

DETERMINATION OF CRITICAL LIMITS OF POTASSIUM FOR WHEAT, POTATO AND GROUNDNUT IN SOME SOILS OF BANGLADESH

A THESIS

**SUBMITTED IN FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF**

**DOCTOR OF PHILOSOPHY
IN
SOIL SCIENCE**

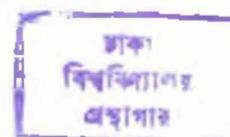
AT THE UNIVERSITY OF DHAKA



BY

384709

S.M. NURUL ISLAM SARKAR



1ST SEPTEMBER, 1997

**SOIL CHEMISTRY LABORATORY
DEPARTMENT OF SOIL SCIENCE
UNIVERSITY OF DHAKA
DHAKA, BANGLADESH**

Se. Sec.

R

631.4

SAD

##

c. 1

Dr. Syed Fazle Elahi
Professor
Department of Soil Science
University of Dhaka
Dhaka
Bangladesh

Dr. Md. Shahidul Islam
Director (Support & Services)
Bangladesh Agricultural
Research Institute,
Joydebpur, Gazipur-1701.
Bangladesh.

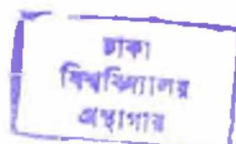
CERTIFICATE

Certified that S.M. Nurul Islam Sarkar has submitted the thesis entitled "Determination of critical limits of potassium for wheat, potato and groundnut in some soils of Bangladesh." in fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Soil Science, University of Dhaka, Bangladesh. The thesis is an original research work carried out under our supervision. No part of the thesis has been submitted anywhere for any other degree or diploma.

384709



Dr. Syed Fazle Elahi
Adviser



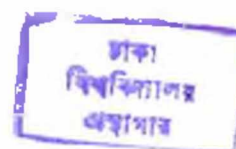
Dr. Md. Shahidul Islam
Adviser

Dedicated to my beloved

MOTHER

Whose departed soul always inspired
me to undertake the study and
complete this dissertation

384709



ACKNOWLEDGMENT

First and foremost praise to Almighty Allah, the Cherisher and Sustainer of the world, whose blessings have enabled me to complete this manuscript. I also thank to my parents and relatives for their encouragement, moral support, love, prayers and sacrifices in achieving my Ph.D. degree.

I gratefully acknowledge my indebtedness to **Dr. M.A. Mazed**, Director General, Bangladesh Agricultural Research Institute for granting me a scholarship and deputation to pursue my Ph. D. degree at the University of Dhaka, Bangladesh.

I express deepest sense of gratitude, appreciation and indebtedness to my advisors:

Dr. Syed Fazle Elahi, Professor, and former Chairman, Department of Soil Science, University of Dhaka, for his active guidance, valuable advice, and generous help in the planning, designing, conducting and completion of the research work and also in writing and editing of the manuscript; and

Dr. Md. Shahidul Islam, Director (Support and Services), Bangladesh Agricultural Research Institute, for his endless dynamic guidance in planning, designing and conducting the research work, in constant encouragement during the execution of the research work and in constructive criticism in writing and improving the manuscript.

I also express my gratitude and indebtedness to:

Dr. Shafiur Rahman, Professor and Chairman, Department of Soil Science, University of Dhaka, for his support and encouragement

during the course of work on this dissertation. I must express my heartfelt thanks and gratitude to all of my reverend teachers and staffs of the Department of Soil Science, University of Dhaka for their constant cooperation and good wishes during the research work;

Dr. A.K. Maqbul Hossain, Chief Scientific Officer and Head, Division of Soil Science, Bangladesh Agricultural Research Institute, Mr. S.M. Shaheed, Director and Mr. Md. Amir Ali, Senior Scientific Officer, Soil Resources Development Institute, for providing me the necessary logistic support in analysing soil and plant sample in the laboratory.

My deep appreciation and sincere thanks to:

Dr. K.H. Kabir, Senior Scientific Officer, Bangladesh Agricultural Research Institute, who helped me a lot in statistical analysis, preparation and arrangement of the manuscript, and for his endless careful editing towards the improvement of the entire manuscript. Mr. M. Masudur Rahman, Scientific Officer, Division of Soil Science, Bangladesh Agricultural Research Institute, for his sincere help in preparing valuable and important graphs in the computer. Mr. M.A. Mannan, Chief Scientific Officer, Division of Entomology, Bangladesh Agricultural Research Institute, for his encouragement and providing me computer facilities in his Division and Dr. M.A. Saleque, Senior Scientific Officer, Division of Soil Science, Bangladesh Rice Research Institute, who helped me in preparation and constant encouragement to finish the manuscript.

My special thanks and deep appreciation also go to:

Mr. M. Nural Anwar, Mr. K. Mazedul Hossain, Mr. M. Jalal Uddin Sarker, Mr. Mojibur Rahman, Senior Scientific Officers, Mr. Zahurul Islam, Scientific Officer and Dr. A.T.M. Farid, Principal Scientific Officer, Division of Soil Science, Bangladesh

Agricultural Research Institute, for their moral support, encouragement, companionship, help, suggestions and inspirations;

Mr. M. Shahiduzzaman, Scientific Officer, Mr. A. Majid, Mr. A. Goffar and Mr. Ratan Kumar Pal, Scientific Assistants and Mr. M. Mahbubur Rahman, Senior Scientific Assistant, Division of Soil Science, Bangladesh Agricultural Research Institute, for their tireless assistance in the laboratory analyses and field work of the research.

Sincere thanks to Mr. M. Zahurul Islam, Typist, Division of Entomology, Mr. M.A. Basharul Islam and Mr. Ramendra Nath Tarafder, Typists, Division of Soil Science, Bangladesh Agricultural Research Institute, for their endless and untiring efforts in preparing the tables, graphs and typing the manuscript.

I also express my sincere thanks and appreciation to all those whom I failed to mentioned but who helped me in one way or another in the conduct of the study or in the preparation of my dissertation.

Lastly but not the least, I extend my heartfelt appreciation to my wife, Dil Afruza Begum (Reshma), for her continuous inspiration, help and sacrifice. I will never forget the sacrifice that my loving son, S.M. Tasnim Rezwan (Rusho) and daughter, Nabila Rezwan (Nitu) made while I was in the pursuit of my Ph.D. degree. For the same reason, I also thank my brothers and sisters.

S.M. NURUL ISLAM SARKAR

CONTENTS

	<u>PAGES</u>
LIST OF TABLES	xii
LIST OF FIGURES	xvii
LIST OF APPENDICES	xxii
ABSTRACT	xxiii
CHAPTER 1.0 INTRODUCTION	1
CHAPTER 2.0 REVIEW OF LITERATURE	11
2.1 Importance of potassium in agriculture	11
2.2 Symptoms of potassium deficiency	11
2.2.1 Symptoms of potassium deficiency in potato	12
2.2.2 Symptoms of potassium deficiency in wheat	12
2.2.3 Symptoms of potassium deficiency in groundnut	13
2.3 Natural sources of potassium in soils	13
2.4 Factors influencing soil potassium availability to plants	14
2.5 Potassium fertility of Bangladesh soils	15
2.6 Loss of potassium from soil	16
2.7 Transformation of added potassium	16
2.8 Release of non-exchangeable potassium	17
2.9 Condition favors the fixation of applied potassium	17
2.10 Potassium uptake by crops	17
2.11 Potassium requirements during the growing season	19
2.12 Methods of potassium determination in soil	19
2.12.1 Common extractants for potassium determination	20

	<u>PAGES</u>
2.12.2 K extraction with 1N ammonium acetate	20
2.12.3 Extractant for available potassium determination	22
2.13 Methods of potassium determination in plant sample	23
2.14 Cation exchange capacity in soil	23
2.15 Status of soil potassium in different extraction methods	25
2.16 Critical limit determination	31
2.16.1 Critical Limit	31
2.16.2 The critical concentration	32
2.16.3 Use of critical limit	32
2.16.4 Limitation to the concept of the critical limit	33
2.16.5 Graphical procedure for critical limit determination	34
2.16.6 Mathematical procedure for critical limit determination	34
2.17 Critical limit of potassium extracted by different extractants	35
2.17.1 Critical limit of soil potassium extracted by 1N NH_4OAc	35
2.17.2 Critical limit of soil potassium extracted by NaHCO_3	38
2.17.3 Critical limit of soil potassium extracted by H_2SO_4	39
2.17.4 Critical limit of soil potassium extracted by HNO_3	40
2.17.5 Critical limit of soil potassium extracted by distilled water	41

	<u>PAGES</u>
2.18 Critical limit of potassium for crops	42
CHAPTER 3.0 MATERIALS AND METHODS	46
3.1. Collection of soil sample	46
3.2. Laboratory analyses	46
3.3. Pot experiment	51
3.4. Determination of critical limit	55
CHAPTER 4.0 RESULTS AND DISCUSSION	57
4.1 Soil characteristics	57
4.2 Determination of soil potassium using five different extractants	63
4.3 Per cent K saturation of the extractable K in five extraction methods	68
4.4 Co-efficient of correlation (r) between soil K values determined by using five extractants and soil properties	70
4.5 Intercorrelation among K values extracted by different methods of extraction	74
4.6 Critical limit of potassium in soil and plant and the response of wheat to applied potash in soils of thirty one locations	77
4.6.1 Effect of K application on the dry matter yield, per cent relative yield, per cent K concentration in plant and K uptake of wheat	77
4.6.2 K concentration in wheat plant and per cent relative yield	81
4.6.3 Correlation coefficient of soil K values of five extractants with various plant parameters of wheat	83

	<u>PAGES</u>
4.6.4 Critical limit of soil potassium for wheat	86
4.6.5 Critical limit of potassium determined from K concentration in wheat plant	104
4.6.6 Efficiency of applied potassium for the dry matter yield of wheat	107
4.7 Critical limit of potassium in soil and plant and the response of potato to applied potash in soils of thirty one locations	110
4.7.1 Effect of K application on the dry matter yield, per cent relative yield, per cent K concentration in plant and K uptake of potato	110
4.7.2 K concentration in potato plant and per cent relative yield	113
4.7.3 Correlation coefficient between soil K values of five extractants and various plant parameters of potato	115
4.7.4 Critical limit of soil potassium for potato	118
4.7.5 Critical limit of potassium determined from K concentration in potato plant	135
4.7.6 Efficiency of applied potassium for the dry matter yield of potato	136

	<u>PAGES</u>
4.8 Critical limit of potassium in soil and plant and the response of groundnut to applied potash in soils of twenty nine locations	141
4.8.1 Effect of K application on the dry matter yield, per cent relative yield, per cent K concentration in plant and K uptake of groundnut	141
4.8.2 K concentration in groundnut plant and per cent relative yield	144
4.8.3 Correlation coefficient of soil K values of five extractants with various plant parameters of groundnut	146
4.8.4 Critical limit of soil potassium for groundnut	147
4.8.5 Critical limit of potassium determined from K concentration in groundnut plant	164
4.8.6 Efficiency of applied potassium for the dry matter yield of groundnut	165
 CHAPTER 5.0 SUMMARY AND CONCLUSIONS	 170
 CHAPTER 6.0 REFERENCES	 181
 CHAPTER 7.0 APPENDICES	 195

LIST OF TABLES

<u>Table No.</u>	<u>Title of the Tables</u>	<u>Pages</u>
3.1.	Location and general characteristics of the soil sampling sites	47
3.2.	Description of methods used for soil and plant sample analyses	52
4.1.	Physicochemical characteristics of soil (0-15cm depth) of thirty one locations	59
4.2.	Particle size distribution and textural classes of the soil of thirty one locations	61
4.3.	Level of potassium in soil from thirty one locations determined by using five extractants	64
4.4.	Per cent K saturation of extractable K from five different extraction methods of soil of thirty one locations	69
4.5.	Coefficient of correlation (r) between soil K values determined by using five extractants and some soil properties	72
4.6.	Coefficient of intercorrelation among different K extraction methods	76
4.7.	Quantity of potassium extracted by different K extractants, dry matter yield and per cent relative yield of wheat grown in soils of thirty one locations	78
4.8.	Effect of K application on the dry matter yield, per cent relative yield, K concentration and K uptake of wheat	80
4.9.	Dry matter yield, K concentration in plant (1N HCl extraction) at different levels of applied K and per cent relative yield of wheat	82

<u>Table No.</u>	<u>Title of the Tables</u>	<u>Pages</u>
4.10.	Correlation coefficient (r) of soil K of different extractants with various plant parameters of wheat	85
4.11.	Critical limits of five soil K extractants for wheat as determined by graphical and mathematical procedures	93
4.12.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (1N NH_4OAc extraction)	94
4.13.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (0.25N NaHCO_3 extraction)	95
4.14.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (1N HNO_3 extraction)	96
4.15.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (cold H_2SO_4 extraction)	97
4.16.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (distilled water extraction)	98
4.17.	Response of wheat to potassium applied in different level of soil K (below and above the critical limit) determined by using five extractants	100
4.18.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat plant (1N HCl extraction)	106

<u>Table No.</u>	<u>Title of the Tables</u>	<u>Pages</u>
4.19.	Efficiency of applied potassium for the dry matter yield of wheat	109
4.20	Quantity of potassium extracted by different extractants, dry matter yield and per cent relative yield of potato grown in soils of thirty one locations	111
4.21.	Effect of K application on the dry matter yield, per cent relative yield, K concentration and K uptake of potato	112
4.22.	Dry matter yield, K concentration in plant (1N HCl extraction) at different levels of applied K and per cent relative yield of potato	114
4.23.	Correlation coefficient (r) between soil potassium values of different extractants with various plant parameters of potato	117
4.24.	Critical limits of potassium of five soil extractants for potato as determined by graphical and mathematical procedures	125
4.25.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (1N NH_4OAc extraction)	126
4.26.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (0.25N NaHCO_3 extraction)	127
4.27.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (1N HNO_3 extraction)	128

<u>Table No.</u>	<u>Title of the Tables</u>	<u>Pages</u>
4.28.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (cold H_2SO_4 extraction)	129
4.29.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (distilled water extraction)	130
4.30.	Response of potato to potassium applied in different level of soil K (below and above the critical limit) determined by using five extractants	132
4.31.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato plant (1N HCl extraction)	138
4.32.	Efficiency of applied K for the dry matter yield of potato	140
4.33.	Quantity of potassium extracted by different extractants, dry matter yield and per cent relative yield of groundnut grown in soils of twenty nine locations	142
4.34.	Effect of K application on the dry matter yield, per cent relative yield, K concentration and K uptake of groundnut	143
4.35.	Dry matter yield, K concentration in plant (1N HCl extraction) at different levels of applied K and per cent relative yield of groundnut	145
4.36.	Correlation coefficient (r) of soil K of different extractants with various plant parameters of groundnut	147

<u>Table No.</u>	<u>Title of the Tables</u>	<u>Pages</u>
4.37.	Critical limits of five soil K extractants for groundnut as determined by graphical and mathematical procedures	154
4.38.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (1N NH_4OAc extraction)	155
4.39.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (0.25N NaHCO_3 extraction)	156
4.40.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (1N HNO_3 extraction)	157
4.41.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (cold H_2SO_4 extraction)	158
4.42.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (distilled water extraction)	159
4.43.	Response of groundnut to potassium applied in different level of soil K (below and above the critical limit) determined by using five extractants	161
4.44.	Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut plant (1N HCl extraction)	167
4.45.	Efficiency of applied K for the dry matter yield of groundnut	169

LIST OF FIGURES

<u>Figure No.</u>	<u>Title of the Figures</u>	<u>Pages</u>
3.1.	Map of Bangladesh showing approximate sampled areas	50
4.1.	Critical limit determination based on the relationship between exchangeable K (1N NH_4OAc extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations	88
4.2.	Critical limit determination based on the relationship between available K (0.25N NaHCO_3 extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations	89
4.3.	Critical limit determination based on the relationship between available K (1N HNO_3 extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations	90
4.4.	Critical limit determination based on the relationship between available K (cold H_2SO_4 extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations	91
4.5.	Critical limit determination based on the relationship between distilled water soluble K (1:10 soil: water extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations	92
4.6.	Response of wheat to potassium applied in different level of soil K (below and above the critical limit) extracted by 1N NH_4OAc	101
4.7.	Response of wheat to potassium applied in different level of soil K (below and above the critical limit) extracted by 0.25N NaHCO_3	101

<u>Figure No.</u>	<u>Title of the Figures</u>	<u>Pages</u>
4.8.	Response of wheat to potassium applied in different level of soil K (below and above the critical limit) extracted by 1N HNO ₃	102
4.9.	Response of wheat to potassium applied in different level of soil K (below and above the critical limit) extracted by cold H ₂ SO ₄	102
4.10.	Response of wheat to potassium applied in different level of soil K (below and above the critical limit) extracted by distilled water	103
4.11.	Critical limit determination based on the relationship between total K (1N HCl extraction) concentration in plant and relative dry matter yield of wheat grown in soils of thirty one locations	105
4.12.	Critical limit determination based on the relationship between exchangeable K (1N NH ₄ OAc extraction) content of soil and relative dry matter yield of potato grown in soils of thirty one locations	120
4.13.	Critical limit determination based on the relationship between available K (0.25N NaHCO ₃ extraction) content of soil and relative dry matter yield of potato grown in soils of thirty one locations	121
4.14.	Critical limit determination based on the relationship between available K (1N HNO ₃ extraction) content of soil and relative dry matter yield of potato grown in soils of thirty one locations	122

<u>Figure No.</u>	<u>Title of the Figures</u>	<u>Pages</u>
4.15.	Critical limit determination based on the relationship between available K (cold H_2SO_4 extraction) content of soil and relative dry matter yield of potato grown in soils of thirty one locations	123
4.16.	Critical limit determination based on the relationship between distilled water soluble K (1:10 soil: water extraction) content of soils and relative dry matter yield of potato grown in soils of thirty one locations	124
4.17.	Response of potato to potassium applied in different level of soil K (below and above the critical limit) extracted by 1N NH_4OAc	133
4.18.	Response of potato to potassium applied in different level of soil K (below and above the critical limit) extracted by 0.25N $NaHCO_3$	133
4.19.	Response of potato to potassium applied in different level of soil K (below and above the critical limit) extracted by 1N HNO_3	134
4.20.	Response of potato to potassium applied in different level of soil K (below and above the critical limit) extracted by cold H_2SO_4	134
4.21.	Response of potato to potassium applied in different level of soil K (below and above the critical limit) extracted by distilled water	135
4.22.	Critical limit determination based on the relationship between total K (1N HCl extraction) concentration in plant and relative dry matter yield of potato grown in soils of thirty one locations	137

<u>Figure No.</u>	<u>Title of the Figures</u>	<u>Pages</u>
4.23.	Critical limit determination based on the relationship between exchangeable K (1N NH_4OAc extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations	149
4.24.	Critical limit determination based on the relationship between available K (0.25N NaHCO_3 extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations	150
4.25.	Critical limit determination based on the relationship between available K (1N HNO_3 extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations	151
4.26.	Critical limit determination based on the relationship between available K (cold H_2SO_4 extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations	152
4.27.	Critical limit determination based on the relationship between distilled water soluble K (1:10 soil: water extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations	153
4.28.	Response of groundnut to potassium applied in different level of soil K (below and above critical limit) extracted by 1N NH_4OAc	162

<u>Figure No.</u>	<u>Title of the Figures</u>	<u>Pages</u>
4.29.	Response of groundnut to potassium applied in different level of soil K (below and above critical limit) extracted by 0.25N NaHCO_3	162
4.30.	Response of groundnut to potassium applied in different level of soil K (below and above critical limit) extracted by 1N HNO_3	163
4.31.	Response of groundnut to potassium applied in different level of soil K (below and above critical limit) extracted by cold H_2SO_4	163
4.32.	Response of groundnut to potassium applied in different level of soil K (below and above critical limit) extracted by distilled water	164
4.33.	Critical limit determination based on the relationship between total K (1N HCl extraction) concentration in plant and relative dry matter yield of groundnut grown in soils of twenty nine locations	166

LIST OF APPENDICES

<u>Appendix No.</u>	<u>Title of the Appendices</u>	<u>Pages</u>
7.1.	Analyses of variances for dry matter yield of wheat grown in net house using soils of thirty one locations.	195
7.2.	Analyses of variances for dry matter yield of potato grown in net house using soils of thirty one locations.	202
7.3.	Analyses of variances for dry matter yield of groundnut grown in net house using soils of twenty nine locations.	209
7.4.	Analyses of variances for per cent K concentration of wheat plant grown in net house using soils of thirty one locations.	215
7.5	Analyses of variances for per cent K concentration of potato plant grown in net house using soils of thirty one locations.	222
7.6.	Analyses of variances for per cent K concentration of groundnut plant grown in net house using soils of twenty nine locations.	229
7.7	Acreage and production of wheat, potato and groundnut during 1989-90 to 1993-94	235
7.8.	Major sources of potassium fertilizer	235

ABSTRACT

A series of pot experiments were conducted in the net house with thirty one soils representing seven general soil types and fourteen agroecological zones of Bangladesh. The major objectives of the study were: (1) to evaluate the suitability of K extractant(s) for soils; and (2) to determine the critical limits of potassium for soils and some selected upland crops wheat (*Triticum aestivum* L.), potato (*Solanum tuberosum* L.) and groundnut (*Arachis hypogaea* L.). Five levels of potassium i.e., 0, 25, 50, 75 and 100mg K Kg⁻¹ for potato, and 0, 15, 30, 45 and 60mg K Kg⁻¹ for wheat and groundnut were applied in pots to observe the response of applied nutrient on the dry matter yield of crops.

The study was conducted with five K extractants and the K extracting ability of five extractants was found in the following order: 1N HNO₃ > cold H₂SO₄ > 0.25N NaHCO₃ > 1N NH₄OAc > distilled water.

For wheat plant, cold H₂SO₄ was the best among five extractants, as it gave highest *r* values with per cent K concentration (K_o) followed by per cent relative yield of wheat. Critical limits of soil K for wheat were found to be 0.13, 0.28 (meq K/100ml soil), 1.86, 0.34 and 0.08 meq K/100g soil for 1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled water respectively worked out by both graphical and mathematical procedures, where as critical K concentration limit in wheat plant was 4.02 and 4.04% calculated by the same procedures as followed in soil for 1N HCl extraction procedure.

For potato plant, 1N NH_4OAc extractable K was highly significant and positively correlated with K uptake (K_o) and K concentration (K_o) among five extractants, as it offered higher r values. Critical limits of soil K for potato obtained by graphical procedure were as 0.29, 0.24 (meq K/100ml soil), 0.90, 0.30 and 0.14 meq K/100g soil for 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water respectively but by mathematical procedure, critical limits were 0.29, 0.25 (meq K/100ml soil), 0.93, 0.31 and 0.15 meq K/100g soil respectively for the same extractants as used in graphical procedure. Critical K concentration limit in potato plant was 6.40 and 6.46% for 1N HCl extractant by graphical and mathematical procedures respectively.

For groundnut plant, distilled water soluble K performed significant and high degree of correlation with K uptake (K_o) of groundnut over the other four extractants. Critical limits of soil K for groundnut extracted by 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water appeared to be 0.36, 0.36 (meq K/100ml soil), 2.16, 0.18 and 0.12 meq K/100g soil respectively for graphical procedure but for mathematical procedure, these values were as 0.36, 0.37 (meq K/100ml soil), 2.17, 0.18 and 0.12 meq K/100g soil. The values of 1.10 and 1.13% were determined as critical K concentration limit in groundnut plant by graphical and mathematical procedures respectively for 1N HCl extraction procedure.

For all extractants and crops, applied K fertilizer use efficiency was found maximum in soils with K values below the critical limit and minimum in soils with K values above the critical limit.

CHAPTER 1.0

INTRODUCTION

Plant needs at least sixteen elements (macro and micro) essential for growth and nutrition. Of those nitrogen (N), phosphorus (P) and potassium (K) are widely known as major plant food elements and are taken up in large quantities. Potassium in particular, is taken up by plants in higher quantities than any other element for vigorous and healthy growth. Potassium occurs as a simple cation (K^+) throughout the soil-plant system. It is rather mobile and therefore, subjected to considerable leaching in sandy soils, especially if the pH is relatively low. Deficiency of this element affects various physiological and biochemical processes and thereby reduces crop yield (Mengel, 1985). Potassium is available in all categories of soils at exchange complex but in greater quantity in clay soils (Charles et al., 1982).

Potassium acts as an activator of dozens of enzymes responsible for several plant processes such as energy metabolism, starch synthesis, nitrate reduction and sugar degradation. Potassium is extremely mobile (FAO, 1984; PPI., 1983; Anonymous, 1985 and PPIC., 1989b) and its high mobility permits it to move quickly from cell to cell or from older plant tissues to newly developing tissues. Its relatively high concentration in plant cells helps to regulate the opening and closing of stomates in the leaves and uptake of water by root cells. The stomatal opening and

closing is strongly controlled by water relations of guard cells. In this respect, K^+ ions are known to be involved in the opening and closing of stomata (Sinha, 1978). At night, due to darkness, high intracellular CO_2 concentrations and abscisic acid induce stomata closure (Beringer, 1978).

Potassium is considered as essential nutrient to cereals for grain formation. It aids in the development of plump and heavy kernels. Adequate supply of potassium is also necessary for tuber development. Potassium tends to prevent undesirable lodging of plants and to counteract the damaging effects of excessive nitrogen by increasing crop resistance to certain diseases by encouraging strong root and stem systems. Potassium also exerts a balancing effect on both nitrogen and phosphorus (Brady, 1984). Unlike nitrogen and phosphorus, potassium is not a constituent of any plant structure or compound, at the same time it is essential in nearly all processes needed to sustain plant life (PPIC., 1989b).

Potassium deficiency generally occurs in acid sandy soils or highly leached lateritic soils. This element is also low in organic soils such as peat and muck soils. The soils which have very high contents of Ca and Mg may also restrict K uptake by the plants leading to K deficiency. Lack of soil moisture may also lead to K deficiency in plants (Nijjar, 1990). As K is highly mobile within the plant, the first symptoms show on older leaves since their K supplies are drained to supply young leaves. The first sign of

potassium deficiency is the reduction of growth rates. Plants become stunted and usually leaves become darker green. At a more advanced stage, specific deficiency symptoms begin to appear as white, yellow or orange chlorotic spots or stripes on older leaves, usually starting from the leaf tips and margins. The base of the leaf generally remains dark green. The symptoms spread to younger leaves and finally the entire plant may die (PPIC., 1989a).

Potato (*Solanum tuberosum* L.) is one of the world's most nutritious food items for human consumption in the world. The ratio of protein to carbohydrates in potato is higher than that in many cereals, roots and tubers. In developing countries, potatoes rank first in energy production per hectare per day, above cassava, the cereals and pulses. In Bangladesh, potato production and acreage are increasing day by day (Appendix 7.7). Potato is one of the potash loving crop generally grown in Bangladesh. Total yield and quality of potato can be influenced by potassium nutrition in a number of ways, including the followings:

- better utilization of N and increased protein content,
- improving the size of tubers,
- shape of seeds and tubers (BARC., 1991).

Being a high biomass yielder, the requirement of potassium in potato is higher than nitrogen (Shah and Ismail, 1983). A good supply of potassium in the form of fertilizer is therefore essential for good potato production (Anonymous, 1985).

Wheat (*Triticum aestivum* L.) is now the second most important cereal crop grown in Bangladesh. It can be grown successfully under a wide range of soil conditions but it is best adapted to fertile, well drained silt and clay loam soils where cool climate persists and supply of soil moisture is adequate for at least 120 days. The climate of Bangladesh is favorable for wheat cultivation. The production and acreage of wheat in Bangladesh are increasing day by day (Appendix 7.7). For optimum growth and maximum yield, wheat needs an adequate and balanced supply of all nutrients along with large quantities of potassium. In Bangladesh, crop quality and high yields are being often constrained by insufficient supply of potassium in many soils (BARC., 1991).

Groundnut (*Arachis hypogaea* L.) commonly known as "badam", is one of the important oil seed crops grown in Bangladesh. It is generally cultivated during rabi and kharif seasons under rainfed condition. It stands fourth in respect of production and fifth in acreage in Bangladesh amongst the oilseed crops (BSS., 1991). Being a legume crop, it increases the fertility of the soil by fixing 80-100 kg atmospheric nitrogen per hectare per year (Islam et al., 1982) and removes approximately 110kg K₂O ha⁻¹ (PPIC., 1989b). The

average yield is recorded in Bangladesh about 1.16 ton ha^{-1} during 1993-94 (BBS., 1995). In Bangladesh, groundnut is generally grown in light textured soils and thereby potash requirement for the optimum growth and yield is higher than that of nitrogen and phosphorus.

Soils of Bangladesh have been divided into three major physiographic groups: Floodplains (9.7 m ha), Terrace (1.0 m ha) and Hills (1.6 m ha). Floodplains of the Ganges, Brahmaputra, Meghna and small rivers occupy flat or very gently undulating relief comprising broad and narrow ridges and depressions. Ganges and Brahmaputra sediments are rich in weatherable minerals which contribute to soil fertility particularly potassium. Piedmont sediments derived from the eastern hills generally have low content of weatherable minerals. Terrace comprises a wide range of soils formed over Modhupur Clays which is low in weatherable minerals.

The available potassium (0.25N NaHCO_3) status of different soils of Bangladesh is classified as low, medium, optimum, high and very high. The potassium status of most hilly soils is low ($0.08-0.17 \text{ me \%}$). Potassium status of most terrace ($0.14-0.27 \text{ me\%}$) and piedmont ($0.08-0.19 \text{ me \%}$) soils is also low to medium. Most soils of Tista Floodplains are deficient in available potassium ($0.13-0.17 \text{ me\%}$). Soils of Surma-Kushiyara Floodplains are also deficient in available potassium ($0.10-0.16 \text{ me \%}$) but the soils of southern part (Ganges Floodplain Soils) of Bangladesh contain high level of

available potassium (0.28-0.71 me%). On the other hand, Meghna and Brahmaputra Floodplain soils contain generally low content of available potassium (0.07-0.15 me%) (BARC., 1991). Most of the alluvial soils and sediments of Bangladesh are rich in K bearing minerals and K content (Habibullah et al., 1971; Karim et al., 1978; Karim, 1980 and Huizing, 1970).

Soil testing for fertilizer requirement is a well known practice for efficient management of fertilizers. Most of the soil testing laboratories in Bangladesh recommend fertilizer application on the basis of soil fertility classes (low, medium, optimum, high and very high) but their recommendation are not adequately equipped with crop response data. As such, the information on proper fertilizer use emanating from soil testing laboratories must primarily be based on critical soil fertility limits of different nutrients of soils and plants (Singh et al., 1991). For the estimation of potassium fertility status of the soils, a number of chemical extractants have widely been used in different laboratories. Among these, only 5 different extractants were used in the present study (1N NH_4OAc , 0.25N NaHCO_3 , cold H_2SO_4 , 1N HNO_3 and distilled water) considering their availability and simplicity of procedure to determine K. In selecting an extractant for a particular soil and nutrient the important consideration is the degree of correlation between the extracted nutrient and plant growth.

Plant analysis can also be used to increase crop production through improve fertilization practices in several ways including evaluation of fertilizer programmes, controlled feeding, diagnosis of abnormal growth or detection of deficiencies, as a guide to harvest and in plant nutrient surveys (Ulrich et al., 1967a). Plant analysis is a diagnostic tool and is still in its infancy as a guide for crop production. The basic principle of the use of the plant analysis is that the chemical composition of the plant reflects its nutrient supply in relation to growth. By comparing the analysis of a series of plant samples drawn through the growing season with critical values, it is possible to determine how well fertilizer is meeting the needs of the crop (Dhillon et al., 1988). In case of plant sample, dilute HCl method was chosen because of being less cumbersome, less time consuming, no hazard of digestion like that of tri-or-diacid digestion system.

Critical limit is a point or a level of nutrient(s) below which the probability of an economic response to added fertilizer is high (soil test value low) and above which the probability of an economic response to added fertilizer is low (soil test value high) (Cate et al., 1965). Since the introduction of the concept of the critical limit by Cate and Nelson (1965), most of the information on critical limit of nutrient is based on the results of pot culture experiment (Gupta et al., 1993). Thus, the crop grown in soils containing K less than the critical level is expected to respond K fertilization significantly. Thus a sound soil testing

programme for rational and judicious fertilizer use with the intention of desired crop yield must be based on critical soil fertility limits of different nutrients in soil of the area (Rao et al., 1992).

The critical limits of K in soil or plant are generally been determined using either of graphical or statistical procedures. Macy (1936) considered the zone of minimum percentage, poverty adjustment and luxury consumption while adopting graphical method to determine the critical limit. The graphical method suggested by Cate and Nelson (1965), involves arbitrary intersecting a pair of perpendicular lines developed through the percent relative yield (Y-axis) against available K in soil or K concentration of plant (X-axis) because the selection of growth just below the maximum growth level was arbitrary (Sharma, 1991). In practice, Cate-Nelson scatter diagram provides a simple yet highly effective tool for evaluation of soil analytical methods (Donovan et al., 1973). Cate and Nelson (1971) reported a mathematical model for determining critical limit of soils or plants for which a large body of data is desired in order to get accurate critical values (Sharma, 1991). Yadav et al. (1984) stated that the Cate-Nelson statistical approach is recently used by many workers because it can able to provide quantifiable values for separating categories of the nutrient by determining critical level.

In view of the above importance and statement of the problem, thirty one locations representing seven general soil types and fourteen agroecological zones of Bangladesh were selected on the basis of low, medium and high exchangeable potassium category for this study. In the present study, five extractants have been used to assess inherent capacity of the soil to supply potassium to growing plants. In order to elicit further information on potassium fertility evaluation, an investigation has undertaken with the objective of identifying the best K availability index of five different K extractants, their response to upland crops and thereafter determine the critical limit of potassium in soils and upland crops (wheat, potato and groundnut) using Cate and Nelson graphical and mathematical procedures.

Critical limit either of soil or plant can be effectively used to separate K responsive soils or crops from the non-responsive ones and be of great help for the extension workers and researchers for judicious and rational K fertilization programme of upland crops. Therefore, the critical limit of K is important in working out fertilizer schedules. The present study was undertaken to fulfill the following objectives.

1. To find out potassium status of the soil of thirty one locations.
2. To chalk out K availability index from five different potassium extractants.

3. To determine the relative yield percentage of wheat, potato and groundnut from the limit of plateau yield response as compared to threshold yield (K_0).
4. To determine potassium concentration in the dry matter of wheat, potato and groundnut at different levels of added potassium for to find out K uptake and per cent relative yield.
5. To calculate the uptake of potassium using the value of potassium concentration and the dry matter yield of wheat, potato and groundnut.
6. To determine the critical limit of potassium in soils and crops i.e., wheat, potato and groundnut using Cate and Nelson graphical and mathematical procedures.
7. To determine the efficiency of applied potassium for the dry matter yield of wheat, potato and groundnut.

CHAPTER 2.0

REVIEW OF LITERATURE

2.1 Importance of potassium in agriculture

Potassium is the third major plant nutrient element in the N-P-K fertilizer grade. It is a cation that has one positive (+ve) charge and is taken up as large quantities than any other element by the plants as K ions (Hignett, 1982). Potassium is essential for the growth and development of plants (Mengel, 1985). Over the years, the crop yield has greatly increased as a result of improved irrigation, more intensive cropping and extensive use of nitrogen fertilizers. On the other hand, the use of mineral fertilizers has been reported to be imbalanced in favor of nitrogen. As a result potassium deficiency is increasing day by day and becoming a limiting factor to crop yield and response to other fertilizer nutrients (Anonymous, 1985).

2.2 Symptoms of potassium deficiency

As potassium is highly mobile within the plant, the first common hunger sign is scorching or firing and browning along leaf margins of the tip of older leaves. This gradually progress inwards and chlorotic areas become necrotic. The tissue dies and leaves dry up. Potassium deficient plants grow slowly. They have poorly developed root systems, stalks are weak, susceptible to lodging, pests, diseases, frost etc. Seeds and fruits are small and shrivelled, low yield and in general poor crop quality. Plants with

inadequate supply of K are very susceptible to unfavorable weather (FAO., 1984; PPI., 1983; Anonymous, 1985 and PPIC., 1989a).

2.2.1 Symptoms of potassium deficiency in potato

The first sign of potassium deficiency in potato is reduced growth rate, slightly smaller leaves and a darker green leaf colour. This is followed by an interveinal chlorosis of the older leaves. As the chlorosis intensifies, leaf tips and margins become necrotic, the leaves curl upwards and dry up (Anonymous, 1985).

2.2.2 Symptoms of potassium deficiency in wheat

Potassium deficient wheat plants get stunted and wilted during dry weather. In the older leaves chlorotic tips appears and result in necrosis. The chlorotic area gradually moves downward on the leaf. As the chlorosis moves faster on the leaf margin than near the midrib, an "arrow" of green tissue is left around the midrib. The culms of potassium deficient wheat becomes thin and weak, thus cannot respond well to nitrogen application and is also more susceptible to frost, drought and diseases. At flowering stage, potassium deficient wheat plant shows yellowing at the tip of the flag leaf. K deficient wheat plants will have poorly filled ears, especially at the top (Anonymous, 1985 and PPIC., 1989a).

Disintegration and decomposition of rocks containing K-bearing minerals are the principal source of K. The minerals that generally considered to be the sources of K are the potash feldspar (KAlSi_3O_8), muscovite ($\text{H}_2\text{KAl}_3\text{SiO}_4$) and biotite ($(\text{H},\text{K})_2(\text{Mg},\text{Fe})_2\text{Al}_2(\text{SiO}_3)$). Potash bearing minerals almost exclusively occur in the sand and silt fractions of the soil and occasionally in coarse clay. The availability of K in these minerals is in the order of biotite > muscovite > potash feldspar. Potassium is also present in the soil in the form of clay minerals such as montmorillonite, illite, vermiculite, chlorite and other minerals (Nijjar, 1990). According to Tandon et al. (1988e) the general sequence of weathering of K bearing minerals in soil can be depicted as follows:

Mica (10% K) $\rightarrow$ Hydrous Mica (6-8% K) $\rightarrow$ Illite (4-6% K) $\rightarrow$ Transitional clay minerals (2-3% K) $\rightarrow$ Montmorillonite, Vermiculite (< 1% K).

2.4 Factors influencing soil potassium availability to plants

Most mineral soils, except sandy are comparatively high in total potassium (35,000 - 55,000 kg potassium per hectare furrow slice) (Brady, 1984).

Several factors may influence the availability of soil potassium to plants. These are: (i) leaching, (ii) amounts and type of clay minerals, (iii) soil pH and liming and (iv) soil

structure, water content and soil temperature (PPIC., 1989b). Chatterjee et al. (1984) reported that the various factors which can affect the availability of potassium are mineralogical characteristics, texture, CEC, organic matter, quantity/intensity relations, interaction with other cations (Ca^{++} , Na^+ NH_4^+ , Al^{+3} etc), moisture regime, environmental stress etc.

2.5 Potassium fertility of Bangladesh soils

Based on critical potassium level (0.17 me%) of the soil for the upland crops, about 50% of the cultivable area of Bangladesh has low exchangeable/ available potassium, 30% has medium (0.18 - 0.34 me%) and the rest 20% has (mostly in southern saline and low lying areas) high exchangeable potassium (>0.51 me%). The potassium status of soils are classified as low ≤ 0.17 , medium 0.18-0.34; optimum 0.35-0.51, high 0.52-0.68 and very high >0.68 me% based on available potassium content of 0.25N NaHCO_3 method (ASI method). Ganges and Brahmaputra sediments are rich in weatherable minerals which contribute potassium to enrich soil fertility. Piedmont sediments derived from the Eastern Hills and Terrace formed over Modhupur clays contain low content of weatherable minerals.

The soils of Surma-Kushiyara, most soils of Tista Floodplains are deficient in exchangeable potassium and most soils of Hills, Terrace and Piedmont contain low to medium exchangeable potassium. But the soils of southern part of Bangladesh contain high level of exchangeable potassium (BARC., 1991).

2.6 Loss of potassium from soil

Nijjar (1990) indicated that the continuous removal of leafy and other crops from the soil without adding any farmyard manure or some other suitable K-bearing minerals to the soil result in loss of considerable quantity of K. leaching and erosion are other sources of K loss from the soil. In the silt-loam and heavier-soils, the losses due to leaching are usually negligible but leaching may be considerable in light textured sandy soils.

2.7 Transformation of added potassium

Potassium fertilizers (KCl , K_2SO_4 etc) are generally water soluble. When K fertilizers are added to the soil they are exposed to soil moisture and are dissociated into the cation K^+ and the anion (Cl^- or SO_4^{2-}). The cation K^+ is largely held on to the exchange complex as an exchangeable cation and a small amount is present in a freely mobile form in the soil solution (Tandon et al., 1988b). The fate of the fertilizer in the soil depends on the type of clay minerals present in the soil. But any of the followings can happen to it (Tandon et al., 1988b and PPI., 1983).

1. It can be attracted to the surfaces of soil clays and organic matter and loosely held there in exchangeable form;
2. Some of it can remain in the soil solution;
3. Some can be taken up immediately by the growing crop;
4. Part of it can be "fixed" or converted to an unavailable or slowly available form in some soils and
5. Part of it can be lost by leaching, particularly in soils with low CEC (e.g., high kaolinitic clays, very sandy and organic soils (peat soils) and coarse texture combined with high rainfall or over irrigation).

2.8 Release of non-exchangeable potassium

Generally soil releases its non-exchangeable (including fixed) potassium, when there are: (i) considerable leaching from the soil; (ii) temperature rises and the soil dries; (iii) acid soils are limed and (iv) rate of crop growth and K uptake is high (Tandon et al., 1988b).

2.9 Condition favors the fixation of applied potassium

Tandon et al. (1988b) reported that a soil fixes a part of the applied potassium if the soil is; (i) rich in montmorillonite, vermiculite and weathered micas and (ii) in acidic condition (if the soil pH is less than 5.5).

2.10 Potassium uptake by crops

Field crops generally uptake potassium faster than they uptake N or P or buildup dry matter. However, the rate of K uptake during the crop growth varies with the variety and climatic condition (Maity et al., 1980). The quantity of K uptake by crops is influenced by its availability, the requirements of the particular crop and the physical, chemical and biological conditions of the environment in which the crop grows. It has been reported that potassium uptake at the peak demand period (midseason) can be 40 to 50 percent more than that measured at maturity. There were substantial losses of potassium observed between flowering to maturity due to leaching from aging leaves, leaf fall, and possibly also by leakage from mature roots (PPIC., 1989b).

Nutrient uptake by potato during the first month after planting is usually very low because the requirement of the plant is minimum (Lorenz et al., 1954). Kleinkopf et al. (1979) reported that the potato plant takes up only about 10% of the total applied nutrients after 30 days of emergence, while Lorenz et al. (1954) indicated that most of the tuber growth occurs and plants accumulate nearly two-thirds of the total nutrient uptake during 40 to 50 days of emergence. Carpenter (1957); Cummings et al. (1968) and Jackson et al. (1959) recorded 100 to 150 kg K uptake per hectare by potato vines and approximately 100 kg in tubers when the yield level was considered as 30 to 40 ton ha⁻¹.

In the studies of the growth rate and uptake of wheat, Anghinoni et al. (1981) reported that shoot growth was exponential with time to 30 days and linear thereafter. They showed with increasing plant age there was decrease in average K uptake rates of 0.90 pmol cm⁻¹s⁻¹ at 5 to 10 days to 0.16 to 0.19 pmol cm⁻¹s⁻¹ between 28 and 48 days.

Zalawadia et al. (1983) found in an experiment that groundnut crop (108 days period) uptake 130 kg KO₂ ha⁻¹. They also reported the K uptake of the crop was 59 kg in the 60 - 108 days period. The utilization of potassium in root crops is higher than the cereals and oil seeds. The approximate uptake of potassium have been estimated 310, 175 and 110 kg ha⁻¹ by potato, wheat and groundnut respectively (PPIC., 1989b).

2.11 Potassium requirements during the growing season

Potassium requirement in a crop varies within a growing season. For annual crops, potassium requirement is low at the beginning of growing season. As the crop grows, its need for potassium increases particularly during the vegetative to flowering stage (PPIC., 1989b).

2.12 Methods of potassium determination in soil

The estimation of potassium in soil is very important and its availability is usually measured by using different chemical extractants. The suitability of any chemical extractant for assessing soil potassium status depends on its ability of extracting potassium from the soil in relation to its uptake by plants. Page et al. (1984) indicated that as an extractant, cold or dilute acid extracts K in a short period of time and removes approximately the same amount of K from most of the soil as does with 1N NH_4OAc . They also mentioned that the cold H_2SO_4 extraction is most useful for acidic and neutral soils but until it is shown to be effective, the 1N NH_4OAc extraction is a safer index for measuring K availability in calcareous soil. Moreover, Page et al. (1984) reported that acid type extractants (cold or dilute) are suitable for many soils that have a CEC < 10 meq/100g soil and relatively low in organic matter content (<5.0%).

2.12.1 Common extractants for potassium determination

For the estimation of potassium fertility status of the soils, a variety of chemical extractants/solutions have widely been used in different laboratories over the years. Among these 1N ammonium acetate, dilute sulphuric acid and hydrochloric acid solution, sodium acetate + acetic acid mixture (Morgan's reagent), calcium ammonium lactate, boiling nitric acid, distilled water, sodium bicarbonate, electro-ultrafiltration (EUF) methods are the common means for extraction of potassium from the soil (Tandon et al., 1988c). Beside these, there are some other extractants are still being used in the United States for estimating K including the Bray-1 extractant (Schulte and Olsen 1970), NaNO_3 , and double acid ($\text{HCl-H}_2\text{SO}_4$), (CSTPA., 1974) extractant. Some of these are used as multipurpose extractants that reduce the time and cost of soil testing (Page et al., 1984).

2.12.2 K extraction with 1N ammonium acetate

Potassium determining extractants are usually maintained equilibrium with neutral 1N NH_4OAc or other cation replacing agents. As such, they remove 80 to 95% of the exchangeable potassium. The most universally employed index to K availability is exchangeable K, i.e., the K extracted by neutral 1N NH_4OAc . The council on soil testing and plant analysis (CSTPA) (1974) reported that neutral 1N NH_4OAc is the most commonly used extraction reagent for determining K, Mg, Ca and Na in most soil testing laboratories in the United States. Pretty (1978) reported that to determine the

K nutrition of plants, exchangeable form of potassium measurement is an important widely used parameter. It has been indicated that many plants, especially trees, are able to absorb greater amounts of potassium from soil than is expected with normal ammonium acetate (Wilde et al., 1979). Thus, the use of other extracting solutions, including nitric or sulphuric acid has been suggested (Pratt and Morse, 1954; Hunter and Pratt, 1957 and Leaf, 1958).

The 1N NH_4OAc extractant is used to extract exchangeable K from the soil Tandon et al. (1988d). Black (1965) indicated that the exchangeable K in soil which is free to exchange with cations of the salt solutions added and readily available to plants. On the other hand, available K in soil is the sum of the exchangeable and water soluble K. In some desert type calcareous soils, K extracted by the Morgan's reagent ($\text{NaOAc} + \text{HOAc}$) was found to be less than half the amount extracted by ammonium acetate (Talati et al., 1974). In India 1N NH_4OAc is commonly and widely being used as an extractant in all the 450 soil testing laboratories to estimate available potassium (Tandon et al., 1988c).

Most laboratories in the central and western USA use 1N NH_4OAc extractant for determining K level in calcareous soil. Many soils in these regions consist of higher exchange capacity requiring strong replacement extractant than is afforded by the weak acid procedures. Fageria et al. (1991) reported that ammonium acetate extractant is suitable for a wide range of soils and most commonly used in routine soil testing laboratories.

2.12.3 Extractant for available potassium determination

There are three types of extractants for estimating K on the basis of K availability. They are 1N NH_4OAc , cold or dilute H_2SO_4 and boiling HNO_3 extractant that are used for determining exchangeable, available as well as non-exchangeable K (Page et al., 1984).

Extraction with cold or dilute H_2SO_4 provides reliable index (Hunter and Pratt, 1957) for the extraction of K from soil. Extraction of soil with boiling HNO_3 is being widely used to estimate the release of K from the non-exchangeable forms (Tandon et al., 1988c and Page et al., 1984). This form of K (non-exchangeable) is abundant in areas of moderate and low rainfall (Page et al., 1984). Acids such as HNO_3 and H_2SO_4 are able to extract more K (Hunter and Pratt, 1957). Panda (1971) and Chowdhury (1984) reported that potassium extracted by boiling with 1N HNO_3 gave the best correlation between dry matter and potassium uptake by rice. Tandon et al. (1988d) indicated that the reserved K (mineral K and non-exchangeable K) is considered as donor K over a long period of time. This form of K is present in between clay plates, not extractable by mild solutions like 1N NH_4OAc extractant, because of the sizeable contribution of the non-exchangeable K to the potassium nutrition of crops is mostly at the expense of K-depletion of the soil.

2.13 Methods of potassium determination in plant sample

The quantity of total K in crop plants and organic materials has been determined through extraction with diacid/triacid mixture and flamephotometry by Chowdhury (1977); Ahmed and Hoque (1978); Anam et al. (1978 and 1982); Hoque et al. (1979); Ali et al. (1980); Khan et al. (1980); Bhuiya and Akhanda (1982); Bhuiya et al. (1982); Islam et al. (1982a) and Mannan et al. (1982). These methods are time consuming, costly and hazardous. On the other hand, dilute (1N) HCl extractant has been used to determine total K in plant sample because the extraction procedure followed is considered as less time consuming and low cost effective method by Yoshida et al. (1976).

2.14 Cation Exchange Capacity in Soil

Except for soils of recent volcanic or alluvial origin, most upland tropical soils have low cation exchange capacities thus limiting their ability to attract and retain soluble basic cations such as K^+ . The effective cation exchange capacity of many acid tropical and sub-tropical soils may be less than 5 meq/100g, a large part of which is due to organic colloids. In the humid tropics an effective CEC of between 4 and 8 meq/100g is needed to retain nutrient cations such as K^+ from leaching losses (PPIC., 1989b).

Tandon et al. (1988d) reported that, because of low CEC, exchangeable K was less in the red soil. The low proportion of non-exchangeable K (fixed K) in the red soil is obviously due to the

abundance of kaolinite clay which cannot fix K. Further, they reported that because of low CEC in the red and laterite tea soils of South India, the proportion of water soluble K was higher.

Higher the soils CEC the more cations it can retain. The CEC of a soil depends on amounts and kind of clay and organic matter present. A high clay soil can hold more exchangeable cations than a low clay soil or sandy soil. It has been reported that the clay minerals usually contain CEC ranging from 10 to 150 meq/100g but organic matter 200 to 400 meq/100g. So the kind and amount of clay and organic matter content greatly influence the CEC of soils (PPI., 1983).

2.15 Status of soil potassium in different extraction methods

Kumar et al. (1991) reported soil potassium status of different extractants and are presented below:

K extractant	K status (kg ha ⁻¹)		Reference
	Low	Medium	
Distilled water soluble K (1:5 soil:water)	8.7-14.3	8.7-20.1	-
Available K (1N NH ₄ OAc, pH 7.0)	72.4-112.7	124.1-155.2	Hanway and Heidal, 1952
Reserve K (Boiling 1N HNO ₃)	194.9-308.6	276.1-322.3	Wood and DeTurk, 1941

Panda et al. (1993) determined the range of K using the following K extractants:

K extractant	Range of K (kg ha ⁻¹)	Reference
Distilled water soluble K	18.8-62.5	MacLean, 1960
1N NH ₄ OAc K	55.0-320.0	Stanford and English, 1949
Boiling 1N HNO ₃ K	420.0-680.0	Reitemeier et al. 1948

Prakash et al. (1986) have given the ranges of soil potassium extracted by various extractants. The results are given below:

K extractant	Range of K (ppm)	Reference
Distilled water soluble K	8.0-51.0	MacLean, 1961
1N NH_4OAc K (pH 7.0)	50.0-275.0	Hanway and Heidel, 1952
Boiling 1N HNO_3 K	792.0-2068.0	Wood and DeTurk, 1941
0.5M NaHCO_3 (pH 8.5)	22.0-154.0	Olsen et al. 1954
6N H_2SO_4	200.0-770.0	Hunter and Pratt, 1957

Singh et al. (1992) worked out the ranges of potassium extracted by different extractants.

K extractant	Range of K (ppm)	Reference
Distilled water soluble K	14.0-30.0	MacLean, 1961
1N NH_4OAc K (pH 7.0)	50.0-200.0	Hanway and Heidel, 1952
1N HNO_3 K	720.0-1920.0	Reitemeir, 1951
0.5M NaHCO_3 (pH 8.5)	25.0-120.0	Olsen et al. 1954
6N H_2SO_4	320.0-608.0	Hunter and Pratt, 1957

Ranges of soil potassium status extracted by different extractants reported by Islam et al. (1994) are as follows:

K extractant	Range of K (mg K kg ⁻¹)	Reference
Distilled water soluble K	4.0-78.0	Hanway and Heidal, 1952
1M NH ₄ OAc K	39.0-312.0	Pratt, 1965
Dilute H ₂ SO ₄ soluble K	82.0-488.0	Hunter and Pratt, 1957
Conc. H ₂ SO ₄ soluble K	410.0-4801.00	Hunter and Pratt, 1957
1M HNO ₃ soluble K	242.0-2496.0	Wood and DeTurk, 1941
0.5M HCl soluble K	121.0-702.0	Attoe and Truog, 1945

Haque et al. (1992) studied on the status of soil K in five selected soil series of Bangladesh. They observed the range of K status of soils using different extractants as follows:

K extractant	Range of K (me %)	Reference
Distilled water soluble K (5:50 Soil: Water)	0.04-0.21	Hanway and Heidal, 1952
1M NH ₄ OAc K (exchangeable K) pH 7	0.26-0.77	Hanway and Heidal, 1952
Non-Exchangeable K 1.4N H ₂ SO ₄ K	0.40-0.97	Hunter and Pratt, 1957
1N HNO ₃ K (boiling)	0.64-1.33	Wood and DeTurk, 1941

Tandon et al. (1988c) reported 1N NH₄OAc solution of pH 7 is a common and widely used K extractant as exchangeable potassium determination in 450 soil testing laboratories in India. They

recorded the K status as low ($<120 \text{ kg K ha}^{-1}$ or $144 \text{ kg K}_2\text{O ha}^{-1}$), medium ($120\text{-}280 \text{ kg K ha}^{-1}$ or $144\text{-}336 \text{ kg K}_2\text{O ha}^{-1}$) and high ($>280 \text{ kg K ha}^{-1}$ or $336 \text{ kg K}_2\text{O ha}^{-1}$).

A field experiment was conducted by Chaudhary *et al.* (1992) during 1987-88 on Alfisols of Bihar, India. They analysed soil potassium using different extractants and the ranges are given below:

K extractant	Range of K (kg ha^{-1})	Reference
Distilled water soluble K	18.9-47.9	Jackson, 1973
Exchangeable K	91.1-148.9	Jackson, 1973
Reserve K	199.8-332.0	Jackson, 1973

Ranges of K estimated by Boruah *et al.* (1992) through the use of different extractants in three major soil orders of Assam are stated below:

K extractant	Range of K (ppm)			Reference
	Entisols	Inceptisols	Alfisols	
Distilled water soluble K	7.9-15	7.9-11.0	4.5-81	-
Exchangeable K (1N NH_4OAc)	29.2-54.1	30.7-50.0	35.6-72.0	-
Non-exchangeable K (1N HNO_3)	220.5-860.3	185.4-505.4	401.7-790.0	Wood & DeTurk, 1941

Potassium status of soils were worked out by Perumal et al. (1991) in different K extraction methods and are given below with references.

K extractant	Range of K (kg ha ⁻¹)	Reference
1N NH ₄ OAc (pH 7)	174-263	Hanway and Heidal, 1952
0.1N HNO ₃	157-241	Sobulo, 1973
6N H ₂ SO ₄	202-403	Hunter and Pratt, 1957
0.5M NaHCO ₃ (pH 8.5)	146-291	Olsen et al. 1954
Distilled water soluble	5.6-33.6	As followed in IARI

Potassium status of alluvial soils in Jorhat district of Assam was analysed by different K extractants. Chamuah (1987) reported the potassium status of soils to a depth of 0-15 cm. as follows:

K extractant	Range of K (ppm)	Reference
Distilled water soluble K (1:25 Soil: Water)	4.0-10.0	Jackson, 1962
Exchangeable K (1M NH ₄ OAc)	40.0-78.0	Jackson, 1962
Non-Exchangeable K (1N HNO ₃)	420.0-740.0	Wood and DeTurk, 1942

Twenty farmers' field of Rajasthan were chosen by Mazumdar et al. (1987) for an initial soil survey and showed a wide variation in distilled water soluble and ammonium acetate extractable K.

Distilled water soluble potassium values were recorded between 2.5 and 16.4 ppm, while the 1N NH_4OAc between 37.5 and 190 ppm.

Bhuiyan et al. (1992) reported that ranges of soil potassium values determined by three different K extraction procedures where soil samples were collected from twenty four locations of Bangladesh.

K extractant	Range of K (me %)	Reference
Exchangeable K (1N NH_4OAc)	0.04-0.42	Pratt, 1965
ASI (0.25N NaHCO_3)	0.03-0.28	Hunter, 1984
Non-exchangeable K (1N HNO_3 , boiling)	0.25-5.60	Wood and DeTurk, 1941

The K availability status of red soils of Rajasthan, India as determined by different extractants were evaluated and reported by Yadav et al. (1984) as follows:

K extractant	Range of K (me%)	Reference
Distilled water soluble K	0.003-0.074	MacLean, 1961
Exchangeable K (1N NH_4OAc)	0.10-0.69	Hanway and Heidal, 1952
HNO_3 soluble K	0.61-3.18	Sutton and Seay, 1958

An experiment was undertaken to evaluate the different forms of K in three major soil orders (Entisols, Inceptisols and Alfisols) of Assam. The estimation of potassium in all the

extractants was done with the help of flamephotometer. Boruah et al. (1992) have given the estimated value of potassium analysed by different extractants as follows:

K extractant	Range of K (ppm)	Reference
Distilled water soluble K	4.5 - 15.0	-
1N NH_4OAc K (pH 7)	29.2 - 72.0	-
Non-exchangeable K (1N HNO_3)	185.4 - 860.3	Wood and DeTurk, 1941

2.16 Critical limit determination

2.16.1 Critical limit

Critical limit is a point or a level of nutrient(s), below which the probability of an economic response to added fertilizer is high (soil test value low) and above which the probability of an economic response to added fertilizer is low (Soil test value high) (Cate et al., 1965).

Ulrich (1952) defined the critical nutrient concentration with respect to plant growth either in terms of the nutrient concentration that is just deficient for maximum growth or that is just adequate for maximum growth. Critical limit has also been defined as the level at which deficiency symptoms appear (Will, 1966).

On the other hand, Ulrich and Hills (1967b) has been defined critical limit is the optimum point on the curve of nutrient level as growth or alternatively, where there is a significant (i.e., 10%) decline in growth. Since the introduction of the concept of the critical limit by Cate and Nelson (1965) most of the information on critical limit of nutrient, is based on the results of pot culture experiment (Gupta et al., 1993).

2.16.2 The critical concentration

Plant analysis is a tool for diagnosis of the nutrient status of plants. The critical concentration is most usefully defined as that concentration of a given form of a specific nutrient with in a specified plant part at which plant growth begins to decline. In practice, the critical concentration is estimated through the use of solution, soil cultures or pot/field experiments in which a series of plants in pots or field plots are supplied with an increasing amount of the nutrient maintaining all other nutrients at adequate levels (Hylton et al., 1964; Ulrich, 1950, 1956 and 1961).

2.16.3 Use of critical limit

A sound soil testing programme for rational and judicious fertilizer management to obtain desired crop response must be based on critical soil fertility limits of different nutrient elements in soils of the area (Rao et al., 1992). The establishment of a precise critical limit soil potassium is the most logical way to

differentiate K responsive soils from the non-responsive ones. Thus the value of the critical limit can be used in developing K fertilization programme (Bhuiyan et al., 1992). Sharma et al. (1993) also reported that the critical limit of the nutrient(s) element can be used to make fertilizer recommendation for different soils and crops. Therefore, the critical limit of K either of soil or plant is important and can be effectively used in working out fertilizer schedule of the crop(s).

2.16.4 Limitation to the concept of the critical limit

The variability associated with sampling, climate and other factors indicates that there is a possibility of doing considerable error for any measurement, and it would be relatively easy to make wrong interpretation if the level is close to the critical value (Mead, 1984). As pointed out by Ulrich and Hills (1967b) the critical value is best defined if the calibration curve shows a sharp transition between deficiency and sufficiency; in practice it is often more of a gradual curve.

The critical limit can vary with the growth parameter chosen and will possibly vary with stand age or development age of the plant (Miller et al., 1981). These suggest that critical limits are generally poorly defined, and it is more reasonable to consider ranges in concentrations indicating low, marginal and adequate levels. The critical limit depends on the other nutrients that are being adequately supplied (Mead, 1984).

2.16.5 Graphical procedure for critical limit determination

In the Cate-Nelson graphical procedure, determination of critical limit depends on the extractant used as well as crop involved. The Cate-Nelson scatter diagram provides a simple but highly effective tool for evaluation of soil analytical methods (Donovan et al., 1973). According to Cate-Nelson (1965) graphical procedure, a scatter diagram of relative yield (Y-axis) versus analysis value of nutrient(s) either of soil and plant samples (X-axis) is plotted on an arithmetic paper. A pair of intersecting perpendicular lines are drawn on the plotted paper so that the line parallel to the x-axis intersects the Y-axis at 80-90% of relative yield and the line parallel to Y-axis is drawn in such a manner that the number of points in the positive quadrant is maximum. Then the intersecting point of this line on X-axis is considered as the critical soil or plant nutrient concentration level.

2.16.6 Mathematical procedure for critical limit determination

This method was described by Waugh et al. (1973) and was developed by Cate and Nelson, 1971 for partitioning soil analysis correlation data in two classes. In this method, where relative yield (Y-axis) is calculated as in the Cate-Nelson's graphical procedure and the values are ordered along with the corresponding soil or plant analyses values (X-axis). The (X,Y) pairs are maintained in this order throughout the analyses. Then, R^2 values are calculated by using the successive tentative critical levels of

two groups. The maximum R^2 value obtained for the group is considered as the range of critical value. The mean of the two classes is the predictive critical value.

2.17 Critical limit of potassium extracted by different extractants

2.17.1 Critical limit of soil potassium extracted by 1N NH_4OAc

Yadav et al. (1984) has been chalked out the critical limit of soil potassium using eleven soil K parameters (intensity, quantity, capacity and rate factors) with maize crop (Var. Ganga-5) under greenhouse condition in red soils of Durgapur district under Rajasthan. They found the critical limit of exchangeable K (1N NH_4OAc extractant) was 0.12 meq/100g soil.

A pot experiment was conducted by Singh Vinay et al. (1992) under greenhouse condition with nineteen soils where lentil was taken as a test crop at different locations of Agra district of Uttar Pradesh. They determine the critical limit of soil K was 100 ppm (0.26 meq/100g soil) for 1N NH_4OAc (pH 7) extractant.

Kumar Basant et al. (1991) conducted an experiment on wheat with Debatoli series and worked out the critical limit of soil K was found 110 kg/ha (0.14 meq/100g soil) for 1N NH_4OAc extractant (pH 7).

A pot culture experiment was conducted by Panda et al. (1993) with fourteen surface soil samples during Kharif season 1988 in Puri district of India. Using the scatter diagram technique of Cate and Nelson (1965), they determined 128 kg/ha (0.16 meq/100g soil) as a critical limit of soil potassium (1N NH_4OAc extraction) for rice.

Roy et al. (1989) calculated 108 kg ha⁻¹ (0.14 meq/100g soil) as the critical limit of soil potassium (1N NH_4OAc extraction) for wheat while working with 17 soil types in India. Critical limits of exchangeable K (1N NH_4OAc extraction) were determined by Venkatasubbiah et al. (1976) in black soils of Andhra Pradesh for bajra and rice. They were 95 ppm (0.24 meq/100g soil) and 100 ppm (0.26 meq/100g soil) respectively.

Jones US (1982) reported 0.20 meq K/100g soil (1N NH_4OAc extraction) as a critical limit for rice in Asia.

Field experiments were conducted by Saleque et al. (1990) in 11 sites from 1987 through 1989 in different areas of Bangladesh to correlate soil K extracted by 1N NH_4OAc with the per cent relative grain yield of wetland rice. They identified 0.075 meq/100g soil as the critical limit of soil potassium for 1N NH_4OAc extractant.

The absolute minimum level of exchangeable K (1N NH_4OAc extraction) for tropical agriculture is considered to be close to 0.10 meq/100 g but may vary from 0.07 to 0.20 meq/100g depending on the kinds of soil and plants involved. A level below 0.15 meq/100g (60 ppm) is usually inadequate to support normal crop growth (PPIC., 1989b).

An attempt was made by Rao et al. (1992) to find out critical level of exchangeable K (1N NH_4OAc extraction) in an Aquic Haplustalf (red sandy loam soil) for nine vegetable crops. They found 100 kg/ha (0.13 meq/100g) as the critical level of K for tomato, 387 kg/ha (0.50 meq/100g) for brinjal, 165 kg/ha (0.21 meq/100g) for cabbage, 348 kg/ha (0.45 meq/100g) for okra, 178 kg/ha (0.23 meq/100 g) for french bean, 147 kg/ha (0.19 meq/100g) for onion, 161 kg/ha (0.21 meq/100g) for green chillies, 186 kg/ha (0.24 meq/100g) for capsicum (sweet pepper) and 176 kg/ha (0.23 meq/100g) for cauliflower.

Kumar et al. (1991) determined the critical limit of exchangeable K (1N NH_4OAc extraction) in Debatoli series (acid, mixed, coarse loamy, hyperthermic Ultic Haplustalfs) by using wheat as the test crop and found 110 kg/ha (0.14 meq/100g) as the critical limit of exchangeable K. A greenhouse experiment on wheat was conducted by Prasad (1990) to calculate the critical limit of soil K using the soils of north Bihar. The critical limit of soil K extracted by 1N NH_4OAc was 60 ppm (0.15 meq K/100g soil).

Bhuiyan et al. (1992) conducted twenty four field trials on potassium during T. Aman (wet) season of 1990 at different locations of Bangladesh using rice (var. BR-11) as a test crop. They calibrated the soil test values of 1N NH_4OAc extractant with the relative grain yields of wetland rice and obtained the K critical levels of 0.10 and 0.075 meq/100g soil by graphical and statistical procedures respectively.

In a greenhouse experiment, the critical limit of K was determined in Calciorthents of North Bihar using wheat as the test crop. In that study, the critical limit of K extracted by 1N NH_4OAc extraction was 60 ppm (0.15 meq/100g soil) (Prasad, 1990).

Rice was grown in pots in twenty surface soils from Gwalior, India to which 0 or 50 ppm fertilizer K had been applied. The soils were analysed using 1N NH_4OAc extractant. The K values of 1N NH_4OAc extractant showed the highest correlation with relative yield. The critical limit of extractable K was found to be 160 ppm (0.41 meq/100g soil) using this extractant (Bansal et al., 1985).

2.17.2 Critical limit of soil potassium extracted by NaHCO_3

With a view to determining critical limit of K, a pot experiment was conducted using nineteen surface soil samples under greenhouse condition with lentil at Agra district of Uttar Pradesh. Through the use of scatter diagram technique of Cate and Nelson (1965), Singh et al. (1992) determined 53 ppm (0.14 meq/100g) as the critical limit of soil K which was extracted by 0.5M NaHCO_3 .

Saleque et al. (1990) conducted eleven field experiments during 1987 to 1989 in different areas of Bangladesh to identify critical limit of soil K extracted by 0.25N NaHCO₃ of wetland rice. Using graphical procedure of Cate and Nelson (1965) they identified 0.065 (meq/100g soil) as the critical limit of K for wetland rice.

Twenty four field trials on potassium were conducted during 1990 at different locations of Bangladesh using BR-11 as a test crop by Bhuiyan et al. (1992). Soil test values of potassium was determined by 0.25N NaHCO₃. The values were calibrated with the relative grain yield of rice and determined 0.075 (meq/100g soil) as the critical limit of soil potassium both by graphical and statistical procedures.

Portch et al. (1984) reviewed the data of critical limit which was worked out by Hunter (1980). They showed 0.20 meq K/100 ml soil was the critical limit for 0.25N NaHCO₃ extractant of upland crops.

2.17.3 Critical limit of soil potassium extracted by H₂SO₄

Singh et al. (1992) conducted a pot experiment using nineteen surface soil samples where lentil was the test crop. They calculated 380 ppm (0.97 meq/100g soil) as the critical limit of soil K for the 6N H₂SO₄ extraction method. Prasad (1990) conducted a greenhouse experiment on wheat using the soils of North Bihar to find out the critical limit of soil K. The critical limit of soil K extracted by 1.38N H₂SO₄ was 1255 ppm (3.22 meq K/100g soil).

2.17.4 Critical limit of soil potassium extracted by HNO_3

A pot culture experiment conducted with maize on red soils of Durgapur district of Rajasthan to determine the critical limit of soil potassium. Yadav et al. (1984) determined 0.87 meq/100g soil as the critical limit of K (1N HNO_3) using statistical procedure of Cate-Nelson (1971)

Panda et al. (1993) worked out a critical limit of K on rice using the scatter diagram technique of Cate and Nelson (1965). The critical limit of 0.5N HNO_3 extractant was 180kg (90 ppm) K per hectare.

Twenty four field trials on potassium were conducted during 1990 on T. Aman (BR-11) at different parts of Bangladesh with the objective to calculate potassium critical limit. Bhuiyan et al. (1992) calculated critical limit of K for 1N HNO_3 extraction method was 1.125 and 0.640 meq/100g soil following graphical (1965) and statistical (1971) procedures of Cate-Nelson respectively.

Mehta et al. (1994) conducted a pot experiment on wheat with Lunkhi soil series. They found that Bray's percent yield was significantly correlated with non-exchangeable K (1N HNO_3). The critical limit for non-exchangeable K (1N HNO_3) in this soil series was found to be at 450 kg K ha^{-1} (0.58 meq/100g).

A greenhouse experiment on wheat conducted by Prasad (1990) to determine the critical limit of K with the soils of North Bihar. He observed the critical limit of soil K extracted by 1N HNO₃ was 1580 ppm (4.05 meq K/100g soil).

2.17.5 Critical limit of soil potassium extracted by distilled water

Singh et al. (1992) conducted a pot experiment on lentil to identify one or more suitable method(s) based on crop response to K on alluvial soils of Agra district of Uttar Pradesh. Scatter diagram technique of Cate and Nelson (1965) was employed for the determination of the critical limit of K. Critical limit of soil K extracted by distilled water was 19 ppm (0.05 meq/100g soil).

Using the procedure of Cate and Nelson (1971), the calculation of co-efficient of determination (R^2) and critical level for best two population split, using the two mean discontinuous model was carried out by Mazumdar et al. (1987) for the area neighbouring Jobner of Rajasthan. This two mean discontinuous model for best two population split provides a critical limit between 6.2 and 6.8 ppm and as such 6.5 ppm can be taken as the critical limit of distilled water soluble K for wheat of the area. Prasad (1990) conducted an greenhouse experiment on wheat to determine the critical limit of K using the soils of north Bihar. The critical limit of K extracted by distilled water was 17.5 ppm (0.04 meq K/100g soil).

2.18 Critical limit of potassium for crops

Kumar *et al.* (1991) plotted Bray's per cent yield of wheat against K concentration (tri-acid digestion Jackson, 1967) and calculated the critical limit as 1.2% of K using the procedure of Cate and Nelson (1965).

Roy *et al.* (1989) also determined the critical limit of K through pot experiment of wheat in Puto series (Alfisols) of Ranchi. They plotted Bray's per cent yield against the K concentration of wheat plant following the graphical method of Cate and Nelson (1965) and found 1.25% as the critical concentration of K in wheat plant.

Sharma (1991) determined the critical limit of K in potato plant (third petiole, Mid stage) using two methods i.e., simple mathematical model (1971) and graphical method (1965) of Cate-Nelson) to determine critical K content in potato plant. They found 7.01 and 7.60% as the critical K content for the simple mathematical model and graphical method respectively of the mid stage potato plant.

Rao et al. (1989) adopted sand culture technique to determine K status of potato, wheat and groundnut at different plant parts and growth stages. Their results are stated below:

Crop	Growth stage	Plant part	Crop K status ^{1/} based on K ⁺ concentration in plant part (% of dry matter)			
			S	SD	MD	ED
Potato	Vegetative (tuber initiation) 37 days	Leaf blades	8.0 - 5.6	5.6-4.4	4.4-2.8	<2.8
		Petioles	17.2-12.8	12.8-9.6	9.6-3.2	<3.2
		Stem	16.8-11.2	11.2-8.4	8.4-4.8	<4.8
Wheat	Tillering (45 Days)	Whole plant	6.1 - 4.1	4.1-3.3	3.3-1.1	<1.1
Groundnut	Vegetative (Pod initiation) 40 days	Leaf	3.0 - 2.2	2.2-1.9	1.9-1.3	<1.3
		Stem	3.0 - 2.2	2.2-2.0	2.0-1.2	<1.2
		Petiole	3.5 - 2.4	2.4-1.9	1.9-1.3	<1.3

^{1/} S= Sufficiency (< 10% yield reduction; SD= Slight deficiency (10-20% yield reduction; MD= Moderate deficiency (20-40% yield reduction); ED= Extreme deficiency (>40% yield reduction)

Information on critical nutrient range (CNR) for potato petioles used to indicate K status after tissue analysis. The results provided by Roberts et al. (1985) are given below:

Growth stage <u>1</u> /	CNR ² / for K in petioles (g/ha)	Reference
Vegetative I to tuberization II (15-45 days)	65-70 (6.5-7.0%)	McDole (1978)
Tuberization II (30-40 days)	95-110 (9.5-11.0%)	Jackson et al. (1974)
Tuberization II (30-40 days)	95-110 (9.5-11.0%)	Roberts et al. (1984) and Middleton et al. (1975)
Tuberization II (30-40 days)	70-80 (7.0-8.0%)	Painter (1973)

1/ Days after emergence

2/ CNR for third to fifth petiole from top of plant (Dow and Roberts, 1982).

Beaton et al. (1985) compiled the data on K⁺ concentration in various parts of wheat. They pointed out the results of an experiment conducted by Schwartz et al. (1978) that the K⁺ concentration of the above ground portion of winter wheat was 60g K kg⁻¹ (6% K) which harvested 2-8 weeks of sowing seeds. They further reported that the K concentration in the entire above ground part declined rapidly between 10 and 15g kg⁻¹ (1-1.5% K) when the plant harvested at maturity. Singh and his colleagues (1992) conducted a pot experiment on lentil in the alluvial soils of Agra district and found the critical limit of K in lentil plants was 1.38%.

Chapman (1967) compiled the data on per cent potassium of potato, wheat and peanut for a specified plant part of given age, stage or condition and arranged the K status as low, adequate and high as follows:

Crop	Plant part used	Status of K (%)		
		Low	Intermediate (adequate)	High
Potato	Leaves including petioles 4th or 5th from the top of principal stalk at early bloom stage	< 4.50	>4.50	-
Potato	Petioles from 4th leaf from top at tuber set period.	<7.00	>9.00	-
Wheat	Upper four leaves during flowering after head has completely emerged	-	2.30 - 3.40	-
Peanut	4th leaf and petiole from principal stalk at early bloom stage	<1.30	>1.30	-

In a greenhouse experiment, the critical limit of K in wheat plant was determined using the soils of North Bihar. Prasad (1990) found the critical limit of K in wheat plant after 46 days of growth was 1.4%.

A plot culture experiment was conducted by Mehta et al. (1994) to determine the critical limit of wheat plant using the soil from Lukhi series. They calculated the critical K concentration in wheat as 1.0%.

CHAPTER 3.0

MATERIALS AND METHODS

3.1 Collection of soil sample

Thirty one locations (Fig. 3.1) representing seven general soil types and fourteen agroecological zones of Bangladesh (Table 3.1) were selected on the basis of low, medium and high exchangeable potassium category for this study. One composite sample of surface soil (0-15cm depth) was collected in bulk quantities (about 50kg) from each location. The soils were mixed, air-dried, pulverized and then passed through 20 mesh sieve and stored for laboratory analyses and net house experiments.

3.2 Laboratory analyses

The soils were analysed for different forms of K using five extractants (i.e., 1N NH_4OAc (pH 7), 0.25N NaHCO_3 (pH 8.5), boiling 1N HNO_3 , cold H_2SO_4 and distilled water). All other physicochemical properties of the soils were also determined following widely used standard methods (Table 3.2).

The plant samples of wheat, potato and groundnut were oven dried and grounded. For wheat, potato and groundnut 465, 465 and

Table 3.1. Location and general characteristics of the soil sampling sites.

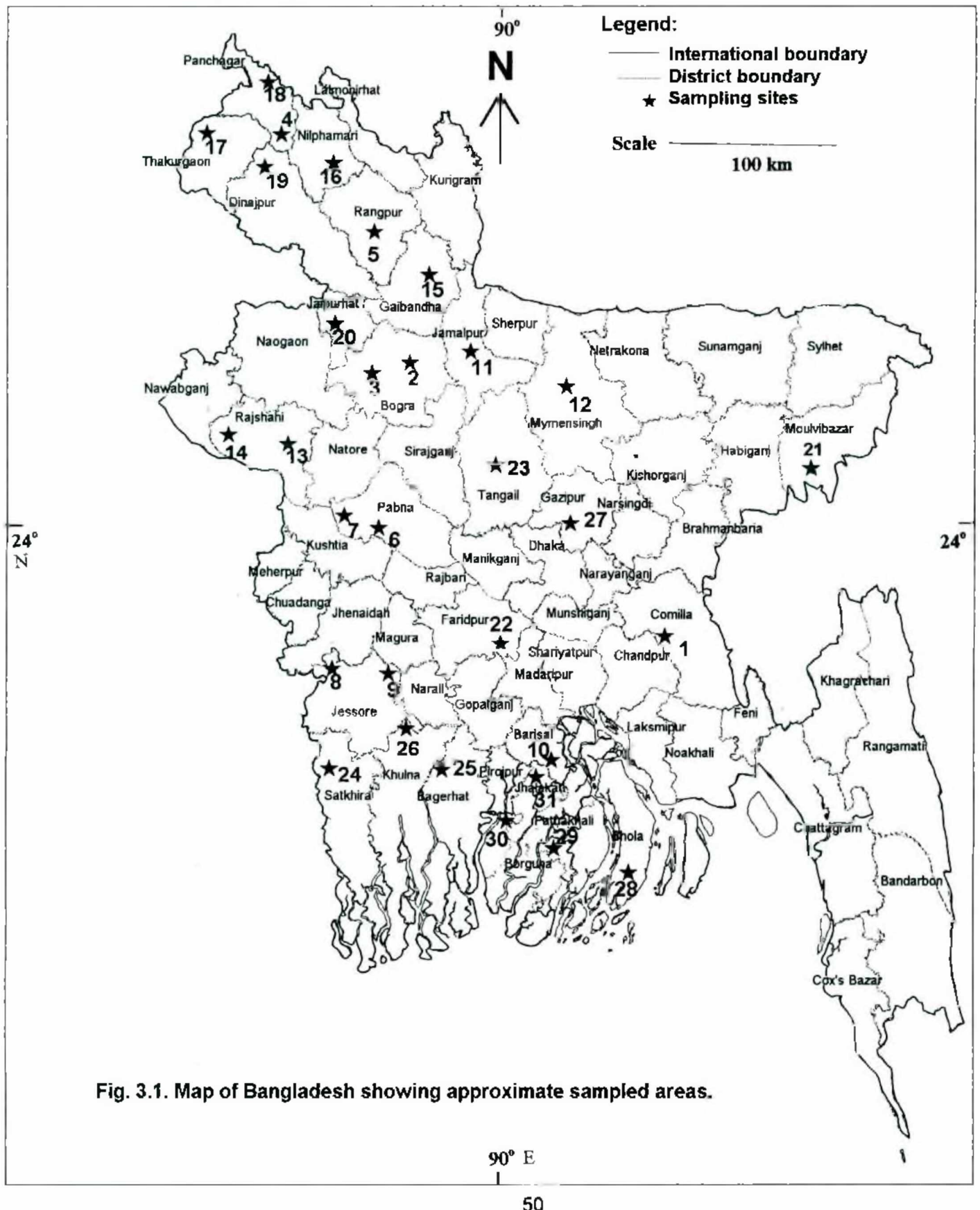
Location No.	Location			Parent material	General soil type	USDA soil taxonomy	Agroecological zone
	Village	Thana	District				
1.	Balashahar	Chandina	Comilla	Old Meghna estuarine alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Middle Meghna River Floodplain (16)
2.	Sandhabari	Gabtali	Bogra	Karatoya Tista alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Karatoya-Bangali Floodplain (4)
3.	Narhatto	Kahaloo	Bogra	Modhupur clay	Grey Terrace Soils	Albaquepts	Level Barind Tract (25)
4.	Natun-Shahar	Debiganj	Panchagarh	Old Himalayan Piedmont alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Tista Meander Floodplain (3)
5.	Nischintapur	Mithapukur	Rangpur	Tista Karatoya alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Tista Meander Floodplain (3)
6.	Monoharpur	Pabna-Sadar	Pabna	Ganges alluvium	Calcareous Dark grey Floodplain Soils	Haplaquepts	Low Ganges River Floodplain (12)
7.	Dikshail	Ishurdi	Pabna	Ganges alluvium	Calcareous Brown Floodplain Soils	Eutrochrepts	Low Ganges River Floodplain (12)
8.	Ishapur	Chowgacha	Jessore	Ganges alluvium	Calcareous Brown Floodplain Soils	Eutrochrepts	High Ganges River Floodplain (11)
9.	Dadpur	Bagherpara	Jessore	Ganges alluvium	Calcareous Brown Floodplain Soils	Eutrochrepts	High Ganges River Floodplain (11)
10.	Rahmatpur	Babuganj	Barisal	Ganges alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Ganges Tidal Floodplain (13)

Table 3.1. continued

Location No.	Location			Parent material	General soil type	USDA soil taxonomy	Agroecological zone
	Village	Thana	District				
11.	Shahajadpur	Melandah	Jamalpur	Brahmaputra alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Young Brahmaputra and Jamuna Floodplain (8)
12.	Baira	Mymensingh Sadar	Mymensingh	Brahmaputra alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Old Brahmaputra Floodplain (9)
13.	Pali	Durgapur	Rajshahi	Ganges alluvium	Calcareous Brown Floodplain Soils	Eutrochrepts	High Ganges River Floodplain (11)
14.	Nazirpur	Godagari	Rajshahi	Modhupur clay	Grey Terrace Soils	Albaquepts	High Barind Tract (26)
15.	South-Dhanghara	Gaibandha-Sadar	Gaibandha	Tista alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Tista Meander Floodplain (3)
16.	Ranochandi	Kishorganj	Nilphamari	Tista alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Tista Meander Floodplain (3)
17.	Lalapur	Baliadangi	Thakurgaon	Old Himalayan Piedmont alluvium	Non-calcareous Darkgrey Floodplain Soils	Haplaquepts	Old Himalayan Piedmont plain (1)
18.	Jatanpukuria	Panchagarh-Sadar	Panchagarh	Old Himalayan Piedmont alluvium	Non-calcareous Darkgrey Floodplain Soils	Haplaquepts	Old Himalayan Piedmont plain (1)
19.	Daulatpur	Birganj	Dinajpur	Himalayan Piedmont alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Old Himalayan Piedmont plain (1)
20.	Kamorgram	Joypurhat-Sadar	Joypurhat	Modhupur clay	Grey Terrace Soils	Albaquepts	Level Barind Tract (25)

Table 3.1. continued

Location No.	Location			Parent material	General soil type	USDA soil taxonomy	Agroecological zone
	Village	Thana	District				
21.	Dewashara	Kamalganj	Moulavi Bazar	Piedmont alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Eastern-Surma Kushiyara Floodplain (20)
22.	Vhanga	Vhanga	Faridpur	Ganges alluvium	Calcareous Darkgrey Floodplain Soils	Haplaquepts	Low Ganges River Floodplain (12)
23.	Palima	Kalibati	Tangail	Brahmaputra alluvium	Non-calcareous Grey Floodplain Soils	Haplaquepts	Young Brahmaputra and Jamuna Floodplain (8)
24.	Benarpota	Satkhira Sadar	Satkhira	Ganges alluvium	Calcareous Grey Floodplain Soils (saline)	Haplaquepts	Ganges Tidal Floodplain (13)
25.	Khazura	Fakirhat	Bagherhat	Ganges alluvium	Calcareous Grey Floodplain Soils (saline)	Haplaquepts	Ganges Tidal Floodplain (13)
26.	Garakhola	Fultola	Khulna	Ganges alluvium	Calcareous Grey Floodplain Soils (saline)	Haplaquepts	Ganges Tidal Floodplain (13)
27.	Mogorkhal	Joydebpur	Gazipur	Modhupur clay	Brown Mottled Terrace Soils	Ustochrepts	Modhupur Tract (28)
28.	Uttar Char Aicha	Char Paeson	Bhola	Ganges alluvium	Calcareous Darkgrey Floodplain Soils (saline)	Haplaquepts	Young Meghana Estuarine Floodplain (18)
29.	Patkhali	Patuakhali Sadar	Patuakhali	Ganges alluvium	Calcareous Grey Floodplain Soils (saline)	Haplaquepts	Ganges Tidal Floodplain (13)
30.	Nadmollah	Vhandaria	Pirojpur	Ganges alluvium	Calcareous Grey Floodplain Soils (non-saline)	Haplaquepts	Ganges Tidal Floodplain (13)
31.	West Jhalakathi	Jhalakathi Sadar	Jhalakathi	Ganges alluvium	Calcareous Grey Floodplain Soils (non-saline)	Haplaquepts	Ganges Tidal Floodplain (13)



435 plant samples respectively were analysed for total K. The plant samples were extracted by 1N HCl as per method described by Yoshida et al. (1976). Quantity of potassium was determined by using flame photometer. Per cent K saturation of the K values obtained from five extractants was calculated by:

$$\frac{\text{Exchangeable/Available K (meq/100g soil)}}{\text{CEC (meq/100g soil)}} \times 100$$

The standard error (SE $\pm$) concept introduced by Clarke (1980) was used in this study to determine the precision of the extractants used for soil analysis and the efficiency of tested extractants for per cent K saturation. K uptake was calculated by multiplying the K content in dry matter with the dry matter yield of wheat, potato and groundnut.

3.3 Pot experiment

Pot experiments under net house were conducted using all thirty one collected soil samples with varied doses of potassium on wheat (*Triticum aestivum* L.), potato (*Solanum tuberosum* L.) and groundnut (*Arachis hypogaea* L.) to determine the per cent relative yield (dry matter basis) and critical limits of potassium. The experiments were carried out during October, 1992 to December, 1995. Variety Kanchan of wheat, Cardinal of potato and Dhaka-1 (Maizchar Badam) of groundnut were taken as test crops. Pot experiments with wheat, potato and groundnut were conducted separately. Five fertilizer treatments were used with three

Table 3.2. Description of methods used for soil and plant sample analyses.

To determine the physical and chemical properties of soil and plant samples, the following analytical methods were used:

Soil properties	Methods of Analyses	Author and Year
Particle size	Mechanical analysis by hydrometer method	Tinsley, 1970
pH	1: 2.5 (soil: water ratio) by glass electrode potentiometer	Hunter, 1984
Organic matter	Sodium dichromate, conc, H_2SO_4 and superfloc	Hunter, 1984
CEC	Saturation with normal NaOAc and NH_4OAc	Satter and Rahman, 1987
Ca, Mg and Na	1N KCl with 10 minutes shaking	Hunter, 1984
K	1. 1N NH_4OAc (pH 7) (1: 2.5, soil: solution) with 10 minutes shaking	Knudsen et al., 1984
	2. 0.25N $NaHCO_3$ (1:10, soil: solution) with 10 minutes shaking	Hunter, 1984
	3. 1N HNO_3 (boiling) (1:10, soil: solution) with 10 minutes boiling	Knudsen et al., 1984
	4. Cold H_2SO_4 (1:2.6, soil: solution) with 30 minutes standing	Knudsen et al., 1984
	5. Distilled water (1:10, soil: water) with 30 minutes shaking.	Hanway and Heidel, 1952
	6. Plant sample analysis: 1N HCl (1:25, plant sample: solution) with 24 hours standing	Yoshida et al. 1976
S	CaH_4 (PO_4) $_2$, H_2O , Conc. HCl and phenol with 10 minutes shaking	Hunter, 1984
P and Zn	0.25N $NaHCO_3$, 0.01M EDTA, 0.01N NH_4F and superfloc with 10 minutes shaking.	Hunter, 1984

replications arranged in a completely randomized design for each crop. The basal dose of NPS and five variable doses of potassium were used in each experiment. The source of fertilizer were N from urea ($\text{NH}_2\text{-CO-NH}_2$); P from calcium metaphosphate ($\text{Ca}(\text{H}_2\text{PO}_4)_2$); K from muriate of potash (KCl) and S from concentrated sulphuric acid (H_2SO_4). The fertilizer treatments for 3 crops were assigned as follows:

Wheat :

T_1	:	N_{90}	P_{75}	K_0	S_{15}	mg kg ⁻¹
T_2	:	N_{90}	P_{75}	K_{15}	S_{15}	mg kg ⁻¹
T_3	:	N_{90}	P_{75}	K_{30}	S_{15}	mg kg ⁻¹
T_4	:	N_{90}	P_{75}	K_{45}	S_{15}	mg kg ⁻¹
T_5	:	N_{90}	P_{75}	K_{60}	S_{15}	mg kg ⁻¹

Potato:

T_1	:	N_{110}	P_{45}	K_0	S_{15}	mg kg ⁻¹
T_2	:	N_{110}	P_{45}	K_{25}	S_{15}	mg kg ⁻¹
T_3	:	N_{110}	P_{45}	K_{50}	S_{15}	mg kg ⁻¹
T_4	:	N_{110}	P_{45}	K_{75}	S_{15}	mg kg ⁻¹
T_5	:	N_{110}	P_{45}	K_{100}	S_{15}	mg kg ⁻¹

Groundnut:

T_1	:	N_{15}	P_{45}	K_0	S_{20}	mg kg ⁻¹
T_2	:	N_{15}	P_{45}	K_{15}	S_{20}	mg kg ⁻¹
T_3	:	N_{15}	P_{45}	K_{30}	S_{20}	mg kg ⁻¹
T_4	:	N_{15}	P_{45}	K_{45}	S_{20}	mg kg ⁻¹
T_5	:	N_{15}	P_{45}	K_{60}	S_{20}	mg kg ⁻¹

Two kilograms of air-dried, ground soil of each location was filled in a plastic pot each measuring 15 cm dia. All nutrients were applied in solution in each pot on the upper surface of the soil by adding required amount of distilled water (65 per cent of the total field moisture capacity) for uniform distribution of nutrients in the soil. Tubers of potato, seeds of wheat and groundnut were sown in each pot when the moisture level in soil was optimum. Young seedlings of three tubers, 10 seedlings of wheat and four seedlings of groundnut were allowed to grow in each pot after establishment (seven days after planting of tubers or sowing seeds) of the seedlings. Distilled water was applied for maintaining field soil moisture during the growth period of the plants when the moisture level dropped to approximately 60 or 70 percent of the field capacity. Plants were allowed to grow for a period of six weeks to obtain maximum vegetative growth. Crops were then harvested by cutting at the base of the crop. Data on the following parameters were recorded:

- a. Fresh weight of plant at harvest.
- b. Dry matter yield.
- c. Collection of plant sample from each crop for the determination of total K.

Following the harvest of the crop, plant samples were cleaned by wiping with distilled water soaked cotton and air-dried. The plant samples were kept in perforated brown paper bags and then dried in

a forced draft oven at 65°C up to constant weight. Weight of the dry matter was taken at room temperature to calculate per cent relative yield using the formula adopted by Donovan *et al.*, 1973.

$$\text{Relative yield} = \frac{\text{Threshold yield (yield without K)}}{\text{Plateau yield (yield with adequate K)}} \times 100$$

Where, relative yield is a measure of the yield response to a single nutrient when the other nutrients are supplied adequately. Threshold yield means yield obtained from the point of deficient nutrient level from which the response to that nutrient could be measured and plateau yield implies that the yield is at its highest point by the adequate nutrient and is holding steady or stable over a certain range of nutrient addition (Donovan *et al.*, 1973).

After weighing, the dried samples were ground in a stainless steel semi-micro wiley mill and passed through 20 mesh screen. The samples were collected in vials and redried before analysis.

3.4 Determination of critical limit

The critical limit of water soluble, exchangeable and available K from soil and the critical K concentration of the dry matter of wheat, potato and groundnut were calculated using the graphical (1965) and mathematical (1971) procedures of Cate and Nelson separately. The graphical procedure of Cate and Nelson (1965) demonstrates a manner in which the points scatter on a plot of

relative yield against the extracted value of nutrient either of soil and plant samples. According to their description, a scatter diagram was made and the critical value was obtained by graphically dividing the plots into two groups (+ ve quadrant and -ve quadrant) in which most of the points fell into the lower left hand quadrant (+ ve quadrant) (low relative yields associated with low soil K) and the upper right hand quadrant (+ve quadrant) (relative yields of 80% or more indicating little or no response to K). Thereby a critical limit of potassium both for soils and plants were identified on X-axis.

In the mathematical model, relative yield (Y-axis) was calculated as in the Cate-Nelson procedure and the values were ordered along with the corresponding soil or plant analyses values (X-axis). Cate and Nelson (1971) partitioned soil and plant response data (relative yield) into two classes (as population-1 and population-2) and then the value of R^2 (co-efficient of determination) was calculated using the following formula proposed by Donovan et al. (1973):

$$R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$$

Where, TCSS = total corrected sum of squares and CSS = corrected sum of squares. The range of critical limit of the nutrient was then determined considering maximum R^2 values of the samples and the mean of the two classes counted as the predicted critical value.

CHAPTER 4.0

RESULTS AND DISCUSSION

4.1 Soil characteristics

The data on physicochemical properties of soil of thirty one locations have been presented in Table 4.1, while particle size distribution of all soils under study are presented in Table 4.2. The physical and chemical characteristics (i.e., particle size distribution, pH, CEC, organic matter, exchangeable Ca, Mg, K, Na, and available P, S, and Zn) of thirty one soils showed wide variations for all properties due to inherent properties of the soil.

The pH values (measured in 1: 2.5 soil: water ratio) ranged from 4.61 to 7.95. The lowest value obtained from the soil of Mogorkhal and while the highest at Benarpota. Similar range of pH were reported by Bhuiyan et al. (1992) and Islam et al. (1984). Among the locations, Dewashara (4.74) and Mogorkhal (4.61) had strongly acidic pH values. Data also indicated that the soils of calcareous alluvium (both saline and non-saline phase) had pH values > 7.0.

The organic matter content of the soil ranged from 0.60 % to 1.30 %. The lowest value (0.60 %) of organic matter was observed both in Ishapur and Shahajadpur but the highest (1.30%) in the soils of Palima. The low organic matter content in most of the

soils of Bangladesh and its declining nature have been reported by Karim (1997). He further indicated that more than 50% of cultivated soils of Bangladesh contained organic matter below the critical limit (1.5 %). Islam et al. (1985) reported low to medium quantity of organic matter present in Bangladesh soils. This low quantity of organic matter present in the soil indicates the exhaustion as well as depletion of organic matter from the soil. This might be due to intensive cropping and run-off rather than additions.

The values of exchangeable cation like Ca, Mg and Na are presented in Table 4.1. The quantity of Ca and Mg in the tested soils ranged from 1.0 (Natun Shahar) to 14.30 (Dikshail) meq/100ml and 0.20 (Natun Shahar) to 5.41 (Garakhola) meq/100ml soil respectively. The quantity of Ca and Mg obtained from the soils were found to be adequate for all locations except Natun Shahar, Jatanpukuria and Dewashara. The critical limits suggested by BARC (1989) were 1.80 and 0.70 meq/100g soil for Ca and Mg respectively. The content of Mg in Nischintapur, Ranochandi, Lalapur, Daulatpur and Mogorkhal was found below the critical limit. Data revealed that the soils of calcareous alluvium had high level of exchangeable Ca and Mg content.

Table 4.1. Physicochemical characteristics of soil (0-15cm depth) of thirty one locations.

Loca- tion No.	pH	O.M. (%)	Ca	Mg	Na	P	S	Zn	CEC (meq/ 100 g)
			(meq/ 100ml)			(µg/ ml)			
1.	5.70	0.79	3.50	1.15	0.50	45	11	3	5.70
2.	6.40	0.75	4.50	1.65	0.45	22	17	3	5.98
3.	5.60	1.12	5.20	1.90	0.56	35	13	5	6.52
4.	5.65	0.83	1.00	0.20	0.40	44	13	3	5.43
5.	6.10	0.95	2.00	0.65	0.44	25	10	2	5.65
6.	7.15	0.95	13.70	5.10	0.55	10	17	3	9.46
7.	7.20	1.05	14.30	5.00	0.56	9	20	3	11.11
8.	7.30	0.60	10.15	1.45	0.43	25	15	4	8.15
9.	7.25	0.80	11.80	3.20	0.36	40	14	4	9.02
10.	6.60	0.65	6.50	4.12	0.57	12	25	5	8.37
11.	6.90	0.60	6.70	1.60	0.45	18	15	3	7.34
12.	6.90	0.72	5.10	2.45	0.62	12	22	3	7.34
13.	6.50	1.10	12.15	3.55	0.54	20	15	3	9.24
14.	5.50	0.94	7.50	3.15	0.44	32	18	7	8.83
15.	6.50	1.05	4.00	1.35	0.45	30	11	3	7.45
16.	5.75	0.83	1.85	0.30	0.42	40	14	3	7.39
17.	5.80	0.75	2.50	0.54	0.50	38	21	3	6.20
18.	5.40	1.15	1.20	0.45	0.54	24	19	2	5.84
19.	5.90	0.88	2.15	0.53	0.50	25	11	3	6.03
20.	5.17	1.00	7.00	3.42	0.75	12	12	8	7.50
21.	4.74	0.85	1.80	0.55	0.44	15	14	5	6.09
22.	7.45	0.90	10.80	1.52	0.42	18	18	4	7.72
23.	5.95	1.30	4.70	1.18	0.38	15	9	3	6.49
24.	7.95	1.00	8.80	3.80	1.32	25	17	2	7.93
25.	7.05	1.10	10.15	4.06	2.25	14	18	2	8.15
26.	7.12	0.95	11.40	5.41	4.10	11	17	3	9.13
27.	4.61	0.65	4.00	0.62	0.40	13	8	5	6.82
28.	7.50	1.25	7.30	4.60	4.50	45	17	5	7.20
29.	7.46	0.91	7.00	4.08	1.05	17	15	4	7.83
30.	7.68	0.95	9.40	3.90	0.64	13	16	4	9.24
31.	7.75	1.10	10.00	4.05	0.84	12	18	5	9.02

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamorgram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

Na content in soils of all locations was with in the range of 0.36 to 4.50 meq/100ml soil. Table 4.1 indicates that the quantity of Na was higher in Uttar Char Aicha (4.50 me%), Garakhola (4.10 me%), Khazura (2.25 me%), Benarpota (1.32 me%) and Patkhali (1.05 me%) than other locations. The soils of these locations were collected from saline areas under the parent material of ganges alluvium.

The available P content of thirty one soils ranged from 9.0 (Dikshail) to 45.00 (Uttar Char Aicha) $\mu\text{g/ml}$ soil. The available P content in most of the soils under study was above the critical limit except Monoharpur, Dikshail, Rahmatpur, Baira, Kamorgram, Garakhola, Mogorkhal, Nadmollah and West Jhalokathi. The content of S ranged from 8.0 (Mogorkhal) to 25.0 (Rahmatpur) $\mu\text{g/ml}$ soil. According to BARC (1989) 10.00 $\mu\text{g/g}$ soil should be considered as the critical limit both for P and S. On the other hand, the extractable Zn content by 0.25N NaHCO_3 could be considered adequate

Table 4.2.

Particle size distribution and textural classes of the soil of thirty one locations.

Location No.	Particle size distribution (%)			Textural class
	Sand	Silt	Clay	
1.	36.00	35.36	28.64	Clay loam (CL)
2.	26.00	48.36	25.64	Loam (L)
3.	22.00	41.36	36.64	Clay loam (CL)
4.	36.00	37.36	26.64	Loam (L)
5.	72.00	5.36	22.64	Sandy clay loam (SCL)
6.	16.00	41.36	42.64	Silty clay (SiC)
7.	16.00	19.36	64.64	Clay (C)
8.	20.00	49.36	30.64	Clay loam (CL)
9.	16.00	41.36	42.64	Silty clay (SiC)
10.	31.00	36.00	33.00	Clay loam (CL)
11.	27.00	53.00	20.00	Silt loam (SiL)
12.	43.00	39.00	18.00	Loam (L)
13.	35.00	32.00	33.00	Clay loam (CL)
14.	31.00	40.00	29.00	Clay loam (CL)
15.	39.00	47.00	14.00	Loam (L)
16.	35.44	53.56	11.00	Silt loam (SiL)
17.	59.00	33.00	8.00	Sandy loam (SL)
18.	50.00	38.00	12.00	Loam (L)
19.	53.00	35.00	12.00	Sandy loam (SL)
20.	45.00	24.00	31.00	Clay loam (CL)
21.	73.00	12.00	15.00	Sandy loam (SL)
22.	39.64	34.36	26.00	Loam (L)
23.	61.64	28.34	10.02	Sandy loam (SL)
24.	36.00	36.00	28.00	Clay loam (CL)
25.	45.66	28.32	26.02	Loam (L)
26.	33.64	26.36	40.00	Clay loam (CL)
27.	43.64	24.44	31.92	Clay loam (CL)
28.	37.64	46.36	16.00	Loam (L)
29.	35.64	40.36	24.00	Loam (L)
30.	31.64	20.36	48.00	Clay (C)
31.	29.64	26.36	44.00	Clay (C)

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamorgram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

(i.e., $> 1.80 \mu\text{g/ml}$ soil) in all soils as the critical limit proposed by BARC (1989) was $1.8 \mu\text{g/g}$ soil for upland crops.

The values of cation exchange capacity (CEC) of the soils of different locations are presented in Table 4.1. The CEC values of different soils ranged from 5.43 to 11.11 meq/100 g soil with the lowest value observed from the loamy soils of Natun Shahar under Panchagarh district (whose parent material was himalayan piedmont alluvium) and highest from clay textured soils of Dikshail and Monoharpur under Pabna district. The parent material and general soil type of the later was ganges alluvium and calcareous brown floodplain soil. The present results indicated that more the clay content (Table 4.2) in the soil the higher the CEC (Table 4.1). Similar relationship on CEC and clay content was recorded by Motiramani et al. (1964).

The particle size distribution of thirty one soils and their textural classes are presented in Table 4.2. A marked variation was observed in particle size distribution in soils of different locations under study and it was varied from sandy loam to clay and clay loam in texture.

4.2 Determination of soil potassium using five different extractants

The quantity of K in soil of thirty one locations determined by using five chemical extractants are presented in Table 4.3. Results revealed that the exchangeable as well as available and water soluble K extracted by different chemical extractants varied widely from as low as 0.04 meq K/100g soil (distilled water) to a maximum of 3.69 meq K/100g soil (boiling 1N HNO₃). The amount of extractable K varied markedly depending on the soils and extractants used.

The extractable K values of different extractants were ranged from 0.08 to 0.57 (1N NH₄OAc), 0.12 to 0.47 (meq K/100ml soil) (0.25N NaHCO₃), 0.37 to 3.69 (1N HNO₃), 0.10 to 0.69 (cold H₂SO₄) and 0.04 to 0.23 meq K/100g soil with the mean values of 0.235, 0.273 (meq K/100ml soil), 2.425, 0.310 and 0.105 meq K/100g soil for 1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled water extractant respectively. Similar range and mean values of different K extractants have also been reported by Panda et al. (1993), Prakash et al. (1986), Singh et al. (1992), Islam et al. (1994), Haque et al. (1992), Yadav et al. (1984), Bhuiyan et al. (1992), Mazumdar et al. (1987), Chamuah et al. (1987), Perumal et al. (1991), Boruah et al. (1992), Chaudhary et al. (1992), Tandon et al. (1988c) and Kumar et al. (1991). The range of K extracted by ammonium acetate was higher than that of sodium bicarbonate and distilled water soluble K. This might be due to presence of

Table 4.3. Level of potassium in soil from thirty one locations determined by using five extractants.

Location No.	Level of K (me %) extracted by				
	1N NH ₄ OAc	0.25N NaHCO ₃	1N HNO ₃ (boiling)	Cold H ₂ SO ₄	Distilled water
1.	0.12	0.23	0.76	0.12	0.07
2.	0.08	0.16	1.81	0.12	0.07
3.	0.28	0.43	0.84	0.29	0.11
4.	0.14	0.23	3.10	0.18	0.08
5.	0.14	0.23	1.99	0.16	0.11
6.	0.53	0.39	3.28	0.63	0.22
7.	0.57	0.43	3.69	0.58	0.23
8.	0.29	0.31	3.08	0.39	0.08
9.	0.35	0.33	3.49	0.44	0.14
10.	0.14	0.20	3.02	0.22	0.10
11.	0.14	0.17	2.34	0.24	0.10
12.	0.09	0.12	2.65	0.25	0.05
13.	0.28	0.21	2.52	0.32	0.15
14.	0.30	0.38	1.91	0.29	0.10
15.	0.12	0.21	3.55	0.27	0.06
16.	0.19	0.21	3.47	0.27	0.08
17.	0.10	0.15	1.78	0.11	0.05
18.	0.14	0.23	1.66	0.17	0.05
19.	0.09	0.17	1.01	0.13	0.04
20.	0.31	0.34	1.23	0.33	0.11
21.	0.19	0.30	0.45	0.16	0.07
22.	0.25	0.23	2.89	0.48	0.12
23.	0.12	0.18	2.77	0.26	0.07
24.	0.42	0.36	3.55	0.69	0.18
25.	0.18	0.19	2.87	0.37	0.08
26.	0.34	0.32	3.14	0.47	0.11
27.	0.11	0.27	0.37	0.10	0.04
28.	0.25	0.27	2.95	0.43	0.10
29.	0.27	0.29	2.99	0.29	0.13
30.	0.41	0.47	3.02	0.34	0.19
31.	0.36	0.46	3.02	0.54	0.17
Range of K	0.08-0.57	0.12-0.47	0.37-3.69	0.10-0.69	0.04-0.23
Mean of K	0.235	0.273	2.425	0.310	0.105
SE $\pm$	0.130	0.097	0.990	0.159	0.050

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahr, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamogram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

ammonium ions which are known to efficiently replace K from exchange sites. These results are in agreement with Prakash et al. (1986). Kumar et al. (1991) obtained relatively low content of available and non-exchangeable K in soils which indicates the possibility of much faster rate of depletion of exchangeable K from the soil during intensive cultivation.

Data indicated that the extractibility of the 1N NH_4OAc , 0.25N NaHCO_3 and cold H_2SO_4 with the mean values of 0.235, 0.273 (meq K/100ml soil) and 0.310 meq K/100g soil were almost similar except some cases in the higher initial soil K level specially for the calcareous soils (both saline and non-saline phase). Ali et al. (1982) observed that the grey floodplain soils of saline phase contained maximum amount of exchangeable K (average 0.50 meq K/100g soil) followed by calcareous darkgrey floodplain and brown floodplain soils (average 0.40 meq K/100g soil) of Bangladesh. According to Habibullah et al. (1971) the exchangeable K content was found highest (1.04 meq/100g soil) in calcareous darkgrey floodplain soil followed by brown mottled terrace soil. Hunter and Pratt (1957) reported that K extraction with cold H_2SO_4 provides a reliable index for the soils of Ohio and New York. Page et al. (1984) indicated that cold or dilute acid extracts K in a short period of time and removes approximately the same amount of K from most of the soils as does with 1N NH_4OAc extractant. They also mentioned that cold H_2SO_4 extraction is most useful for acidic and neutral soils but until it is shown to be effective, 1N NH_4OAc extraction is a safer index for measuring K availability in

calcareous soil. Moreover, acid type extractants (cold or dilute) are suitable for many soils that have a CEC <10 meq /100g soil and that are relatively low in organic matter content (< 5 %).

In the present study, the extracting power of the exchangeable as well as available and water soluble K content of the soil by different K extractants was found to be in the following decreasing order: 1N HNO₃ > cold H₂SO₄ > 0.25N NaHCO₃ > 1N NH₄OAc > distilled water. Similar findings on extracting power of the K extractants were reported by Perumal *et al.* (1991), Prakash *et al.* (1986), Panda *et al.* (1993), Singh *et al.* (1992), Islam *et al.* (1994), Bhuiyan *et al.* (1992) and Haque *et al.* (1992). The quantity of K extracted by 1N HNO₃ (boiling) which comprised of non-exchangeable form as well, was higher than that obtained with weak acid, salt solutions and distilled water soluble fraction. Similar high values of soil potassium extracted with 1N HNO₃ (boiling) was reported by Prakash *et al.* (1986). The high values of K extracted by 1N HNO₃ might be due to some K adsorbed on interlattice sites of clay which could not be replaced by NH₄⁺ but could be extracted with HNO₃, a part of exchange complex (Singh *et al.*, 1985). Tandon *et al.* (1988d) reported that the reserve K (mineral K and the non-exchangeable K (1N HNO₃) can be visualized as the donor K and found between the clay plates. This reserve K can not be extracted by mild solutions like 1N NH₄OAc because of the sizeable contribution of the non-exchangeable K to the potassium nutrition of crops (by becoming gradually exchangeable) is mostly at the expense of K-depletion of the soil. Krishnakumari *et al.* (1989) stated that as

an extractant, 1N HNO₃ extracted the non-exchangeable K released in the form of available K from K bearing minerals during crop growth. Both 1N NH₄OAc (average 0.235 meq K/100g soil) and 0.25N NaHCO₃ (average 0.273 meq K/100ml soil) extractants extracted lower quantity of K than cold H₂SO₄ (average 0.310 meq K/100 g soil) but all the values were higher than that extracted by distilled water (average 0.105 meq K/100g soil). This findings are similar to those of the results reported by Haque and Ali (1990). On the other hand, Datta and Kalbande (1967) reported that mineral acids extract higher quantity of soil potassium not only extract the exchangeable form but also some non-exchangeable form which was brought in to solution by the breakdown of primary and secondary minerals.

In order to evaluate the performance of extractants for K extraction from soil, standard error ($\pm$) of K values of each extractant was considered (Table 4.3). The concept of using standard error to measure the precision of an experiment was introduced by Clarke (1980). Results revealed that standard error of the K extractants varied markedly from as low as 0.050 for distilled water and as high as 0.990 for 1N HNO₃ extractant. Considering the concept of Clarke (1980), the present results led to assume that lesser the value of standard error, the higher the precision of the extractant towards the extraction of K from soil. Considering the values of standard error, the precision of K extraction was in the following order: distilled water > 0.25N NaHCO₃ > 1N NH₄OAc > cold H₂SO₄ > 1N HNO₃.

4.3 Per cent K saturation of the extractable K in five extraction methods

Per cent base (Ca^{++} , Mg^{++} , K^+ , H^+ , Na^+ etc.) saturation is a factor which affects soil fertility. The per cent K saturation of extractable K in five extraction methods are shown in Table 4.4. Distilled water soluble K offered the lowest range and mean value of per cent K saturation (0.53 to 2.33 and 1.33%) followed by 1N NH_4OAc (1.23 to 5.60 and 2.98%), 0.25N NaHCO_3 (1.63 to 6.59 and 3.61%) and cold H_2SO_4 extractable K (1.47 to 8.70 and 3.96%). On the other hand, 1N HNO_3 extractable K gave the highest range (5.43 to 57.09%) and mean value (31.73%) of per cent K saturation. This might be due to higher quantity of non-exchangeable K extracted in the form of available K by 1N HNO_3 . It has been reported that 2 to 5 per cent base saturation of K is assumed to be optimum for crop production in most soils (PPI., 1983). Yadav et al. (1984) reported that the per cent K saturation is the method of determining indirect K mobility in the soil and they found the range and mean value of per cent K saturation of 1N NH_4OAc extractable K as 0.56 to 2.26 and 0.99% respectively.

Similar to extracted K values, standard error ($\pm$) was also used to determine the efficiency of tested extractants for per cent K saturation. The results are shown in Table 4.4 which indicate that the value of standard error was lower for distilled water (0.50) and higher for 1N HNO_3 (12.01). It is assumed that the lower

Table 4.4. Per cent K saturation of extractable K from five different extraction methods of soil of thirty one locations.

Location No.	K saturation (%) for the extractable K of five extraction methods				
	IN NH_4OAc	0.25N NaHCO_3	Cold H_2SO_4	IN HNO_3	Distilled water
1.	2.11	4.03	2.11	13.33	0.53
2.	1.34	2.68	2.01	30.27	1.17
3.	4.29	6.59	4.45	12.88	1.69
4.	2.58	4.24	3.31	57.09	1.47
5.	2.48	4.07	2.83	35.22	1.95
6.	5.60	4.12	6.66	34.67	2.33
7.	5.13	3.87	5.22	33.21	2.07
8.	3.56	3.80	4.79	37.79	0.98
9.	3.88	3.66	4.88	38.69	1.55
10.	1.67	2.39	2.63	36.08	1.19
11.	1.91	2.32	3.27	31.88	1.36
12.	1.23	1.63	3.41	36.10	0.68
13.	3.03	2.27	3.46	27.27	1.62
14.	3.40	4.30	3.28	21.63	1.13
15.	1.61	2.82	3.62	47.65	0.81
16.	2.57	2.84	3.65	46.96	1.08
17.	1.61	2.42	1.77	28.71	0.81
18.	2.40	3.94	2.91	28.42	0.86
19.	1.49	2.82	2.16	16.75	0.66
20.	4.13	4.53	4.40	16.40	1.47
21.	3.12	4.93	2.63	7.39	1.15
22.	3.24	2.98	6.22	37.44	1.55
23.	1.85	2.77	4.01	42.68	1.08
24.	5.30	4.54	8.70	44.77	2.27
25.	2.21	2.33	4.54	35.21	0.98
26.	3.72	3.50	5.15	34.39	1.20
27.	1.61	3.96	1.47	5.43	0.59
28.	3.47	3.75	5.97	40.97	1.39
29.	3.45	3.70	3.70	38.19	1.66
30.	4.44	5.09	3.68	32.68	2.06
31.	3.99	5.10	5.99	34.48	1.88
Range:	1.23-5.60	1.63-6.59	1.47- 8.70	5.43-57.09	0.53-2.33
Mean:	2.98	3.61	3.96	31.73	1.33
SE _E :	1.23	1.07	1.61	12.01	0.50

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamorgram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

the value of standard error ($\pm$), the higher the capacity of per cent base (K) saturation of the extractant. As such, the performance of the extractants for K saturation was in the following order: (distilled water) > (0.25N NaHCO_3) > (1N NH_4OAc) > (cold H_2SO_4) > (1N HNO_3).

4.4 Coefficient of correlation (r) between soil K values determined by using five extractants and soil properties

Coefficient of correlation between the values of different K extractants (1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water) and some selected soil properties (i.e., pH, sand, silt, clay, Ca, Mg, organic matter and CEC) were examined with a view to identify the suitable soil properties involved in the regulation of K extraction. The results are presented in Table 4.5.

The exchangeable K extracted by 1N NH_4OAc extractant varied from 0.08 to 0.57 meq K/100g soil (Table 4.3). The quantity of K extracted by 1N NH_4OAc was significantly correlated with pH ($r=0.523$ **), clay ($r=0.783$ **), Ca ($r=0.802$ **), Mg ($r=0.731$ **) and CEC ($r=0.809$ **) but did not have significant relationship with organic matter. Islam et al. (1994) observed the significant and positive correlation of 1N NH_4OAc extractable K with pH and clay content, while Saleque et al. (1990) found strong positive correlation of 1N NH_4OAc extractable K with the clay content of soil. Among the soil properties, CEC revealed the highest degree of correlation ($r=0.809$ **) followed by Ca ($r=0.802$ **) content of

the soil in 1N NH_4OAc extraction. Data also indicated that 1N NH_4OAc had a negative relationship with sand and silt contents in soil (Table 4.5). The significantly positive correlation between 1N NH_4OAc extractable K and clay content indicates that clay fraction appeared to be the primary reservoir of readily exchangeable K. Boruah et al. (1992) and Islam et al. (1994) also found similar relationship of 1N NH_4OAc extractable K with clay, CEC and organic matter. They also reported that organic matter and clay fraction are the primary reservoir of exchangeable K in the soil but in the present study, organic matter could not be considered as a reservoir of exchangeable K since it had no significant effect on the release of K with 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , and distilled water extraction. This might be due to insufficient and low quantities of organic matter present in the soil.

The extracted K values (0.12 to 0.47 meq K/100ml soil) obtained from 0.25N NaHCO_3 extractant had significantly positive correlation with clay ($r=0.748^{**}$), Ca ($r=0.519^{**}$), Mg ($r=0.524^{**}$) and CEC ($r=0.570^{**}$) except pH and organic matter. Results also revealed that this form of K extractant established higher degree of correlation with clay content. Like 1N NH_4OAc extractant, 0.25 N NaHCO_3 also showed negative relationship with sand and silt content of the soil.

Table 4.5. Coefficient of correlation (r) between soil K values determined by using five extractants and some soil properties.

Soil property	K extractant				
	1N NH_4OAc	0.25N NaHCO_3	1N HNO_3 (boiling)	Cold H_2SO_4	Distilled water
pH	0.523 **	0.264 NS	0.772 **	0.732 **	0.612 **
Sand	-0.567 **	-0.453 **	-0.455 **	-0.523 **	-0.532 **
Silt	-0.037 NS	-0.168 NS	0.318 NS	0.140 NS	-0.158 NS
Clay	0.783 **	0.748 **	0.281 NS	0.574 **	0.781 **
Ca	0.802 **	0.519 **	0.541 **	0.823 **	0.769 **
Mg	0.731 **	0.524 **	0.502 **	0.735 **	0.720 **
Organic matter	0.299 NS	0.290 NS	0.183 NS	0.365 *	0.281 NS
CEC	0.809 **	0.570 **	0.604 **	0.751 **	0.764 **

** = Significant at 1% level, * = Significant at 5% level, NS = Not significant.

The estimated K values (0.37 to 3.69 meq K/100g soil) extracted by 1N HNO_3 (boiling) revealed significantly positive correlation with pH ($r = 0.772$ **), Ca ($r = 0.541$ **), Mg ($r = 0.502$ **) and CEC ($r = 0.604$ **). Similar relationship between 1N HNO_3 soluble K and CEC was observed by Singh *et al.* (1985), Islam *et al.* (1994) and Boruah *et al.* (1992). This might be due to K^+ adsorbed on the edges of inner site of the lattice, which could not be replaced by NH_4^+ but be extracted with 1N HNO_3 (Singh *et al.*, 1985 and Islam *et al.*, 1994).

Correlation coefficient of the values of K (0.10 to 0.69 meq K/100g soil) extracted by cold H_2SO_4 are presented in Table 4.5. Cold H_2SO_4 extractable K showed highly significant and positive correlation with pH ($r=0.732$ **), clay ($r=0.574$ **), Ca ($r=0.823$ **) Mg ($r=0.735$ **), organic matter ($r=0.365$ *), and CEC ($r=0.751$ **). The high degree of correlation obtained between K values of cold H_2SO_4 and calcium. This relationship might be due to presence of high content of K bearing minerals in the finer fractions of the soil (Islam et al., 1994).

The quantity of K extracted by distilled water varied from 0.04 to 0.23 meq K/100g soil (Table 4.3). It is evident from the Table 4.5 that K values (distilled water) had highly significant positive relationship with pH ($r=0.612$ **), Clay ($r=0.781$ **), Ca ($r=0.769$ **), Mg ($r=0.720$ **) and CEC ($r=0.764$ **). Pal et al. (1992) also reported significantly positive correlation of distilled water extractable K with pH and silt. In the present study, distilled water extractable K did not show any significant relation with organic matter but established negative relationship with sand ($r=-0.532$ **) and silt ($r=-0.158$). Islam et al. (1994) found negative correlation of distilled water extractable K with the silt content of the soils of Bangladesh. Among the soil properties, clay content had higher degree of correlation ($r=0.781$ **) with the distilled water extracted K followed by calcium content ($r=0.769$ **) of the soil.

When values of r contained in Table 4.5 are compared, it is found that the highest degree of correlation was found between 1N NH_4OAc extractable K and CEC, 0.25N NaHCO_3 extractable K and clay, 1N HNO_3 extractable K and pH, cold H_2SO_4 extractable K and calcium, and distilled water soluble K and clay. Among these, the highest r value was obtained between cold H_2SO_4 extractable K and calcium content of soil.

4.5 Intercorrelation among K values extracted by different methods of extraction

Coefficient of intercorrelation values among different K extractants are presented in Table 4.6. Intercorrelation values indicate that all extractants (i.e., ammonium acetate, sodium bicarbonate, nitric acid, sulphuric acid and distilled water) had significant positive correlation among themselves except 0.25N NaHCO_3 and 1N HNO_3 ($r = 0.142$). Significant positive correlation led to assume the existence of equilibrium between different K extractants of soil. Similar results were found by Yadav et al. (1984), Roy et al. (1989), Kumar et al. (1991), Perumal et al. (1991), Islam et al. (1994) and Negi et al. (1981). Pal et al. (1992) reported that 1N NH_4OAc extractable K had significant positive correlation with available K and 1N HNO_3 extractable K, while Saleque et al. (1990) found significant positive correlation of 1N NH_4OAc extractant with the 0.25N NaHCO_3 .

The coefficient of correlation among different K extractants was found in the following order: 1N NH_4OAc and distilled water ($r=0.918^{**}$) > 1N NH_4OAc and cold H_2SO_4 ($r=0.860^{**}$) > 1N NH_4OAc and 0.25N NaHCO_3 ($r=0.840^{**}$) > cold H_2SO_4 and distilled water ($r=0.800^{**}$) > 0.25N NaHCO_3 and distilled water ($r=0.730^{**}$) > 1N HNO_3 and cold H_2SO_4 ($r=0.663^{**}$) > 0.25N NaHCO_3 and cold H_2SO_4 ($r=0.607^{**}$) > 1N HNO_3 and distilled water ($r=0.520^{**}$) > 1N NH_4OAc and 1N HNO_3 ($r=0.461^{**}$) > 0.25N NaHCO_3 and 1N HNO_3 ($r=0.142$). Similar significantly positive relationship of K extractants was observed with the extractable K of 1N NH_4OAc and 0.25N NaHCO_3 by Saleque et al. (1990), 1N NH_4OAc with dilute H_2SO_4 and 1M HNO_3 with distilled water by Islam et al. (1994), distilled water with 1N NH_4OAc and 1N HNO_3 by Pal et al. (1992) and Prasad (1990), distilled water with 1N NH_4OAc and 1N HNO_3 , 1N NH_4OAc with distilled water and 1N HNO_3 , 1N HNO_3 with distilled water by Kumar et al. (1991) and 1.38 N H_2SO_4 by Prasad (1990) and among all the similar extractants under study by Perumal et al. (1991).

Nazirkar et al. (1991) reported that the degree of correlation coefficient among the extractants and plant response to soil and fertilizer should be considered in selecting a best extractant. According to Goswami et al. (1971), correlation coefficient between two variables should be greater than 0.85 for inferring a close relationship.

Table 4.6. Coefficient of intercorrelation among different K extraction methods.

Potassium extractant	1N NH ₄ OAc K	0.25N NaHCO ₃ K	1N HNO ₃ K (boiling)	Cold H ₂ SO ₄ K	Distilled water
1N NH ₄ OAc K	-	0.840 **	0.461 **	0.860 **	0.918 **
0.25N NaHCO ₃ K	-	-	0.142 NS	0.607 **	0.730 **
1N HNO ₃ K (boiling)	-	-	-	0.663 **	0.520 **
Cold H ₂ SO ₄ K	-	-	-	-	0.800 **
Distilled water K	-	-	-	-	-

** = Significant at 1% level, * = Significant at 5% level,
NS = Not significant

In the present study, two K extractants (distilled water and cold H₂SO₄) with 1N NH₄OAc were found to be more effective for the extraction of available K from the soil since they had r values > 0.85. The strong correlation between extractants indicating the equal effectiveness for the extraction of soil K. Tandon et al. (1988d) reported that the distilled water soluble K (water soluble K) is a very small fraction of total K in the soil which is present in the soil solution. This form of K is in direct equilibrium with exchangeable K. According to Singh et al. (1992) the extractants like distilled water and 0.5M NaHCO₃ are known to be best for simultaneous extraction of more than one nutrient elements.

From the simple correlation among the extractants, it could be inferred that the 1N NH₄OAc extractable K was more related to distilled water (r= 0.918**) and cold H₂SO₄ (r= 0.860 **) followed

by 0.25N NaHCO₃ ($r=0.840$ **) extractant as evidenced by high r values (Table 4.6). Similar results were also reported by Perumal et al. (1991) but Islam et al. (1994) found higher degree of correlation of 1N NH₄OAc extractable K with the K values of 0.7M H₂SO₄ and 1N HNO₃ extractants.

4.6 Critical limit of potassium in soil and plant and the response of wheat to applied potash in soils of thirty one locations

4.6.1 Effect of K application on the dry matter yield, per cent relative yield, per cent K concentration in plant and K uptake of wheat

The data on threshold yield, plateau yield and per cent relative yield of wheat with extractable K values of five extractants are presented in Table 4.7. The exchangeable as well as available and water soluble potassium status of different soils of the pot culture experiment showed marked variation among different K extractants. Due to differences in soil potassium content, distinct variation were also observed for the threshold yield (2.37 to 5.44 g pot⁻¹), plateau yield (2.99 to 6.36 g pot⁻¹) and per cent relative yield at optimum K level (59 to 95 %) of wheat. The present results (Table 4.8.) clearly indicated that the dry matter yield of wheat increased with increasing levels of K application up to 30 to 45 mg k kg⁻¹ levels.

Table 4.7.

Quantity of potassium extracted by different K extractants, dry matter yield and per cent relative yield of wheat grown in soils of thirty one locations.

Location No.	Quantity of K (me %) extracted by					Dry matter yield (g pot ⁻¹)		Relative yield (%)
	1N NH ₄ OAc	0.25N NaHCO ₃	1N HNO ₃ (boiling)	Cold H ₂ SO ₄	Distilled water	Threshold yield	Plateau yield	
1.	0.12	0.23	0.76	0.12	0.07	4.21	6.33	67
2.	0.08	0.16	1.81	0.12	0.07	2.96	5.03	59
3.	0.28	0.43	0.84	0.29	0.11	3.57	4.85	74
4.	0.14	0.23	3.10	0.18	0.08	3.10	3.93	79
5.	0.14	0.23	1.99	0.16	0.11	5.16	6.36	81
6.	0.53	0.39	3.28	0.63	0.22	2.90	3.36	86
7.	0.57	0.43	3.69	0.58	0.23	2.99	3.47	86
8.	0.29	0.31	3.08	0.39	0.08	3.45	3.69	94
9.	0.35	0.33	3.49	0.44	0.14	3.35	3.78	89
10.	0.14	0.20	3.02	0.22	0.10	2.81	3.73	75
11.	0.14	0.17	2.34	0.24	0.10	3.60	4.47	81
12.	0.09	0.12	2.65	0.25	0.05	2.73	3.73	73
13.	0.28	0.21	2.52	0.32	0.15	3.43	4.46	77
14.	0.30	0.38	1.91	0.29	0.10	3.79	4.68	81
15.	0.12	0.21	3.55	0.27	0.06	3.78	5.82	65
16.	0.19	0.21	3.47	0.27	0.08	3.21	4.63	69
17.	0.10	0.15	1.78	0.11	0.05	2.50	3.87	65
18.	0.14	0.23	1.66	0.17	0.05	3.33	3.83	87
19.	0.09	0.17	1.01	0.13	0.04	2.38	3.76	63
20.	0.31	0.34	1.23	0.33	0.11	3.23	4.19	77
21.	0.19	0.30	0.45	0.16	0.07	4.06	4.92	83
22.	0.25	0.23	2.89	0.48	0.12	3.49	4.14	84
23.	0.12	0.18	2.77	0.26	0.07	4.10	4.66	88
24.	0.42	0.36	3.55	0.69	0.18	3.54	3.84	92
25.	0.18	0.19	2.87	0.37	0.08	3.91	4.13	95
26.	0.34	0.32	3.14	0.47	0.11	3.53	3.82	92
27.	0.11	0.27	0.37	0.10	0.04	2.37	3.54	67
28.	0.25	0.27	2.95	0.43	0.10	2.55	2.99	85
29.	0.27	0.29	2.99	0.29	0.13	5.44	6.22	87
30.	0.41	0.47	3.02	0.34	0.19	5.34	5.64	95
31.	0.36	0.46	3.02	0.54	0.17	4.98	5.88	85

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamogram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

These results are in agreement with the observation of Kumar et al. (1991) and Goswami et al. (1976). Further increasing the dose of K, the dry matter yield of wheat decreased in soils which contained high levels of initial K. Islam et al. (1994) reported that the yield is more affected than uptake by many factors other than the available nutrient status in the surface soils such as application of other nutrients, environment and management practices relating K uptake with its soil test value.

The per cent K concentration (K_o) of wheat plant varied markedly due to variation of initial K values in soils and it ranged from 2.41 to 5.83% (Table 4.8). Similar findings of the range of K (< 1.1 to 4.1%) on wheat have been reported by Rao et al. (1989) while Chapman (1967) indicated 2.30 to 3.40% as the intermediate K status of wheat harvested at flowering stage. On the other hand, Kumar et al. (1991) found 1.10 to 1.40% K in the wheat plant of K control plot.

The results of potassium uptake by wheat plant are presented in Table 4.8. It is revealed that K uptake by wheat plant at 42 days of sowing increased with increasing levels of K application up to 30 to 45 mg K kg⁻¹ and ranged from 60 to 467 mg K kg⁻¹. This results agreed with the findings of Prakash et al. (1986), Mazumdar et al. (1987) and Kumar et al. (1991). It is observed that the magnitude of K uptake was higher in 30 to 45 mg K kg⁻¹ application as compared 0 to 15 mg K kg⁻¹ levels.

Table 4.8. Effect of K application on the dry matter yield, per cent relative yield, K concentration and K uptake of wheat.

Location No.	Dry matter yield (g pot ⁻¹)					Relative yield (%)	% K Conc. at K ₀	Potassium uptake (mg pot ⁻¹)				
	K applied (mg K kg ⁻¹)							K applied (mg K kg ⁻¹)				
	0	15	30	45	60			0	15	30	45	60
1.	4.21e	4.71d	5.16c	5.65b	6.33a	67	2.83	119	204	258	315	380
2.	2.96c	3.44bc	3.93b	3.88b	5.03a	59	3.50	104	158	193	184	273
3.	3.57c	4.10bc	4.29ab	4.85a	3.75bc	74	3.17	113	174	250	319	288
4.	3.10b	3.47ab	3.60a	3.73a	3.93a	79	4.00	124	188	216	227	301
5.	5.16c	5.51b	5.52b	5.55b	6.36a	81	4.17	215	280	373	421	445
6.	2.90b	3.16ab	2.90b	3.36a	3.10ab	86	4.08	118	179	181	193	163
7.	2.99b	3.47a	2.96b	3.10ab	3.01b	86	5.08	152	223	210	240	216
8.	3.45b	3.15c	3.31b	3.34b	3.69a	94	5.17	178	215	237	236	231
9.	3.35b	3.78a	3.50b	3.52b	3.77a	89	5.42	182	239	251	258	254
10.	2.81d	2.84cd	3.00c	3.18b	3.73a	75	4.33	122	168	170	196	239
11.	3.60b	3.97b	4.47a	3.77b	4.03ab	81	4.33	156	241	291	254	262
12.	2.73d	2.97cd	3.19bc	3.52ab	3.73a	73	5.41	148	188	207	235	255
13.	3.43b	4.16a	4.32a	4.46a	4.24a	77	5.50	189	270	327	338	314
14.	3.79b	3.89b	4.05b	4.68a	4.49a	81	5.75	218	249	307	293	307
15.	3.78d	4.31c	4.66c	5.24b	5.82a	65	3.50	132	240	322	385	451
16.	3.21c	3.65bc	4.13ab	4.63a	4.17ab	69	4.29	138	161	247	239	226
17.	2.50b	3.60a	3.87a	3.77a	3.87a	65	2.41	60	105	155	163	148
18.	3.33b	3.37b	3.83a	3.40b	3.43b	87	3.50	117	140	198	226	211
19.	2.38d	3.05c	3.12c	3.76a	3.45b	63	4.25	101	160	208	197	201
20.	3.23d	3.44c	3.56c	3.77b	4.19a	77	4.91	159	229	240	264	269
21.	4.06c	4.45b	4.57b	4.88a	4.92a	83	3.16	128	185	224	281	332
22.	3.49b	4.14a	3.71b	3.57b	3.52b	84	5.58	195	276	269	277	261
23.	4.10b	4.25b	4.15b	4.66a	4.02b	88	4.08	167	234	242	287	197
24.	3.54b	3.73a	3.84a	3.30c	3.56b	92	5.83	206	230	259	234	255
25.	3.91abc	3.79bc	3.65c	4.13a	3.96ab	95	4.25	166	171	173	207	208
26.	3.53ab	3.82a	3.35b	3.04c	2.66d	92	5.08	179	280	212	223	173
27.	2.37c	3.09b	3.29ab	3.54a	3.42a	67	2.58	61	127	159	180	174
28.	2.55a	2.67a	2.84a	2.99a	2.93a	85	4.16	106	140	144	142	139
29.	5.44d	5.65cd	5.91b	6.22a	5.77bc	87	5.00	272	438	433	467	346
30.	5.34a	5.64a	5.03a	4.94a	4.92a	95	5.58	298	437	352	353	295
31.	4.98c	5.80a	5.61ab	5.55ab	5.36bc	85	5.50	274	397	374	351	322

In a column, means followed by a common letter are not significantly different at 5% level.

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamorgram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

4.6.2 K concentration in wheat plant and per cent relative yield

The concentration of K in wheat plant in K control pots ranged from 2.41 To 5.83 % (% in dry matter) and are presented in Table 4.9. Wide variations in the dry matter yield and per cent K concentration of wheat was observed due to differences of potassium fertility in the soil. It appeared from the data that the higher K values in the initial soil resulted the highest K concentration in wheat plant especially in the calcareous soil both saline and non-saline phases. Data further revealed that the concentration of K increased in almost all soils with increasing the level of applied K up to 30 to 45 mg K kg⁻¹ and it was ranging from 2.41 to 7.75%. According to Rao et al. (1989) the range of K concentration in wheat plant was < 1.0 to 6.1% at 45 days of sowing but the range was 2.30 to 3.40 % as reported by Chapman (1967).

On the basis of K concentration in wheat plant, per cent relative yield was calculated from the corresponding dry matter yield of wheat and it ranged from 59 to 100% (Table 4.9).

Table 4.9. Dry matter yield, K concentration in plant (1N HCl extraction) at different levels of applied K and per cent relative yield of wheat.

Location No.	Dry matter yield (g pot ⁻¹)					K concentration (% in dry matter)					Relative yield (%)
	K applied (mg K kg ⁻¹)					K applied (mg K kg ⁻¹)					
	0	15	30	45	60	0	15	30	45	60	
1.	4.21	4.71	5.16	5.65	6.33	2.83e	4.33d	5.00c	5.58b	6.00a	67
2.	2.96	3.44	3.93	3.88	5.03	3.50e	4.58d	4.92b	4.75c	5.42a	59
3.	3.57	4.10	4.29	4.85	3.75	3.17e	4.25d	5.83c	6.58b	7.67a	95
4.	3.10	3.47	3.60	3.73	3.93	4.00d	5.42c	6.00b	6.08b	7.67a	79
5.	5.16	5.51	5.52	5.55	6.36	4.17e	5.08d	6.75c	7.58a	7.00b	93
6.	2.90	3.16	2.90	3.36	3.10	4.08e	5.67c	6.25a	5.75b	5.25d	100
7.	2.99	3.47	2.96	3.10	3.01	5.08d	6.42c	7.08b	7.75a	7.17b	96
8.	3.45	3.15	3.31	3.34	3.69	5.17e	6.83c	7.17a	7.08b	6.25d	93
9.	3.35	3.78	3.50	3.52	3.77	5.42c	6.13b	7.16a	7.33a	6.75b	95
10.	2.81	2.84	3.00	3.18	3.73	4.33e	5.92c	5.67d	6.17b	6.42a	75
11.	3.60	3.97	4.47	3.77	4.03	4.33d	6.08c	6.50b	6.75a	6.50b	95
12.	2.73	2.97	3.19	3.52	3.73	5.41e	6.33d	6.50c	6.67b	6.83a	73
13.	3.43	4.16	4.32	4.46	4.24	5.50c	6.50b	7.58a	7.58a	7.41ab	79
14.	3.79	3.89	4.05	4.68	4.49	5.75e	6.41c	7.58a	6.25d	6.83b	94
15.	3.78	4.31	4.66	5.24	5.82	3.50e	5.58d	6.91c	7.25b	7.75a	65
16.	3.21	3.65	4.13	4.63	4.17	4.29e	4.40d	5.98a	5.16c	5.41b	78
17.	2.50	3.60	3.87	3.77	3.87	2.41e	2.91d	4.00b	4.33a	3.83c	66
18.	3.33	3.37	3.83	3.40	3.43	3.50e	4.16d	5.16c	6.66a	6.16b	98
19.	2.38	3.05	3.12	3.76	3.45	4.25d	5.25c	6.66a	5.25c	5.83b	76
20.	3.23	3.44	3.56	3.77	4.19	4.91d	6.66b	6.75b	7.00a	6.41c	86
21.	4.06	4.45	4.57	4.88	4.92	3.16e	4.16d	4.91c	5.75b	6.75a	83
22.	3.49	4.14	3.71	3.57	3.52	5.58e	6.66d	7.25c	7.75a	7.41b	98
23.	4.10	4.25	4.15	4.66	4.02	4.08e	5.50c	5.83b	6.16a	4.91d	88
24.	3.54	3.73	3.84	3.30	3.56	5.83e	6.16d	6.75c	7.08b	7.16a	99
25.	3.91	3.79	3.65	4.13	3.96	4.25b	4.50b	4.75a	5.00a	5.25a	99
26.	3.53	3.82	3.35	3.04	2.66	5.08d	7.33a	6.33c	7.33a	6.50b	92
27.	2.37	3.09	3.29	3.54	3.42	2.58d	4.12c	4.83b	5.08a	5.08a	67
28.	2.55	2.67	2.84	2.99	2.93	4.16b	5.25ab	5.08ab	4.75ab	4.75ab	96
29.	5.44	5.65	5.91	6.22	5.77	5.00e	7.75a	7.33c	7.50b	6.00d	96
30.	5.34	5.64	5.03	4.94	4.92	5.58e	7.75a	7.00c	7.15b	6.00d	95
31.	4.98	5.88	5.61	5.55	5.36	5.50e	6.75a	6.66b	6.33c	6.00d	85

In a column, means followed by a common letter are not significantly different at 5% level.

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamogram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

4.6.3 Correlation coefficient of soil K values of five extractants with various plant parameters of wheat

Simple correlation coefficient of threshold yield, plateau yield, per cent relative yield (dry matter basis), per cent K concentration (at K_0) and K uptake (at K_0) of wheat with the K values of five K extractants are presented in Table 4.10. All extractants (1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water) were found to be useful for estimating exchangeable as well as available and water soluble soil K on the basis of their significant positive correlations with per cent relative yield, per cent K concentration (at K_0) and also with the K uptake (at K_0) of wheat plant. Kumar et al. (1991) reported significantly positive correlation of the K values of different extractants (distilled water, 1N NH_4OAc and 1N HNO_3) with per cent relative yield, per cent K concentration (at K_0) and K uptake of wheat. Singh et al. (1992) observed significantly positive correlations of 1N NH_4OAc , 0.5M NaHCO_3 and distilled water with per cent relative yield and K uptake by lentil plant. Perumal et al. (1991) recorded significant and positive relationship of K uptake by sorghum with distilled water and 1N NH_4OAc extractable K. Similar findings with distilled water have also been reported by Ekpote (1972) using sorghum as a test crop. Panda et al. (1993) observed significant correlation of the extractable K values of 1N NH_4OAc and 0.5N HNO_3 with dry matter yield, per cent relative yield, per cent K concentration and K uptake of rice while the 1N HNO_3 extractable K correlated with threshold yield, per cent relative

yield and K uptake with relatively lower r values. Roy et al. (1989) found significantly positive correlation of distilled water and 1N NH_4OAc extractable K only with the per cent relative yield of wheat.

The correlation coefficient between soil K of different extractants and K uptake of wheat showed significantly positive relationship and found to be in the following decreasing order: distilled water > 0.25N NaHCO_3 > 1N NH_4OAc > cold H_2SO_4 > 1N HNO_3 (Table 4.10). The above relationship indicated that the wheat plants able to absorb exchangeable K from the soil more easily than non-exchangeable form. This condition led to assume that most of the soils under the study require K fertilization for wheat cultivation.

Results of correlation coefficient (Table 4.10) revealed that cold H_2SO_4 was the most important K extractant which influenced the per cent K concentration ($r = 0.652^{**}$) and relative yield ($r = 0.642^{**}$) of wheat. Datta et al. (1967) and Prakash et al. (1986) observed similar significant relationship of 6N H_2SO_4 extractable K with the per cent relative yield as well as K uptake of rice and wheat plants respectively. Prasad (1990) found significant correlation of 1N HNO_3 extractable K with the K uptake of wheat. This might be explained by the fact that plant could use more K from the soil than the exchangeable form alone (Prakash et al., 1986).

Table 4.10. Correlation coefficient (r) of soil K of different extractants with various plant parameters of wheat.

Plant parameter	K extractant				
	1N NH_4OAc	0.25N NaHCO_3	1N HNO_3 (boiling)	Cold H_2SO_4	Distilled water
Threshold dry matter yield (K control yield)	0.176 NS	0.357 *	0.118 NS	0.086 NS	0.302 NS
Plateau dry matter yield (Maximum yield)	-0.143 NS	0.074 NS	-0.024 NS	-0.221 NS	0.037 NS
Relative dry matter yield (%)	0.603 **	0.493 **	0.481 **	0.642 **	0.530 **
K concentration (%) at K_0	0.566 **	0.369 *	0.595 **	0.652 **	0.567 **
K uptake at K_0	0.463 **	0.483 **	0.430 *	0.439 **	0.547 **

** = Significant at 1% level, * = Significant at 5% level, NS = Not significant.

In the present study, it has been observed that the extractants (1N NH_4OAc , 1N HNO_3 , cold H_2SO_4 and distilled water) did not show any significant relationship with threshold and plateau yield of wheat except 0.25N NaHCO_3 (Table 4.10). This extractant had significant correlation with threshold yield at lower r value ($r=0.357$ *). Among all K extractants, 1N NH_4OAc , 1N HNO_3 and cold H_2SO_4 extractable K indicated negatively insignificant correlation with plateau yield of wheat. This was probably due to fact that the release of K from the non-exchangeable source and its utilization by growing crop was restricted for the adequate supply of readily available (distilled water and exchangeable) K fractions in soils

(Panda et al., 1993). Ganeshamurthy et al. (1985) reported that contribution of non-exchangeable K to crops become significant only after exhaustion of the readily available potassium fraction by repeated cropping in plots receiving no potassium fertilizer.

The correlation coefficient between extractable K of different chemical extractants and various plant parameters of wheat highlighted the superiority of the cold H_2SO_4 extractant over the other four as it manifested the highest correlation coefficient value with per cent K concentration (at K_0) ($r = 0.652^{**}$) followed by per cent relative yield of wheat ($r = 0.642^{**}$).

4.6.4 Critical limit of soil potassium for wheat

To find out the critical limits of exchangeable, available and water soluble K for wheat scatter graphical technique as well as mathematical procedure of Cate and Nelson (1965 and 1971) were used. In case of scatter graphical technique, the per cent relative yield of wheat (dry matter basis) was plotted against soil K extracted by five different extractants (Table 4.7 and Figures 4.1 to 4.5). According to Cate and Nelson (1965) graphical procedure, 0.13, 0.28 (meq K/100ml soil), 1.86, 0.34 and 0.08 meq K/100g soil were found to be as critical limits by 1N NH_4OAc , 0.25N $NaHCO_3$, 1N HNO_3 , cold H_2SO_4 and distilled water extractants respectively (Table 4.11). A soil was considered as non-responsive to K when the per cent relative dry matter yield of wheat was more than 76, 83, 74,

84 and 73 for 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water extractions respectively (Figures 4.1 to 4.5).

The results of the graphical technique were further confirmed by mathematical procedure of Cate and Nelson (1971) to rectify human bias while drawing partition line particularly the one parallel to Y-axis. By using the mathematical procedure of Cate and Nelson (1971), the calculation of coefficient of determination (R^2) and critical limit for best two population split using the two mean discontinuous model was done (Tables 4.12 to 4.16) for the soils with the same K extractants as used in the graphical procedure. This two mean discontinuous model for best two population split provides a critical limit between 0.12 to 0.14 meq K/100g soil for 1N NH_4OAc , 0.27 and 0.29 meq K/100ml soil for 0.25N NaHCO_3 , 1.81 and 1.91 meq K/100g soil for 1N HNO_3 , 0.33 and 0.34 meq K/100g soil for cold H_2SO_4 and 0.07 and 0.08 meq K/100g soil for distilled water soluble K (Tables 4.12 to 4.16). As such 0.13, 0.28 (meq K/100ml soil), 1.86, 0.34 and 0.08 meq K/ 100g soil could be considered as critical limits both graphical and mathematical procedures for 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water extractants respectively (Table 4.11). Several investigators determined critical limits for 1N NH_4OAc extractable K such as 0.14 meq K/100g soil for wheat (Kumar et al., 1991), 0.16 meq K/100g soil for rice (Panda et al., 1993), 0.14 meq K/100g soil for wheat (Roy et al., 1989), 0.20 meq K/100g soil for rice (Jones, 1982) and 0.15 meq K/100g soil for wheat (Prasad, 1990).

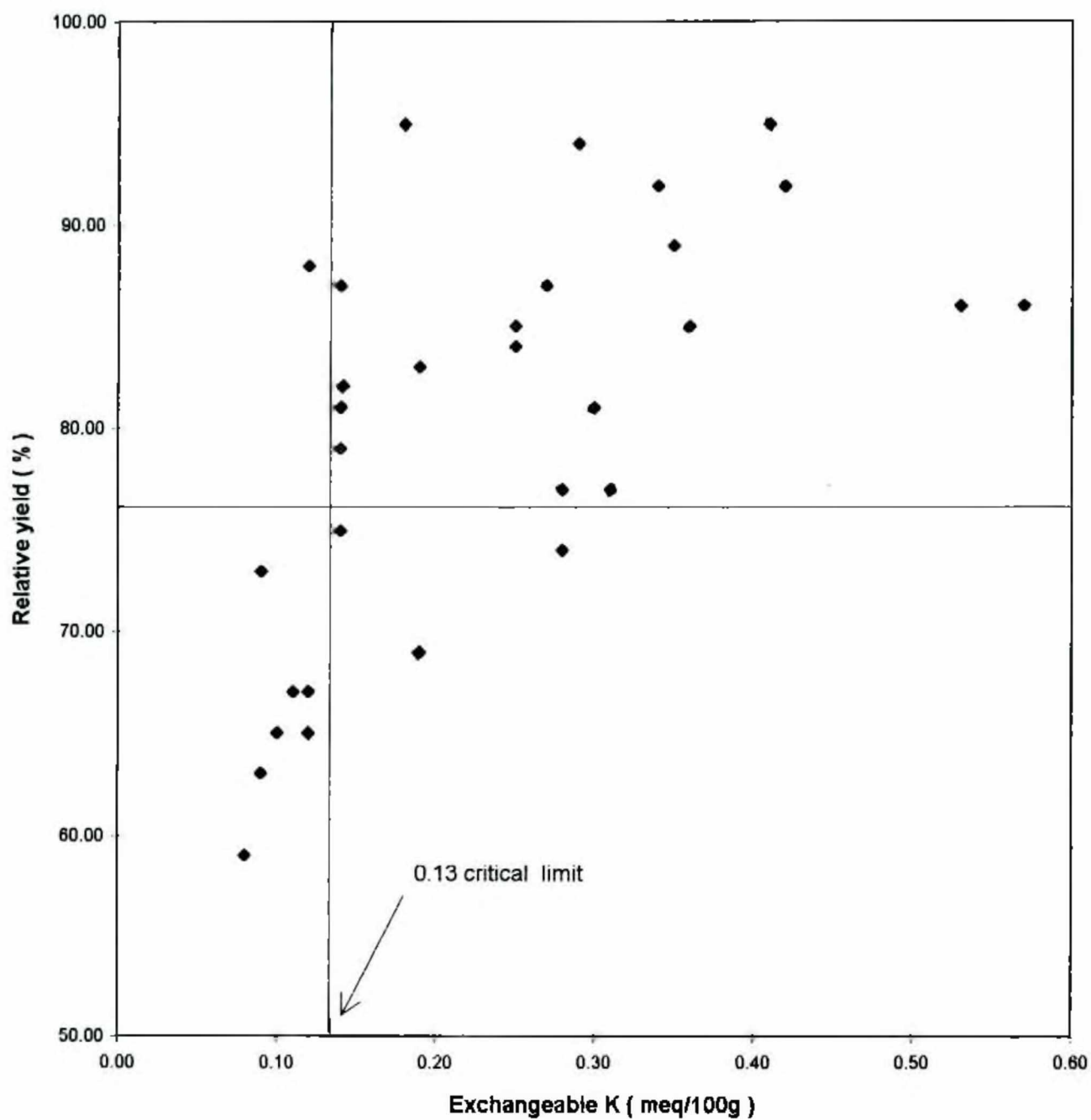


Fig.4.1. Critical limit determination based on the relationship between exchangeable K (1 N NH_4OAc extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations.

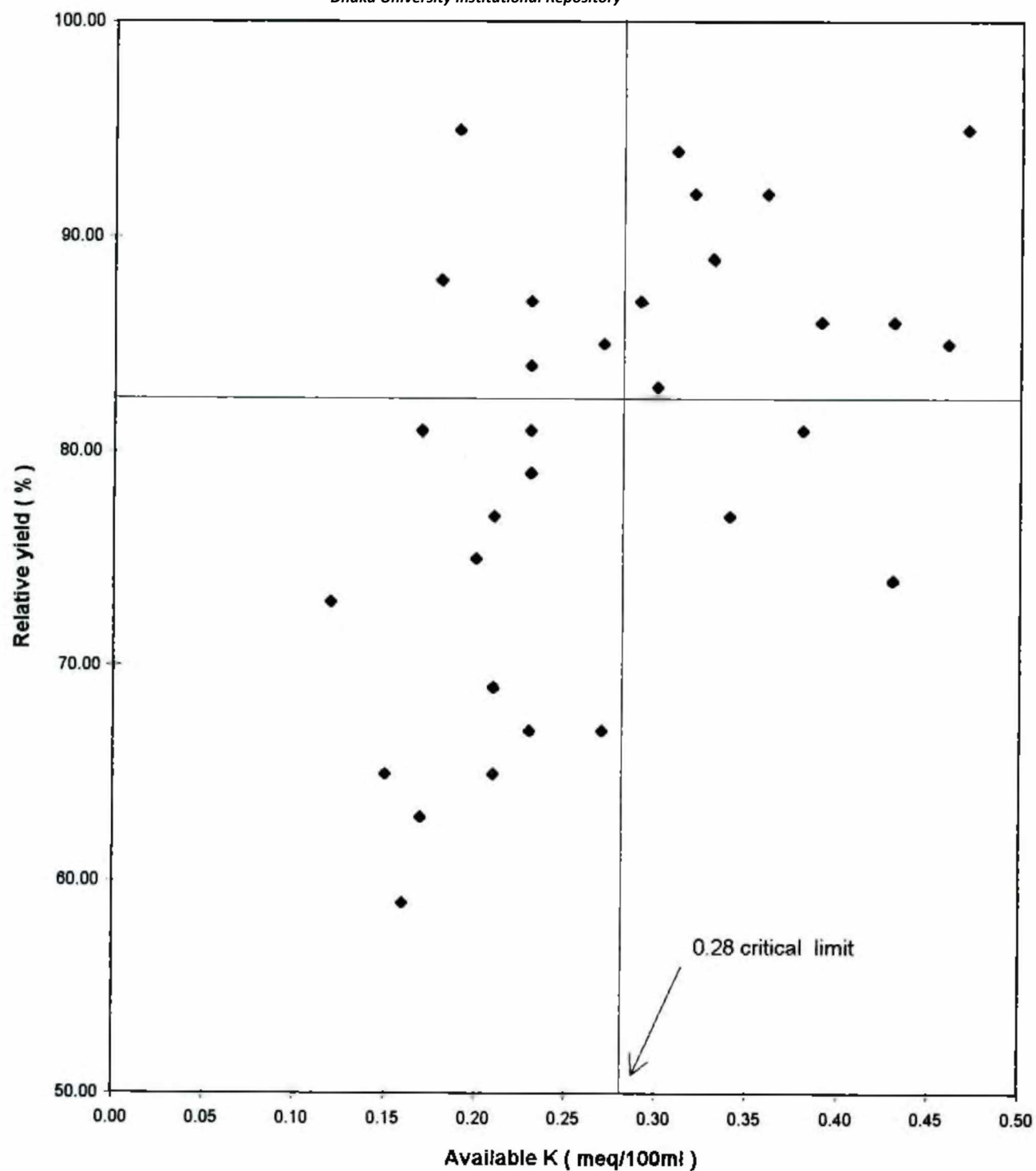


Fig.4.2. Critical limit determination based on the relationship between available K (0.25N NaHCO_3 extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations.

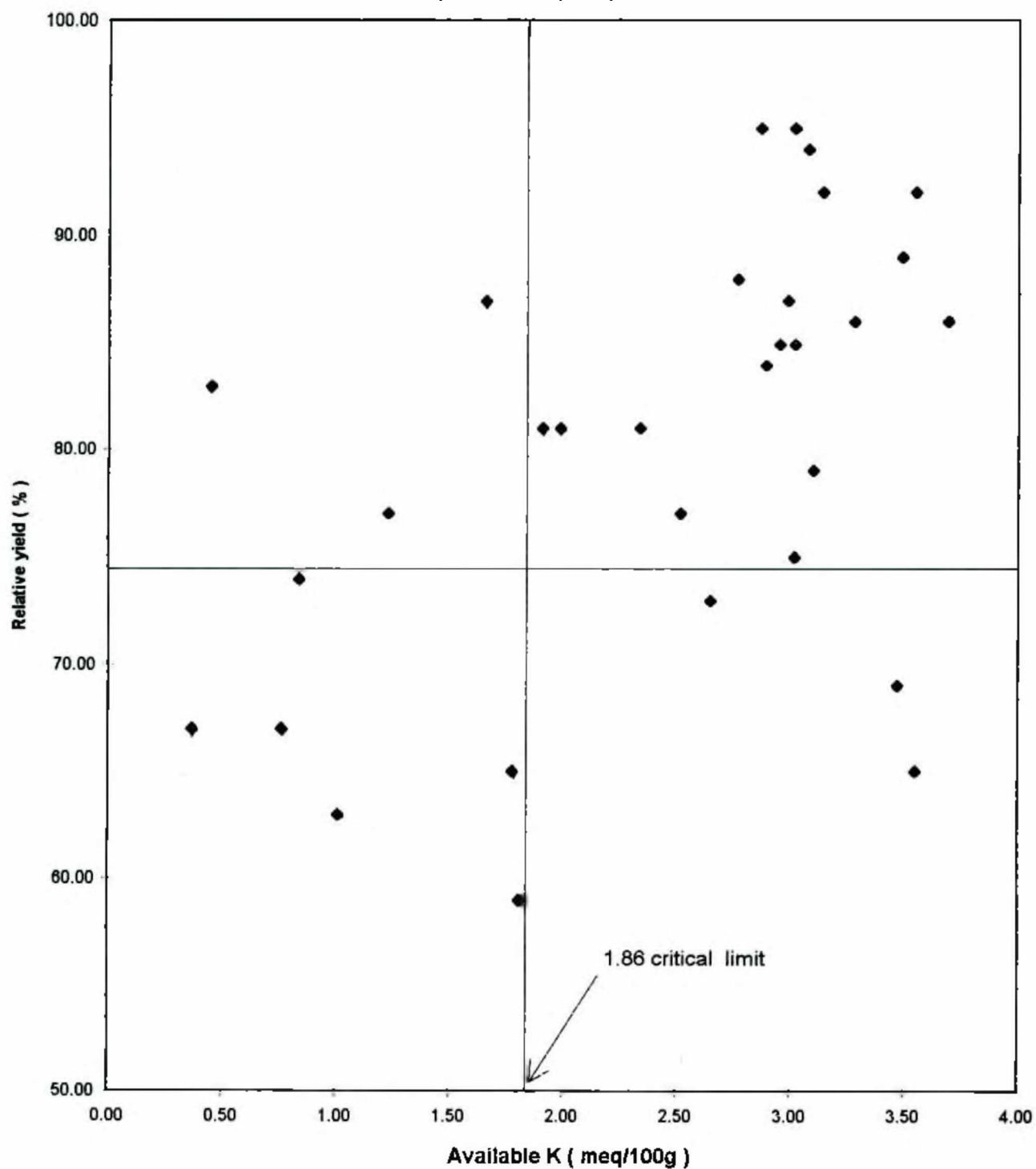


Fig.4.3. Critical limit determination based on the relationship between available K (1 N HNO_3 extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations.

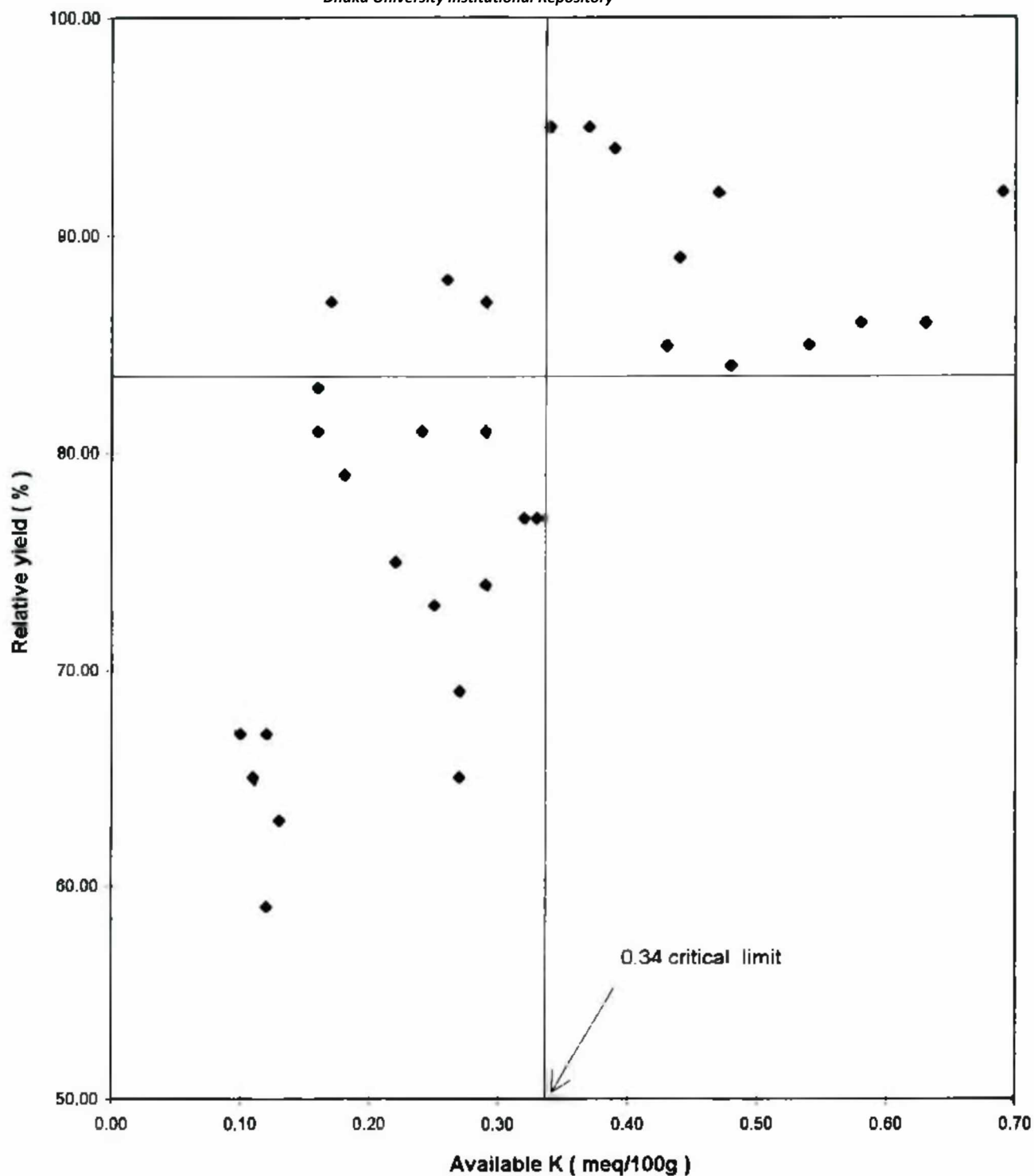


Fig 4.4. Critical limit determination based on the relationship between available K (cold H_2SO_4 extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations.

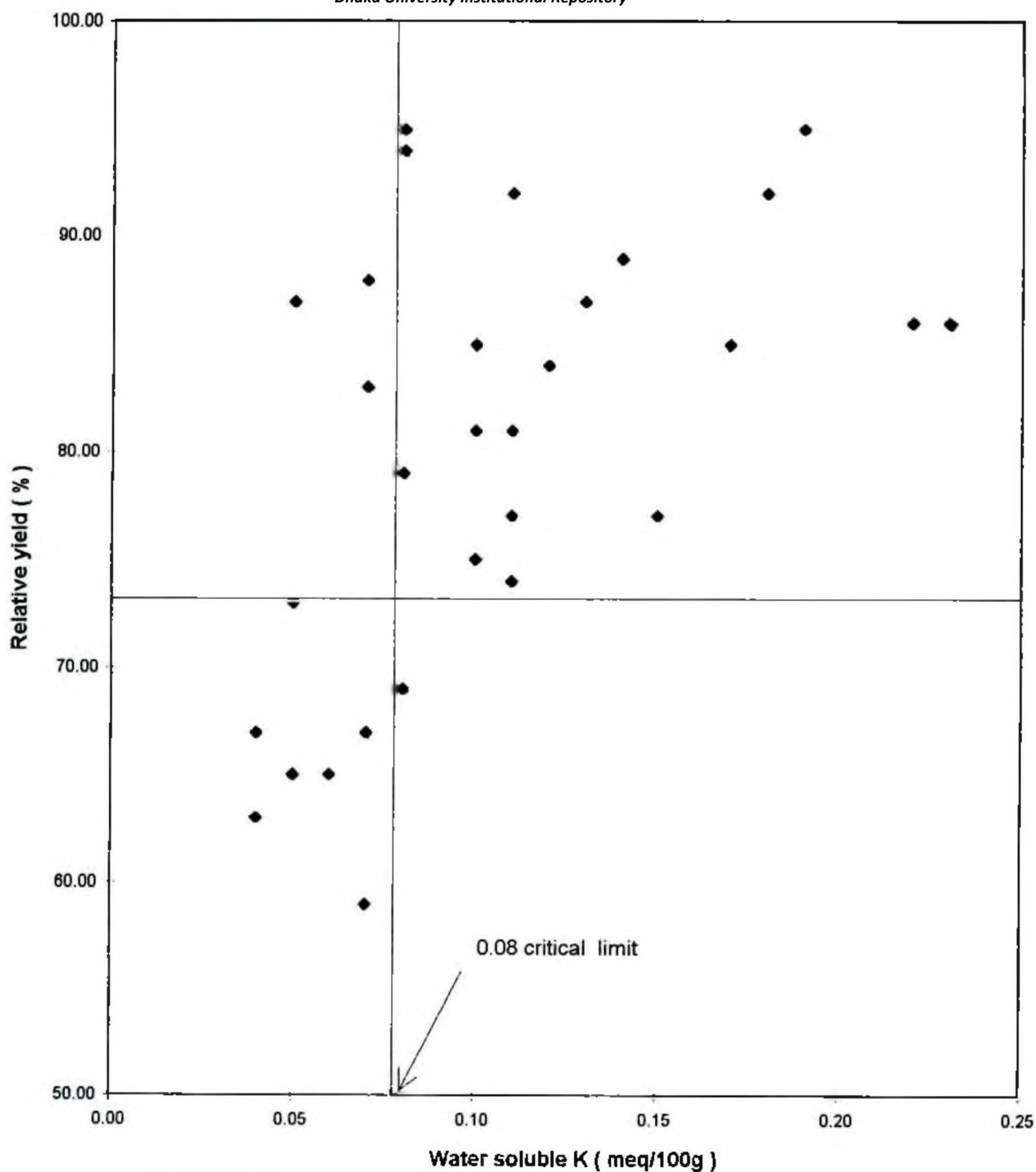


Fig.4.5. Critical limit determination based on the relationship between distilled water soluble K (1:10 soil : water extraction) content of soil and relative dry matter yield of wheat grown in soils of thirty one locations.

Table 4.11. Critical limits of five soil K extractants for wheat as determined by graphical and mathematical procedures.

Soil K extractant	Methods of determining critical limit of K	
	Graphical	Mathematical
1N NH_4OAc	0.13 (meq K/100g soil)	0.13 (meq K/100g soil) (0.12-0.14)*
0.25N NaHCO_3	0.28 (meq K/100 ml soil)	0.28 (meq K/100ml soil) (0.27-0.29)*
1N HNO_3	1.86 (meq K/100g soil)	1.86 (meq K/100g soil) (1.81-1.91)*
Cold H_2SO_4	0.335 (meq K/100g soil) (=0.34)	0.335 (meq K/100g soil) (=0.34) (0.33-0.34)*
Distilled water	0.076 (meq K/100g soil) (=0.08)	0.075 (meq K/100g soil) (=0.08) (0.07-0.08)*

* Indicate the range of K critical limit

Like 1N NH_4OAc extractable K, the results of critical limits for different K extractants are in agreement with several workers. Portch et al. (1984) reported 0.20 meq K/100ml soil as the critical limit of 0.25N NaHCO_3 extractant for upland crops. Mehta et al. (1994), Mazumdar (1987) and Bhuiyan et al. (1992)

384709

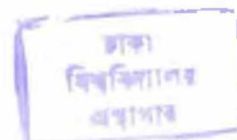


Table 4.12. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (1N NH_4OAc extraction).

Last value of exchangeable soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.08	59	0	81	2638	0.08 & 0.09	0.1476
0.09	65	104	82	2240	0.09 & 0.10	0.2426
0.10	65	104	82	1953	0.10 & 0.11	0.3353
0.11	65	107	83	1711	0.11 & 0.12	0.4125
0.12	68	550	84	1080	0.12 & 0.14	0.4733 <u>2/</u>
0.14	73	1085	85	927	0.14 & 0.18	0.3499
0.18	75	1531	84	822	0.18 & 0.19	0.2397
0.19	75	1632	86	562	0.19 & 0.25	0.2911
0.25	76	1800	86	558	0.25 & 0.27	0.2381
0.27	76	1917	86	557	0.27 & 0.28	0.2006
0.28	76	1923	88	304	0.28 & 0.29	0.2804
0.29	77	2219	87	260	0.29 & 0.30	0.1990
0.30	77	2233	88	220	0.30 & 0.31	0.2074
0.31	77	2233	89	87	0.31 & 0.34	0.2503
0.34	78	2440	89	79	0.34 & 0.35	0.1860
0.35	78	2558	89	79	0.35 & 0.36	0.1479
0.36	79	2601	90	61	0.36 & 0.41	0.1398
0.41	79	2860	88	24	0.41 & 0.42	0.0681
0.42	80	3019	86	0	0.42 & 0.53	0.0245
0.53	80	3058	86	0	0.53 & 0.57	0.0119

1/ $R^2 = \frac{\text{TCSS} - (\text{CSS}^1 + \text{CSS}^2)}{\text{TCSS}}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.12 and 0.14 with an average of 0.13 meq K/100g soil

Table 4.13. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (0.25N NaHCO_3 extraction).

Last value of available soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.12	73	0	80	3044	0.12 & 0.15	0.0164
0.15	69	32	81	2803	0.15 & 0.16	0.0839
0.16	66	99	82	2311	0.16 & 0.17	0.2213
0.17	68	309	82	1952	0.17 & 0.18	0.2694
0.18	72	636	82	1918	0.18 & 0.19	0.1747
0.19	75	1109	82	1744	0.19 & 0.20	0.0781
0.20	75	1109	82	1169	0.20 & 0.21	0.0927
0.21	74	1229	84	1169	0.21 & 0.23	0.2251
0.23	76	1586	85	830	0.23 & 0.27	0.2193
0.27	76	1748	86	486	0.27 & 0.29	0.2781 <u>2/</u>
0.29	76	1873	86	486	0.29 & 0.30	0.2377
0.30	77	1917	86	475	0.30 & 0.31	0.2271
0.31	77	2209	86	412	0.31 & 0.32	0.1531
0.32	78	2414	85	368	0.32 & 0.33	0.1011
0.33	78	2530	85	350	0.33 & 0.34	0.0694
0.34	78	2532	86	286	0.34 & 0.36	0.0894
0.36	79	2709	85	238	0.36 & 0.38	0.0478
0.38	79	2713	85	223	0.38 & 0.39	0.0513
0.39	79	2760	85	222	0.39 & 0.43	0.0365
0.43	79	2833	90	50	0.43 & 0.46	0.0684
0.46	80	2863	95	0	0.46 & 0.47	0.0749

1/ $R^2 = \frac{\text{TCSS} - (\text{CSS}^1 + \text{CSS}^2)}{\text{TCSS}}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.27 and 0.29 with an average of 0.28 meq K/100ml soil.

Table 4.14. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (1N HNO_3 extraction).

Last value of available soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.37	67	0	80	2919	0.37 & 0.45	0.0568
0.45	75	128	80	2913	0.45 & 0.76	0.0174
0.76	72	171	81	2727	0.76 & 0.84	0.0636
0.84	73	173	81	2679	0.84 & 1.01	0.0785
1.01	71	249	82	2338	1.01 & 1.23	0.1641
1.23	72	281	82	2314	1.23 & 1.66	0.1615
1.66	74	478	82	2288	1.66 & 1.78	0.1062
1.78	73	549	83	1994	1.78 & 1.81	0.1783
1.81	71	720	84	1415	1.81 & 1.91	0.3101 <u>2/</u>
1.91	72	804	84	1408	1.91 & 1.99	0.2852
1.99	73	873	84	1401	1.99 & 2.34	0.2652
2.34	74	930	84	1392	2.34 & 2.52	0.2497
2.52	74	940	84	1340	2.52 & 2.65	0.2633
2.65	74	941	85	1203	2.65 & 2.77	0.3072
2.77	75	1126	85	1194	2.77 & 2.87	0.2503
2.87	76	1506	84	1084	2.87 & 2.89	0.1631
2.89	77	1564	84	1084	2.89 & 2.95	0.1444
2.95	77	1631	84	1084	2.95 & 2.99	0.1227
2.99	78	1725	84	1075	2.99 & 3.02	0.0953
3.02	79	2067	84	870	3.02 & 3.08	0.0510
3.08	79	2294	82	748	3.08 & 3.10	0.0171
3.10	79	2295	83	735	3.10 & 3.14	0.0209
3.14	80	2451	81	635	3.14 & 3.28	0.0028
3.28	80	2488	80	607	3.28 & 3.47	0.00001
3.47	80	2605	83	450	3.47 & 3.49	0.0129
3.49	80	2690	81	402	3.49 & 3.55	0.0009
3.55	80	3058	86	0	3.55 & 3.69	0.0119

1/ $R^2 = \frac{\text{TCSS} - (\text{CSS}^1 + \text{CSS}^2)}{\text{TCSS}}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 1.81 and 1.91 with an average of 1.86 meq K/100g soil.

Table 4.15. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (cold H_2SO_4 extraction).

Last value of available soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.10	67	0	80	2919	0.10 & 0.11	0.0568
0.11	66	2	81	2672	0.11 & 0.12	0.1360
0.12	65	43	82	1944	0.12 & 0.13	0.3579
0.13	64	45	83	1556	0.13 & 0.16	0.4727
0.16	69	499	83	1551	0.16 & 0.17	0.3376
0.17	72	774	83	1536	0.17 & 0.18	0.2536
0.18	72	824	83	1519	0.18 & 0.22	0.2429
0.22	73	830	84	1449	0.22 & 0.24	0.2636
0.24	73	895	84	1442	0.24 & 0.25	0.2449
0.25	73	895	84	1322	0.25 & 0.26	0.2863
0.26	74	1093	84	1307	0.26 & 0.27	0.2245
0.27	73	1198	86	644	0.27 & 0.29	0.4048
0.29	75	1412	87	447	0.29 & 0.32	0.3993
0.32	75	1417	88	329	0.32 & 0.33	0.4358
0.33	75	1422	89	189	0.33 & 0.34	0.4794 <u>2/</u>
0.34	76	1807	89	154	0.34 & 0.37	0.3663
0.37	77	2156	88	111	0.37 & 0.39	0.2675
0.39	77	2442	87	72	0.39 & 0.43	0.1877
0.43	78	2496	88	65	0.43 & 0.44	0.1725
0.44	78	2617	88	64	0.44 & 0.47	0.1337
0.47	79	2799	87	39	0.47 & 0.48	0.0830
0.48	79	2825	87	31	0.48 & 0.54	0.0772
0.54	79	2860	88	24	0.54 & 0.58	0.0681
0.58	79	2905	89	18	0.58 & 0.63	0.0555
0.63	80	2947	92	0	0.63 & 0.69	0.0478

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.33 and 0.34 with an average of 0.335 meq K/100g soil.

Table 4.16. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat (distilled water extraction).

Last value of distilled water soluble K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.04	65	8	81	2604	0.04 & 0.05	0.1560
0.05	71	376	82	2233	0.05 & 0.06	0.1570
0.06	70	406	82	1940	0.06 & 0.07	0.2419
0.07	72	1000	84	1070	0.07 & 0.08	0.3311 <u>2/</u>
0.08	75	1921	84	599	0.08 & 0.10	0.1857
0.10	76	2056	85	486	0.10 & 0.11	0.1786
0.11	77	2310	87	208	0.11 & 0.12	0.1864
0.12	78	2354	87	199	0.12 & 0.13	0.1751
0.13	78	2439	87	199	0.13 & 0.14	0.1476
0.14	78	2556	87	195	0.14 & 0.15	0.1111
0.15	78	2558	89	79	0.15 & 0.17	0.1479
0.17	79	2601	90	61	0.17 & 0.18	0.1398
0.18	79	2774	89	54	0.18 & 0.19	0.0862
0.19	80	3019	86	0	0.19 & 0.22	0.0245
0.22	80	3058	86	0	0.22 & 0.23	0.0119

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.07 and 0.08 with an average of 0.075 meq K/100g soil.

determined 0.58 as the critical limit for 1N HNO₃ of wheat, 0.02 for distilled water soluble K of wheat and 1.13 meq K/100g soil for 1N HNO₃ of rice respectively.

It was assumed that the soils rated below the critical limits for wheat plant would respond to K application. Thus, based on the critical limits of all extractants, soils of experimental sites were partitioned into two categories i.e., below the critical limit and above it. With soils below the critical limits, there was an increasing trend of response to potassium application for all extractants (Table 4.17 and Figures 4.6 to 4.10). The response in terms of dry matter yield of wheat ranged from 3.13 to 4.46g pot⁻¹ when potassium was applied from 0 to 60 mg K kg⁻¹ levels. It appeared from the results (Table 4.17) that 26, 58, 29, 65 and 32 per cent of the total soils (thirty one locations) were responded economically for 1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and

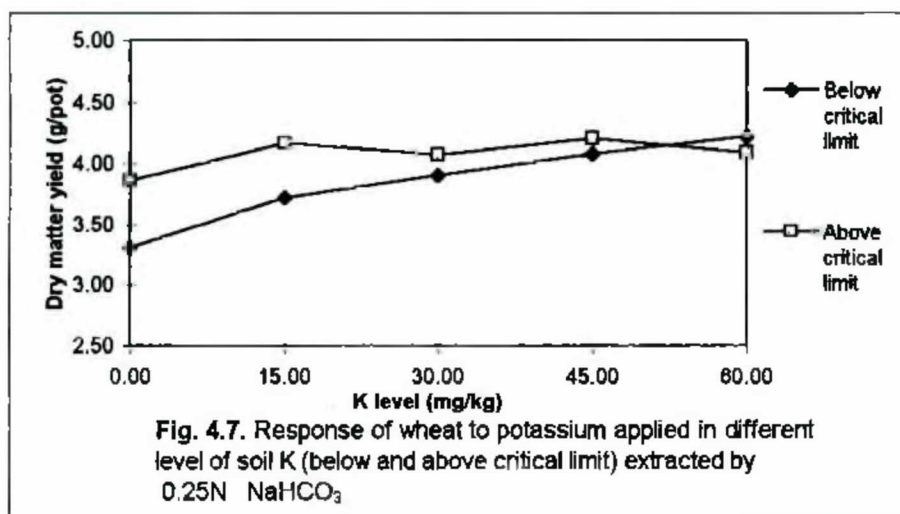
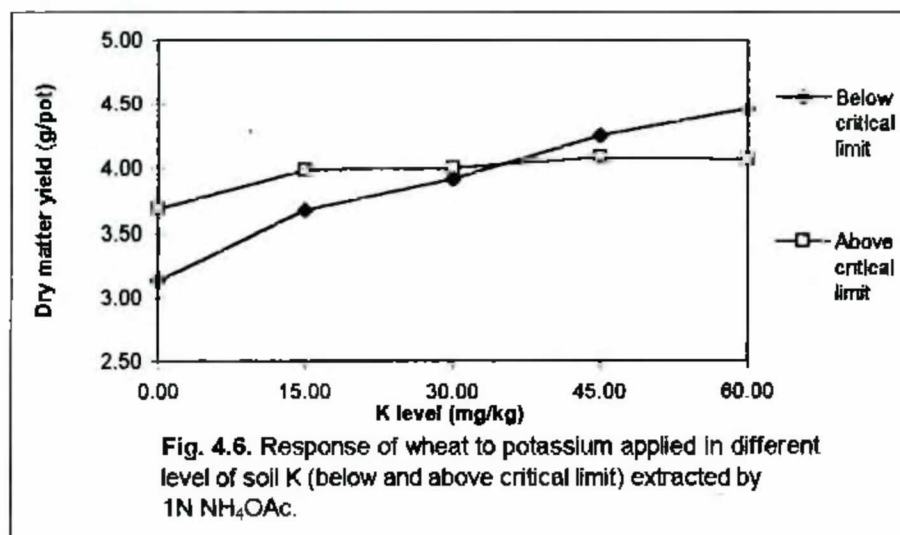
Table 4.17. Response of wheat to potassium applied in different level of soil K (below and above the critical limit) determined by using five extractants.

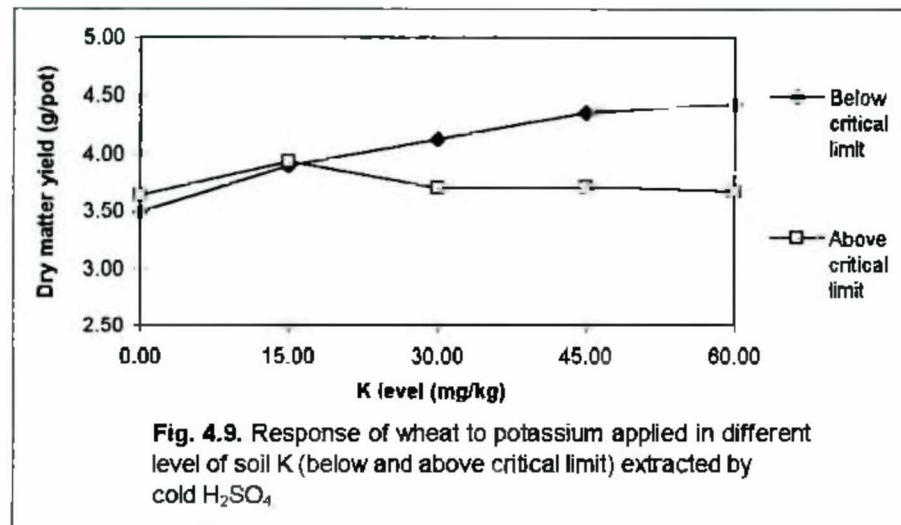
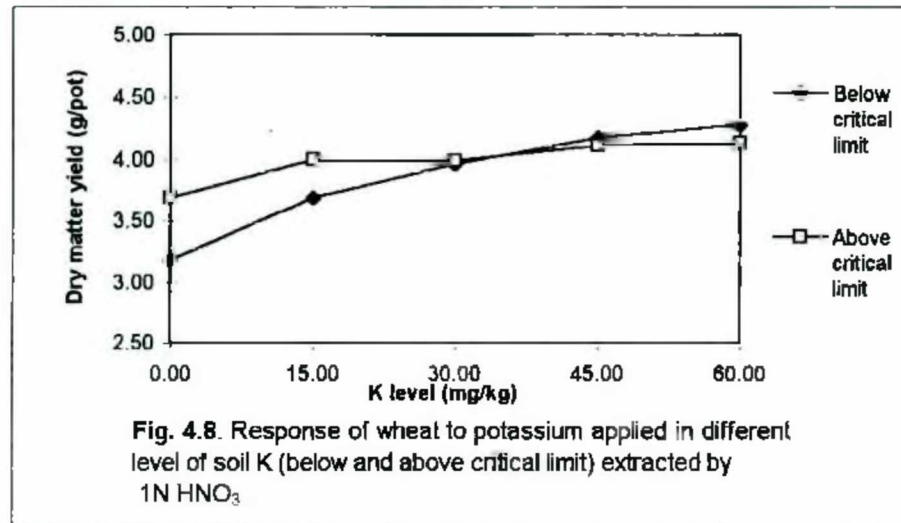
Soil K extractant	Level of K in soil (me %)	Number of soils responded	Average dry matter yield (g pot ⁻¹)				
			K applied (mq K kg ⁻¹)				
			0	15	30	45	60
1N NH ₄ OAc	<0.13 (0.08-0.12) ¹	8 (26)	3.13	3.68	3.92	4.25	4.46
	>0.13 (0.14-0.57) ¹	23 (74)	3.69	3.99	4.00	4.09	4.07
0.25N NaHCO ₃	<0.28 (0.12-0.27) ¹	18 (58)	3.31	3.72	3.91	4.08	4.22
	>0.28 (0.29-0.47) ¹	13 (42)	3.86	4.17	4.07	4.20	4.09
1N HNO ₃	<1.86 (0.37-1.81) ¹	9 (29)	3.18	3.69	3.96	4.17	4.27
	>1.86 (1.91-3.69) ¹	22 (71)	3.69	4.00	3.99	4.11	4.13
Cold H ₂ SO ₄	<0.34 (0.10-0.33) ¹	20 (65)	3.49	3.90	4.13	4.36	4.43
	>0.34 (0.34-0.69) ¹	11 (35)	3.64	3.93	3.70	3.71	3.68
Distilled water	<0.08 (0.04-0.07) ¹	10 (32)	3.24	3.72	3.98	4.23	4.40
	>0.08 (0.08-0.23) ¹	21 (68)	3.68	4.00	4.00	4.08	4.05

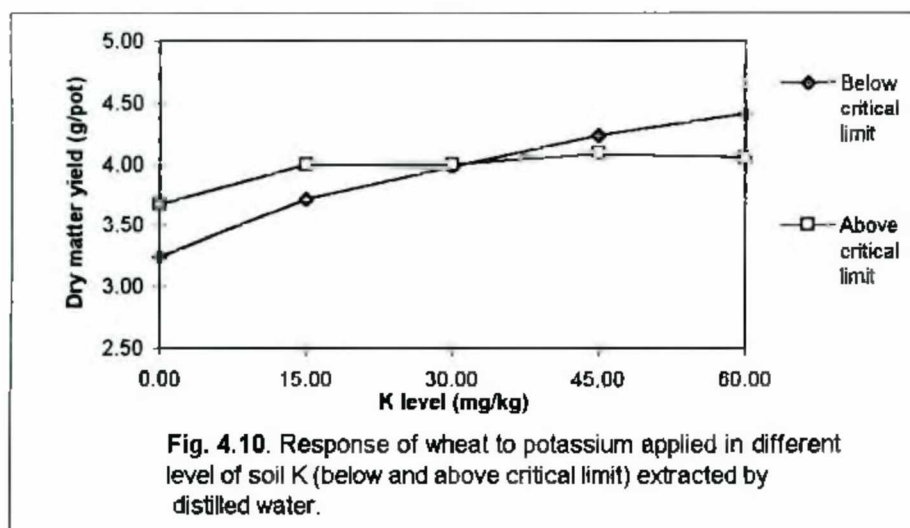
* Figures in parentheses indicate per cent of the total

¹ Range of K (me%) in soil

distilled water soluble K respectively since the level of K of these extractants was rated to be K deficient i.e., below the critical limit. Maximum crop response was obtained from cold H₂SO₄ extractable K followed by 0.25N NaHCO₃ as they covered 65 and 58 per cent of the total soils. On the other hand, soils having potassium content above the critical limits, the increase of the







dry matter yield of wheat was marginal, varying from 3.64 to 4.20 g pot⁻¹ with the application of same amount of potassium in the soil. Due to marginal increase in dry matter yield, no economic response was found beyond this level (Table 4.17 and Figures 4.6 to 4.10).

From the present results it can be concluded that wheat plant would not respond economically to potassium application in these soils if 1N NH₄OAc K, 0.25N NaHCO₃ K, 1N HNO₃ K, cold H₂SO₄ K and distilled water soluble K are remain above 0.13, 0.28 (meq K/100ml soil), 1.86, 0.34 and 0.08 meq K/100g soil respectively. These values (critical limits) can be effectively used to separate K

responsive soils from the non-responsive ones and be of great help in the development rational K fertilization programme for wheat cultivation.

4.6.5 Critical limit of potassium determined from K concentration in wheat plant

To determine the critical limit of potassium from K concentration in wheat, a scatter graphical method and mathematical procedure of Cate and Nelson (1965 and 1971) were followed using the total K concentration of wheat (K_o) for thirty one locations. The results on K concentration of wheat are presented in Table 4.9. In the scatter graphical method, plotting of total K (K_o pot) extracted by 1N HCl was done against the per cent relative yield of wheat (Figure 4.11). The critical limit of 1N HCl extractable K for wheat was found to be 4.02% by graphical method (Figure 4.11) indicating that below this level of K concentration an economic response of wheat is highly expected. It may assumed from the present results that wheat plant was non-responsive to K as the per cent relative dry matter yield was more than 75 (Figure 4.11).

The critical limit obtained by scatter graphical method was further tested by mathematical procedure of Cate and Nelson (1971) to avoid human bias. Using the mathematical procedure, the calculation of coefficient of determination (R^2) and critical limit for best two population split using the two mean discontinuous model was done for the K concentration (at K_o pot) and per cent

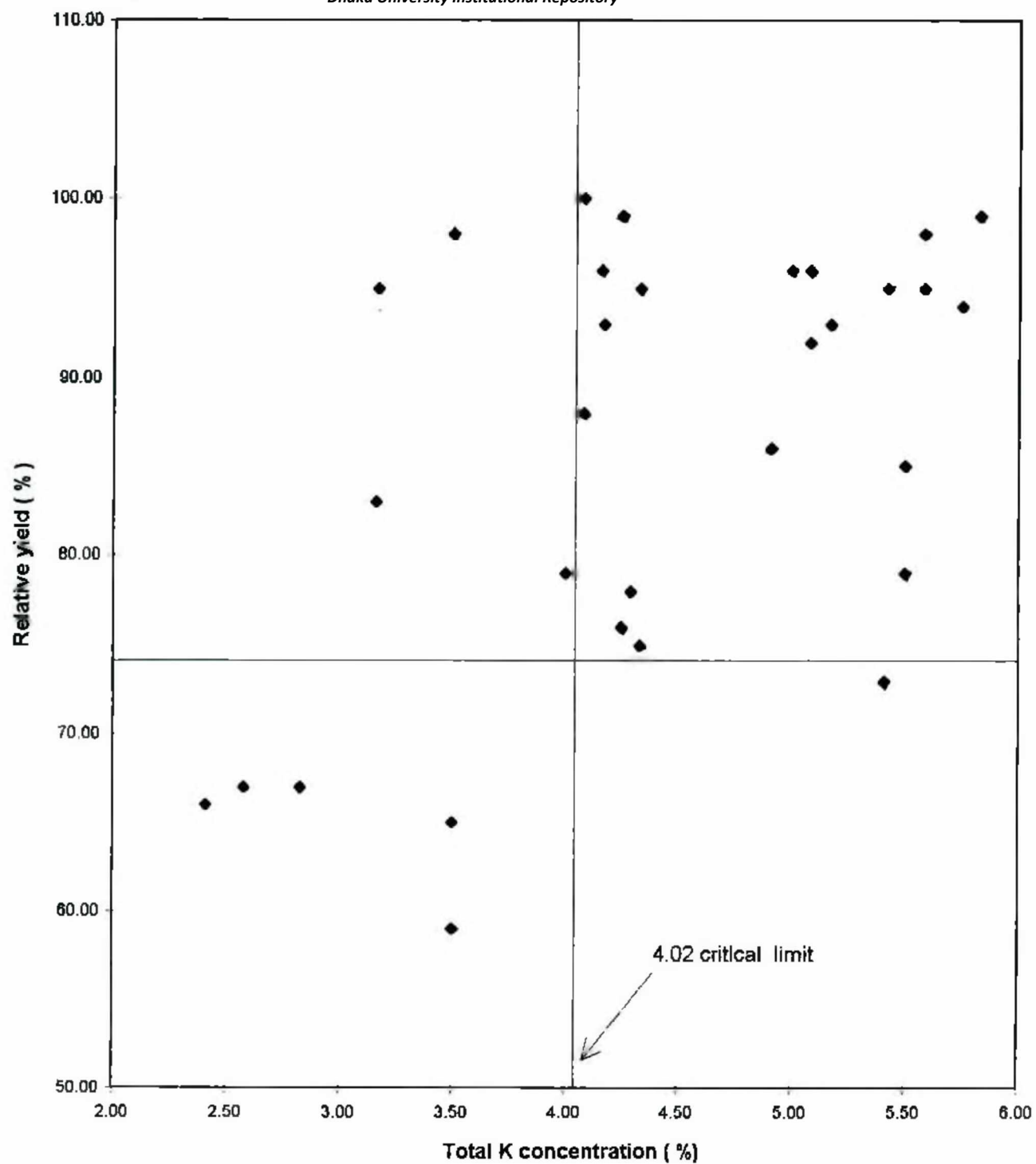


Fig. 4.11. Critical limit determination based on the relationship between total K (1 N HCl extraction) concentration in plant & relative dry matter yield of wheat grown in soils of thirty one locations.

Table 4.18. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for wheat plant (1N HCl extraction).

Last value of K conc. (%) included in population 1	Population 1		Population 2		Postulated critical limit* between values	R^2 for postulated critical limit 1/
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
2.41	66	0	86	4095	2.41 & 2.58	.0901
2.58	67	0.5	87	3703	2.58 & 2.83	.1771
2.83	67	0.67	88	3283	2.83 & 3.16	.2704
3.16	71	201	88	3259	3.16 & 3.17	.2312
3.17	76	671	88	3209	3.17 & 3.50	.1379
3.50	75	1558	90	1684	3.50 & 4.00	.2796
4.00	75	1572	90	1567	4.00 & 4.08	.3025 2/
4.08	79	2208	90	1461	4.08 & 4.16	.1848
4.16	80	2478	89	1418	4.16 & 4.17	.1343
4.17	81	2628	89	1404	4.17 & 4.25	.1041
4.25	82	2961	89	1133	4.25 & 4.29	.0903
4.29	82	2976	90	997	4.29 & 4.33	.1172
4.33	82	3195	91	738	4.33 & 4.91	.1261
4.91	82	3208	91	712	4.91 & 5.00	.1290
5.00	83	3385	91	688	5.00 & 5.08	.0950
5.08	84	3611	90	655	5.08 & 5.17	.0521
5.17	84	3688	90	646	5.17 & 5.41	.0370
5.41	84	3813	92	325	5.41 & 5.42	.0806
5.42	84	3930	92	315	5.42 & 5.50	.0568
5.50	84	3959	97	17	5.50 & 5.58	.1166
5.58	85	4244	97	13	5.58 & 5.75	.0541
5.75	85	4321	99	0	5.75 & 5.83	.0399

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 4.00 and 4.08 with an average of 4.04 %.

relative yield of wheat. This two mean discontinuous model provided a critical limit between 4.00 and 4.08% (Table 4.18) and as such 4.04% could be considered as the critical K concentration of wheat plant for thirty one locations. Similar critical K concentration (3.3 to 4.1%) in wheat plant was observed by Roy et al. (1989) while Beaton et al. (1985) obtained 6.0%.

The critical K concentration values obtained by following graphical and mathematical procedures are as follows:

Graphical	4.02%
Mathematical	4.04%

These values could be considered to separate K deficient plants from the adequate ones.

4.6.6 Efficiency of applied potassium for the dry matter yield of wheat

In order to test the reliability of critical limit, the efficiency of applied potassium was evaluated considering the level of K in soil and different extractants. Non-K added pot (Ko) served as check for comparison. The efficiency of applied potassium by wheat plant in presence of NPS fertilizers in soils of thirty one locations under study was compared on the basis of the dry matter yield increase over the control (Ko) for each mg of applied K (Table 4.19). It is evident from the results that K application at the rate of 15 mg K kg⁻¹ produced 27.33 to 36.67 mg dry matter of wheat by each mg of applied K in soils having K values below the

critical limit. But the soils having K values above the critical limit, produced low dry matter yield as compared to deficient soils and ranging from 19.33 to 21.33 mg by each mg of applied K for all the five K extractants.

Data presented in Table 4.19 revealed that the dry matter yield decreased with the increase in K levels (30 to 60 mg K kg⁻¹) in soils having K values below and above the critical limit of all K extractants. This trend of fertilizer K use efficiency was found similar for all the extractants used in this study. Results showed that the fertilizer K use efficiency by wheat plant was maximum in plants of low K soils (soils value below the critical limit) and minimum in soils that had K values above the critical limit. It is assumed from the present results the increasing the levels of applied K resulted in low K utilization and hence, fertilizer K use efficiency decreased. From this study, it is advisable to apply K fertilizer to wheat only when the soils value remain below the critical limit.

Table 4.19. Efficiency of applied potassium for the dry matter yield of wheat.

Soil K extractant	Level of K in soil (me %)	Number of soils responded	K fertilizer use efficiency (mg yield mg K ⁻¹)				
			K applied (mg K kg ⁻¹)				
			0	15	30	45	60
1N NH ₄ OAc	<0.13 (0.08-0.12)	8	-	36.67	26.33	24.89	22.17
	>0.13 (0.14-0.57)	23	-	20.00	10.33	8.89	6.33
0.25N NaHCO ₃	<0.28 (0.12-0.27)	18	-	27.33	20.00	17.11	15.17
	>0.28 (0.29-0.47)	13	-	20.67	7.00	7.56	3.83
1N HNO ₃	<1.86 (0.37-1.81)	9	-	34.00	26.00	22.00	18.17
	>1.86 (1.91-3.69)	22	-	20.67	10.00	9.33	7.33
Cold H ₂ SO ₄	<0.34 (0.10-0.33)	20	-	27.33	21.33	19.33	15.67
	>0.34 (0.34-0.69)	11	-	19.33	2.00	1.56	0.67
Distilled water	<0.08 (0.04-0.07)	10	-	32.00	24.67	22.00	19.33
	>0.08 (0.08-0.23)	21	-	21.33	10.00	8.89	6.17

4.7 Critical limit of potassium in soil and plant and the response of potato to applied potash in soils of thirty one locations

4.7.1 Effect of K application on the dry matter yield, per cent relative yield, per cent K concentration in plant and K uptake of potato

The results of dry matter yield (threshold and plateau yield) and percent relative yield (dry matter basis) of potato with the extractable K values of all extractants are presented in Table 4.20. Per cent K concentration (K_o) and K uptake (K_o) with the dry matter yield of potato obtained from without and with added potassium of thirty one locations are presented in Table 4.21.

Table 4.20 indicated that the level of exchangeable as well as available and water soluble potassium in the soils used in pot culture experiment as determined by different extractants varied widely. With the variation in soil fertility, marked variation were also recorded for the threshold yield (4.70 to 10.25g pot⁻¹), plateau yield (5.97 to 14.21g pot⁻¹) and per cent relative yield at optimum K level (50 to 93%) of potato. It was also observed that the dry matter yield of potato increased with increasing the level of K up to 50 to 75 mg K kg⁻¹ in most of the soils under study (Table 4.21). The per cent K concentration (K_o) was varied with the variation of initial soil K fertility in thirty one locations. The range of K concentration of potato plant at K_o pot was from 3.08 to 11.08%. These results were similar to those findings (< 4.5 to > 7.0%) reported by Chapman (1967). Rao et al. (1989) found < 2.8 to 12.8% K concentration in the leaf blades and petioles of

Table 4.20. Quantity of potassium extracted by different extractants, dry matter yield and per cent relative yield of potato grown in soils of thirty one locations.

Location No.	Quantity of K (me %) extracted by					Dry matter yield (g pot ⁻¹)		Relative yield (%)
	1N NH ₄ OAc	0.25N NaHCO ₃	1N HNO ₃ (boiling)	Cold H ₂ SO ₄	Distilled water	Threshold yield	Plateau yield	
1.	0.12	0.23	0.76	0.12	0.07	7.15	9.80	73
2.	0.08	0.16	1.81	0.12	0.07	5.40	6.41	84
3.	0.28	0.43	0.84	0.29	0.11	5.60	11.30	50
4.	0.14	0.23	3.10	0.18	0.08	4.70	7.40	64
5.	0.14	0.23	1.99	0.16	0.11	5.60	9.15	61
6.	0.53	0.39	3.28	0.63	0.22	7.87	8.78	90
7.	0.57	0.43	3.69	0.58	0.23	7.43	8.50	87
8.	0.29	0.31	3.08	0.39	0.08	7.47	9.10	82
9.	0.35	0.33	3.49	0.44	0.14	10.25	14.21	72
10.	0.14	0.20	3.02	0.22	0.10	7.73	10.00	77
11.	0.14	0.17	2.34	0.24	0.10	7.66	9.81	78
12.	0.09	0.12	2.65	0.25	0.05	7.75	9.25	84
13.	0.28	0.21	2.52	0.32	0.15	6.39	7.53	85
14.	0.30	0.38	1.91	0.29	0.10	6.29	7.01	90
15.	0.12	0.21	3.55	0.27	0.06	6.22	8.19	76
16.	0.19	0.21	3.47	0.27	0.08	6.01	7.63	79
17.	0.10	0.15	1.78	0.11	0.05	5.40	7.70	70
18.	0.14	0.23	1.66	0.17	0.05	5.27	6.38	83
19.	0.09	0.17	1.01	0.13	0.04	6.30	8.11	78
20.	0.31	0.34	1.23	0.33	0.11	6.90	8.60	80
21.	0.19	0.30	0.45	0.16	0.07	5.56	9.79	57
22.	0.25	0.23	2.89	0.48	0.12	8.59	11.99	72
23.	0.12	0.18	2.77	0.26	0.07	5.02	5.97	84
24.	0.42	0.36	3.55	0.69	0.18	6.40	6.86	93
25.	0.18	0.19	2.87	0.37	0.08	6.24	7.31	85
26.	0.34	0.32	3.14	0.47	0.11	8.13	8.75	93
27.	0.11	0.27	0.37	0.10	0.04	6.28	7.60	83
28.	0.25	0.27	2.95	0.43	0.10	7.30	7.88	93
29.	0.27	0.29	2.99	0.29	0.13	10.08	11.50	88
30.	0.41	0.47	3.02	0.34	0.19	7.19	9.16	79
31.	0.36	0.46	3.02	0.54	0.17	7.37	8.62	86

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamorgram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

Table 4.21. Effect of K application on the dry matter yield, per cent relative yield, K concentration and K uptake of potato.

Location No.	Dry matter yield (q pot ⁻¹)					Relative yield (%)	% K Conc. at K ₀	Potassium uptake (mg pot ⁻¹)				
	K applied (mg K kg ⁻¹)							K applied (mg K kg ⁻¹)				
	0	25	50	75	100			0	25	50	75	100
1.	7.15c	7.53c	8.77b	9.80a	7.79c	73	5.08	363	477	607	596	383
2.	5.40b	6.14ab	6.14ab	5.97ab	6.41a	84	3.67	198	322	322	309	379
3.	5.60c	5.67c	7.40b	7.77b	11.30a	50	6.42	360	387	542	589	848
4.	4.70d	6.30b	7.40a	5.65c	5.60c	64	6.25	294	478	568	447	542
5.	5.60c	7.70b	9.15a	8.00b	8.00b	61	8.67	486	783	968	894	886
6.	7.87a	7.92a	8.78a	7.58a	7.70a	90	11.00	866	944	1170	1055	1110
7.	7.43bc	8.50a	7.88ab	7.66bc	7.03c	87	8.66	643	842	801	817	738
8.	7.47c	7.67c	8.21b	9.10a	8.36b	82	7.75	579	773	766	849	738
9.	10.25b	13.16a	14.21a	13.90a	14.20a	72	10.00	1025	1513	1658	1761	1799
10.	7.73b	8.50b	10.00a	9.90a	9.50a	77	5.17	400	567	708	660	475
11.	7.66b	9.81a	9.39a	8.82ab	8.45ab	78	4.58	351	523	540	654	556
12.	7.75e	8.21c	9.25a	7.99d	8.52b	84	7.58	587	725	863	779	696
13.	6.39b	6.77ab	7.53a	6.72ab	7.38a	85	6.67	426	598	552	538	541
14.	6.29a	6.55a	7.01a	6.84a	7.05a	90	10.66	671	726	946	855	905
15.	6.22b	8.19a	7.69a	7.82a	7.62a	76	7.42	462	641	763	691	667
16.	6.01c	6.33b	7.63a	6.84b	6.12c	79	6.67	401	591	763	667	592
17.	5.40b	6.08b	7.18a	7.60a	7.70a	70	5.91	319	410	526	621	635
18.	5.27b	5.99ab	6.13a	6.11a	6.38a	83	4.08	215	325	357	377	447
19.	6.30c	7.08b	7.16b	7.60ab	8.11a	78	6.17	389	466	531	646	764
20.	6.90b	7.13b	8.17a	8.60a	8.57a	80	5.50	380	463	578	609	614
21.	5.56a	7.62d	7.99c	9.79a	9.22b	57	8.25	459	806	979	1166	1083
22.	8.59c	9.46c	10.00b	10.90ab	11.99a	72	8.16	456	1017	1116	1262	1428
23.	5.02c	5.65b	5.70ab	5.97a	5.66b	84	5.33	268	367	371	433	340
24.	6.40b	6.43b	6.52b	6.53b	6.86a	93	10.42	667	756	788	795	903
25.	6.24b	7.31a	6.89a	7.14a	7.26a	85	4.92	307	488	373	369	351
26.	8.13a	8.07a	8.75a	8.75a	8.36a	93	6.92	563	565	766	737	717
27.	6.28bc	6.03c	6.15c	7.02ab	7.60a	83	3.08	193	297	323	427	500
28.	7.30ab	7.88a	7.03b	7.22b	7.34ab	93	7.75	566	690	562	570	606
29.	10.08c	10.08c	10.30bc	10.66b	11.50a	88	6.50	655	756	773	800	978
30.	7.19c	8.64ab	9.16a	8.47b	8.17b	79	11.08	797	1044	1152	1228	1144
31.	7.37c	7.91b	7.76b	8.62a	8.53a	86	10.58	780	890	886	1020	960

In a column, means followed by a common letter are not significantly different at 5% level.

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamorgram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

potato plant harvested at 37 days of emergence. Similarly, Roberts et al. (1985) provided critical K range as 6.5 to 11.00% since the potato crop harvested at 45 days of emergence.

K uptake of potato plant (at 42 days of harvesting) increased with increasing levels of K up to 50 to 75 mg K kg⁻¹ levels and it ranged from 193 to 1761 mg pot⁻¹ (Table 4.21). The highest K uptake of potato plant observed with the highest K application particularly in soils with low to medium initial K content. This might be due to differences in K concentration of the plant itself, which enhance to increase the level of K through addition with initial available K in soil. This could be contributing factor to the yield as well as uptake of potato.

4.7.2 K concentration in potato plant and per cent relative yield

The concentration of K and per cent relative yield of potato are shown in Table 4.22. The concentration of K in the K control treatment of potato plant ranged from 3.08 to 11.08% (per cent in dry matter). The higher K concentration was recorded ($\geq 10.00\%$) in Monoharpur, Dadpur, Nazirpur, Benarpota, Nadmollah and West Jhalakathi. This higher K concentration in potato plant might be due to higher initial K fertility of the soil. All locations that contained higher K concentrations were included under the parent material ganges alluvium except Nazirpur which belonged to Modhupur clay.

Table 4.22. Dry matter yield, K concentration in plant (1N HCl extraction) at different levels of applied K and per cent relative yield of potato.

Location No.	Dry matter yield (g pot ⁻¹)					K concentration (% in dry matter)					Relative yield (%)
	K applied (mg K kg ⁻¹)					K applied (mg K kg ⁻¹)					
	0	25	50	75	100	0	25	50	75	100	
1.	7.15	7.53	8.77	9.80	7.79	5.08d	6.33b	6.92a	6.08c	4.92e	82
2.	5.40	6.14	6.14	5.97	6.41	3.67b	5.25a	5.25a	5.17a	5.92a	84
3.	5.60	5.67	7.40	7.77	11.30	6.42e	6.83d	7.33c	7.58a	7.50b	72
4.	4.70	6.30	7.40	5.65	5.60	6.25e	7.58d	7.67c	7.92b	9.67a	84
5.	5.60	7.70	9.15	8.00	8.00	8.57e	10.17d	10.58c	11.17a	11.08b	70
6.	7.87	7.92	8.78	7.58	7.70	11.00e	11.92d	13.33c	13.92b	14.42a	102
7.	7.43	8.50	7.88	7.66	7.03	8.66e	9.91d	10.16c	10.66a	10.50b	97
8.	7.47	7.67	8.21	9.10	8.36	7.75d	10.08a	9.33b	9.33b	8.83c	97
9.	10.25	13.16	14.21	13.90	14.20	10.00d	11.50c	11.67b	12.67a	12.67a	74
10.	7.73	8.50	10.00	9.90	9.50	5.17c	6.67b	7.08a	6.67b	5.00d	77
11.	7.66	9.81	9.39	8.82	8.45	4.58e	5.33d	5.75c	7.42a	6.58b	87
12.	7.75	8.21	9.25	7.99	8.52	7.58e	8.83c	9.33b	9.75a	8.17d	97
13.	6.39	6.77	7.53	6.72	7.38	6.67d	8.83a	7.33c	8.00b	7.33c	94
14.	6.29	6.55	7.01	6.84	7.05	10.66e	11.08d	13.50a	12.50c	12.83b	90
15.	6.22	8.19	7.69	7.82	7.62	7.42e	7.83d	9.92a	8.83b	8.75c	81
16.	6.01	6.33	7.63	6.84	6.12	6.67e	9.33d	10.00a	9.75b	9.67c	79
17.	5.40	6.08	7.18	7.60	7.70	5.91e	6.75d	7.33c	8.17b	8.25a	70
18.	5.27	5.99	6.13	6.11	6.38	4.08e	5.42d	5.83c	6.17b	7.00a	83
19.	6.30	7.08	7.16	7.60	8.11	6.17d	6.58d	7.42c	8.50b	9.42a	78
20.	6.90	7.13	8.17	8.60	8.57	5.50d	6.50c	7.08b	7.08b	7.17a	81
21.	5.56	7.62	7.99	9.79	9.22	8.25e	10.58d	12.25a	11.91b	11.75c	70
22.	8.59	9.46	10.00	10.90	11.99	8.16e	10.75d	11.16c	11.58b	11.91a	72
23.	5.02	5.65	5.70	5.97	5.66	5.33d	6.50b	6.50b	7.25a	6.00c	84
24.	6.40	6.43	6.52	6.53	6.86	10.42e	11.75d	12.08c	12.17b	13.17a	93
25.	6.24	7.31	6.89	7.14	7.26	4.92d	6.67a	5.42b	5.17c	4.83e	85
26.	8.13	8.07	8.75	8.75	8.36	6.92e	7.00d	8.75a	8.42c	8.58b	92
27.	6.28	6.03	6.15	7.02	7.60	3.08e	4.92d	5.25c	6.08b	6.58a	83
28.	7.30	7.88	7.03	7.22	7.34	7.75e	8.75a	8.00c	7.90d	8.25b	93
29.	10.08	10.08	10.30	10.66	11.50	6.50c	7.50b	7.50b	7.50b	8.50a	88
30.	7.19	8.64	9.16	8.47	8.17	11.08e	12.08d	12.58c	14.50a	14.00b	85
31.	7.37	7.91	7.76	8.62	8.53	10.58d	11.25c	11.42b	11.83a	11.25c	85

In a column, means followed by a common letter are not significantly different at 5% level.

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahr, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamorgam, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

Added K had marked influence on the increase of K concentration in potato plant. K concentration increased with increasing the K application up to 50 to 75 mg K kg⁻¹ level. The range of K was found to be in between 3.08 to 14.50% for all treatments of all locations under study. According to Rao et al. (1989) the K concentration in the petioles of potato plant was < 3.2 to 17.2% when the plant harvested at 37 days of emergence, while Chapman (1967) and Roberts et al. (1985) reported < 7.0 to 9.0% and 6.5 to 11.0% respectively.

Considering K concentration in potato plant, per cent relative yield was determined from the corresponding dry matter yield of potato and it was ranged from 70 to 102% (Table 4.22).

4.7.3 Correlation coefficient between soil K values of five extractants and various plant parameters of potato

Correlation coefficient of the soil K values of five extractants (1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled water) with different plant parameters (threshold yield, plateau yield, per cent relative yield, per cent K concentration (K_o) and K uptake at K_o) of potato are presented in Table 4.23. Results revealed that the threshold yield, per cent relative yield, per cent K concentration (K_o) and K uptake (K_o) of potato had significantly positive relationship with all K extractants except threshold yield and per cent relative yield. These two parameters of potato did not show any significant relationship but manifested

positive relationship with 0.25N NaHCO_3 extractant. Per cent relative yield of potato showed positive but insignificant relationship with distilled water soluble K. Panda et al. (1993) found significant and positive correlation of 1N HNO_3 extractable K with the dry matter yield, per cent relative yield and K uptake of rice. In the present study, similar findings were observed with the extractable K of 1N HNO_3 . Kumar et al. (1991) observed significantly positive correlation of different K extractants (distilled water, 1N NH_4OAc and 1N HNO_3) with per cent relative yield, per cent K concentration (K_o) and K uptake of wheat. Table 4.23 also indicated that none of the extractants had significant correlation with the plateau yield of potato. Among all extractants 1N NH_4OAc extractable K showed the highest degree of correlation with the K uptake (K_o) ($r = 0.739$ **) followed by per cent K concentration (K_o) ($r = 0.709$ **) of potato. The correlation coefficient values of per cent K concentration (K_o) and K uptake (K_o) of potato with the extractable K of different extractants was found in the following order: 1N NH_4OAc > distilled water > cold H_2SO_4 > 0.25N NaHCO_3 > 1N HNO_3 . This might be due to the presence of plenty of exchangeable K in the soil, thus, plants could absorb the nutrient in a more efficient manner. Islam et al. (1994) suggested that neutral ammonium acetate extractant is suitable for exchangeable K determination in soils of Bangladesh because of significant crop response.

Table 4.23. Correlation coefficient (r) between soil potassium values of different extractants with various plant parameters of potato.

Plant parameter	K extractant				
	1N NH_4OAc	0.25N NaHCO_3	1N HNO_3 (boiling)	Cold H_2SO_4	Distilled water
Threshold dry matter yield (K control yield)	0.431 *	0.247 NS	0.400 *	0.467 **	0.419 *
Plateau dry matter yield (Maximum yield)	0.207 NS	0.224 NS	0.056 NS	0.153 NS	0.229 NS
Relative dry matter yield (%)	0.337 *	0.079 NS	0.441 **	0.474 **	0.273 NS
K concentration (%) at K_0	0.709 **	0.658 **	0.461 **	0.666 **	0.686 **
K uptake at K_0	0.739 **	0.631 **	0.528 **	0.687 **	0.704 **

** = Significant at 1% level, * = Significant at 5% level,
NS = Not significant.

From the simple correlation, it could be inferred that the 1N NH_4OAc extractable K was more related to the K uptake (K_0) as evidenced by higher r values ($r = 0.739$ **) followed by per cent K concentration (K_0) ($r = 0.709$ **). Krishnakumari et al. (1989) reported similar higher degree of correlation of 1N NH_4OAc extractable K with K uptake by wheat plant.

4.7.4 Critical limit of soil potassium for potato

The critical limits of exchangeable, available and water soluble K for potato were determined adopting following scatter diagram technique and mathematical procedures of Cate and Nelson (1965 and 1971). The scatter diagram technique of Cate and Nelson (1965) was employed for the determination of critical limits of K by drawing extractable K of five extractants (1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water) versus per cent relative yield (dry matter basis) of potato (Table 4.20 and Figures 4.12 to 4.16). Using the scatter diagram technique of Cate and Nelson (1965), the values of 0.29, 0.24 (meq K/100ml soil), 0.90, 0.30 and 0.14 meq K/100g soil were found to be the critical limits of K by 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water extractants respectively (Table 4.24). A soil was considered as non-responsive to K where the per cent relative dry matter yield of potato was more than 85, 85, 75, 84 and 86 for 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water extractions respectively (Figures 4.12 to 4.16).

The most commonly used scatter diagram technique of Cate and Nelson (1965) suffers from human bias in drawing partition line particularly, the one parallel to Y-axis. To overcome the error of scatter diagram technique, the data were also subjected to analyse through mathematical procedure of Cate and Nelson (1971) for the determination of critical limits of K. In this procedure,

coefficient of determination (R^2) and critical limit for best two population split (crop categories I and II) was calculated for the soils with the same K extractants as used in the scatter diagram procedure (Tables 4.25 to 4.29). The best two population split in the mathematical procedure provided a critical limit between 0.28 and 0.29 meq K/100g soil for 1N NH_4OAc , 0.23 and 0.27 meq K/100ml soil for 0.25N NaHCO_3 , 0.84 and 1.01 meq K/100g soil for 1N HNO_3 , 0.29 and 0.32 meq K/100g soil for cold H_2SO_4 and 0.14 and 0.15 meq K/100g soil for distilled water soluble K (Tables 4.25 to 4.29). Therefore, 0.29, 0.25 (meq K/100ml soil), 0.93, 0.31 and 0.15 meq K/100g soil can be taken as critical limits as determined by the mathematical procedure (Table 4.24) for 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water extractants respectively. It appeared from the results (Table 4.24) that the critical limits obtained from different K extractants through scatter diagram technique were fairly close to that of mathematical procedure. Similar results on critical limit with 1N NH_4OAc extractable K was reported (0.20 meq K/100g soil) for rice by Jones (1982). Portch et al. (1984) reported 0.20 meq K/100ml as K critical limit of 0.25N NaHCO_3 extractant in soil for upland crops, where as Bhuiyan et al. (1992) found the critical limit of rice as 1.13 meq K/100g soil for 1N HNO_3 .

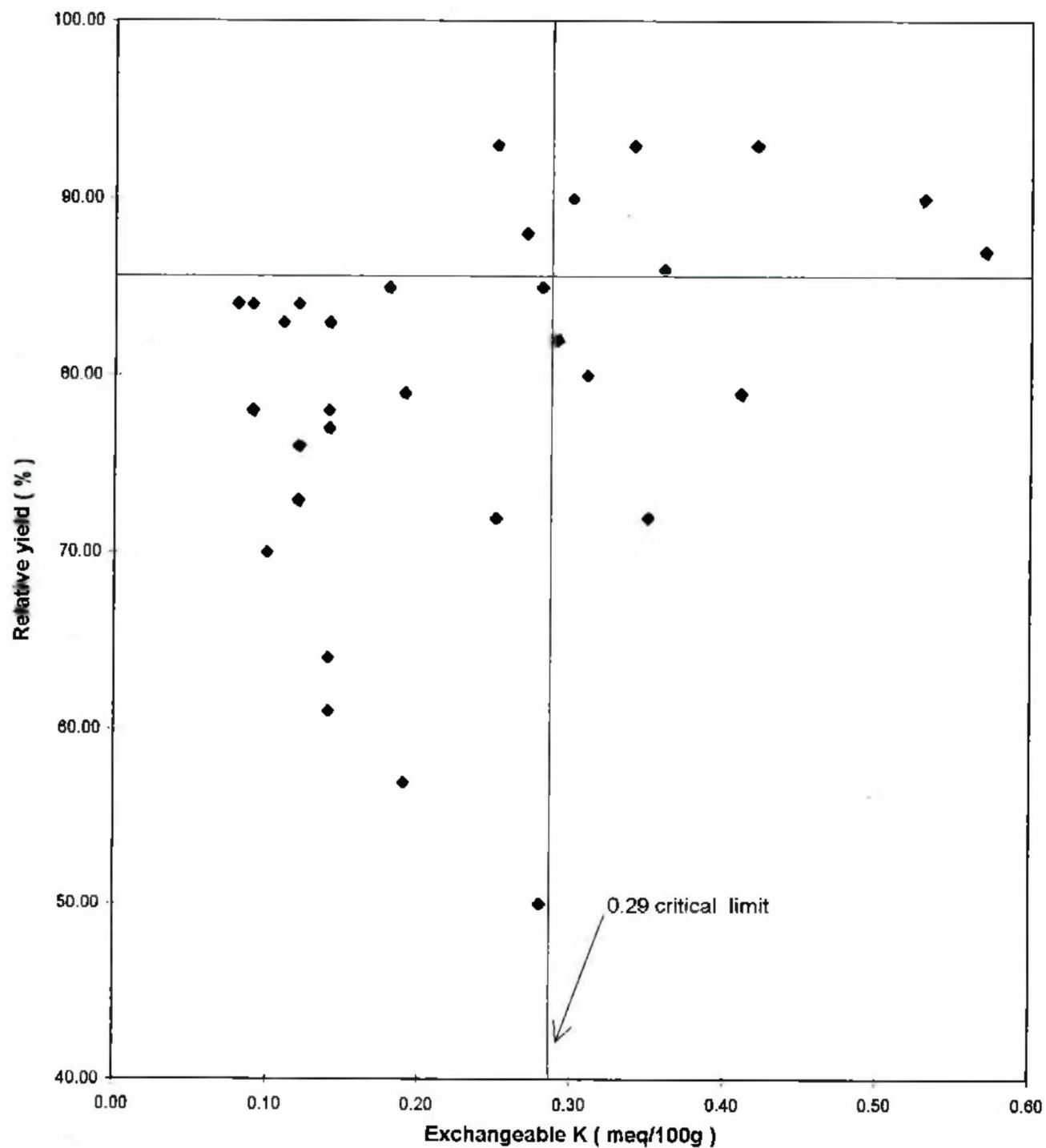


Fig.4.12. Critical limit determination based on the relationship between exchangeable K (1 N NH_4OAc extraction) content of soil and relative dry matter yield of potato grown in soils of thirty one locations.

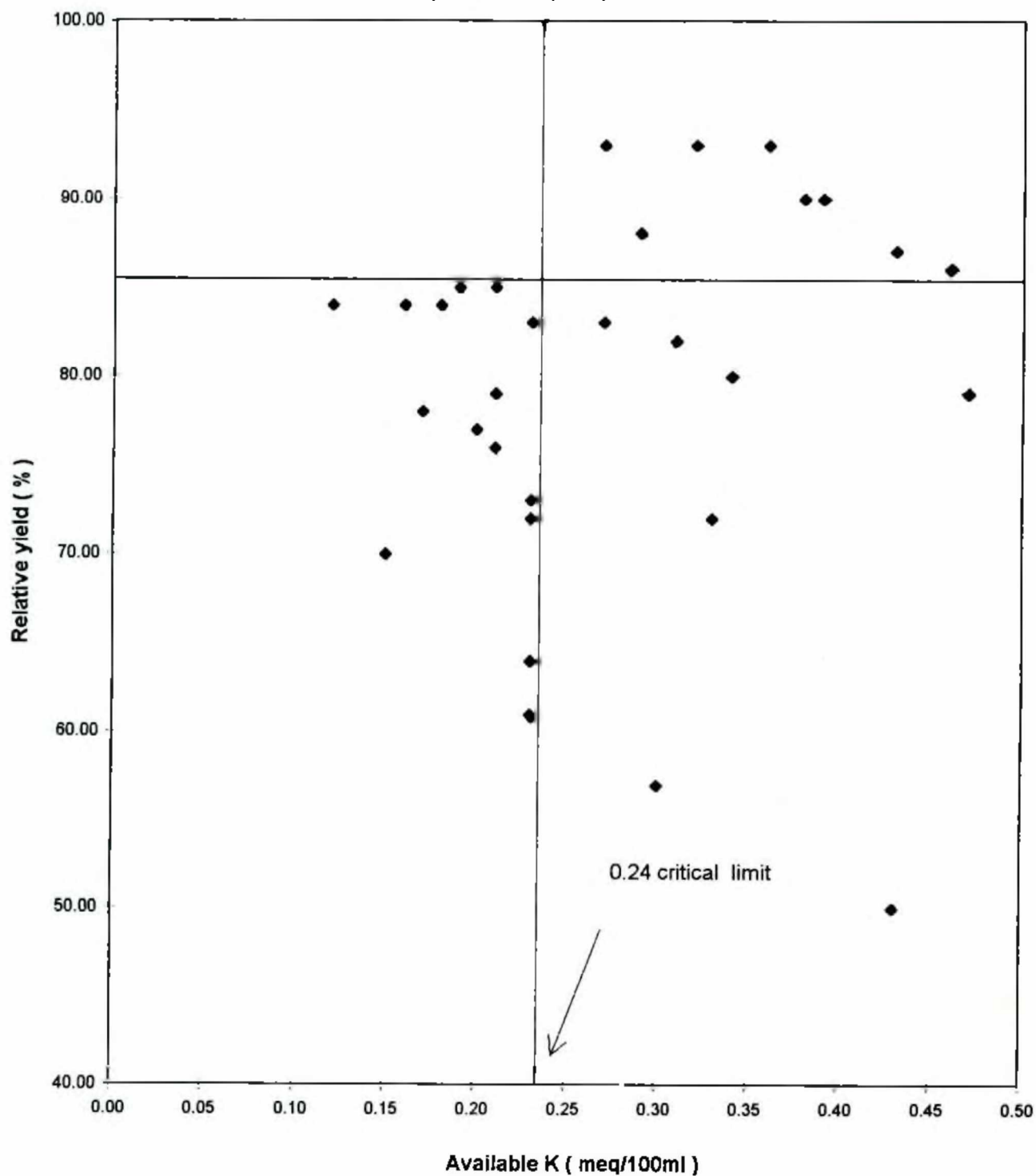


Fig. 4.13. Critical limit determination based on the relationship between available K (0.25 N NaHCO_3 extraction) content of soil and relative dry matter yield of potato grown in soils of thirty one locations.

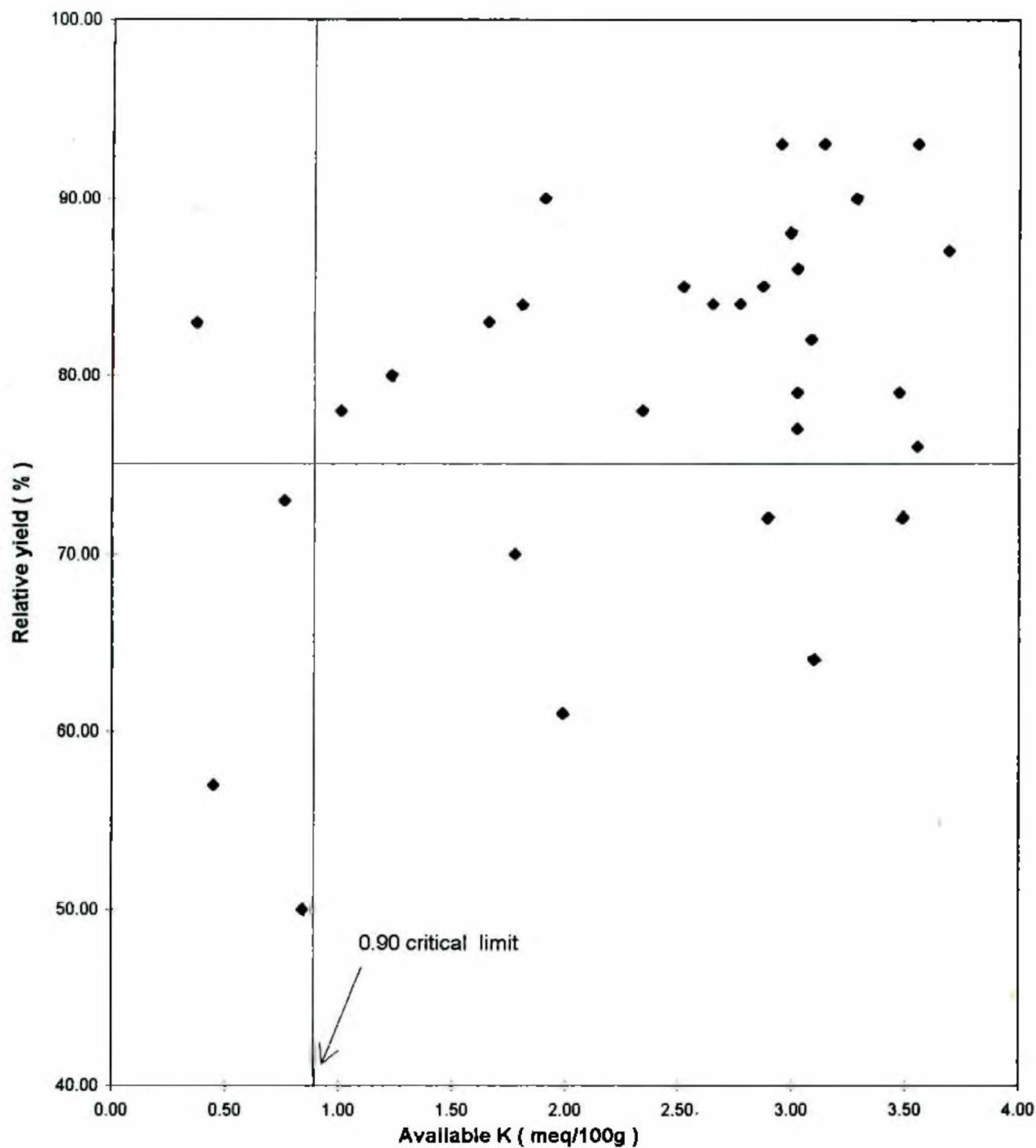


Fig.4.14. Critical limit determination based on the relationship between available K (1 N HNO_3 extraction) content of soil and relative dry matter yield of potato grown in soils of thirty one locations.

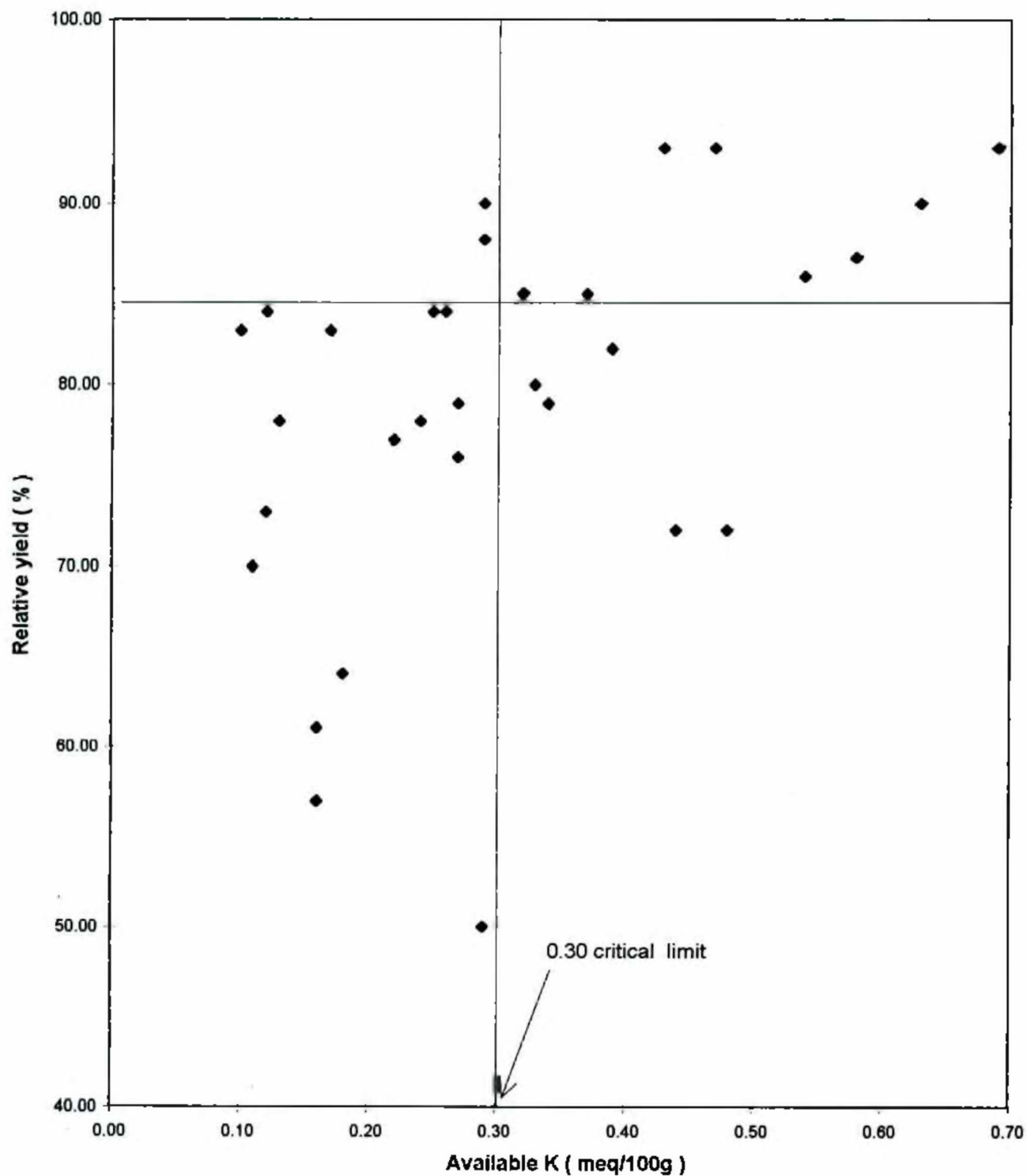


Fig.4.15. Critical limit determination based on the relationship between available K (cold H_2SO_4 extraction) content of soil and relative dry matter yield of potato grown in soils of thirty one locations.

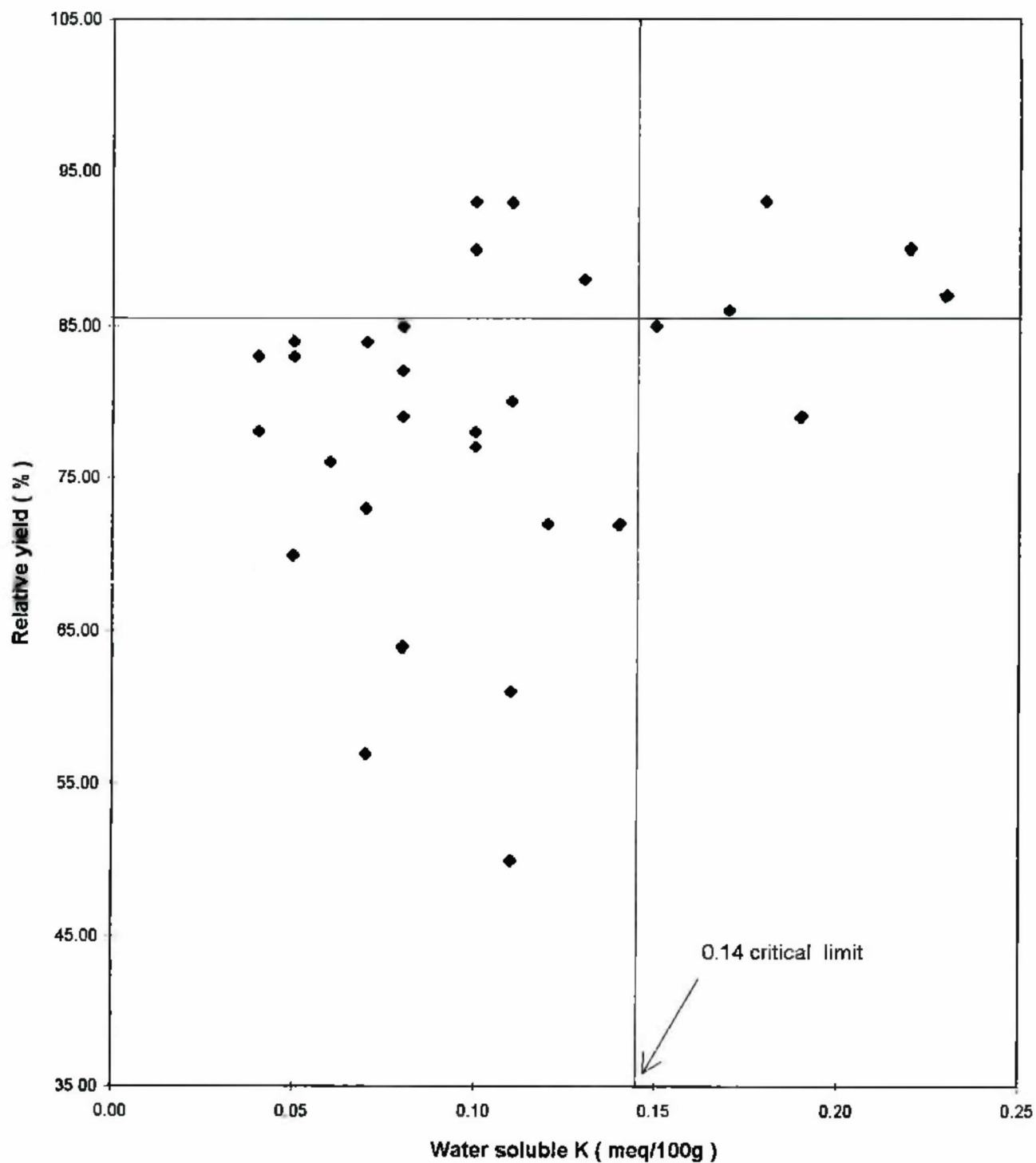


Fig.4.16. Critical limit determination based on the relationship between distilled water soluble K (1:10 soil : water extraction) content of soil and relative dry matter yield of potato grown in soils of thirty one locations.

Table 4.24. Critical limit of potassium of five soil extractants for potato as determined by graphical and mathematical procedures.

Soil K extractant	Methods of determining critical limit of K	
	Graphical	Mathematical
1N NH_4OAc	0.29 (meq K/100g soil)	0.285 (meq K/100g soil). (=0.29). (0.28-0.29)*
0.25N NaHCO_3	0.239 (meq K/100ml soil) (=0.24)	0.25 (meq K/100ml soil). (0.23-0.27)*
1N HNO_3	0.90 (meq K/100g soil)	0.925 (meq K/100g soil) (=0.93). (0.84-1.01)*
Cold H_2SO_4	0.30 (meq K/100g soil)	0.305 (meq K/100g soil) (=0.31) (0.29-0.32)*
Distilled water	0.144 (meq K/100g soil) (=0.14)	0.145 (meq K/100g soil) (=0.15). (0.14-0.15)*

* Indicate the range of K critical limit

Based on the critical limits of five K extractants, all soils were grouped into two categories i.e., below the critical limit and above it. Results indicated that there was an increasing trend of response to potassium application for all five K extractants in soils that remained below the critical limit (Table 4.30 and Figures 4.17 to 4.21). The dry matter yield of potato ranged from 6.15 to 8.98/ g pot^{-1} when potassium fertilizer was applied from 0 to 100 mg K kg^{-1} levels. On the other hand, for soils containing

Table 4.25. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (1N NH_4OAc extraction).

Last value of exchangeable soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.08	84	0	79	3292	0.08 & 0.09	0.00706
0.09	82	24	79	3266	0.09 & 0.10	0.00766
0.10	79	132	79	3183	0.10 & 0.11	0.00012
0.11	80	145	79	3169	0.11 & 0.12	0.00042
0.12	79	218	79	3097	0.12 & 0.14	0.00012
0.14	77	709	81	2445	0.14 & 0.18	0.04868
0.18	77	776	81	2429	0.18 & 0.19	0.03330
0.19	76	1164	83	1807	0.19 & 0.25	0.10388
0.25	77	1460	83	1587	0.25 & 0.27	0.08096
0.27	77	1580	82	1556	0.27 & 0.28	0.05411
0.28	76	2367	85	422	0.28 & 0.29	0.15877 <u>2/</u>
0.29	77	2397	86	410	0.29 & 0.30	0.15335
0.30	77	2568	85	388	0.30 & 0.31	0.10840
0.31	77	2575	86	359	0.31 & 0.34	0.11504
0.34	78	2811	85	298	0.34 & 0.35	0.06226
0.35	78	2845	87	110	0.35 & 0.36	0.10871
0.36	78	2911	87	109	0.36 & 0.41	0.08910
0.41	78	2912	90	18	0.41 & 0.42	0.11625
0.42	79	3127	89	5	0.42 & 0.53	0.05532
0.53	79	3253	87	0	0.53 & 0.57	0.01882

1/ $R^2 = \frac{\text{TCSS} - (\text{CSS}^1 + \text{CSS}^2)}{\text{TCSS}}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.28 and 0.29 with an average of 0.285 meq K/100g soil.

Table 4.26. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (0.25N NaHCO_3 extraction).

Last value of available soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.12	84	0	79	3292	0.12 & 0.15	0.00706
0.15	77	98	79	3207	0.15 & 0.16	0.00314
0.16	79	131	79	3185	0.16 & 0.17	0.00017
0.17	79	133	79	3182	0.17 & 0.18	0.00012
0.18	80	155	79	3159	0.18 & 0.19	0.00042
0.19	80	180	79	3123	0.19 & 0.20	0.00374
0.20	80	190	79	3119	0.20 & 0.21	0.00193
0.21	80	232	79	3073	0.21 & 0.23	0.00314
0.23	77	833	82	2328	0.23 & 0.27	0.04657 <u>2/</u>
0.27	78	1096	81	2181	0.27 & 0.29	0.01158
0.29	79	1185	80	2121	0.29 & 0.30	0.00284
0.30	78	1636	82	1548	0.30 & 0.31	0.03963
0.31	78	1654	82	1548	0.31 & 0.32	0.03420
0.32	79	1871	81	1414	0.32 & 0.33	0.00917
0.33	78	1913	82	1327	0.33 & 0.34	0.02274
0.34	78	1916	82	1323	0.34 & 0.36	0.02304
0.36	79	2121	80	1185	0.36 & 0.38	0.00284
0.38	79	2238	78	1073	0.38 & 0.39	0.00133
0.39	80	2347	76	905	0.39 & 0.43	0.01912
0.43	79	3268	83	25	0.43 & 0.46	0.00676
0.46	79	3315	79	0	0.46 & 0.47	0.00012

1/ $R^2 = \frac{\text{TCSS} - (\text{CSS}^1 + \text{CSS}^2)}{\text{TCSS}}$. TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.23 and 0.27 with an average of 0.25 meq K/100ml soil.

Table 4.27. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (1N HNO₃ extraction).

Last value of available soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS ¹)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS ²)		
0.37	83	0	79	1101	0.37 & 0.45	0.00434
0.45	70	338	80	2795	0.45 & 0.76	0.05502
0.76	71	344	80	2747	0.76 & 0.84	0.06768
0.84	66	675	81	1807	0.84 & 1.01	0.25137 <u>2/</u>
1.01	68	795	81	1796	1.01 & 1.23	0.21850
1.23	70	911	81	1794	1.23 & 1.66	0.18411
1.66	72	1052	81	1791	1.66 & 1.78	0.14249
1.78	72	1056	82	1657	1.78 & 1.81	0.18170
1.81	73	1189	82	1652	1.81 & 1.91	0.14309
1.91	75	1446	81	1581	1.91 & 1.99	0.08699
1.99	74	1619	82	1147	1.99 & 2.34	0.16571
2.34	74	1637	83	1127	2.34 & 2.52	0.16631
2.52	75	1750	82	1120	2.52 & 2.65	0.13434
2.65	75	1829	82	1118	2.65 & 2.77	0.11112
2.77	76	1898	82	1115	2.77 & 2.87	0.09121
2.87	77	1974	82	1107	2.87 & 2.89	0.07070
2.89	76	1994	83	998	2.87 & 2.95	0.09755
2.95	77	2257	82	886	2.95 & 2.99	0.05200
2.99	78	2367	82	847	2.99 & 3.02	0.03059
3.02	78	2433	82	800	3.02 & 3.08	0.02485
3.08	78	2447	82	800	3.08 & 3.10	0.02063
3.10	78	2645	84	439	3.10 & 3.14	0.06980
3.14	78	2868	83	351	3.14 & 3.28	0.02908
3.28	79	2998	81	289	3.23 & 3.47	0.00857
3.47	79	2998	82	282	3.47 & 3.49	0.01068
3.49	79	3043	85	149	3.49 & 3.55	0.03722
3.55	79	3253	87	0	3.55 & 3.69	0.01882

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.84 and 1.01 with an average of 0.925 meq K/100g soil.

Table 4.28. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (cold H_2SO_4 extraction).

Last value of available soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.10	83	0	79	3301	0.10 & 0.11	0.00434
0.11	77	85	79	3215	0.11 & 0.12	0.00465
0.12	78	149	79	3153	0.12 & 0.13	0.00404
0.13	78	149	80	3150	0.13 & 0.16	0.00495
0.16	72	651	81	2229	0.16 & 0.17	0.13133
0.17	74	752	81	2225	0.17 & 0.18	0.10207
0.18	73	834	82	1917	0.18 & 0.22	0.17024
0.22	73	852	82	1891	0.22 & 0.24	0.17265
0.24	73	875	82	1873	0.24 & 0.25	0.17114
0.25	74	977	82	1870	0.25 & 0.26	0.14128
0.26	75	1063	82	1867	0.26 & 0.27	0.11625
0.27	75	1078	83	1812	0.27 & 0.29	0.12831
0.29	76	2095	84	625	0.29 & 0.32	0.17959 <u>2/</u>
0.32	76	2180	84	625	0.32 & 0.33	0.15395
0.33	76	2195	85	604	0.33 & 0.34	0.15576
0.34	76	2203	85	568	0.34 & 0.37	0.16420
0.37	77	2274	85	568	0.37 & 0.39	0.14279
0.39	77	2301	86	556	0.39 & 0.43	0.13826
0.43	78	2548	85	495	0.43 & 0.44	0.08216
0.44	77	2578	87	307	0.44 & 0.47	0.12982
0.47	78	2812	86	261	0.47 & 0.48	0.07311
0.48	78	2847	89	30	0.48 & 0.54	0.13223
0.54	78	2912	90	18	0.54 & 0.58	0.11625
0.58	78	2989	92	5	0.58 & 0.63	0.09694
0.63	79	3119	93	0	0.63 & 0.69	0.05924

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.29 and 0.32 with an average of 0.305 meq K /100g soil.

Table 4.29. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato (distilled water extraction).

Last value of distilled water soluble K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.04	81	13	79	3299	0.04 & 0.05	.00103
0.05	80	137	79	3177	0.05 & 0.06	.00042
0.06	79	148	79	3167	0.06 & 0.07	.00012
0.07	77	686	80	2569	0.07 & 0.08	.01822
0.08	77	947	81	2272	0.08 & 0.10	.02908
0.10	79	1310	80	2001	0.10 & 0.11	.00133
0.11	77	2619	84	458	0.11 & 0.12	.07191
0.12	77	2648	85	308	0.12 & 0.13	.10840
0.13	78	2759	85	298	0.13 & 0.14	.07794
0.14	77	2790	87	113	0.14 & 0.15	.12439 <u>2/</u>
0.15	78	2845	87	110	0.15 & 0.17	.10871
0.17	78	2911	87	109	0.17 & 0.18	.08910
0.18	79	3127	85	65	0.18 & 0.19	.03722
0.19	79	3127	89	5	0.19 & 0.22	.05532
0.22	79	3253	87	0	0.22 & 0.23	.01882

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.14 and 0.15 with an average of 0.145 meq K/100g soil.

potassium above the critical limits, the increase of the dry matter yield of potato was beneficial and ranged from 6.92 to 8.83g pot⁻¹ with the application of same of amount of potassium fertilizer. The present results also indicated that no economic response was observed beyond this level due to beneficial increase in dry matter yield of potato (Table 4.30 and Figures 4.17 to 4.21). Considering the critical limits, 68, 35, 13, 58 and 77 per cent soils of the total (thirty one) were rated as K deficient i.e., below the critical limit and remaining 32, 65, 87, 42 and 23 per cent soils fell above the critical limits for 1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled water extractants respectively (Table 4.30). Among all K extraction methods, the highest crop response was recorded from distilled water (77%) followed by 1N NH₄OAc (68%) and cold H₂SO₄ (58%) extractable K.

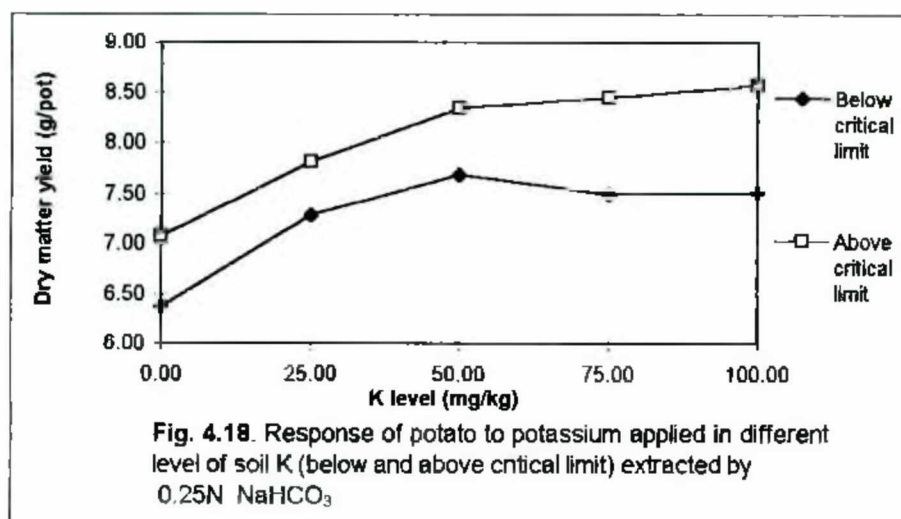
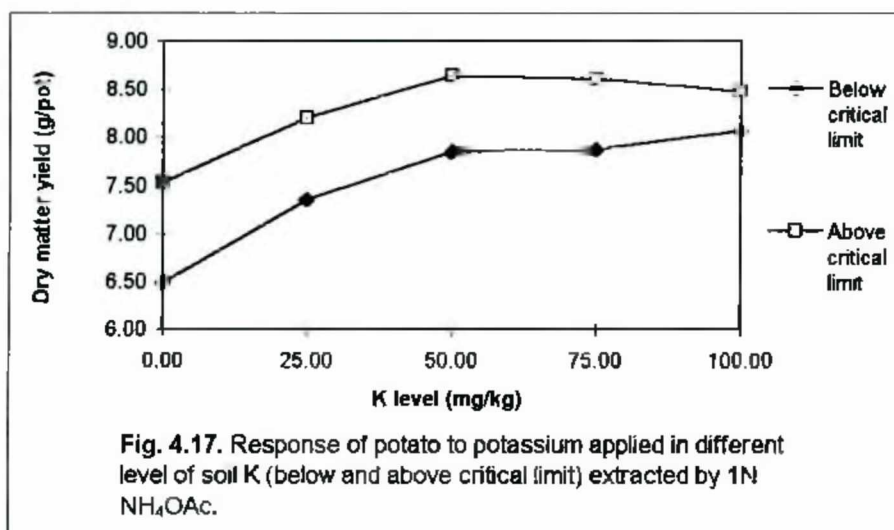
From this study, it could be concluded that potato plant would respond to K application economically in these soils if 1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled water soluble K are below the critical limits determined both by graphical and mathematical procedures. Therefore, the values of critical limits can be judiciously used to separate K responsive soils from the non-response ones and be helpful to make fertilizer recommendation for potato. Potash should be applied in fields where the values of K of all extractants are lower than the critical limit and the application rate should be decreased on the soil where K remain above the critical limit of nutrient potassium.

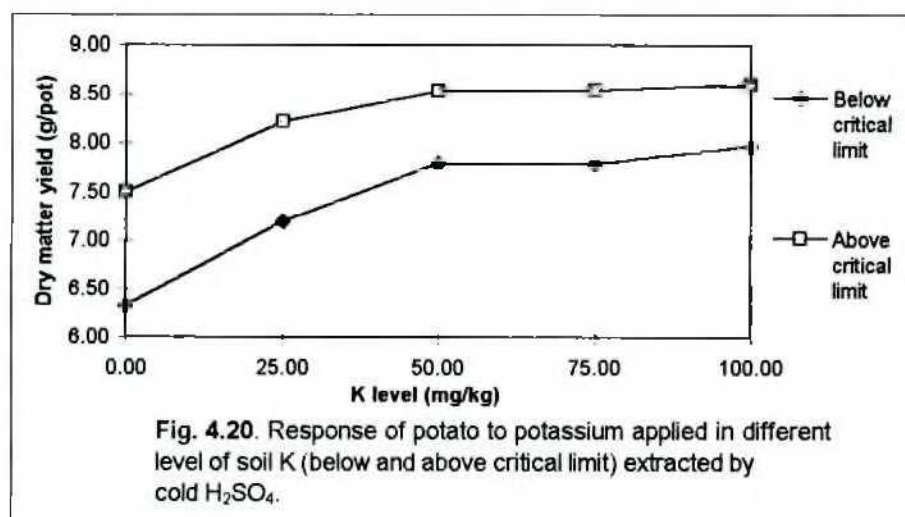
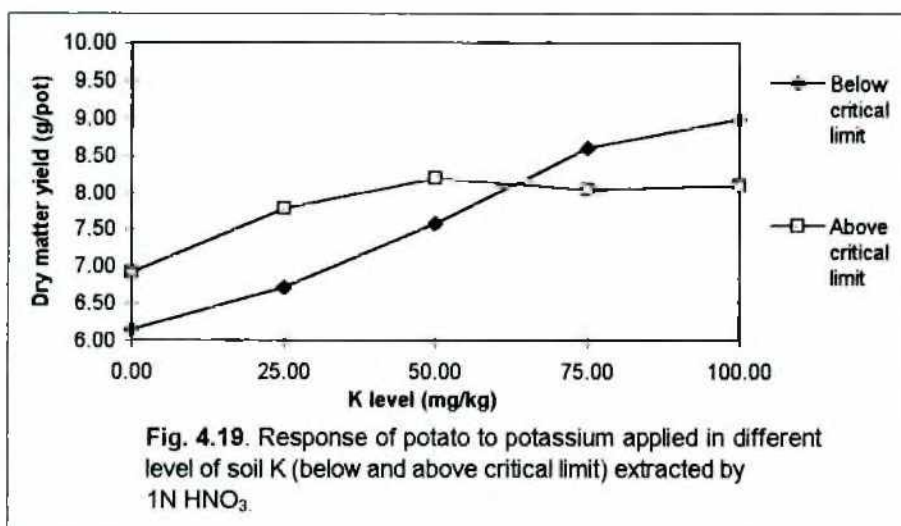
Table 4.30. Response of potato to potassium applied in different level of soil K (below and above the critical limit) determined by using five extractants.

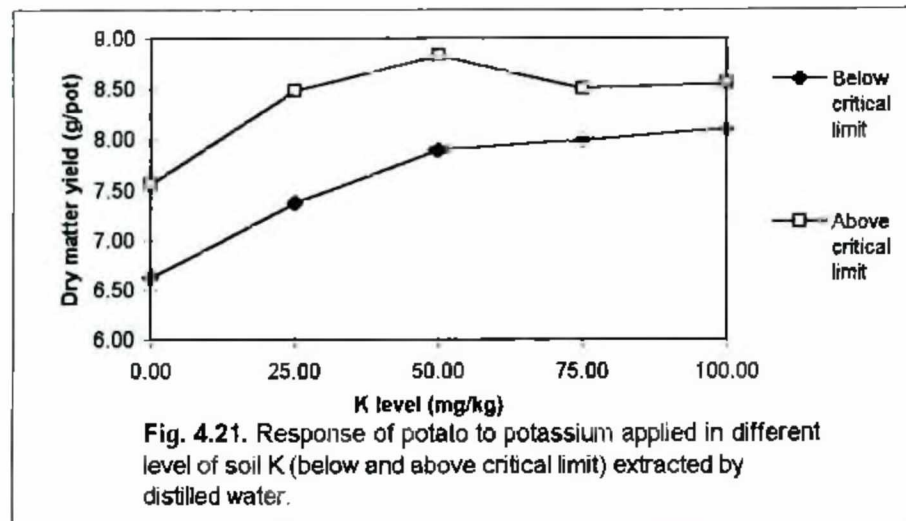
Soil K extractant	Level of K in soil (me %)	Number of soils responded	Average dry matter yield (g pot ⁻¹)				
			K applied (mg K kg ⁻¹)				
			0	25	50	75	100
1N NH ₄ OAc	<0.29 (0.08-0.28) ¹	21 (68)*	6.49	7.35	7.85	7.87	8.07
	>0.29 (0.29-0.57) ¹	10 (32)	7.53	8.20	8.65	8.61	8.48
0.25N NaHCO ₃	<0.23 (0.12-0.21) ¹	11 (35)	6.37	7.28	7.69	7.49	7.52
	>0.23 (0.23-0.47) ¹	20 (65)	7.07	7.81	8.34	8.45	8.58
1N HNO ₃	<0.90 (0.37-0.84) ¹	4 (13)	6.15	6.71	7.58	8.60	8.98
	>0.90 (1.01-3.69) ¹	27 (87)	6.92	7.78	8.19	8.04	8.09
Cold H ₂ SO ₄	<0.30 (0.10-0.29) ¹	18 (58)	6.33	7.19	7.80	7.79	7.92
	>0.30 (0.32-0.69) ¹	13 (42)	7.50	8.22	8.53	8.55	8.60
Distilled water	<0.14 (0.04-0.13) ¹	24 (77)	6.61	7.37	7.90	7.99	8.10
	>0.14 (0.14-0.23) ¹	7 (23)	7.56	8.48	8.83	8.50	8.55

* Figures in parentheses indicate percent of the total

¹ Range of K (me %) in soil.







4.7.5 Critical limit of potassium determined from K concentration in potato plant

For estimating the critical K concentration in potato plant, extractable K content (1N HCl as extractant) and per cent relative yield of potato were subjected to analyse through graphical and mathematical procedures of Cate and Nelson (1965 and 1971). The values of 6.40 and 6.46% were found to be the critical K concentration in potato plant for graphical (Figure 4.22) and mathematical procedures (Table 4.31) respectively.

The present results led to assume that potato plant could be considered as non-responsive to K when the per cent relative dry matter yield was more than 87 (Figure 4.22). Results indicated that the critical K concentration obtained from the graphical method was nearly close to that of mathematical procedure. Sharma (1991) determined 7.01 and 7.60% as the critical K concentration for mid stage potato plant for the mathematical and graphical methods respectively, while Roberts et al. (1985) reported 5.7 to 6.0% as critical nutrient range of potato plant (vegetative to tuberization). Chapman (1967) compiled the data on per cent potassium content in potato and found < 7.0% as low K status in the potato plant. On the other hand, Rao et al. (1989) worked out 3.2 to 9.6% as the range of critical K concentration in the petioles of potato plants. It may be concluded that the critical values of plant tissue K concentration of potato could distinguish the K deficient plants from the other adequate ones. As such an economic response is highly expected below these levels of critical K concentration of potato.

4.7.6 Efficiency of applied potassium for the dry matter yield of potato

The efficiency of applied potassium by potato plant in presence of NPS fertilizers for soils of thirty one locations was quantified on the basis of the dry matter yield increase over the control (K_0) for each mg of applied K in order to test the

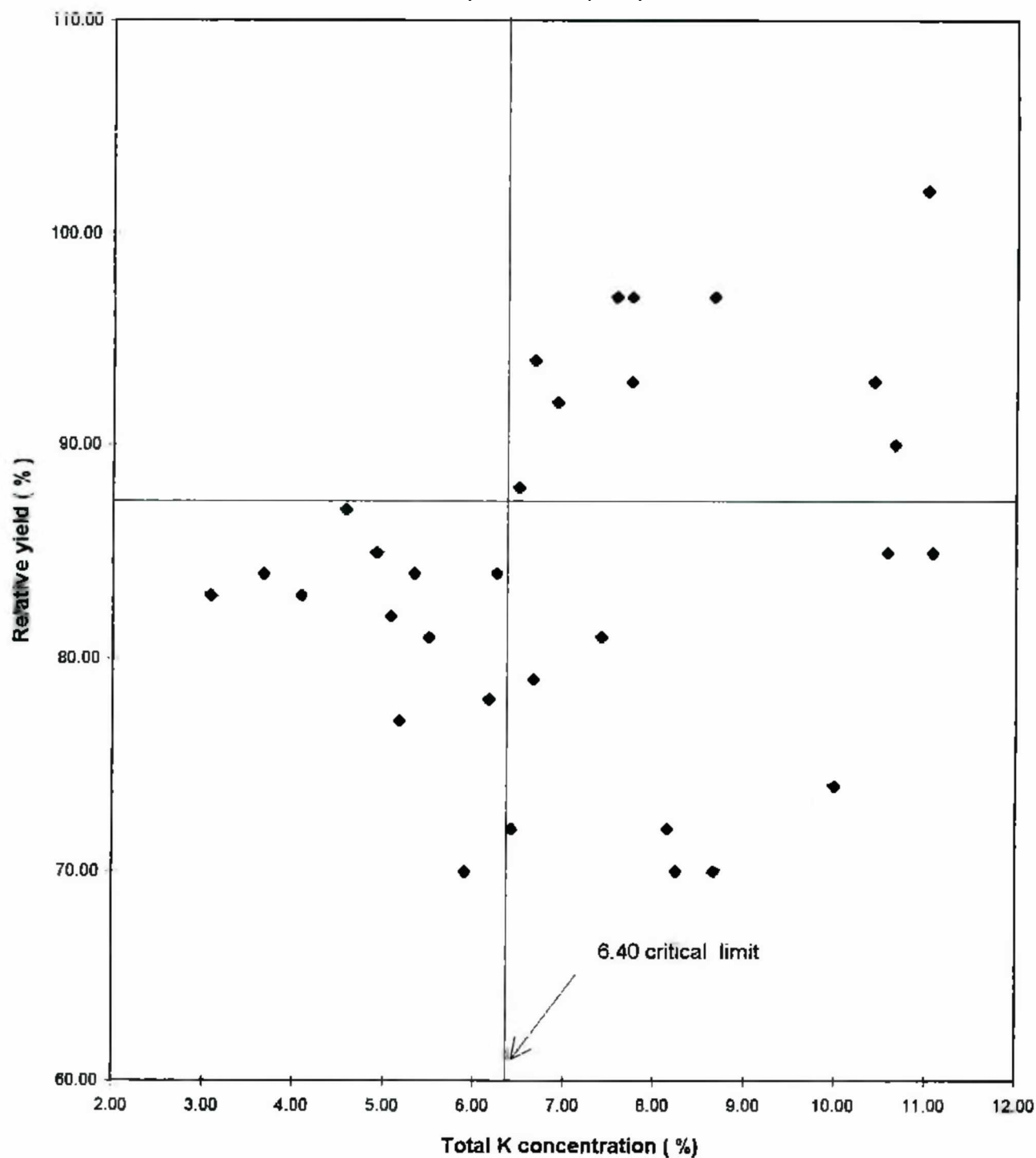


Fig.4.22. Critical limit determination based on the relationship between total K (1 N HCl extraction) concentration in plant & relative dry matter yield of potato grown in soils of thirty one locations.

Table 4.31. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for potato plant (1N HCl extraction).

Last value of K conc. (%) included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
3.08	83	0	84	2329	3.08 & 3.67	.00051
3.67	84	0.5	84	2329	3.67 & 4.08	.00029
4.08	83	0.66	84	2327	4.08 & 4.58	.00108
4.58	84	11.00	84	2319	4.58 & 4.92	.00008
4.92	84	11.00	84	2319	4.92 & 5.08	.00008
5.08	84	16.00	84	2314	5.08 & 5.17	.00008
5.17	83	58.00	85	2260	5.17 & 5.33	.00523
5.33	83	59.00	85	2260	5.33 & 5.50	.00480
5.50	83	63.00	85	2247	5.50 & 5.91	.00866
5.91	82	212.00	85	2021	5.91 & 6.17	.04171
6.17	81	224.00	86	1964	6.17 & 6.25	.06102
6.25	82	231.00	86	1961	6.25 & 6.42	.05930
6.42	81	314.00	87	1758	6.42 & 6.50	.11080 <u>2/</u>
6.50	81	363.00	87	1756	6.50 & 6.67	.09063
6.67	82	523.00	87	1644	6.67 & 6.92	.07003
6.92	83	618.00	86	1612	6.92 & 7.42	.04299
7.42	82	620.00	87	1583	7.42 & 7.58	.05458
7.58	83	821.00	86	1465	7.58 & 7.75	.01896
7.75	84	1081.00	84	1248	7.75 & 8.16	.00051
8.16	84	1226.00	85	1093	8.16 & 8.25	.00480
8.25	83	1407.00	87	836	8.25 & 8.66	.03741
8.66	84	1591.00	86	722	8.66 & 8.67	.00737
8.67	83	1772.00	88	439	8.67 & 10.00	.05115
10.00	83	1853.00	91	198	10.00 & 10.42	.11071
10.42	83	1953.00	91	193	10.42 & 10.58	.07904
10.58	83	1956.00	92	153	10.58 & 10.66	.09492
10.66	84	1999.00	94	145	10.66 & 11.00	.07990
11.00	84	2329.00	85	0	11.00 & 11.08	.00051

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 6.42 and 6.50 with an average of 6.46%.

reliability of critical limits. The results of the efficiency of applied potassium on potato are presented in Table 4.32. It is appeared from the data that application of potassium @ 25mg K Kg^{-1} produced 22.40 to 36.40mg dry matter of potato by each mg of applied K in soils having potassium values below the critical limit but the soils contained K above the critical limit, gave low dry matter yield as compared to K deficient soils. These values ranged from 26.80 to 36.80mg dry matter by each mg of applied K for all five K extractants.

Results also revealed that the dry matter yield of potato decreased with increasing the K levels (50 to 100 mg K kg^{-1}) in soils of both categories (below and above the critical limits). This trend of K use efficiency was equally applicable for K values of all extractants under the study except 1N HNO_3 extractable K for deficient soils. In K deficient soils the dry matter yield increased up to 75mg K kg^{-1} , this might be due to sufficiency of 1N HNO_3 extractable K in soils having K values below the critical limit. K use efficiency by potato plant was found highest in plants of K deficient soils (soils K below the critical limit) and lowest in soils-whose K values remained above the critical limit.

Table 4.32. Efficiency of applied K for the dry matter yield of potato.

Soil K extractant	Level of K in soil (me %)	Number of soils responded	K fertilizer use efficiency (mg yield mg k ⁻¹)				
			K applied (mg K kg ⁻¹)				
			0	25	50	75	100
1N NH ₄ OAc	<0.29 (0.08-0.28)	29	-	34.40	27.20	18.40	15.80
	>0.29 (0.29-0.57)	10	-	26.80	22.40	14.40	9.50
0.25N NaHCO ₃	<0.23 (0.12-0.21)	11	-	36.40	26.40	14.93	11.50
	>0.23 (0.23-0.47)	20	-	29.60	25.40	18.40	15.10
1N HNO ₃	<0.90 (0.37-0.84)	4	-	22.40	28.60	32.67	28.30
	>0.90 (1.01-3.69)	27	-	34.40	25.40	14.93	11.70
Cold H ₂ SO ₄	<0.30 (0.10-0.29)	18	-	34.40	29.40	19.47	15.90
	>0.30 (0.32-0.69)	13	-	28.80	20.60	14.00	11.00
Distilled water	<0.14 (0.04-0.13)	24	-	30.40	25.80	18.40	14.90
	>0.14 (0.14-0.23)	7	-	36.80	25.40	12.53	9.90

The utilization of K by potato plant was low when the level of applied K increasing and thereby decreased the fertilizer K use efficiency. Hence, it is advisable to apply K fertilizer to potato plant only when the soils value remain below the critical limit.

4.8 Critical limit of potassium in soil and plant and the response of groundnut to applied potash in soils of twenty nine locations

4.8.1 Effect of K application on the dry matter yield, per cent relative yield, per cent K concentration in plant and K uptake of groundnut

The estimated dry matter yield (threshold and plateau yield) and per cent relative yield of groundnut along with K values of five extractants are presented in Table 4.33. The per cent relative yield of groundnut at optimum K level for twenty nine soils showed wide variation ranging from 67 to 97% due to marked variation observed in soil potassium fertility. Similar wide variation in yield was also recorded for threshold and plateau yield of groundnut which ranged from 6.83 to 24.83g pot⁻¹ and 8.47 to 27.60g pot⁻¹ respectively. It is observed from the Table 4.34 that application of potassium increased dry matter yield of groundnut with increasing the level of K up to 30 to 45mg K kg⁻¹ application in most of the soils under study.

The present results revealed that initial soil potassium fertility as well as added potassium had marked influence on the per cent K concentration (at K₀) of groundnut plant across all locations. The per cent K concentration obtained from K control pot ranged from 0.79 to 5.41% (Table 4.34).

Table. 4.33. Quantity of potassium extracted by different extractants, dry matter yield and per cent relative yield of groundnut grown in soils of twenty nine locations.

Location No.	Quantity of K (me %) extracted by					Dry matter yield (g pot ⁻¹)		Relative yield (%)
	1N NH ₄ OAc	0.25N NaHCO ₃	1N HNO ₃ (boiling)	Cold H ₂ SO ₄	Distilled water	Threshold yield	Plateau yield	
1.	0.12	0.23	0.76	0.12	0.07	10.53	13.20	80
2.	0.08	0.16	1.81	0.12	0.07	10.54	14.52	73
3.	0.28	0.43	0.84	0.29	0.11	8.70	9.91	88
4.	0.14	0.23	3.10	0.18	0.08	7.31	8.47	86
5.	0.14	0.23	1.99	0.16	0.11	11.10	15.63	71
6.	0.53	0.39	3.28	0.63	0.22	20.93	23.73	88
7.	0.57	0.43	3.69	0.58	0.23	24.83	26.47	94
8.	-	-	-	-	-	-	-	-
9.	0.35	0.33	3.49	0.44	0.14	21.03	27.60	76
10.	0.14	0.20	3.02	0.22	0.10	18.67	21.13	88
11.	0.14	0.17	2.34	0.24	0.10	16.53	17.07	97
12.	0.09	0.12	2.65	0.25	0.05	20.50	24.70	83
13.	0.28	0.21	2.52	0.32	0.15	19.80	23.00	86
14.	0.30	0.38	1.91	0.29	0.10	18.93	21.25	89
15.	-	-	-	-	-	-	-	-
16.	0.19	0.21	3.47	0.27	0.08	18.70	21.87	86
17.	0.10	0.15	1.78	0.11	0.05	9.00	11.92	76
18.	0.14	0.23	1.66	0.17	0.05	7.95	10.78	74
19.	0.09	0.17	1.01	0.13	0.04	17.87	21.90	82
20.	0.31	0.34	1.23	0.33	0.11	12.70	15.30	83
21.	0.19	0.30	0.45	0.16	0.07	14.01	18.32	76
22.	0.25	0.23	2.89	0.48	0.12	15.39	16.00	96
23.	0.12	0.18	2.77	0.26	0.07	14.98	18.78	80
24.	0.42	0.36	3.55	0.69	0.18	14.85	17.48	85
25.	0.18	0.19	2.87	0.37	0.08	14.66	17.32	85
26.	0.34	0.32	3.14	0.47	0.11	11.01	14.17	78
27.	0.11	0.27	0.37	0.10	0.04	12.76	15.40	83
28.	0.25	0.27	2.95	0.43	0.10	6.83	10.23	67
29.	0.27	0.29	2.99	0.29	0.13	13.33	14.57	92
30.	0.41	0.47	3.02	0.34	0.19	13.66	14.07	97
31.	0.36	0.46	3.02	0.54	0.17	11.90	13.22	90

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamorgram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

Table 4.34. Effect of K application on the dry matter yield, per cent relative yield, K concentration and K uptake of groundnut.

Location No.	Dry matter yield (g pot ⁻¹)					Relative yield (%)	% K Conc. at K ₀	Potassium uptake (mg pot ⁻¹)				
	K applied (mg K kg ⁻¹)							K applied (mg K kg ⁻¹)				
	0	15	30	45	60			0	15	30	45	60
1.	10.53c	11.73b	11.80b	13.20a	10.13c	80	1.41	148	235	295	417	295
2.	10.54c	11.86b	12.58b	14.52a	13.61a	73	1.50	158	267	293	363	362
3.	8.70c	9.91a	8.94bc	9.10abc	9.75ab	68	3.33	290	380	380	387	422
4.	7.31c	7.72bc	8.47a	8.05ab	7.23c	86	2.08	152	193	318	282	247
5.	11.10c	12.93b	15.63a	12.27b	13.00b	71	3.08	342	485	572	572	476
6.	20.93c	23.73a	22.27b	20.80c	22.53ab	68	1.33	278	572	759	501	507
7.	24.83b	25.47a	24.57b	22.60c	25.73ab	94	1.25	310	439	408	735	844
8.	-	-	-	-	-	-	-	-	-	-	-	-
9.	21.03d	23.07c	24.93b	27.60a	23.80c	76	2.75	578	768	873	919	733
10.	18.67bc	21.13a	19.07b	18.80bc	17.47c	88	2.20	411	545	587	547	524
11.	16.53ab	16.85a	17.07a	15.80b	14.97c	97	1.25	207	224	411	329	274
12.	20.50c	22.40b	23.40b	24.70a	23.33b	83	1.00	205	280	351	287	292
13.	19.80c	21.07b	23.00a	21.22b	19.27c	86	2.08	412	560	633	531	472
14.	18.93c	19.97b	21.25a	18.38c	18.27c	89	2.66	504	615	797	658	623
15.	-	-	-	-	-	-	-	-	-	-	-	-
16.	18.70b	19.13b	21.87a	18.80b	8.19b	86	2.41	451	509	674	453	455
17.	9.00c	10.24b	11.92a	8.92c	9.77b	76	1.25	113	187	198	134	171
18.	7.95c	9.46b	9.92ab	10.78a	10.63ab	74	0.79	63	118	107	162	176
19.	17.87c	19.63b	19.73b	21.90a	20.43b	82	1.25	223	277	296	383	306
20.	12.70c	15.30a	14.09b	13.77bc	14.02b	83	1.91	243	471	410	344	382
21.	14.01c	15.48b	15.60b	18.32a	16.29b	76	1.00	140	194	195	304	270
22.	15.39b	16.00a	14.57c	14.78c	13.16d	96	2.08	320	586	497	480	416
23.	14.98c	16.12bc	18.78a	16.48b	17.00b	80	2.08	312	403	438	412	439
24.	14.85c	15.33bc	17.48a	16.21b	14.94c	85	3.83	569	587	699	634	572
25.	14.66b	15.24b	15.11b	16.86a	17.32a	85	2.00	293	329	277	266	317
26.	11.01c	12.32b	12.82b	12.54b	14.17a	78	4.41	486	585	513	564	684
27.	12.76c	12.07c	15.40a	14.76ab	14.22b	83	1.00	128	140	231	196	201
28.	6.83c	8.32b	9.06b	10.23a	8.76b	67	3.33	227	298	332	392	270
29.	13.33b	13.59ab	13.80ab	14.57a	13.55ab	92	2.08	227	326	345	388	339
30.	13.66ab	14.07a	13.19ab	12.96b	13.40ab	97	4.91	671	832	747	648	748
31.	11.90b	12.38ab	13.22a	12.15b	11.66b	90	5.41	644	784	847	891	831

In a column, means followed by a common letter are not significantly different at 5% level.

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamogram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

Similar findings on per cent K concentration of groundnut were reported by Chapman (1967) and Rao et al. (1989). The results of potassium uptake by groundnut plant indicated that the uptake increased with increasing level of added potassium and ranged from 63 to 919 mg pot⁻¹. The trend of K uptake was found higher within 30 to 45 mg K kg⁻¹ application.

4.8.2 K concentration in groundnut plant and per cent relative yield

The concentration of K in groundnut plants and per cent relative yield are presented in Table 4.35. K concentration in groundnut plants at K control pot varied (0.79 to 5.41%) widely due to wide variation of soil K fertility, which affected the dry matter yield. Both the parameters such as dry matter yield and K concentration in groundnut plants were influenced by added K and initial K of the soil. On the basis of the dry matter yield obtained from all treatments, the K concentration in groundnut plants for the soils of all locations varied and it was ranging from 0.79 to 7.33%. Chapman (1967) and Rao et al. (1989) reported the range of K < 1.30 to > 1.3 and < 1.3 to 3.5% respectively in the petiole of groundnut, which was harvested at 40 days of sowing.

Per cent relative yield was calculated considering the K concentration and corresponding dry matter yield of groundnut and was varied from 67 to 98% (Table 4.35).

Table 4.35. Dry matter yield, K concentration in plant (1N HCl extraction) at different levels of applied K and per cent relative yield of groundnut.

Location No.	Dry matter yield (g pot ⁻¹)					K concentration (% in dry matter)					Relative yield (%)
	K applied (mg K kg ⁻¹)					K applied (mg K kg ⁻¹)					
	0	15	30	45	60	0	15	30	45	60	
1.	10.53	11.73	11.80	13.20	10.13	1.41e	2.00d	2.50c	3.16a	2.91b	80
2.	10.54	11.86	12.58	14.52	13.61	1.50e	2.25d	2.33c	2.50b	2.66a	77
3.	8.70	9.91	8.94	9.10	9.75	3.33d	3.83c	4.25b	4.25b	4.33a	89
4.	7.31	7.72	8.47	8.05	7.23	2.08e	2.50d	3.75a	3.50b	3.41c	86
5.	11.10	12.93	15.63	12.27	13.00	3.08b	3.75b	3.66ab	4.66a	3.66ab	90
6.	20.93	23.73	22.27	20.80	22.53	1.33d	2.41b	3.41a	2.41b	2.25c	94
7.	24.83	26.47	24.57	22.60	25.73	1.25d	1.66c	1.66c	3.25b	3.28a	97
8.	-	-	-	-	-	-	-	-	-	-	-
9.	21.03	23.07	24.93	27.60	23.80	2.75d	3.33b	3.50a	3.33b	3.08c	84
10.	18.67	21.13	19.07	18.80	17.47	2.20e	2.58d	3.08a	2.91c	3.00b	98
11.	16.53	16.85	17.07	15.80	14.97	1.25e	1.33d	2.41a	2.08b	1.83c	97
12.	20.50	22.40	23.40	24.70	23.33	1.00d	1.25b	1.50a	1.16c	1.25b	88
13.	19.80	21.07	23.00	21.22	19.27	2.08e	2.66b	2.75a	2.50c	2.45d	86
14.	18.93	19.97	21.25	18.38	18.27	2.66e	3.08d	3.75a	3.58b	3.41c	89
15.	-	-	-	-	-	-	-	-	-	-	-
16.	18.70	19.13	21.87	18.80	8.19	2.41d	2.66b	3.08a	2.41d	2.50c	86
17.	9.00	10.24	11.92	8.92	9.77	1.25e	1.83a	1.66c	1.50d	1.75b	88
18.	7.95	9.46	9.92	10.78	10.63	0.79e	1.25c	1.08d	1.50b	1.66a	75
19.	17.87	19.63	19.73	21.90	20.43	1.25d	1.41c	1.50b	1.75a	1.50b	82
20.	12.70	15.30	14.09	13.77	14.02	1.91e	3.08a	2.91b	2.50d	2.58c	83
21.	14.01	15.48	15.60	18.32	16.29	1.00c	1.25b	1.25b	1.66a	1.66a	76
22.	15.39	16.00	14.57	14.78	13.16	2.08c	3.66a	3.41ab	3.25ab	3.16ab	96
23.	14.98	16.12	18.78	16.48	17.00	2.08d	2.50b	2.33c	2.50b	2.58a	88
24.	14.85	15.33	17.48	16.21	14.94	3.83c	3.83c	4.00a	3.91b	3.83c	85
25.	14.66	15.24	15.11	16.86	17.32	2.00b	2.16a	1.83bc	1.58c	1.83bc	96
26.	11.01	12.32	12.82	12.54	14.17	4.41d	4.75b	4.00e	4.50c	4.83a	78
27.	12.76	12.07	15.40	14.76	14.22	1.00e	1.16d	1.50a	1.33c	1.41b	83
28.	6.83	8.32	9.06	10.23	8.76	3.33c	3.58b	3.66b	3.83a	3.08d	67
29.	13.33	13.59	13.80	14.57	13.55	2.08d	2.41c	2.50b	2.66a	2.50b	91
30.	13.66	14.07	13.19	12.96	13.40	4.91c	5.91a	5.66b	5.00c	5.58b	97
31.	11.90	12.38	13.22	12.15	11.66	5.41c	6.33bc	6.41bc	7.33a	7.13ab	98

In a column, means followed by a common letter are not significantly different at 5% level.

- | | | | |
|------------------|-------------------|----------------------|-----------------------|
| 1. Balashahar, | 2. Sandhabari, | 3. Narhatto, | 4. Natun Shahar, |
| 5. Nischintapur, | 6. Monoharpur, | 7. Dikshail, | 8. Ishapur, |
| 9. Dadpur, | 10. Rahmatpur, | 11. Shahajadpur, | 12. Baira, |
| 13. Pali, | 14. Nazirpur, | 15. South Dhanghara, | 16. Ranochandi, |
| 17. Lalapur, | 18. Jatanpukuria, | 19. Daulatpur, | 20. Kamorgram, |
| 21. Dewashara, | 22. Vhanga, | 23. Palima, | 24. Benarpota, |
| 25. Khazura, | 26. Garakhola, | 27. Mogorkhal, | 28. Uttar Char Aicha, |
| 29. Patkhali, | 30. Nadmollah, | 31. West Jhalakathi. | |

4.8.3 Correlation coefficient of soil K values of five extractants with various plant parameters of groundnut

Different plant parameters (threshold yield, plateau yield, per cent relative yield, per cent K concentration (K_o) and K uptake (K_u) of groundnut were correlated with the extracted soil K values of different extractants (1N NH_4OAc , 0.25N $NaHCO_3$, 1N HNO_3 , cold H_2SO_4 and distilled water). The results are presented in Table 4.36. Which suggest that per cent K concentration and per cent K uptake had significant and positive correlation with all five K extractants except per cent K concentration with 1N HNO_3 , which showed insignificant correlation. This insignificant relationship might be due to release of K from non-exchangeable form and its absorption by growing crop was less. Hinderance of absorption may occur due to sufficient supply of readily exchangeable as well as available K from most groundnut growing soil. Ganeshamurthy *et al.* (1985) reported that the release of non-exchangeable K and its uptake by groundnut crop is significant only when readily available K exhausted in the soil.

The results revealed that distilled water soluble K had high degree of correlation with K uptake of groundnut ($r = 0.621^{**}$). The correlation of other extractants was found to be in the following order: 1N NH_4OAc > 0.25N $NaHCO_3$ > Cold H_2SO_4 > 1N HNO_3 . This relationship indicates that the groundnut crop absorb easily the readily exchangeable form of K from the soil than the non-exchangeable form, but the requirement of K might not be sufficient for growing groundnut, as such soils need K fertilization.

Table 4.36. Correlation coefficient (r) of soil K of different extractants with various plant parameters of groundnut.

Plant parameter	K extractant				
	1N NH_4OAc	0.25N NaHCO_3	1N HNO_3 (boiling)	Cold H_2SO_4	Distilled water
Threshold dry matter yield (K control yield)	0.338 *	0.080 NS	0.135 NS	0.258 NS	0.429 *
Plateau dry matter yield (Maximum yield)	0.258 NS	0.007 NS	0.072 NS	0.189 NS	0.338 *
Relative dry matter yield (%)	0.193 NS	0.153 NS	-0.127 NS	0.083 NS	0.335 NS
K concentration (%) at K_0	0.413 *	0.544 **	0.246 NS	0.419 *	0.486 **
K uptake at K_0	0.538 **	0.521 **	0.392 *	0.517 **	0.621 **

** = Significant at 1% level, * = Significant at 5% level,
NS = Not significant.

4.8.4 Critical limit of soil potassium for groundnut

Similar to wheat and potato, a scatter graphical approach and mathematical procedure of Cate and Nelson (1965 and 1971) were used to determine the critical limits of soil potassium for groundnut. The scatter graphical diagram was drawn by plotting extractable K values of five different extractants against the per cent relative yield of groundnut using the procedure described by Cate and Nelson (1965) (Table 4.33 and Figures 4.23 to 4.27). In this procedure, critical limit of soil K extracted by 1N NH_4OAc was found to be 0.36 meq K/100g soil indicating that below this level of K, an

economic response is highly expected. Such limit for 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water method of K extraction appeared to be 0.36 (meq K/100ml soil), 2.16, 0.18 and 0.12 meq K/100g soil respectively (Table 4.37). A soil was considered as non-responsive to K where the per cent relative dry matter yield of groundnut was more than 89, 87, 84, 83 and 89 for 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water extractions respectively (Figures 4.23 to 4.27).

The critical limits obtained from graphical approach were also confirmed by employing the mathematical procedure of Cate and Nelson (1971). By using the mathematical procedure, the calculation of coefficient of determination (R^2) and critical limit for best two population split to differentiate fields in the crop response categories I and II using the two mean discontinuous model was done for the soils with the same extractant as used in the graphical method. This method provided critical limit between 0.35 and 0.36 meq K/100g soil for 1N NH_4OAc , 0.36 and 0.38 meq K/100ml soil for 0.25N NaHCO_3 , 1.99 and 2.34 meq K/100g soil for 1N HNO_3 , 0.17 and 0.18 meq K/100g soil for cold H_2SO_4 and 0.11 and 0.12 meq K/100g soil for distilled water soluble K (Tables 4.38 to 4.42). So the values 0.36, 0.37 (meq K/100ml soil), 2.17, 0.18 and 0.12 meq K/100g soil were taken as the critical limits for 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water extractants respectively (Table 4.37).

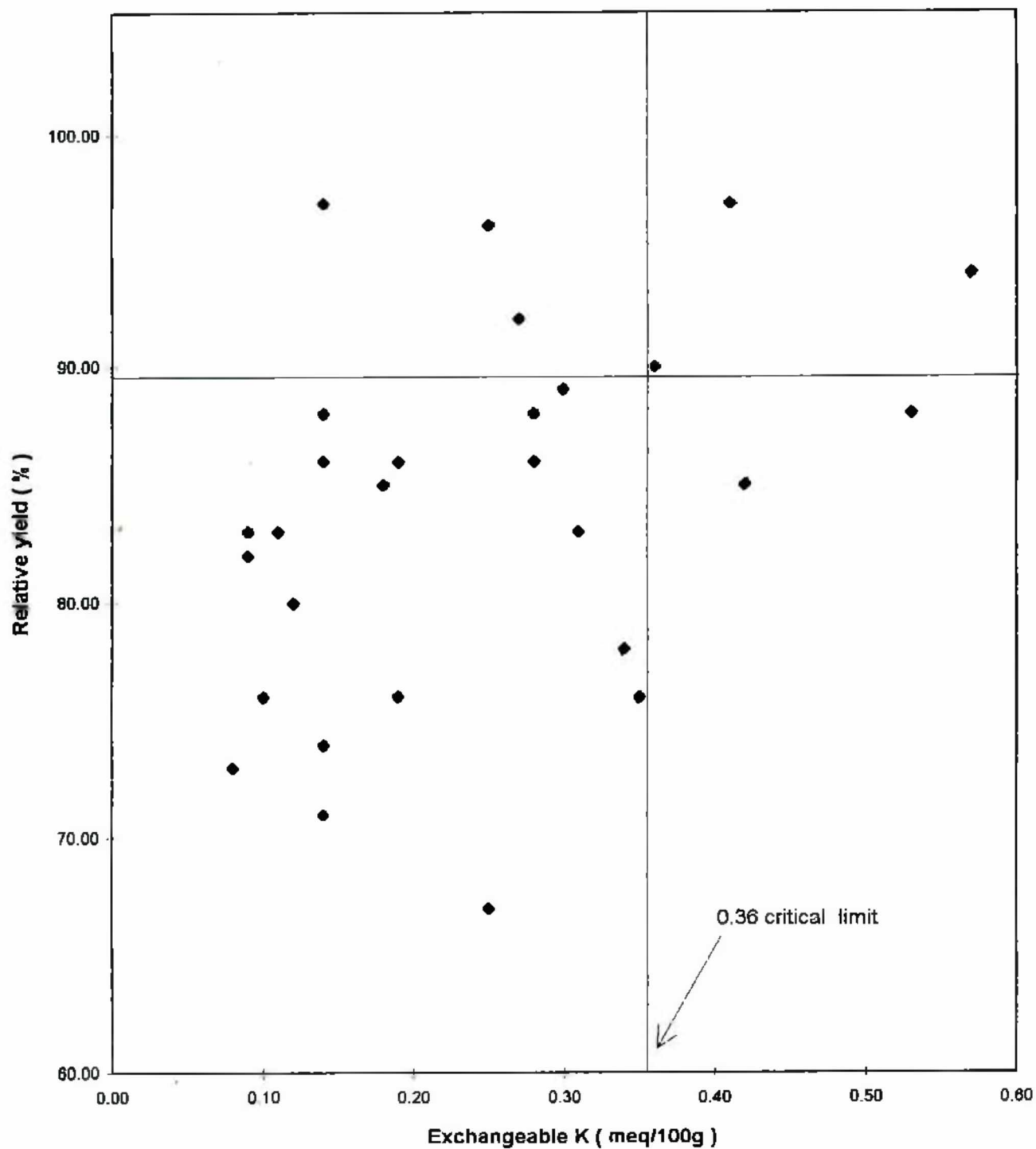


Fig.4.23. Critical limit determination based on the relationship between exchangeable K (1 N NH_4OAc extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations.

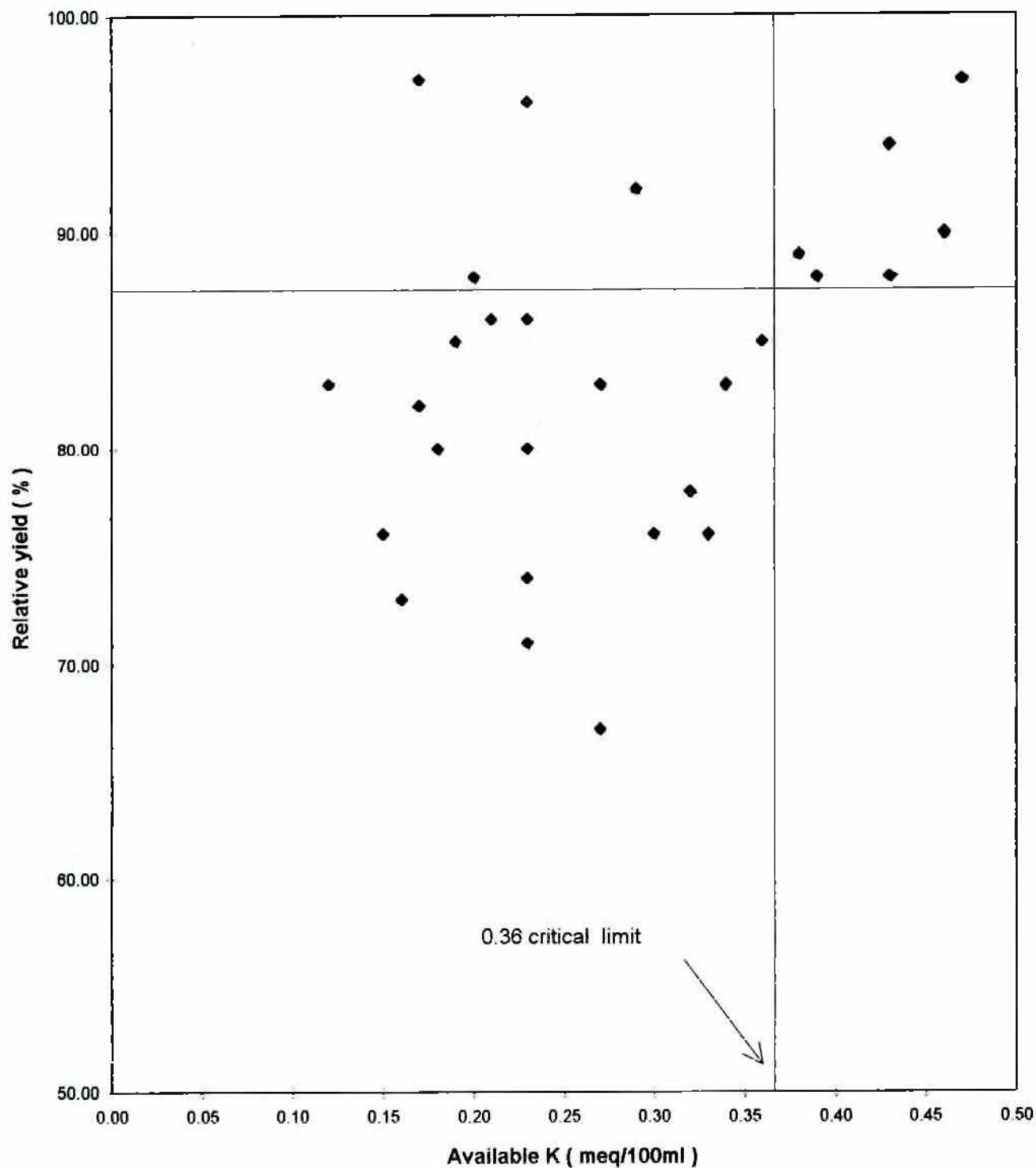


Fig.4.24. Critical limit determination based on the relationship between available K (0.25N NaHCO_3 extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations.

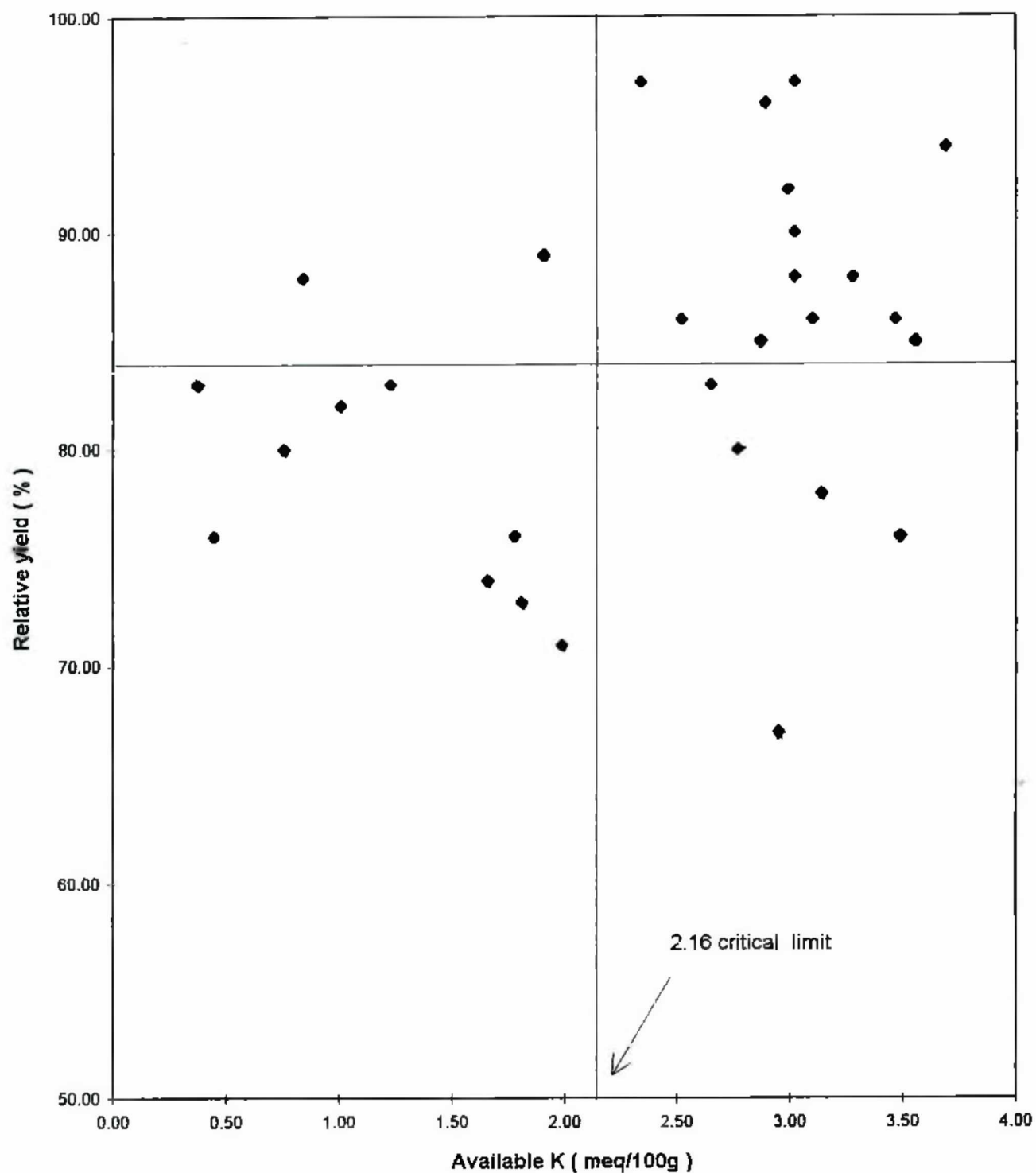


Fig.4.25. Critical limit determination based on the relationship between available K (1 N HNO_3 extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations.

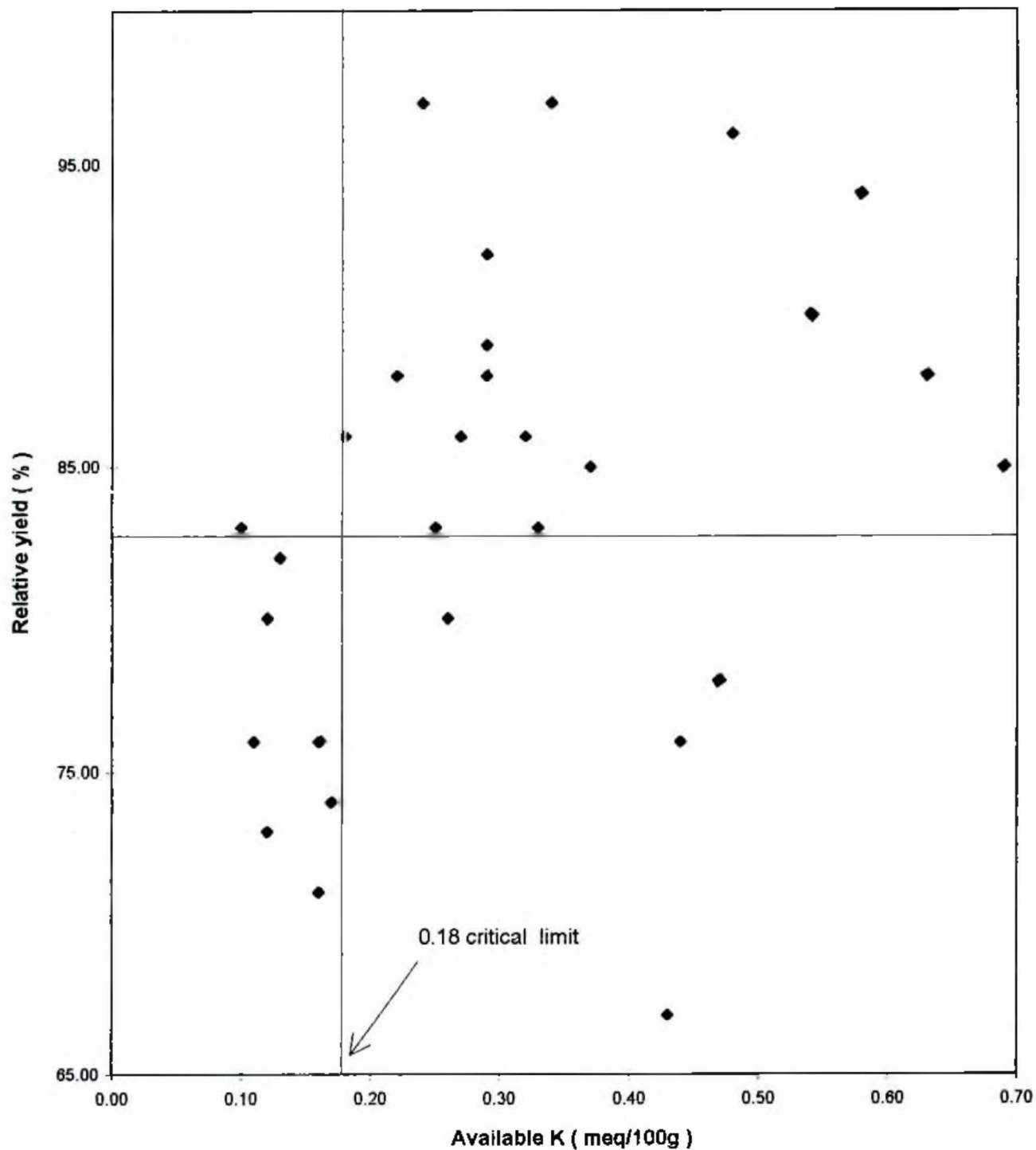


Fig.4.26. Critical limit determination based on the relationship between available K (cold H_2SO_4 extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations.

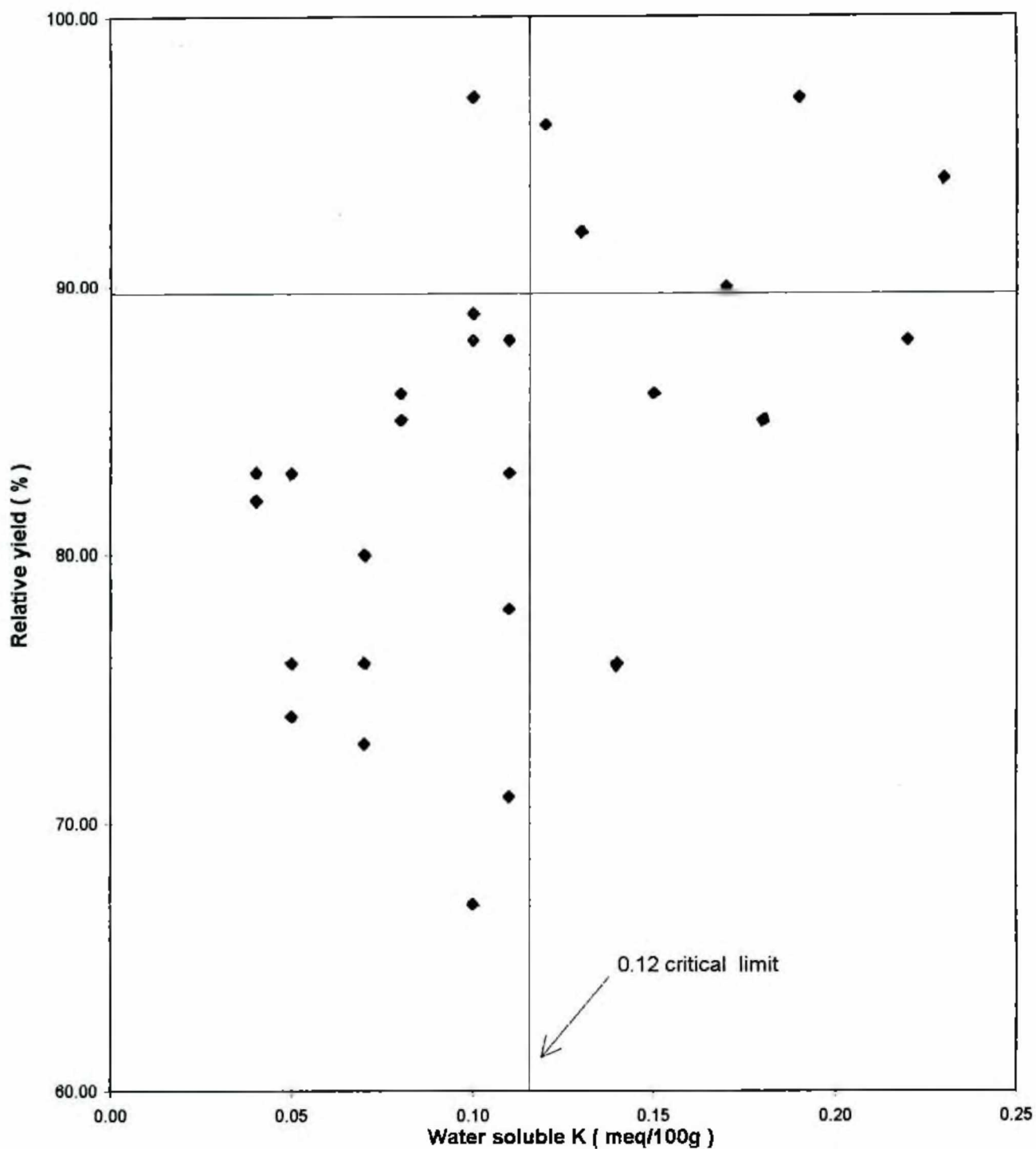


Fig.4.27. Critical limit determination based on the relationship between distilled water soluble K (1:10 soil : water extraction) content of soil and relative dry matter yield of groundnut grown in soils of twenty nine locations.

Table 4.37. Critical limits of five soil K extractants for groundnut as determined by graphical and mathematical procedures.

Soil K extractant	Methods of determining critical limit of K	
	Graphical	Mathematical
1N NH_4OAc	0.355 (meq K/100g soil) (=0.36)	0.355 (meq K/100g soil). (=0.36). (0.35-0.36)*
0.25N NaHCO_3	0.36 (meq K/100ml soil)	0.37 (meq K/100ml soil). (0.36-0.38)*
1N HNO_3	2.16 (meq K/100g soil)	2.165 (meq K/100g soil) (=2.17). (1.99-2.34)*
Cold H_2SO_4	0.175 (meq K/100g soil) (=0.18)	0.175 (meq K/100g soil) (=0.18) (0.17-0.18)*
Distilled water	0.116 (meq K/100g soil) (=0.12)	0.115 (meq K/100g soil) (=0.12). (0.11-0.12)*

* Indicate the range of K critical limit

Table 4.37 indicated that the critical limits of K calculated by mathematical procedure for groundnut were found nearly same as obtained from scatter graphical procedure. Portch et al. (1984) reported 0.20 meq K/100ml soil (which was worked out by Hunter, 1980) as the critical limit of 0.25N NaHCO_3 extractant for most of the upland crops.

Table 4.38. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (1N NH_4OAc extraction).

Last value of exchangeable soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS ¹)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS ²)		
0.08	73	0	84	1593	0.08 & 0.09	0.0702
0.09	79	61	84	1587	0.09 & 0.10	0.0381
0.10	79	69	85	1516	0.10 & 0.11	0.0748
0.11	79	85	85	1513	0.11 & 0.12	0.0673
0.12	80	86	85	1466	0.12 & 0.14	0.0941
0.14	81	579	86	988	0.14 & 0.18	0.0853
0.18	81	593	86	987	0.18 & 0.19	0.0778
0.19	81	643	86	887	0.19 & 0.25	0.1069
0.25	81	1064	87	412	0.25 & 0.27	0.1385
0.27	82	1171	87	386	0.27 & 0.28	0.0912
0.28	82	1219	87	384	0.28 & 0.30	0.0643
0.30	83	1260	86	378	0.30 & 0.31	0.0439
0.31	83	1260	87	365	0.31 & 0.34	0.0515
0.34	83	1282	88	273	0.34 & 0.35	0.0924
0.35	82	1323	91	91	0.35 & 0.36	0.1746 <u>2/</u>
0.36	83	1380	91	90	0.36 & 0.41	0.1420
0.41	83	1579	89	42	0.41 & 0.42	0.0538
0.42	83	1583	91	18	0.42 & 0.53	0.0655
0.53	83	1605	94	0	0.53 & 0.57	0.0632

1/ $R^2 = \frac{\text{TCSS} - (\text{CSS}^1 + \text{CSS}^2)}{\text{TCSS}}$. TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.35 and 0.36 with an average of 0.355 meq K/100g soil.

Table 4.39. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (0.25N NaHCO_3 extraction).

Last value of available soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit 1/
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.12	83	0	84	1713	0.12 & 0.15	0.00018
0.15	80	25	84	1650	0.15 & 0.16	0.02236
0.16	77	53	85	1523	0.16 & 0.17	0.08014
0.17	82	143	84	1356	0.17 & 0.18	0.00835
0.18	82	347	84	1338	0.18 & 0.19	0.01652
0.19	82	355	84	1338	0.19 & 0.20	0.01185
0.20	83	384	84	1323	0.20 & 0.21	0.00368
0.21	84	398	84	1315	0.21 & 0.23	0.00018
0.23	83	814	85	875	0.23 & 0.27	0.01418
0.27	82	1051	86	527	0.27 & 0.29	0.07897
0.29	83	1147	86	492	0.29 & 0.30	0.04337
0.30	82	1187	87	386	0.30 & 0.32	0.08189
0.32	82	1203	88	300	0.32 & 0.33	0.12275
0.33	82	1237	89	144	0.33 & 0.34	0.19395
0.34	82	1238	90	99	0.34 & 0.36	0.21963
0.36	82	1249	91	68	0.36 & 0.38	0.23111 2/
0.38	82	1297	91	63	0.38 & 0.39	0.20621
0.39	82	1330	92	49	0.39 & 0.43	0.19512
0.43	83	1485	94	25	0.43 & 0.46	0.11866
0.46	83	1532	97	0	0.46 & 0.47	0.10582

1/ $R^2 = \frac{\text{TCSS} - (\text{CSS}^1 + \text{CSS}^2)}{\text{TCSS}}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.36 and 0.38 with an average of 0.37 meq K/100ml soil.

Table 4.40. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (1N HNO_3 extraction).

Last value of available soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)		
0.37	83	0	84	1713	0.37 & 0.45	0.00018
0.45	80	25	84	1650	0.45 & 0.76	0.02236
0.76	80	25	84	1633	0.76 & 0.84	0.03228
0.84	82	77	84	1618	0.84 & 1.01	0.01068
1.01	82	77	84	1613	1.01 & 1.23	0.01360
1.23	82	78	84	1612	1.23 & 1.66	0.01360
1.66	81	133	85	1503	1.66 & 1.78	0.04512
1.78	80	154	85	1424	1.78 & 1.81	0.07897
1.81	79	200	86	1270	1.81 & 1.91	0.14201
1.91	80	282	86	1259	1.91 & 1.99	0.10057
1.99	80	363	86	1036	1.99 & 2.34	0.18345 <u>2/</u>
2.34	81	642	86	916	2.34 & 2.52	0.09064
2.52	81	665	86	915	2.52 & 2.65	0.07780
2.65	82	668	86	908	2.65 & 2.77	0.03811
2.77	81	670	86	871	2.77 & 2.87	0.10057
2.87	82	682	86	859	2.87 & 2.89	0.09473
2.89	82	876	86	769	2.89 & 2.95	0.03987
2.95	82	1102	87	392	2.95 & 2.99	0.12800
2.99	82	1205	87	368	2.99 & 3.02	0.08189
3.02	83	1483	85	221	3.02 & 3.10	0.00543
3.10	84	1490	85	220	3.10 & 3.14	0.00193
3.14	83	1519	86	169	3.14 & 3.28	0.01477
3.28	84	1540	85	163	3.28 & 3.47	0.00601
3.47	84	1546	85	162	3.47 & 3.49	0.00309
3.49	83	1602	90	41	3.49 & 3.55	0.04103
3.55	83	1605	94	0	3.55 & 3.69	0.06321

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 1.99 and 2.34 with an average of 2.165 meq K/100g soil.

Table 4.41. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (cold H_2SO_4 extraction).

Last value of available soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit 1/
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)		
0.10	83	0	84	1713	0.10 & 0.11	0.00018
0.11	80	25	84	1650	0.11 & 0.12	0.0223
0.12	78	58	85	1501	0.12 & 0.13	0.09006
0.13	79	71	85	1494	0.13 & 0.16	0.08656
0.16	77	123	86	1203	0.16 & 0.17	0.22605
0.17	77	133	86	1057	0.17 & 0.18	0.30543 2/
0.18	78	207	86	1057	0.18 & 0.22	0.25224
0.22	79	299	86	1054	0.22 & 0.24	0.21030
0.24	81	597	86	934	0.24 & 0.25	0.10640
0.25	81	602	86	926	0.25 & 0.26	0.10815
0.26	81	603	86	889	0.26 & 0.27	0.12917
0.27	81	629	86	889	0.27 & 0.29	0.11399
0.29	83	820	85	837	0.29 & 0.32	0.03286
0.32	83	831	85	837	0.32 & 0.33	0.02644
0.33	83	831	86	830	0.33 & 0.34	0.03053
0.34	84	1023	84	686	0.34 & 0.37	0.00251
0.37	84	1025	84	686	0.37 & 0.43	0.00134
0.43	83	1287	87	345	0.43 & 0.44	0.04745
0.44	82	1332	89	212	0.44 & 0.47	0.09882
0.47	82	1351	91	79	0.47 & 0.48	0.16535
0.48	83	1531	89	43	0.48 & 0.54	0.08131
0.54	83	1579	89	42	0.54 & 0.58	0.05187
0.58	84	1693	87	5	0.58 & 0.63	0.00893
0.63	84	1712	85	0	0.63 & 0.69	0.00076

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.17 and 0.18 with an average of 0.175 meq K/100g soil.

Table 4.42. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut (distilled water extraction).

Last value of distilled water soluble soil K included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit 1/
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.04	83	1	84	1709	0.04 & 0.05	0.00193
0.05	80	73	85	1536	0.05 & 0.07	0.06088
0.07	79	120	86	1240	0.07 & 0.08	0.20621
0.08	80	235	86	1238	0.08 & 0.10	0.14026
0.10	82	800	86	741	0.10 & 0.11	0.10057
0.11	81	966	89	342	0.11 & 0.12	0.23656 2/
0.12	82	1173	89	292	0.12 & 0.13	0.14493
0.13	82	1269	88	278	0.13 & 0.14	0.09706
0.14	82	1309	90	110	0.14 & 0.15	0.17177
0.15	82	1323	91	91	0.15 & 0.17	0.17469
0.17	83	1380	91	90	0.17 & 0.18	0.14201
0.18	83	1386	93	42	0.18 & 0.19	0.16652
0.19	83	1583	91	18	0.19 & 0.22	0.06555
0.22	83	1605	94	0	0.22 & 0.23	0.06321

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 0.11 and 0.12 with an average of 0.115 meq K/100g soil.

Based on the K critical limits of all extractants, soils of experimental sites were partitioned into two categories i.e., below and above the critical limit. It is observed from the present results that soils below the critical limits showed increasing trend of dry matter yield up to the range of 30 to 45mg K kg⁻¹ application for all extractants (Table 4.43 and Figures 4.28 to 4.32). The dry matter yield of groundnut ranged from 11.72 to 15.87g pot⁻¹ when potassium was applied from 0 to 60mg K kg⁻¹. On the other hand, the beneficial yield increase was also observed with the soils containing K values above the critical limit and it was ranging from 15.49 to 18.56g pot⁻¹ with the application of same amount of potassium in soil. No economic response was found beyond this level due to beneficial increase in dry matter yield of groundnut (Table 4.43 and Figures 4.28 to 4.32). The results also indicated that maximum crop response was obtained from 1N NH₄OAc followed by 0.25N NaHCO₃ extractable K since they responded 83 and 76 percent of the total soils respectively (Table 4.43).

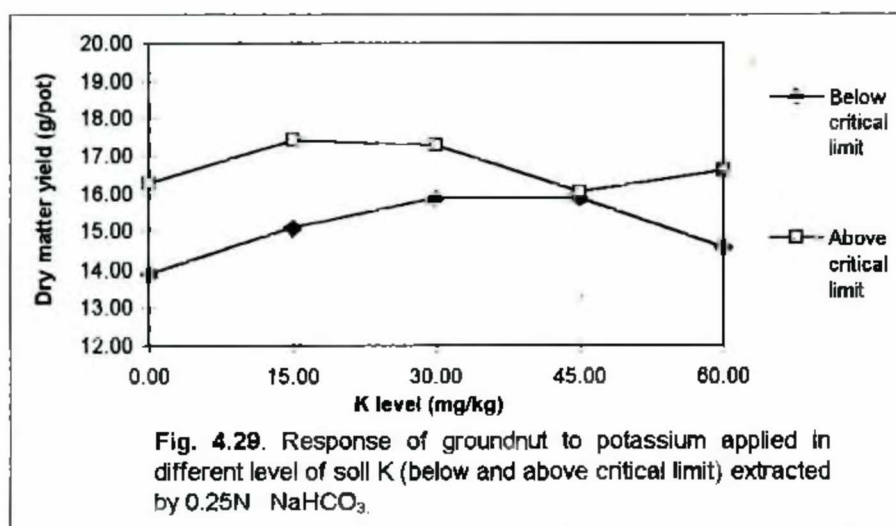
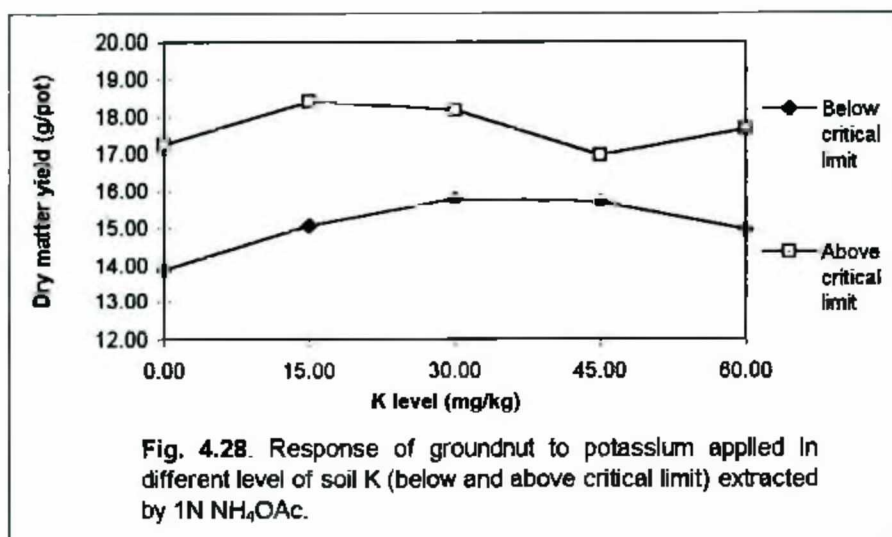
From this study, it could be concluded that groundnut plant might respond to K application economically in these soils if 1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled water soluble K are remain below the critical limits in both the methods for determining critical limit (graphical and mathematical). Therefore, the values of K critical limits can effectively be used to separate K responsive soils from the non-responsive ones and be helpful in rationalizing K fertilization programme for groundnut cultivation.

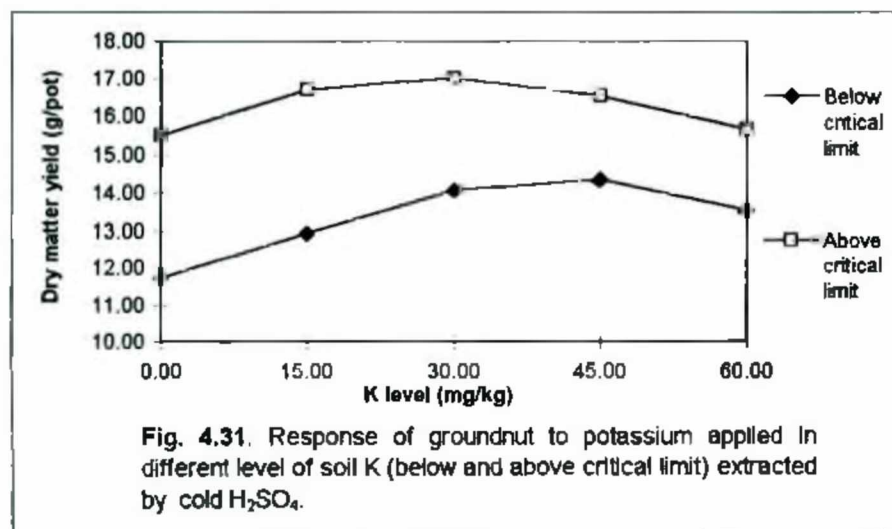
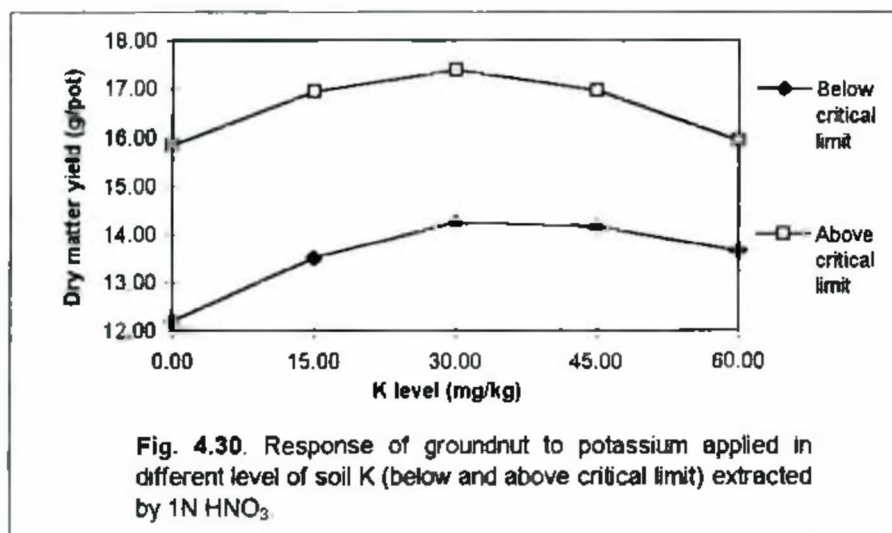
Table 4.43. Response of groundnut to potassium applied in different level of soil K (below and above the critical limit) determined by using five extractants.

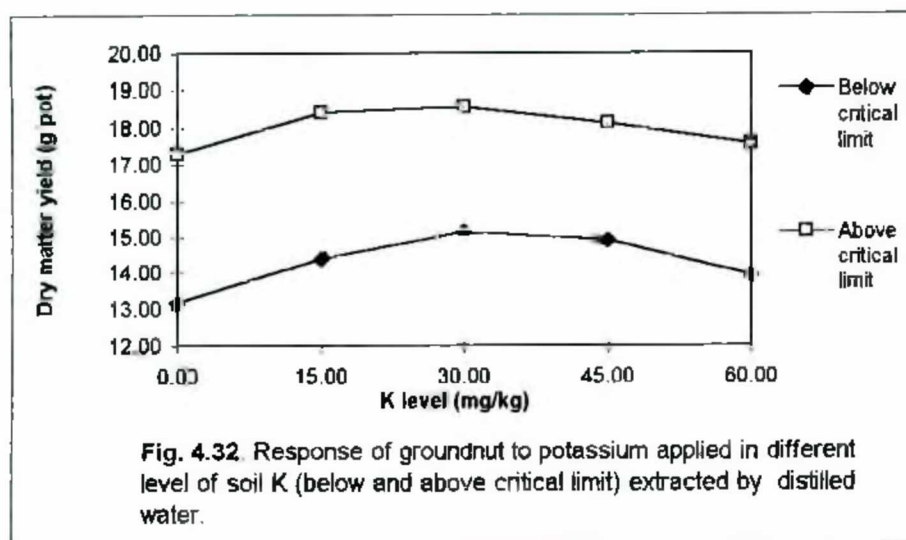
Soil K extractant	Level of K in soil (me %)	Number of soils responded	Average dry matter yield (g pot ⁻¹)				
			K applied (mg K kg ⁻¹)				
			0	15	30	45	60
1N NH ₄ OAc	<0.36 (0.08-0.35) ¹	24 (83)*	13.87	15.06	15.78	15.68	14.93
	>0.36 (0.36-0.57) ¹	5 (17)	17.23	18.40	18.15	16.94	17.65
0.25N NaHCO ₃	<0.36 (0.12-0.34) ¹	22 (76)	13.87	15.08	15.87	15.86	14.56
	>0.36 (0.36-0.47) ¹	7 (24)	16.26	17.41	17.27	16.03	16.61
1N HNO ₃	<2.16 (0.37-1.99) ¹	11 (38)	12.19	13.51	14.26	14.17	13.65
	>2.16 (2.34-3.69) ¹	18 (62)	15.83	16.94	17.37	16.95	15.92
Cold H ₂ SO ₄	<0.18 (0.10-0.17) ¹	8 (28)	11.72	12.93	14.07	14.33	13.51
	>0.18 (0.18-0.69) ¹	21 (72)	15.49	16.67	17.00	16.50	15.64
Distilled water	<0.12 (0.04-0.11) ¹	20 (69)	13.16	14.39	15.13	14.91	13.93
	>0.12 (0.12-0.23) ¹	9 (31)	17.30	18.41	18.56	18.10	17.56

* Figures in parentheses indicate percent of the total

¹ Range of K (me %) in soil







4.8.5 Critical limit of potassium determined from K concentration in groundnut plant

For evaluating the critical K concentration in groundnut plant, both graphical and mathematical methods of Cate and Nelson (1965 and 1971) were employed. A value of 1.10% for 1N HCl extraction was found to be as critical K concentration in groundnut plant for graphical method (Figure 4.33). Figure 4.33 revealed that the crop could be considered as non-responsive to K where per cent relative dry matter yield was found more than 77 for groundnut. Critical K concentration limit for mathematical procedure appeared

to be as 1.13% with the same extractant as used in graphical method (Table 4.44). The critical K concentration values obtained from graphical and mathematical procedures are as follows:

Graphical	1.10%
Mathematical	1.13%

These values are fairly close to each other. Similar values of critical K concentration in groundnut was reported by many workers. Chapman (1967) reported <1.30% as low K concentration in peanut plant at early bloom stage, while Rao et al. (1989) indicated < 1.3% as extremely deficient and 1.3 to 1.9% as moderately deficient K concentration in groundnut plant.

It may be concluded that an economic response of groundnut plant might be expected below the critical K concentration level and it could help to distinguish the K deficient plants from the adequate ones.

4.8.6 Efficiency of applied potassium for the dry matter yield of groundnut

The efficiency of applied potassium was calculated in order to test the reliability of critical limits on the basis of the dry matter yield increase over the control (K_0) for each mg of applied

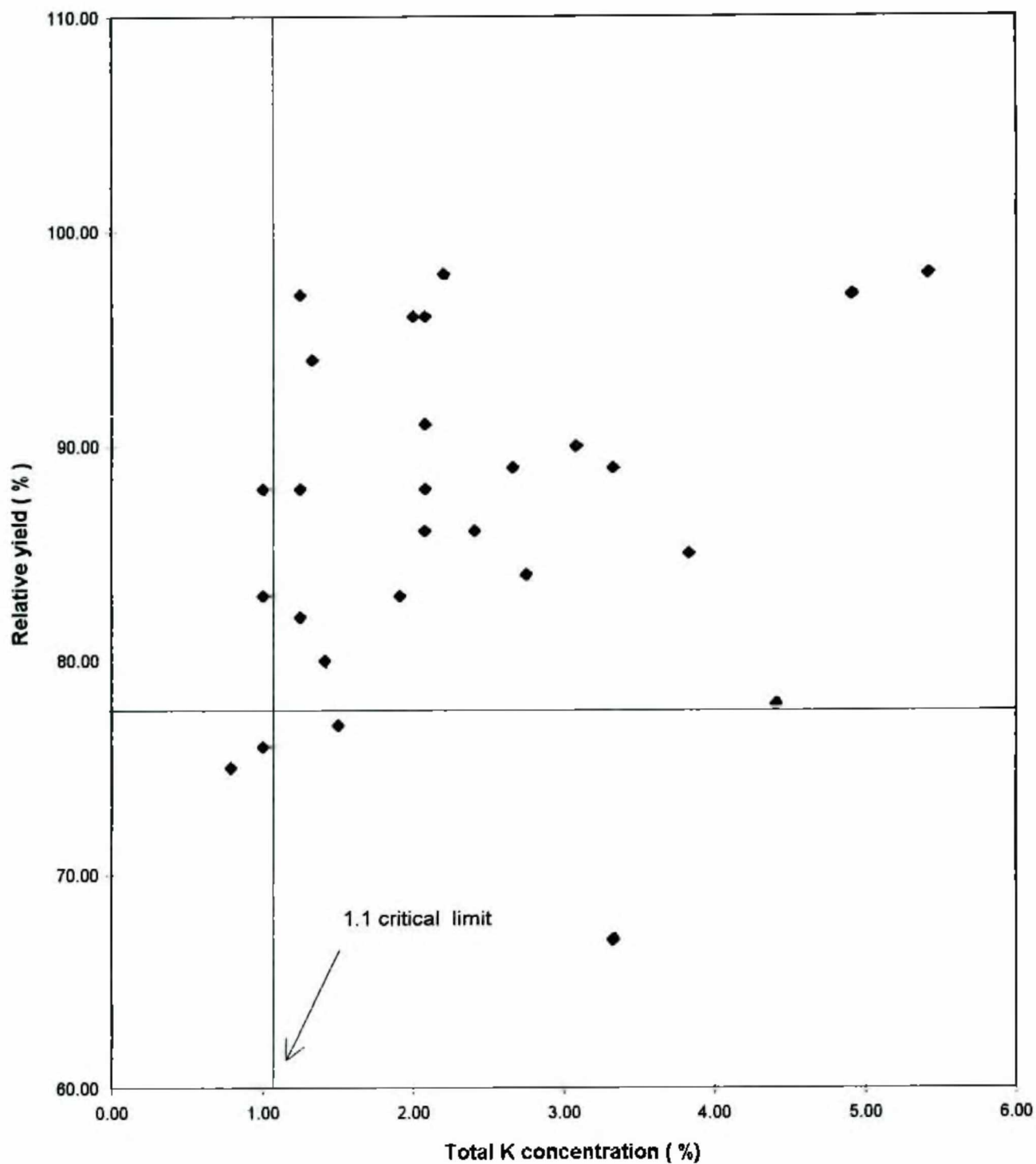


Fig.4.33. . Critical limit determination based on the relationship between total K (1 N HCl extraction) concentration in plant & relative dry matter yield of groundnut grown in soils of twenty nine locations.

Table 4.44. Co-efficient of determination (R^2) and K critical limit for best two population split using the 2-mean discontinuous model for groundnut plant (1N HCl extraction).

Last value of K conc. (%) included in population 1	Population 1		Population 2		Postulated critical limit between values	R^2 for postulated critical limit <u>1/</u>
	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
0.79	75	0	87	1607	0.79 & 1.00	.0853
1.00	81	113	88	1446	1.00 & 1.25	.1126 <u>2/</u>
1.25	86	496	88	1243	1.25 & 1.33	.0102
1.33	87	556	87	1199	1.33 & 1.41	.0011
1.41	86	596	88	1145	1.41 & 1.50	.0090
1.50	85	670	88	1027	1.50 & 1.91	.0341
1.91	85	674	88	998	1.91 & 2.00	.0483
2.00	86	786	88	938	2.00 & 2.08	.0187
2.08	87	903	87	853	2.08 & 2.20	.0005
2.20	87	1021	86	728	2.20 & 2.41	.0045
2.41	87	1023	86	728	2.41 & 2.66	.0033
2.66	87	1025	86	720	2.66 & 2.75	.0068
2.75	87	1036	86	715	2.75 & 3.08	.0033
3.08	87	1043	86	699	3.08 & 3.33	.0085
3.33	87	1448	90	281	3.33 & 3.83	.0159
3.83	87	1450	91	254	3.83 & 4.41	.0301
4.41	86	1521	98	0.5	4.41 & 4.91	.1040
4.91	87	1632	98	0	4.91 & 5.41	.0711

1/ $R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$, TCSS = Total corrected sum of squares

2/ Critical limit lies between 1.00 and 1.25 with an average of 1.125%.

K in presence of NPS fertilizers (Table 4.45). Application of K @ 15mg K kg⁻¹ produced 79.33 to 88.00mg dry matter of groundnut by each mg of applied K in soils having K values below the critical limit but the soils which had K values above the critical limit produced low dry matter yield as compared to deficient soils (soils below the critical limit). Dry matter yield from K adequate soils ranged from 74.00 to 78.67mg by each mg of applied K, applicable for all five K extractants. Table 4.45 indicated that in both the soil levels (below and above the critical limit) the dry matter yield decreased with increasing K levels (30 to 60mg K kg⁻¹). Similar trend of fertilizer K use efficiency was observed for all the five extractants used in this study. The fertilizer K use efficiency by groundnut plant was found maximum in K deficient soil (soils value below the critical limit) and minimum in K adequate soils. It is assumed from the present results that increasing the levels of applied K also resulted in low K utilization and hence, fertilizer K use efficiency decreased. From this study, it can be concluded that for groundnut cultivation, it is essential to apply K fertilizer only when the soil K value remain below the critical limit.

Table 4.45. Efficiency of applied K for the dry matter yield of groundnut.

Soil K extractant	Level of K in soil (me %)	Number of soils responded	K fertilizer use efficiency (mg yield mg k ⁻¹)				
			K applied (mg K kg ⁻¹)				
			0	15	30	45	60
1N NH ₄ OAc	<0.36 (0.08-0.35)	24	-	79.33	63.67	40.22	17.67
	>0.36 (0.36-0.57)	5	-	78.00	30.67	-6.44	7.00
0.25N NaHCO ₃	<0.36 (0.12-0.34)	22	-	80.67	66.67	44.22	11.50
	>0.36 (0.36-0.47)	7	-	76.67	33.67	-5.11	5.83
1N HNO ₃	<2.16 (0.37-1.99)	11	-	88.00	69.00	44.00	24.33
	>2.16 (2.34-3.69)	18	-	74.00	51.33	24.89	1.50
Cold H ₂ SO ₄	<0.18 (0.10-0.17)	8	-	80.67	78.33	58.00	29.83
	>0.18 (0.18-0.69)	21	-	78.67	50.33	22.44	2.50
Distilled water	<0.12 (0.04-0.11)	20	-	82.00	65.67	38.89	12.83
	>0.12 (0.12-0.23)	9	-	74.00	42.00	17.78	4.33

CHAPTER 5.0

SUMMARY AND CONCLUSIONS

For proper growth and nutrition, plant needs at least sixteen essential elements, of which potassium is taken up in large quantities than any other elements. Deficiency of this element affects various physiological and biological processes and thereby reduces crop yield. As potassium is highly mobile within the plant, the first common deficiency symptom is scorching or firing and browning usually starts from the leaf tips and margins of the older leaves.

Potassium deficiency generally occurs in acid sandy soils or highly leached lateritic soils. The soils which have very high contents of Ca and Mg may also restrict K uptake by the plants leading to K deficiency.

Upland crops like wheat, potato and groundnut were taken as test crops for net house experiment to determine critical limits of potassium in soils and crops using Cate and Nelson graphical and mathematical procedures.

Thirty one soils (0-15cm depth) were collected from different locations representing seven general soil types and fourteen agroecological zones of Bangladesh on the basis of low, medium and high exchangeable potassium category.

From soil analyses, it was found that soil pH varied from 4.61 to 7.95 and organic matter ranged from 0.60 to 1.30%. The quantity of Ca (1.00 to 14.30 meq/100ml) and Mg (0.20 to 5.41 meq/100ml soil) obtained from the soil seemed to be adequate in all locations except Natun Shahar, Jatanpukuria and Dewashara but the content of Mg was found below the critical limit (0.70 meq/100g soil) in five locations (i.e., Nischintapur, Ranochandi, Lalapur, Daulatpur and Mogorkhal). Na and Zn contents were found adequate in soils of thirty one locations and P content ranged from 9.0 to 45.00 μ g/ml and S from 8.00 to 25.00 μ g/ml soil.

The CEC of soils ranged from 5.43 to 11.11 meq/100g soil with the lowest value observed from the soil of Natun Shahar and highest from Dikshail and Monoharpur. Particle size distribution in all tested soils was found to be sandy loam to clay and clay loam in texture.

Among five K extraction methods, the range of K extracted by ammonium acetate was higher than that of sodium bicarbonate and distilled water soluble K. The K extracting capacity of different extractants was found in the following order: 1N HNO₃ > cold H₂SO₄ > 0.25N NaHCO₃ > 1N NH₄OAc > distilled water.

The efficiency of the potassium saturation percentage of tested extractants was measured by the value of standard error. It is assumed that the lower the value of standard error ($\pm$), the higher the capacity of per cent K saturation. As such, the

performance of the extractant for K saturation was found in the following order: 0.50 (distilled water) > 1.07 (0.25N NaHCO₃) > 1.23 (1N NH₄OAc) > 1.61 (cold H₂SO₄) > 12.01 (1N HNO₃).

A correlation study was done between extractable K of five extractants and soil properties. The highest degree of correlation was found between cold H₂SO₄ extractable K and Ca ($r = 0.823$ **), 1N NH₄OAc extractable K and CEC ($r = 0.809$ **), distilled water soluble K and clay ($r = 0.781$ **), 1N HNO₃ extractable K and pH ($r = 0.772$ **) and 0.25N NaHCO₃ extractable K and clay ($r = 0.748$ **).

From intercorrelation study it could be inferred that among different extractants, 1N NH₄OAc extractable K was more related to distilled water ($r = 0.918$ **) and cold H₂SO₄ ($r = 0.860$ **) followed by 0.25N NaHCO₃ ($r = 0.840$ **) extractant as evidenced by higher r values.

The dry matter yield of wheat increased with increasing levels of K up to 30 to 45 mg K kg⁻¹ levels. Due to differences of initial soil K distinct variation was also observed for the threshold yield (2.37 to 5.44g pot⁻¹), Plateau yield (2.99 to 6.36g pot⁻¹) and per cent relative yield at optimum K level (59 to 95%) of wheat. Marked variation was also observed in K concentration of wheat at K_o due to variation in initial K fertility and it ranged from 2.41 to 5.83%. Simultaneously, K uptake was increased with increasing levels of applied K up to 30 to 45 mg K kg⁻¹ levels and ranged from 60 to 467 mg K kg⁻¹.

The K concentration in wheat plant increased with increasing levels of applied K up to 30 to 45 mg K kg⁻¹ level and ranged from 2.41 to 7.75%. On the basis of K concentration in wheat plant, per cent relative yield was calculated from the corresponding dry matter yield of wheat and it ranged from 59 to 100%.

Analyses of simple correlation coefficient calculation were done between K contents of five extractants and various plant parameters of wheat. All soil K extractants (1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled water) were found to be useful for estimating K from the soil due to their significant and positive correlations with per cent relative yield, per cent K concentration (at K₀) and K uptake (at K₀) of wheat plant. None of the tested extractants had any significant relationship with threshold and plateau yield except 0.25N NaHCO₃, which correlated significantly with the threshold yield at lower r value (r= 0.357 *).

Among all K extractants, cold H₂SO₄ highlighted the superiority over the other four, as it gave higher r value with per cent K concentration (at K₀) (r= 0.652 **) followed by per cent relative yield of wheat (r= 0.642 **).

The critical limits of soil K calculated for wheat both by graphical and mathematical procedures of Cate and Nelson were found to be 0.13, 0.28 (meq K/100ml soil), 1.86, 0.34 and 0.08 meq K/100g soil for 1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled

water extractants. Wheat plants responded to potassium application when extractable soil K of 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water were found below the critical limits. Among all K extractants, maximum crop response was obtained from cold H_2SO_4 extractable K followed by 0.25N NaHCO_3 as they covered 65 and 58% of the total soils when the soils remained below the critical limit. The response was minimum when the soils K value remained above the critical limit.

The critical K concentration limit of wheat plant obtained by graphical and mathematical procedures were as 4.02 and 4.04% for 1N HCl extraction procedure.

In order to test the reliability of critical limit, the efficiency of applied potassium was evaluated considering the level of K in soil and different extractants. Results revealed that the fertilizer K use efficiency by wheat plants was maximum in low K soils (soils K below the critical limit) and minimum in soils that had K values above the critical limit. Increasing levels of applied K resulted in low K utilization and hence, fertilizer K use efficiency decreased. This trend of fertilizer K use efficiency was found similar for all the extractants used in this study.

Due to wide variability of K fertility in the tested soil, the marked variation was also recorded for threshold yield (4.70 to 10.25g pot^{-1}), plateau yield (5.97 to 14.21g pot^{-1}) and per cent relative yield (50 to 93%) of potato. The dry matter yield of

potato increased with increasing the level of K up to 50 to 75 mg K kg⁻¹ for all soils under study. The range of K concentration (at K₀) in potato plant ranged from 3.08 to 11.08%. Results revealed that K uptake of potato plant (at 42 days of harvesting) increased with the increasing levels of K up to 50 to 75 mg K kg⁻¹ levels and it ranged from 193 to 1761 mg pot⁻¹.

Added K had marked influence on the increase of K concentration in potato plant. Results indicated that K concentration increased with increasing the K application up to 50 to 75 mg K kg⁻¹ level and ranged from 3.08 to 14.50% for all treatments. Per cent relative yield was calculated from the K concentration and corresponding dry matter yield of potato which was ranged from 70 to 102%.

The threshold yield, per cent relative yield, per cent K concentration (at K₀) and K uptake (at K₀) of potato manifested significantly positive relationship with all the K extractants (1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled water) except threshold and per cent relative yield. The latter did not show significant relationship but revealed positive relationship with 0.25N NaHCO₃ extractant. None of the extractants had statistically significant correlation with the plateau yield of potato. Among all extractants, 1N NH₄OAc extractable K gave the highest degree of correlation with K uptake ($r = 0.739^{**}$) followed by per cent K concentration ($r = 0.709^{**}$) of potato and they found in the following order: 1N NH₄OAc > distilled water > cold H₂SO₄ >

0.25N NaHCO₃ > 1N HNO₃. From this correlation, it could be inferred that 1N NH₄OAc extractable K was more related to K uptake as it gave higher r value (r= 0.739 **) followed by per cent K concentration (at K₀) (r= 0.709 **).

The critical limits of soil K determined by graphical procedure for 1N NH₄OAc, 0.25N NaHCO₃, 1N HNO₃, cold H₂SO₄ and distilled water were as 0.29, 0.24 (meq K/100ml soil), 0.90, 0.30 and 0.14 meq K/100g soil respectively but for mathematical procedure, the values were 0.29, 0.25 (meq K/100ml soil), 0.93, 0.31 and 0.15 meq K/100g soil respectively for potato.

There was an increasing trend of response to potassium application for five K extractants in soils contained K below the critical limit but the soils contained K values above the critical limit, the increase of the dry matter yield of potato was marginal.

Among the tested extractants the highest crop response was recorded from distilled water (77%) followed by 1N NH₄OAc (68%) extractable K.

The critical K concentration limit in potato plant by graphical and mathematical procedures were 6.40 and 6.46% respectively for 1N HCl extraction procedure.

Results indicated that the maximum efficiency of applied potassium was found in soils having potassium values below the

critical limit but the soils contained K values above the critical limit, gave minimum use efficiency as compared to K deficient soils. This trend of K use efficiency was equally applicable for K values of all extractants except IN HNO_3 extractable K for deficient soils. The dry matter yield of potato decreased by increasing K levels in both the soil levels (i.e., below and above the critical limit). This trend was similar for all extractants used in this study.

Application of potassium increased the dry matter yield of groundnut with increasing the levels of K up to 30 to 45 mg K kg^{-1} level. Initial soil K fertility and added K had great influence on the threshold, plateau and per cent relative yield of groundnut. The threshold, plateau and per cent relative yield of groundnut were 6.83 to 24.83 g pot^{-1} , 8.47 to 27.60g pot^{-1} , and 67 to 97% respectively.

Both initial soil potassium fertility as well as added potassium had marked effect on the per cent K concentration (at K_0) of groundnut plant and it ranged from 0.79 to 5.41%. Uptake of K by groundnut plant increased with increasing the level of added K and ranged from 63 to 919 mg pot^{-1} . The trend of K uptake was found higher within 30 to 45 mg K kg^{-1} application.

Applied K and initial K content of the soil had great influence on the K concentration of groundnut plant for the soils of all locations and it ranged from 0.79 to 7.33%. Per cent

relative yield was calculated on the basis of the K concentration and corresponding dry matter yield of groundnut and was varied from 67 to 98%.

Simple correlation coefficient between soil potassium values of five extractants and various plant parameters of groundnut indicated that per cent K concentration and per cent K uptake established significant and positive correlation with five K extractants (i.e., 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water) except per cent K concentration with 1N HNO_3 , which was insignificant. Among all K extractants, distilled water soluble K had high degree of correlation with the K uptake (at K_0) of groundnut ($r = 0.621^{**}$) and found in the following order: distilled water > 1N NH_4OAc > 0.25N NaHCO_3 > cold H_2SO_4 > 1N HNO_3 .

Critical limits of soil K extracted by 1N NH_4OAc , 0.25N NaHCO_3 , 1N HNO_3 , cold H_2SO_4 and distilled water appeared to be 0.36, 0.36 (meq K/100ml soil), 2.16, 0.18 and 0.12 meq K/100g soil respectively for graphical procedure but for mathematical procedure, these values were respectively as 0.36, 0.37 (meq K/100ml soil), 2.17, 0.18 and 0.12 meq K/100g soil for groundnut.

Results indicated that soils K remained below the critical limits showed increasing trend of dry matter yield up to the range of 30 to 45 mg K kg^{-1} level for all extractants. The dry matter yield ranged from 11.72 to 15.87 g pot^{-1} when K added from 0 to 60 mg K kg^{-1} . But marginal yield increase was observed in soils where

K values remained above the critical limit and ranged from 15.49 to 18.56 g pot⁻¹ with the same amount of added potassium.

Maximum crop response was obtained from 1N NH₄OAc followed by 0.25N NaHCO₃ extractable K since they responded 83 and 76% of the total soils, respectively.

The efficiency of applied potassium was calculated to test the reliability of critical limits. Results revealed that maximum efficiency of applied potassium was observed in soils having K values below the critical limit but soil having K values above the critical limit gave low efficiency of applied potassium. In both the soil levels (i.e., below and above the critical limit) dry matter yield decreased with increasing K levels. This trend was equally applicable for all K extractants.

Following the graphical and mathematical procedures, the values of 1.10 and 1.13%, respectively were found to be the critical K concentration in groundnut plant for 1N HCl extraction procedure.

The results of the present investigations may led the following conclusions:

1. All soil K extractants were found to be useful for estimating K from the soil due to their significant and positive correlation with per cent K concentration (K_o) and K uptake

(Ko) of crops under study. Among the five extractants, cold H_2SO_4 was found to be the best in determining the level of soil K considering the response of wheat. Similarly, 1N NH_4OAc for potato and distilled water for groundnut.

2. The estimated critical limit of soil K using mathematical procedure were 0.34 meq K/100g soil extracted by cold H_2SO_4 for wheat, 0.29 meq K/100g soil extracted by 1N NH_4OAc for potato and 0.12 meq K/100g soil extracted by distilled water for groundnut, while the values of critical K concentration of wheat, potato and groundnut plant were as 4.04, 6.46 and 1.13% by HCl extraction procedure. Mathematical procedure appeared to be slightly better than the graphical procedure due to possible human bias in the latter in drawing partition line.
3. The estimated critical limits either of soil or of plant can be effectively used by researchers; extensionists or related policy makers-

to differentiate K responsive soils from the non-responsive ones;

in working out K fertilizer schedule of different crops, and

used for rational and judicious K fertilizer management programme to obtain desired crop yield.

CHAPTER 6.0

REFERENCES

- AHMED, Z and M H HAQUE. 1978. Nutrient uptake by rice plant at different stages of growth. *Bangladesh J. Soil Sci.* 14: 169-172.
- ALI, M S; M Y CHOWDHURY; A KARIM and A K CHOWDHURY. 1980. A study on interionic correlations in IRRI strains of rice. *Bangladesh J. Agric.* 5(1): 35-47.
- ALI, M I; E H BHUIYA; M M RAHMAN and A K M HABIBULLAH. 1982. Studies on the plant nutrient status in Bangladesh Soils. *Bangladesh J. Agric. Sci.* 9(1): 25-39.
- ANAM, K; S M IMAMUL HUQ; A AZIZ and M AHMED. 1978. A study on two rubber producing soils of Chittagong. *Bangladesh J. Soil Sci.* 14: 161-168.
- ANAM, K; D ALAM; S RAHMAN and S M I HUQ. 1982. Evaluation of the suitability of the methods of assessment of nutrients of Datmara soils with respect to rubber plant. *Dhaka Univ. Studies, B.* 30(2): 181-182.
- ANGHINONI, I; V C BALIGAR and S A BARBER. 1981. Growth and uptake rates of P, K, Ca and Mg in wheat. *J. Plant Nutr.* 3: 923-933.
- ANONYMOUS. 1985. Diagnosis and correction of potassium deficiency in major crops. 3rd Edition. Published jointly by the Academia Sinica, Institute of Soil Science, Nanjing, China; the International Potash Institute (Switzerland) and the Potash Phosphate Institute (North America).
- ATTOE, O J and E TRUOG. 1945. Exchangeable and acid soluble potassium as regards availability and reciprocal relationships. *Proc. Soil Sci. Soc. Am.* 10: 81-86.
- BANSAL, K N; U P S BHADORIA and J N DUBE. 1985. Effect of applied potassium on nutrient contents of rice grown in three soils. *Plant and Soil.* B1 (2): 275-278.
- BARC (Bangladesh Agricultural Research Council). 1989. Fertilizer recommendation guide. BARC soils publication No. 32. BARC, Dhaka-1215, Bangladesh.
- BARC (Bangladesh Agricultural Research Council). 1991. Potash research in Bangladesh (1986-1991). BARC soils publication No. 35. published by BARC and CIDA.

- BBS (Bangladesh Bureau of Statistics). 1991. Statistical Yearbook of Bangladesh. Bangladesh bureau of statistics. Statistics Div. Ministry of Planning, Govt. of the Peoples Republic of Bangladesh. pp. 196.
- BBS (Bangladesh Bureau of Statistics). 1995. Statistical Yearbook of Bangladesh. Sixteenth edition. Bangladesh bureau of statistics. Statistics Div. Ministry of Planning, Govt. of the Peoples Republic of Bangladesh.
- BEATON, J D and G S SEKHON. 1985. Potassium nutrition of wheat and other small grains. In: Proc. of an international symposium on Potassium in Agriculture held 7-10 July 1985 in Atlanta. Georgia. 715-720.
- BERINGER, H. 1978. Functions of potassium in plant metabolism with particular reference to yield. In: Proc. "Potassium in soils and crops. Potash Research Institute of India. New Delhi. 186-188.
- BHUIYA, M R and M S AKHANDA. 1982. Effect of different sources of organic materials alone and in combination with two fertilizer levels on growth parameters and composition of rice. *Bangladesh J. Agric.* 7(3-4):32-39.
- BHUIYA, Z H; A K M HABIBULLAH; S A HAQUE; I ALI; F A CHOWDHURY; M JAHIR UDDIN and M M RAHMAN. 1982. A report on efficiency of muriate of potash fertilizer in cereal production in Bangladesh (1979-82). BAU and INA, Mymensingh, Bangladesh.
- BHUIYAN, N I; P K SHAHA; M A SALEQUE and M NURUZZAMAN. 1992. A new critical level of soil potassium for wet land rice. *Bangladesh J. Soil Sci.* 23 (1&2):1-14.
- BLACK, C A. 1965. Methods of soil analysis. Part-II, Madison, Wisconsin, USA.
- BORUAH, H C and A K NATH. 1992. Potassium status in three major soil orders of Assam. *Indian Soc. Soil Sci.* 40(3): 559-561.
- BRADY, N C. 1984. The nature and properties of soils. 9th edition. pp. 349.
- CATE, R B JR and LARRY A NELSON. 1965. A rapid method for correlation of soil test analyses with plant response data. Technical Bull. No. 1, ISFEI series, North Carolina State University, Raleigh, N.C.
- CATE, R B JR and LARRY A NELSON. 1971. A simple statistical procedure for partitioning soil test correlation data into two classes. *Soil Sci. Soc. Amer. Proc.* 35(4): 658-659.

- CARPENTER, P N. 1957. Mineral accumulation in potato plants. Maine Agric. Exp. Stn. Bull. pp. 562. In : Potassium in agriculture. Proc. Int. symposium held 7-10 July 1985 in Atlanta, Georgia.
- CHARLES D SOPHER and JACK V BAIRD. 1982. Soils and soil management. Second edition. Reston publishing company, Inc. A prentice Hall Company, Reston, Virginia. 182-183.
- CHAPMAN, H D. 1967. Plant analysis values suggestive of nutrient status of selected crops. Soil testing and plant analysis. Plant analysis, Part-II. Special publication No. 2. *Soil Sci. Soc. America*. 82-84.
- CHATTERJEE, R K and B MAJI. 1984. Physico-chemical factors affecting the availability of potassium in soils. *PRII Research Review Series No. 1*: 62-75.
- CHAMUAH, G S. 1987. Potassium status of some soils growing rice. *J. Indian Soc. Soil Sci.* 35(1): 129-131.
- CHAUDHARY, S K AND H K ROY. 1992. Effect of levels and methods of potash application on yield and K uptake by maize and forms of K in alfisols. *J. Indian Soc. Soil Sci.* 40(4): 868-870.
- CHOWDHURY, M M. 1977. Utilization of tea waste in the growth of lady's finger. *Bangladesh J. Soil Sci.* 13: 125-131.
- CHOWDHURY, S A. 1984. M.Sc. thesis, Department of Soil Science, Dhaka University, Bangladesh.
- CLARKE, G M. 1980. Precision of results. Statistics and experimental design. Edward Arnold (Publishers) LTD. London. pp. 124.
- CSTPA (COUNCIL ON SOIL TESTING AND PLANT ANALYSIS). 1974. Handbook on reference methods for soil testing. Council on soil testing and plant analysis, Athens, Ga.
- CUMMINGS, G A and G A WILCOX. 1968. Effect of potassium on quality factors fruit and vegetables. The role of potassium in agric. 243-267. In : Potassium in agriculture. Proc. Int. symposium held 7-10 July 1985 in Atlanta, Georgia.
- DATTA, N P AND A R KALBANDE. 1967. Correlation of response in paddy with soil test for potassium in different Indian soils. *J. Indian Soc. Soil Sci.* 15(1): 1-6.
- DHILLON, N S; A C VIG and M P S GILL. 1988. Critical limits of nitrogen and phosphorus in Mustard. *J. Indian Soc. Soil Sci.* 36(4): 809-812.

- DONOVAN, L WAUGH; CATE R B JR. and L A NELSON. 1973. Discontinuous model for rapid correlation, interpretation and utilization of soil analysis and fertilizer response data. Technical Bulletin No. 7. International soil fertility evaluation and improvement programme. 11-17.
- DOW, A I and S ROBERTS. 1982. Proposal: Critical nutrient ranges for crop diagnosis. *Agron. J.* 74: 401-403.
- DOW, A I and T A CLINE. 1980. Growth curve, yield, nutrient removal and petiole nutrient levels of potatoes grown on sandy soils under three center pivot irrigation system. Proc. of the 31st Annual North West Fertilizer conf., Salt lake city. 14-16. July. 61-74. In: Potassium in agriculture. Proc. Int. symposium held 7-10 July 1985 in Atlanta, Georgia.
- EKPETE, D M. 1972. *Soil Sci.* 113: 213.
- FAGERIA, N K; V C BALIGAR and C A JONES. 1991. Growth and mineral nutrition of field crops. Marcel Dekker Inc. New York, Basel-Hongkong.
- FAO (FOOD AND AGRICULTURE ORGANIZATION). 1984. Fertilizer and plant nutrition guide. Rome. pp. 176.
- GANESHAMURTHY, A N and C R BISWAS. 1985. Contribution of potassium from non-exchangeable sources in soil to crops. *J. Indian Soc. Soil Sci.* 33(1): 60-66.
- GOSWAMI, N N; S R BAPAT and U N PATHAK. 1971. Nutrient status and response of rice and wheat to fertilizers in different soils. *Indian Fmg.* 20(2): 29-32.
- GOSWAMI, N N; S R BAPAT; C R LEELAVATI and R N SINGH. 1976. Potassium deficiency in rice and wheat in relation to soil type and fertility status. *Bull. Indian Soc. Soil Sci.* 10: 186-194.
- GUPTA, P K and K K VYAS. 1993. Critical limit of available phosphorus for soybean in vertisols of chambal command area of Rajasthan. *J. Indian Soc. Soil Sci.* 41(3): 504-507.
- HABIBULLA, A K M; D J GREENLAND and H BRAMMER. 1971. Clay mineralogy of some seasonally flooded soils of East Pakistan. *J. Soil Sci.* 22: 179-190.
- HAEDER, H E; K MENGEL and H FORSTER. 1973. The effect of potassium on translocation of photosynthates and yield pattern of potato plants. *J. Sci. Food Agric.* 24: 1479-1487. In: Potassium in agriculture. Proc. Int. symposium held 7-10 July 1985 in Atlanta, Georgia.

- HANWAY, J J and H HEIDEL. 1952. Soil analysis method as used in Iowa state college soil testing laboratory. *Agric. Bull.* 57: 1-31.
- HAQUE, M Q and M I ALI. 1990. Potassium status of some selected soils of Bangladesh. *Bangladesh J. Soil Sci.* 21(1): 8-12.
- HAQUE, M Q; M I ALI; A ISLAM and S HOQUE. 1992. Potassium status and release behaviour of five selected soil series of Bangladesh. In: Proc. Intercongress conference of commission IV on "Improving soil management for intensive cropping in the tropics and sub-tropics", ISSS, BARC and SSSB, Dhaka, Bangladesh. 141-145.
- HIGNETT, T P. 1982. Primary nutrient roles in plants. The fertilizer hand book. Published by the fertilizer Institute, Washington D.C. 16-17.
- HOQUE, S; A ISLAM and T H KHAN. 1979. Effect of different sources of organic matter on the growth and yield of wheat. Part-I. direct effect. *Bangladesh J. Soil Sci.* 15: 192-206.
- HUIZING, H G J. 1970. A reconnaissance study of the mineralogy of fraction from East Pakistan. Dept. of soil Survey, Govt. of Bangladesh.
- HUNTER, A H and P F PRATT. 1957. Extraction of potassium from soils by sulphuric acid. *Soil Sci. Soc. Am. Proc.*, 21: 595-598.
- HUNTER, A H. 1980. Laboratory and greenhouse techniques for nutrient survey to determine the soil amendments required for optimum plant growth. Mimeograph: Agro Services International, Box 667, Orange City, Florida, USA.
- HUNTER, A H. 1984. Soil fertility analytical services in Bangladesh. Consultancy report, BARC, Dhaka, March, 1984.
- HYLTON, L O; D E JR. WILLIAMS; A ULRICH and D R CORNELIUS. 1964. Critical nitrate levels for growth of Italian ryegrass. *Crop Sci.* 4: 16-19.
- ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1991. Groundnut-A global perspective. Proc. International Workshop. 25-29 November, ICRISAT Centre. pp. 539.
- ISLAM, M S and S NOOR. 1982a. Performance of groundnut under different levels of phosphate fertilizer in grey floodplain soils of Jamalpur. *Bangladesh J. Agril. Res.* 1: 35-40.

- ISLAM, M S; S RAZIA and K M HOSSAIN. 1982b. Effect of different fertilizer elements on the growth and yield of potato. *Bangladesh J. Agric.* 7(3-4): 56-63.
- ISLAM, A; T H KHAN; B AHMED and G M PANAUULLAH. 1974. Phosphate and potassium status of some soils of Bangladesh. In: Proc. Planning and organization meeting, Fertilizer I N P U T S Project. East-West Centre. Honolulu, Hawaii. 146-157.
- ISLAM, M S; K M HOSSAIN and S RAZIA. 1984. The yield response of wheat to NPKSZn fertilization in non-calcareous brown floodplain and calcareous brown floodplain soils of Bangladesh. In: Proc. Soil test crop response correlation studies, BARC and SSSB. 453-468.
- ISLAM, M S; S ALTAMASH; N I SARKAR and K M HOSSAIN. 1985. Potassium responses in greenhouse and field studies in Bangladesh. In: Proc. Potassium in agricultural soils, held at Dhaka, March 9-10, 1985. Organized by SSSB and BARC. 70-89.
- ISLAM, M S; N K KAR; A M MUSA and M EAQUB. 1994. Efficiency of different methods of potassium determination in some selected soils of Bangladesh. *J. Indian Soc. Soil Sci.* 42(3): 408-413.
- JACKSON, R D and J L HADDOCK. 1959. Growth and nutrient uptake of Russet Burbank Potatoes. *Am. Potato J.* 36: 22-28. In: Potassium in agriculture. Proc. Int. symposium held 7-10 July 1985 in Atlanta, Georgia.
- JACKSON, M L. 1962. Soil Chemical Analysis. Asia Publishing House, Bombay.
- JACKSON, M L. 1967. Soil Chemical Analysis. Indian reprint. Prentice Hall of India Pvt. Ltd, New Delhi.
- JACKSON, M L. 1973. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd. New Delhi.
- JACKSON, T L; W A SHEETS; E H GARDNER; R L SMITH; R M BULLOCK; J MCDERMID; C COOK; W LIGHTY and H WERTH. 1974. Effect of fertilizers on yield and quality of potatoes in the Willamette Valley. Oregon State Univ. Agric. Exp. Stn. Tech. Bull. 129.
- JAMES, D W; W H WEAVER and R L REEDER. 1968. Soil test index of plant available potassium and the effects of cropping and fertilization in central Washington irrigated soils. Wash. Agric. Exp. Stn. Bull. pp. 697. In: Potassium in agriculture. Proc. Int. symposium held 7-10 July 1985 in Atlanta, Georgia.

- JONES, J B JR. 1967. Interpretation of plant analysis for several agronomic crops. Soil testing and plant analysis. Plant analysis, Part-II. Special publication No. 2. *Soil Sci. Soc. of America*. 51-52.
- JONES, U S. 1982. Fertilizers and Soil Fertility. Second edition. Prentice Hall Company, Retson, Verginia, USA. pp. 208.
- KARIM, Z; M A RAHMAN and S H CHOWDHURY. 1978. Mineralogy of some selected tea and rice soils of Bangladesh. *B. J. Sci. Res.* 1: 87-97.
- KARIM, Z. 1980. Potassium in Bangladesh Soils and crop response. *BARC*, 6: 1-18.
- KARIM, Z. 1997. Accelerating agricultural growth in Bangladesh. In: Seminar on agricultural research and development in Bangladesh. 24-27 February, 1997, BARC, Dhaka, Bangladesh. pp.7.
- KHAN, M J; M A ROUF and A M M TAREQUE. 1980. Studies on the chemical composition of three types of water hyacinth. *Bangladesh J. Agric.* 5(3): 167-172.
- KLEINKOPF, G E; D T WESTERMANN and C G PAINTER. 1979. Nitrogen effects and Russet Burbank potato growth. Proc. of the 30th Annual North west Fertilizer Conf., Spokane, WA 17-19 July. 143-150. In: Potassium in agriculture. Proc. Int. symposium held 7-10 July 1985 in Atlanta, Georgia.
- KNUDSEN D; G A PETERSON and P F PRATT. 1984. Lithium, sodium and potassium. In: Methods of soil analysis, Number 9, Part-II, Second edition, 1984. Madison, Wisconsin, USA. 225-246.
- KRISHNAKUMARI, M and M S KHERA. 1989. Relative efficiency of soil test methods for potassium to measure changes in K status due to K uptake, addition and release of potassium in micaceous soils. *J. Indian Soc. Soil Sci.* 37(3): 495-498.
- KUMAR BASANT; H K ROY and AJAY KUMAR. 1991. Critical limits of potassium in a soil series. *J. Indian Soc. Soil Sci.* 39(3): 504-508.
- KUNKEL, R. 1973. Yield goals in potato production. In: Proc. of the 24th Annual Northwest Fertilizer Conf., Pendleton, OR. July 10-12. 44-54. In: Potassium in agriculture. Proc. Int. symposium held 7-10 July 1985 in Atlanta, Georgia.
- LEAF, A L. 1958. *Soil Sci. Soc. Am. Proc.*, 22: 458-469.

- LORENZ, O A; J C BISHOP; B J HOYLE; M P ZOBEL; P A MINGES; L D DONEEN and A ULRICH. 1954. Potato fertilizer experiments in California. Calif. Agric. Exp. Stn. Bull. 744. In: Potassium in agriculture. Proc. Int. Symposium held 7-10 July 1985 in Atlanta, Georgia.
- MACY, P. 1936. *PL. Physiol.* 11. pp. 749.
- MACLEAN, A J. 1960. Trans. 7th Int. Congs. Soil Sci. 3:86.
- MACLEAN, A J. 1961. Potassium-supplying power of some Canadian Soils. *Can. J. Soil Sci.* 41: 196-206.
- MAHABOOB BASHA, S K and G RAJESHWARA RAO. 1980. Effect of potassium deficiency on growth and metabolism of peanut plants. *Proc. Indian Acad. Sci. (Plant Sci.)*, 89: 415-420.
- MAITY, K and P N ARORA. 1980. Effect of varieties, levels and sources of potash on K composition and uptake in potato. *Indian J. Agron.* 25(1): 1-8.
- MANNAN, M A; A IDRIS.; Z UDDIN; A ALI; K ANAM; H RAHMAN; M EAQUB and M S ISLAM. 1982. Coordinated soil test crop response correlation studies. First annual report on Soils and Irrigation. Publication No. 9, BARC, Dhaka, Bangladesh.
- MAZUMDAR, S P and S N SAXENA. 1987. Determination of critical limit of soil solution concentration of potassium for wheat crop in some areas around Jaipur. *J. Indian Soc. Soil Sci.* 35(2): 313-315.
- MCDOLE, R E; G F. STALLKNECHT; R B DWELLE and J J PAVEK. 1978. Response of four potato varieties to potassium fertilization in a seed growing area of eastern Idaho. *Am. Potato J.* 55: 495-504.
- MEAD, D J. 1984. Diagnosis of nutrient deficiencies in plantations. Nutrition of plantation forests. G D Bowen and E K S Nambier, 273-276.
- MEHTA, S C; N SINGH; S B MITTAL; M SINGH and A K KAPOOR. 1994. Critical limit of potassium in soil and response of wheat in Lunkhi soil series (India). *Agrochimica (Italy)*, 38(3): 204-210.
- MENGEL, K. 1985. Potassium movement with in plants and its importance in assimilate transport. Potassium in agriculture (ed. R.D. Monsoon). Proc. International Symposium, Atlanta, GA, USA. Potash and Phosphate Institute. 397-409.

- MIDDLETON, J E; S ROBERTS; D W JAMES; T A CLINE; B L MCNEAL and B L CARLILE. 1975. Irrigation and fertilizer management for efficient crop production on a sandy soil. College of Agric. Res. Center Bull. 811. Washington State University, Pullman.
- MILLER, H G; J D MILLER and J M COOPER. 1981. *Canadian J. for Res.* 11: 563-572.
- MOTIRAMANI, D P ; R V TAMHANE and Y P BALI. 1964. Soils their chemistry and fertility in Tropical Asia. New Delhi, India. pp. 162.
- NAZIRKAR, R B and K R SONAR. 1991. Calibration of soil test methods of available nitrogen in black soils (Inceptisols) for sorghum. *J. Indian Soc. Soil Sci.* 39(2): 383-385.
- NEGI, A S; R C SHARMA; K C SUD and B S BIST. 1981. *J. Indian Soc. Soil Sci.* 29: 86.
- NIJJAR, G S. 1990. Nutrition of fruit trees. Kalyani Publishers. New Delhi, Ludhiana. pp. 82.
- OLSEN, S R; C V COLE; F S WATANABE and L A DEAN. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Dep. Agric. Circ. 939.
- PAGE A L; R H MILLER and D R KEENEY. 1984. Methods of soil analysis. Part-II. Second edition, Madison, Wisconsin, USA.
- PAINTER, C G. 1973. Potato fertilization in southwestern Idaho, off-station testing. Idaho Agric. Res. Progress Rep. 167, July.
- PAL, S K and A K MUKHOPADHYAY. 1992. Potassium status in some Inceptisols of West Bengal. *J. Indian Soc. Soil Sci.* 40(3): 562-565.
- PANDA, N. 1971. Correlation of soil tests for nitrogen, phosphorus and potassium with responses of paddy. In: Proc. Seminar on paddy fertilization. F.A.I. Eastern Region, Calcutta. 83-90.
- PANDA, M and A K PANDA. 1993. Evaluation of some potassium soil tests for rice in a Fluventic Ustochrept. *J. Indian Soc. Soil Sci.* 41(1): 188-189.
- PERUMAL, R; M J SELVARAJ; P DURAISAMY and S BASKARAN. 1991. Relationship between soil tests methods and fractions of potassium with sorghum as a test crop. *J. Indian Soc. Soil Sci.* 39(3): 500-503.

- PORTCH, S. and M S ISLAM. 1984. Nutrient status of some of the more important agricultural soils of Bangladesh. In: Proc. International symposium on soil test crop response correlation studies, Bangladesh Agril. Res. Council and Soil Sci. Soc. of Bangladesh, Commission IV: 97-106.
- PPIC (Potash Phosphate Institute of Canada). 1989a. Symptoms of potassium deficiency. Potash: Its need and use in modern agriculture. Potash and Phosphate Institute of Canada.
- PPIC (Potash Phosphate Institute of Canada). 1989b. Potassium in plants. Potash: Its need and use in modern agriculture. Potash and Phosphate Institute of Canada. pp. 1.
- PPI (Potash Phosphate Institute). 1983. Soil fertility manual. Potash Phosphate Institute, Atlanta, GA 30329.
- PRATT, P F and H H MORSE. 1954. Potassium release from exchangeable and non-exchangeable forms in Ohio soils. Ohio. Agr. Exp. Sta., Bull. 747.
- PRATT, P F. 1965. Methods of Soil Analysis, Part-II, Am. Soc. Agron. Madison, WI, USA. 1022-1030.
- PRAKASH, C. and V SINGH. 1986. Evaluation of soil test methods for available potassium in alluvial soils. *J. Indian Soc. Soil Sci.* 34: 425-427.
- PRASAD, B. 1990. Availability and critical limits of potassium in wheat and Jogdishpur Bagha soil series (Calciorrhents) of Bihar. *J. of Potassium Res.* 6(3): 96-105.
- PRETTY, K M. 1978. Factors influencing potassium requirements and response to potassium fertilization. North American experience. In: Proc. of a symposium on potassium in soils and crops. New Delhi. 47-60.
- RAO, N R and G S SEKHON. 1989. Critical potassium levels in selected crops. PRII special publication 2. Potash Research Institute of India, Hariyana, India.
- RAO M HARIPRAKASA; T R SUBRAMANIAN and V R SRINIVASAN. 1992. Critical levels of available N, P and K for different vegetable crops in an Alfisol. *J. Indian Soc. Soil Sci.* 40(4): 860-861.
- REITEMEIER, R F; R S HOMES; I C BROWN; T W KLIPP and R Z PARKS. 1948. Release of non-exchangeable potassium by greenhouse, Neubauer and laboratory methods. In: *Proc. Soil Sci. Soc. Am.* 12: 158-162.

- REITEMEIER, R F. 1951. The chemistry of soil potassium. *Adv. Agron.* 3: 113-159.
- RICH, C I and W R BLACK. 1964. Potassium exchange as affected by cation size, pH and mineral structure. *Soil Sci.* 97: 384-390.
- ROBERTS, S; A I DOW and T A CLINE. 1984. "Slow release" nitrogen evaluations and phosphorus and potassium requirements for potatoes on sandy soil. College of Agric. and Home Economics Res. Center Bull. 0943. Washington State University, Pullman.
- ROBERTS, S and R E MCDOLE. 1985. Potassium nutrition of potatoes. In: Proc. International symposium on Potassium in Agriculture held 7-10 July 1985. in Atlanta, Georgia. 799-818.
- ROUSE, R D. 1967. Organizing data for soil test interpretations. Soil testing and plant analysis. Soil testing, Part-I. Special publication No. 2. *Soil Sci. Soc. of America.* pp. 115.
- ROY, H K; A KUMAR and A K SARKAR. 1989. Critical limits of potassium in soil and plant and response of wheat in soils of Puto series (Alfisols) of Ranchi. *J. Potassium Research.* 5(4): 157-163, In: Soils and Fertilizers, 54(3), March 1991.
- SALEQUE, M A; P K SAHA; G M PANAUULLAH and N I BHUIYAN. 1990. Calibration of soil potassium tests with yield of wet season lowland rice in Bangladesh. Bangladesh. *J. Soil Sci.* 21(2): 1-10.
- SAMUEL, R ALDRICH. 1967. Plant analyses: Problems and opportunities. Soil testing and plant analysis. Plant analysis, Part-II. Special publication No. 2. *Soil Sci. Soc. of America,* 1-5.
- SATTER, M A and M M RAHMAN. 1987. The techniques of soil analysis. Department of soil science, BAU, Mymensingh.
- SCHULTE, E E and C C OLSEN (ed.). 1970. Wisconsin soil testing and plant analyses procedures. Soil fertility series No. 6, Dep. of Soil Sci., Univ. of Wisconsin, Madison.
- SCHWARTZ, S and U KAFKAFI. 1978. Mg, Ca, and K status of silage corn and wheat at periodic stages of growth in the field. *Agron. J.* 70: 227-231. In: Potassium nutrition of wheat and other small grains. In: Proc. of an international symposium on Potassium in Agriculture held 7-10 July, 1985 in Atlanta, Georgia.
- SHARMA, U C. 1991. Simple mathematical model to determine the critical nutrient levels in soils and plants. *J. Indian Soc. Soil Sci.* 39(3): 509-513.

- SHARMA, U C. 1992. Critical limit of phosphorus for potato in Alfisols of Meghalaya. *J. Indian Soc. Soil Sci.* 40(1). pp. 211.
- SHARMA, S R and S N SAXENA. 1993. Critical limit of available phosphorus for wheat in typic torripsamments of Rajasthan. *J. Indian Soc. Soil Sci.* 41(2): 381-382.
- SHAH, M A and M ISMAIL. 1983. The effect of different levels of NPK on potato yield. *J. Indian Pot. Assoc.* 10(3/4): 134-149. 25th Sci. Rept., CPRI, Simla. pp. 29.
- SINGH, Y P; M SINGH and R SINGH. 1985. Forms of soil potassium in western part of Haryana. *J. Indian Soc. Soil Sci.* 33(2): 284-291.
- SINGH, B and S R BISHNOI. 1991. Critical limit of available phosphorus for Raya (*Brassica Juncea*) in Soils. *J. Indian Soc. Soil Sci.* 39(2). pp. 388.
- SINGH VINAY; RAM BIR SINGH and RAM PHOOL SINGH. 1992. Evaluation of soil test methods for potassium in alluvial soils for lentil. *J. Indian Soc. Soil Sci.* 40(4): 871-872.
- SINHA, S K. 1978. Influence of potassium on tolerance to stress. Proc. "Potassium in soils and crops" Potash Research Institute of India, New Delhi. pp. 224.
- SOBULO, R A. 1973. Evaluation of analytical methods for determining potassium status of Nigerian soils. In: Potassium in tropical crops and soils. Proc. Colloq. Int. Potash Inst. Abidjan, Ivory Coast, 10: 119-129.
- STANFORD, S and L ENGLISH. 1949. *Agron. J.* 41: 446.
- SUTTON, D and W A SEAY. 1958. Relationship between the potassium removed by millet and red clover, and the potassium extracted by 4 chemical methods for 6 Kentucky soils. *Proc. Soil Sci. Soc. Am.* 22: 110-115.
- TALATI, N R et al. 1974. Behaviour of available and non-exchangeable K in soil and its uptake in wheat crop. *J. Indian Soc. Soil Sci.* 22: 139-144.
- TANDON, H L S and G S SEKHON. 1988a. Potassium research and agricultural production in India. Fertilizer development and consultation organization, New Delhi. pp. 1.
- TANDON, H L S and G S SEKHON. 1988b. Transformation of added potassium. Potassium research and agricultural production in India. Fertilizer development and consultation organization, New Delhi. 28-30.

- TANDON, H L S and G S SEKHON. 1988c. Potassium fertility in Indian soils. Potassium research and agricultural production in India. Fertilizer development and consultation organization, New Delhi. pp. 30.
- TANDON, H L S and G S SEKHON. 1988d. Forms of soil potassium. Potassium research and agricultural production in India. Fertilizer development and consultation organization, New Delhi. 25-28.
- TANDON, H L S and G S SEKHON. 1988e. Release of soil potassium by weathering. Potassium research and agricultural production in India. Fertilizer development and consultation organization, New Delhi. pp. 23.
- TINSLEY, J. 1970. A manual of experiments for students of soil science. Department of soil science, University of Aberdeen, Scotland, U.K.
- ULRICH, A. 1950. Critical nitrate levels of sugarbeets estimated from analysis of petioles and blades with special reference to yields and sucrose concentrations. *Soil Sci.* 69: 291-309.
- ULRICH, A. 1952. A Rev. *PL. Physiol.* 3. pp. 207.
- ULRICH, A. 1956. Plant analysis as a guide to the mineral nutrition of alfalfa. Int. Grassland Congr. Proc. 7th Palmerston, New Zeal., Paper 29.
- ULRICH, A. 1956. Plant analysis as a guide to the mineral nutrition of alfalfa. Int. Grassland Congr. Proc. 7th Palmerston, New Zeal., Paper 29.
- ULRICH, A. 1961. The relative constancy of the critical nitrogen concentration of sugarbeet plants. Plant analysis and fertilizer problems. Amer. Inst. Biol. Sci., Washington, D.C. 372-391.
- ULRICH, A and F J HILLS. 1967a. Principles and practices of plant analysis. Soil testing and plant analysis. Plant analysis, Part-II. Special publication No. 2. *Soil Sci. Soc. of America.* 17-20.
- ULRICH, A and F J HILLS. 1967b. In: "Soil testing and plant analysis", Part-II. 11-24. SSSA special publ. *Soil Sci. Soc. Am. Madison, Wisconsin.*
- VENKATASUBBIAH, V J; VENKATESWARLU and V V K SASTRY. 1976. Potassium supplying power of black soils of west Godavari, Andhra Pradesh. In: Potassium in soil, crops and fertilizers. *Bull. 10, Indian Society Soil Sci., New Delhi.* 219-226.

- WAUGH, D L and J W FITTS. 1966. Soil test interpretation studies: Laboratory and potted plant. Technical bulletin no. 3. International soil testing series. North Carolina State University and Agency for International Development, Department of State, Washington, D.C. pp. 33.
- WAUGH, D L; R B CATE, JR and L A NELSON. 1973. Mathematical Procedure. Discontinuous models for rapid correlation, interpretation, and utilization of soil analysis and fertilizer response data. Technical bulletin No. 7. International soil fertility evaluation and improvement programme. Washington, D.C. pp. 22.
- WILL, G M. 1966. *N. Z. J. for Sci.* 8: 4-14.
- WILDE, S A; R B COREY; J G IYER and G K VOIGT. 1979. Soil and plant analysis for tree culture. 5th edition. Mohan Pramlani, Oxford and IBH publishing Co., New Delhi. pp. 80.
- WOOD, L K and E E DETURK. 1941. The adsorption of potassium in soils in non-replaceable forms. *Soil Sci. Soc. Am. Proc.* (1940), 5: 152-161.
- WOOD, L K and E E DETURK. 1942. *Proc. Soil Sci. Soc. Am.* 7: 148.
- YADAV, B S and B N SWAMI. 1984. Critical limits of soil potassium for maize crop in Red Soils (Haplustalfs) of Dungarpur district of Rajasthan, India. In: *Proc. International Symposium on Soil Test Crop Response Correlation Studies*, BARC, Dhaka, Bangladesh. pp. 84.
- YOSHIDA, S; D A FORNO; J COCK and K A GOMEZ. 1976. Laboratory manual for physiological studies of rice. Third edition, IRRI, Los Banos, Philippines.
- ZALAWADIA, N M and M S PATEL. 1983. Effect of irrigation and P application on concentration and uptake of N, P, K, Ca, Mg and S at various growth stages of groundnut. *Indian J. Agric. Chem.*, 15(3): 61-67.

CHAPTER 7.0

APPENDICES

Appendix : 7.1. Analyses of variances for dry matter yield of wheat grown in net house using soils of thirty one locations.

Appendix 7.1.1. (Location-Balashahar)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	8.09150	2.02287	83.96**
Error	10	0.24093	0.02409	
Total	14	8.33244		

CV = 3.0 %

Appendix 7.1.2. (Location-Sandhabari)

Treatment	4	7.06420	1.76605	12.46**
Error	10	1.41700	0.14170	
Total	14	8.48120		

CV = 9.8 %

Appendix 7.1.3. (Location-Narhatto)

Treatment	4	3.00737	0.75184	6.56**
Error	10	1.14640	0.11464	
Total	14	4.15377		

CV = 8.2 %

Appendix 7.1.4. (Location-Natun Shahr)

Treatment	4	1.17333	0.29333	4.89*
Error	10	0.60000	0.06000	
Total	14	1.77333		

CV = 6.9 %

Appendix 7.1.5. (Location-Nischintapur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	2.38436	0.59609	86.47**
Error	10	0.06893	0.00689	
Total	14	2.45329		

CV = 1.5 %

Appendix 7.1.6. (Location-Monoharpur)

Treatment	4	0.45057	0.11264	4.91*
Error	10	0.22920	0.02292	
Total	14	0.67977		

CV = 4.9 %

Appendix 7.1.7. (Location-Dikshail)

Treatment	4	0.51989	0.12997	3.05 NS
Error	10	0.42626	0.04262	
Total	14	0.94616		

CV = 6.6 %

Appendix 7.1.8. (Location-Ishapur)

Treatment	4	0.48257	0.12064	21.39**
Error	10	0.05640	0.00564	
Total	14	0.53897		

CV = 2.2 %

Appendix 7.1.9. (Location-Dadpur)

Treatment	4	0.41416	0.10354	11.53**
Error	10	0.08980	0.00898	
Total	14	0.50396		

CV = 2.6 %

Appendix 7.1.10. (Location-Rahmatpur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	1.69980	0.42495	50.59**
Error	10	0.08400	0.00840	
Total	14	1.78380		

CV = 2.9 %

Appendix 7.1.11. (Location-Shahajadpur)

Treatment	4	1.28666	0.32166	5.13*
Error	10	0.62666	0.06266	
Total	14	1.91333		

CV = 6.3 %

Appendix 7.1.12. (Location-Baira)

Treatment	4	1.93986	0.48496	11.75**
Error	10	0.41273	0.04127	
Total	14	2.35260		

CV = 6.3 %

Appendix 7.1.13. (Location-Pali)

Treatment	4	1.95937	0.48984	12.32**
Error	10	0.39766	0.03976	
Total	14	2.35704		

CV = 4.8 %

Appendix 7.1.14. (Location-Nazirpur)

Treatment	4	1.79930	0.44982	13.55**
Error	10	0.33206	0.03320	
Total	14	2.13137		

CV = 4.4 %

Appendix 7.1.15. (Location-South Dhanghara)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	7.59129	1.89782	31.73**
Error	10	0.59820	0.05982	
Total	14	8.18949		

CV = 5.1 %

Appendix 7.1.16. (Location-Ranochandi)

Treatment	4	3.55457	0.88864	11.57**
Error	10	0.76800	0.07680	
Total	14	4.32257		

CV = 7.0 %

Appendix 7.1.17. (Location-Lalapur)

Treatment	4	4.04400	1.01100	45.99**
Error	10	0.22000	0.02200	
Total	14	4.26400		

CV = 4.2 %

Appendix 7.1.18. (Location-Jatanpukuria)

Treatment	4	0.50266	0.12566	3.85*
Error	10	0.32666	0.03266	
Total	14	0.82933		

CV = 5.2 %

Appendix 7.1.19. (Location-Daulatpur)

Treatment	4	3.19837	0.79959	73.72**
Error	10	0.10846	0.01084	
Total	14	3.30684		

CV = 3.3 %

Appendix 7.1.20. (Location-Kamorgram)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	1.58956	0.39739	32.31**
Error	10	0.12300	0.01230	
Total	14	1.71256		

CV = 3.1 %

Appendix 7.1.21. (Location-Dewashara)

Treatment	4	1.47524	0.36881	30.70**
Error	10	0.12013	0.01201	
Total	14	1.59537		

CV = 2.4 %

Appendix 7.1.22. (Location-Vhanga)

Treatment	4	0.87082	0.21770	3.99*
Error	10	0.54573	0.05457	
Total	14	1.41656		

CV = 6.3 %

Appendix 7.1.23. (Location-Palima)

Treatment	4	0.75602	0.18900	6.08**
Error	10	0.31073	0.03107	
Total	14	1.06676		

CV = 4.2 %

Appendix 7.1.24. (Location-Benarpota)

Treatment	4	0.50062	0.12515	21.93*
Error	10	0.05706	0.00570	
Total	14	0.55769		

CV = 2.1 %

Appendix 7.1.25. (Location-Khazura)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	0.36129	0.09032	4.82*
Error	10	0.18720	0.01872	
Total	14	0.54849		

CV = 3.5 %

Appendix 7.1.26. (Location-Garakhola)

Treatment	4	2.41310	0.60327	23.50**
Error	10	0.25673	0.02567	
Total	14	2.66984		

CV = 4.9 %

Appendix 7.1.27. (Location-Mogorkhal)

Treatment	4	2.54716	0.63679	26.90**
Error	10	0.23673	0.02367	
Total	14	2.78389		

CV = 4.9 %

Appendix 7.1.28. (Location-Uttar Char Aicha)

Treatment	4	0.27944	0.06986	1.39 NS
Error	10	0.50213	0.05021	
Total	14	0.78157		

CV = 8.2 %

Appendix 7.1.29. (Location-Patkhal)

Treatment	4	1.01989	0.25497	17.30**
Error	10	0.14740	0.01474	
Total	14	1.16729		

CV = 2.1 %

Appendix 7.1.30. (Location-Nadmollah)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	1.14022	0.28505	1.51 NS
Error	10	1.88393	0.18839	
Total	14	3.02416		

CV = 8.4 %

Appendix 7.1.31. (Location-West Jhalakathi)

Treatment	4	1.34564	0.33641	5.99*
Error	10	0.56153	0.05615	
Total	14	1.90717		

CV = 4.3 %

* = Significant at 5 % level

** = Significant at 1 % level

NS = Not significant

Appendix : 7.2. Analyses of variances for dry matter yield of potato grown in net house using soils of thirty one locations.

Appendix 7.2.1. (Location-Balashahar)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	11.95777	2.98944	41.28 **
Error	10	0.72420	0.07242	
Total	14	12.68197		

CV = 3.3 %

Appendix 7.2.2. (Location-Sandhabari)

Treatment	4	1.69990	0.42497	2.76 NS
Error	10	1.53866	0.15386	
Total	14	3.23857		

CV = 6.5 %

Appendix 7.2.3. (Location-Narhatto)

Treatment	4	64.44400	16.11100	246.60**
Error	10	0.65333	0.06533	
Total	14	65.09733		

CV = 3.4 %

Appendix 7.2.4. (Location-Natun Shahr)

Treatment	4	11.99400	2.99850	31.07**
Error	10	0.96500	0.09650	
Total	14	12.95900		

CV = 5.2 %

Appendix 7.2.5. (Location-Nischintapur)

Treatment	4	20.07600	5.01900	29.79**
Error	10	1.68500	0.16850	
Total	14	21.76100		

CV = 5.3 %

Appendix 7.2.6. (Location-Monoharpur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	2.67004	0.66751	1.38 NS
Error	10	4.84833	0.48483	
Total	14	7.51837		

CV = 8.7 %

Appendix 7.2.7. (Location-Dikshail)

Treatment	4	3.58484	0.89621	6.61**
Error	10	1.35633	0.13563	
Total	14	4.94117		

CV = 4.8 %

Appendix 7.2.8. (Location-Ishapur)

Treatment	4	4.93576	1.23394	16.32**
Error	10	0.75593	0.07559	
Total	14	5.69169		

CV = 3.4 %

Appendix 7.2.9. (Location-Dadpur)

Treatment	4	33.59556	8.39889	12.12**
Error	10	6.92820	0.69282	
Total	14	40.52376		

CV = 6.3 %

Appendix 7.2.10. (Location-Rahmatpur)

Treatment	4	11.53056	2.88264	9.57**
Error	10	3.01140	0.30114	
Total	14	14.54196		

CV = 6.0 %

Appendix 7.2.11. (Location-Shahajadpur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	8.36196	2.09049	3.34 NS
Error	10	6.25980	0.62598	
Total	14	14.62176		

CV = 9.0 %

Appendix 7.2.12. (Location-Baira)

Treatment	4	4.04376	1.01094	85.67**
Error	10	0.11800	0.01180	
Total	14	4.16176		

CV = 1.3 %

Appendix 7.2.13. (Location-Pali)

Treatment	4	2.74822	0.68705	3.78*
Error	10	1.81706	0.18170	
Total	14	4.56529		

CV = 6.1 %

Appendix 7.2.14. (Location-Nazirpur)

Treatment	4	1.24926	0.31231	1.72 NS
Error	10	1.81766	0.18176	
Total	14	3.06693		

CV = 6.3 %

Appendix 7.2.15. (Location-South Dhanghara)

Treatment	4	7.85740	1.96435	14.65**
Error	10	1.34040	0.13404	
Total	14	9.19780		

CV = 4.9 %

Appendix 7.2.16. (Location-Ranochandi)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	5.13590	1.28397	35.46**
Error	10	0.36206	0.03620	
Total	14	5.49797		

CV = 2.8 %

Appendix 7.2.17. (Location-Lalapur)

Treatment	4	12.22396	3.05599	19.84**
Error	10	1.54053	0.15405	
Total	14	13.76449		

CV = 5.8 %

Appendix 7.2.18. (Location-Jatanpukuria)

Treatment	4	2.14286	0.53571	3.07 NS
Error	10	1.74246	0.17424	
Total	14	3.88533		

CV = 7.0 %

Appendix 7.2.19. (Location-Daulatpur)

Treatment	4	5.39782	1.34945	16.79**
Error	10	0.80386	0.08038	
Total	14	6.20169		

CV = 3.9 %

Appendix 7.2.20. (Location-Kamorgram)

Treatment	4	7.78117	1.94529	33.44**
Error	10	0.58180	0.05818	
Total	14	8.36297		

CV = 3.1 %

Appendix 7.2.21. (Location-Dewashara)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	32.27093	8.06773	485.42**
Error	10	0.16620	0.01662	
Total	14	32.43713		

$$CV = 1.6 \%$$

Appendix 7.2.22. (Location-Vhanga)

Treatment	4	24.69817	6.17454	14.82**
Error	10	4.16526	0.41652	
Total	14	28.86344		

$$CV = 6.4 \%$$

Appendix 7.2.23. (Location-Palima)

Treatment	4	1.46142	0.36535	14.97**
Error	10	0.24406	0.02440	
Total	14	1.70549		

$$CV = 2.8 \%$$

Appendix 7.2.24. (Location-Benarpota)

Treatment	4	0.39869	0.09967	3.87*
Error	10	0.25780	0.02578	
Total	14	0.65649		

$$CV = 2.5 \%$$

Appendix 7.2.25. (Location-Khazura)

Treatment	4	2.29596	0.57399	5.92*
Error	10	0.96880	0.09688	
Total	14	3.26476		

$$CV = 4.5 \%$$

Appendix 7.2.26. (Location-Garakhola)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	1.28304	0.32076	< 1
Error	10	3.25753	0.32575	
Total	14	4.54057		

CV = 6.8 %

Appendix 7.2.27. (Location-Mogorkhal)

Treatment	4	5.40184	1.35046	7.42**
Error	10	1.82100	0.18210	
Total	14	7.22284		

CV = 6.4 %

Appendix 7.2.28. (Location-Uttar Char Aicha)

Treatment	4	1.20202	0.30050	2.65 NS
Error	10	1.13553	0.11355	
Total	14	2.33756		

CV = 4.6 %

Appendix 7.2.29. (Location-Patkhal)

Treatment	4	4.22170	1.05542	16.56**
Error	10	0.63746	0.06374	
Total	14	4.85917		

CV = 2.4 %

Appendix 7.2.30. (Location-Nadmollah)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	6.39509	1.59877	16.94**
Error	10	0.94386	0.09438	
Total	14	7.33896		

CV = 3.7 %

Appendix 7.2.31. (Location-West Jhalakathi)

Treatment	4	3.34957	0.83739	33.22**
Error	10	0.25206	0.02520	
Total	14	3.60164		

CV = 2.0 %

* = Significant at 5 % level

** = Significant at 1 % level

NS = Not significant

Appendix : 7.3. Analyses of variances for dry matter yield of groundnut grown in net house using soils of twenty nine locations.

Appendix 7.3.1. (Location-Balashahar)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	17.50400	4.37600	16.09**
Error	10	2.72000	0.27200	
Total	14	20.22400		

CV = 4.5 %

Appendix 7.3.2. (Location-Sandhabari)

Treatment	4	28.54396	7.13599	24.37**
Error	10	2.92820	0.29282	
Total	14	31.47216		

CV = 4.3 %

Appendix 7.3.3. (Location-Narhatto)

Treatment	4	3.31509	0.82877	3.47 NS
Error	10	2.38540	0.23854	
Total	14	5.70049		

CV = 5.3 %

Appendix 7.3.4. (Location-Natun Shahar)

Treatment	4	3.18502	0.79625	7.31**
Error	10	1.08926	0.10892	
Total	14	4.27429		

CV = 4.3 %

Appendix 7.3.5. (Location-Nischintapur)

Treatment	4	33.25733	8.31433	46.19**
Error	10	1.80000	0.18000	
Total	14	35.05733		

CV = 3.3 %

Appendix 7.3.6. (Location-Monoharpur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	17.77066	4.44266	9.69**
Error	10	4.58666	0.45866	
Total	14	22.35733		

CV = 3.1 %

Appendix 7.3.7. (Location-Dikshail)

Treatment	4	25.60933	6.40233	10.42**
Error	10	6.14666	0.61466	
Total	14	31.75600		

CV = 3.2 %

Appendix 7.3.9. (Location-Dadpur)

Treatment	4	70.63957	17.65989	45.87**
Error	10	3.84960	0.38496	
Total	14	74.48917		

CV = 2.6 %

Appendix 7.3.10. (Location-Rahmatpur)

Treatment	4	21.38666	5.34666	12.23**
Error	10	4.37333	0.43733	
Total	14	25.76000		

CV = 3.5 %

Appendix 7.3.11. (Location-Shahajadpur)

Treatment	4	8.86933	2.21733	10.95**
Error	10	2.02500	0.20250	
Total	14	10.89433		

CV = 2.8 %

Appendix 7.3.12. (Location-Baira)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	29.04666	7.26166	18.98**
Error	10	3.82666	0.38266	
Total	14	32.87333		

CV = 2.7 %

Appendix 7.3.13. (Location-Pali)

Treatment	4	25.23400	6.30850	18.69**
Error	10	3.37500	0.33750	
Total	14	28.60900		

CV = 2.8 %

Appendix 7.3.14. (Location-Nazirpur)

Treatment	4	18.85216	4.71304	17.65**
Error	10	2.67073	0.26707	
Total	14	21.52289		

CV = 2.7 %

Appendix 7.3.16. (Location-Ranochandi)

Treatment	4	25.63989	6.40997	26.52**
Error	10	2.41706	0.24170	
Total	14	28.05696		

CV = 2.5 %

Appendix 7.3.17. (Location-Lalapur)

Treatment	4	17.83770	4.45942	39.66**
Error	10	1.12433	0.11243	
Total	14	18.96204		

CV = 3.4 %

Appendix 7.3.18. (Location-Jatanpukuria)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	15.61550	3.90387	8.72**
Error	10	4.47793	0.44779	
Total	14	20.09344		

CV = 6.9 %

Appendix 7.3.19. (Location-Daulatpur)

Treatment	4	25.55066	6.38766	30.91**
Error	10	2.06666	0.20666	
Total	14	27.61733		

CV = 2.3 %

Appendix 7.3.20. (Location-Kamorgram)

Treatment	4	10.34073	2.58518	6.69**
Error	10	3.86360	0.38636	
Total	14	14.20433		

CV = 4.4 %

Appendix 7.3.21. (Location-Dewashara)

Treatment	4	29.52593	7.38148	18.79**
Error	10	3.92906	0.39290	
Total	14	33.45500		

CV = 3.9 %

Appendix 7.3.22. (Location-Vhanga)

Treatment	4	13.58700	3.39675	42.46**
Error	10	0.79993	0.07999	
Total	14	14.38693		

CV = 1.9 %

Appendix 7.3.23. (Location-Palima)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	23.27540	5.81885	12.81**
Error	10	4.54220	0.45422	
Total	14	27.81760		

CV = 4.0 %

Appendix 7.3.24. (Location-Benarpota)

Treatment	4	14.50606	3.62651	9.29**
Error	10	3.90393	0.39039	
Total	14	18.41000		

CV = 4.0 %

Appendix 7.3.25. (Location-Khazura)

Treatment	4	16.55676	4.13919	14.20**
Error	10	2.91520	0.29152	
Total	14	19.47196		

CV = 3.4 %

Appendix 7.3.26. (Location-Garakhola)

Treatment	4	15.32342	3.83085	18.10**
Error	10	2.11686	0.21168	
Total	14	17.44029		

CV = 3.7 %

Appendix 7.3.27. (Location-Mogorkhal)

Treatment	4	23.16156	5.79039	21.70**
Error	10	2.66780	0.26678	
Total	14	25.82936		

CV = 3.7 %

Appendix 7.3.28. (Location-Uttar Char Aicha)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	18.29273	4.57318	19.46**
Error	10	2.35046	0.23504	
Total	14	20.64320		

CV = 5.6 %

Appendix 7.3.29. (Location-Patkhalī)

Treatment	4	2.76056	0.69014	2.02 NS
Error	10	3.41233	0.34123	
Total	14	6.17289		

CV = 4.2 %

Appendix 7.3.30. (Location-Nadmollah)

Treatment	4	2.24022	0.56005	1.90 NS
Error	10	2.94553	0.29455	
Total	14	5.18576		

CV = 4.0 %

Appendix 7.3.31. (Location-West Jhalakathi)

Treatment	4	4.30102	1.07525	4.64*
Error	10	2.31826	0.23182	
Total	14	6.61929		

CV = 3.9 %

* = Significant at 5 % level

** = Significant at 1 % level

NS = Not significant

Appendix : 7.4. Analyses of variances for per cent K concentration in wheat plant grown in net house using soils of thirty one locations.

Appendix 7.4.1. (Location-Balashahar)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	18.53004	4.63251	2895.32**
Error	10	0.01600	0.00160	
Total	14	18.54604		

CV = 0.8 %

Appendix 7.4.2. (Location-Sandhabari)

Treatment	4	6.00576	1.50144	1364.95**
Error	10	0.01100	0.00110	
Total	14	6.01676		

CV = 0.7 %

Appendix 7.4.3. (Location-Narhatto)

Treatment	4	38.92680	9.73170	11315.93**
Error	10	0.00860	0.00086	
Total	14	38.93540		

CV = 0.5 %

Appendix 7.4.4. (Location-Natun Shahar)

Treatment	4	20.98176	5.24544	1821.33**
Error	10	0.02880	0.00288	
Total	14	21.01056		

CV = 0.9 %

Appendix 7.4.5. (Location-Nischintapur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	24.56076	6.14019	9029.69**
Error	10	0.00680	0.00068	
Total	14	24.56756		

CV = 0.4 %

Appendix 7.4.6. (Location-Monoharpur)

Treatment	4	8.04840	2.01210	1622.66**
Error	10	0.01240	0.00124	
Total	14	8.06080		

CV = 0.7 %

Appendix 7.4.7. (Location-Dikshail)

Treatment	4	11.71446	2.92861	223.44**
Error	10	0.13106	0.01310	
Total	14	11.84553		

CV = 1.7 %

Appendix 7.4.8. (Location-Ishapur)

Treatment	4	8.17680	2.04420	1703.50**
Error	10	0.01200	0.00120	
Total	14	8.18880		

CV = 0.5 %

Appendix 7.4.9. (Location-Dadpur)

Treatment	4	7.57350	1.89337	24.94**
Error	10	0.75926	0.07592	
Total	14	8.33277		

CV = 4.1 %

Appendix 7.4.10. (Location-Rahmatpur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	7.99644	1.99911	1723.37**
Error	10	0.01160	0.00116	
Total	14	8.00804		

CV = 0.6 %

Appendix 7.4.11. (Location-Shahajadpur)

Treatment	4	11.55804	2.88951	5350.94**
Error	10	0.00540	0.00054	
Total	14	11.56344		

CV = 0.4 %

Appendix 7.4.12. (Location-Baira)

Treatment	4	3.71784	0.92946	1010.28**
Error	10	0.00920	0.00092	
Total	14	3.72704		

CV = 0.5 %

Appendix 7.4.13. (Location-Pali)

Treatment	4	8.31442	2.07860	7.65**
Error	10	2.71606	0.27160	
Total	14	11.03049		

CV = 7.7 %

Appendix 7.1.14. (Location-Nazirpur)

Treatment	4	5.66376	1.41594	919.44**
Error	10	0.01540	0.00154	
Total	14	5.67916		

CV = 0.6 %

Appendix 7.4.15. (Location-South Dhanghara)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	35.05044	8.76261	7553.97**
Error	10	0.01160	0.00116	
Total	14	35.06204		

CV = 0.5 %

Appendix 7.4.16. (Location-Ranochandi)

Treatment	4	6.02004	1.50501	2150.01**
Error	10	0.00700	0.00070	
Total	14	6.02704		

CV = 0.5 %

Appendix 7.4.17. (Location-Lalapur)

Treatment	4	7.75176	1.93794	6056.06**
Error	10	0.00320	0.00032	
Total	14	7.75496		

CV = 0.5 %

Appendix 7.4.18. (Location-Jatanpukuria)

Treatment	4	21.00144	5.25036	10096.85**
Error	10	0.00520	0.00052	
Total	14	21.00664		

CV = 0.4 %

Appendix 7.4.19. (Location-Daulatpur)

Treatment	4	9.38544	2.34636	3555.09**
Error	10	0.00660	0.00066	
Total	14	9.39204		

CV = 0.5 %

Appendix 7.4.20. (Location-Kamorgram)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	8.26716	2.06679	807.34**
Error	10	0.02560	0.00256	
Total	14	8.29276		

CV = 0.8 %

Appendix 7.4.21. (Location-Dewashara)

Treatment	4	23.12916	5.78229	14455.72**
Error	10	0.00400	0.00040	
Total	14	23.13316		

CV = 0.4 %

Appendix 7.4.22. (Location-Vhanga)

Treatment	4	8.70722	2.17680	1898.38**
Error	10	0.01146	0.00114	
Total	14	8.71869		

CV = 0.5 %

Appendix 7.4.23. (Location-Palima)

Treatment	4	8.10276	2.02569	1776.92**
Error	10	0.01140	0.00114	
Total	14	8.11416		

CV = 0.6 %

Appendix 7.4.24. (Location-Benarpota)

Treatment	4	4.07630	1.01907	710.98**
Error	10	0.01433	0.00143	
Total	14	4.09064		

CV = 0.6 %

Appendix 7.4.25. (Location-Khazura)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	2.64166	0.66041	13.26**
Error	10	0.49806	0.04980	
Total	14	3.13973		

CV = 4.6 %

Appendix 7.4.26. (Location-Garakhola)

Treatment	4	10.26636	2.56659	2916.58**
Error	10	0.00880	0.00088	
Total	14	10.27516		

CV = 0.5 %

Appendix 7.4.27. (Location-Mogorkhal)

Treatment	4	13.44384	3.36096	6224.00**
Error	10	0.00540	0.00054	
Total	14	13.44924		

CV = 0.5 %

Appendix 7.4.28. (Location-Uttar Char Aicha)

Treatment	4	4.19844	1.04961	1.82 NS
Error	10	5.76940	0.57694	
Total	14	9.96784		

CV = 15.2 %

Appendix 7.4.29. (Location-Patkhal)

Treatment	4	16.55436	4.13859	1738.90**
Error	10	0.02380	0.00238	
Total	14	16.57816		

CV = 0.7 %

Appendix 7.4.30. (Location-Nadmollah)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	11.93270	2.98317	2062.10**
Error	10	0.01446	0.00144	
Total	14	11.94717		

CV = 0.6 %

Appendix 7.4.31. (Location-West Jhalakathi)

Treatment	4	3.14844	0.78711	1357.09**
Error	10	0.00580	0.00058	
Total	14	3.15424		

CV = 0.4 %

* = Significant at 5 % level

** = Significant at 1 % level

NS = Not significant

Appendix : 7.5. Analyses of variances for per cent K concentration in potato plant grown in net house using soils of thirty one locations.

Appendix 7.5.1. (Location-Balashahar)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	8.65416	2.16354	6363.35**
Error	10	0.00340	0.00034	
Total	14	8.65756		

CV = 0.30 %

Appendix 7.5.2. (Location-Sandhabari)

Treatment	4	2.37504	0.59376	< 1
Error	10	6.12440	0.61244	
Total	14	8.49944		

CV = 14.9 %

Appendix 7.5.3. (Location-Narhatto)

Treatment	4	2.94276	0.73569	3344.05**
Error	10	0.00220	0.00022	
Total	14	2.94496		

CV = 0.2 %

Appendix 7.5.4. (Location-Natun Shahar)

Treatment	4	17.93244	4.48311	13185.62**
Error	10	0.00340	0.00034	
Total	14	17.93584		

CV = 0.2 %

Appendix 7.5.5. (Location-Nischintapur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	12.33516	3.08379	5316.88**
Error	10	0.00580	0.00058	
Total	14	12.34096		

CV = 0.2 %

Appendix 7.5.6. (Location-Monoharpur)

Treatment	4	24.31344	6.07836	7997.84**
Error	10	0.00760	0.00076	
Total	14	24.32104		

CV = 0.2 %

Appendix 7.5.7. (Location-Dikshail)

Treatment	4	7.53744	1.88436	4958.84**
Error	10	0.00380	0.00038	
Total	14	7.54124		

CV = 0.2 %

Appendix 7.5.8. (Location-Ishapur)

Treatment	4	8.86536	2.21634	10074.27**
Error	10	0.00220	0.00022	
Total	14	8.86756		

CV = 0.2 %

Appendix 7.5.9. (Location-Dadpur)

Treatment	4	14.43804	3.60951	5013.21**
Error	10	0.00720	0.00072	
Total	14	14.44524		

CV = 0.2 %

Appendix 7.5.10. (Location-Rahmatpur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	11.05044	2.76261	3733.26**
Error	10	0.00740	0.00074	
Total	14	11.05784		

CV = 0.4 %

Appendix 7.5.11. (Location-Shahajadpur)

Treatment	4	14.44550	3.61137	7420.64**
Error	10	0.00486	0.00048	
Total	14	14.54037		

CV = 0.4 %

Appendix 7.5.12. (Location-Baira)

Treatment	4	9.13944	2.28486	3685.26**
Error	10	0.00620	0.00062	
Total	14	9.14564		

CV = 0.3 %

Appendix 7.5.13. (Location-Pali)

Treatment	4	8.03544	2.00886	4185.13**
Error	10	0.00480	0.00048	
Total	14	8.04024		

CV = 0.3 %

Appendix 7.5.14. (Location-Nazirpur)

Treatment	4	17.29776	4.32444	6552.18**
Error	10	0.00660	0.00066	
Total	14	17.30436		

CV = 0.2 %

Appendix 7.5.15. (Location-South Dhanghara)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	11.37180	2.84295	2961.41**
Error	10	0.00960	0.00096	
Total	14	11.38140		

CV = 0.4 %

Appendix 7.5.16. (Location-Ranochandi)

Treatment	4	22.54176	5.63544	6552.84**
Error	10	0.00860	0.00086	
Total	14	22.55036		

CV = 0.3 %

Appendix 7.5.17. (Location-Lalapur)

Treatment	4	11.67984	2.91996	2807.65**
Error	10	0.01040	0.00104	
Total	14	11.69024		

CV = 0.4 %

Appendix 7.5.18. (Location-Jatanpukuria)

Treatment	4	13.89180	3.47295	48.23.54**
Error	10	0.00720	0.00072	
Total	14	13.89900		

CV = 0.5 %

Appendix 7.5.19. (Location-Daulatpur)

Treatment	4	18.37810	4.59452	60.67**
Error	10	0.75726	0.07572	
Total	14	19.13537		

CV = 3.6 %

Appendix 7.5.20. (Location-Kamorgram)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	5.95176	1.48794	1260.97**
Error	10	0.01180	0.00118	
Total	14	5.96356		

CV = 0.5 %

Appendix 7.5.21. (Location-Dewashara)

Treatment	4	32.03544	8.00886	8898.73**
Error	10	0.00900	0.00090	
Total	14	32.04444		

CV = 0.3 %

Appendix 7.5.22. (Location-Vhanga)

Treatment	4	26.71044	6.67761	7588.19**
Error	10	0.00880	0.00088	
Total	14	26.71924		

CV = 0.3 %

Appendix 7.5.23. (Location-Palima)

Treatment	4	6.03636	1.50909	5030.30**
Error	10	0.00300	0.00030	
Total	14	6.03936		

CV = 0.3 %

Appendix 7.5.24. (Location-Benarpota)

Treatment	4	11.78844	2.94711	2728.81**
Error	10	0.01080	0.00108	
Total	14	11.79924		

CV = 0.3 %

Appendix 7.5.25. (Location-Khazura)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	6.66444	1.66611	2082.64**
Error	10	0.00800	0.00080	
Total	14	6.67244		

CV = 0.5 %

Appendix 7.5.26. (Location-Garakhola)

Treatment	4	9.65976	2.41494	1271.02**
Error	10	0.01900	0.00190	
Total	14	9.67876		

CV = 0.5 %

Appendix 7.5.27. (Location-Mogorkhal)

Treatment	4	21.75744	5.43936	7554.67**
Error	10	0.00720	0.00072	
Total	14	21.76464		

CV = 0.5 %

Appendix 7.5.28. (Location-Uttar Char Aicha)

Treatment	4	1.83900	0.45975	160.75**
Error	10	0.02860	0.00286	
Total	14	1.86760		

CV = 0.7 %

Appendix 7.5.29. (Location-Patkhal)

Treatment	4	6.00000	1.50000	551.47**
Error	10	0.02720	0.00272	
Total	14	6.02720		

CV = 0.7 %

Appendix 7.5.30. (Location-Nadmollah)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	23.53104	5.88276	1500.70**
Error	10	0.03920	0.00392	
Total	14			

CV = 0.5 %

Appendix 7.5.31. (Location-West Jhalakathi)

Treatment	4	2.43876	0.60969	622.13**
Error	10	0.00980	0.00098	
Total	14	2.44856		

CV = 0.3 %

* = Significant at 5 % level

** = Significant at 1 % level

NS = Not significant

Appendix : 7.6. Analyses of variances for per cent K concentration in groundnut plant grown in net house using soils of twenty nine locations.

Appendix 7.6.1. (Location-Balashahar)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	5.96316	1.49079	4384.68**
Error	10	0.00340	0.00034	
Total	14	5.96656		

CV = 0.8 %

Appendix 7.6.2. (Location-Sandhabari)

Treatment	4	2.39844	0.59961	1998.70**
Error	10	0.00300	0.00030	
Total	14	2.40144		

CV = 0.8 %

Appendix 7.6.3. (Location-Narhatto)

Treatment	4	2.13504	0.53376	988.44**
Error	10	0.00540	0.00054	
Total	14	2.14044		

CV = 0.6 %

Appendix 7.6.4. (Location-Natun Shahr)

Treatment	4	6.19644	1.54911	2093.39**
Error	10	0.00740	0.00074	
Total	14	6.20384		

CV = 0.9 %

Appendix 7.6.5. (Location-Nischintapur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	5.66544	1.41636	2.41 NS
Error	10	5.88260	0.58826	
Total	14	11.58804		

CV = 19.4 %

Appendix 7.6.6. (Location-Monoharpur)

Treatment	4	6.54144	1.63536	5110.50**
Error	10	0.00320	0.00032	
Total	14	6.54464		

CV = 0.8 %

Appendix 7.6.7. (Location-Dikshail)

Treatment	4	11.25780	2.81445	46907.50**
Error	10	0.00060	0.00006	
Total	14	11.25840		

CV = 0.3 %

Appendix 7.6.9. (Location-Dadpur)

Treatment	4	1.02204	0.25551	751.50**
Error	10	0.00340	0.00034	
Total	14	1.02544		

CV = 0.6 %

Appendix 7.6.10. (Location-Rahmatpur)

Treatment	4	1.58496	0.39624	825.50**
Error	10	0.00480	0.00048	
Total	14	1.58976		

CV = 0.8 %

Appendix 7.6.11. (Location-Shahajadpur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	1.53840	0.38460	1373.57**
Error	10	0.00280	0.00028	
Total	14	1.54120		

CV = 1.1 %

Appendix 7.6.12. (Location-Baira)

Treatment	4	0.39444	0.09861	308.16**
Error	10	0.00320	0.00032	
Total	14	0.39764		

CV = 1.5 %

Appendix 7.6.13. (Location-Pali)

Treatment	4	0.79884	0.19971	384.06**
Error	10	0.00520	0.00052	
Total	14	0.80404		

CV = 0.9 %

Appendix 7.6.14. (Location-Nazirpur)

Treatment	4	2.25276	0.56319	1340.93**
Error	10	0.00420	0.00042	
Total	14	2.25696		

CV = 0.6 %

Appendix 7.6.16. (Location-Ranochandi)

Treatment	4	0.94644	0.23661	695.91**
Error	10	0.00340	0.00034	
Total	14	0.94984		

CV = 0.7 %

Appendix 7.6.17. (Location-Lalapur)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	0.63444	0.15861	720.95**
Error	10	0.00220	0.00022	
Total	14	0.63664		

CV = 0.9 %

Appendix 7.6.18. (Location-Jatanpukuria)

Treatment	4	1.41276	0.35319	2207.44**
Error	10	0.00160	0.00016	
Total	14	1.41436		

CV = 1.0 %

Appendix 7.6.19. (Location-Daulatpur)

Treatment	4	0.39444	0.09861	4930.50**
Error	10	0.00020	0.00002	
Total	14	0.39464		

CV = 0.3 %

Appendix 7.6.20. (Location-Kamorgram)

Treatment	4	6.72276	1.68059	1714.99**
Error	10	0.00980	0.00098	
Total	14	6.73256		

CV = 1.1 %

Appendix 7.6.21. (Location-Dewashara)

Treatment	4	1.00116	0.25029	595.93**
Error	10	0.00420	0.00042	
Total	14	1.00536		

CV = 1.5 %

Appendix 7.6.22. (Location-Vhanga)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	5.30110	1.32527	4.81*
Error	10	2.75706	0.27570	
Total	14	8.05817		

CV =17.6 %

Appendix 7.6.23. (Location-Palima)

Treatment	4	0.47904	0.11976	92.12**
Error	10	0.01300	0.00130	
Total	14	0.49204		

CV = 1.5 %

Appendix 7.6.24. (Location-Benarpota)

Treatment	4	0.06840	0.01710	15.55**
Error	10	0.01100	0.00110	
Total	14	0.07940		

CV = 0.9 %

Appendix 7.6.25. (Location-Khazura)

Treatment	4	1.87006	0.46751	11.94**
Error	10	0.39146	0.03914	
Total	14	2.26153		

CV =10.0 %

Appendix 7.6.26. (Location-Garakhola)

Treatment	4	1.28844	0.32211	328.68**
Error	10	0.00980	0.00098	
Total	14	1.29824		

CV = 0.7 %

Appendix 7.6.27. (Location-Mogorkhal)

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARES	OBSERVED F
Treatment	4	0.48180	0.12045	177.13**
Error	10	0.00680	0.00068	
Total	14	0.48860		

CV = 2.0 %

Appendix 7.6.28. (Location-Uttar Char Aicha)

Treatment	4	1.03836	0.25959	68.31**
Error	10	0.03800	0.00380	
Total	14	1.07636		

CV = 1.8 %

Appendix 7.6.29. (Location-Patkhal)

Treatment	4	0.55680	0.13920	154.67**
Error	10	0.00900	0.00090	
Total	14	0.56580		

CV = 1.2 %

Appendix 7.6.30. (Location-Nadmollah)

Treatment	4	2.27844	0.56961	38.49**
Error	10	0.14800	0.01480	
Total	14	2.42644		

CV = 2.2 %

Appendix 7.6.31. (Location-West Jhalakathi)

Treatment	4	16.48810	4.12202	6.34**
Error	10	6.50246	0.65024	
Total	14	22.99057		

CV = 12.2 %

* = Significant at 5 % level, ** = Significant at 1 % level,
NS = Not significant

Appendix 7.7. Acreage and production of wheat, potato and groundnut during 1989-90 to 1993-94 (BBS., 1995).

Year	Wheat		Potato		Groundnut	
	Area ('000 acres)	Production ('000 M tons)	Area ('000 acres)	Production ('000 M tons)	Area ('000 acres)	Production ('000 M tons)
1989-90	63	890	288	1066	95	41
1990-91	1480	1004	306	1237	95	41
1991-92	1420	1065	311	1366	96	42
1992-93	1574	1176	320	1384	88	39
1993-94	1520	1131	324	1438	88	41

Appendix 7.8. Major sources of potassium fertilizer (PPIC., 1989)

Fertilizer material	Formula	% K	Colour
Potassium chloride	KCl	60-62	Pink, grey or white
Potassium sulphate	K ₂ SO ₄	50-53	White
Potassium nitrate	KNO ₃	44-46	White
Potassium magnesium sulphate	K ₂ SO ₄ ·MgSO ₄	22	White