

Saeed Khattak, M., Amjad Iqbal and Iqtidar A. Khalil. 2001. J. Sci. and Tech. Univ. Peshawar, 25: 47-51.

Salah, M.M.S and Abd, D.J. 1989. Effect of GA_3 and NAA on growth, yield and quality of Onion. Dirsat, 16: 39-51.

Salisbury, F.B. and Ross, C.W. 1985. Hormones and Growth Regulators: Auxins, Gibberellins and Cytokinins: In Plant Physiology, 3rd edition. Wadsworth Publishing Company Belmont, California, pp: 309-348.

Sarkar, P.K., Haque, M.S. and Abdul Karim, M. 2002. Effects of GA_3 and IAA and their frequency of application of morphology, yield contributing characters and yield of soybean. Pak. J. of Agronomy, 1(4): 119-122.

Samuel, L Tisdale, Warner L. D. Nelson James, Beaton. John L. Havilson. 1993. Funciton of micronutrients in plants. In soil fertility and fertilizer. Publ. Prentice-Hall, Inc.; Englewood Cliffs, U.S.A., 66-73.

Samuel, L Tisdale, Warner L. D. Nelson James, Beaton. John L. Havilson. 1993. Micronutrients and other beneficial elements in soil and fertilizers. In soil fertility and fertilizer. Publ. Prentic-Hall, Inc.; Englewood Cliffs, N.J., U.S.A., 304-363.

Sastry, K.S.K. and Muir, R.M. 1965. Effects of gibberellic acid on utilization of auxin precursors by apical segments of the *Avena* coleoptiles. Plant Physiology, 40: 294-298.

Scott, T.K. 1972. Auxins and roots. Annulus of Revision of Plant Physiology, 23: 235-258.

Selman, I.W. and Bora, P.C. 1968. The effect of Gibberellic acid and nutrient spray on growth and yield of Brussels sprout. Annulus of Applied Biology, 61: 131-138.

Sembdner, G., Gross, D., Liebisch, H.W. and Schneider, G. 1980. Biosythesis and metabolism of plant hormones. Encyclopedia of Plant Physiology, 9: 281-444.

Senthil,-A; Pathmanaban,-G; Srinivasan,-P-S. 2003. Effect of bioregulators on some physiological and biochemical parameters of soybean (*Glycine max* L.). Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, India. Legume-Research, 26(1): 54-56.

Sharma, P.N.and R. Amchandra, T., 1990. Water relation and photosynthesis in mustard plants subject to boron deficiency. Indian Journal of plant physiology, 33: 150-154.

Shinde, S.S., Bhalerao, R.K., Raut, R.H. and Shinde, S.D. 1989. Effect of growth regulators on yield and some physio-chemical parameters in sorghum. J. of Maharashtra Agril. Univ., 14: 360-361.

Shishido, Y. and Saito, T. 1984. Effects of plant growth regulators on low temperature induction of flower buds in Onion plants. Journal of Japanese Society and Horticultural Science, 53: 45-51.

Singh, A.R., Pankage, S.L. and Singh, G.N. 1983. Effect of growth regulators on the growth, yield and quality of Onion. Jouranl of Punjab Horticultural Science, 23: 100-104.

Singh, B.P. 1966. Influence of GA on vegetative growth and flowering of Tomato. Science and Culture, 32: 5511-5512.

Singh, K. and Sambhi, M.S. 1967. Response of lettuce to plant growth regulator sprays. Jounal of Research, Ludhiana, 4: 382-387.

Singh, R.P. and Kumar, A. 1991. Effect of phytohormones onyield attributes and seed yield of Mustard (*Brassica juncea*). Indian Journal of Agronomy, 36(3): 379-381.

Skoog, F. (1940). Relationship between zinc and auxin in the growth of higher plants. Am. J. Bot., 27: 939.

Soltanpour, P.N. 1985. Use of ammonium becarbonate-DTPA soil test to evaluate elemental availability and toxicity. Common Science Plant Analysis, 16: 323-338.

Sontakey, P.Y., Belsore, W.V., Deotale, R.D., Takzure, S.C. and Wankhede, S.Z. 1991. Relative influence of growth hormones on gorwth and yield performance of sesamum (*Sesamum indicum* L.) New Agriculturist, 1: 207-208.

Stoyanov, D., Sedlarka, B. and Strativa, S. 1991. Effects of zinc and boron on sunflower grown on leached chernozem soil. Field crop Abst., 44: 5583.

Stratieva, S., B. Sedlarsk, and D. Stoyanov. 1991. Effect of zinc and boron on sugar beet brown on leached chernozem soil. Field crop Abst., 44: 5709.

Tahir, M., A. Rashid and A. Saeed Bhatti. 1982. Micronutrient concentrations in corn and a comparison of the various extractants for soil Zn and Cu Pak. J. Sci. Ind. Res., 25(5).

Taiz, L. and Zeiger, E. 1998. Hormones and Growth Regulators: Auxins, gibberellins and Cytokinins: In Plant Physiology, 2nd edition. Sinaver Associates, Publishers Sunderland, Massachusetts, pp:543-648.

Thangaraj, M., Maibangsa, S. and Stephen, R. 1999. Effects of foliar spray of growth regulators and botanicals on certain physiological characters and yield of rice.

Plant Physiology for Sustainable Agricultre. Pointer Publishers, Jaipur. India, pp: 214.

Tuominen, H., Puech, L., Frink, S. and Sunberg, B. 1997. A radial concentration of Indole-3-acetic acid in relation to secondary xylem development in hybrid Aspen. Plant Phyiology, 115: 577-585.

Tyksinski, W., E-Kozik, J-Roszyk, O-Nowosielski. 1995. Foliar nutrition of greenhouse tomatowith microelements. Materialy ogolnopolskiej konferencji naukowej Nauka Praktyce Ogrodniczej z okazji XXV-lecia Wydzialu grodniczego Akademii Rolniczej w Lublinie, 521-524.

Uddin, M.R. 1985 Manipulation of reproductive sink yield in kidney beans (*Phaseolus vulgaris* L.). Legume Research, 8(1): 30-34.

Ulskov, P., Nielson, T.H., Seiden, P. and Marcussen, J. 1992. Cytokinins and leaf development in sweet pepper. Planta, 188(1): 70-77.

Upadhyay, R.G. 1994. Effect of bioregulators on growth, development, flowering behavior and yield of chickpea (*Cicer arietinum* L.). Legume Research, 17(1): 60-62.

Valenzuela, J.L. and I. Romero.1984. Biochemical Indicators and Iron Index for the appraisal of the mineral status in leaves of cucumber and tomato. J. of Plant Nutri., 11(6-11): 1177-1184.

Vant Hof, J. 1968. The action of IAA and kinetin on the mitotic cycle of proliferative and stationary phase excised root meristem. Experimental Cell Research, 51: 167-176.

Viets, F.G. 1966. Zinc deficiency in the soil plant system. Prasad ed. Charles C. Thomas, Publisher, spring field, 90-127.

Wang, Q., Little, C.H.A. and Oden, P.C. 1997. Control of longitudinal and cambial growth by Gibberellic acid and Indole-3-acetic acid in shoots of *Pinus sylvestris*. Physiologia plantarum, 95: 187-194.

Wang, Q., Little, C.H.A. and Oden, P.C. 1997. Control of longitudinal and cambial growth by Gibberellic acid and Indole-3-acetic acid in shoots of *Pinus sylvestris*. Physiologia plantarum, 95: 187-194.

Went, F.W. (1935). Auxin, the plant growth-hormone. Botanical Revision, 10: 162-182

Wiklander, L. 1958. The soil. In W. Rhuland, ed; Encyclopedia of Plant Physiology, 4:118. Berlin:Sirinagar.

Yadav, PVS., Abha-Tikkoo, 2001. Effect of zinc and boron application on growth, flowering and fruiting of tomato (*Lycopersicon esculentum* Mill). Haryana J. of Horti. Sci., 30(1-2): 105-107.

Yahiro, M. and Oryoji, 1980. Effects of gibberellic and cytokinins treatments on the promotion of germinating papaya (*Carica papaya* L.) seeds. Plant Growth Regulators Abstracts, 16: 45-51.

Yang, Y., X. Zhenchi, R.K. Bell, Y. Yang and Z.C., Xie. 1995. A brief introduction to the appraisal of the ACIAR Project "Management of boron and zinc nutrition in oil seed crop in China." , 32(4): 449-453.

Zeroni, M. and Hall, M.A. 1984. Molecular effects of hormonal treatments on tissue. In: Mac. Millon J. (Edit.). Hormonal regulation of development. Encyclopedia of Plant Physiology. N.S. Vol., (9): 511-586.