

Table of Contents

Acknowledgement i
List of Abbreviations ii
Table of Contents iv
List of Tables ix
List of Figures xii
Abstract..... xiv

INTRODUCTION	1
REVIEW OF LITERATURE	8
2.1. Natural Physico chemical properties of boron (B)	10
2.2. Prevalent B uses and environmental impacts of B	11
2.3 Role of B in animal and human nutrition	12
2.4 Boron in water and food sources	13
2.5 Worldwide boron status of soils	16
2.6 Factors affecting B availability in soil	19
2.6.1 Effect of CaCO ₃ on B availability	20
2.6.2 Effect of pH on B availability	22
2.6.3 Effect of organic matter (OM) on B availability	24
2.6.4 Role of soil texture in adsorption of B	25
2.6.5 Effect of soil moisture on B adsorption	26
2.6.7 B adsorption and competing ions	27
2.7 Processes of B-adsorption in soils	27
2.8 Boron fractions present in soils	29
2.9 Reactions and chemistry of B in soil	32
2.10 Role of B in plant functions	33
2.11 Role of B in plant cell wall	36
2.12 Role of B in cell division	37
2.13 Effect of B on plasma membranes	37
2.14 B responsibility in ion fluxes	37
2.15 Effect of B in phenol metabolism	39
2.16 Role of B in N-fixation	39
2.17 Role of B in plant reproductive growth	40
2.18 Boron mobility in plants and its role in plant physiology	42
2.19 Toxicity in different crops due to boron	43
2.20 Boron toxicity symptoms	45
2.21 Techniques/methods of B determination in soils and plant	47
2.22 Crop responses to boron	47

2.23 Cotton responses to boron application	49
2.23.1 Foliar application	49
2.23.2 Soil application	51
2.23.3 Cotton leaf photosynthesis characteristics	53
2.24 Responses of wheat to B application	53
2.25 Sources of boron	60
2.27 Carryover or residual influences of boron applied to soil	61
MATERIALS AND METHODS	62
Study 1	62
3.1 Boron status of soils under wheat–cotton cropping system as influenced by soil pH, organic matter, calcium carbonate (CaCO ₃) and soil texture.	62
3.1.1 Selection of the experimental site	62
3.1.2 Sample collection and preparation	62
3.1.3 Preparation of saturated soil paste	63
3.1.4 pH of saturated soil paste	63
3.1.5 Electrical conductivity (EC _e) of saturation extract	63
3.1.6 Soluble calcium + magnesium	63
3.1.7 Soluble potassium	63
3.1.8 CaCO ₃ or lime	63
3.1.9 Particle size analysis	64
3.1.10 Available phosphorus	64
3.1.11 Organic matter	64
3.1.12 Soil extraction By 0.05 M HCl for B determination	64
3.1.13 Technique for Soil B	65
3.1.14 Total N (%)	65
3.1.15 Plant Analysis	65
3.1.15.1 Apparatus	65
3.1.15.2 Reagents	66
3.1.15.3 Buffer- masking reagent	66
3.1.15.4 Azomethine-H reagent	66
3.1.15.5 Working solution	66
3.1.15.6 Boron stock solution	66
3.1.15.7 Boron standards	66
3.1.15.8 Dilute H ₂ SO ₄ (0.36 N)	66
3.1.15.9 Sample preparation	67
3.1.15.10 Colour development	67
3.1.15.11 Calculations	67
3.1.15.12 Statistical analysis	67
Study 2	68

3.2 Boron content in canal and ground water samples collected from wheat-cotton growing areas of Punjab.	68
3.2.1 Collection of canal water samples	68
3.2.2 Collection of ground water (tubewell water) samples	68
3.2.3 Statistical analysis	68
3.3 FIELD STUDIES	69
3.3.1 Effect of boron application (as soil amendment) on growth and yield of cotton and wheat in calcareous soils of Pakistan	69
3.3.1.1 Cotton (<i>Gossypium hirsutum L.</i>)	69
3.3.1.2 Wheat (<i>Triticum aestivum L.</i>)	70
3.3.2 Foliar B application on cotton and wheat sown under alkaline calcareous soils	71
3.3.3 Residual effect of B applied to previous cotton on wheat	71
3.3.4 Plant analysis	72
3.3.5 Dry ashing	72
3.3.6 Statistical analysis	73
3.4 LABORATORY STUDY	73
3.4 Fractionation of soil boron under wheat cotton cropping system	73
3.4.1 Procedural scheme for B fractionation	73
3.4.1.1 Boron extraction from soil	73
3.4.1.2 0.05 M HCl extractable or water soluble B (B ₀)	73
3.4.1.3 (B ₁) Exchangeable B fraction	74
3.4.1.4 (B ₂) 0.02 M HNO ₃ -H ₂ O ₂ extractable B fraction	74
3.4.1.5 (B ₃) NH ₄ -oxalate extractable B fraction	75
3.4.1.6 (B ₄) Residual fraction	75
3.4.1.7 Data analysis	75
3.5.1 Index for determination of B responses	77
RESULTS AND DISCUSSION	77
STUDY 1	77
4.1 Boron status of soils under wheat–cotton system as influenced by soil pH, organic matter, calcium carbonate (CaCO ₃) and texture.	77
4.1.1. Soil analysis (2005-2006)	77
4.1.2. Soil analysis (2006-2007)	78
4.1.3 HCl (0.05 M) extractable soil B (mg kg ⁻¹)	79
4.1.4. Soil pHs	82
4.1.5. CaCO ₃ (%)	84
4.1.6. Organic matter (OM) content (%)	86
4.1.7 Effect of soil texture on B concentration	87
4.1.8. Plant analysis	90
CONCLUSIONS	95

STUDY 2	97
4.2 Boron content in canal and ground water samples collected from wheat-cotton growing areas of Punjab	97
4.2.1. Canal water samples analyzed for B, EC, pH and TSS during winter season (December-January, 2005-06)	97
4.2.2 Canal water samples analyzed for B, EC, pH and TSS during monsoon season (July – August, 2006-07)	100
4.2.3 Ground water (tubewell water) samples analyzed for B, EC, pH and TSS during 2005-06	104
4.2.4 Tubewell water samples analyzed for B, EC, pH and TSS during 2006-07	106
CONCLUSIONS	111
STUDY 3	112
4.3 Boron fractionation in alkaline calcareous soil of Pakistan by using different extractants and its application under wheat-cotton cropping system	112
4.3.1 Soil classification, taxonomy and texture of the twenty soil series	112
4.3.2 Physico-chemical characteristics of soils:	113
4.3.3 B concentration in soils extracted by different extractants	114
4.3.4 B fractions present in high pH calcareous soils:	115
CONCLUSIONS	124
STUDY 4	125
4.4 Effect of boron application on growth and yield of cotton in calcareous soils:	125
4.4.1 Effect of boron application on numbers of bolls per plant	126
4.4.2 Effect of boron application on boll weight	129
4.4.3 Seed cotton yield (kg ha^{-1})	133
4.4.4 Lint percentages	137
4.4.6 Plant analysis	140
4.4.6.1 Leaf boron concentration (mg kg^{-1})	140
4.4.6.2 Total boron uptake (g ha^{-1}) by cotton plants	143
CONCLUSIONS	146
STUDY 5	148
4.5 Foliar B application on cotton sown under alkaline calcareous soils	148
4.5.1 Effect of B on number of bolls Plant^{-1}	149
4.5.2 Effect of boron application on boll weight	151
4.5.3 Seed cotton yield (t ha^{-1})	153
4.5.4 Leaf B concentration (mg kg^{-1})	157
4.5.5 Total B uptake (g ha^{-1}) by cotton plants	158
CONCLUSIONS	160
STUDY 6	161
4.6 Effect of boron application on growth and yield of wheat in calcareous soils	161
4.6.1 Effect of B on grain and straw yields of wheat during 2006	161
4.6.2 Effect of B fertilization on grain and straw yields of wheat (t ha^{-1}) during	165

2007	
4.6.3 Effect of B on number of grains per spike	168
4.6.4 Effect of B application on thousand-grain weight (g) in 2006 and 2007	171
4.6.5 Spike length of wheat (cm) during 2006 and 2007	173
4.6.6 Effect of B on number of tillers per metre ² (2006-2007)	174
4.6.7 Effect of B application on plant height	176
4.6.8 Boron concentration (mg kg ⁻¹) in wheat leaves	177
4.6.9 Effect of B application on total B uptake (g ha ⁻¹)	179
4.6.10 Effect of B on protein content of wheat	180
4.7 Effect of foliar boron on wheat in high pH and calcareous soils	181
4.7.1 Effect of foliar B on growth and yield parameters during 2006	182
4.7.2 Boron concentration (mg kg ⁻¹) in wheat leaves	184
4.7.3 Effect of B application on total B uptake (g ha ⁻¹)	185
CONCLUSIONS	186
STUDY 7	187
4.8 Residual effect of B applied to previous cotton on wheat	187
4.8.1 Grain and straw yield (t ha ⁻¹) of wheat	190
4.8.2 Spike length (cm) and number of grains produced per spike	193
4.8.3 Thousand-grain weight (g)	195
4.8.4 Effect of residual B on plant height (cm) of wheat	196
4.8.5 B concentration (mg kg ⁻¹) in wheat leaves	197
4.8.6 Residual or carryover impacts on boron uptake by wheat	199
4.8.7 Effect of B on protein content of wheat	200
CONCLUSIONS	202
4.9.1 Index for determination of B responses	203
SUMMARY	206
MAIN FINDINGS OF THE RESEARCH STUDIES	212
THE WAY FORWARD/FUTURE RESEARCH NEEDS	213
LITERATURE CITED	214