STUDIES ON GROWTH, YIELD AND QUALITY TRAITS OF POTATO (*Solanum tuberosum* L.) AS INFLUENCED BY BIOFERTILIZER, POTASSIUM AND CULTIVAR

4.8.2003

A Thesis
submitted to the
Bidhan Chandra Krishi Viswavidyalaya
for the award of the Degree of Doctor of Philosophy
in
AGRICULTURE (AGRONOMY)

By
Dhiman Ray

DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
BIDHAN CHANDRA KRISHI VISWAVIDYALAYA
MOHANPUR, NADIA, WEST BENGAL
INDIA

2002

Dedicated

to

my loving parents

as well as

to

those who

dream for a good world

speak for a better

and

act too for the best

BIDHAN CHANDRA KRISHI VISWAVIDYALAYA

College of Agriculture

APPROVAL OF EXAMINEERS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRICULTURE (AGRONOMY)

We, the undersigned, having been satisfied with the performance of Mr. Dhiman Ray, in the viva-voce examination, conducted today, the 9th July, 2003, recommended that thesis be accepted for the award of the degree.

Name		Signature
1. Dr. S. K. Mukhopadhyay Reader, Dept. of Agronomy	Chairman, Advisory Committee	
2. Prof. B. C. Nayak Dean, College of Agric., OUAT	External Examiner	
3. Dr. B. K. Mandal Professor, Dept. of Agronomy	Member, Advisory Committee	9.7.2003
4. Dr. S. S. Mandal Professor, Dept. of Agronomy	Member, Advisory Committee	
5. Dr. H. Sen Professor, Dept. of Agronomy	Member, Advisory Committee	
6. Dr. T. K. Maity Reader, Dept. of Vegetable Crops	Member, Advisory Committee	
7. Prof. A. L. Kundu Professor of Agronomy	Departmental Nominee	9/7/03
8. Dr. B. K. Mandal Professor, Dept. of Agronomy	Head, Department of Agronomy	9.7.2003

BIDHAN CHANDRA KRISHI VISWAVIDYALAYA

Regional Research Station

New Alluvial Zone

From :
Dr S. K. Mukhopadhyay,
Reader (R) in Agronomy

P.O.-Gayespur, Dist.-Nadia
West Bengal, Pin-741235,
INDIA
Ph. : (033)2582-9880

Ref. No..... *Date* 27.01.2003

CERTIFICATE

This is to certify that the work recorded in the thesis entitled "STUDIES ON GROWTH, YIELD AND QUALITY TRAITS OF POTATO (*Solanum tuberosum* L.) AS INFLUENCED BY BIOFERTILIZER, POTASSIUM AND CULTIVAR" submitted by Mr. Dhiman Ray, for the award of Degree of Doctor of Philosophy in Agronomy of Bidhan Chandra Krishi Viswavidyalaya, is the faithful and bonafide research work carried out by him under my personal supervision and guidance. The thesis is, in my opinion, worthy of consideration for the Degree of Doctor of Philosophy in accordance with regulations of the Viswavidyalaya. The results of the investigation embodied in the thesis have not so far been submitted to any other University or Institute for the award of any Degree or Diploma. The assistance and help received during the course of investigation and sources of literature have been duly acknowledged.

.....

(DR. S. K. MUKHOPADHYAY)

Chairman,
Advisory Committee

ACKNOWLEDGEMENT

Verbose style is perhaps little enough to unfold ones ribbon of gratitude. Yet many occasions appear when this gratitude finds no alternative but to avail itself such a printed pavement acknowledging its homage with inexplicable sentiment for far and near well wishers.

Indeed, it fills my heart with joy unspeakable to pour my veneration and profound gratitude to Dr. S. K. Mukhopadhyay, Reader (Research), Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, West Bengal for his ceaseless endeavour, active allegiance, painstaking effort, staunchest support, sagacious guidance, incessant encouragement and horizon of outlook during the course of rummage and constructive criticism in finalizing the manuscript. No linguistic expression is adequate and befitting to quantify such a personality and I feel proud being a scholar under the guidance of such a learnt man.

Mere words can never suffice to express the sense of my indebtedness, heartfelt gratitude and fathomless regards to Dr. B. K. Mandal, Professor & Head; Dr. S. S. Mandal, Professor; Dr. H. Sen, Professor, Department of Agronomy, Faculty of Agriculture and Dr. T. K. Maity, Reader & Head, Department of Vegetable Crops, Faculty of Horticulture for their intensive guidance, innovative ideas and unstained help right from the beginning of investigation to the final preparation of manuscript.

I wish to express my infinitum gratitude to Dr. P. Bandyopadhyay, Reader; Dr. R. K. Ghosh, Reader; Dr. K. Sengupta, Reader; Dr. A. M. Puste, Reader; Dr. P. K. Jana, Professor; Dr. S. P. Bhattacharya, Professor and Dr. S. Maity, Professor; Department of Agronomy for their unstinted co-operation, constant inspiration and valuable suggestions throughout the course of investigation.

It would be my dereliction if my special gratitude is not duly conveyed to Dr. A. B. Mondal, Professor, Department of Plant Breeding; Dr. M. Chettri, Sr. Lecturer, Department of Agronomy; Dr. A. Konar, Reader, Department of Agricultural Entomology; Dr. A. Basu, Reader, Department of Plant Pathology and other staff members of the All India Co-ordinated Potato Improvement Project (AICPIP), Kalyani for their valuable advice, helpful suggestion and energetic encouragement.

May be, I do inexorable inadvertence unless I express my immense indebtedness to Dr. R. S. Dhua, Reader, Department of Post-Harvest Technology of Horticultural Crops and Dr. Md. A. Hasan, Reader, Department of Fruits and Orchard Management for providing necessary facilities for conducting biochemical analysis and Dr. A. K. Das, Reader, Department of Agricultural Statistics for protagonist help in the statistical analysis.

I'm thankful to the Vice-Chancellor and Registrar of this Viswavidyalaya for selecting me as a University Research Scholar and providing financial assistance throughout the tenure.

I implore my earnest gratefulness to all the staff members of the Department of Agronomy for their cordial co-operation throughout the period.

The hands of co-operation extended by the staff members of Central Library as well as Nodule Research Laboratory have also been sincerely acknowledged.

The author feels panicity of words in expressing his overwhelming gratitude to the Dean, Post-Graduate Studies and Dean, Faculty of Agriculture of their kind co-operation during the entire course of study.

The silent blessing and best wishes of my jethu-jethima, popaidi-tusharda, bhaituda-chhandadi, sumadi-tanmayda, tutudi-parthada and other near and dear ones were the source of my strength that bestow over my head silently but constantly throughout my life.

I would not have completed the work from its embryonic stage without all those faiths, blessings, encouragements, inspirations and love from my dida, mama-maima, masi-mesho, bapaida-boudi, atoshi-ananda, dola-sanu, koel, pritam, sulagna, munan, tina, disha, ayush and very very sweet little tiasha, whose muting faces transformed all of my depressing moments very much stimulating.

I do not like to miss the opportunity to acknowledge at least masi-mesho, laltuda-boudi, suchhanda, tia, rai, gora, riju and ever loving prattusha and recollect the sweet memories of my association with them in this dream occasion.

A chalice of thanks are extended to Ratanda, Ranajoyda, Sanjit, Kusal, Subendu, Sirsendu, Biplab, Hirak, Kaushik and other research scholars whose company kept me gay and lively throughout the tenure of my research works.

My obligation to Subratada, Mohanda and Barunda of The Institute of Computer Engineers (India) who performed the arduous task of computerized composing and printing of the manuscript with quick and artistic efforts, good humour and finesse is natural.

Belatedly I keep a special mention of my mates Sanjib and Saswati for their immense love, indomitable inspiration and whole hearted co-operation which act as a saviour in the face of all sorts of perils, had always been very much zealing.

In omega, my vocabulary will over remain insufficient to express my indebtedness to my adorable parents and beloved dada-boudi for their infinitive love, cordial affection, incessant inspiration, moral support and silent prayer to God for my well being. To my mother and father, it has been a sweet dream to see me awarded with the Degree of Doctor of Philosophy. It is my parents' blessings that has helped me in achieving the goal in my life, surpassing all sorts of hindrance and that will also help in reaching the position of paramount importance in future. I wish to record my heartfelt respect to their blessings, bestowed on me silently and constantly since my birth.

Dated,... Mohanpur..
The. 27th Jan.., 2003

Dhiman Ray....
(DHIMAN RAY)

ABSTRACT

Field experiments were carried out during 1999-2000 and 2000-2001 at Block Seed Farm, Adisaptagram, Hooghly, West Bengal, to study: (a) the role of biofertilizers in economizing N and P rates for potato production; (b) the effect of levels and methods of potassium application on growth, yield and storage behaviour of potato and (c) the physical and biochemical parameters of some Dutch and Indian cultivars in order to identify suitable cultivars on the basis of processing quality and productivity. The objective was to standardize the doses of N, P and K nutrients and the best method of potassium application when used in conjunction with different biofertilizers as inoculants for better economy and efficiency and to identify suitable high yielding potato varieties for processing for the Gangetic Alluvial Zone of West Bengal.

The first experiment comprising eight combinations of inorganic N and P along with biofertilizers was laid out in RBD with three replications. Application of biofertilizers imparted significant influence on plant growth parameters, tubers hill^{-1}, size of tubers, total tuber yield, NPK uptake and soil fertility. Though biofertilizers viz. Azotobacter + Phosphobacteria along with 100% N and P + 1% urea + 1% sodium bicarbonate recorded highest yield, treatments containing 75% N and P along with 1% urea + 1% sodium bicarbonate + Azotobacter + Phosphobacteria and Bacillus spp. exhibited 3.86 and 1.38 cent^{-1} higher yield of tuber compared to uninoculated control of 100% N and P alone. The NPK uptake by leaves, stems and tubers were higher in treatment containing 100% N and P + 1% urea + 1% sodium bicarbonate + Azotobacter + Phosphobacteria. The soil fertility status showed a build up in the initial available NPK after the completion of experiment in both the years. The net return rupee^{-1} invested was also higher in biofertilizer inoculated treatments.

The second experiment consisting of five levels and four methods of potassium application was arranged in a RBD with three replicates. The maximum values of all the growth attributes, yield and NPK uptake by leaves, stems and tubers were recorded at 200 kg K_2O ha^{-1} when applied in two equal splits. But potassium applied at 150 kg K_2O ha^{-1} accrued the maximum number of tubers $hill^{-1}$ when applied $^2/_3$ rd as basal + $^1/_3$ rd as top dressing at 30 days after planting (DAP). There was a build up of available soil N and P after the completion of the experiment with all the levels of potassium; however, in the treatments of 0 and 50 kg K_2O ha^{-1}, a decline in available K was noticed during both the years. The minimum physiological loss in weight and rotting of tubers after 90 days of storage was recorded at 200 kg K_2O ha^{-1} when applied full at 30 DAP as top dressing. The economic optimum dose of potassium was worked out as 157.8 kg K_2O ha^{-1}.

The trial to evaluate processing quality of nine Dutch and Indian potato cultivars was carried out in a RBD with three replications. The LAI, DM accumulation, LAD and tubers $hill^{-1}$ was highest in Indian cultivar Kufri Chipsona-1, whereas CGR, TBR and NAR was highest in Dutch cultivar Diamant but Cardinal produced the maximum percentage of large sized tubers, tuber yield and recorded the minimum peeling loss of tubers. Kufri Chipsona-1 and Kufri Chipsona-2 recorded low reducing sugars, total sugars and gave acceptable light colour chips. Total acids and vitamin C content was maximum in Ajax; total soluble solids were maximum in Sante while specific gravity was highest in Kufri Chipsona-2. Kufri Chipsona-1 showed minimum physiological loss in weight while Kufri Chipsona-2 resulted in minimum rotting of tubers after 90 days of storage. Though tuber yield of Dutch cultivars Cardinal and Diamant as well as popular local cultivar Kufri Jyoti was higher, they failed to meet the minimum processing quality standards and were susceptible to late blight. In contrast, late blight resistant cultivars Kufri Chipsona-1 and Kufri Chipsona-2 yielded higher, and met the requirement of processing quality standards of high dry matter content, specific gravity and low reducing sugars to give light colour chips.

CONTENTS

CHAPTER NO.	PARTICULARS	PAGE NO.
1	**INTRODUCTION**	**1-8**
1.1	Potato as a potential food crop	2
1.2	Potato production scenario	3
1.3	Challenges and scopes	4
1.3.1	Scope of using biofertilizers in potato	4
1.3.2	Scopes in potato processing	6
2	**REVIEW OF LITERATURE**	**9-25**
2.1	Fertilizer economy in potato by the use of biofertilizers	9
2.1.1	Growth parameters	9
2.1.2	Yield parameters and tuber yield	10
2.1.3	Nutrient removal and soil fertility status	11
2.1.4	Economic feasibility	12
2.2	Levels and methods of potassium application for increasing its efficiency in potato	13
2.2.1	Growth parameters	13
2.2.2	Graded tuber yield	14
2.2.3	Concentration and uptake of nutrients	16
2.2.4	Keeping quality of potatoes	17
2.2.5	Production economics	18
2.3	Evaluation of exotic and Indian potato cultivars for processing	18
2.3.1	Growth parameters	19
2.3.2	Tuber yield	20
2.3.3	Quality traits of potato cultivars	21
2.3.4	Storage behaviour	24
3	**MATERIALS AND METHODS**	**26-46**
3.1	Experimental location	26
3.2	Soil characteristics	26

CHAPTER NO.	PARTICULARS	PAGE NO.
3.3	Agro-climatic condition	26
3.3.1	Temperature	28
3.3.2	Relative humidity	28
3.3.3	Rainfall	28
3.3.4	Sunshine	28
3.4	Cropping history	30
3.5	Experimental details	30
3.5.1	Experiment No. 1: Fertilizer economy in potato by the use of biofertilizers	30
3.5.1.1	Details of plan of layout	30
3.5.1.2	Details of the treatments	31
3.5.1.3	Biofertilizer inoculation	31
3.5.2	Experiment No. 2: Levels and methods of potassium application for increasing its efficiency in potato	32
3.5.2.1	Details of plan of layout	32
3.5.2.2	Details of the treatments	33
3.5.3	Experiment No. 3: Evaluation of Dutch and Indian potato cultivars for processing	33
3.5.3.1	Details of plan of layout	34
3.5.3.2	Details of the treatments	34
3.6	Cultural operations	34
3.7	Management practices of soil and crop	34
3.7.1	Land preparation	34
3.7.2	Layout	35
3.7.3	Fertilizer application	36
3.7.4	Seed treatment	36
3.7.5	Planting of seed tubers	36
3.7.6	Irrigation	36
3.7.7	Intercultural operations	36
3.7.8	Plant protection measures	37

CHAPTER NO.	PARTICULARS	PAGE NO.
3.7.9	Dehaulming	37
3.8	Crop assessment studies	37
3.8.1	Growth functions	37
3.8.1.1	Leaf area index	37
3.8.1.2	Dry matter accumulation	38
3.8.1.3	Crop growth rate	38
3.8.1.4	Tuber bulking rate	38
3.8.1.5	Net assimilation rate	38
3.8.1.6	Leaf area duration	39
3.8.2	Harvesting of the crop	39
3.8.2.1	Final yield of tubers	39
3.8.2.2	Grading of tubers	39
3.9	Chemical analysis	39
3.9.1	Soil analysis	39
3.9.1.1	Collection of soil samples	39
3.9.1.2	Mechanical analysis of soil samples	40
3.9.1.3	Chemical analysis of soil samples	40
3.9.1.3.1	Organic carbon content	40
3.9.1.3.2	Nitrogen content	40
3.9.1.3.3	Phosphorus content	40
3.9.1.3.4	Potassium content	40
3.9.1.3.5	pH determination	41
3.9.2	Plant analysis	41
3.9.2.1	Methods of preparation of plant samples	41
3.9.2.2	Chemical analysis of plant samples	41
3.9.2.2.1	Nitrogen uptake	41
3.9.2.2.2	Phosphorus uptake	41
3.9.2.2.3	Potassium uptake	42
3.10	Physico-chemical analysis	42

CHAPTER NO.	PARTICULARS	PAGE NO.
3.10.1	Physical characters	42
3.10.1.1	Specific gravity	42
3.10.1.2	Peeling	42
3.10.1.3	Storage losses	42
3.10.1.3.1	Physiological loss in weight	43
3.10.1.3.2	Rotting of tubers	43
3.10.2	Biochemical constituents	43
3.10.2.1	Total sugars	43
3.10.2.2	Reducing sugars	43
3.10.2.3	Total acidity	43
3.10.2.4	Total soluble solids	44
3.10.2.5	Vitamin C content	44
3.10.3	Chip colour	44
3.11	Response function	44
3.12	Statistical analysis	45
3.13	Economics of crop production	45
4	**RESULTS AND DISCUSSION**	**47-146**
4.1	Experiment No. 1: Fertilizer economy in potato by the use of biofertilizers	47
4.1.1	Growth parameters	47
4.1.1.1	Leaf area index	47
4.1.1.2	Dry matter accumulation	49
4.1.1.2.1	Dry weight of leaves	49
4.1.1.2.2	Dry weight of stems	51
4.1.1.2.3	Dry weight of tubers	53
4.1.1.2.4	Total dry matter production	55
4.1.1.3	Crop growth rate	56
4.1.1.4	Tuber bulking rate	58
4.1.1.5	Net assimilation rate	60
4.1.1.6	Leaf area duration	62

CHAPTER NO.	PARTICULARS	PAGE NO.
4.1.2	Yield components	63
4.1.2.1	Tubers $hill^{-1}$	63
4.1.2.2	Tuber yield	63
4.1.2.3	Grades of tubers	65
4.1.3	Plant nutrient analysis	67
4.1.3.1	NPK uptake by leaves	67
4.1.3.2	NPK uptake by stems	69
4.1.3.3	NPK uptake by tubers	69
4.1.3.4	Total uptake of NPK	72
4.1.4	Soil available NPK	74
4.1.5	Economics	76
4.2	Experiment No. 2: Levels and methods of potassium application for increasing its efficiency in potato	78
4.2.1	Growth parameters	78
4.2.1.1	Leaf area index	78
4.2.1.2	Dry matter accumulation	80
4.2.1.2.1	Dry weight of leaves	80
4.2.1.2.2	Dry weight of stems	80
4.2.1.2.3	Dry weight of tubers	83
4.2.1.2.4	Total dry matter production	85
4.2.1.3	Crop growth rate	87
4.2.1.4	Tuber bulking rate	89
4.2.1.5	Net assimilation rate	89
4.2.1.6	Leaf area duration	92
4.2.2	Yield components	93
4.2.2.1	Tubers $hill^{-1}$	93
4.2.2.2	Tuber yield	94
4.2.2.3	Grades of tubers	96
4.2.3	Plant nutrient analysis	98
4.2.3.1	NPK uptake by leaves	98

CHAPTER NO.	PARTICULARS	PAGE NO.
4.2.3.2	NPK uptake by stems	100
4.2.3.3	NPK uptake by tubers	100
4.2.3.4	Total uptake of NPK	103
4.2.4	Soil available NPK	105
4.2.5	Storage behaviour	107
4.2.5.1	Physiological loss in weight	107
4.2.5.2	Rotting of tubers	107
4.2.6	Response function	110
4.2.7	Economics	110
4.3	Experiment No. 3: Evaluation of Dutch and Indian potato cultivars for processing	112
4.3.1	Growth parameters	112
4.3.1.1	Leaf area index	112
4.3.1.2	Dry matter accumulation	114
4.3.1.2.1	Dry weight of leaves	114
4.3.1.2.2	Dry weight of stems	116
4.3.1.2.3	Dry weight of tubers	116
4.3.1.2.4	Total dry matter production	119
4.3.1.3	Crop growth rate	121
4.3.1.4	Tuber bulking rate	123
4.3.1.5	Net assimilation rate	125
4.3.1.6	Leaf area duration	125
4.3.2	Yield components	127
4.3.2.1	Tubers hill^{-1}	127
4.3.2.2	Tuber yield	128
4.3.2.3	Grades of tubers	128
4.3.3	Physical characters	131
4.3.3.1	Specific gravity	131
4.3.3.2	Peeling losses	134
4.3.4	Quality characters	134

CHAPTER NO.	PARTICULARS	PAGE NO.
4.3.4.1	Reducing sugars	134
4.3.4.2	Total sugars	137
4.3.4.3	Total acids	137
4.3.4.4	Total soluble solids	139
4.3.4.5	Vitamin C content	139
4.3.4.6	Chip colour	141
4.3.5	Storage losses	141
4.3.5.1	Physiological loss in weight	141
4.3.5.2	Rotting of tubers	143
4.3.6	Economics	145
5	**SUMMARY AND CONCLUSION**	**147-151**
6	**FUTURE SCOPE OF RESEARCH**	**152**
	BIBLIOGRAPHY	(i-x)

LIST OF TABLES

TABLE NO.	PARTICULARS	PAGE NO.
3.1	Physico-chemical properties of the experimental soil	27
3.2	Meteorological data of the experimental site during the period of experimentation	29
3.3	Cropping history of the experimental area	30
3.4	Calendar of cultural operations in potato planting during 1999-2000 and 2000-2001	35
4.1.1	Effect of biofertilizers on leaf area indices of potato at different stages of growth	48
4.1.2	Effect of biofertilizers on dry weight production of leaves (gm^{-2}) of potato at different stages of growth	50
4.1.3	Effect of biofertilizers on dry weight production of stems (gm^{-2}) of potato at different stages of growth	52
4.1.4	Effect of biofertilizers on dry matter production of tubers (gm^{-2}) of potato at different stages of growth	54
4.1.5	Effect of biofertilizers on total dry matter production (gm^{-2}) of potato at different stages of growth	56
4.1.6	Effect of biofertilizers on crop growth rate ($gm^{-2}d^{-1}$) of potato during different growth intervals	57
4.1.7	Effect of biofertilizers on tuber bulking rate ($gm^{-2}d^{-1}$) of potato during different growth intervals	59
4.1.8	Effect of biofertilizers on net assimilation rate ($gm^{-2}d^{-1}$) of potato during different growth intervals	61
4.1.9	Effect of biofertilizers on leaf area duration (days) of potato	62
4.1.10	Effect of biofertilizers on number of tubers $hill^{-1}$ of potato	64
4.1.11	Effect of biofertilizers on tuber yield (t ha^{-1}) of potato	64
4.1.12	Effect of biofertilizers on the production of different grades of tubers ($cent^{-1}$) in potato	66
4.1.13	Effect of biofertilizers on NPK uptake (kg ha^{-1}) by leaves of potato	68
4.1.14	Effect of biofertilizers on NPK uptake (kg ha^{-1}) by stems of potato	70

TABLE NO.	PARTICULARS	PAGE NO.
4.1.15	Effect of biofertilizers on NPK uptake (kg ha^{-1}) by tubers of potato	71
4.1.16	Effect of biofertilizers on total uptake of NPK (kg ha^{-1}) by potato plant	73
4.1.17	Effect of biofertilizers on soil available NPK (kg ha^{-1})	75
4.1.18	Effect of biofertilizers on the economics of cultivation of potato	77
4.2.1	Leaf area indices of potato as influenced by levels and methods of potassium application at different stages of growth	79
4.2.2	Dry weight production of leaves (gm^{-2}) of potato as influenced by levels and methods of potassium application at different stages of growth	81
4.2.3	Dry weight production of stems (gm^{-2}) of potato as influenced by levels and methods of potassium application at different stages of growth	82
4.2.4	Dry matter production of tubers (gm^{-2}) of potato as influenced by levels and methods of potassium application at different stages of growth	84
4.2.5	Total dry matter production (gm^{-2}) of potato as influenced by levels and methods of potassium application at different stages of growth	86
4.2.6	Crop growth rate ($gm^{-2}d^{-1}$) of potato as influenced by levels and methods of potassium application during different growth intervals	88
4.2.7	Tuber bulking rate ($gm^{-2}d^{-1}$) of potato as influenced by levels and methods of potassium application during different growth intervals	90
4.2.8	Net assimilation rate ($gm^{-2}d^{-1}$) of potato as influenced by levels and methods of potassium application during different growth intervals	91
4.2.9	Leaf area duration (days) of potato as influenced by levels and methods of potassium application	93
4.2.10	Number of tubers $hill^{-1}$ of potato as influenced by levels and methods of potassium application	95
4.2.11	Tuber yield (t ha^{-1}) of potato as influenced by levels and methods of potassium application	95

TABLE NO.	PARTICULARS	PAGE NO.
4.2.12	Production of different grades of tubers (cent^{-1}) in potato as influenced by levels and methods of potassium application	97
4.2.13	NPK uptake (kg ha^{-1}) by leaves of potato as influenced by levels and methods of potassium application	99
4.2.14	NPK uptake (kg ha^{-1}) by stems of potato as influenced by levels and methods of potassium application	101
4.2.15	NPK uptake (kg ha^{-1}) by tubers of potato as influenced by levels and methods of potassium application	102
4.2.16	Total uptake of NPK (kg ha^{-1}) by potato plant as influenced by levels and methods of potassium application	104
4.2.17	Soil available NPK (kg ha^{-1}) as influenced by levels and methods of potassium application	106
4.2.18	Physiological loss in weight (cent^{-1}) of stored potato tubers under normal room condition as influenced by levels and methods of potassium application	108
4.2.19	Rotting (cent^{-1}by weight) of stored potato tubers under normal room condition as influenced by levels and methods of potassium application	109
4.2.20	Economics of cultivation of potato as influenced by levels of potassium application	111
4.3.1	Leaf area indices of Dutch and Indian potato cultivars at different stages of growth	113
4.3.2	Dry weight production of leaves (gm^{-2}) of Dutch and Indian potato cultivars at different stages of growth	115
4.3.3	Dry weight production of stems (gm^{-2}) of Dutch and Indian potato cultivars at different stages of growth	117
4.3.4	Dry matter production of tubers (gm^{-2}) of Dutch and Indian potato cultivars at different stages of growth	118
4.3.5	Total dry matter production (gm^{-2}) of Dutch and Indian potato cultivars at different stages of growth	120
4.3.6	Crop growth rate (gm^{-2}d^{-1}) of Dutch and Indian potato cultivars during different growth intervals	122
4.3.7	Tuber bulking rate (gm^{-2}d^{-1}) of Dutch and Indian potato cultivars during different growth intervals	124
4.3.8	Net assimilation rate (gm^{-2}d^{-1}) of Dutch and Indian potato cultivars during different growth intervals	126

TABLE NO.	PARTICULARS	PAGE NO.
4.3.9	Leaf area duration (days) of Dutch and Indian potato cultivars	127
4.3.10	Number of tubers hill^{-1} of Dutch and Indian potato cultivars	129
4.3.11	Tuber yield (t ha^{-1}) of Dutch and Indian potato cultivars	129
4.3.12	Production of different grades of tubers (cent^{-1}) of Dutch and Indian potato cultivars	130
4.3.13	Specific gravity of tubers of Dutch and Indian potato cultivars	132
4.3.14	Peeling loss (cent^{-1}) of tubers of Dutch and Indian potato cultivars	132
4.3.15	Tuber characters of Dutch and Indian potato cultivars after harvest	133
4.3.16	Reducing sugar content (cent^{-1} fresh weight) of tubers of Dutch and Indian potato cultivars	136
4.3.17	Total sugar content (cent^{-1} fresh weight) of tubers of Dutch and Indian potato cultivars	136
4.3.18	Total acid content (cent^{-1} fresh weight) of tubers of Dutch and Indian potato cultivars	138
4.3.19	Total soluble solids (^{0}Brix) of tubers of Dutch and Indian potato cultivars	138
4.3.20	Vitamin C content (mg 100 g^{-1} fresh weight) of tubers of Dutch and Indian potato cultivars	140
4.3.21	Chip colour score of tubers of Dutch and Indian potato cultivars	140
4.3.22	Physiological loss in weight (cent^{-1}) of stored Dutch and Indian potato cultivars under normal room condition at fortnightly intervals	142
4.3.23	Rotting (cent^{-1}by weight) of stored Dutch and Indian potato cultivars under normal room condition	144
4.3.24	Economics of cultivation of Dutch and Indian potato cultivars	146

LIST OF FIGURES

FIGURE NO.	PARTICULARS	PAGES IN BETWEEN
3.1	Meteorological data of the experimental site during the period of experimentation	29-30
3.2	Layout of Experiment No. 1	30-31
3.3	Layout of Experiment No. 2	32-33
3.4	Layout of Experiment No. 3	33-34
4.1.1	Effect of biofertilizers on leaf area indices of potato	48-49
4.1.2	Effect of biofertilizers on total dry matter accumulation of potato	48-49
4.1.3	Effect of biofertilizers on crop growth rate of potato	57-58
4.1.4	Effect of biofertilizers on tuber bulking rate of potato	57-58
4.1.5	Effect of biofertilizers on leaf area duration of potato	62-63
4.1.6	Effect of biofertilizers on number of tubers $hill^{-1}$ of potato	62-63
4.1.7	Effect of biofertilizers on tuber yield of potato	64-65
4.1.8	Effect of biofertilizers on the production of different grades of tubers	64-65
4.1.9	Effect of biofertilizers on NPK uptake by tubers of potato	71-72
4.1.10	Effect of biofertilizers on total uptake of NPK by potato plant	71-72
4.2.1	Effect of levels and methods of potassium application on leaf area indices of potato	79-80
4.2.2	Effect of levels and methods of potassium application on total dry matter accumulation of potato	79-80
4.2.3	Effect of levels and methods of potassium application on crop growth rate of potato	88-89

FIGURE NO.	PARTICULARS	PAGES IN BETWEEN
4.2.4	Effect of levels and methods of potassium application on tuber bulking rate of potato	88-89
4.2.5	Effect of levels and methods of potassium application on leaf area duration of potato	93-94
4.2.6	Effect of levels and methods of potassium application on number of tubers hill^{-1} of potato	93-94
4.2.7	Effect of levels and methods of potassium application on tuber yield of potato	95-96
4.2.8	Effect of levels and methods of potassium application on the production of different grades of tubers	95-96
4.2.9	Effect of levels and methods of potassium application on total uptake of NPK by potato plant	104-105
4.2.10	Effect of levels and methods of potassium application on rotting of stored potato tubers	104-105
4.2.11	Response of potato to levels of potassium	110-111
4.3.1	Effect of Dutch and Indian potato cultivars on leaf area indices	113-114
4.3.2	Effect of Dutch and Indian potato cultivars on total dry matter accumulation	113-114
4.3.3	Effect of Dutch and Indian potato cultivars on crop growth rate	122-123
4.3.4	Effect of Dutch and Indian potato cultivars on tuber bulking rate	122-123
4.3.5	Effect of Dutch and Indian potato cultivars on leaf area duration	127-128
4.3.6	Effect of Dutch and Indian potato cultivars on number of tubers hill^{-1}	127-128
4.3.7	Effect of Dutch and Indian potato cultivars on tuber yield	129-130
4.3.8	Effect of Dutch and Indian potato cultivars on the production of different grades of tubers	129-130

FIGURE NO.	PARTICULARS	PAGES IN BETWEEN
4.3.9	Effect of Dutch and Indian potato cultivars on specific gravity of tubers	133-134
4.3.10	Effect of Dutch and Indian potato cultivars on peeling loss of tubers	133-134
4.3.11	Effect of Dutch and Indian potato cultivars on reducing sugar content of tubers	136-137
4.3.12	Effect of Dutch and Indian potato cultivars on total sugar content of tubers	136-137
4.3.13	Effect of Dutch and Indian potato cultivars on total acid content of tubers	138-139
4.3.14	Effect of Dutch and Indian potato cultivars on total soluble solids of tubers	138-139
4.3.15	Effect of Dutch and Indian potato cultivars on vitamin C content of tubers	140-141
4.3.16	Effect of Dutch and Indian potato cultivars on rotting of stored potato tubers	140-141

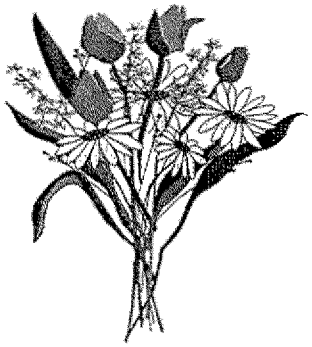
LIST OF PLATES

PLATE NO.	PARTICULARS	PAGES IN BETWEEN
4.3.1	Potato plants of Ajax, Cardinal and Diamant at 60 days after planting	115-116
4.3.2	Potato plants of Fresco, Marfona and Sante at 60 days after planting	115-116
4.3.3	Potato plants of Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti at 60 days after planting	115-116
4.3.4	Cut and whole tubers of Ajax, Cardinal and Diamant	130-131
4.3.5	Cut and whole tubers of Fresco, Marfona and Sante	130-131
4.3.6	Cut and whole tubers of Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti	130-131
4.3.7	Starch and chips of Ajax, Cardinal and Diamant	141-142
4.3.8	Starch and chips of Fresco, Marfona and Sante	141-142
4.3.9	Starch and chips of Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti	141-142

LIST OF ABBREVIATIONS

@	:	at the rate of	LAD	:	Leaf Area Duration
&	:	and	LAI	:	Leaf Area Index
^0C	:	degree celsius	m	:	metre
CIP	:	Centro International de la Papa (International Potato Centre)	m^2	:	square metre
CPRI	:	Central Potato Research Institute	m ha	:	million hectare
C.D.	:	Critical Difference	ml	:	millilitre
CGR	:	Crop Growth Rate	mm	:	millimetre
cm	:	centimetre	mt	:	million tonne
cv.	:	cultivar	N	:	Nitrogen
DAP	:	Days After Planting	NAR	:	Net Assimilation Rate
et al.	:	and others	%	:	per cent
Fig.	:	Figure	P	:	Phosphorus
f. wt.	:	fresh weight	pH	:	Concentration of active hydrogen ion
g	:	gram	P_2O_5	:	Phosphate (Phosphate pentoxide)
gm^{-2}	:	gram per square metre	q	:	quintal
$gm^{-2}d^{-1}$	:	gram per square metre per day	q ha^{-1}	:	quintal per hectare
ha	:	hectare	RH	:	Relative Humidity
i.e.	:	*id est* (that is)	Rs.	:	Rupees
K	:	Potassium	S.Em	:	Standard error of mean
K_2O	:	Potash (Potassium oxide)	t	:	tonne
kg	:	kilogram	TBR	:	Tuber Bulking Rate
kg ha^{-1}	:	kilogram per hectare	t ha^{-1}	:	tonne per hectare
l	:	litre	*viz.*	:	*videlicet* (namely)

Chapter-1



Introduction

1. INTRODUCTION

Mankind had already stepped into the 21st century. Scientists of all fields of human activities are extremely worried about the future of mankind owing to the steadily mounting demographic pressure in our country by leaps and bounds. With the progress of civilization, human knowledge has increased enormously and rigorous research works of the agricultural scientists have led to a tremendous progress in the arena of agricultural production. But the world food scenario is becoming more and more complex with the demands of food increasing at higher rate from a scarcer resource base and the quality aspect receiving greater attention as never before.

India, a home for 18 $cent^{-1}$ of the world population and over 15 $cent^{-1}$ of the world livestock has only 2 $cent^{-1}$ of land resource to meet their basic requirements. Having achieved food grain production of 211 million tonnes (m t) in 2000-2001, India would further need to produce an additional 5-6 m t of food grains annually in the next two decades to meet the requirement of estimated population of 1360 million in 2020 AD. However, $capita^{-1}$ availability of land for producing agricultural commodities has declined from 0.48 ha in 1951 to about 0.20 ha in 1981 and 0.15 ha in 2000 AD and it is expected to decline further to about 0.09 ha by 2050 AD (Singh *et al.*, 2002). This situation warrants maintenance of soil health and other resource base to produce more quality food from less and less land area for the survival of the mankind and other biotic population. The burgeoning population also necessitates significant increase in the production of other agricultural products.

We have been relying heavily on the major cereal crops – rice, wheat and maize – to feed the ever-increasing population in our country. Such an over dependence on cereals should end, if we have to ensure food security in the decades to come. Therefore, we cannot afford to be complacent and should look for alternative foods from among the high productivity crops like tubers and

roots. Tuber crops are the most important food crops after cereals and grain legumes and find an inevitable niche in the socio-economics of small and marginal farmers in the southern, eastern and north-eastern regions of India.

The eminent agricultural scientist, Dr. M. S. Swaminathan, wrote, "The present vulnerability of national food budgets to the vagaries of weather arises from our dependence on too few crops for our daily bread. Potato can help to widen the food supply base and thereby help to minimize the risk of serious food shortages in the tropics and sub-tropics" (Shekhawat, 1999). Hence, in order to increase agricultural production further, the only option is to grow high productivity crops, like potato.

1.1 Potato as a potential food crop:

Potato, a nourishing and wholesome food plays a pivotal role in the farm economy. It can contribute substantially towards providing both food and nutrition security in the years to come as it is one of the most productive edible crops known to man and it produces the highest amount of dry matter, carbohydrate, minerals, edible protein, dietary fibre and vitamins unit^{-1} area unit^{-1} time among all the major food crops. The favourable protein carbohydrate balance and the extremely high quality of potato protein are potential assets for improving the nutritional status of malnourished populations whose diets are based on cereals and other roots and tubers. A short duration crop like potato being nutritionally superior, capable of producing high amount of food unit^{-1} area and time and amenable for inclusion in intensive cropping systems has a great potential in modern agriculture. In developing countries with large population to feed, potato is perhaps the one of the best alternatives to meet the growing food needs.

Dr. R. L. Sawyer, former Director General, CIP, said, "If one had to live on one food alone, the potato would be better by far than any other major food crop available today." The potential role of potato as a food crop in developing countries has been greatly underestimated. It is one of the world's most efficient

crops for converting natural resources, labour and capital into a high quality food. The nutritional qualities of potato often go unrecognized by most of us. The eminent potato physiologist, Dr. W. G. Burton, said, "It is a reasonable approximation to state that the nutritive value of the produce from a hectare of potatoes would have been about three times as great as that from a hectare of cereals." Considering the trend of population growth and consequently the increased demand for food in the country and the dwindling cultivable land area, the potato is likely to play a very important role in the future. Because of its exceptionally high productivity coupled with high food value, potato demands greater attention and should not be treated merely as a vegetable but it needs to be elevated to its rightful status of a supplementary food as in China, Europe and North America. By giving due attention and care, potato can contribute greatly to the food and nutrition security of our country.

1.2 Potato production scenario:

Globally, potato is sharing about 1.35 $cent^{-1}$ of the total cultivated land area and in India, potato is being grown accounting for 0.70 $cent^{-1}$ of the total cropped area. India has made major strides in potato improvement and now ranks 4th in acreage and 3rd in production but 10th in productivity among the major potato producing countries in the world. During the year 2000-2001, the country has reaped 22.28 m t of potatoes from 1.23 m ha with an average yield of 18.15 t ha^{-1} (Khurana, 2002), quite hitting the targets set by the National Commission of Agriculture. It has carved a niche for itself in the intensive cropping systems particularly in the five states of the Indo-Gangetic region *viz.* Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal, which together constitute the potato bowl of India accounting for 90 $cent^{-1}$ of potato production (Shekhawat, 2001).

West Bengal after independence, especially since late 60's made tremendous progress in potato production as a result of disease free seed production programme, release of a number of high yielding varieties and

development of improved cultivation practices for different agro-climatic regions of the state. With an average yield of 25.61 t ha^{-1}, West Bengal not only heads the list of Indian states in productivity but also stands 2nd in both area (0.30 m ha) and production (7.67 m t). The crop is grown to a certain extent throughout West Bengal. The major producing areas are confined to three south and western districts of the state *viz.*, Hooghly, Burdwan and Midnapore to the extent of 65-70 $cent^{-1}$ of the total coverage. Even then, a large gap exists between the yield potentiality of potato achieved so far and that of highest potato producing countries in the world.

Thus, there is a need to appreciate the several advantages of this wonderful crop and to find out ways and means to ensure that the production keeps an upward trend. Hence, there is a need to direct a massive research effort towards the development of sustainable and environment friendly agro-techniques which has become a major issue in most of the developing countries.

1.3 Challenges and scopes:

According to the estimates of International Food Policy Research Institute (IFPRI) and International Potato Centre (CIP), India has recorded highest annual compound growth rates for potato production (5.7 $cent^{-1}$) and productivity (2.4 $cent^{-1}$) as compared to 0.3 and 0.9 $cent^{-1}$, respectively in the world during last 37 years but the worldwide demand of potatoes is expected to increase by 40 $cent^{-1}$ by the year 2020. This scenario calls for concerted efforts to capture global market by producing international quality potatoes and processed products. Projections made by Central Potato Research Institute (CPRI) also indicate production of 49 m t potatoes from an area of 2 m ha by the year 2020.

1.3.1 Scope of using biofertilizers in potato:

As there is no scope for horizontal expansion of our agricultural land, additional amount of production has to be harnessed vertically, in which fertilizer takes the lead role. Potato crop has strict requirement for a balanced fertilizer management, without which growth and development of the crop are

poor, and both the yield and quality of tubers are diminished. Since the crop produces abundant food within a short period, sufficient plant nutrients need to be supplied in assimilable form to sustain rapid growth and tuberization for production of sizeable yield.

Among the major nutrients, nitrogen, phosphorus and potassium play an important role in improving the growth and yield of potato. However, there is increasing concern of the effects of chemical fertilizers in maintaining long-term soil productivity. The regular use of acid or acidogenic fertilizers cause a drop in pH over a period of time and thus reduces crop yields drastically and also damages the soil physical properties (Gaur, 2002). In order to minimize these ill effects organic farming practices involving biofertilizers, organic manures, crop residues etc. must be adopted for sustainable agriculture especially in heavy feeder crop like potato. Evidence is also growing of favourable effect of *Azotobacter* and phosphate solubilising bacteria in providing plant nutrients to several crops and in supplementing the expensive inorganic fertilizers. In this context, use of biofertilizers in an excellent option owing their low cost and environment friendly nature. Biofertilizers help to maintain the long-term soil fertility and ecological sustainability required for increasing crop productivity. The role of different biofertilizers like *Azotobacter* in fixing atmospheric nitrogen and phosphate solubilising bacteria (PSB) in their ability to bring sparingly insoluble inorganic or organic phosphates into soluble form by secreting organic acids has been well established by several workers. Apart from this, the micro-organisms secrete phytohormones and build up organic status of the soil due to which the availability of other nutrients also increases.

The other major nutrient, potassium not only improves yield but also benefits various aspects of quality *viz.* tuber size, percentage of dry matter, starch content, internal blackening, storability, resistance to mechanical damage and resistance against pests and diseases and drought and frost stresses. Potassium is fundamental to potato for the translocation of carbohydrates and storing of starch in the tubers. During relative short growth period of potato

plants in the plains, abundant supply of potassium is needed to maintain a high rate of metabolic activity for good yields. Potassium balances the effect of both nitrogen and phosphorus and influences the size and chemical composition of tubers. However, application of potassium at proper time with appropriate method and amount is much more important and one of the strategies to reduce various losses of nutrient that, in turn increases the nutrient use efficiency. However, the research work with biofertilizers in combination with N and P fertilizers is very meager. Hence, this aspect needs thorough investigation.

1.3.2 Scopes in potato processing:

Processing support is a must for sustaining increased potato production. In developed countries, potato is put to diversified uses like human consumption as fresh staple food and processed products; industrial use for starch and alcohol production, and livestock feed. In developing countries, however, it is still primarily used as a vegetable. In India about 0.1 cent^{-1} of total production is exported, 0.3 cent^{-1} is processed in different forms, 10 cent^{-1} is used as seed, 17 cent^{-1} goes waste, and remaining about 73 cent^{-1} is consumed either as vegetable or other fresh house hold preparations (Khurana, 2002). Processing is a fast growing sector in the potato world economy. Most of the potato processing is presently confined to the developed countries and is only in its infancy in most of the developing countries with the exception of China (20 cent^{-1}), Korea DPR (6 cent^{-1}) and Mexico (8 cent^{-1}). In Netherlands and USA, processing industry absorbs about 55 cent^{-1} and 60 cent^{-1}, respectively of the annual potato production. However, fast growth in potato processing is expected to occur in India due to increased urbanization, preferences for easy-to-prepare and fast foods, rise in capita^{-1} income, increase in number of working women and expanding tourist trade. Processing provides an effective means of utilizing surplus potatoes especially during glut in some years as it reduces wastage and helps in decreasing the demand for refrigerated storage space, the capacity of which is hardly 40 cent^{-1} of the total production both in India and in West Bengal.

With the liberalization of economy, potato processing has picked up and the processors have started using the available varieties developed for consumption as table potatoes like Kufri Chandramukhi and Kufri Jyoti, which, though not ideal for processing, have been found acceptable. However, the growth of organized processing industry in the country and in West Bengal has remained slow. This can be mainly attributed to non-availability of suitable raw materials i.e. lack of processing varieties and their continuous supply. A demand was, therefore, created for development of varieties suitable for processing having desirable tuber size and shape, higher dry matter (more than 21 $cent^{-1}$) and low reducing sugars (less than 150 mg 100 g^{-1} fresh weight) and also resistance to late blight along with high recovery of light colour chips.

A breeding programme to meet the demand for varieties suitable for processing was, therefore, initiated at Central Potato Research Institute (CPRI), Shimla in 1990. In 1998, the CPRI released two varieties for processing *viz.* Kufri Chipsona-1 (hybrid MP/90-83) and Kufri Chipsona-2 (hybrid MP/91-G) having high dry matter and low reducing sugars as desired for chipping (Gaur *et al.*, 1998 and Gaur *et al.*, 1999 a). Use of high dry matter potatoes resulted in lower energy requirement for removing water either during frying or dehydration, lower uptake of cooking medium during frying and higher yields of the products (Ezekiel *et al.*, 1999). A number of promising hybrids and some exotic cultivars were also selected for assessment of various biochemical attributes required for processing, higher yield and resistance to late blight. So the performances of these cultivars in the climatic conditions of West Bengal need to be evaluated.

Again, it is well known that low temperature storage at 3-4^{0}C is unfavourable for processing potatoes owing to accumulation of high amount of reducing sugars. Hence, there is a need to investigate the keeping quality of different cultivars under non-refrigerated storage conditions since most of the potato varieties in West Bengal cannot be stored under ordinary conditions where high temperature and humidity prevail soon after its harvest.

Against the backdrop of this changed scenario of potato production, it is, therefore considered worthwhile to undertake investigations in order to identify suitable high yielding potato varieties for processing with better keeping quality for the Gangetic Alluvial Plains (Entisol) of West Bengal and to standardize doses of N and P when used in conjunction with different biofertilizers as inoculants for better economy and efficiency. Application of potassium at proper time and amount is also an important aspect for increasing its efficiency in potato and its effect on storage behaviour of tuber under normal room condition is needed to be evaluated.

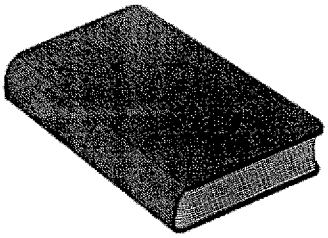
Keeping the above objectives in view, following three experiments have been carried out in the Gangetic Alluvial Plains of West Bengal:

i) Fertilizer economy in potato by the use of biofertilizers,

ii) Levels and methods of potassium application for increasing its efficiency in potato and its role on storage behaviour of tubers under normal room condition and

iii) Evaluation of Dutch and Indian potato cultivars for processing on the basis of yield, chip colour and keeping quality.

Chapter-2



Review of Literature

2. REVIEW OF LITERATURE

Potato production and utilization pattern in the world is changing very fast. Such changes offer many opportunities and challenges. If we want to be globally competitive, we have to keep pace and adapt to the new emerging potato production and utilization trends.

A good amount of work has been done by several research workers in India and abroad for the successful growing and utilization of potato. Some salient findings related to the present investigation have been reviewed in this chapter.

2.1 Fertilizer economy in potato by the use of biofertilizers:

The modern day intensive crop cultivation requires the use of chemical fertilizers but fertilizers are not only in short supplied, they are also expensive in developing countries. Therefore, the current trend is to explore the possibility of supplementing chemical fertilizers with organic ones, more particularly biofertilizers of microbial origin. Microbial processes are not only quick but consume relatively less energy than industrial processes.

2.1.1 Growth parameters:

A field experiment was conducted at Upper Shillong with four biofertilizer treatments (*Azotobacter* and phospho-inoculant culture strain *Pseudomonas striata* alone and in combination and the control. Singh (2001) evaluated that combined inoculation of *Azotobacter* + phospho-inoculant culture produced highest number of stems m^{-2} (34.2) and compound leaves m^{-2} (429.3). The number of stems m^{-2} and compound leaves m^{-2} in *Azotobacter* inoculation was 32.1 and 389.6, phospho-inoculant culture (33.7 and 402.8) and at control (31.3 and 340.5), respectively.

Kumar *et al.* (2001 b) reported from an experiment with 2 fertility levels of N and P along with biofertilizers treatment *viz.* *Azotobacter* + phosphobacteria, *Bacillus* (strain M_1) & *Bacillus* (strain B_5) that the number of leaves plant^{-1} at 45 days was maximum in the treatments comprising 100% N and P (65.6), closely followed by treatments with 100% N and P + soaking of tubers in solution containing 1% each of urea and sodium bicarbonate + *Azotobacter* + phosphobacteria (65.4). However, at 75 days the effect was just reverse to that at 45 days and the number of leaves plant^{-1} were 76.0 and 73.2 in two treatments, respectively.

A field experiment was conducted to evaluate the efficacy of biofertilizers namely, *Azotobacter* + phosphate solubilising bacteria (PSB) and *Bacillus* spp. along with varying levels of N and P on potato cv. Kufri Jyoti, Ray and Mukhopadhyay (2002) stated that soaking of tubers in solution containing 1% urea and 1% $NaHCO_3$ along with *Azotobacter* and PSB at 100% NP level produced maximum leaf area index, dry matter accumulation, crop growth rate and tuber bulking rate, closely followed by tubers inoculated with *Bacillus* spp. suspension at 100% NP level at all the crop growth stages.

2.1.2 Yield parameters and tuber yield:

The effectiveness of seed tuber inoculation with *Azotobacter* was assessed in pot (cv. Cardinal) and field (cv. Desiree) experiments at Faisalabad under optimum fertilizer application (250:150:150 and 200:100:100 kg N:P:K ha^{-1}, respectively), Zahir and Arshad (1996) revealed from the pot experiment that inoculation significantly increased the number of tubers plant^{-1} (up to 82.4 cent^{-1}) and tuber yield (up to 45.3 cent^{-1}) compared with the control (fertilizer application alone). Similarly, under field conditions, inoculation increased the number of tubers plant^{-1} (up to 50.0 cent^{-1}) and tuber yield (up to 32.3 cent^{-1}) compared with controls.

In a field experiment in Tamil Nadu, potatoes were given various combinations of 50, 75 or 100% recommended NPK rates and soil inoculation with *Azospirillum* and Phosphobacteria. The application of the recommended

NPK rate + soil inoculation with *Azospirillum* and Phosphobacteria gave the highest tuber yield of 25.87 t ha^{-1} (Mahendran and Kumar, 1998).

Field experiments with biofertilizers *viz. Azotobacter* and Phosphobacteria using potato cv. Kufri Jyoti were conducted at Patna, Praharaj *et al.* (1999) stated that soaking of tubers in solution containing 1% urea and 1% $NaHCO_3$ for 5 minutes along with biofertilizer application resulted in significantly higher tuber yield (268 and 235 q ha^{-1}) over control (234 and 218 q ha^{-1}) and soaking of tubers in solution containing only 1% urea and 1% $NaHCO_3$ for 5 minutes (250 and 225 q ha^{-1}) in both the years, respectively.

A significant increase in growth and yield of potato plants were obtained by treating seed potatoes with suspension of two *Bacillus* spp. *viz. B. subtilis* and *B. cereus* before planting in field soil as observed by Sunaina *et al.* (1999). Both strains showed significant $cent^{-1}$ increase in yield $plant^{-1}$, values ranging between 26 to 31.

Yadav *et al.* (1999) evaluated the effect of biofertilizer *Azotobacter* in potato cv. Kufri Sutlej in the absence and presence of nitrogen fertilizer. The results indicated that *Azotobacter* inoculation along with 75% fertilizer nitrogen had increased tuber yield and at par with 100% fertilizer nitrogen alone thus showing a net saving of 25 $cent^{-1}$ fertilizer nitrogen.

Field experiments were conducted at CPRS, Shillong to evaluate the efficiency of biofertilizer (*Azotobacter* and phospho-inoculant culture) alone and in combination with soil applied varying N levels. Singh (1999 c) opined that combined application of both biofertilizers along with 150 kg N ha^{-1} produced the highest tuber yield (19.9 t ha^{-1}) whereas control (no nitrogen and biofertilizers) gave lowest tuber yield (10.2 t ha^{-1}). On an average, *Azotobacter* gave 7.9 and phospho-inoculant culture 8.6 $cent^{-1}$ higher tuber yield over control when applied separately.

2.1.3 Nutrient removal and soil fertility status:

Field experiments were conducted with varying levels of NPK application along with biofertilizers, *viz. Azospirillum* and *phosphobacterium* on potato cv.

Kufri Jyoti. Mahendran and Chandramani (1998) observed that the uptake of N by potato plant was maximum at split application of recommended dose of NPK with biofertilizers. Similarly maximum P and K uptake was also recorded under this treatment. However, the maximum soil available NPK was recorded in basal application of recommended dose of NPK along with *Azospirillum* and *phosphobacterium* and the cent^{-1} increase in available NPK values at this treatment were 8.45, 14.54 and 7.33 respectively over basal application of recommended dose of NPK alone.

A field experiment was conducted comprising four treatments of biofertilizers (*Azotobacter* and phospho-inoculant culture strain *Pseudomonas striata* alone and in combination and the control) and four levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}). Singh (2001) reported that the N uptake was higher by 13, 11 and 23.4 cent^{-1} with *Azotobacter*, phospho-inoculant culture and combined inoculation of both the biofertilizer respectively over the control. Corresponding to that P uptake was higher by 14.5, 37.1 and 49.8 cent^{-1} and K was 11.2, 10.1 and 21.3 cent^{-1} respectively.

Singh and Sharma (2002) obtained relatively higher N and P uptake by potato plants with inoculation of seed tubers with phosphorus solubilising bacteria (*Pseudomonas striata*) from an experiment at Meghalaya with potato cultivar Kufri Jyoti.

2.1.4 Economic feasibility:

From an experiment in Meghalaya, Singh (1999 b) estimated the efficiency of phosphate solubilising bacteria with various levels of phosphorus on potato production. The phosphate solubilising bacteria enhanced the net return by Rs. 10,325 ha^{-1}. A net return of Rs. 3,474 was obtained from the best combination of phosphate solubilising bacteria + 120 kg P_2O_5 ha^{-1}.

The effect of biofertilizer (*Azotobacter chroococcum*) and other organic sources along with fertilizer levels (100, 125 and 150% of recommended dose of NPK) on potato crops was investigated. Krishnamurthy *et al.* (2001) inferred

that biofertilizer application recorded the highest incremental cost benefit ratio (ICBR).

2.2 Levels and methods of potassium application for increasing its efficiency in potato:

It cannot be denied that successful potato growing depends on potassic fertilizer and not only this, the crop also responds miraculously to potash application. The potato crop like the legume, is not very efficient in taking up potassium which it needs in large amounts and the only way to correct this is to enrich the soil solution to its optimal level by applying potassium that facilitates the roots in taking up this nutrient.

2.2.1 Growth parameters:

Shukla and Singh (1976) observed that the increasing levels of potassium excited linear response in mean fresh and dry weight of shoots and tubers, number of tubers and tuber bulking rate at all the stages of growth.

Singh and Grewal (1979) reported that the application of 83 kg K_2O ha^{-1} produced 493 kg more dry matter than no potash treatment. Dry matter of leaf at maximum tuber bulking stage was maximum in potassium treated plots. It is clear that the potassic fertilizer helped to store maximum amount of photosynthates in the tuber.

The investigation carried out at Ludhiana with 5 levels of potassium (30, 60, 90, 120 and 150 kg K_2O ha^{-1}) and 2 cultivars (Kufri Chandramukhi and Kufri Sindhuri) showed that increase in the level of potassium had no significant effect on leaf area $plant^{-1}$. However, leaf area increased from 16.3 cm^2 to 17.7 cm^2 at 90 kg K_2O ha^{-1} and then decreases at higher doses in Kufri Chandramukhi while in case of Kufri Sindhuri leaf area increased up to 120 kg K_2O ha^{-1} (23.2 cm^2) and then decreases at higher levels of K_2O (Singh *et al.*, 1993).

An experiment was conducted with 5 levels of potassium and 6 methods of its application to potato cv. Kufri Badshah. Levels of potassium significantly increased the fresh weight of leaves $hill^{-1}$ up to 50 DAP, thereafter the fresh

weight of leaves decreased. The maximum fresh weight of leaves i.e. 28.6 g at 30 DAP and 87.6 g at 50 DAP with 200 kg K_2O ha^{-1} and 82.9 g with 150 kg K_2O ha^{-1} at 70 DAP was recorded. The maximum fresh weight of stems $hill^{-1}$ was recorded with 200 kg K_2O ha^{-1} at 50 DAP (61.7 g) and 150 kg K_2O ha^{-1} at 70 DAP (55.0 g). Singh and Singh (1995 a) also obtained the highest fresh weight of leaves (36.7 g at 30 DAP) with full basal application of potassium, 92.2 g at 50 DAP and 93.2 g at 70 DAP with ½ basal + ½ top dressing. Again the highest fresh weight of stems $hill^{-1}$ was observed under full basal application at 30 DAP (20.8 g) and ½ basal +½ top dressing at 50 DAP (69.0 g) and 70 DAP (61.4 g).

In field trials in Brazil, potato~~es~~ cv. Achat ~~were~~ was given 0, 180 or 360 kg N ha^{-1}; 0, 300 or 600 kg P_2O_5 ha^{-1}; 0, 90 or 180 kg K_2O $ha^{-1}$and 0 or 20 kg B ha^{-1}. Dry matter yields increased linearly with increasing rates of applied N, P and K as stated by Peixoto *et al.* (1996).

Potato cv. HPS 1/13 ~~were~~ was given no fertilizers, 25 $cent^{-1}$ less or 25 $cent^{-1}$ more than the recommended rate of fertilizer (125 kg N + 100 kg P_2O_5 + 125 kg K_2O ha^{-1}) in field trials on alfisol at Karnataka. Veeranna and Khalak (1997) found that application of 25 $cent^{-1}$ more fertilizers than the recommended rate significantly increased the leaf area $plant^{-1}$, leaf area index, leaf area duration and total dry matter production $plant^{-1}$ compared with lower fertilizer rates.

Field experiments were conducted at Gurgaon, Haryana and in Meerut region of Uttar Pradesh with 5 rates of potassium *viz.* 0, 100, 150, 200 and 225 kg K_2O ha^{-1}. The highest dry matter content of tubers were measured at potassium rates of 150 kg K_2O ha^{-1} and the effect of potassium was more pronounced at 225 kg K_2O ha^{-1} (Bansal and Maibaum, 1999).

2.2.2 Graded tuber yield:

Field experiment was conducted at Jalandhar with sixteen combinations of 4 rates of K applied at planting and earthing and 2 potato cultivars. Application of potassium up to 66 kg K ha^{-1} at the time of planting significantly increased the mean tuber yield of cv. Kufri Jyoti from 32.8 to 36.6 t ha^{-1}. But significant response to basal application of K was up to 33 kg ha^{-1} in cv. Kufri

Chandramukhi when it enhanced mean tuber yields from 26.5 to 28.1 t ha^{-1}. Kufri Jyoti gave significant mean response to K applied at earthing up to 66 kg ha^{-1} but cv. Kufri Chandramukhi did not respond to K when applied at earthing (30 DAP) (Trehan and Grewal, 1991).

Potatoes were given 0, 100, 150, 200 or 250 kg N; 0, 75, 100 or 125 kg P_2O_5; 0, 50, 75 or 100 kg K_2O and 20 t FYM ha^{-1} at Pakistan. Khan (1993) reported that total tuber yield ranged from 8.66 t ha^{-1} without fertilizers to 64.59 t with 250 kg N, 125 kg P_2O_5, 100 kg K_2O and 20 t FYM ha^{-1}. Seed potato yield was highest (45.31 t ha^{-1}) with 200 kg N, 125 kg P_2O_5, 75 kg K_2O and 20 t FYM ha^{-1}, while graded ware potato yield was highest (26.81 t) with 200 kg N, 125 kg P_2O_5, 75 kg K_2O and 20 t FYM ha^{-1}.

An experiment was conducted on potato cv. Kufri Badshah with five levels and six techniques of potassium application at BHU, Varanasi. Singh and Singh (1995 b) worked out that increasing levels of potassium influenced the number and weight of different grades of tuber $hill^{-1}$ and yield. The maximum number of large and medium sized tubers was obtained with 200 kg K_2O ha^{-1} while minimum was in control (no potassium). Among the techniques, maximum number of large and medium sized tubers $hill^{-1}$ was observed with ½ basal + ½ at 30 DAP of potassium application while minimum values were noted under no basal + ½ at 30 DAP + ½ at 50 DAP treatment. The maximum yield of large and medium sized tubers was noted with 200 kg K_2O ha^{-1}. The decreasing trend of small sized tubers from 0 to 200 kg K_2O ha^{-1} was noted in both years. Again the maximum yield (238.66 and 212.41 q ha^{-1} in two years) was obtained with ½ basal + ½ top dressing of potassium at 30 DAP.

Field experiment at Shimla and Jalandhar showed that a balanced N x K fertilization increased tuber yield. Increasing K doses decreased the yield of small grade tubers and increased the proportion of large tubers. A maximum yield of 40.8 t ha^{-1} was obtained at Kufri (Shimla) when applied with 180 kg N, 100 kg P_2O_5 and 150 kg K_2O ha^{-1}, against a tuber yield of only 14.6 t ha^{-1} at the control plots (Imas and Bansal, 1999).

Field experiments conducted at Shimla with different doses of potassium revealed that there was a highly significant response of potato to potassium. The tuber yield increased with the increase in potassium from 75 to 150 kg K_2O ha^{-1} and the effect was most conspicuous on the yield of large sized tubers (75 g) (Sharma *et al.*, 1999).

Singh and Raghav (2000) worked out from an experiment at Pantnagar that the maximum tuber yield of potato cv. Kufri Ashoka was recorded under the highest level of potassium fertilization (267 q ha^{-1} at 120 kg K ha^{-1}) and the minimum was observed in 30 kg K ha^{-1}.

2.2.3 Concentration and uptake of nutrients:

Trehan and Grewal (1991) worked out from an experiment with 4 rates of K (0, 33, 66 and 99 kg ha^{-1}) at Jalandhar that application of K both at planting and at earthing significantly increased concentration of K in petioles, leaflets and tubers and removal of K by tubers in both Kufri Jyoti and Kufri Chandramukhi. However, the increase of K in petioles and leaflets at planting was more than that at earthing but the magnitude of increase in the tubers at planting was similar to that at earthing in Kufri Jyoti.

A field experiment was conducted with three levels each of nitrogen and potassium in Karnataka. The nutrient uptake indicated that the potato could not respond to higher doses of fertilizers beyond 150 kg K and 200 kg N ha^{-1}. The K uptake by cv. Kufri Chandramukhi was 79, 100 and 84 kg ha^{-1} and that of cv. Kufri Jyoti was 67, 84 and 75 kg ha^{-1} at K levels 100, 150 and 200 kg ha^{-1}, respectively (Chadachan *et al.*, 1993).

Field experiments were conducted in potato crop with fertilizer rates (0, 75, 100 or 125 $cent^{-1}$ of the recommended NPK rate of 125 kg N + 100 kg P_2O_5 + 125 kg K_2O ha^{-1}). Veeranna *et al.* (1997) found that the uptake of N, P and K was significantly higher with the highest NPK rate. The percentage recovery of N (45.55 $cent^{-1}$) and P (7.93 $cent^{-1}$) was maximum at the recommended NPK rate whereas percentage recovery of K (47.49 $cent^{-1}$) was maximum with the application of 75 $cent^{-1}$ of recommended rate.

Field experiments were conducted at CPRS, Jalandhar with four levels of soil applied K at planting and four foliar spray on potato cv. Kufri Badshah. Increasing dose of soil applied K from 0 to 99 kg ha^{-1} increased K concentration in leaves from 1.6 to 2.5 $cent^{-1}$. Similarly, K uptake by tubers increased from 61 to 92 kg ha^{-1} with increase in soil applied K from 0 to 99 kg ha^{-1} (Trehan and Sharma, 1998).

Results of the field experiment at Shimla on the interaction effect of N and K on resultant soil fertility revealed that application of K increased the N concentration of tubers, which suggests that K helped in utilization of N. Application of K also increased K composition of tubers, but N had no effect on K but increased its own composition. The post harvest analysis of soil showed that application of K increased organic carbon and available K status of the soil while N had little effect (Sharma *et al.*, 1999).

2.2.4 Keeping quality of potatoes:

A field experiment was conducted at Indian Agricultural Research Institute, New Delhi to study the storage behaviour of potato cultivars under varying levels of potash. Sharma and Ezekiel (1993) observed from the results that there was not any significant difference in weight loss of tubers at 30 and 60 DAS due to K application. However, the weight loss varies between 6.0-8.0 $cent^{-1}$ (K_0) to 6.3-8.7 $cent^{-1}$ (K_{80}) at 30 DAS and 10.6-15.1 $cent^{-1}$ (K_0) to 10.8-16.5 $cent^{-1}$ (K_{80}) at 60 DAS depending upon the cultivars.

Singh *et al.* (1996) estimated the keeping quality of tubers of potato cv. Kufri Badshah at varying levels of K. At 11 weeks after storage maximum weight loss of 9.4 $cent^{-1}$ was found both at 0 and 120 kg K_2O ha^{-1} and minimum (8.3 $cent^{-1}$) at 180 kg K_2O ha^{-1}. However, at 14 weeks after storage maximum weight loss of 20.4 $cent^{-1}$ was found at 0 kg and weight loss decreases with further increase in K levels. Maximum rotting of potato tubers (7.9 $cent^{-1}$) was found at 120 kg K_2O ha^{-1} and minimum (4.8 $cent^{-1}$) at higher doses (180 kg K_2O ha^{-1}).

Post harvest storage losses of tubers were significantly reduced at 4 weeks in the experiment conducted at Gurgaon, Haryana with five levels of potassium (0, 100, 150, 200 and 225 kg K_2O ha^{-1}) and two sources (muriate of potash and sulphate of potash) (Bansal and Maibaum, 1999).

2.2.5 Production economics:

Indian potato cv. Kufri Badshah were given 50, 75 or 100 $cent^{-1}$ of the recommended NPK rate (180 kg N, 80 kg P_2O_5 and 120 kg K_2O ha^{-1}) in a field experiment at Jalandhar and the highest net returns were obtained with the recommended NPK rate as reported by Jaiswal (1995).

An experiment was conducted at Zonal Agricultural Research Station, Chhindwara, Madhya Pradesh with four levels each of phosphorus (0, 50, 100 and 150 kg P_2O_5 ha^{-1}) and potassium (0, 60, 120 and 180 kg K_2O ha^{-1}) to potato tubers. Nandekar *et al.* (1999) reported from the economics of cultivation that maximum C:B ratio of 2.39 and 2.16 was recorded with 100 kg P_2O_5 and 120 kg K_2O ha^{-1}, respectively.

Singh (1999 a) reported from the field experiment applied with varying levels of NPK (50:60:25, 100:120:50 or 150:180:75 kg ha^{-1}) that the highest net return was obtained with the application of 100:120:50 kg NPK ha^{-1}.

Field studies conducted at Central Potato Research Station, Patna with three potato varieties (Kufri Ashoka, K. Jyoti and K. Sindhuri) and three levels of nutrients (100, 125 and 150 $cent^{-1}$ recommended doses of N, P and K) showed that the net returns and benefit : cost ratio were highest in K. Sindhuri, followed by K. Ashoka and K. Jyoti. Kumar *et al.* (2001 a) also opined that 150 $cent^{-1}$ recommended dose of fertilizer fetched the highest net return (Rs 24,378 ha^{-1}) and benefit: cost ratio (1.63).

2.3 Evaluation of exotic and Indian potato cultivars for processing:

While the ways and means for boosting potato output have been deliberated in the national and global food security, conservation and

preservation of it has received very little attention in the overall food security agenda. With burgeoning population, low productivity, diminishing arable land and expensive inputs, the country can hardly afford to waste what is produced. This makes it important to complement agricultural productivity with adequate post harvest food preservation technology.

2.3.1 Growth parameters:

Shaheen *et al.* (1995) reported that Cardinal produced the highest dry matter content (21.7 $cent^{-1}$) while determining the processing quality of four potato cv. Desiree, Cardinal, Diamant and Laale-Faisal.

New potato hybrids MP/90-74, MP/90-83, MP/90-94 and MP/91-G were assessed for tuber dry matter and compared with cv. Kufri Jyoti and Frito Lay hybrids 1533 and 1584. MP/90-83, MP/90-94 and MP/91-G produced higher tuber dry matter contents (20.3-22.3 $cent^{-1}$) than Kufri Jyoti (Singh *et al.*, 1997).

Kufri Chipsona-1 and Kufri Chipsona-2 produced above 20 $cent^{-1}$ tuber dry matter and quite comparable with the popular processing variety Kufri Jyoti and American variety FL 1533 from field trials at 8 locations of India (Pandey *et al.*, 1999).

From an experiment at Modipuram, Gaur *et al.* (1999 b) stated that Kufri Chipsona-2 is a medium-tall, erect, vigorous and having profusely branched stems with high dry matter content. Tuber dry matter of Kufri Chipsona-2 ranged from 22-23 $cent^{-1}$ as against 18-20.1 $cent^{-1}$ in Kufri Jyoti.

Processing quality of three potato varieties namely, Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti, along with one advanced hybrid MP/90-94 were tested at five locations; Dharwad, Midnapore, Patna, Faizabad and Modipuram. Kumar *et al.* (1999 c) reported from the results that the dry matter content was around 21 $cent^{-1}$ or more in Kufri Chipsona-1 and 2 and advanced hybrid MP/90-94 at all the five locations as against around 19 $cent^{-1}$ in Kufri Jyoti.

Das *et al.* (2001) stated that two recently released processing varieties, *viz.* Kufri Chipsona-1 and Kufri Chipsona-2 had high dry matter content of 21.2

and 22.0 cent^{-1} respectively as against Kufri Jyoti (18.9 cent^{-1}) and Kufri Sindhuri (18.6 cent^{-1}) from an experiment conducted at CPRS, Patna.

In a study on chemical maturity of processing potato varieties at CPRS, Modipuram exotic cv. FL 1533 produced maximum dry matter (22.43 cent^{-1}) at 80 DAP whilst among the Indian cultivars, the order was Kufri Chipsona-1 (20.64 cent^{-1}), Kufri Chipsona-2 (19.45 cent^{-1}), Kufri Jyoti (18.28 cent^{-1}) and Kufri Lauvkar (17.90 cent^{-1}) at 80 DAP (Kumar *et al.*, 2001 c).

2.3.2 Tuber yield:

Jekic and Stojanov (1992) found from field experiments at Yugoslavia with 5 Dutch potato cultivars that cv. Junior gave the lowest proportion of small tubers, cv. Escost the highest proportion but cv. Diamant the highest overall yield.

In field trials on sandy loam and silty clay loam soil at Bangladesh, Khan *et al.* (1992) opined that exotic potato cv. Cardinal produced the highest tuber yield (22.2 t ha^{-1}) at both sites and indigenous cv. Dohazari the lowest (8.6-9.2 t ha^{-1}) among the six cultivars *viz.* Cardinal, Patrones and Kufri Sindhuri (exotic) and Zaubilati, Lalpakri and Dohazari (indigenous) cultivated.

Nandekar *et al.* (1993) working on stability parameters of seven potato varieties in Chhindwara, Madhya Pradesh during *Kharif*, autumn and *rabi* seasons opined that *rabi* was the most favourable planting season. A significant genotype-environment interaction for tuber yield was observed and Kufri Jyoti showed average stability and gave desirable tuber yield under varied environmental conditions.

Ghimbasan (1997) conducted an experiment on five potato cultivars of Dutch origin in Romania on humus-semi clayey and sandy (stony) soils. The tuber yields of Doritta and Aminca were not significantly different from the standard variety Sante, whereas Novita and Carlita produced significantly lower yields than Sante on both types of soil.

From a processing varietal trial of potato in West Bengal, Roy *et al.* (1999) opined that the highest tuber yield was recorded in Kufri Chipsona-1

(19.3 t ha^{-1}) followed by MP/90-94 (17.9 t ha^{-1}) and Kufri Chipsona-2 (17.5 t ha^{-1}). Kufri Jyoti produced an yield of 15.5 t ha^{-1}. In another trial comprising eight Dutch varieties *viz.* Ajax, Agria, Anosta, Cardinal, Diamant, Marfona, Fresco and Sante along with Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti, only Cardinal (22.3 t ha^{-1}), Kufri Chipsona-1 (21.5 t ha^{-1}), Kufri Chipsona-2 (20.9 t ha^{-1}) and Ajax (20.2 t ha^{-1}) were at par in yield and better than Kufri Jyoti (15.5 t ha^{-1}).

Eight potato varieties from Holland along with the newly developed varieties Kufri Chipsona-1 and Kufri Chipsona-2, and popular processing variety Kufri Jyoti were evaluated in north-western plains at Modipuram and eastern plains at Midnapore. Gaur *et al.* (1999 a) reported that Kufri Chipsona-2 produced the highest tuber yield (287.6 q ha^{-1}) followed by Cardinal (286.7 q ha^{-1}) and Kufri Chipsona-1 (279.5 q ha^{-1}) at Modipuram whereas at Midnapore, Cardinal produced the highest tuber yield (223.0 q ha^{-1}) followed by Kufri Chipsona-1 (215.0 q ha^{-1}) and Kufri Chipsona-2 (209.0 q ha^{-1}).

Gaur *et al.* (1999 b) stated that tubers of Kufri Chipsona-2 are of medium-size, round to oval in shape and have creamy-yellow flesh with a waxy texture and yields of Kufri Chipsona-2 are similar to those of Kufri Jyoti and is tolerant of late blight (*Phytophthora infestans*) and frost.

Six Dutch and two Indian potato cultivars suitable for processing were evaluated in West Bengal taking Kufri Jyoti as the standard (control). Chettri *et al.* (2001) found that Dutch cv. Cardinal and Indian cv. Kufri Chipsona-1 showed higher yield potential over other cultivars. Cardinal (339.4 q ha^{-1}), Kufri Chipsona-1 (317.8 q ha^{-1}), Diamant (291.8 q ha^{-1}) and Kufri Chipsona-2 (253.8 q ha^{-1}) produced higher tuber yield over standard cv. Kufri Jyoti (238.3 q ha^{-1}). Cardinal as well as Kufri Chipsona-1 also produced more than 85 $cent^{-1}$ marketable yields and have potential for large-scale cultivation.

2.3.3 Quality traits of potato cultivars:

Gonzalez and Carreno (1993) working on potato cv. Kennebec and Sebago at Venezuela found that since specific gravity and content of total solids,

starch and pectic substances were higher and enzymatic browning lower in Kennebec than in Sebago, it was recommended for manufacture of dried products.

Processing quality of potato cv. Desiree, Cardinal, Diamant and Laale-Faisal tubers were determined. At harvest Cardinal had the highest specific gravity (1.082) while Diamant and Cardinal were best for making French fries and potato balls (Shaheen *et al.*, 1995).

A field trial was conducted at Modipuram, Meerut with four new potato hybrids and compared with Kufri Jyoti and American Frito Lay hybrids. The new potato hybrids MP/90-83, MP/90-94 and MP/91-G contained low reducing sugars content between 150-216 mg 100 g^{-1} fresh wt. and had lighter chip colour than Kufri Jyoti but not Frito Lay hybrids (Singh *et al.*, 1997).

Gaur *et al.* (1998) stated that the variety Kufri Chipsona-1 produced acceptable light colour chips of grade 1-3 (on 1-8 scale where 1 is the lightest and 8 is the dark brown colour) from the tubers of the trials conducted at Modipuram and several other locations. In contrast, Kufri Jyoti always produced unacceptable brown colour chips of grade 5-6 at Modipuram and relatively lighter chips at Patna and Midnapore. Since Kufri Chipsona-1 produces oblong tubers with fleet eyes, peeling loss in this variety was less (9.0 $cent^{-1}$) than in Kufri Jyoti (10.4 $cent^{-1}$).

In a field trial in Jalandhar, Punjab, 9 Indian and 5 exotic potato cultivars were evaluated for suitability for processing. The reducing sugar content of the exotic cultivars was very low (72-112 mg 100 g^{-1} f. wt.) in comparison to the Indian cultivars (164-332 mg 100 g^{-1} f. wt.). Peeling losses in the Indian cultivars varied between 10.4 $cent^{-1}$ (Kufri Jyoti) to 16.5 $cent^{-1}$ (Kufri Sindhuri) while the exotic cultivars showed peeling losses from 10.9 $cent^{-1}$ (FL 1291) to 13.7 $cent^{-1}$ (FL 1584) (Marwaha, 1998 a).

In a trial conducted at CPRS, Modipuram, Kufri Chipsona-1 and Kufri Chipsona-2 possess low reducing sugars (45-100 mg and 44-93 mg 100 g^{-1} fresh wt., respectively) and produce golden coloured chips comparable to the

processing varieties developed by the American Company Frito Lay and Dutch varieties Agria, Ajax, Anosta, Cardinal, Diamant, Fresco, Marfona and Sante (Ezekiel *et al.*, 1999).

Uppal (1999) worked out from an experiment among five potato varieties *viz.* Kufri Ashoka, Kufri Pukhraj, Kufri Sutlej, Kufri Jawahar and Kufri Jyoti that reducing sugar content varied among varieties and was lowest in Kufri Jyoti (304 mg 100 g^{-1} f. wt.). Total sugars also followed the same trend and lowest in Kufri Jyoti (536 mg 100 g^{-1} f. wt.). Differences in Vitamin C content of potato varieties were observed and it ranged between 8.25-11.48 mg 100 g^{-1} f. wt.

Gaur *et al.* (1999 a) reported while comparing the varieties Kufri Chipsona-1 and Kufri Chipsona-2 with Kufri Jyoti for 4 consecutive years at Modipuram for biochemical characters that both the varieties have low reducing sugars (108 and 112 mg 100 g^{-1} fresh wt., respectively) as against 245 mg 100 g^{-1} fresh wt. in Kufri Jyoti. Kufri Chipsona-1 and Kufri Chipsona-2 produced chips in the range of 1-3 (on 1-10 scale where 1 is white and 10 the dark brown colour) as compared to 5-6 in Kufri Jyoti. The chip colour in the range of 1-3 has high acceptance in the market.

Kumar *et al.* (1999 a) stated that out of the thirteen cultivars of potato investigated at Modipuram only five, namely Kufri Chipsona-1, Kufri Chipsona-2, Kufri Kuber, Atlantic and Frito Lay 1533 were found to have acceptable chip colour of 3 or below, reducing sugars content less than 100 mg 100 g^{-1} fresh wt., specific gravity of 1.080 or more.

Processing characteristics of the newly released Indian potato cultivars Kufri Chipsona-1 and Kufri Chipsona-2 were compared with two American cultivars and the standard Indian processing cv. Kufri Jyoti. The newly released cultivars had the best processing quality with low reducing sugars (below 200 mg 100 g^{-1} fresh wt.) and acceptable light colour chips (up to grade 3) as compared to Kufri Jyoti (454 mg 100 g^{-1} fresh wt. of reducing sugars and unacceptable colour chips of grade 5) (Kumar *et al.*, 1999 b).

An experiment was conducted at CPRS, Patna with four Indian potato varieties. Results revealed that the processing varieties Kufri Chipsona-1 and Kufri Chipsona-2 ~~contained~~ gave higher chip yield and the chip colour in these two varieties was better (3.2 and 3.0 respectively) than that in Kufri Jyoti (4.0) and Kufri Sindhuri (3.5). The peeling loss in these two processing varieties was also low (11.3 $cent^{-1}$ in Kufri Chipsona-1 and 11.9 $cent^{-1}$ in Kufri Chipsona-2) (Das *et al.*, 2001).

A field experiment was conducted with nine potato processing varieties during *rabi* 2000-2001. Ray *et al.* (2002) reported that the newly developed Indian varieties Kufri Chipsona-1 and Kufri Chipsona-2 attained minimum levels of reducing sugars and produced acceptable light colour chips. Total soluble solids were minimum in Kufri Jyoti and maximum in Sante while Ajax contained maximum content of total acids.

2.3.4 Storage behaviour:

Tubers of four advanced stage hybrids (E 4486, JE 808, JF 5106 and JI 5857) and six commercial varieties (Kufri Badshah, Kufri Bahar, Kufri Chandramukhi, Kufri Jyoti, Kufri Lalima and Kufri Lauvkar) were stored at ambient temperatures (from 13^0C min. to 46^0C max.) to study the performance of individual genotypes. Weight loss increased linearly with storage period for all the varieties and the loss was below 10 $cent^{-1}$ up to 70 days, over 20 $cent^{-1}$ the next 30 days to about 35 $cent^{-1}$ in the next 40 days. Weight loss was initially due to respiration and evaporation whereas in the later stages of storage, sprouting and rotting contributed to weight loss. The results suggest that it is not worth storing potatoes commercially at ambient temperatures beyond 70 days. All the genotypes studied had equal storability for 45 days. Rotting did not occur during first 70 days. During the next 30 days rotting averaged 1 $cent^{-1}$ and in the next 40 days, about another 10 $cent^{-1}$ loss. Thus, after 100 days of storage, rotting was a significant contributor to percentage weight loss (Kang and Gopal, 1993).

Storage quality of eight British potato cultivars was compared with the recommended cultivar, Diamant of Dutch origin. Average weight loss of the

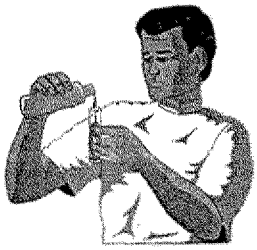
British cultivars due to dehydration was 19.00 $cent^{-1}$ in the second and 17.55 $cent^{-1}$ in the third generation tubers whilst the loss was 18.16 $cent^{-1}$ and 20.55 $cent^{-1}$, respectively in the controls. Average loss of the British cultivars due to rotting was 13.33 $cent^{-1}$ in the second and 8.75 $cent^{-1}$ in the third generation, compared with 10.00 $cent^{-1}$ and 16.67 $cent^{-1}$ in the controls. *Erwinia* spp. and *Fusarium* spp. were identified as the cause of rot disease (Hossain *et al.*, 1995).

Eleven advanced hybrids along with three control varieties were evaluated for their storability at room temperature at CPRS, Jalandhar. Minimum total weight loss at 90 and 120 days of storage was observed in hybrid JW 160 followed by JW 96, JX 216 and MS/89-60, ~~respectively~~. These four hybrids had significantly lower total weight loss than the best control variety Kufri Badshah. The percentage rotting ranged from 3.33 (JW 160) to 21.00 (85-P-670) at 90 days and 3.75 (JW 160) to 33.83 (MS/90-542) at 120 days of storage (Kang *et al.*, 2001).

Sharma *et al.* (2001) studied the storage behaviour of two advanced potato hybrids, *viz.* HB/83-39 and HB/82-372 and two commercial varieties, *viz.* Kufri Jyoti and Kufri Giriraj from December-June at room temperatures in country store at Kufri (Fagu). The advanced hybrids were found superior in respect of weight loss and sprouting behaviour than commercial cultivars. From storage point of view they stored well until February for ware potatoes and until April as seed.

Storage behaviour of seven advanced hybrids along with two popular varieties *viz.* Kufri Bahar and Kufri Sutlej stored for four months at ambient temperature at Modipuram revealed minimum sprouting and least physiological and total weight loss in hybrids JW 160 followed by MS/89-60. Physiological weight reduction ranged from 12.03-24.10 $cent^{-1}$ while that of loss due to rotting ranged from 22.67 $cent^{-1}$ in JW 160 to 38.15 $cent^{-1}$ in JX 230 (Singh *et al.*, 2001 a).

Chapter-3



Materials and Methods

3. MATERIALS AND METHODS

Three separate field experiments were carried out during the *rabi* seasons of two consecutive years (1999-2000 and 2000-2001) to study the role of biofertilizers in economizing N and P rates for potato production (cv. Kufri Jyoti); the effect of levels and methods of potassium application on growth and yield of potato (cv. Kufri Jyoti); and physical and biochemical parameters of potato cultivars (six Dutch cvs. *viz.* Ajax, Cardinal, Diamant, Fresco, Marfona, Sante and three Indian cvs. *viz.* Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti) in order to identify suitable cultivars on the basis of processing quality and productivity in Gangetic Alluvial Zone of West Bengal. Storage behaviour of potato tubers under normal room condition of all the cultivars was evaluated for processing and the effect of potassium on this aspect was also studied for two years.

3.1 Experimental location:

The experiments were conducted at the Block Seed Farm, Adisaptagram, Hooghly, West Bengal. The geographical location of the experimental site is 22^0 57'N latitude and $88^0$20'E longitude and an elevation of 7.8 m above the mean sea level.

3.2 Soil characteristics:

The soil of the experimental site is endowed with typical Gangetic Alluvium (Entisol) and sandy loam in texture. The physico-chemical analyses of the soil was done by collecting four samples at a depth of 0-30 cm of the experimental field and have been summarized in Table 3.1.

3.3 Agro-climatic condition:

The climate of this region is sub-tropical humid in nature and situated just south of the Tropic of Cancer. The entire year can be classified into three distinct

cropping seasons *viz.* (a) *rabi* or winter (November-February), (b) pre-*kharif* or summer (March-May) and (c) *kharif* or rainy (June-October).

The area is not subjected to extreme weather conditions and encounters fairly hot summer and moderately cool winter. From the long-term average, it appears that the mean monthly maximum temperature does not exceed 32.9^{0}C in March and the minimum temperature does not fall below 10.0^{0}C during January. The normal average annual rainfall in this locality is 1396 mm, most of which (about 80 cent^{-1}) is received during the months of June to October and only a scanty amount of rainfall occurs during the growth period of potato (November to February) (Table 3.2 and Fig. 3.1).

Table 3.1 : Physico-chemical properties of the experimental soil

Particulars	Values		Methods followed
	1999-2000	2000-2001	
Mechanical composition			
Sand (%)	53.97	52.15	International pipette method (Piper, 1966)
Silt (%)	30.67	31.12	
Clay (%)	15.36	16.73	
Chemical properties			
Organic carbon (%)	0.87	0.82	Rapid titration method (Walkley and Black, 1934)
Available nitrogen (kg N ha^{-1})	223.17	207.58	Modified macro-kjeldhal method (Jackson, 1973)
Available phosphorus (kg P ha^{-1})	8.39	9.16	Olsen's method (Jackson, 1973)
Available potassium (kg K ha^{-1})	169.15	182.27	Flame photometer method (Muhr *et al.*, 1965)
pH	5.9	5.6	Beckman's pH meter method (Jackson, 1973)

3.3.1 Temperature:

During the crop growth period, the mean monthly maximum temperature did not exceed 30.8^{0}C in November, 2000 and mean monthly minimum temperature did not fall below 9.4^{0}C in January in the year 2001. The mean maximum temperature also did not go beyond 33.5^{0}C in March, 2001 during harvesting. The daily mean temperature during the crop growth period remained congenial to sustain growth and development for high production of tubers, which persisted up to the end of February in both the years and afterwards the temperature began to rise. Again the mean minimum temperature during the last 30 days of crop growth (during February) is more than 12^{0}C which is quite suitable for the production of high dry matter content in tubers. From March onwards temperature started rising and reached the highest value during May-June (more than 35^{0}C). High temperature and high average relative humidity during these months are hardly conducive for the storage of biologically active potato tubers that contain about 75-80 cent^{-1} water.

3.3.2 Relative humidity:

The mean monthly maximum and minimum relative humidity varied from 91.0-99.9 cent^{-1} and 42.5-73.4 cent^{-1}, respectively during the period of investigation in the first year. The corresponding values in the second year varied from 91.2-99.5 cent^{-1} and 38.8-78.8 cent^{-1}, respectively.

3.3.3 Rainfall:

The total rainfall of 28.8 mm was received during the crop growth period in the first year while during the second year the total rainfall received was 6.0 mm.

3.3.4 Sunshine:

The crop intercepted more than 8 hours of bright sunshine during the growth period in both the years.

Table 3.2 : Meteorological data of the experimental site during the period of experimentation

Year	Month	Temperature (^{0}C)				Relative humidity(cent^{-1})		Total rainfall (mm)		Bright sunshine (hours)
		Maximum		Minimum		Maximum	Minimum	LTA	CGP	
		LTA	CGA	LTA	CGP					
1999	November	29.4	30.2	16.1	17.4	98.0	57.9	13.2	8.0	8.8
	December	25.9	27.6	12.4	12.7	99.2	51.3	1.8	0.0	8.7
2000	January	25.3	26.6	10.0	11.4	99.9	52.0	12.2	4.8	8.7
	February	27.9	25.1	13.4	14.1	95.0	52.0	20.6	24.0	8.3
	March	32.9	32.5	19.9	19.6	91.0	42.5	25.4	0.0	9.3
	April	36.8	34.9	23.9	24.1	93.9	57.3	62.3	88.7	9.0
	May	36.4	34.6	25.1	24.3	95.0	66.8	102.6	280.6	8.2
	June	36.6	33.3	25.0	25.5	94.6	73.4	274.3	224.1	6.9
2000	November	29.4	30.8	16.1	18.6	98.9	49.8	13.2	0.2	8.9
	December	25.9	26.8	12.4	11.8	99.5	45.6	1.8	0.0	8.9
2001	January	25.3	25.4	10.0	9.4	96.2	39.4	12.2	0.0	8.8
	February	27.9	29.8	13.4	16.9	95.7	38.8	20.6	6.0	9.3
	March	32.9	33.5	19.9	19.0	95.1	41.8	25.4	18.3	9.0
	April	36.8	35.9	23.9	23.7	91.2	50.9	62.3	33.8	7.3
	May	36.4	35.0	25.1	24.5	92.3	64.9	102.6	155.5	6.4
	June	36.6	32.6	25.0	25.5	96.6	78.8	274.3	315.2	3.8

LTA = Long Term Average, represents monthly mean of preceding 20 years
CGP = Crop Growth Period

Source : AICRP on Agrometeorology, BCKV, Kalyani, Nadia, West Bengal.

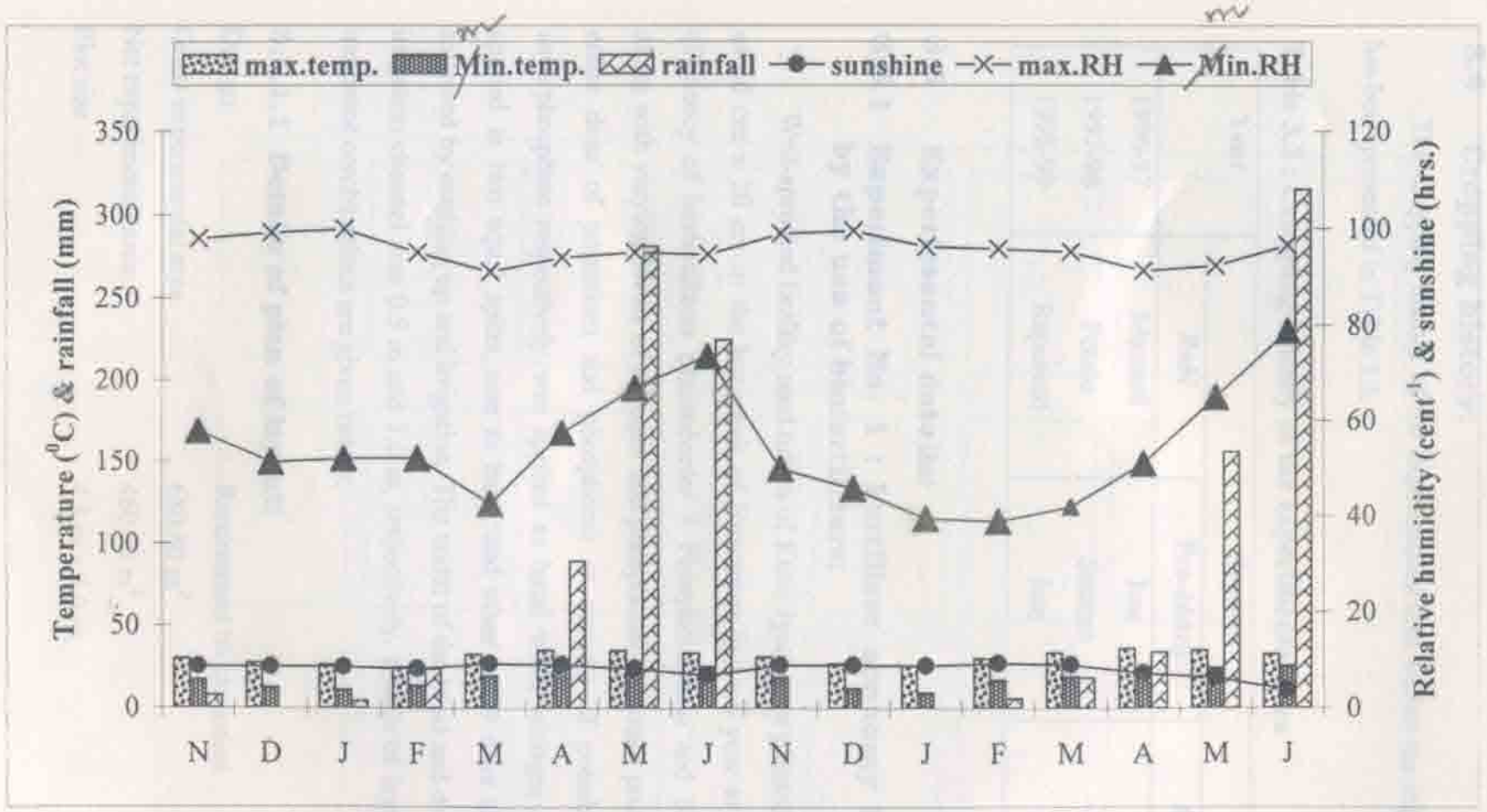


Fig. 3.1: Meteorological data of the experimental site during the period of experimentation.

3.4 Cropping history:

The cropping history of the experimental area before the experimentation has been presented in Table 3.3.

Table 3.3 : Cropping history of the experimental area

Year	Seasons		
	Rabi	**Pre-*kharif***	***Kharif***
1996-97	Mustard	Jute	Rice
1997-98	Potato	Sesame	Rice
1998-99	Rapeseed	Jute	Rice

3.5 Experimental details:

3.5.1 Experiment No. 1 : Fertilizer economy in potato by the use of biofertilizers:

Well-sprouted healthy seed tubers of Kufri Jyoti were planted at a spacing of 60 cm x 20 cm in the last week of November in each year to evaluate the efficiency of biofertilizers (*Azotobacter* + Phosphobacteria and *Bacillus* spp.) along with varying levels of nitrogen and phosphorus on potato production. The entire dose of potassium and phosphorus as muriate of potash and single superphosphate respectively was applied as basal while nitrogen as urea was applied in two equal splits, one as basal and other at 30 days after planting followed by earthing up and irrigation. The width of the bund and drainage-cum-irrigation channel was 0.5 m and 1.0 m, respectively. Details of layout plan and treatment combinations are given below:

3.5.1.1 Details of plan of layout:

Design	:	Randomised block design
Gross experimental area	:	680.80 m^2
Net experimental area	:	460.80 m^2
Plot size	:	4.8 m x 4.0 m

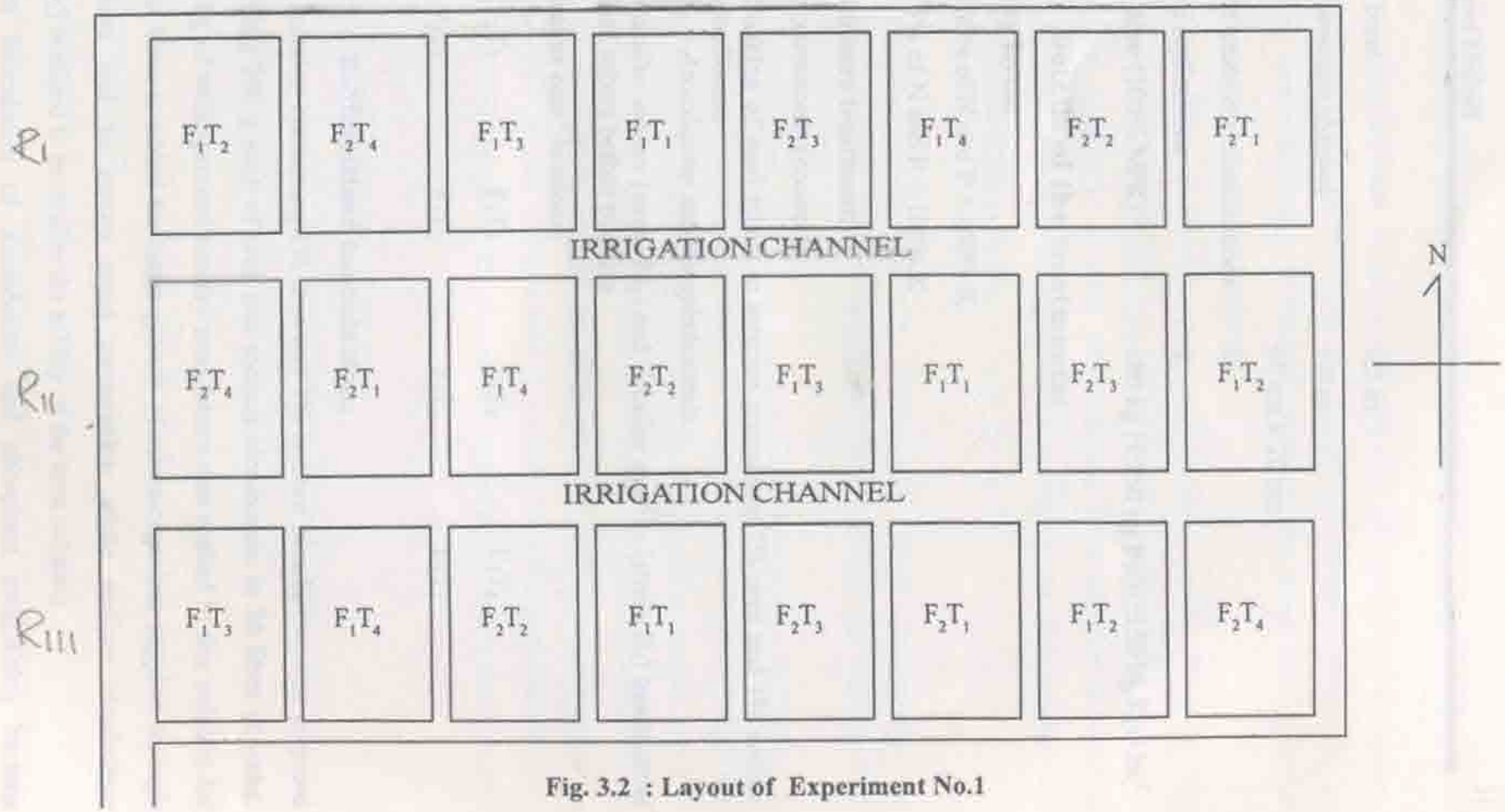


Fig. 3.2 : Layout of Experiment No.1

Width of bund	:	0.5 m
Width of drainage channel	:	1.0 m
Spacing	:	60 cm x 20 cm
Number of treatment combinations	:	8
Number of replications	:	3
Fertilizer dose (100% NPK)	:	180 kg N:150 kg P_2O_5 :150 kg K_2O ha^{-1}

3.5.1.2 Details of the treatments:

A. Fertility levels:

F_1 = 100% of N and P + 100% K

F_2 = 75% of N and P + 100% K

B. Biofertilizers treatment:

T_1 = No treatment (control)

T_2 = Soaking of seed tubers in solution containing 1% urea and 1% sodium bicarbonate

T_3 = T_2 + *Azotobacter* and Phosphobacteria

T_4 = *Bacillus cereus* (strain M_1) and *Bacillus subtilis* (strain B_5) treatment of seed tubers before planting

C. Treatment combinations:

F_1T_1	F_1T_2	F_1T_3	F_1T_4
F_2T_1	F_2T_2	F_2T_3	F_2T_4

3.5.1.3 Biofertilizer inoculation:

A solution containing 1% urea and 1% sodium bicarbonate was prepared by dissolving 200 g each of urea and sodium bicarbonate in 20 litres of water. Then 50 kg of well-sprouted healthy seed tubers was soaked in this solution for 5 minutes. Urea is added for better growth of micro-organism supplied through biofertilizers and to ensure rapid germination while sodium bicarbonate ($NaHCO_3$) is added to neutralize the acidity of the urea solution.

For inoculation of *Azotobacter* and phosphate solubilising bacteria culture, a jaggery solution was prepared by dissolving 100 g of jaggery in one

litre of water. Biofertilizers weighing 200 g of each was added to this solution. The solution was spread on 250 kg of seed tubers and was mixed thoroughly so that uniform and even spread of biofertilizers over the tubers was achieved. Tubers were then allowed to dry in shade.

For inoculation of *Bacillus cereus* and *Bacillus subtilis*, 250 g of each culture was suspended in 50 litres of water. A solution was prepared by boiling 2 kg of jaggery in one litre of water. After cooling, it was added to the solution of bioagent. Seed tubers (250 kg) were then dipped in this solution for 30 minutes and then dried in shade.

3.5.2 Experiment No. 2 : Levels and methods of potassium application for increasing its efficiency in potato:

The investigation was carried out with the potato variety Kufri Jyoti to find out the effect of levels and methods of potassium application on growth and productivity of potato. Treatments comprised five levels of potassium and four methods of application. Altogether there were seventeen treatment combinations. All the plots were fertilized with the same doses of nitrogen and phosphorus utilizing the same sources as discussed in Experiment No. 1 and by following the same methods. The details of the plan of layout and the treatment combinations are highlighted as under:

3.5.2.1 Details of plan of layout:

Design	: Factorial experiment in randomised block design
Gross experimental area	: 895.40 m^2
Net experimental area	: 550.80 m^2
Plot size	: 3.6 m x 3.0 m
Treatment combinations	: 17
Number of replications	: 3
Fertilizer dose	: 180 kg N:150 kg P_2O_5 ha^{-1} (K_2O as per treatments)

R_I	K_1M_4	K_4M_1	K_3M_2	K_2M_4	K_3M_3	K_1M_1	K_2M_2	K_1M_3	K_4M_2	K_3M_1	K_2M_3	K_0	K_1M_2	K_4M_3	K_3M_4	K_2M_1	K_4M_4

IRRIGATION CHANNEL

R_{II}	K_2M_1	K_3M_4	K_1M_3	K_4M_4	K_1M_2	K_0	K_3M_1	K_4M_3	K_2M_2	K_1M_4	K_4M_1	K_3M_2	K_2M_4	K_4M_2	K_2M_3	K_1M_1	K_3M_3

IRRIGATION CHANNEL

R_{III}	K_4M_3	K_1M_4	K_2M_3	K_3M_1	K_4M_4	K_2M_1	K_1M_2	K_3M_4	K_0	K_4M_1	K_1M_3	K_2M_4	K_3M_2	K_1M_1	K_4M_2	K_3M_3	K_2M_2

Fig. 3.3 : Layout of Experiment No. 2

3.5.2.2 Details of the treatments:

A. Factor A : Levels of potassium (kg K_2O ha^{-1}):

K_0 = 0 (control)

K_1 = 50

K_2 = 100

K_3 = 150

K_4 = 200

B. Factor B : Methods of potassium application:

M_1 = Full as basal

M_2 = 2/3rd as basal + 1/3rd as top dressing at 30 days after planting (DAP)

M_3 = 1/2 as basal + 1/2 as top dressing at 30 DAP

M_4 = Full top dressing at 30 DAP

C. Treatment combinations:

K_1M_1	K_1M_2	K_1M_3	K_1M_4
K_2M_1	K_2M_2	K_2M_3	K_2M_4
K_3M_1	K_3M_2	K_3M_3	K_3M_4
K_4M_1	K_4M_2	K_4M_3	K_4M_4

K_0 (control)

3.5.3 Experiment No. 3 : Evaluation of Dutch and Indian potato cultivars for processing:

The trial involved nine potato cultivars (six Dutch and three Indian cultivars) while Kufri Jyoti was used as the standard. The crop was planted in the last week of November in each year and dehaulmed at 80 days after planting and recommended package of practices were followed as discussed earlier (Experiment No. 1). Layout plan and treatments were as follows:

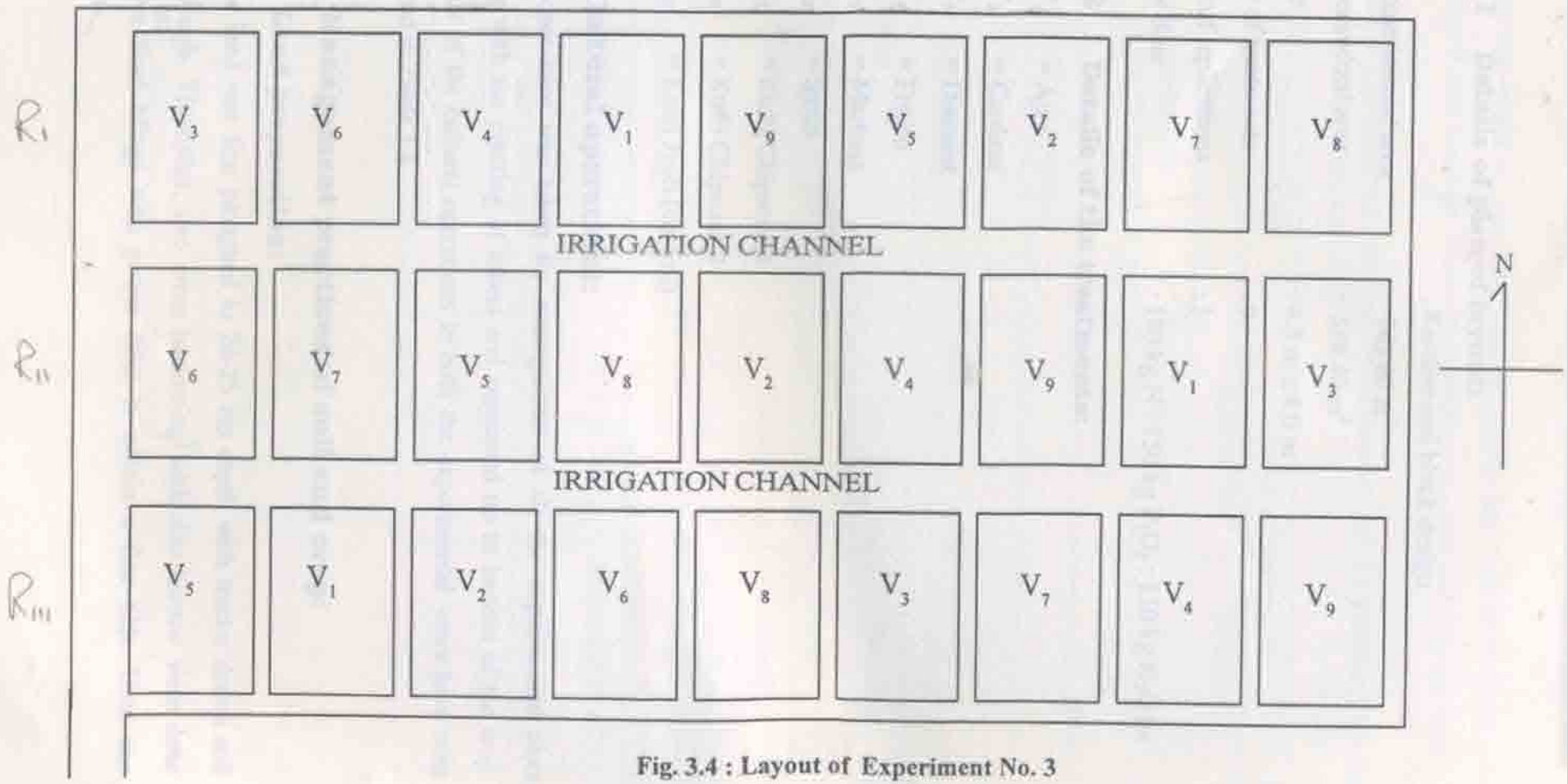


Fig. 3.4 : Layout of Experiment No. 3

3.5.3.1 Details of plan of layout:

Design	: Randomised block design
Gross experimental area	: 763.60 m^2
Net experimental area	: 518.40 m^2
Plot size	: 4.8 m x 4.0 m
Number of treatments	: 9
Number of replications	: 3
Fertilizer dose	: 180 kg N : 150 kg P_2O_5 : 150 kg K_2O ha^{-1}

3.5.3.2 Details of the treatments:

V_1 = Ajax

V_2 = Cardinal

V_3 = Diamant

V_4 = Fresco

V_5 = Marfona

V_6 = Sante

V_7 = Kufri Chipsona-1

V_8 = Kufri Chipsona-2

V_9 = Kufri Jyoti (control)

3.6 Cultural operations:

Proper care was taken for management of all the experimental plots beginning with the planting of tubers and continued up to harvest of the crop. The details of the cultural operations in both the experimental years have been summarized in Table 3.4.

3.7 Management practices of soil and crop:

3.7.1 Land preparation:

The land was first ploughed to 20-25 cm depth with tractor drawn soil turning plough. Thereafter, two cross harrowing with disc harrow were done following a final tillage with power tiller to obtain a fine tilth. Then one

laddering was given to make the surface smooth and well levelled for good irrigation and easy drainage. Weeds and stubbles were removed from the field.

Table 3.4 : Calendar of cultural operations in potato planting during 1999-2000 and 2000-2001

Sl. No.	Operations	Date of operation	
		1999-2000	2000-2001
1.	Land preparation	Nov. 10	Nov. 05
2.	Layout	Nov. 25	Nov. 20
3.	Fertilizer application		
	Basal	Nov. 26	Nov. 21
	Top dressing	Dec. 26	Dec. 21
4.	Planting	Nov. 26	Nov. 21
5.	Intercultural operations		
	Earthing up	Dec. 26	Dec. 21
	Weeding	Dec. 16 & Jan. 10	Dec. 11 & Jan. 05
6.	Plant protection measures		
	Fungicide application	Jan. 05 & Jan. 25	Dec. 31 & Jan. 20
	Pesticide application	Jan. 10 & Jan. 30	Jan. 05 & Jan. 25
7.	Dehaulming	Feb. 14	Feb. 09
8.	Harvesting	Feb. 26	Feb. 21

3.7.2 Layout:

The plots under each replication of three experiments were demarcated by bunds. Subsequently irrigation cum drainage channels were prepared by constructing 1.0 m wide bunds and plots were made using spade. The plans of layout of three experiments have been presented in Fig. 3.2, 3.3 and 3.4.

3.7.3 Fertilizer application:

A basal dose of half of nitrogen and full dose of phosphate through urea and single superphosphate, respectively were applied in furrows of each plot and thoroughly mixed with soil before planting of seed potato tubers. The rest half of nitrogen was top dressed at 30 days after planting. Potash was applied to different plots either as basal (Experiment No. 1 and 3) or as per the treatment schedule (Experiment No. 2) in the form of muriate of potash.

3.7.4 Seed treatment:

Well-sprouted healthy tubers were dipped in 0.25% Dithane M-45 (Mancozeb) solution for 10 minutes and dried in shade before planting.

3.7.5 Planting of seed tubers:

Furrows were opened by big tynes drawn by hand 60 cm apart and tubers weighing 25-35 g each were placed in upright position in different plots in the furrows at a distance of 20 cm and depth of 3-4 cm with final covering of 4-5 cm over the seed tubers.

3.7.6 Irrigation:

Two light irrigation was given at 5 days interval within 12 days after planting. Then five irrigation was given at an interval of 7-8 days and the last two irrigation was given at 12 days interval. The water level in each irrigation was maintained below two-third height of the ridges. Irrigation was completely withheld 12 days before harvest of the crop.

3.7.7 Intercultural operations:

The dominating weeds in the experimental plots were *Cyperus rotundus*, *Cynodon dactylon* and *Chenopodium album*. One hand weeding at 20 days after planting was done to control the weeds. Earthing up was done at 30 days after planting and ridges were made by manual labour with the help of spade. Afterwards the crop started to attain a good crop canopy, which kept the plots

more or less weed free. However, another hand weeding at 45 days after planting was given to the plots wherever necessary.

3.7.8 Plant protection measures:

Potato crop suffers from different pathological malady resulting in considerable loss in yield. Therefore, as a prophylactic measure two sprayings with Dithane M-45 (Mancozeb) @ 2.5 kg ha^{-1} at 40 and 60 days after planting were done. Metasystox (Oxydemeton-methyl) 25 EC (1.0%) was also sprayed two times at 45 and 65 days after planting for prophylactic measures against aphids and other insects.

3.7.9 Dehaulming:

Haulms were cut by sickle after 80 days of planting and lifting of potato tubers was done 12 days after haulm cutting from each plot with the help of spade.

3.8 Crop assessment studies:

3.8.1 Growth functions:

For growth analyses, five representative plant samples were collected randomly at 50, 60, 70 and 80 DAP from each plot and brought to the laboratory. The leaves, stems and tubers of the sample plants were separated, washed with water and sliced into pieces for quick drying. The samples were, then collected in labelled paper bags and dried in hot air oven until constant weights were attained.

3.8.1.1 Leaf area index:

Leaf punches of 2.25 cm^2 each were taken from 10 leaves randomly with the help of steel punch. The punched samples of leaves were kept in labelled small brown paper envelope and dried in hot air oven to constant weight. From known area of leaf samples and their dry weight, area-weight relationship of leaves was established. Then, using the relationship and total dry weight of leaves from a unit land area, leaf area index was calculated for each plot.

3.8.1.2 Dry matter accumulation:

Dry weights of different plant parts were recorded individually and summed up to get total dry matter accumulation for a particular sampling date. The procedure of recording dry weights had been described earlier.

3.8.1.3 Crop growth rate:

Crop growth rate (CGR) is the rate of dry matter accumulation unit^{-1} area of crop in a unit time expressed as g m^{-2}day^{-1}.

$$CGR = \frac{w_2 - w_1}{t_2 - t_1}$$

where w_2 and w_1 are dry weight of plants from a land of unit area on two different times t_2 and t_1, respectively (Watson, 1956).

3.8.1.4 Tuber bulking rate:

Tuber bulking rate (TBR) is the dry weight of tubers accumulated by plant unit^{-1} area and time and expressed as g m^{-2}day^{-1}.

$$TBR = \frac{m_2 - m_1}{t_2 - t_1}$$

where m_2 and m_1 are the dry weight of tubers from a unit area on two different times t_2 and t_1, respectively.

3.8.1.5 Net assimilation rate:

Net assimilation rate (NAR) is the increase in dry weight of plant unit^{-1} leaf area unit^{-1} time and expressed as g m^{-2}day^{-1}.

$$NAR = \frac{(w_2 - w_1)(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

where L_2 and L_1 are total leaf area at times t_2 and t_1, respectively; w_1 and w_2 are total dry weights at times t_1 and t_2, respectively.

3.8.1.6 Leaf area duration:

Leaf area duration (LAD) is a measure of the ability of the plant to produce and maintain leaf area and is obtained by integrating the mean leaf area index $(\overline{L})$ over crop growth period and expressed in days.

$$LAD = \overline{L} \times M$$

where $\overline{L}$ is the mean leaf area index and M is the number of days in the crop growth period.

$$\overline{L} = \frac{L_2 - L_1}{\log_e L_2 - \log_e L_1}$$

where L_2 and L_1 are total leaf area at times t_2 and t_1, respectively.

3.8.2 Harvesting of the crop:

Tubers of half portion of the undisturbed demarcated area of each plot were harvested after 92 days of planting.

3.8.2.1 Final yield of tubers:

The fresh weight of tubers of each plot was taken in kg and then converted in t ha^{-1}.

3.8.2.2 Grading of tubers:

The harvested produce of each plot was graded into three groups, *viz.* large (above 50 g), medium (25-50 g) and small (less than 25 g). These graded yields were taken in kg and then converted into percentages.

3.9 Chemical analysis:

3.9.1 Soil analysis:

3.9.1.1 Collection of soil samples:

Soil samples from the experimental plots were collected before planting and after harvest. Soil samples from 3 locations in each plot at 0-15 cm depth were collected by soil auger. Samples were mixed, dried, and powdered evenly and passed through fine sieve to collect in polythene bags. From each stock

sample small amount of soils were taken in paper packets at required weights for different chemical analyses.

3.9.1.2 Mechanical analysis of soil samples:

The relative percentage of sand, silt and clay in the soil was estimated by international pipette method as described by Piper (1966).

3.9.1.3 Chemical analysis of soil samples:

3.9.1.3.1 Organic carbon content:

Organic carbon content in the soil was analysed according to rapid titration method as described by Walkley and Black (1934) and expressed in $cent^{-1}$.

3.9.1.3.2 Nitrogen content:

Modified kjeldhal method was used to analyse available nitrogen content of soil (Jackson, 1973). Two grams of soil was digested in sulphuric acid to convert organic nitrogen into inorganic form. After distillation of the solution, released ammonia gas was collected in boric acid solution that consequently formed ammonium borate. This ammonium borate solution was again titrated with sulphuric acid and from the titrated value, available nitrogen content was calculated and converted into kg ha^{-1}.

3.9.1.3.3 Phosphorus content:

Soil samples were analysed for determining available phosphorus content in soil following the Olsen's method described by Jackson (1973). Soil sample (2.5 g) was extracted in sodium bicarbonate and then filtered. The soil extract was mixed with stannous chloride as reducing agent for colour development. Available phosphorus was estimated by a photoelectric calorimeter using red filter and expressed in kg ha^{-1}.

3.9.1.3.4 Potassium content:

Available potassium content in soil was analysed by extracting 2.5 g soil sample in ammonium acetate and then filtered. Soil extracts were analysed for

available potassium by flame photometer method (Muhr *et al.*, 1965) and converted into kg ha^{-1}.

3.9.1.3.5 pH determination:

Determination of soil pH was done by using Beckman's pH meter. Soil sample (10 g) was taken in 1 : 2.5 soil-water ratio and solution was stirred thoroughly. The pH meter was initially standardized using buffer solutions, and then readings were taken.

3.9.2 Plant analysis:

3.9.2.1 Methods of preparation of plant samples:

Plant samples from the plots were collected during dehaulming and leaves, stems and tubers were separated, dried in oven, ground, sieved and kept in polythene bags. Samples were then analyzed separately for nitrogen, phosphorus and potassium content ($cent^{-1}$).

3.9.2.2 Chemical analysis of plant samples:

3.9.2.2.1 Nitrogen uptake:

Total nitrogen content of plant samples were analyzed by modified macro-kjeldhal method (Jackson, 1973) and expressed in percentage. Plant sample weighing 500 mg was digested and distilled following the standard procedure. Then the solution was titrated against (N/10) H_2SO_4 to calculate the total nitrogen content of plant samples. Nitrogen uptake by different plant parts were obtained by multiplying total biomass of each plant parts with total nitrogen content expressed in kg ha^{-1}.

3.9.2.2.2 Phosphorus uptake:

Plant phosphorus content was determined by olsen's method as described by Jackson (1973). Plant parts (100 µg each) were taken to form the extract solution and readings were recorded from the calorimeter using red filter. Phosphorus uptake by different plant parts was calculated multiplying total biomass production with plant phosphorus content and expressed in kg ha^{-1}.

3.9.2.2.3 Potassium uptake:

Potassium content in the plant was measured by flame photometer method (Muhr *et al.*, 1965) after extracting 100 ml of different plant parts and expressed in percentage. Potassium uptake by each plant part was calculated by multiplying the potassium content unit^{-1} sample with the total biomass production and expressed in kg ha^{-1}.

3.10 Physico-chemical analysis (Experiment No. 3):

3.10.1 Physical characters:

3.10.1.1 Specific gravity:

Specific gravity of tuber is the weight of tuber (g) unit^{-1} volume (cc). It was determined from the formula and correction factor given by Baskar (1975). This formula is based on water immersion method for the determination of specific gravity. It has been established that specific gravity of potatoes is directly proportional to their dry matter content, i.e., the DM content of potato tubers increases with an increase in their specific gravity (Ezekiel *et al.* 1999).

3.10.1.2 Peeling:

Potato peeling results in the removal of the skin, which is done using abrasive peelers. Care was taken to ensure removal of at least 80-90 cent^{-1} of the skin without removing too much of the flesh of the potatoes. Usually large sized potatoes (>50 g) have lower peeling losses, as smaller tubers have larger surface area in relation to their weight. Similarly, peeling losses in potatoes with deep eyes are much greater, than in potatoes with shallow eyes, as larger proportion of the tissue has to be removed for proper peeling of potatoes with deep eyes.

3.10.1.3 Storage losses:

Stored potatoes suffer losses due to loss in weight and spoilage. Immediately after harvest, 5 kg healthy and clean tubers of uniform size (40-50 g) from each plot were kept in hessian cloth bags at room temperature (minimum 19-26^{0}C and maximum 32-36^{0}C). The data was recorded on physiological loss in

weight (cent^{-1}) and rotting (cent^{-1}) of tubers at 15 days interval up to 90 days from the date of harvesting.

3.10.1.3.1 Physiological loss in weight:

The physiological loss in weight (moisture loss) was calculated by weighing ten randomly marked tubers from each plot at fortnightly intervals till the end of storage period.

3.10.1.3.2 Rotting of tubers:

The rotting of tubers was recorded by eye estimation from the total number of tubers of each experimental plot that was kept in storage. The data was recorded fortnightly up to 90 days of storage.

3.10.2 Biochemical constituents:

3.10.2.1 Total sugars:

Total sugar content of tuber was determined by titrimetic procedures. Firstly the non-reducing sugar content of tuber was converted into reducing sugar by acid hydrolysis. After conversion, the sugar of the aqueous solution was determined by titrating against the freshly prepared mixture containing 2 ml each of Fehling A and B solution and using methylene blue as an indicator (A.O.A.C., 1984) and expressed in cent^{-1} fresh weight basis.

3.10.2.2 Reducing sugars:

The reducing sugar contents of the aqueous extract were determined by titrating against the Fehling A and B solution as stated above.

3.10.2.3 Total acidity:

The acidity of tubers of each plot was estimated by titrating the aqueous extract of 100 ml potato juice against standard alkali (N/10 NaOH) solution using phenolphthalein as an indicator and expressed as percentage in terms of citric acid (A.O.A.C., 1984).

3.10.2.4 Total soluble solids:

Total soluble solids (TSS) content of tuber was estimated with the help of hand refractometer. A few drops of cloth stained tuber juice was squeezed out from each sample and instilled on the plate to record the refractometer reading, calibrated in ^{0}Brix.

3.10.2.5 Vitamin C content:

Vitamin C content (ascorbic acid) of tubers of each experimental plot was estimated by using 2, 6-dichlorophenol indophenol dye titration method (A.O.A.C., 1984) and expressed as mg 100 g^{-1} fresh weight.

3.10.3 Chip colour:

From each plot, 2 kg potato tubers were peeled and cut into 1.4 mm thick slices by a hand slicer. The slices were allowed to fall directly in cold water to which 1 $cent^{-1}$ common salt was added. After one hour, the slices were removed and blanched for five minutes and then spread on a polythene sheet and sun dried for two days. The air temperature during the period of sun drying ranged from 30-40^{0}C. The dried slices were fried in refined edible oil at 180^{0}C for about 1 to $1^1/2$ minutes and subjectively scored for colour and assigned a value according to the scale of 1 to 10 (lower number-better colour) of the PC/SFA (Gould *et al.*, 1979). Chips scoring 1 to 3 were considered acceptable.

3.11 Response function (Experiment No. 2):

The yield responses to different levels of potassium were fitted into a mathematical equation based on the shape of the curve.

Quadratic regression was worked out by the following formula:

$$Y = a + b X + c X^2$$

where Y = estimated tuber yield (q ha^{-1})

X = Potassium dose (kg K_2O ha^{-1})

a, b and c = constants

From the regressions, the expected yield values at various levels of potassium and the potassium level giving the maximum and economically optimum yield were worked out by the procedure described by Heady and Dhillon (1966).

(i) Potassium level giving maximum yield (physical optimum)

$$P_y = \frac{-b}{2c}$$

(ii) Economic optimum level of potassium

$$P_p = \frac{1}{2c}\left(\frac{q}{p} - b\right)$$

where q and p are the prices of potassic fertilizer (kg^{-1} K_2O) and tubers (q ha^{-1}), respectively.

3.12 Statistical analysis:

Five representative plants were selected from each plot for recording growth parameters at different stages of observations. In case of yield of tubers, the total yield $plot^{-1}$ was recorded and converted into ha^{-1} basis in tonne. The data obtained in two years were analysed by analysis of variance by a standard method (Panse and Sukhatme, 1995) and the significance of different sources of variation was tested by error mean square by Fisher Snedecor's 'F' test at probability level of 0.05. For determination of critical difference (C.D.) at 5% level of significance, Fisher and Yates (1979) table was consulted. For the calculation of percentage data, angular transformation was done by consulting angular corresponding to percentage table (Gomez and Gomez, 1983).

3.13 Economics of crop production:

The cost of cultivation was calculated according to the treatments received by different plots in all the experiments. The market rates of seed, fertilizers and

other miscellaneous cost have been accounted for the calculation of cost of cultivation, gross and net return and benefit : cost ratio. The input and output cost prices were recorded and enlisted below:

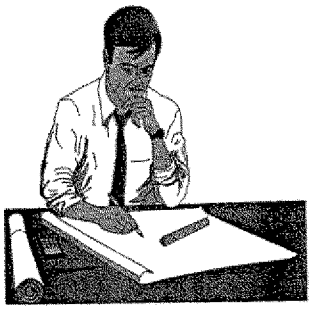
A. Input cost:

I. Cost of seed tubers	Rs. 7.00 kg^{-1}
II. Fertilizer costs	
(a) Urea	Rs. 9.15 kg^{-1} N
(b) Single superphosphate	Rs. 17.50 kg^{-1} P_2O_5
(c) Muriate of potash	Rs. 6.64 kg^{-1} K_2O
III. Biofertilizer cost	Rs. 30.00 kg^{-1}
IV. Miscellaneous costs	
(a) Wages of daily labour (8 working hours day^{-1})	Rs. 50.00 day^{-1} (1999-2000) Rs. 60.00 day^{-1} (2000-2001)
(b) Sodium bicarbonate	Rs. 13.00 kg^{-1}

B. Output cost:

I. Cost of potato	Rs. 3.00 kg^{-1}

Chapter-4



Results and Discussion

4. RESULTS AND DISCUSSION

4.1 Experiment No. 1 : Fertilizer economy in potato by the use of biofertilizers:

4.1.1 Growth parameters:

4.1.1.1 Leaf area index:

Application of biofertilizers imparted significant effect on leaf area indices (LAI) at all the stages of observation during both the years (Table 4.1.1; Fig. 4.1.1). LAI kept on increasing up to 70 days after planting (DAP) irrespective of different treatments and thereafter it declined till the last observation recorded at 80 DAP. This might be due to leaf senescence at the later stages of crop growth. The increase in LAI was relatively slow in the early growth stages (50 to 60 DAP), became faster between 60-70 DAP and then slowed down gradually in all the treatments, with the exception in treatment F_2T_4 (75% N and P + *Bacillus* spp. treatment of tubers) which showed relatively faster increase in leaf area between 50 and 60 DAP.

Treatment F_1T_3 (100% N and P +1% urea and 1% sodium bicarbonate + *Azotobacter* and Phosphobacteria) recorded maximum LAI but remained statistically at par with treatment F_1T_4 (100% N and P +*Bacillus* spp.) at all the growth stages except at 70 and 80 DAP in 2000-01, where the effect was just reversed. Marwaha (1995) also reported similar results. LAI in treatment F_2T_3 (75% N and P + 1% urea and 1% sodium bicarbonate + *Azotobacter* and Phosphobacteria) remained at par with treatment F_1T_3 and F_1T_4 at all the stages of observation except after 50 and 60 days in the second year where significant differences prevailed. Control plots receiving 75% N and P (F_2T_1) produced lower leaf area and consequently minimum LAI values at all the stages of crop growth except at 50, 60 and 80 DAP in the first year, where treatment F_2T_2 (75% N and P + 1% urea and 1% sodium bicarbonate) exhibited the minimum value.

Table 4.1.1 : Effect of biofertilizers on leaf area indices of potato at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled
F_1T_1	2.02	1.87	1.95	2.25	2.10	2.18	2.56	2.56	2.56	2.42	2.36	2.39
F_1T_2	2.05	2.04	2.05	2.27	2.15	2.21	2.66	2.66	2.66	2.51	2.40	2.46
F_1T_3	2.29	2.13	2.21	2.48	2.32	2.40	2.83	2.71	2.77	2.68	2.51	2.60
F_1T_4	2.19	2.10	2.15	2.39	2.30	2.35	2.78	2.75	2.77	2.62	2.54	2.58
F_2T_1	1.97	1.77	1.87	2.18	1.95	2.07	2.45	2.41	2.43	2.35	2.18	2.27
F_2T_2	1.93	2.01	1.97	2.11	2.06	2.09	2.49	2.44	2.47	2.32	2.25	2.29
F_2T_3	2.25	1.93	2.09	2.45	2.21	2.33	2.70	2.61	2.66	2.59	2.44	2.52
F_2T_4	2.10	1.85	1.98	2.36	2.25	2.31	2.58	2.52	2.55	2.48	2.30	2.39
S.Em(±)	0.03	0.04	0.02	0.07	0.02	0.03	0.07	0.05	0.04	0.06	0.04	0.03
C.D.(P=0.05)	0.10	0.12	0.07	0.22	0.07	0.10	0.21	0.16	0.13	0.20	0.14	0.09

Leaf area indices can a good note in the (a) table should be given

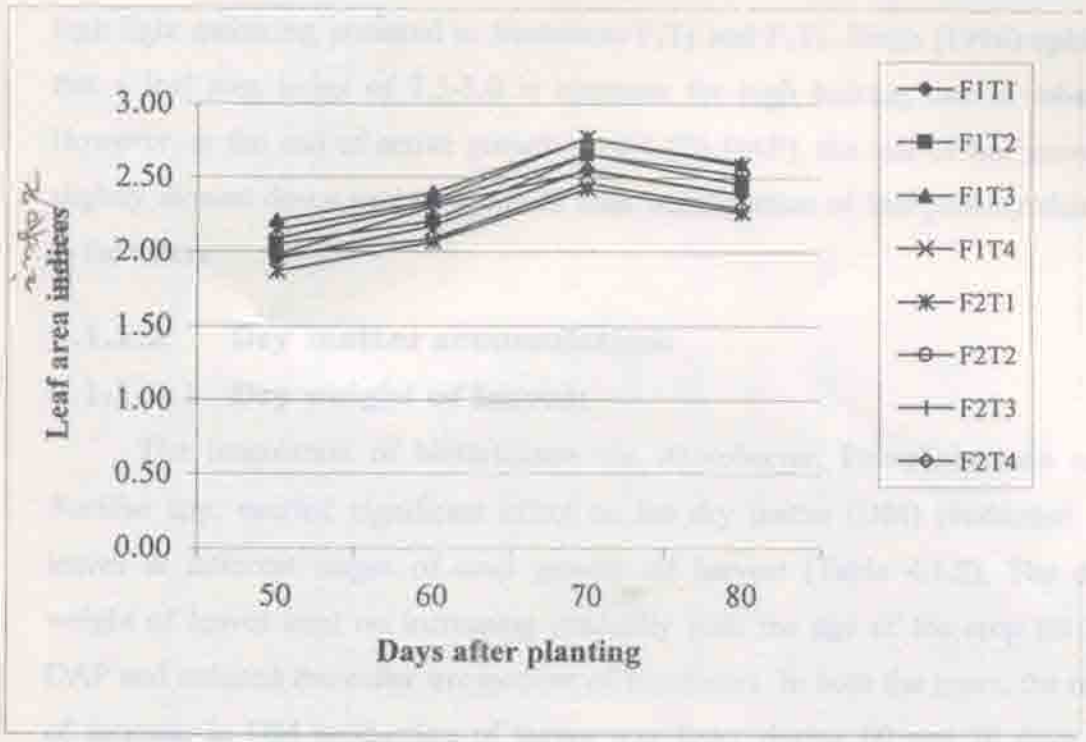


Fig.4.1.1: Effect of biofertilizers on leaf area indices of potato.

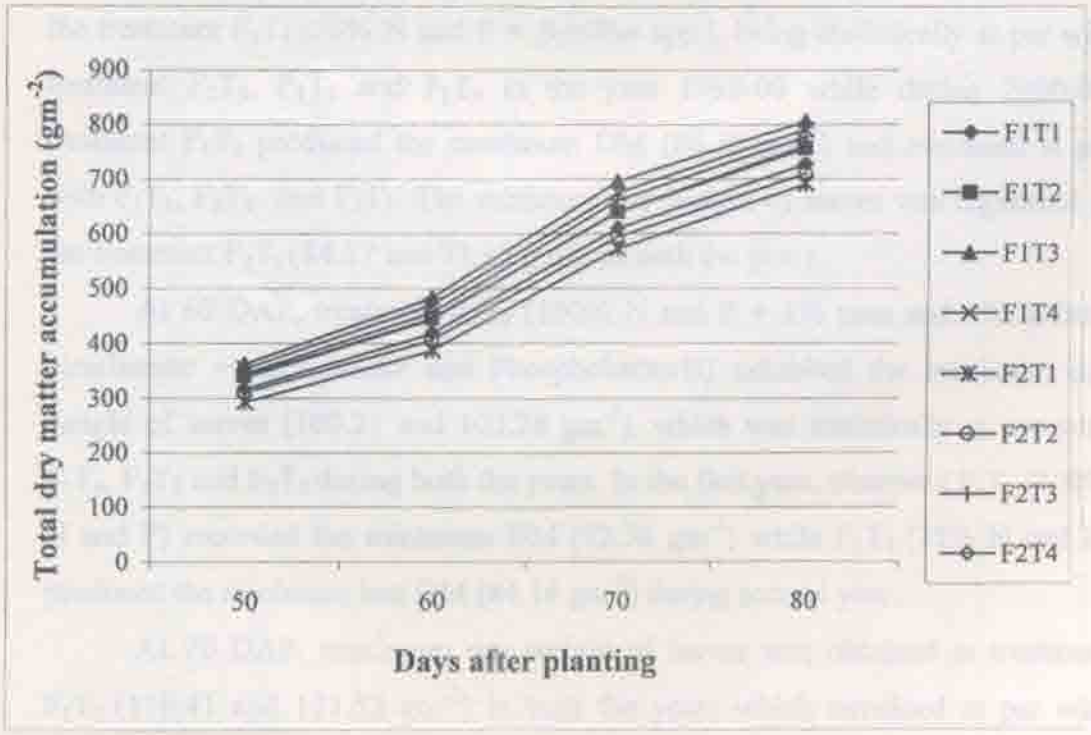


Fig.4.1.2:Effect of biofertilizers on total dry matter accumulation of potato.

The results reveal that the high LAI values of more than 2.75 conferred a high light gathering potential in treatments F_1T_3 and F_1T_4. Singh (1996) opined that a leaf area index of 2.5-3.0 is optimum for high bulking rate of tubers. However, at the end of active growth period (70 DAP), the rate of leaf growth slightly slowed down probably due to bulk translocation of leaf photosynthates to the tubers.

4.1.1.2 Dry matter accumulation:

4.1.1.2.1 Dry weight of leaves:

The inoculation of biofertilizers *viz. Azotobacter*, Phosphobacteria and *Bacillus* spp. exerted significant effect on the dry matter (DM) production of leaves at different stages of crop growth till harvest (Table 4.1.2). The dry weight of leaves kept on increasing gradually with the age of the crop till 70 DAP and reduced thereafter irrespective of treatments. In both the years, the rate of increase in DM production of leaves was faster during 60 and 70 days as compared to dry weight production during 50 and 60 DAP.

At 50 DAP, maximum dry weight of leaves of 90.28 gm^{-2} was recorded in the treatment F_2T_4 (75% N and P + *Bacillus* spp.), being statistically at par with treatment F_2T_3, F_1T_3 and F_1T_4 in the year 1999-00 while during 2000-01, treatment F_1T_3 produced the maximum DM (86.20 gm^{-2}) and remained at par with F_1T_2, F_2T_4 and F_2T_3. The minimum dry weight of leaves was registered in the treatment F_2T_1 (84.77 and 73.12 gm^{-2}) in both the years.

At 60 DAP, treatment F_1T_3 (100% N and P + 1% urea and 1% sodium bicarbonate + *Azotobacter* and Phosphobacteria) exhibited the maximum dry weight of leaves (100.21 and 103.26 gm^{-2}), which was statistically at par with F_1T_4, F_2T_3 and F_2T_4 during both the years. In the first year, treatment F_1T_1 (100% N and P) recorded the minimum DM (92.36 gm^{-2}) while F_2T_1 (75% N and P) produced the minimum leaf DM (84.14 gm^{-2}) during second year.

At 70 DAP, maximum dry weight of leaves was obtained in treatment F_1T_3 (116.41 and 121.52 gm^{-2}) in both the years which remained at par with

Table 4.1.2 : Effect of biofertilizers on dry weight production of leaves (g m^{-2}) of potato at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled
F_1T_1	86.52	80.40	83.46	92.36	91.25	91.81	100.00	107.14	103.57	98.71	93.61	96.16
F_1T_2	86.29	83.46	84.88	94.33	96.63	95.48	103.11	112.35	107.73	95.33	97.41	96.37
F_1T_3	88.51	86.20	87.36	100.21	103.26	101.74	116.41	121.52	118.97	100.61	105.59	103.10
F_1T_4	88.02	82.50	85.26	99.22	100.37	99.80	114.22	114.25	114.24	97.61	106.15	101.88
F_2T_1	84.77	73.12	78.95	96.52	84.14	90.33	110.20	96.88	103.54	96.11	90.70	93.41
F_2T_2	85.35	79.58	82.47	92.58	90.17	91.38	104.27	105.43	104.85	93.80	93.12	93.46
F_2T_3	89.95	81.83	85.89	98.11	97.11	97.61	113.54	112.33	112.94	100.79	99.88	100.34
F_2T_4	90.28	82.10	86.19	98.52	98.32	98.42	111.20	114.56	112.88	96.95	99.85	98.40
S.Em(±)	0.86	1.44	0.75	0.81	2.09	1.35	2.57	1.94	1.51	0.77	1.55	0.63
C.D.(P=0.05)	2.63	4.39	2.28	2.46	6.34	4.09	7.79	5.89	4.59	2.34	4.72	1.93

F_1T_4, F_2T_3 and F_2T_4 in the year 1999-00. However, during 2000-01, there were significant differences among these treatments. Treatment F_1T_1 and F_2T_1 recorded the minimum values of DM (100.00 and 96.88 gm^{-2} in 1999-00 and 2000-01, respectively).

At 80 DAP, dry weight of leaves slightly decreased over the previous stage (70 DAP). Treatment F_2T_3 recorded the maximum DM of leaves (100.79 gm^{-2}) in the first year and no statistical differences prevailed with the treatments F_1T_3 and F_1T_1. However in 2000-01, F_1T_4 recorded the maximum DM (106.15 gm^{-2}) being statistically at par with F_1T_3 and significantly superior to the rest of the treatments. Minimum DM was obtained in treatments F_2T_2 (93.80 gm^{-2}) and F_2T_1 (90.70 gm^{-2}) in consecutive years of study.

The results clearly justify that biofertilizer application accumulated greater DM in leaves and showed superiority over check at all the crop growth stages during two years trial. Kumar *et al.*(2001 b) also observed that combined inoculation of *Azotobacter*, Phosphobacteria and *Bacillus* strain (M_1 and B_5) increased the number of leaves $plant^{-1}$ at 45 and 75 days.

4.1.1.2.2 Dry weight of stems:

The application of varying levels of N and P along with biofertilizers significantly influenced the dry weight of stems at all the stages of observation in both the years of experimentation (Table 4.1.3). The stem dry weight increased steadily with the age of the crop till 70 DAP irrespective of treatments which might be due to increase in shoot length and branches and decreased thereafter. However, the increase in stem dry weight was faster during 50 and 60 DAP and relatively slower afterwards between 60 and 70 DAP and then declined gradually till maturity.

During initial stage (50 DAP), dry weight of stem was maximum (85.22 gm^{-2}) in the treatment F_2T_3 (75% N and P + 1% urea and 1% sodium bicarbonate + *Azotobacter* and Phosphobacteria), which remained at par with treatments F_1T_2, F_2T_4 and F_1T_4 during the year 1999-00 while in the second year, treatments F_1T_3 (100% N and P + 1% urea and 1% sodium bicarbonate + *Azotobacter* and

Table 4.1.3 : Effect of biofertilizers on dry weight production of stems (g m^{-2}) of potato at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled
F_1T_1	81.69	77.35	79.52	90.75	89.12	89.94	98.27	100.89	99.58	94.95	94.63	94.79
F_1T_2	84.79	77.39	81.09	93.66	86.47	90.07	99.77	94.47	97.12	97.14	94.28	95.71
F_1T_3	83.62	83.24	83.43	96.92	97.08	97.00	108.92	106.99	107.96	105.32	104.25	104.79
F_1T_4	83.81	78.98	81.40	95.01	90.61	92.81	107.01	98.57	102.79	103.12	96.54	99.83
F_2T_1	80.34	67.95	74.15	90.49	77.82	84.16	99.61	83.25	91.43	97.70	79.33	88.52
F_2T_2	82.80	75.30	79.05	91.36	84.88	88.12	96.82	94.25	95.54	94.21	93.05	93.63
F_2T_3	85.22	77.48	81.35	95.83	90.52	93.18	104.70	99.27	101.99	102.35	97.12	99.74
F_2T_4	84.00	79.55	81.78	92.26	90.14	91.20	98.68	100.13	99.41	95.56	98.10	96.83
S.Em(±)	0.94	2.55	1.51	0.65	2.45	1.39	2.43	2.13	1.28	1.62	3.96	1.21
C.D.(P=0.05)	2.85	7.75	4.58	1.99	7.44	4.23	7.39	6.46	3.89	4.91	12.03	3.68

Phosphobacteria) accounted for the highest DM of stems (83.24 gm^{-2}), being statistically at par with F_2T_4, F_1T_4 and F_2T_3. During both the years, F_2T_1 recorded the minimum values of DM (80.34 and 67.95 gm^{-2}).

At 60 DAP, maximum dry weight of stem was computed in the treatment F_1T_3 (96.92 and 97.08 gm^{-2}) in both the years and statistically at par with F_2T_3 and F_1T_4 during 1999-00 and 2000-01, respectively. Similarly, treatment F_2T_1 produced the minimum stem dry weight (90.49 and 77.82 gm^{-2}) in both the years.

At 70 DAP, DM production in stem was maximum in F_1T_3 (108.92 and 106.99 gm^{-2} during both the years), and statistically superior to all other treatments except F_1T_4 and F_2T_3 in the year 1999-00 and F_1T_1 in 2000-01. During the year 1999-00, the minimum dry weight of stem was recorded in treatment F_2T_2 (96.82 gm^{-2}), however, F_2T_1 showed the minimum value (83.25 gm^{-2}) in 2000-01.

At maturity (80 DAP), stem DM declined slightly over the previous stage. Treatment F_1T_3 recorded the maximum DM of stems (105.32 and 104.25 gm^{-2}) in both years, though the effect was statistically at par with F_1T_4 and F_2T_3. The minimum value of DM was obtained in F_2T_2 (94.21 gm^{-2}) and F_2T_1 (79.33 gm^{-2}) during the year 1999-00 and 2000-01, respectively.

It is evident from the results that DM accumulation in stem was markedly influenced by the combined inoculation of biofertilizers. A positive response of stem number $plant^{-1}$ of potato crop with inoculation of seed tubers with *Azotobacter*, *Bacillus cereus* and *B. subtilis* was also indicated by Sood and Sharma (2001).

4.1.1.2.3 Dry weight of tubers:

Dry weight of tubers differed significantly with different biofertilizer treatments at different stages of observation during two successive crop seasons (Table 4.1.4). The dry weight of tubers increased gradually with the advancement of crop age till maturity irrespective of treatments. However, the rate in DM accumulation was not uniform at different growth stages. The rate of

Table 4.1.4 : Effect of biofertilizers on dry matter production of tubers (g m^{-2}) of potato at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled
F_1T_1	158.25	150.13	154.19	250.25	224.67	237.46	425.65	388.80	407.23	557.65	514.80	536.23
F_1T_2	173.90	177.27	175.59	263.20	257.71	260.46	440.90	429.04	434.97	576.20	551.94	564.07
F_1T_3	198.13	186.30	192.22	298.63	270.87	284.75	489.83	449.17	469.50	617.13	579.80	598.47
F_1T_4	192.53	182.81	187.67	290.43	265.84	278.14	474.83	441.34	458.09	610.33	568.44	589.39
F_2T_1	148.00	132.10	140.05	230.70	197.17	213.94	399.90	355.83	377.87	535.70	482.30	509.00
F_2T_2	156.80	143.53	150.17	243.00	211.70	227.35	414.30	374.00	394.15	552.80	493.33	523.07
F_2T_3	185.55	170.72	178.14	282.55	248.82	265.69	470.75	422.48	446.62	602.85	551.65	577.25
F_2T_4	177.15	164.11	170.63	272.35	236.85	254.60	453.45	404.41	428.93	592.25	536.98	564.62
S.Em(±)	10.46	9.10	6.96	12.84	10.25	8.26	14.94	10.93	9.36	14.35	11.83	9.54
C.D.(P=0.05)	31.75	27.61	21.14	38.96	31.11	25.06	45.34	33.18	28.42	43.54	35.89	28.97

increase in tuber DM was slower in the initial stage (50-60 DAP), became faster between 60 and 70 DAP and again slowed down during 70-80 DAP.

There were significant variations in the dry weight of tubers among the treatments and it ranged between 132.10 and 198.13 gm^{-2}; 197.17 and 298.63 gm^{-2}; 355.83 and 489.83 gm^{-2}; and 482.30 and 617.13 gm^{-2} at 50, 60, 70 and 80 DAP, respectively during two years trial. Treatment F_1T_3 (100% N and P + 1% urea and 1% sodium bicarbonate + *Azotobacter* and Phosphobacteria) recorded the maximum tuber DM and remained at par with F_1T_4 and F_2T_3 at all the stages of crop growth during two years of experimentation. At 60, 70 and 80 DAP in the second year, treatment F_1T_3 differed significantly with F_2T_4 and uninoculated controls (F_1T_1 and F_2T_1). The minimum dry weight of tuber was recorded in the treatment F_2T_1 at all the crop growth stages during two years of study.

The results reveal that potato tubers maintained conspicuously higher DM with the combined inoculation of *Azotobacter* + Phosphobacteria and *Bacillus* spp. Bhattacharyya *et al.* (2000) also reported significant response of tuber weight $plant^{-1}$ of potato to biofertilizers.

4.1.1.2.4 Total dry matter production:

Total dry matter (DM) production of potato plants progressively increased as the growth of the crop progressed till the last observation was recorded at 80 DAP (Table 4.1.5; Fig. 4.1.2). This might be due to continued photosynthesis which took place throughout the growth period. However, the rate of total DM production reached its peak during 60 to 70 DAP.

DM content of potato plant varied among the treatments and it ranged between 273.17 and 370.26 gm^{-2}; 359.13 and 495.76 gm^{-2}; 535.96 and 715.16 gm^{-2}; and 652.33 and 823.06 gm^{-2} at 50, 60, 70 and 80 DAP, respectively during two years. The inoculation of biofertilizers, however, produced a uniform trend and exhibited consistent influence on the total DM accumulation. The highest value was observed in the treatment F_1T_3 (100% N and P + 1% urea and 1% sodium bicarbonate + *Azotobacter* and Phosphobacteria), which remained

Table 4.1.5 : Effect of biofertilizers on total dry matter production (g m^{-2}) of potato at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled
F_1T_1	326.46	307.88	317.17	433.36	405.04	419.20	623.92	596.83	610.38	751.31	703.04	727.18
F_1T_2	344.98	338.12	341.55	451.19	440.81	446.00	643.78	635.86	639.82	768.67	743.63	756.15
F_1T_3	370.26	355.74	363.00	495.76	471.21	483.49	715.16	677.68	696.42	823.06	789.64	806.35
F_1T_4	364.36	344.29	354.33	484.66	456.82	470.74	696.06	654.16	675.11	811.06	771.13	791.10
F_2T_1	313.11	273.17	293.14	417.71	359.13	388.42	609.71	535.96	572.84	729.51	652.33	690.92
F_2T_2	324.95	298.41	311.68	426.94	386.75	406.85	615.39	573.68	594.54	740.81	679.50	710.16
F_2T_3	360.72	330.03	345.38	476.49	436.45	456.47	688.99	634.08	661.54	805.99	748.65	777.32
F_2T_4	351.43	325.76	338.60	463.13	425.31	444.22	663.33	619.10	641.22	784.76	734.93	759.85
S.Em(±)	7.55	7.23	5.65	8.07	7.37	5.96	8.47	6.35	5.82	9.16	6.56	6.22
C.D.(P=0.05)	22.90	21.93	17.14	24.48	22.38	18.09	25.72	19.28	17.68	27.80	19.92	18.89

statistically at par with F_1T_4 (100% N and P + *Bacillus* spp.) at all the stages of observation recorded except at 70 DAP in the year 2000-01 where they significantly differed from each other. Control plots receving 75% N and P alone (F_2T_1) recorded the lowest DM production at all the dates of plant growth.

The results emphasize that biofertilizer inoculation improved the total biomass production of potato plants. The increase in total DM accumulation can be ascribed to N addition through biological N fixation by *Azotobacter* and greater availability of phosphorus by Phosphobacteria. The above results are similar with the findings of Sidorenko *et al.* (1996).

4.1.1.3 Crop growth rate:

Application of biofertilizers imparted significant effect on the crop growth rate (CGR) of potato plants at different stages of observation till harvest (Table 4.1.6; Fig.4.1.3). CGR had also an increasing trend with the age of the crop and attained its maximum value between 60-70 days and then declined irrespective of treatments.

During 50-60 and 60-70 DAP, treatment F_1T_3 accomplished signifcantly higher values of CGR (12.55 and 21.94 $gm^{-2}d^{-1}$ in 1999-00 and 11.55 and 20.65 $gm^{-2}d^{-1}$ in 2000-01, respectively) and remained statistically superior over the rest of the treatments. The minimum CGR was achieved in the treatment F_2T_2 (75% N and P + 1% urea and 1% sodium bicarbonate) in 1999-00 but during 2000-01, treatment F_2T_1 (75% N and P alone) recorded the minimum CGR during this time. Higher CGR in treatment F_1T_3 during 50-70 DAP was mainly due to high LAI which accumulated DM at a faster rate unit^{-1} leaf area unit^{-1} time. The results corroborated the works of Yadav *et al.* (1999). However, during 70-80 DAP, treatment F_1T_1 (100% N and P alone) superseded the effect of F_1T_3 and showed the highest CGR (12.74 $gm^{-2}d^{-1}$) in the first year, being statistically at par with F_2T_2. Contrary to this, in the second year treatment F_1T_4 (100% N and P + *Bacillus* spp.) recorded the highest CGR (11.70 $gm^{-2}d^{-1}$) and remained at par with F_2T_1. The lowest CGR was obtained in treatment F_1T_3 (10.79 $gm^{-2}d^{-1}$) and F_2T_2 (10.58 $gm^{-2}d^{-1}$) during the first and second year,

Table 4.1.6 : Effect of biofertilizers on crop growth rate (g $m^{-2}d^{-1}$) of potato during different growth intervals

Treatments	50-60 DAP			60-70 DAP			70-80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
F_1T_1	10.69	9.71	10.20	19.06	19.18	19.12	12.74	10.62	11.68
F_1T_2	10.62	10.27	10.45	19.26	19.51	19.38	12.49	10.78	11.63
F_1T_3	12.55	11.55	12.05	21.94	20.65	21.29	10.79	11.20	10.99
F_1T_4	12.03	11.25	11.64	21.14	19.73	20.44	11.50	11.70	11.60
F_2T_1	10.46	8.60	9.53	19.20	17.68	18.44	11.98	11.64	11.81
F_2T_2	10.20	8.83	9.52	18.85	18.69	18.77	12.54	10.58	11.56
F_2T_3	11.58	10.64	11.11	21.25	19.76	20.51	11.70	11.46	11.58
F_2T_4	11.17	9.96	10.56	20.02	19.38	19.70	12.14	11.58	11.86
S.Em(±)	0.14	0.09	0.06	0.10	0.27	0.12	0.11	0.08	0.04
C.D.(P=0.05)	0.43	0.29	0.19	0.31	0.83	0.37	0.33	0.25	0.13

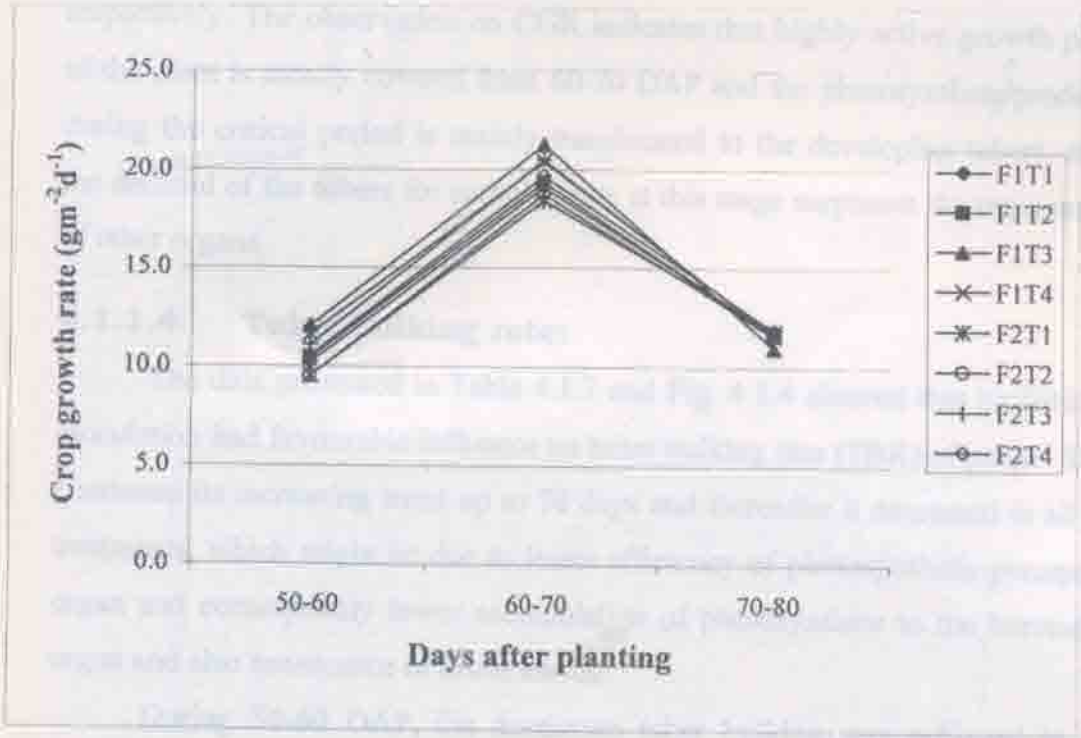


Fig.4.1.3:Effect of biofertilizers on crop growth rate of potato.

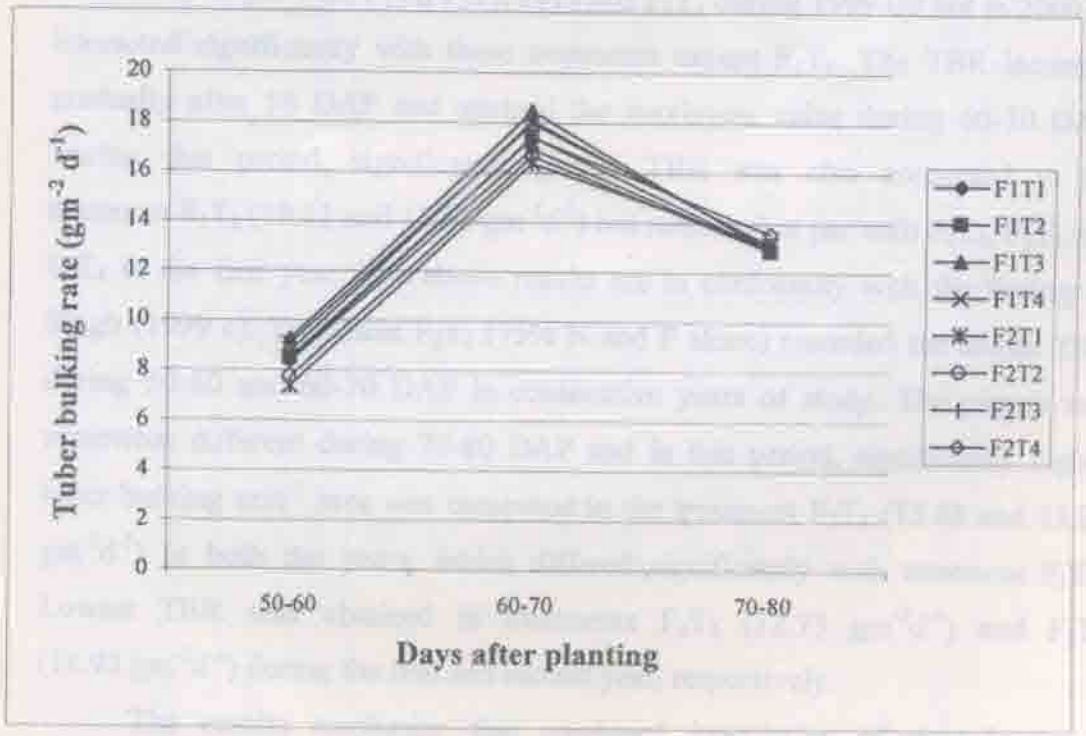


Fig.4.1.4:Effect of biofertilizers on tuber bulking rate of potato.

respectively. The observation on CGR indicates that highly active growth phase of the plant is mostly covered from 60-70 DAP and the photosynthate produced during the critical period is mainly translocated to the developing tubers, since the demand of the tubers for carbohydrate at this stage surpasses the requirement of other organs.

4.1.1.4 Tuber bulking rate:

The data presented in Table 4.1.7 and Fig. 4.1.4 showed that biofertilizer inoculation had favourable influence on tuber bulking rate (TBR) of potato. TBR continued its increasing trend up to 70 days and thereafter it decreased in all the treatments, which might be due to lesser efficiency of photosynthetic perceptive organ and consequently lower accumulation of photosynthate to the harvesting organ and also senescence of lower leaves.

During 50-60 DAP, the maximum tuber bulking was achieved in the treatment F_1T_3 (10.05 and 8.46 $gm^{-2}d^{-1}$) in both the years, which remained statistically at par with F_1T_4, F_2T_3, F_2T_4 and F_1T_1 during 1999-00 but in 2000-01 interacted significantly with these treatments except F_1T_4. The TBR increased gradually after 50 DAP and attained the maximum value during 60-70 DAP. During this period, significantly greater TBR was also accounted in the treatment F_1T_3 (19.12 and 17.83 $gm^{-2}d^{-1}$) but remained at par with F_1T_4, F_2T_3 and F_2T_4 in the first year. The above results are in conformity with the finding of Singh (1999 c). Treatment F_2T_1 (75% N and P alone) recorded the lowest TBR during 50-60 and 60-70 DAP in consecutive years of study. The picture was somewhat different during 70-80 DAP and in this period, significantly higher tuber bulking $unit^{-1}$ area was computed in the treatment F_2T_4 (13.88 and 13.26 $gm^{-2}d^{-1}$) in both the years, which differed significantly with treatment F_2T_3. Lowest TBR was obtained in treatments F_1T_3 (12.73 $gm^{-2}d^{-1}$) and F_2T_2 (11.93 $gm^{-2}d^{-1}$) during the first and second year, respectively.

The results emphasize that combined inoculation of *Azotobacter* + Phosphobacteria and *Bacillus* spp. significantly accelerated the bulking of tubers at all the crop growth stages. The higher TBR between 60-70 DAP was

Table 4.1.7 : Effect of biofertilizers on tuber bulking rate (g $m^{-2}d^{-1}$) of potato during different growth intervals

Treatments	50-60 DAP			60-70 DAP			70-80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
F_1T_1	9.20	7.45	8.33	17.54	16.41	16.98	13.20	12.60	12.90
F_1T_2	8.93	8.04	8.49	17.77	17.13	17.45	13.53	12.29	12.91
F_1T_3	10.05	8.46	9.26	19.12	17.83	18.48	12.73	13.06	12.90
F_1T_4	9.79	8.30	9.05	18.44	17.55	18.00	13.55	12.71	13.13
F_2T_1	8.27	6.47	7.37	16.92	15.87	16.40	13.58	12.65	13.12
F_2T_2	8.62	6.82	7.72	17.13	16.23	16.68	13.85	11.93	12.89
F_2T_3	9.70	7.81	8.76	18.82	17.37	18.10	13.21	12.92	13.07
F_2T_4	9.52	7.27	8.40	18.11	16.76	17.44	13.88	13.26	13.57
S.Em(±)	0.29	0.13	0.08	0.46	0.08	0.21	0.17	0.11	0.05
C.D.(P=0.05)	0.88	0.41	0.25	1.40	0.27	0.65	0.53	0.33	0.16

contributed by the leaf dry weight, the source of carbohydrate production which attained its maximum level during 60-70 DAP.

4.1.1.5 Net assimilation rate:

Net assimilation rate (NAR) differed significantly with the application of biofertilizers at all the growth stages during two successive crop seasons (Table 4.1.8). NAR increased gradually from the initial growth stage up to 70 DAP and afterwards it decreased. The data recorded on NAR reveal that the NAR reached its peak during the period between 60 and 70 days. The NAR was found to be higher during the initial growth period (50-70 days), which might be due to mutual shading effect of leaves at the later stages (70-80 DAP) of plant growth. NAR increased with increase in nutrient supply from low rates but became independent of nutrient supply at higher rates (Watson, 1958). However, Welbank (1962) reported that NAR increased with increasing N-supply over an extended range.

During 50-60 DAP, treatment F_1T_3 accounted for significantly greater NAR values (5.27 and 5.19 $gm^{-2}d^{-1}$) in both years, closely followed by treatment F_1T_4 (5.26 $gm^{-2}d^{-1}$) and F_2T_3 (5.15 $gm^{-2}d^{-1}$) in the first and second year, respectively. Minimum NAR value was recorded in treatment F_1T_2 (4.92 $gm^{-2}d^{-1}$) and F_2T_2 (4.34 $gm^{-2}d^{-1}$) during 1999-00 and 2000-01, respectively.

During highly active growth period (60-70 DAP), significantly higher net assimilation $unit^{-1}$ leaf area was computed in treatments F_2T_1 (8.30 $gm^{-2}d^{-1}$) and F_2T_2 (8.32 $gm^{-2}d^{-1}$) during the first and second year, respectively, which remained at par with treatments F_1T_3, F_2T_3 and F_2T_4 in both the crop seasons. The lowest NAR value of 7.83 $gm^{-2}d^{-1}$ each was recorded in the treatment F_1T_2 and F_1T_4 during 1999-00 and 2000-01, respectively.

During 70-80 DAP, NAR remained significantly greater in the treatment F_2T_2 (5.22 $gm^{-2}d^{-1}$) and F_2T_1 (5.08 $gm^{-2}d^{-1}$) in both the years. However, the value of NAR was minimum in treatments F_1T_3 (3.92 $gm^{-2}d^{-1}$) and F_1T_2 (4.26 $gm^{-2}d^{-1}$) during the first and second year, respectively.

Table 4.1.8 : Effect of biofertilizers on net assimilation rate (g $m^{-2}d^{-1}$) of potato during different growth intervals

Treatments	50-60 DAP			60-70 DAP			70-80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
F_1T_1	5.01	4.89	4.95	7.93	8.25	8.09	5.12	4.31	4.72
F_1T_2	4.92	4.90	4.91	7.83	8.14	7.99	4.83	4.26	4.55
F_1T_3	5.27	5.19	5.23	8.28	8.23	8.25	3.92	4.30	4.11
F_1T_4	5.26	5.11	5.19	8.20	7.83	8.01	4.26	4.42	4.34
F_2T_1	5.04	4.62	4.83	8.30	8.13	8.22	4.99	5.08	5.03
F_2T_2	5.05	4.34	4.70	8.21	8.32	8.27	5.22	4.51	4.86
F_2T_3	4.93	5.15	5.04	8.26	8.23	8.24	4.42	4.54	4.48
F_2T_4	5.02	4.88	4.95	8.11	8.15	8.13	4.80	4.81	4.81
S.Em(±)	0.09	0.09	0.06	0.17	0.09	0.04	0.13	0.10	0.08
C.D.(P=0.05)	0.30	0.29	0.18	0.52	0.28	0.13	0.41	0.31	0.25

4.1.1.6 Leaf area duration:

Inoculation of biofertilizers in combination with inorganic N and P imparted significant effect on the leaf area duration (LAD) of potato during both the years (Table 4.1.9; Fig. 4.1.5). The LAD was longer in the treatment F_1T_3 (74.40 and 69.44 days) in two consecutive years and remained statistically at par with F_2T_3 (72.48 days) and F_1T_4 (69.39 days) in the first and second year, respectively but was significantly superior over the control F_1T_1 (66.42 and 63.17 days).

The beneficial role of biofertilizer was the result of presence of several useful traits like supply of N and P and production of plant growth promoting substances. Similar results were conciliated with Praharaj *et al.* (1999) and Singh (1999 c). The lowest value of LAD was noted in the treatments F_2T_2 (63.57 days) and F_2T_1 (59.04 days) during 1999-00 and 2000-01, respectively.

Table 4.1.9 : Effect of biofertilizers on leaf area duration (days) of potato

Treatments	1999-2000	2000-2001	Pooled
F_1T_1	66.42	63.17	64.79
F_1T_2	68.17	66.45	67.31
F_1T_3	74.40	69.44	71.92
F_1T_4	71.96	69.39	70.67
F_2T_1	64.63	59.04	61.83
F_2T_2	63.57	63.83	63.70
F_2T_3	72.48	65.25	68.87
F_2T_4	68.54	62.01	65.27
S.Em(±)	0.93	0.87	0.65
C.D.(P=0.05)	2.85	2.67	1.99

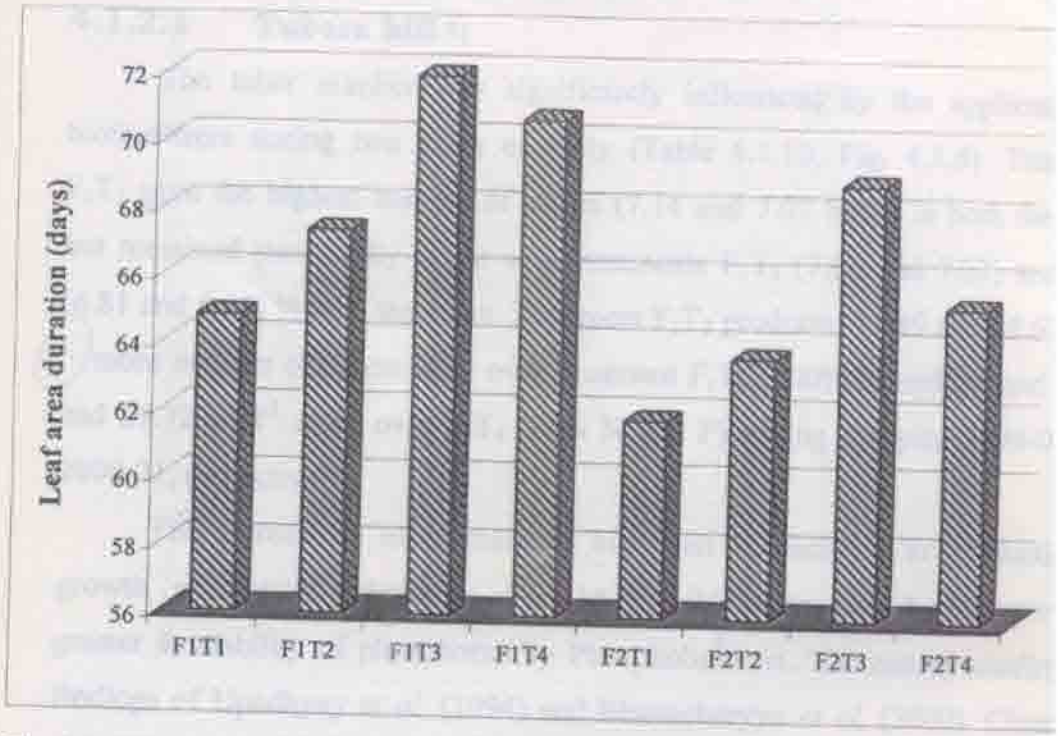


Fig.4.1.5:Effect of biofertilizers on leaf area duration of potato.

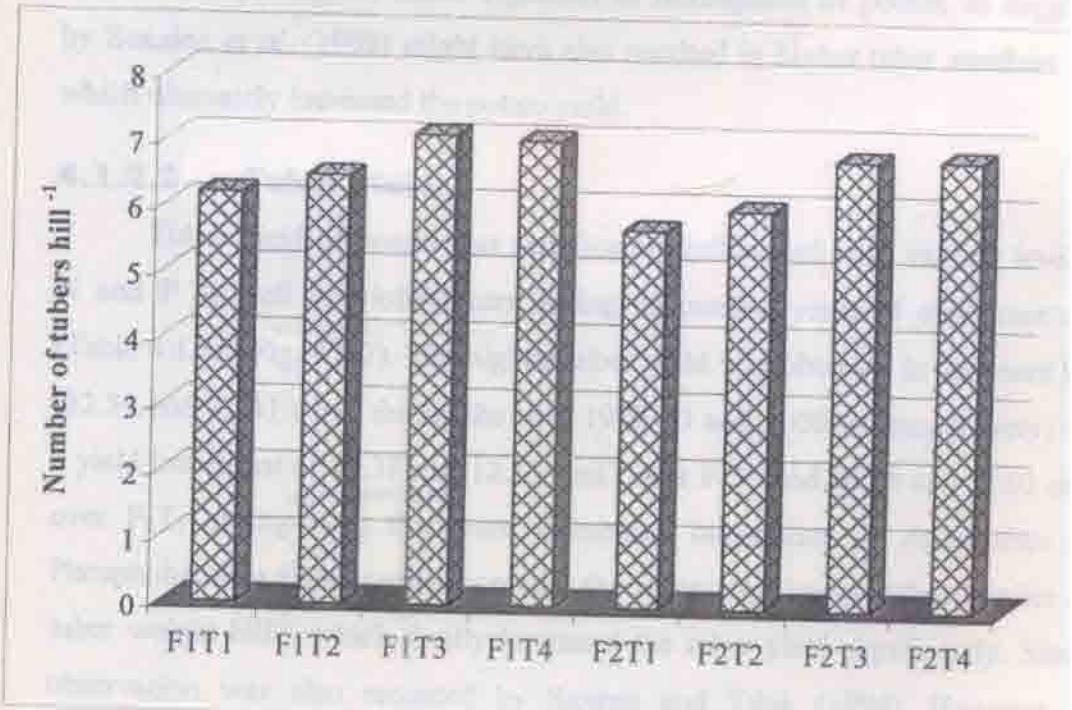


Fig.4.1.6:Effect of biofertilizers on number of tubers hill $^{-1}$ of potato.

4.1.2 Yield components:

4.1.2.1 Tubers hill^{-1}:

The tuber number was significantly influenced by the application of biofertilizers during two years of study (Table 4.1.10; Fig. 4.1.6). Treatment F_1T_3 gave the highest number of tubers (7.14 and 7.07 hill^{-1}) in both the years but remained statistically at par with treatments F_1T_4 (7.06 and 7.02) and F_2T_4 (6.81 and 6.83) in both the years. Treatment F_1T_3 produced 11.39 and 18.62 cent^{-1} more number of tubers hill^{-1} over treatment F_1T_1 (100% N and P); and 20.00 and 29.72 cent^{-1} more over F_2T_1 (75% N and P) during the year 1999-00 and 2000-01, respectively.

The increase in tuber numbers hill^{-1} can be ascribed to production of growth promoting substances like IAA, gibbrellins by *Azotobacter* and greater availability of phosphorus by Phosphobacteria. The results confirm the findings of Upadhyay *et al.* (1994) and Bhattacharyya *et al.* (2000). Chemicals released by *Bacillus* spp. with antagonistic properties in suppressing the activities of pathogenic micro-organism in rhizosphere of potato, as suggested by Sunaina *et al.* (1999) might have also resulted in higher tuber numbers hill^{-1} which ultimately increased the potato yield.

4.1.2.2 Tuber yield:

Tuber yield of potato was significantly influenced with varying levels of N and P as well as biofertilizers during successive years of experimentation (Table 4.1.11; Fig. 4.1.7). The highest tuber yield was obtained in treatment F_1T_3 (32.59 and 32.41 t ha^{-1} during the year 1999-00 and 2000-01, respectively) with a yield increment of 11.38 and 12.53 cent^{-1} over F_1T_1 and 20.53 and 22.03 cent^{-1} over F_2T_1 during both the years. Combined inoculation of *Azotobacter* and Phosphobacteria significantly increased the compound leaves, tuber number and tuber weight hill^{-1}, which finally increased the tuber yield significantly. Similar observation was also recorded by Saxena and Tilak (1994). However, the treatment F_1T_3 remained at par with F_2T_3 (30.92 t ha^{-1}), F_1T_4 (30.67 t ha^{-1}) and

Table 4.1.10 : Effect of biofertilizers on number of tubers hill^{-1} of potato

Treatments	1999-2000	2000-2001	Pooled
F_1T_1	6.41	5.96	6.19
F_1T_2	6.60	6.34	6.47
F_1T_3	7.14	7.07	7.11
F_1T_4	7.06	7.02	7.04
F_2T_1	5.95	5.45	5.70
F_2T_2	6.23	5.81	6.02
F_2T_3	6.93	6.67	6.80
F_2T_4	6.81	6.83	6.82
S.Em(±)	0.12	0.11	0.08
C.D.(P=0.05)	0.37	0.34	0.27

Table 4.1.11 : Effect of biofertilizers on tuber yield (t ha^{-1}) of potato

Treatments	1999-2000	2000-2001	Pooled
F_1T_1	29.26	28.80	29.03
F_1T_2	30.19	30.98	30.59
F_1T_3	32.59	32.41	32.50
F_1T_4	30.67	31.62	31.15
F_2T_1	27.04	26.56	26.80
F_2T_2	27.78	27.28	27.53
F_2T_3	30.92	29.38	30.15
F_2T_4	30.37	28.49	29.43
S.Em(±)	0.93	0.91	0.78
C.D.(P=0.05)	2.82	2.77	2.38

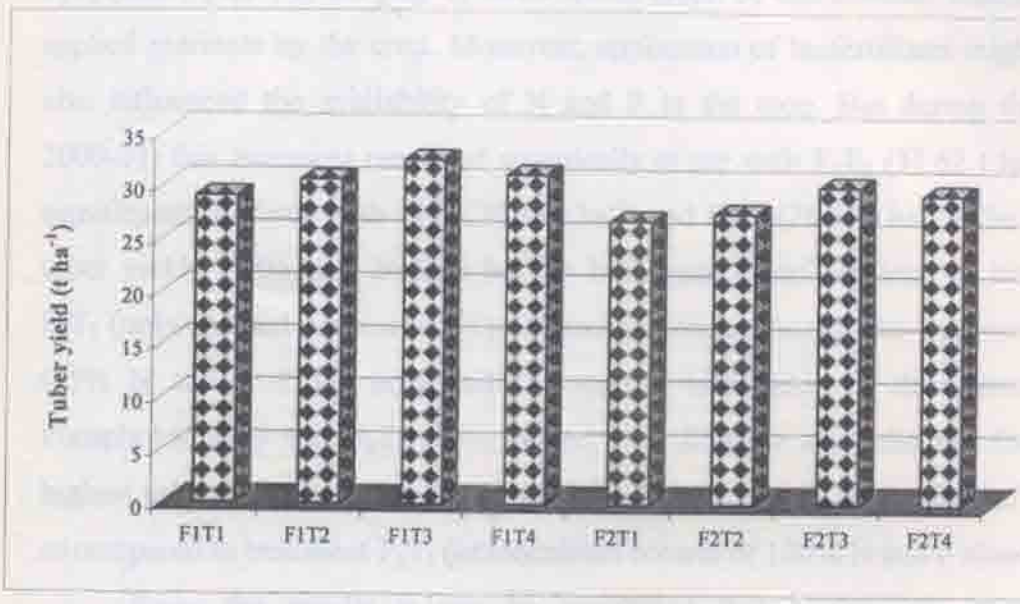


Fig.4.1.7:Effect of biofertilizers on tuber yield of potato.

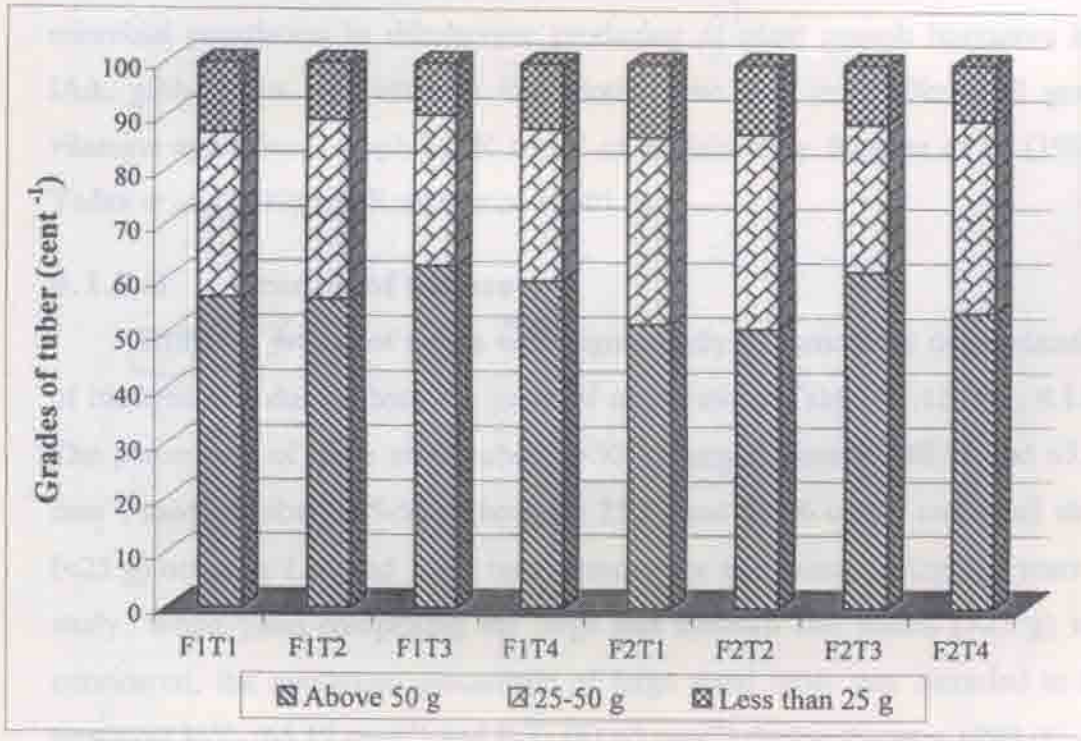


Fig.4.1.8:Effect of biofertilizers on the production of different grades of tubers.

F_2T_4 (30.37 t ha^{-1}) in the year 1999-00 which might be due to better utilization of applied nutrients by the crop. Moreover, application of biofertilizers might have also influenced the availability of N and P to the crop. But during the year 2000-01, this treatment remained statistically at par with F_1T_4 (31.62 t ha^{-1}) but significantly differed with F_2T_3 (29.38 t ha^{-1}) and F_2T_4 (28.49 t ha^{-1}). The lowest tuber yield (27.04 and 26.56 t ha^{-1} in both years) was obtained in treatment F_2T_1 (uninoculated control of 75% N and P alone). Though the treatment F_2T_3 (75% N and P + 1% urea and 1% sodium bicarbonate + *Azotobacter* and Phosphobacteria) and F_2T_4 (75% N and P + *Bacillus* spp.) did not fetch the highest tuber yield, yet they produced 3.86 and 1.38 $cent^{-1}$ more yield of tubers as compared to treatment F_1T_1 (uninoculated control of 100% N and P alone).

From the results it can be concluded that biofertilizer inoculation increased the efficiency of applied N and P and reduced the extent of N and P fertilizer requirement of the crop by 25 $cent^{-1}$. Such spectacular response of biofertilizer inoculation on growth characters and yield was due to change in microbial population in rhizosphere producing of plant growth hormones like IAA, gibberellins and vitamins like biotin, folic acid and different B group vitamins apart from supplying N and P as explained by Sunaina *et al.* (1999), Yadav *et al.* (1999) and Kumar *et al.* (2001 b).

4.1.2.3 Grades of tubers :

Different grades of tubers were significantly influenced by the application of biofertilizers during both the years of observation (Table 4.1.12; Fig. 4.1.8). The percentage of large sized tubers (>50 g) ranged between 48.81 and 65.17 $cent^{-1}$, medium sized (25-50 g) between 25.19 and 38.26 $cent^{-1}$ and small sized (<25 g) between 7.24 and 15.00 $cent^{-1}$ among the treatments during two years of study. When yield comprising the large and medium size tubers (>25 g) was considered, the maximum percentage of large sized tuber was recorded in the treatment F_1T_3 (65.17 $cent^{-1}$) and F_2T_3 (63.65 $cent^{-1}$) during the year 1999-00 and 2000-01, respectively. Contrary to this, treatments F_2T_2 (38.26 $cent^{-1}$) and F_2T_4 (37.22 $cent^{-1}$) gave the highest percentage of medium sized tubers during both

Table 4.1.12 : Effect of biofertilizers on the production of different grades of tubers (cent^{-1}) in potato

Treatments	Above 50 g			25-50 g			Less than 25 g		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
F_1T_1	52.28 (46.31)	61.23 (51.51)	56.75 (48.91)	33.15 (35.12)	27.45 (31.56)	30.30 (33.34)	14.57 (22.29)	11.32 (19.62)	12.95 (20.96)
F_1T_2	55.67 (48.26)	57.36 (49.24)	56.51 (48.75)	30.42 (33.45)	35.40 (36.50)	32.91 (34.98)	13.91 (21.79)	7.24 (15.49)	10.58 (18.64)
F_1T_3	65.17 (53.86)	60.28 (50.95)	62.73 (52.41)	25.19 (30.10)	30.15 (33.27)	27.67 (31.69)	9.64 (17.71)	9.57 (17.84)	9.60 (17.78)
F_1T_4	61.73 (51.79)	58.31 (49.79)	60.02 (50.79)	26.53 (30.97)	29.25 (32.71)	27.89 (31.84)	11.74 (19.79)	12.44 (20.49)	12.09 (20.14)
F_2T_1	48.81 (44.31)	55.72 (48.30)	52.26 (46.31)	36.19 (36.95)	32.26 (34.55)	34.23 (35.75)	15.00 (22.69)	12.02 (19.93)	13.51 (21.31)
F_2T_2	50.15 (45.08)	52.56 (46.46)	51.36 (45.77)	38.26 (38.18)	33.27 (35.20)	35.76 (36.69)	11.59 (19.73)	14.17 (21.86)	12.88 (20.80)
F_2T_3	60.10 (50.85)	63.65 (52.93)	61.87 (51.89)	28.54 (32.25)	25.65 (30.40)	27.10 (31.33)	11.36 (19.60)	10.70 (18.89)	11.03 (19.25)
F_2T_4	57.72 (49.44)	51.10 (45.63)	54.41 (47.54)	33.45 (35.32)	37.22 (37.58)	35.34 (36.45)	8.83 (17.18)	11.68 (19.90)	10.25 (18.54)
S.Em(±)	1.03	1.35	0.82	1.27	1.16	0.97	1.11	0.87	0.56
C.D.(P=0.05)	3.14	4.12	2.49	3.87	3.53	2.95	3.36	2.66	1.70

Values in parentheses are angular transformed

the years. The percentage of tuber yield containing small sized tubers (<25 g) was highest in the treatments F_2T_1 (15.00 $cent^{-1}$) and F_2T_2 (14.17 $cent^{-1}$) in the first and second year, respectively.

The gradewise distribution of tubers reveals that the increase in yield of large and medium sized tubers was due to the cumulative effect of both increase in number and size of tubers which conciliated with the findings of Upadhyay *et al.* (1994) and Sharma *et al.*(1996).

4.1.3 Plant nutrient analysis:

4.1.3.1 NPK uptake by leaves:

Varying levels of N and P in conjunction with biofertilizers had a positive influence on N, P and K uptake by leaves during two years of study (Table 4.1.13). The maximum N and P uptake by leaves was recorded with the treatment F_1T_3 (16.42 and 17.95 kg ha^{-1} N and 1.02 and 1.74 kg ha^{-1} P during 1999-00 and 2000-01, respectively). Pooled data show that the N uptake was higher by 37.41 and 9.11 $cent^{-1}$ with F_1T_3 and F_1T_4 treatment, respectively over uninoculated control of 100% N and P (F_1T_1). In case of P uptake the corresponding increase was 72.50 and 23.75 $cent^{-1}$, respectively. Higher recovery of P was recorded because of inoculation of phosphorus solubilizing bacterial culture that released the fixed P from the soil and made available to the plants. Similar observation was also recorded by Mahendran and Chandramani (1998).

The minimum uptake of N and P was noticed in the treatment F_2T_2 (8.73 and 0.46 kg ha^{-1}) in 1999-00 and F_2T_1 (9.53 and 0.54 kg ha^{-1}) in 2000-01, respectively. Regarding K uptake, treatment F_1T_4 recorded the maximum uptake by leaves (11.43 kg ha^{-1})in the first year and remained at par with F_1T_2 (10.71 kg ha^{-1}) and F_1T_3 (10.65 kg ha^{-1}), but during second year treatment F_1T_3 recorded the highest K uptake (13.28 kg ha^{-1}) which was significantly higher over the rest of the treatments. Likewise pooled data reveal that the K uptake was higher by 27.78, 31.97 and 16.98 $cent^{-1}$ with F_1T_4, F_1T_3 and F_1T_2 treatments,

Table 4.1.13 : Effect of biofertilizers on NPK uptake (kg ha^{-1}) by leaves of potato

Treatments	N uptake			P uptake			K uptake		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
F_1T_1	12.56	12.46	12.51	0.65	0.95	0.80	8.56	9.57	9.07
F_1T_2	11.68	13.11	12.40	0.69	1.27	0.98	10.71	10.50	10.61
F_1T_3	16.42	17.95	17.19	1.02	1.74	1.38	10.65	13.28	11.97
F_1T_4	11.69	15.60	13.65	0.72	1.27	0.99	11.43	11.75	11.59
F_2T_1	9.72	9.53	9.63	0.50	0.54	0.52	8.44	7.35	7.90
F_2T_2	8.73	11.57	10.15	0.46	0.72	0.59	7.72	7.34	7.53
F_2T_3	12.07	13.18	12.63	0.86	1.08	0.98	8.05	9.60	8.83
F_2T_4	12.39	11.59	11.99	0.81	1.03	0.92	9.04	9.70	9.37
S.Em(±)	0.15	0.30	0.18	0.07	0.15	0.04	0.31	0.30	0.16
C.D.(P=0.05)	0.47	0.93	0.55	0.23	0.46	0.12	0.95	0.91	0.49

respectively over F_1T_1 (100% N and P). Treatment F_2T_2 recorded the minimum K uptake (7.72 and 7.34 kg ha^{-1}) during both the years.

4.1.3.2 NPK uptake by stems:

The application of biofertilizers along with N and P significantly influenced the N, P and K uptake by stems during consecutive years of study (Table 4.1.14). The N uptake was maximum in the treatment F_1T_4 (11.64 kg ha^{-1}) and F_1T_3 (11.92 kg ha^{-1}) during first and second year, respectively and was significantly superior to other treatments. Pooled data indicate that the N uptake was higher by 8.45, 7.40 and 7.51 $cent^{-1}$ with F_1T_4, F_1T_3 and F_1T_2 treatments, respectively over uninoculated control (F_1T_1). Correspondingly P uptake was higher by 14.89, 36.17 and 29.79 $cent^{-1}$ over F_1T_1. Maximum P uptake was noticed in the treatment F_2T_3 (0.56 kg ha^{-1}) during 1999-00 and F_1T_3 (0.84 kg ha^{-1}) in 2000-01. Application of *Azotobacter*, Phosphobacteria and *Bacillus* spp. with enhanced doses of N and P would have resulted in high soil available N and P, ultimately leading to higher biomass production and N and P utilization. These results support the findings of Sharma (1989) and Singh (2001).

During 1999-00, minimum N (6.32 kg ha^{-1}) and P (0.27 kg ha^{-1}) uptake was obtained in treatment F_2T_2 but treatment F_2T_1 recorded the minimum uptake (8.40 and 0.43 kg ha^{-1} N and P, respectively) in 2000-01. K uptake was maximum with the treatment F_1T_3 (15.55 and 17.74 kg ha^{-1}) during both the years showing an increment of 18.34 $cent^{-1}$ over F_1T_1 from the pooled data. Treatment F_1T_4 recorded the minimum K uptake by stems (11.84 and 13.31 kg ha^{-1}) in both the years.

4.1.3.3 NPK uptake by tubers:

The inoculation of *Azotobacter*, Phosphobacteria and *Bacillus* spp. imparted significant effect on the N, P and K uptake by tubers during two years of experimentation (Table 4.1.15; Fig. 4.1.9). Treatment F_1T_3 recorded the maximum N and P uptake (131.96 and 123.86 kg ha^{-1} N and 14.53 and 18.58

Table 4.1.14 : Effect of biofertilizers on NPK uptake (kg ha^{-1}) by stems of potato

Treatments	N uptake			P uptake			K uptake		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
F_1T_1	8.83	10.34	9.59	0.40	0.53	0.47	13.20	14.93	14.07
F_1T_2	9.41	11.20	10.31	0.43	0.78	0.61	13.59	16.52	15.06
F_1T_3	8.67	11.92	10.30	0.45	0.84	0.64	15.55	17.74	16.65
F_1T_4	11.64	9.16	10.40	0.53	0.54	0.54	11.84	13.31	12.58
F_2T_1	9.57	8.40	8.99	0.31	0.43	0.37	14.14	14.96	14.55
F_2T_2	6.32	10.27	8.30	0.27	0.55	0.41	13.37	15.44	14.41
F_2T_3	8.71	11.21	9.96	0.56	0.67	0.62	12.47	15.71	14.09
F_2T_4	9.61	9.62	9.62	0.47	0.58	0.52	14.44	14.55	14.50
S.Em(±)	0.32	0.12	0.17	0.07	0.09	0.03	0.30	0.29	0.19
C.D.(P=0.05)	0.97	0.37	0.53	0.22	0.28	0.10	0.93	0.89	0.58

Table 4.1.15 : Effect of biofertilizers on NPK uptake (kg ha^{-1}) by tubers of potato

Treatments	N uptake			P uptake			K uptake		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
F_1T_1	105.86	95.51	100.69	9.10	10.19	9.65	125.25	111.73	118.49
F_1T_2	110.04	111.25	110.65	10.27	16.48	13.38	123.69	125.14	124.42
F_1T_3	131.96	123.86	127.91	14.53	18.58	16.56	131.08	128.85	129.97
F_1T_4	121.97	121.29	121.63	11.81	14.77	13.29	129.80	132.19	131.00
F_2T_1	100.41	80.27	90.34	6.59	7.35	6.97	120.32	100.04	110.18
F_2T_2	108.58	88.07	98.33	7.65	8.50	8.08	123.00	102.68	112.84
F_2T_3	131.68	103.61	117.65	12.83	13.33	13.08	134.12	118.47	126.30
F_2T_4	117.89	103.16	110.53	10.84	11.92	11.38	127.26	107.19	117.23
S.Em(±)	5.37	3.39	2.43	0.64	0.56	0.27	1.18	0.79	0.53
C.D.(P=0.05)	16.29	10.31	7.39	1.96	1.71	0.82	3.60	2.42	1.62

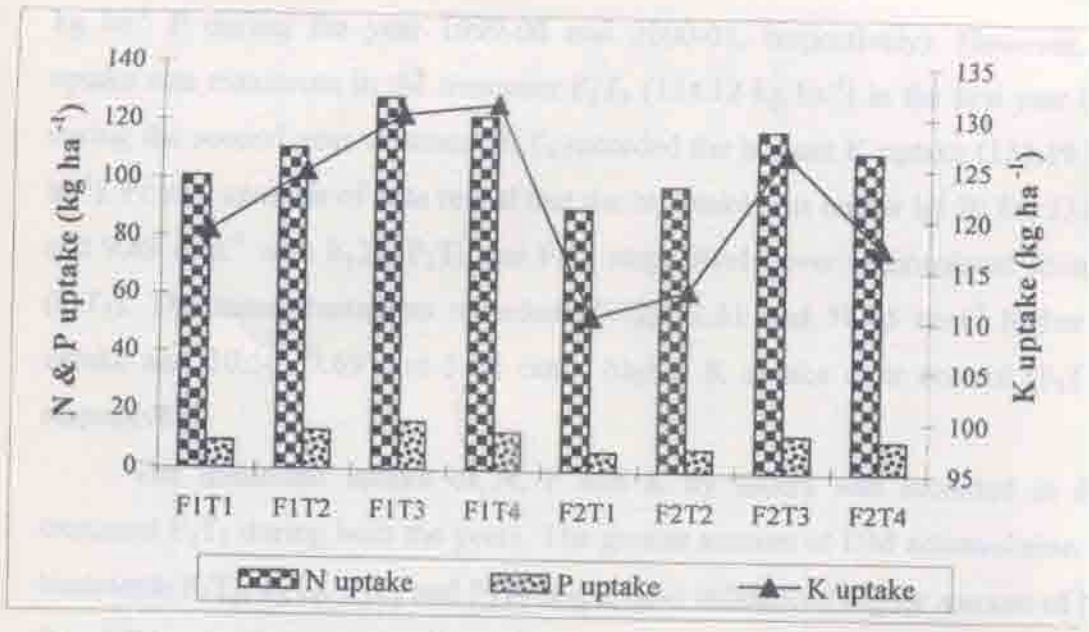


Fig.4.1.9:Effect of biofertilizers on NPK uptake by tubers of potato.

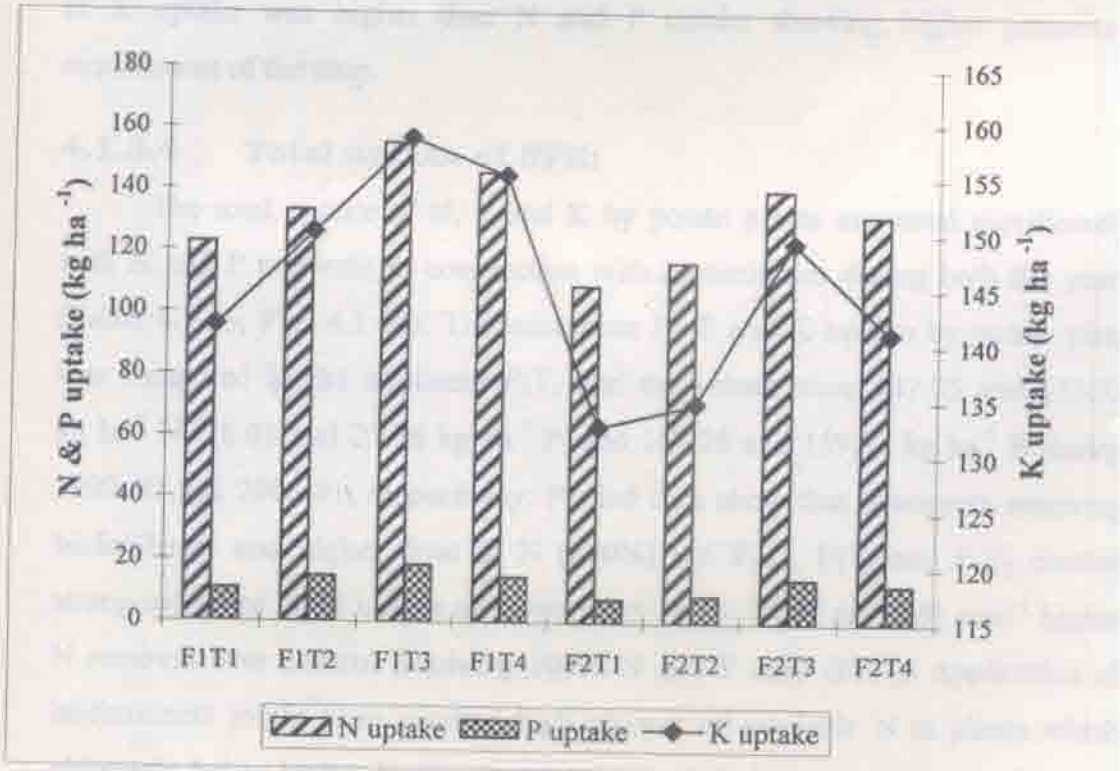


Fig.4.1.10:Effect of biofertilizers on total uptake of NPK by potato plant.

kg ha^{-1} P during the year 1999-00 and 2000-01, respectively). However, K uptake was maximum in the treatment F_2T_3 (134.12 kg ha^{-1}) in the first year but during the second year treatment F_1T_4 recorded the highest K uptake (132.19 kg ha^{-1}). Pooled analysis of data reveal that the N uptake was higher by 20.80, 27.03 and 9.89 $cent^{-1}$ with F_1T_4, F_1T_3 and F_1T_2 respectively over uninoculated control (F_1T_1). The same treatments recorded 37.72, 71.61 and 38.65 $cent^{-1}$ higher P uptake and 10.56, 9.69 and 5.00 $cent^{-1}$ higher K uptake over control (F_1T_1), respectively.

The minimum uptake of N, P and K by tubers was recorded in the treatment F_2T_1 during both the years. The greater amount of DM accumulation in treatments F_1T_3, F_1T_4, F_2T_3 and F_2T_4 might have influenced higher amount of N, P and K removal as compared to other treatments. An increase in the amount of N and P uptake by potato with inoculation of phosphorus solubilising bacteria was also reported by Singh and Sharma (2002). It was also noted that the value of K uptake was higher than N and P uptake showing higher potassium requirement of the crop.

4.1.3.4 Total uptake of NPK:

The total uptake of N, P and K by potato plants increased significantly with N and P nutrients in conjunction with biofertilizers during both the years (Table 4.1.16; Fig. 4.1.10). The maximum N, P and K uptake by potato plant was computed in the treatment F_1T_3 and the values were 157.05 and 153.73 kg ha^{-1} N; 16.01 and 21.16 kg ha^{-1} P; and 157.28 and 159.87 kg ha^{-1} K during 1999-00 and 2000-01, respectively. Pooled data show that treatments receiving biofertilizers and higher dose of N (100%) *viz.* F_1T_4, F_1T_3 and F_1T_2 exerted strong influence on N uptake and computed 18.65, 26.57 and 8.61 $cent^{-1}$ higher N removal over control receiving 100% N and P only (F_1T_1). Application of biofertilizers might have resulted high amount of available N to plants which ultimately led to higher biomass production and N utilization. In case of total P uptake the corresponding increase was 35.71, 70.24 and 37.00 $cent^{-1}$ over control (F_1T_1) which emphasized the phosphate solubilizing characteristics of PSB and

Table 4.1.16 : Effect of biofertilizers on total uptake of NPK (kg ha^{-1}) by potato plant

Treatments	N uptake			P uptake			K uptake		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
F_1T_1	127.25	118.31	122.78	10.15	11.68	10.92	147.01	136.23	141.62
F_1T_2	131.13	135.56	133.35	11.39	18.53	14.96	147.99	152.15	150.07
F_1T_3	157.05	153.73	155.40	16.01	21.16	18.59	157.28	159.87	158.58
F_1T_4	145.30	146.05	145.68	13.06	16.58	14.82	153.08	157.43	155.25
F_2T_1	119.70	98.20	108.95	7.41	8.32	7.86	142.90	122.35	132.62
F_2T_2	123.63	109.91	116.77	8.38	9.77	9.08	144.09	125.45	134.77
F_2T_3	152.46	128.00	140.24	14.26	15.09	14.68	154.64	143.79	149.22
F_2T_4	139.89	124.37	132.13	12.12	13.53	12.83	150.74	131.44	141.09
S.Em(±)	5.36	5.73	5.05	0.63	1.49	0.76	1.19	2.30	1.28
C.D.(P=0.05)	16.26	17.38	15.34	1.93	4.52	2.31	3.61	7.00	3.88

Bacillus. The same treatments were also found to have influenced higher K uptake computing 9.62, 11.97 and 5.97 cent^{-1} more uptake respectively over control (F_1T_1). Treatment F_2T_1 (75% N and P only) accounted for the lowest N, P and K uptake in both the years. The value of K uptake was higher than N and P uptake, showing higher K requirement of the crop. The observation was also in agreement with the findings of Mahendran and Chandramani (1998).

The results indicate that when both *Azotobacter* and Phosphobacteria cultures were applied together, they exerted synergistic effect on each other and gave higher recovery of applied nutrients. Similar observation was also recorded by Singh (2001).

4.1.4 Soil available NPK:

Initial status of available N, P and K of the soil was recorded before the planting of potato crop and again after the harvest of the crop in both the years (Table 4.1.17). Sesame (pre-*kharif*) and paddy (*kharif*) crops were grown between two potato crops. Sesame was grown after potato on the residual fertility of the soil and after sesame, paddy was grown as per recommended package of practices. However, a build up of soil available N, P and K was registered in all the treatments after the harvest of potato crop. The maximum soil available N, P and K was recorded in the treatment F_1T_3 accounting for 325.30 and 321.37 kg ha^{-1} N, 20.90 and 21.29 kg ha^{-1} P and 194.34 and 225.43 kg ha^{-1} K during the first and second year, respectively and remained statistically at par with treatment F_1T_4. The data presented in the Table 4.1.17 also indicate that the increase in available N in the treatment F_1T_3 was 8.91 and 13.35 cent^{-1} higher over uninoculated control of 100% N and P (F_1T_1) during 1999-00 and 2000-01, respectively. The corresponding increase in available P was 25.60 and 23.42 cent^{-1} and that of available K was 3.92 and 12.08 cent^{-1} higher over treatment F_1T_1 during both the years. However, treatment F_1T_4 (100% N and P + *Bacillus* spp.) computed an increase of 5.88 and 9.40 cent^{-1} available N, 14.48 and 15.19 cent^{-1} available P and 2.19 and 9.57 cent^{-1} available K over F_1T_1 during 1999-00 and 2000-01, respectively.

Table 4.1.17 : Effect of biofertilizers on soil available NPK (kg ha^{-1})

Treatments	Available N				Available P				Available K			
	1999-2000		2000-2001		1999-2000		2000-2001		1999-2000		2000-2001	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
F_1T_1	223.17	298.70	207.58	283.51	8.39	16.64	9.16	17.25	169.15	187.01	182.27	201.13
F_1T_2	223.17	311.65	207.58	303.10	8.39	18.28	9.16	18.79	169.15	189.65	182.27	216.04
F_1T_3	223.17	325.30	207.58	321.37	8.39	20.90	9.16	21.29	169.15	194.34	182.27	225.43
F_1T_4	223.17	316.27	207.58	310.17	8.39	19.05	9.16	19.87	169.15	191.11	182.27	220.37
F_2T_1	223.17	259.50	207.58	247.23	8.39	12.65	9.16	11.88	169.15	176.95	182.27	186.87
F_2T_2	223.17	271.18	207.58	266.85	8.39	12.98	9.16	13.39	169.15	179.32	182.27	193.65
F_2T_3	223.17	293.52	207.58	289.62	8.39	15.10	9.16	16.42	169.15	182.37	182.27	206.71
F_2T_4	223.17	284.15	207.58	274.73	8.39	14.29	9.16	15.19	169.15	180.77	182.27	196.96
S.Em(±)	-	6.59	-	8.38	-	1.34	-	1.41	-	1.10	-	2.39
C.D.(P=0.05)	-	19.99	-	25.42	-	4.09	-	4.29	-	3.35	-	7.27

This might be due to application of biofertilizers which might have increased the residual NPK status of the soil along with the application of inorganic fertilizers as also reported by Sharma (1989). Treatment F_2T_1 (75% N and P) recorded the minimum values of soil available N, P and K (259.50 and 247.23 kg ha^{-1} N; 12.65 and 11.88 kg ha^{-1} P; and 176.95 and 186.87 kg ha^{-1} K) during the first and second year, respectively.

4.1.5 Economics:

The data presented in Table 4.1.18 show marginal increase in cost of cultivation from Rs. 40,023 ha^{-1} (100% N and P) to Rs. 40,545 ha^{-1} (100% N and P + 1% urea and 1% sodium bicarbonate + *Azotobacter* and Phosphobacteria) and Rs. 40,373 ha^{-1} (100% N and P + *Bacillus* spp.). However, the corresponding increase at 75% recommended N and P levels was from Rs. 38,955 ha^{-1} (F_2T_1) to Rs. 39,477 ha^{-1} (F_2T_3) and Rs. 39,305 ha^{-1} (F_2T_4). During the first year, cost of cultivation was lower than that of second year in all the treatments due to higher cost of inputs in the second year. Mean data of two years show that treatment F_1T_3 recorded the highest gross return of Rs. 97,500 ha^{-1}, followed by treatments F_1T_4, F_1T_2, F_2T_3 and F_2T_4 with corresponding gross returns of Rs. 93,435; Rs. 91,755; Rs. 90,450 and Rs. 88,290 ha^{-1}, respectively. Likewise highest net return was obtained with the combined inoculation of *Azotobacter* and Phosphobacteria with 100% N and P (F_1T_3), followed by treatments F_1T_4, F_2T_3 and F_2T_4. These treatments produced 21.01, 12.74, 8.30 and 4.08 $cent^{-1}$ higher net return, respectively over treatment F_1T_1. Singh (2001) and Singh and Sharma (2002) also obtained higher net return with the combined inoculation of *Azotobacter* and phospho-inoculant culture. The net return $rupee^{-1}$ invested was higher with treatments F_1T_3 (1.40), F_1T_4 (1.31), F_2T_3 (1.29) and F_2T_4 (1.25) as compared to uninoculated controls (1.18 at 100% N and P; and 1.06 at 75% N and P).

It could be concluded that the net return $rupee^{-1}$ invested can be maximised with marginal investment on biofertilizers as a cheaper source and

Table 4.1.18 : Effect of biofertilizers on the economics of cultivation of potato

Treatments	Cost of cultivation (Rs. ha^{-1})			Gross return (Rs. ha^{-1})			Net profit (Rs. ha^{-1})			Benefit : Cost (Rs.)		
	1999-00	2000-01	Mean	1999-00	2000-01	Mean	1999-00	2000-01	Mean	1999-00	2000-01	Mean
F_1T_1	39,268	40,778	40,023	87,780	86,400	87,090	48,512	45,622	47,067	1.24	1.12	1.18
F_1T_2	39,440	40,950	40,195	90,570	92,940	91,755	51,130	51,990	51,560	1.30	1.27	1.28
F_1T_3	39,790	41,300	40,545	97,770	97,230	97,500	57,980	55,930	56,955	1.46	1.35	1.40
F_1T_4	39,618	41,128	40,373	92,010	94,860	93,435	52,392	53,732	53,062	1.32	1.31	1.31
F_2T_1	38,200	39,710	38,955	81,120	79,680	80,400	42,920	39,970	41,445	1.12	1.01	1.06
F_2T_2	38,372	39,882	39,127	83,334	81,840	82,587	44,962	41,958	43,460	1.17	1.05	1.11
F_2T_3	38,722	40,232	39,477	92,760	88,140	90,450	54,038	47,908	50,973	1.40	1.19	1.29
F_2T_4	38,550	40,060	39,305	91,110	85,470	88,290	52,560	45,410	48,985	1.36	1.13	1.25

may be used for sustaining agricultural production specially in heavy feeder crop like potato.

4.2 Experiment No. 2: Levels and methods of potassium application for increasing its efficiency in potato:

4.2.1 Growth parameters:

4.2.1.1 Leaf area index:

Potassium had profound influence on the leaf area index (LAI) which can be established from the fact that during initial stage (50 DAP) the lowest pooled value of LAI (1.86) was observed in control and the highest (2.15) in the plots treated with 200 kg K_2O ha^{-1} (Table 4.2.1; Fig. 4.2.1). LAI increased from 50 to 70 DAP which might be due to increase in stem length and branches and decreased afterwards irrespective of fertilizer treatments. This was probably due to the leaf senescence as the crop approached maturity. The LAI also increased with the increase in potassium level. Pooled data indicate that the highest LAI was recorded with 200 kg K_2O ha^{-1} (2.15, 2.48, 2.80 and 2.65 at 50, 60, 70 and 80 DAP, respectively), which was statistically at par with 150 and 100 kg K_2O ha^{-1} in the year 1999-00 but superior to 100 kg ha^{-1} at 50 and 60 DAP in 2000-01. Control plots (K_0) always recorded the lowest LAI (1.86, 2.08, 2.35 and 2.25 at successive dates of observation). The positive effect of potassium on LAI was also reported by Singh *et al.* (1993).

The various methods of potassium application showed significant effect on the LAI at different growth stages of the crop. The highest LAI of 2.17, 2.51, 2.82 and 2.66 at consecutive growth stages were recorded when potassium was applied full as basal (M_1), which was, however statistically at par with M_2 (2/3rd as basal + 1/3rd as top dressing at 30 DAP) and M_3 (1/2 as basal + 1/2 at 30 DAP as top dressing) in the first year and significantly superior to treatment M_3 during second year at all the dates of observation. Potassium applied full as

Table 4.2.1 : Leaf area indices of potato as influenced by levels and methods of potassium application at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})												
K_0 0	1.98	1.73	1.86	2.13	2.02	2.08	2.41	2.29	2.35	2.32	2.18	2.25
K_1 50	2.07	1.83	1.95	2.34	2.13	2.24	2.63	2.48	2.56	2.48	2.35	2.42
K_2 100	2.13	1.88	2.01	2.41	2.19	2.30	2.76	2.52	2.64	2.63	2.43	2.53
K_3 150	2.17	2.01	2.09	2.49	2.32	2.41	2.83	2.67	2.75	2.67	2.53	2.60
K_4 200	2.19	2.11	2.15	2.56	2.39	2.48	2.88	2.71	2.80	2.73	2.58	2.65
SEm(±)	0.02	0.05	0.02	0.05	0.05	0.02	0.06	0.06	0.03	0.04	0.05	0.01
CD(P=0.05)	0.08	0.15	0.06	0.15	0.15	0.08	0.18	0.19	0.09	0.13	0.16	0.05
K_0 vs. rest												
CD(P=0.05)	0.12	0.21	0.09	0.23	0.22	0.11	0.26	0.27	0.14	0.20	0.24	0.07
Methods of application												
M_1 full Muriate	2.20	2.13	2.17	2.58	2.43	2.51	2.89	2.75	2.82	2.70	2.62	2.66
M_2 2/3 S + 1/3 [illegible]	2.14	2.01	2.08	2.53	2.33	2.43	2.83	268	2.76	2.67	2.55	2.61
M_3 1/2 S + 1/2 [illegible]	2.13	1.85	1.99	2.42	2.15	2.29	2.79	2.48	2.64	2.68	2.39	2.54
M_4 full Sulph	2.08	1.84	1.96	2.26	2.12	2.19	2.57	2.46	2.52	2.45	2.33	2.39
SEm(±)	0.03	0.05	0.02	0.05	0.05	0.02	0.06	0.06	0.03	0.4	0.05	0.01
CD(P=0.05)	0.08	0.15	0.06	0.16	0.16	0.07	0.18	0.19	0.09	0.14	0.17	0.05

[illegible] mention the treatment abbreviations in the body of the table or at least in a footnote [illegible] table

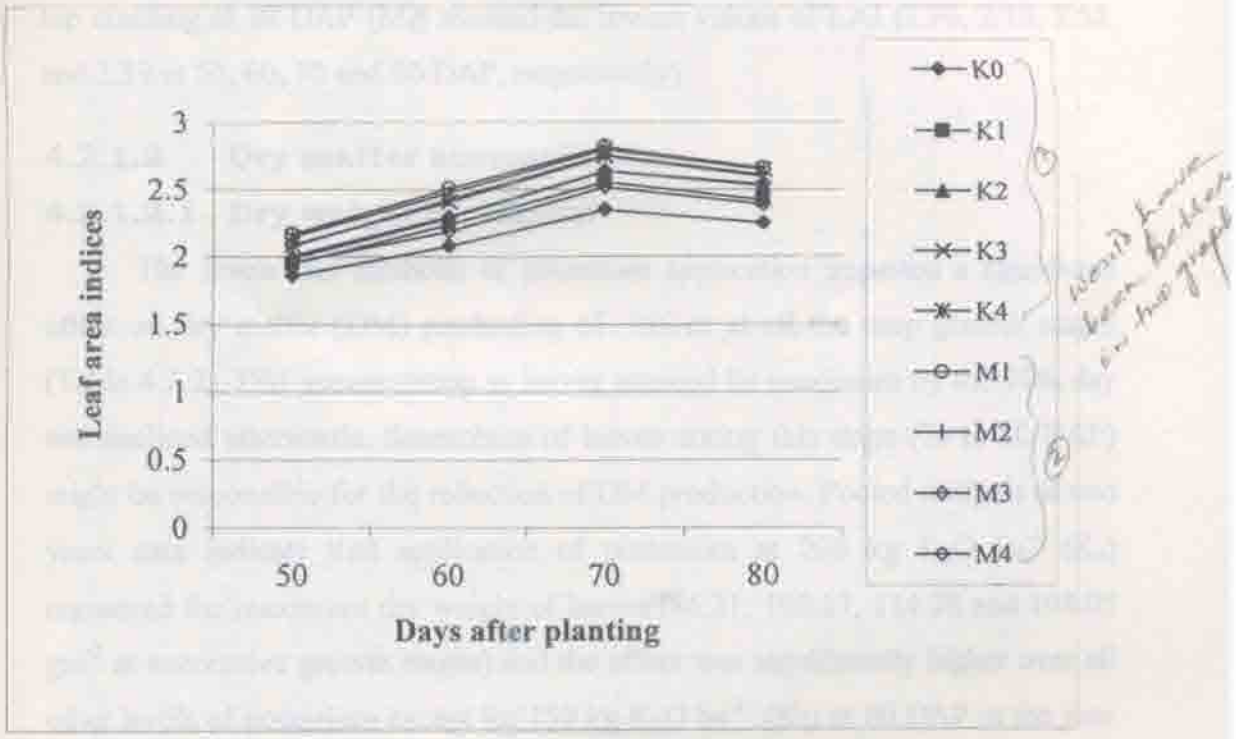


Fig.4.2.1: Effect of levels and methods of potassium application on leaf area indices of potato.

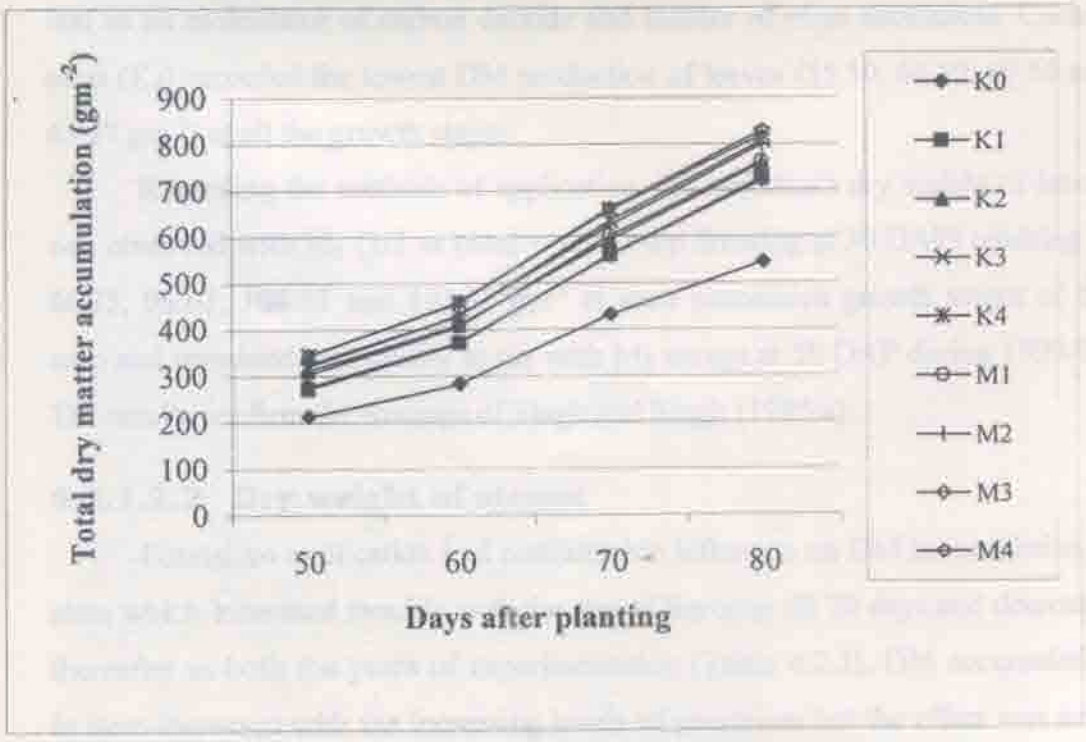


Fig.4.2.2: Effect of levels and methods of potassium application on total dry matter accumulation of potato.

top dressing at 30 DAP (M_4) showed the lowest values of LAI (1.96, 2.19, 2.52 and 2.39 at 50, 60, 70 and 80 DAP, respectively).

4.2.1.2 Dry matter accumulation:

4.2.1.2.1 Dry weight of leaves:

The levels and methods of potassium application imparted a significant effect on dry matter (DM) production of leaves at all the crop growth stages (Table 4.2.2). DM accumulation in leaves attained its maximum by the 70th day and declined afterwards. Senescence of leaves during this stage (70 to 80 DAP) might be responsible for the reduction of DM production. Pooled analysis of two years data indicate that application of potassium at 200 kg K_2O ha^{-1} (K_4) registered the maximum dry weight of leaves (86.21, 100.17, 114.08 and 108.05 gm^{-2} at successive growth stages) and the effect was significantly higher over all other levels of potassium except for 150 kg K_2O ha^{-1} (K_3) at 60 DAP in the year 1999-00 and at 60 and 70 DAP in 2000-01. The increase in dry weight of leaves with potassium application might be due to its association with the efficiency of leaf as an assimilator of carbon dioxide and builder of plant substances. Control plots (K_0) recorded the lowest DM production of leaves (55.50, 60.50, 67.50 and 65.17 gm^{-2}) at all the growth stages.

Regarding the methods of application, the maximum dry weight of leaves was observed with M_3 (1/2 as basal + 1/2 as top dressing at 30 DAP) resulting in 86.75, 96.67, 108.13 and 103.34 gm^{-2} at each successive growth stages of the crop and remained statistically at par with M_2 except at 50 DAP during 1999-00. The results confirm the findings of Singh and Singh (1995 a).

Not tallying with the LAI as P. 78

4.2.1.2.2 Dry weight of stems:

Potassium application had considerable influence on DM accumulation in stem which increased steadily with the age of the crop till 70 days and decreased thereafter in both the years of experimentation (Table 4.2.3). DM accumulation in stem increased with the increasing levels of potassium but the effect was more pronounced at lower doses up to 100 kg K_2O ha^{-1} (K_2). Pooled data show that the

Table 4.2.2 : Dry weight production of leaves (g m^{-2}) of potato as influenced by levels and methods of potassium application at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})												
K_0	62.67	48.33	55.50	66.67	54.33	60.50	73.33	61.67	67.50	71.67	58.67	65.17
K_1	78.75	66.42	72.59	84.67	74.92	79.80	89.92	81.25	85.59	88.33	77.67	83.00
K_2	84.25	74.33	79.29	90.83	81.42	86.13	97.42	84.92	91.17	94.17	82.83	88.50
K_3	85.83	78.33	82.08	95.08	89.58	92.33	108.92	105.33	107.13	103.08	101.33	102.21
K_4	88.92	83.50	86.21	101.17	99.17	100.17	112.33	115.83	114.08	106.67	109.42	108.05
SEm(±)	1.86	3.64	2.23	1.30	3.30	1.85	2.31	3.35	1.64	1.66	3.20	1.54
CD(P=0.05)	5.38	10.50	6.45	3.77	9.53	5.35	6.66	9.65	4.73	4.80	9.22	4.45
K_0 vs. rest												
CD(P=0.05)	7.84	15.31	9.40	5.50	13.90	7.79	9.71	14.07	6.90	7.00	13.45	6.48
Methods of application												
M_1	82.83	75.25	79.04	92.17	85.17	88.67	100.83	95.42	98.13	97.08	91.75	94.42
M_2	86.33	78.42	82.38	95.33	88.92	92.13	104.25	99.58	101.92	101.17	95.50	98.34
M_3	91.75	81.75	86.75	98.17	95.17	96.67	108.83	107.42	108.13	104.17	102.50	103.34
M_4	76.83	67.17	72.00	86.08	75.83	80.96	94.67	84.92	89.80	89.83	81.50	85.67
SEm(±)	1.86	3.65	2.23	1.30	3.31	1.85	2.31	3.35	1.64	1.66	3.20	1.54
CD(P=0.05)	5.38	10.51	6.45	3.77	9.54	5.35	6.66	9.65	4.73	4.80	9.22	4.44

Table 4.2.3 : Dry weight production of stems (g m^{-2}) of potato as influenced by levels and methods of potassium application at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})												
K_0	51.33	43.33	47.33	56.67	47.33	52.00	63.33	50.67	57.00	61.67	49.33	55.50
K_1	72.08	58.92	65.50	79.42	64.58	72.00	88.25	69.75	79.00	84.08	67.33	75.71
K_2	78.08	69.58	73.83	85.67	73.50	79.59	92.83	79.42	86.13	89.50	73.25	81.38
K_3	82.92	74.25	78.59	92.42	84.42	88.42	100.08	92.25	96.17	97.58	90.33	93.96
K_4	83.33	79.58	81.46	94.17	91.42	92.80	103.17	101.42	102.30	99.33	97.17	98.25
SEm(±)	1.64	3.35	1.59	1.53	3.01	1.45	2.23	3.27	2.04	2.52	2.93	2.47
CD(P=0.05)	4.73	9.67	4.58	4.43	8.67	4.19	6.45	9.44	5.89	7.28	8.45	7.12
K_0 vs. rest												
CD(P=0.05)	6.90	14.10	6.67	6.46	12.64	6.10	9.40	13.77	8.60	10.61	12.32	10.38
Methods of application												
M_1	75.67	68.75	72.21	84.00	76.42	80.21	90.42	84.00	87.21	86.67	79.42	83.05
M_2	79.92	72.17	76.05	90.17	79.08	84.63	99.33	85.92	92.63	96.08	83.00	89.54
M_3	87.33	78.25	82.79	96.42	87.92	92.17	106.00	95.58	100.79	102.92	92.92	97.92
M_4	73.50	63.17	68.34	81.08	70.50	75.79	88.58	77.33	82.96	84.83	72.75	78.79
SEm(±)	1.64	3.36	1.58	1.54	3.00	1.45	2.23	3.28	2.05	2.52	2.93	2.47
CD(P=0.05)	4.74	9.68	4.57	4.44	8.67	4.18	6.45	9.45	5.90	7.28	8.45	7.12

highest stem dry weight was recorded when potassium was applied at 200 kg K_2O ha^{-1} (81.46, 92.80, 102.30 and 98.25 gm^{-2}) but the effect was statistically at par with 150 kg K_2O ha^{-1} at all growth stages in both the years. Control plots (K_0) computed the least values (47.33, 52.00, 57.00 and 55.50 gm^{-2} during 50, 60, 70 and 80 DAP, respectively). The increase in dry weight with potassium application might be ascribed to increase in the number of main stems. The results confirmed the findings of Singh and Raghav (2000).

Among the methods of application, the highest dry weight of stem was obtained when potassium was applied in two equal splits (M_3) producing 82.79, 92.17, 100.79 and 97.92 gm^{-2} dry weight after 50, 60, 70 and 80 DAP respectively, which was significantly superior to other methods of potassium application except at 80 DAP in the first year and 50 DAP in the second year when M_2 and M_3 did not interact significantly.

4.2.1.2.3 Dry weight of tubers:

The DM production of tubers was affected significantly by the levels and methods of potassium application at all the successive growth stages of the crop (Table 4.2.4). The DM yield of tubers increased with advancement of the age of crop till maturity, however, the rate of increase was rapid up to 70 DAP and thereafter it slowed down. Pooled data indicate that all the potassium levels maintained their distinct superiority to control (K_0), and 200 kg K_2O ha^{-1} (K_4) accounted for the highest value at all the growth stages (176.79, 264.92, 441.59 and 613.25 gm^{-2}). However, this treatment (K_4) remained statistically at par with treatment K_3 (150 kg K_2O ha^{-1}) at all the stages except at 50 DAP in 2000-01. The control plots receiving no potassium (K_0) recorded the lowest DM of tubers (109.84, 170.83, 307.50 and 424.17 gm^{-2}) at consecutive crop growth stages. Potassium is known to be responsible for enhancing the metabolic activities of plants and thus brings about better growth and size of tubers which is ultimately reflected by higher DM production of tubers. The results are in harmony with Bansal and Maibaum (1999).

Table 4.2.4 : Dry weight production of tubers (g m^{-2}) of potato as influenced by levels and methods of potassium application at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})												
K_0	105.67	114.00	109.84	178.33	163.33	170.83	316.67	298.33	307.50	441.67	406.67	424.17
K_1	133.67	134.25	133.96	223.00	215.42	219.21	403.42	389.17	396.30	580.08	555.33	567.71
K_2	158.50	159.42	158.96	253.92	235.83	244.88	434.17	396.92	415.55	610.33	567.00	588.67
K_3	165.67	155.00	160.34	255.83	242.92	249.38	443.75	417.83	430.79	627.92	591.67	609.80
K_4	179.75	173.83	176.79	275.25	254.58	264.92	456.50	426.67	441.59	629.75	596.75	613.25
SEm(±)	5.11	4.95	4.38	6.96	6.48	6.26	6.55	7.27	4.88	5.95	8.00	6.83
CD(P=0.05)	14.72	14.26	12.63	20.07	18.69	18.04	18.88	20.96	14.05	17.18	23.08	19.70
K_0 vs. rest												
CD(P=0.05)	21.45	20.80	18.41	29.25	27.24	26.29	27.53	30.56	20.48	25.04	33.64	28.71
Methods of application												
M_1	152.17	152.92	152.55	241.42	235.00	238.21	429.17	404.25	416.71	597.25	571.50	584.38
M_2	170.58	163.00	166.79	264.17	243.42	253.80	440.25	419.00	429.63	630.17	590.92	610.55
M_3	180.50	168.33	174.42	279.75	260.92	270.34	470.17	433.83	452.00	648.67	606.17	627.42
M_4	134.33	138.25	136.29	222.67	209.42	216.05	398.25	373.50	385.88	572.00	542.17	557.09
SEm(±)	5.10	4.95	4.38	6.96	6.48	6.25	6.55	7.27	4.87	5.95	8.00	6.83
CD(P=0.05)	14.71	14.27	12.63	20.07	18.69	18.03	18.89	20.96	14.05	17.17	23.08	19.69

Considering the methods of potassium application, the highest DM of tubers was registered in treatment M_3 (174.42, 270.34, 452.00 and 627.42 gm^{-2} at 50, 60, 70 and 80 DAP, respectively), which remained statistically at par with M_2 at all the stages except at 70 and 80 DAP in the first year when they differed significantly.

4.2.1.2.4 Total dry matter production:

It is evident from the Table 4.2.5 and Fig. 4.2.2 that DM production gradually increased up to maturity of the crop and also increased with the increment of potassium application up to 200 kg K_2O ha^{-1} (344.50, 458.00, 658.00 and 819.50 gm^{-2} at 50, 60, 70 and 80 DAP, respectively) from pooled data of two years and the effect was significantly superior to the rest of the potassium levels, except at 70 and 80 DAP in the year 1999-00 and 80 DAP during 2000-01 where treatment K_3 remained at par with K_4. The data also reveal that association between tuber DM and total DM production became very much stronger with the advancement of the age of crop. Sharma and Ezekiel (1993), Nandekar *et al.* (1999) and Umar *et al.* (1999) also reported that application of potassium increased the contents of DM. The lowest total DM production was observed in the treatment K_0 (212.67, 283.33, 432.00 and 544.67 gm^{-2}) at consecutive growth stages of the crop.

Split application of potassium in two equal doses (M_3) exhibited the highest total DM accumulation (343.92, 459.00, 660.92 and 828.67 gm^{-2} at successive growth stages) which differed significantly with rest of the methods of application except at 50 DAP in the second year where no statistical difference prevailed between M_2 and M_3. The increase in DM production by split application of potassium might be due to minimum loss of potassium though leaching and maximum availability during the crop period. Corroborative findings have also reported by Shukla and Singh (1976) and Singh and Singh (1995 b).

Table 4.2.5 : Total dry matter production (g m^{-2}) of potato as influenced by levels and methods of potassium application at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})												
K_0	219.67	205.67	212.67	301.67	265.00	283.33	453.33	410.67	432.00	575.00	514.67	544.67
K_1	284.50	259.58	272.08	387.08	354.92	370.92	581.58	540.17	561.00	752.50	700.33	726.25
K_2	320.83	303.33	312.08	430.42	390.75	410.42	624.42	561.25	592.92	794.00	723.08	758.50
K_3	334.42	307.58	321.00	443.33	416.92	430.08	652.75	615.42	634.08	828.58	783.33	806.00
K_4	352.00	336.92	344.50	470.58	445.17	458.00	672.00	643.92	658.00	835.75	803.33	819.50
SEm(±)	5.20	7.82	4.35	6.45	8.96	5.52	6.96	9.00	6.06	6.02	9.62	6.25
CD(P=0.05)	14.99	22.55	12.54	18.60	25.82	15.91	20.07	25.95	17.47	17.36	27.73	18.03
K_0 vs. rest												
CD(P=0.05)	21.86	32.87	18.27	27.12	37.64	23.19	29.25	37.83	25.47	25.31	40.43	26.29
Methods of application												
M_1	310.67	296.92	303.83	417.58	396.58	407.17	620.42	583.67	602.17	781.00	742.67	761.75
M_2	336.83	313.58	325.25	449.67	411.42	430.50	643.83	604.50	624.25	827.42	769.42	798.42
M_3	359.58	328.33	343.92	474.33	444.00	459.00	685.00	636.83	660.92	855.75	801.58	828.67
M_4	284.67	268.58	276.67	389.83	355.75	372.75	581.50	535.75	558.67	746.67	696.42	721.42
SEm(±)	5.20	7.82	4.35	6.46	8.96	5.52	6.96	9.01	6.06	6.03	9.62	6.25
CD(P=0.05)	15.00	22.55	12.53	18.61	25.82	15.91	20.07	25.96	17.47	17.37	27.74	18.03

4.2.1.3 Crop growth rate:

Crop growth rate (CGR) interacted significantly with the levels and methods of potassium application at different growth stages of the crop till harvest (Table 4.2.6; Fig. 4.2.3). The CGR unit^{-1} area increased gradually from 50 days reaching the maximum between 60-70 days. After 70 days, there was a reduction in the ~~rate of~~ CGR. In the early stages of growth (50-60 DAP), 200 kg K_2O ha^{-1} (K_4) produced the highest CGR (11.86 gm^{-2}d^{-1}) in 1999-00 which was significantly higher over the rest of the potassium levels. However, during 2000-01 potassium application at 150 kg K_2O ha^{-1}(K_3) recorded the highest CGR (10.93 gm^{-2}d^{-1}) but remained at par with the highest dose K_4(10.83 gm^{-2}d^{-1}). During the peak growth stage of the crop (60-70 DAP) the highest CGR was obtained with 150 kg K_2O ha^{-1} (20.94 gm^{-2}d^{-1})which remained statistically at par with 200 kg K_2O ha^{-1} (20.14 gm^{-2}d^{-1}) in the first year but during 2000-01, the effect was just reversed and treatment K_4 registered the highest CGR of 19.88 gm^{-2}d^{-1}, closely followed by K_3 (19.85 gm^{-2}d^{-1}). The rapid increase in fresh weight of leaves and stems resulted in higher CGR at this stage and was due to availability of more nutrients for sustaining the plant as explained by Singh and Singh (1964). During 70-80 DAP, potassium application at 150 kg K_2O ha^{-1} (K_3) recorded the highest CGR (17.58 and 16.79 gm^{-2}d^{-1} in 1999-00 and 2000-01, respectively) and remained significantly superior to 200 kg K_2O ha^{-1} (K_4). Pooled data show that plots receiving no potassium (K_0) as usual recorded the lowest rate (7.07, 14.87 and 11.29 gm^{-2}d^{-1})during consecutive time intervals.

Potassium when applied half as basal and other half at 30 DAP (M_3) recorded the highest CGR between 50 and 60 DAP (11.48 and 11.57 gm^{-2}d^{-1} during first and second year, respectively). However, during 60-70 DAP, though the same treatment (M_3) produced the highest CGR (21.07 gm^{-2}d^{-1}) in the first year, M_2 (potassium when applied 2/3 rd as basal and 1/3 rd at 30 DAP) recorded the highest value (19.31 gm^{-2}d^{-1}) in the second year. The highest CGR values during 70-80 DAP (18.36 and 16.49 gm^{-2}d^{-1} in 1999-00 and 2000-01, respectively) were also recorded with M_2.

Table 4.2.6 : Crop growth rate (g $m^{-2}d^{-1}$) of potato as influenced by levels and methods of potassium application during different growth intervals

Treatments	50-60 DAP			60-70 DAP			70-80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})									
K_0	8.20	5.93	7.07	15.17	14.57	14.87	12.17	10.40	11.29
K_1	10.26	9.53	9.90	19.45	18.53	18.99	17.09	16.02	16.56
K_2	10.96	8.74	9.85	19.40	17.05	18.23	16.96	16.18	16.57
K_3	10.89	10.93	10.91	20.94	19.85	20.40	17.58	16.79	17.19
K_4	11.86	10.83	11.35	20.14	19.88	20.01	16.38	15.94	16.16
SEm(±)	0.23	0.53	0.32	0.41	0.32	0.46	0.27	0.12	0.21
CD(P=0.05)	0.67	1.54	0.94	1.19	0.93	1.33	0.78	0.35	0.62
K_0 vs. rest									
CD(P=0.05)	0.97	2.25	1.36	1.74	1.35	1.94	1.14	0.52	0.91
Methods of application									
M_1	10.69	9.97	10.33	20.28	18.71	19.50	16.06	15.90	15.98
M_2	11.28	9.78	10.53	19.42	19.31	19.37	18.36	16.49	17.43
M_3	11.48	11.57	11.53	21.07	19.28	20.18	17.08	16.48	16.78
M_4	10.52	8.72	9.62	19.17	18.00	18.59	16.52	16.07	16.30
SEm(±)	0.23	0.53	0.32	0.41	0.32	0.46	0.27	0.12	0.21
CD(P=0.05)	0.67	1.54	0.94	1.19	0.93	1.33	0.78	0.35	0.62

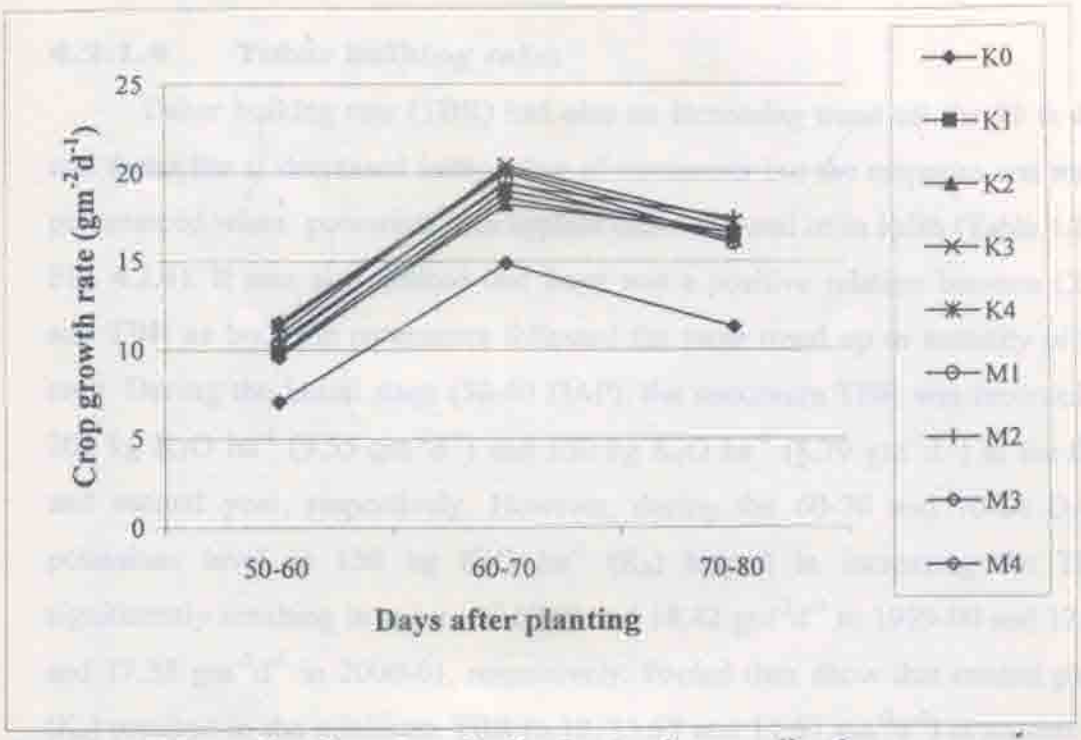


Fig.4.2.3: Effect of levels and methods of potassium application on crop growth rate of potato.

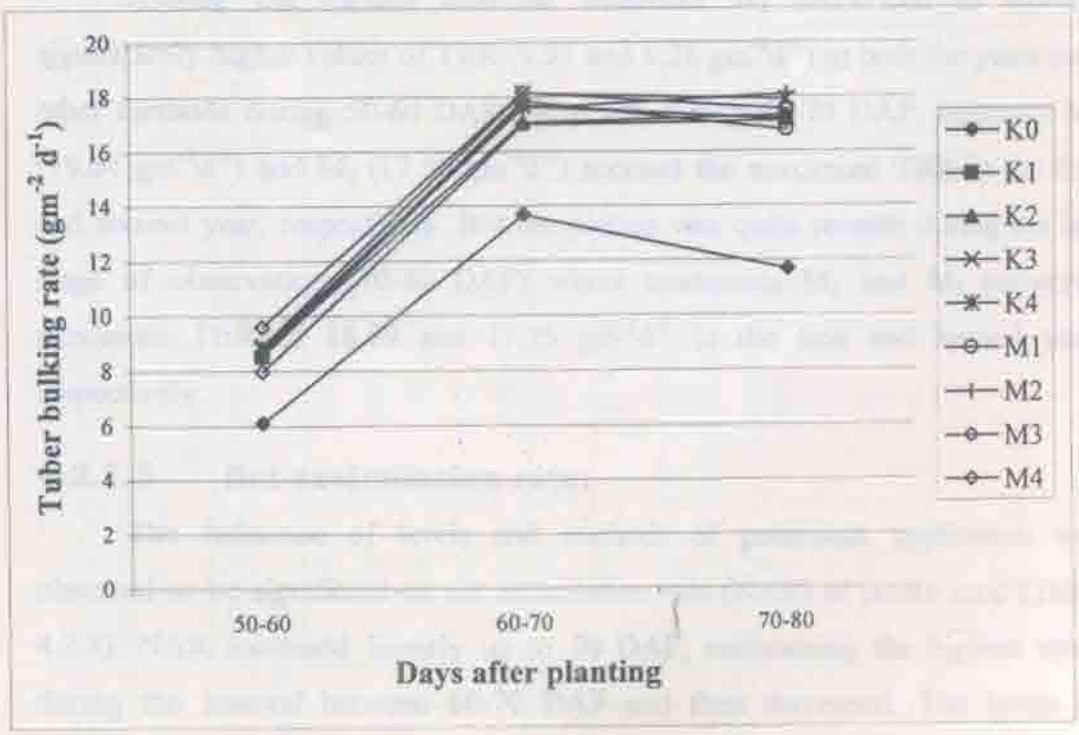


Fig.4.2.4: Effect of levels and methods of potassium application on tuber bulking rate of potato.

4.2.1.4 Tuber bulking rate:

Tuber bulking rate (TBR) had also an increasing trend till the 70 th day and thereafter it decreased irrespective of treatments but the response was more pronounced when potassium was applied either as basal or in splits (Table 4.2.7; Fig. 4.2.4). It was also noticed that there was a positive relation between CGR and TBR as both the parameters followed the same trend up to maturity of the crop. During the initial stage (50-60 DAP), the maximum TBR was recorded at 200 kg K_2O ha^{-1} (9.55 $gm^{-2}d^{-1}$) and 150 kg K_2O ha^{-1} (8.79 $gm^{-2}d^{-1}$) in the first and second year, respectively. However, during the 60-70 and 70-80 DAP, potassium level at 150 kg K_2O ha^{-1} (K_3) helped in increasing the TBR significantly resulting in values of 18.79 and 18.42 $gm^{-2}d^{-1}$ in 1999-00 and 17.49 and 17.38 $gm^{-2}d^{-1}$ in 2000-01, respectively. Pooled data show that control plots (K_0) resulted in the minimum TBR (6.10, 13.67 and 11.67 $gm^{-2}d^{-1}$) at successive time intervals.

Among the various methods, treatment M_3 influenced to increase significantly higher values of TBR (9.93 and 9.26 $gm^{-2}d^{-1}$) in both the years over other methods during 50-60 DAP. However, during 60-70 DAP, treatment M_3 (19.04 $gm^{-2}d^{-1}$) and M_2 (17.56 $gm^{-2}d^{-1}$) accrued the maximum TBR in the first and second year, respectively. But the picture was quite reverse during the last stage of observation (70-80 DAP) where treatments M_2 and M_3 registered maximum TBR of 18.99 and 17.23 $gm^{-2}d^{-1}$ in the first and second year, respectively.

4.2.1.5 Net assimilation rate:

The influence of levels and methods of potassium application was observed to be significant on net assimilation rate (NAR) of potato crop (Table 4.2.8). NAR increased linearly up to 70 DAP, maintaining the highest value during the interval between 60-70 DAP and then decreased. The levels of potassium application, however, failed to produce a uniform trend and exhibited inconsistent influence on the NAR values. During the initial growth stage (50-60

Table 4.2.7 : Tuber bulking rate (g $m^{-2}d^{-1}$) of potato as influenced by levels and methods of potassium application during different growth intervals

Treatments	50-60 DAP			60-70 DAP			70-80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})									
K_0	7.27	4.93	6.10	13.83	13.50	13.67	12.50	10.83	11.67
K_1	8.93	8.12	8.53	18.04	17.38	17.71	17.67	16.62	17.15
K_2	9.54	7.64	8.59	18.03	16.11	17.07	17.62	17.01	17.32
K_3	9.02	8.79	8.91	18.79	17.49	18.14	18.42	17.38	17.90
K_4	9.55	8.08	8.82	18.13	17.21	17.67	17.33	17.01	17.17
SEm(±)	0.14	0.27	0.11	0.19	0.28	0.17	0.24	0.14	0.21
CD(P=0.05)	0.42	0.77	0.33	0.55	0.82	0.50	0.70	0.40	0.61
K_0 vs. rest									
CD(P=0.05)	0.62	1.13	0.48	0.80	1.20	0.73	1.02	0.59	0.89
Methods of application									
M_1	8.93	8.21	8.57	18.78	16.93	17.86	16.81	16.73	16.77
M_2	9.36	8.04	8.70	17.61	17.56	17.59	18.99	17.19	18.09
M_3	9.93	9.26	9.60	19.04	17.29	18.17	17.85	17.23	17.54
M_4	8.83	7.12	7.98	17.56	16.41	16.99	17.38	16.87	17.13
SEm(±)	0.15	0.27	0.11	0.19	0.29	0.17	0.24	0.14	0.21
CD(P=0.05)	0.43	0.77	0.33	0.55	0.83	0.50	0.70	0.40	0.61

Table 4.2.8 : Net assimilation rate (g $m^{-2}d^{-1}$) of potato as influenced by levels and methods of potassium application during different growth intervals

Treatments	50-60 DAP			60-70 DAP			70-80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})									
K_0	4.01	3.24	3.63	6.77	6.78	6.78	5.08	4.58	4.83
K_1	4.78	4.91	4.85	7.97	8.19	8.08	6.78	6.64	6.71
K_2	4.97	4.80	4.89	7.70	7.60	7.65	6.52	6.76	6.64
K_3	4.80	5.21	5.01	8.09	8.22	8.16	6.63	6.64	6.64
K_4	5.19	5.08	5.14	7.68	8.13	7.91	5.99	6.25	6.12
SEm(±)	0.11	0.10	0.07	0.11	0.16	0.08	0.17	0.11	0.21
CD(P=0.05)	0.32	0.29	0.22	0.33	0.46	0.25	0.50	0.33	0.61
K_0 vs. rest									
CD(P=0.05)	0.46	0.41	0.33	0.48	0.66	0.37	0.73	0.48	0.89
Methods of application									
M_1	4.65	4.55	4.60	7.74	7.38	7.56	5.80	6.17	5.99
M_2	4.88	4.77	4.83	7.28	8.02	7.65	6.90	6.48	6.69
M_3	5.19	6.10	5.65	8.24	8.65	8.45	6.36	6.80	6.58
M_4	5.02	4.59	4.81	8.18	8.08	8.13	6.86	6.85	6.86
SEm(±)	0.11	0.09	0.07	0.11	0.15	0.08	0.17	0.11	0.21
CD(P=0.05)	0.31	0.28	0.22	0.33	0.45	0.25	0.50	0.33	0.61

DAP), application of potassium at 200 kg (K_4) and 150 kg K_2O ha^{-1} (K_3) produced the highest NAR values of 5.19 and 5.21 $gm^{-2}d^{-1}$ in the first and second year respectively. However, during the peak period of growth (60-70 DAP), potassium applied at 150 kg K_2O ha^{-1}(K_3) accounted for the highest NAR values (8.09 and 8.22 $gm^{-2}d^{-1}$ in both the years) and remained statistically at par with 50 kg K_2O ha^{-1} (K_1). During the last stages of observation (70-80 DAP), highest value of NAR was registered with K_1 (6.78 $gm^{-2}d^{-1}$) and K_2 (6.76 $gm^{-2}d^{-1}$) in 1999-00 and 2000-01, respectively. Pooled analysis of data show that the control plots (K_0) receiving no potassium attained the lowest NAR values (3.63, 6.78 and 4.83 $gm^{-2}d^{-1}$) at successive time intervals.

Split application of potassium, half as basal and another half at 30 DAP (M_3) fetched the highest NAR values during 50-60 DAP (5.19 and 6.10 $gm^{-2}d^{-1}$) and 60-70 DAP (8.24 and 8.65 $gm^{-2}d^{-1}$) in both the years. But during 70-80 DAP, potassium applied 2/3 rd as basal + 1/3 rd at 30 DAP (M_2) recorded the highest NAR (6.90 $gm^{-2}d^{-1}$) in the first year and potassium applied fully at 30 DAP as top dressing (M_4) achieved the highest value (6.85 $gm^{-2}d^{-1}$) in the second year.

4.2.1.6 Leaf area duration:

The various levels and methods of potassium application imparted significant effect on leaf area duration (LAD) of potato during two years (Table 4.2.9; Fig. 4.2.5). LAD values increased as the level of potassium increased and potassium applied at 200 kg K_2O ha^{-1} (K_4) recorded the longest LAD (73.50 and 70.11 days), which remained statistically at par with 150 kg K_2O ha^{-1} (72.34 and 67.80 days) during two successive years. These findings are in general agreement with Singh *et al.* (1993). Control plots (K_0) resulted in the lowest values of LAD (64.37 and 58.39 days) in both the years.

Among the methods, potassium applied full as basal (M_1) registered the longest LAD (73.24 and 71.00 days) and remained statistically at par with M_2 (71.86 and 68.08 days) during two years. The minimum value of LAD was

recorded in M_4 (67.80 and 62.26 days) in both the years when entire amount of potassium was applied after 30 days of crop growth.

Table 4.2.9 : Leaf area duration (days) of potato as influenced by levels and methods of potassium application

Treatments	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})			
K_0	64.37	58.39	61.38
K_1	68.06	62.38	65.22
K_2	71.14	64.30	67.72
K_3	72.34	67.80	70.07
K_4	73.50	70.11	71.81
SEm(±)	1.44	1.53	1.56
CD(P=0.05)	4.14	4.44	4.50
K_0 vs. rest			
CD(P=0.05)	6.06	6.48	6.54
Methods of application			
M_1	73.24	71.00	72.12
M_2	71.86	68.08	69.97
M_3	71.83	63.25	67.54
M_4	67.80	62.26	65.03
SEm(±)	1.44	1.53	1.56
CD(P=0.05)	4.14	4.44	4.50

4.2.2 Yield components:

4.2.2.1 Tubers hill^{-1}:

Levels and methods of potassium application accomplished significant effect on the number of tubers hill^{-1}during consecutive years of study (Table 4.2.10; Fig. 4.2.6). In the first year, the tubers hill^{-1} increased with each additional dose of potassium and the maximum number of tubers hill^{-1} was noted with treatment K_4 (8.58) which remained at par with K_3 (8.17). However, during the second year, the highest value (9.75) was recorded with potassium at 150 kg

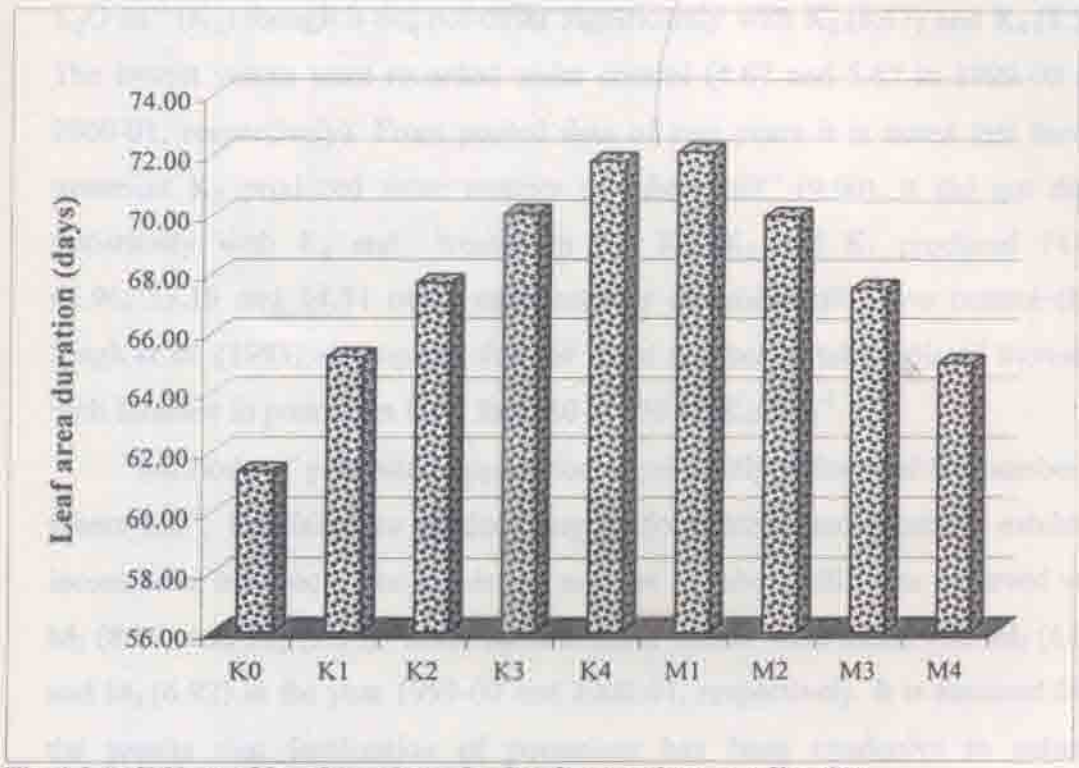


Fig.4.2.5: Effect of levels and methods of potassium application on leaf area duration of potato.

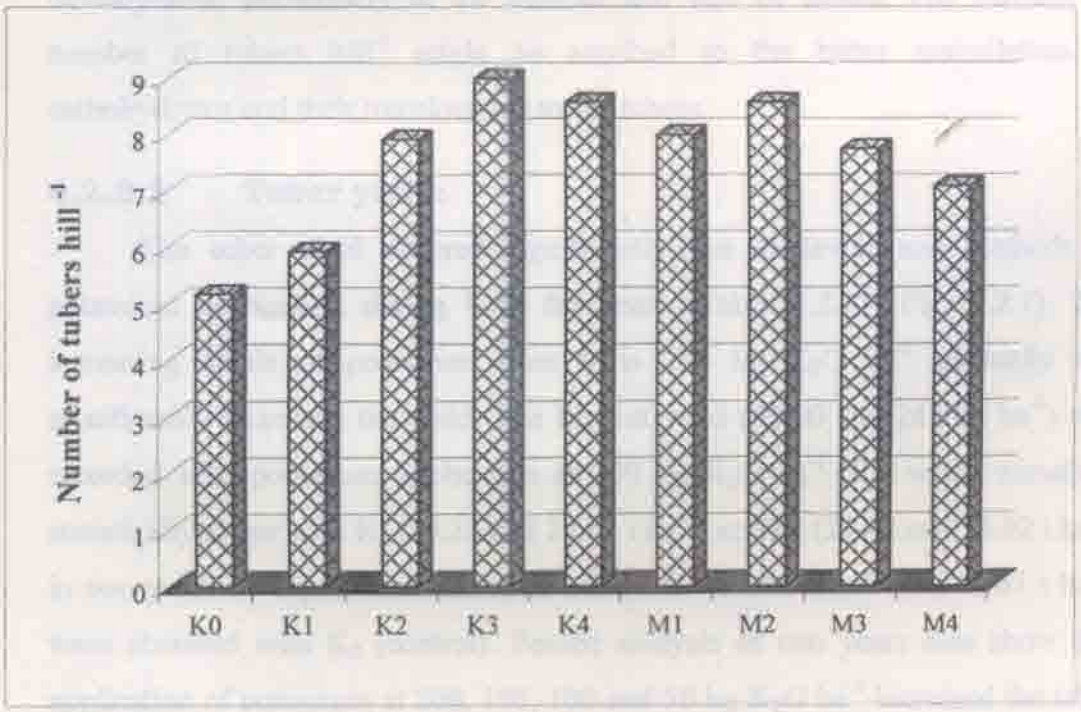


Fig.4.2.6: Effect of levels and methods of potassium application on number of tubers hill^{-1}.

K_2O ha^{-1} (K_3) though it did not differ significantly with K_2 (8.67) and K_4 (8.50). The lowest values were recorded under control (4.67 and 5.67 in 1999-00 and 2000-01, respectively). From pooled data of two years it is noted that though treatment K_3 produced more number of tubers $hill^{-1}$ (9.00), it did not differ statistically with K_4 and treatments K_3, K_4, K_2 and K_1 produced 74.08, 65.96, 53.19 and 14.51 $cent^{-1}$ more number of tubers $hill^{-1}$ over control (K_0). Singh *et al.* (1993) also opined that the mean number of tubers $plant^{-1}$ increased with increase in potassium level form 30 to 150 kg K_2O ha^{-1}.

Methods of potassium application significantly influenced the number of tubers $hill^{-1}$, but failed to produce any uniform trend and therefore exhibited inconsistent influence. The maximum number of tubers $hill^{-1}$ was observed with M_2 (8.00) and M_3 (9.50), while the minimum values were noted with M_3 (6.08) and M_4 (6.92) in the year 1999-00 and 2000-01, respectively. It is assumed from the results that fertilization of potassium has been conducive to enhance metabolic activities within the plant, bringing about better growth and development, particularly in the number and size of tubers. The increase in number of tubers $hill^{-1}$ might be ascribed to the better assimilation of carbohydrates and their translocation to the tubers.

4.2.2.2 Tuber yield:

The tuber yield differed significantly due to levels and methods of potassium application during both the years (Table 4.2.11; Fig. 4.2.7). The increasing levels of potassium from 0 to 200 kg K_2O ha^{-1} gradually and significantly increased the yield. The highest yield (30.00 and 28.00 t ha^{-1}) was recorded with potassium application at 200 kg K_2O ha^{-1} (K_4) which remained statistically at par with K_3 (29.25 and 27.92 t ha^{-1}) and K_2 (27.08 and 25.92 t ha^{-1}) in two years of experimentation. The minimum values (20.33 and 18.67 t ha^{-1}) were obtained with K_0 (control). Pooled analysis of two years data show that application of potassium at 200, 150, 100 and 50 kg K_2O ha^{-1} increased the tuber yield by 47.43, 45.30, 34.72 and 28.77 $cent^{-1}$ over control (K_0). Higher enzymatic activities and translocation of photosynthates due to potassium

Table 4.2.10. Number of tubers hill^{-1} of potato as influenced by levels and methods of potassium application

Treatments	2000-2001	1999-2000	Pooled
Levels of K_2O (kg ha^{-1})			
K_0	4.67	5.67	5.17
K_1	5.08	6.67	5.92
K_2	7.00	8.67	7.92
K_3	8.17	9.75	9.00
K_4	8.58	8.50	8.58
SEm(±)	0.39	0.61	0.27
CD(P=0.05)	1.14	1.76	0.80
K_0 vs. rest			
CD(P=0.05)	1.65	2.57	1.16
Methods of application			
M_1	7.67	8.17	8.00
M_2	8.00	9.00	8.58
M_3	6.08	9.50	7.75
M_4	7.08	6.92	7.08
SEm(±)	0.39	0.61	0.27
CD(P=0.05)	1.14	1.76	0.79

Table 4.2.11 : Tuber yield (t ha^{-1}) of potato as influenced by levels and methods of potassium application

Treatments	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})			
K_0	20.33	18.67	19.67
K_1	25.83	24.67	25.33
K_2	27.08	25.92	26.50
K_3	29.25	27.92	28.58
K_4	30.00	28.00	29.00
SEm(±)	1.04	0.93	0.71
CD(P=0.05)	3.01	2.69	2.07
K_0 vs. rest			
CD(P=0.05)	4.38	3.93	3.02
Methods of application			
M_1	26.83	25.42	26.08
M_2	29.17	27.75	28.50
M_3	29.92	28.83	29.42
M_4	26.25	24.50	25.42
SEm(±)	1.04	0.94	0.71
CD(P=0.05)	3.01	2.70	2.07

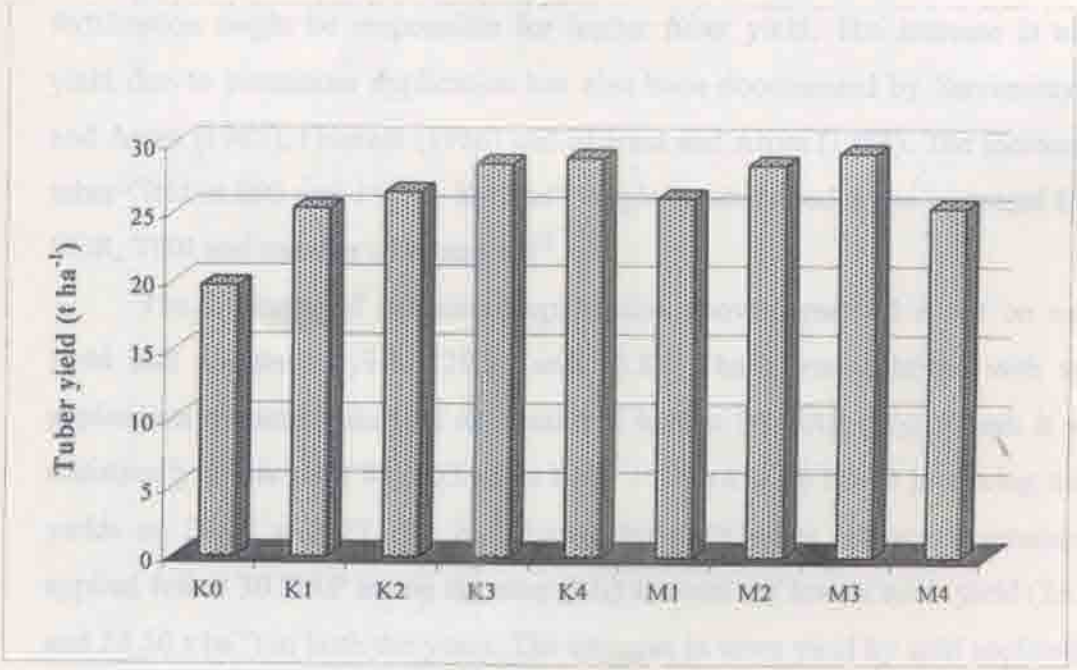


Fig.4.2.7: Effect of levels and methods of potassium application on tuber yield of potato.

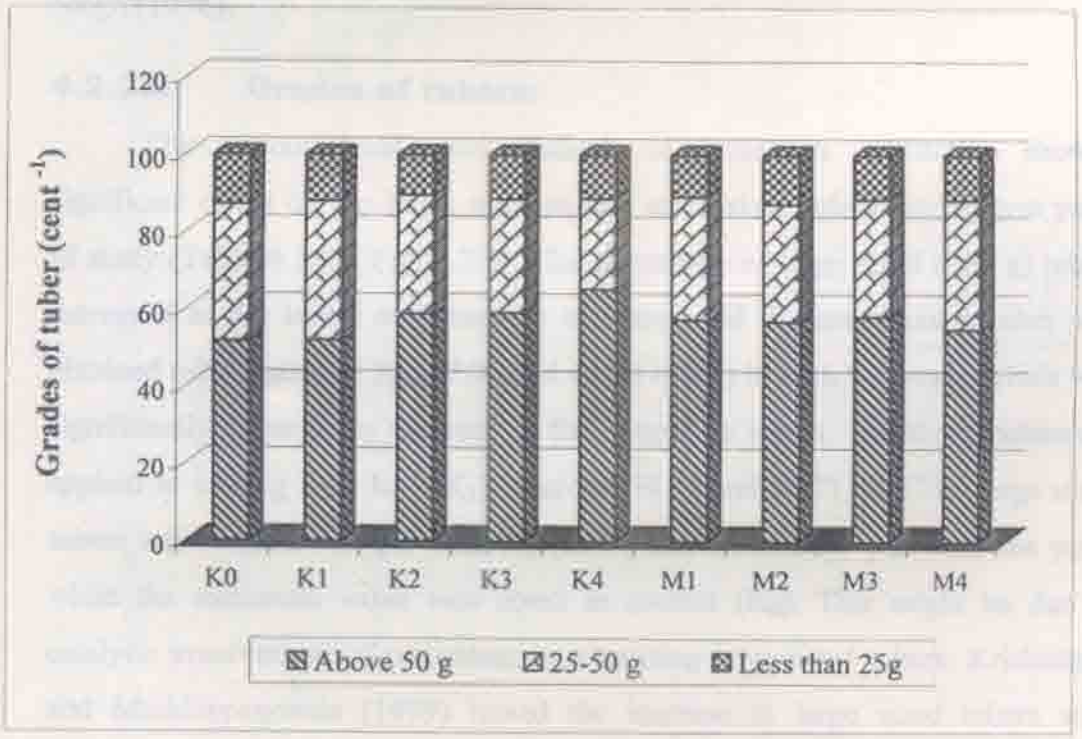


Fig.4.2.8: Effect of levels and methods of potassium application on the production of different grades of tubers.

fertilization might be responsible for higher tuber yield. The increase in tuber yield due to potassium application has also been documented by Satyanarayana and Arora (1985), Humadi (1986) and Sharma and Arora (1988). The increase in tuber yield at 200 and 150 kg K_2O ha^{-1} might be attributed to the increased LAI, CGR, TBR and number of tubers $hill^{-1}$.

The methods of potassium application showed marked effect on tuber yield and maximum yield (29.92 and 28.83 t ha^{-1}) was obtained with split application of potassium half as basal and half at 30 DAP (M_3) though it was statistically at par with M_2 (2/3 rd as basal + 1/3 rd at 30 DAP) producing tuber yields of 29.17 and 27.75 t ha^{-1} during both the years. However, potassium applied full at 30 DAP as top dressing (M_4) showed the lowest tuber yield (26.25 and 24.50 t ha^{-1}) in both the years. The increase in tuber yield by split application of potassium might be due to minimum loss of potassium through leaching and maximum availability during the crop growing period as evinced by Shukla and Singh (1976).

4.2.2.3 Grades of tubers:

The various levels and methods of potassium application showed significant effect on the large, medium and small sized tubers during two years of study (Table 4.2.12; Fig. 4.2.8). The percentage of large sized (>50 g) tubers increased as the levels of potassium increased and the maximum number was obtained with treatment K_4 (67.36 and 63.32 $cent^{-1}$) in both the years, which was significantly superior to the rest of the potassium levels. However, potassium applied at 150 kg K_2O ha^{-1} (K_3) recorded 59.82 and 58.71 $cent^{-1}$ of large sized tubers and remained at par with K_2 (59.74 and 58.16 $cent^{-1}$) in both the years while the minimum value was noted in control (K_0). This might be due to catalytic involvement of potassium in increasing large sized tubers. Krishnappa and Muddappagowda (1979) linked the increase in large sized tubers with increase in potassium dose. Application of potassium at 50 kg K_2O ha^{-1} (K_1) registered the maximum percentage of medium sized (25-50 g) tubers (34.58 and 37.22 $cent^{-1}$) and no statistical differences prevailed with K_0 (34.43 and 36.31

Table 4.2.12 : Production of different grades of tubers (cent^{-1}) in potato as influenced by levels and methods of potassium application

Treatments	Above 50 g			25-50 g			Less than 25 g		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})									
K_0	52.87 (46.65)	50.81 (45.46)	51.84 (46.06)	34.43 (35.90)	36.31 (37.04)	35.36 (36.47)	12.71 (20.43)	12.89 (20.92)	12.80 (20.68)
K_1	53.09 (46.78)	51.10 (45.63)	52.10 (46.21)	34.58 (35.98)	37.22 (37.58)	35.90 (36.78)	12.33 (20.35)	11.68 (19.90)	12.00 (20.13)
K_2	59.74 (50.64)	58.16 (49.71)	58.95 (50.18)	30.09 (33.16)	31.09 (33.83)	30.59 (33.50)	10.17 (18.43)	10.76 (18.88)	10.46 (18.66)
K_3	59.82 (50.70)	58.71 (50.04)	59.27 (50.37)	28.35 (32.11)	30.32 (33.36)	29.33 (32.74)	11.83 (19.85)	10.97 (19.10)	11.40 (19.48)
K_4	67.36 (55.19)	63.32 (52.75)	65.34 (53.97)	21.12 (27.32)	25.71 (30.40)	23.41 (28.86)	11.52 (19.81)	10.98 (19.10)	11.25 (19.46)
SEm(±)	0.49	0.55	0.47	0.59	0.59	0.42	0.01	0.07	0.03
CD(P=0.05)	1.43	1.60	1.37	1.72	1.72	1.21	0.02	0.22	0.09
K_0 vs. rest									
CD(P=0.05)	2.09	2.34	2.00	2.50	2.50	1.76	0.03	0.33	0.14
Methods of application									
M_1	54.95 (47.86)	60.09 (50.84)	57.52 (49.35)	34.62 (35.99)	28.76 (32.37)	31.69 (34.18)	10.44 (18.66)	11.15 (19.34)	10.79 (19.00)
M_2	56.77 (48.92)	57.34 (49.27)	57.05 (49.10)	30.75 (33.61)	29.81 (32.95)	30.28 (33.28)	12.48 (20.48)	12.85 (20.82)	12.67 (20.65)
M_3	59.46 (50.50)	57.46 (49.31)	58.46 (49.91)	29.45 (32.73)	30.94 (33.73)	30.19 (33.23)	11.10 (19.13)	11.61 (19.71)	11.35 (19.42)
M_4	54.34 (47.50)	56.10 (48.53)	55.22 (48.02)	32.64 (34.82)	33.92 (35.58)	33.28 (35.20)	13.03 (20.80)	9.98 (18.12)	11.51 (19.46)
SEm(±)	0.50	0.56	0.47	0.59	0.59	0.42	0.01	0.08	0.03
CD(P=0.05)	1.44	1.61	1.37	1.72	1.72	1.21	0.02	0.23	0.09

values in parenthesis are .....

proportion / percentage

cent^{-1}). The maximum yield of small sized (<25 g) tubers was recorded under control (K_0) in both the years (12.71 and 12.89 cent^{-1}). Hooda and Pandita (1978) and Singh and Grewal (1987) indicated that every successive increment of potassium application resulted in bigger sized tubers.

The methods of potassium application, however, failed to produce a uniform trend and exhibited inconsistent influence on the different grades of tuber. The maximum percentage of large sized tubers (59.46 and 60.09 cent^{-1}) was recorded when potassium was applied half as basal and half at 30 DAP (M_3) and full basal (M_1) in the first and second year, respectively. However, the maximum percentage of medium sized tubers was noted with M_1 (34.62 cent^{-1}) and M_4 (33.92 cent^{-1}) and that of small sized tubers with M_4 (13.03 cent^{-1}) and M_2 (12.85 cent^{-1}) in 1999-00 and 2000-01, respectively. Singh and Singh (1995 b) also recorded that split application of potassium produced maximum number and weight of large sized tubers.

4.2.3 Plant nutrient analysis:

4.2.3.1 NPK uptake by leaves:

Potassium levels and methods significantly influenced the N, P and K uptake by leaves during consecutive years of study (Table 4.2.13). The N, P and K uptake by leaves varied and it ranged between 7.33-12.08, 0.36-0.68 and 5.54-11.06 kg ha^{-1}, respectively during both the years. The maximum uptake of N, P and K by leaves was noted by the application of 200 kg K_2O ha^{-1} (K_4) whilst the minimum uptake was recorded in treatment K_0. Similar results were reported earlier by Sharma (1992). Pooled data show that the increase in N uptake over control (K_0) due to fertilization of potassium levels at 200, 150 and 100 kg K_2O ha^{-1} was 54.24, 39.63 and 28.16 cent^{-1}, respectively. However, such increase in P and K uptake was 65.00, 60.00 and 40.00 cent^{-1} and 83.19, 62.86 and 43.70 cent^{-1}, respectively.

In general, split application of potassium significantly increased the N, P and K uptake by leaves over its full application as basal or as top dressing. The

Table 4.2.13 : NPK uptake (kg ha^{-1}) by leaves of potato as influenced by levels and methods of potassium application

Treatments	N uptake			P uptake			K uptake		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})									
K_0	8.00	7.33	7.67	0.44	0.36	0.40	6.37	5.54	5.95
K_1	10.17	8.92	9.55	0.48	0.41	0.45	7.68	6.57	7.13
K_2	10.58	9.08	9.83	0.64	0.49	0.56	8.86	8.23	8.55
K_3	11.25	10.17	10.71	0.65	0.61	0.64	9.75	9.61	9.69
K_4	11.58	12.08	11.83	0.68	0.64	0.66	11.06	10.72	10.90
SEm(±)	0.32	0.21	0.16	0.04	0.04	0.02	0.37	0.29	0.24
CD(P=0.05)	0.94	0.62	0.47	0.12	0.13	0.06	1.07	0.84	0.70
K_0 vs. rest									
CD(P=0.05)	1.36	0.91	0.69	0.18	0.18	0.11	1.55	1.22	1.02
Methods of application									
M_1	10.42	9.33	9.88	0.58	0.52	0.55	8.78	8.23	8.51
M_2	11.42	10.58	11.00	0.67	0.56	0.61	9.82	9.20	9.51
M_3	11.83	11.58	11.71	0.68	0.61	0.65	10.58	10.31	10.45
M_4	9.92	8.75	9.34	0.52	0.46	0.49	8.16	7.40	7.79
SEm(±)	0.32	0.21	0.16	0.04	0.04	0.02	0.37	0.29	0.24
CD(P=0.05)	0.94	0.62	0.47	0.12	0.13	0.06	1.06	0.83	0.70

highest and lowest uptake of N, P and K by leaves was recorded with M_3 (1/2 as basal + 1/2 at 30 DAP) and M_4 (potassium applied full as top dressing at 30 DAP), respectively. Trehan and Grewal (1991) also reported that application of potassium at planting as well as at earthing increased the potassium uptake in leaflets in all the growth stages and this increase in potassium application at planting was more than that at earthing.

4.2.3.2 NPK uptake by stems:

A perusal of data presented in Table 4.2.14 reveal that the NPK uptake by stems increased substantially due to potassium application up to 200 kg K_2O ha^{-1}. The N, P and K uptake by stems varied between 6.00-9.75, 0.16-0.55 and 7.74-15.91 kg ha^{-1}, respectively during two years of study. Application of potassium at 200 kg K_2O ha^{-1} (K_4) recorded the maximum uptake of N, P and K by stems whereas the minimum uptake was obtained by treatment K_0 (control). Pooled analysis of two years data show that the N uptake was higher by 41.23, 39.43 and 36.13 $cent^{-1}$ with application of 200, 150 and 100 kg K_2O ha^{-1}, respectively over control (K_0). Corresponding to that P uptake was higher by 147.37, 110.53 and 89.47 $cent^{-1}$ and K uptake by 68.23, 60.67 and 47.59 $cent^{-1}$, respectively. This might be explained due to better absorption of N, P and K from the soil perhaps due to good rooting behaviour of the plants as explained by Sharma *et al.* (1999).

The various methods of potassium application showed significant effect on the uptake of N, P and K by stems. Potassium applied half as basal and half at 30 DAP (M_3) registered the maximum N, P and K uptake by stems. This was followed by potassium applied 2/3 rd as basal + 1/3 rd at 30 DAP (M_2) during consecutive years of study.

4.2.3.3 NPK uptake by tubers:

Uptake of NPK was significantly increased not only with the levels of potassium but also by the methods of its application (Table 4.2.15). Pooled analysis of data reveal that successive increase in potassium application up to

Table 4.2.14 : NPK uptake (kg ha^{-1}) by stems of potato as influenced by levels and methods of potassium application

Treatments	N uptake			P uptake			K uptake		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})									
K_0	7.33	6.00	6.67	0.23	0.16	0.19	9.69	7.74	8.72
K_1	9.08	8.25	8.67	0.35	0.31	0.33	12.52	10.44	11.48
K_2	9.33	8.83	9.08	0.38	0.33	0.36	14.18	11.55	12.87
K_3	9.67	8.92	9.30	0.46	0.35	0.40	15.21	12.80	14.01
K_4	9.75	9.08	9.42	0.55	0.39	0.47	15.91	13.42	14.67
SEm(±)	0.16	0.21	0.12	0.02	0.02	0.01	0.36	0.32	0.29
CD(P=0.05)	0.47	0.61	0.35	0.06	0.06	0.04	1.05	0.93	0.84
K_0 vs. rest									
CD(P=0.05)	0.69	0.89	0.52	0.09	0.12	0.06	1.53	1.35	1.22
Methods of application									
M_1	9.17	8.50	8.84	0.42	0.33	0.38	13.84	11.55	12.70
M_2	9.83	9.00	9.42	0.45	0.37	0.41	15.15	12.45	13.80
M_3	10.33	9.83	10.08	0.48	0.40	0.44	16.12	13.97	15.05
M_4	8.50	7.75	8.13	0.40	0.29	0.35	12.72	10.23	11.48
SEm(±)	0.16	0.21	0.12	0.02	0.02	0.01	0.36	0.32	0.29
CD(P=0.05)	0.47	0.61	0.35	0.05	0.06	0.04	1.05	0.93	0.83

Table 4.2.15 : NPK uptake (kg ha^{-1}) by tubers of potato as influenced by levels and methods of potassium application

Treatments	N uptake			P uptake			K uptake		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})									
K_0	75.67	63.67	69.67	6.74	5.45	6.09	85.76	80.24	83.00
K_1	86.33	71.42	78.88	8.49	7.02	7.76	97.53	87.50	92.51
K_2	90.58	80.08	85.33	9.21	7.85	8.53	102.71	96.49	99.60
K_3	95.25	86.50	90.88	9.75	8.17	8.96	106.86	102.02	104.45
K_4	99.75	90.83	95.29	10.39	8.67	9.53	112.05	104.79	108.42
SEm(±)	0.85	0.76	0.71	0.52	0.21	0.16	1.92	1.83	1.64
CD(P=0.05)	2.47	2.20	2.07	1.52	0.62	0.47	5.53	5.27	4.73
K_0 vs. rest									
CD(P=0.05)	3.59	3.21	3.02	2.21	0.91	0.69	8.06	7.69	6.90
Methods of application									
M_1	92.08	81.00	86.54	9.21	7.63	8.42	103.75	96.84	100.30
M_2	93.67	83.17	88.42	9.75	8.02	8.89	106.51	99.60	103.06
M_3	95.17	83.83	89.50	10.43	8.67	9.55	110.66	101.68	106.17
M_4	91.00	80.83	85.92	8.46	7.38	7.92	98.21	92.69	95.45
SEm(±)	0.85	0.76	0.71	0.52	0.21	0.16	1.92	1.83	1.64
CD(P=0.05)	2.46	2.20	2.07	1.52	0.62	0.47	5.53	5.27	4.74

200 kg K_2O ha^{-1} (K_4) significantly increased the N and P uptake by tubers. In contrast, K uptake increased significantly only up to 100 kg K_2O ha^{-1} (K_2). The maximum N, P and K uptake by tubers were observed with K_4 while control plots (K_0) accounted for the minimum uptake. Potassium levels at 200 (K_4), 150(K_3) and 100 kg (K_2) K_2O ha^{-1} accounted for 36.77, 30.44 and 22.48 $cent^{-1}$ higher uptake of N over control (K_0) respectively. However, such increase in P and K uptake was 56.47, 47.13 and 40.07 $cent^{-1}$ and 30.63, 25.84 and 20.00 $cent^{-1}$, respectively. The results, therefore, reveal that higher doses of potassium tended to increase higher uptake of N, P and K which in turn influenced the tuber yield of potato. It was also noticed that K uptake was higher than N and P uptake indicating low requirement of P and higher K requirement of crop. These results are in conformity with the observation made by Krishnappa and Gowda (1988). Trehan and Sharma (1998) found that K uptake by tubers increased from 61 to 92 kg ha^{-1} with increase in soil applied potassium from 0 to 99 kg ha^{-1}. Such a significant improvement in the uptake of nutrients could be attributed tc better vegetative growth of the plant and proliferous root system which led tc higher absorption of nutrients.

The uptake of N, P and K by tubers was significantly affected by the methods of application. The application of potassium in two equal splits (M_3) recorded the maximum N, P and K uptake by tubers and the minimum uptake was registered by potassium applied full as top dressing at 30 DAP (M_4) in both the years. Similar observation was also made by Trehan and Grewal (1991) whc observed that application of potassium both at planting and at earthing significantly increased the concentration of K in tubers and removal of K by tubers.

4.2.3.4 Total uptake of NPK:

The uptake of N and K by potato plants increased significantly with subsequent increase in potassium level from 0 to 200 kg K_2O ha^{-1}, while I uptake increased significantly only up to 100 kg K_2O ha^{-1} (Table 4.2.16 Fig.4.2.9). Potassium applied at 200 kg K_2O ha^{-1} (K_4) accounted for th

Table 4.2.16 : Total uptake of NPK (kg ha^{-1}) by potato plant as influenced by levels and methods of potassium application

Treatments	N uptake			P uptake			K uptake		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})									
K_0	91.00	77.00	84.00	7.41	5.96	6.69	101.82	93.52	97.67
K_1	105.58	88.50	97.04	9.32	7.74	8.53	117.72	104.51	111.12
K_2	110.50	98.00	104.25	10.23	8.66	9.44	125.75	116.27	121.01
K_3	116.17	105.58	110.88	10.86	9.15	10.00	131.83	124.43	128.14
K_4	121.08	112.00	116.54	11.64	9.74	10.69	139.03	128.92	133.98
SEm(±)	0.93	0.89	0.85	0.52	0.29	0.27	1.97	1.92	1.86
CD(P=0.05)	2.86	2.57	2.47	1.51	0.84	0.77	5.69	5.54	5.38
K_0 vs. rest									
CD(P=0.05)	3.91	3.74	3.59	2.20	1.22	1.13	8.29	8.08	7.84
Methods of application									
M_1	111.67	98.83	105.25	10.21	8.51	9.36	126.37	116.62	121.50
M_2	114.92	102.67	108.80	10.86	8.95	9.91	131.49	121.25	126.37
M_3	117.33	105.25	111.29	11.58	9.69	10.64	137.37	125.95	131.66
M_4	109.42	97.33	103.38	9.39	8.14	8.76	119.11	110.32	114.71
SEm(±)	0.93	0.89	0.85	0.52	0.29	0.27	1.97	1.92	1.86
CD(P=0.05)	2.68	2.57	2.46	1.51	0.83	0.77	5.69	5.54	5.38

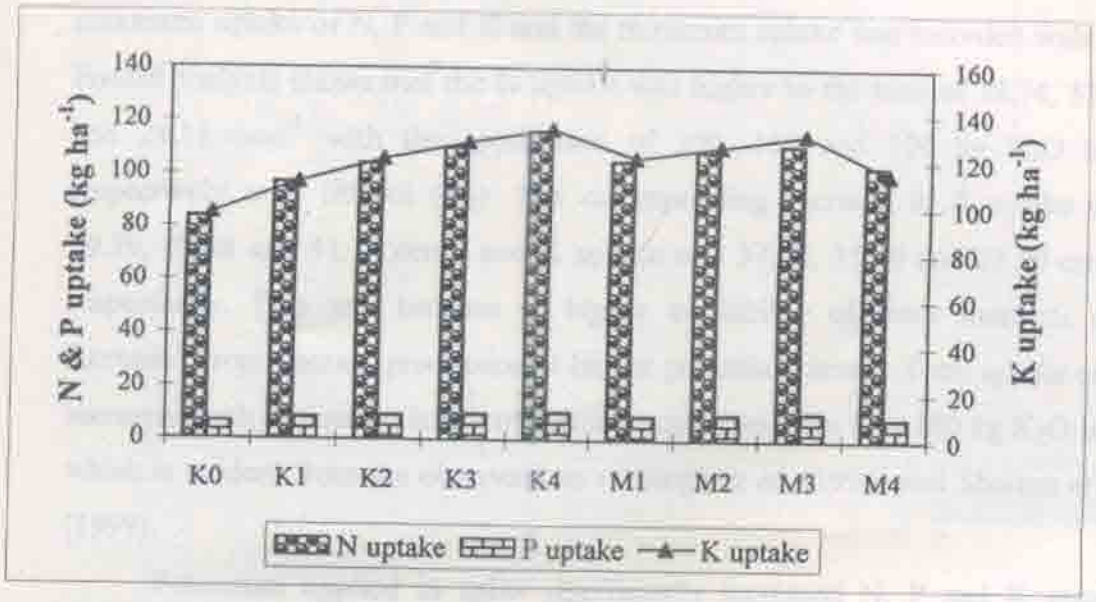


Fig.4.2.9: Effect of levels and methods of potassium application on total uptake of NPK by potato plant.

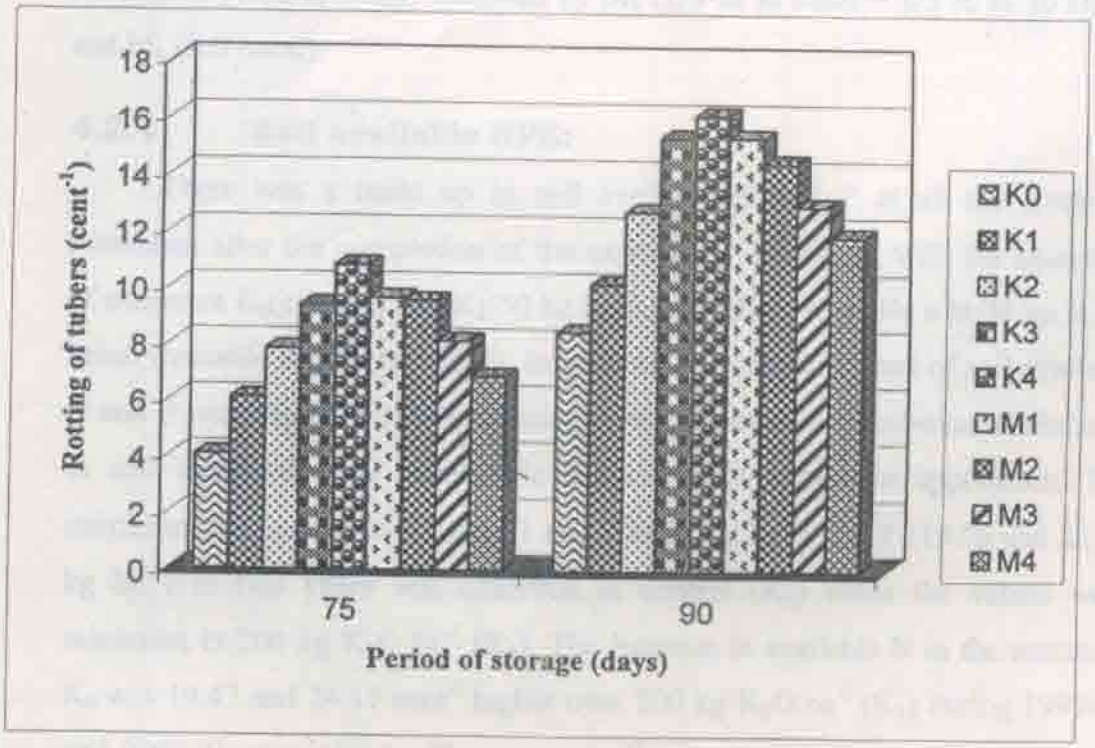


Fig.4.2.10: Effect of levels and methods of potassium application on rotting of stored potato tubers.

maximum uptake of N, P and K and the minimum uptake was recorded with K_0. Pooled analysis shows that the N uptake was higher to the tune of 38.74, 32.00 and 24.11 $cent^{-1}$ with the application of 200, 150 and 100 kg K_2O ha^{-1}, respectively over control (K_0). The corresponding increase in P uptake was 59.79, 49.48 and 41.11 $cent^{-1}$ and K uptake was 37.18, 31.20 and 23.90 $cent^{-1}$, respectively. This was because of higher availability of these nutrients and increased crop biomass production at higher potassium levels. Total uptake of K increased with increasing levels of applied potassium from 0 to 180 kg K_2O ha^{-1}, which is evident from the observations of Singh *et al.* (1996) and Sharma *et al.* (1999).

Potassium applied in splits significantly increased N, P and K uptake by plants than its full application as basal or as top dressing. The treatment M_3 (1/2 as basal + 1/2 at 30 DAP) accrued the maximum N, P and K uptake during successive years of study, followed by M_2 (2/3 rd as basal + 1/3 rd at 30 DAP) and M_1 (full basal).

4.2.4 Soil available NPK:

There was a build up in soil available N and P at all the levels of potassium after the completion of the experiment. However, with the exception of treatment K_0(control) and K_1(50 kg K_2O ha^{-1}), there was also a build up in the initial available K (Table 4.2.17). In general, a decreasing trend of soil available N and P was observed with increasing levels of potassium, however available K in soil increased with increase in the levels of potassium application. The maximum soil available N (306.21 and 290.62 kg ha^{-1}) and P (19.76 and 21.67 kg ha^{-1}) in two years was observed in control (K_0) while the values were minimum in 200 kg K_2O ha^{-1} (K_4). The increase in available N in the treatment K_0 was 19.47 and 24.17 $cent^{-1}$ higher over 200 kg K_2O ha^{-1} (K_4) during 1999-00 and 2000-01, respectively. The corresponding increase in available P was 58.08 and 44.47 $cent^{-1}$ during both the years. Potassium application, however, affects the K dynamics in the soil and showed a negative balance in soil with its

Table 4.2.17 : Soil available NPK (kg ha^{-1}) as influenced by levels and methods of potassium application

Treatments	Available N				Available P				Available K			
	1999-2000		2000-2001		1999-2000		2000-2001		1999-2000		2000-2001	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Levels of K_2O (kg ha^{-1})												
K_0	223.17	306.21	207.58	290.62	8.39	19.76	9.16	21.67	169.15	143.31	182.27	150.33
K_1	223.17	290.75	207.58	276.25	8.39	18.08	9.16	20.80	169.15	165.08	182.27	176.75
K_2	223.17	277.88	207.58	261.40	8.39	16.88	9.16	18.85	169.15	172.13	182.27	184.30
K_3	223.17	264.50	207.58	247.50	8.39	14.75	9.16	16.75	169.15	178.43	182.27	190.08
K_4	223.17	256.30	207.58	234.05	8.39	12.50	9.16	15.00	169.15	183.90	182.27	193.88
SEm(±)	-	5.00	-	5.21	-	0.75	-	0.70	-	3.41	-	2.31
CD(P=0.05)	-	14.42	-	15.00	-	2.18	-	2.02	-	9.85	-	6.66
K_0 vs. rest												
CD(P=0.05)	-	21.02	-	21.87	-	3.18	-	2.94	-	14.36	-	9.71
Methods of application												
M_1	223.17	256.75	207.58	235.90	8.39	13.25	9.16	15.60	169.15	166.15	182.27	178.75
M_2	223.17	265.88	207.58	246.30	8.39	14.88	9.16	17.25	169.15	172.08	182.27	182.55
M_3	223.17	279.05	207.58	263.75	8.39	16.33	9.16	18.80	169.15	176.93	182.27	188.33
M_4	223.17	287.75	207.58	273.25	8.39	17.75	9.16	19.75	169.15	184.38	182.27	195.38
SEm(±)	-	5.00	-	5.21	-	0.75	-	0.70	-	3.41	-	2.31
CD(P=0.05)	-	14.42	-	15.00	-	2.18	-	2.01	-	9.85	-	6.66

application at 0 and 50 kg K_2O ha^{-1}. The maximum soil available K was registered at 200 kg K_2O ha^{-1} (183.90 and 193.88 kg ha^{-1}) in both the years.

Among the various methods, full application of potassium at 30 DAP (M_4) recorded the maximum soil available N, P and K values, which remained statistically at par with potassium applied in two equal splits (M_3) except the available K in 2000-01 where statistical differences prevailed.

4.2.5 Storage behaviour:

4.2.5.1 Physiological loss in weight:

Significant variations were observed in the physiological weight losses of stored potato tubers at varying levels and methods of potassium application from two years trial (Table 4.2.18). Physiological weight reduction increases as the period of storage proceeds and the losses varied from 0.77 to 1.55, 1.67 to 2.46, 2.63 to 3.78, 4.07 to 5.28, 7.13 to 8.93 and 10.83 to 13.73 $cent^{-1}$ after 15, 30, 45, 60, 75 and 90 days of storage, respectively. Application of potassium at 200 kg K_2O ha^{-1} (K_4) exhibited the minimum weight loss and possess better keeping quality up to 90 th day of storage, followed by its lower doses of 150 kg (K_3) and 100 kg K_2O ha^{-1} (K_2). On the other hand, control plots (K_0) receiving no potassium showed very poor keeping quality with maximum weight reduction during consecutive years of study. Singh *et al.* (1996) reported that application of 180 kg K_2O ha^{-1} reduced the weight loss in tubers by 22 $cent^{-1}$ over no potassium after 14 weeks of storage.

Pooled data reveal that potassium applied full at 30 DAP as top dressing (M_4) recorded the minimum weight loss at each fortnightly intervals up to 90 th day of storage except at 60 th day of storage where potassium applied half as basal and half at 30 DAP (M_3) showed minimum weight loss. The results corroborate the findings of Sharma and Ezekiel (1993).

4.2.5.2 Rotting of tubers:

There were significant variations in the spoilage of stored potato tubers at varying levels and methods of potassium application (Table 4.2.19; Fig. 4.2.10).

Table 4.2.18 : Physiological loss in weight (cent^{-1}) of stored potato tubers under normal room condition as influenced by levels and methods of potassium application

Treatments	Period of storage (days)																	
	15			30			45			60			75			90		
	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled
Levels of K_2O(kg ha^{-1})																		
K_0	1.58 (1.43)	1.42 (1.37)	1.50 (1.40)	2.28 (1.66)	2.46 (1.72)	2.37 (1.69)	3.13 (1.90)	3.78 (2.07)	3.46 (1.99)	5.03 (2.35)	5.28 (2.40)	5.16 (2.38)	8.84 (3.06)	8.93 (3.07)	8.89 (3.07)	13.73 (3.77)	13.09 (3.69)	13.41 (3.73)
K_1	1.44 (1.39)	1.57 (1.43)	1.50 (1.41)	2.37 (1.69)	2.33 (1.68)	2.35 (1.69)	3.23 (1.93)	3.66 (2.03)	3.45 (2.00)	4.86 (2.31)	5.10 (2.37)	4.98 (2.34)	8.57 (3.01)	8.54 (3.01)	8.56 (3.01)	13.49 (3.74)	12.78 (3.64)	13.14 (3.69)
K_2	1.20 (1.30)	1.21 (1.30)	1.21 (1.30)	2.05 (1.59)	2.13 (1.62)	2.09 (1.61)	2.93 (1.85)	3.46 (1.98)	3.20 (1.92)	4.51 (2.24)	4.67 (2.27)	4.59 (2.26)	8.09 (2.93)	8.01 (2.91)	8.05 (2.92)	12.81 (3.64)	12.00 (3.54)	12.41 (3.59)
K_3	0.96 (1.20)	0.98 (1.21)	0.97 (1.21)	1.81 (1.51)	1.91 (1.54)	1.86 (1.53)	2.75 (1.80)	3.16 (1.91)	2.96 (1.86)	4.28 (2.18)	4.27 (2.18)	4.28 (2.18)	7.62 (2.84)	7.59 (2.84)	7.61 (2.84)	11.95 (3.52)	11.24 (3.42)	11.60 (3.47)
K_4	0.77 (1.12)	0.83 (1.15)	0.80 (1.14)	1.67 (1.47)	1.73 (1.49)	1.70 (1.48)	2.63 (1.77)	2.80 (1.82)	2.72 (1.80)	4.13 (2.15)	4.07 (2.13)	4.10 (2.14)	7.13 (2.76)	7.33 (2.80)	7.23 (2.78)	11.37 (3.45)	10.83 (3.37)	11.10 (3.41)
S.Em(±)	0.03	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01
CD(P=0.05)	0.09	0.08	0.04	0.07	006	0.06	0.04	0.06	0.04	0.06	0.05	0.04	0.05	0.06	0.06	0.05	0.04	0.04
K_0 vs. rest																		
CD(P=0.05)	0.14	0.11	0.06	0.10	0.09	0.08	0.06	0.09	0.06	0.09	0.08	0.06	0.07	0.09	0.09	0.08	0.07	0.06
Methods of application																		
M_1	1.48 (1.40)	1.50 (1.40)	1.49 (1.40)	2.20 (1.64)	2.27 (1.66)	2.24 (1.65)	3.17 (1.91)	3.73 (2.05)	3.45 (1.98)	4.91 (2.32)	5.10 (2.37)	5.01 (2.35)	8.68 (3.03)	8.74 (3.04)	8.71 (3.04)	13.45 (3.73)	12.78 (3.64)	13.12 (3.69)
M_2	1.37 (1.36)	1.33 (1.34)	1.35 (1.35)	2.28 (1.66)	2.38 (1.69)	2.33 (1.68)	3.06 (1.88)	3.61 (2.02)	3.34 (1.95)	4.73 (2.28)	4.91 (2.32)	4.82 (2.30)	8.38 (2.98)	8.35 (2.97)	8.37 (2.98)	13.18 (3.70)	12.44 (3.59)	12.81 (3.65)
M_3	1.23 (1.30)	1.13 (1.26)	1.18 (1.28)	2.05 (1.59)	2.13 (1.61)	2.09 (1.60)	2.87 (1.83)	3.43 (1.98)	3.15 (1.91)	4.43 (2.21)	4.73 (2.29)	4.58 (2.25)	8.18 (2.94)	8.09 (2.93)	8.14 (2.94)	12.81 (3.64)	12.12 (3.55)	12.47 (3.60)
M_4	1.11 (1.26)	1.21 (1.29)	1.16 (1.28)	1.98 (1.56)	2.06 (1.59)	2.02 (1.58)	2.95 (1.85)	3.30 (1.94)	3.13 (1.90)	4.60 (2.25)	4.57 (2.24)	4.59 (2.25)	7.88 (2.89)	7.88 (2.89)	7.88 (2.89)	12.53 (3.60)	11.78 (3.50)	12.16 (3.55)
SEm(±)	0.03	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01
CD(P=0.05)	0.10	0.07	0.04	0.06	0.06	0.06	0.04	0.06	0.04	0.06	0.06	0.04	0.05	0.06	0.06	0.06	0.05	0.04

Figures in parentheses are ....

Table 4.2.19 : Rotting (cent^{-1} by weight) of stored potato tubers under normal room condition as influenced by levels and methods of potassium application

Treatments	Period of storage (days)					
	75			90		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Levels of K_2O (kg ha^{-1})						
K_0	10.30 (3.27)	11.28 (3.41)	10.79 (3.34)	14.40 (3.84)	17.83 (4.26)	16.12 (4.05)
K_1	9.16 (3.09)	9.59 (3.15)	9.38 (3.12)	15.73 (4.01)	14.93 (3.91)	15.33 (3.96)
K_2	7.29 (2.77)	8.33 (2.94)	7.81 (2.86)	12.57 (3.60)	13.35 (3.71)	12.96 (3.66)
K_3	5.40 (2.40)	6.75 (2.52)	6.08 (2.46)	9.73 (3.18)	10.53 (3.21)	10.13 (3.20)
K_4	3.40 (1.97)	4.67 (2.06)	4.04 (2.02)	7.83 (2.86)	9.00 (2.72)	8.42 (2.79)
S.Em(±)	0.08	0.10	0.04	0.10	0.12	0.05
CD(P=0.05)	0.25	0.31	0.13	0.29	0.36	0.16
K_0 vs. rest						
CD(P=0.05)	0.37	0.45	0.18	0.41	0.52	0.11
Methods of application						
M_1	8.56 (2.98)	10.65 (3.23)	9.61 (3.11)	15.48 (3.97)	15.18 (3.92)	15.33 (3.95)
M_2	9.60 (3.15)	9.42 (3.12)	9.51 (3.14)	13.28 (3.69)	15.59 (3.99)	14.44 (3.84)
M_3	7.53 (2.81)	8.64 (2.93)	8.09 (2.87)	12.49 (3.59)	13.34 (3.70)	12.92 (3.65)
M_4	6.46 (2.60)	7.23 (2.74)	6.85 (2.67)	11.19 (3.39)	12.53 (3.50)	11.86 (3.45)
SEm(±)	0.08	0.10	0.04	0.10	0.12	0.05
CD(P=0.05)	0.25	0.30	0.13	0.29	0.36	0.15

Values in parenthesis . . . .

Rotting of stored potato tubers started after 60 days of storage and the values ranged between 3.40-11.28 and 7.83-17.83 cent^{-1} at 75 and 90 days, respectively. Rotting of tubers decreased by increasing the levels of potassium and showed minimum value in the treatment K_4 (200 kg K_2O ha^{-1}) which interacted significantly with other levels of potassium application. Control plots receiving no potassium (K_0) exhibited the maximum rotting of tubers. The results are in accordance with Singh *et al.* (1996).

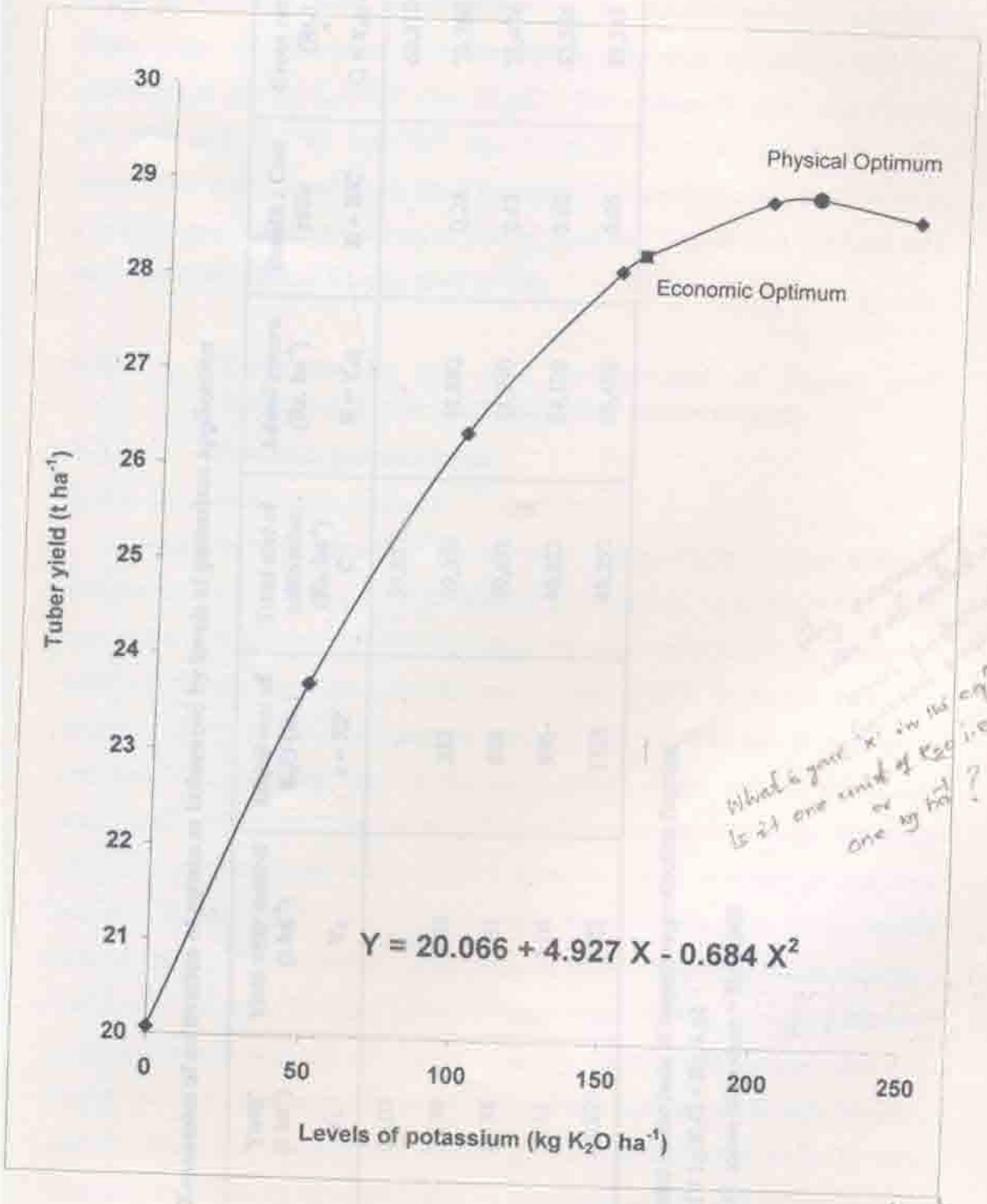
Full application of potassium at 30 DAP as top dressing (M_4) computed the minimum spoilage of tubers, being statistically at par with M_3 during both the years but significantly differed with treatment M_2 and M_1. The results indicate the possibility of storing potatoes under normal room temperature for a period up to 90 days.

4.2.6 Response function:

The relationship between mean tuber yields of potato and potassium levels was worked out by fitting quadratic production function. The response curve (Fig. 4.2.11) shows that with increasing amount of fertilizer input the yields increased with diminishing return up to 200 kg K_2O ha^{-1}. The economic optimum dose of potassium was worked out as 157.8 kg K_2O ha^{-1} and the corresponding value of optimum yield was 28.29 t ha^{-1}. Under the existing soil and weather conditions, potassium levels can be extended to the maximum of 216 kg K_2O ha^{-1} (physical optimum level) with the highest tuber yield of 28.94 t ha^{-1}.

4.2.7 Economics:

The response of potato tubers to each kilogram of applied potassium (kg tuber kg^{-1} K_2O) was maximum at 50 kg K_2O ha^{-1} being 72.6 kg ha^{-1}. The response decreased with increase in the levels of K_2O with values 63.1 and 53.6 kg ha^{-1} at 100 and 150 kg K_2O ha^{-1}, respectively and was minimum at 200 kg K_2O ha^{-1} (44.1 kg ha^{-1}). The benefit : cost ratio increased with increase in potassium levels and ranged from 0.28 to 0.66 (Table 4.2.20) and was maximum



What is your 'x' in the eqn? Is it one unit of K_2O i.e. 50 kg K_2O or one kg ha^{-1}?

Fig. 4.2.11: Response of potato to levels of potassium

$-\frac{b}{2c} = 180$ kg ha^{-1} = Phy opt

$\frac{(4/p-b)}{2c} = 175$ kg ha^{-1} = Eco opt.

Table 4.2.20 : Economics of cultivation of potato as influenced by levels of potassium application

Levels of K_2O (kg ha^{-1}) X	Yield[a] (t ha^{-1}) Y_1	Yield over control (t ha^{-1}) Y_2	Added cost of K_2O (Rs.) c = XP	Total cost of cultivation (Rs. ha^{-1}) C	Added return (Rs. ha^{-1}) $R = Y_2q$	Benefit : Cost ratio B = R/C	Gross return (Rs.) $G = Y_1q - c$
K_0	20.07	-	-	39,027	-	-	60,210
K_1	23.70	3.63	332	39,359	10,890	0.28	70,768
K_2	26.38	6.31	664	39,691	18,930	0.48	78,476
K_3	28.11	8.04	996	40,023	24,120	0.60	83,334
K_4	28.89	8.82	1328	40,355	26,460	0.66	85,342

Yield [a] = Calculated on the basis of respective production function

P = Price of 1 kg K_2O = Rs. 6.64

q = Price of 1 tonne of produce = Rs. 3,000

at 200 kg K_2O ha^{-1} (0.66). At optimum dose, the benefit : cost ratio was 0.62. Gross return also increased with increase in potassium application and was maximum at 200 kg K_2O ha^{-1} (Rs. 85,342). The increase in gross return at 50, 100, 150 and 200 kg K_2O ha^{-1} was 17.54, 30.34, 38.41 and 41.74 $cent^{-1}$, respectively over no potassium level (control). The results suggest that there was a positive response of potato up to 200 kg K_2O ha^{-1}. The finding confirms well with the observation of Sharma *et al.* (1999).

4.3 Experiment No. 3 : Evaluation of Dutch and Indian potato cultivars for processing:

4.3.1 Growth parameters:

4.3.1.1 Leaf area index:

Variation in the growth of leaf area was noticed among different cultivars at various stages of crop growth in both the years (Table 4.3.1; Fig. 4.3.1). Leaf area index (LAI) increased with the age of the plant and reached its maximum value at 70 days and thereafter the rate of leaf growth decreased in all the cultivars, owing to leaf senescence for aging of the crop. The rate of increase in leaf area was relatively slow in the early growth stages (till 60 DAP) and between 60 and 70 DAP the rate of leaf growth became faster with the exception of Dutch cultivar Sante which showed relatively faster increase of leaf area between 50 and 60 DAP as compared to later stages of crop growth. The pooled data of two years show that the Indian cultivar Kufri Chipsona-1 produced larger leaf area (1.90, 2.16, 2.42 and 2.30 at different stages of crop growth till harvest) and significantly superior to all other cultivars. Indian cultivars also registered higher leaf area indices as compared to the Dutch cultivars at 70 and 80 DAP. But this trend was not observed at early growth stages (50 and 60 DAP) when Cardinal and Diamant recorded higher or equal LAI values with respect to Kufri Jyoti. However, among the Dutch cultivars, Cardinal exhibited greater LAI values (1.67, 2.10 and 1.98 at 50, 70 and 80 DAP, respectively) but at 60 DAP Diamant recorded the greater LAI (1.84). Similarly the minimum LAI value was

Table 4.3.1 : Leaf area indices of Dutch and Indian potato cultivars at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Ajax	1.48	1.27	1.38	1.68	1.57	1.63	1.97	1.78	1.88	1.88	1.70	1.79
Cardinal	1.75	1.58	1.67	1.90	1.72	1.81	2.28	1.91	2.10	2.17	1.78	1.98
Diamant	1.42	1.74	1.58	1.63	2.04	1.84	1.88	2.29	2.09	1.76	2.16	1.96
Fresco	1.25	1.18	1.22	1.38	1.42	1.40	1.76	1.66	1.71	1.63	1.58	1.61
Marfona	1.52	1.31	1.42	1.75	1.50	1.63	2.06	1.75	1.91	1.95	1.64	1.80
Sante	1.13	1.05	1.09	1.51	1.31	1.41	1.62	1.53	1.58	1.47	1.40	1.44
K.Chipsona-1	1.96	1.83	1.90	2.20	2.11	2.16	2.47	2.36	2.42	2.35	2.24	2.30
K.Chipsona-2	1.89	1.52	1.71	2.09	1.82	1.96	2.38	2.10	2.24	2.22	1.95	2.09
K. Jyoti	1.67	1.38	1.53	1.98	1.64	1.81	2.21	2.05	2.13	2.11	1.91	2.01
S.Em(±)	0.02	0.02	0.01	0.01	0.03	0.02	0.01	0.02	0.01	0.01	0.02	0.01
C.D.(P=0.05)	0.06	0.07	0.04	0.04	0.11	0.07	0.04	0.06	0.03	0.03	0.07	0.04

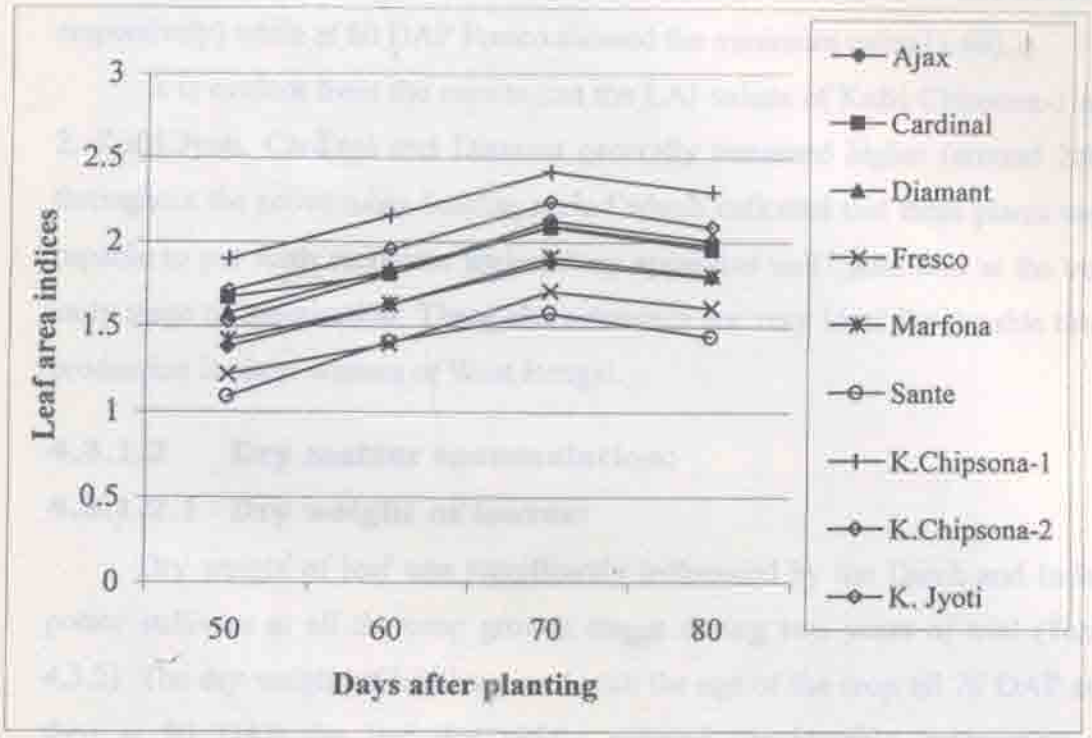


Fig.4.3.1: Effect of Dutch and Indian potato cultivars on leaf area indices.

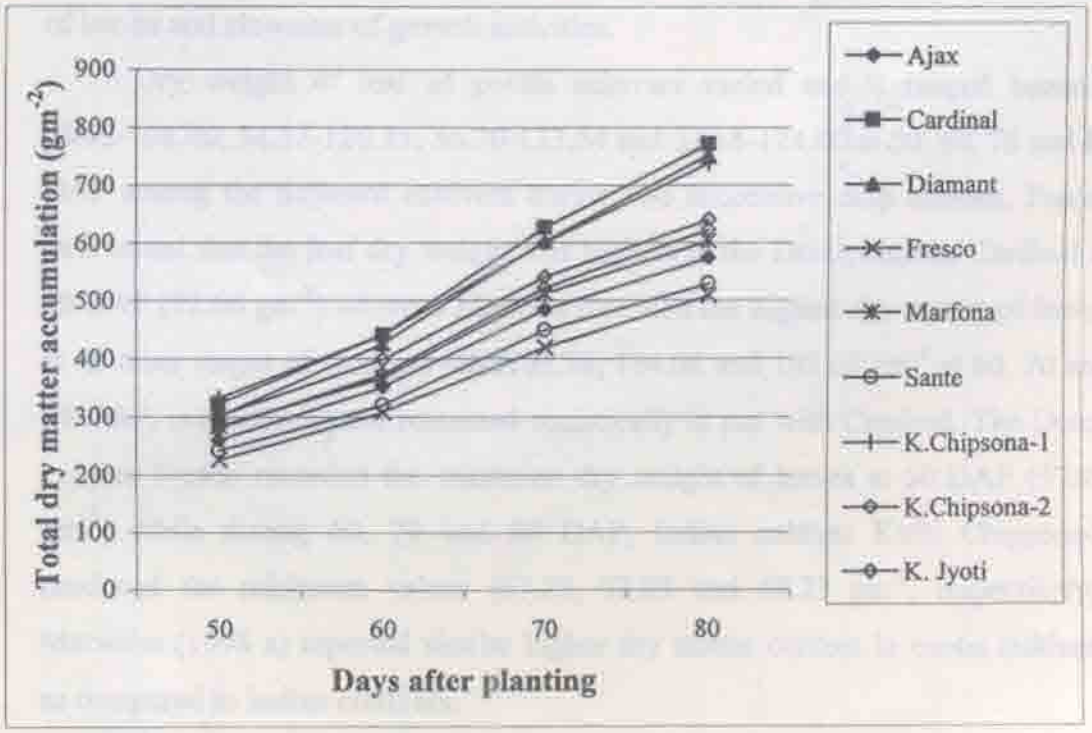


Fig.4.3.2:Effect of Dutch and Indian potato cultivars on total dry matter accumulation.

recorded in the Dutch cultivar Sante (1.09, 1.58 and 1.44 at 50, 70 and 80 DAP, respectively) while at 60 DAP Fresco showed the minimum value (1.40).

It is evident from the results that the LAI values of Kufri Chipsona-1 and 2, Kufri Jyoti, Cardinal and Diamant generally remained higher (around 2.00) throughout the active tuber bulking period which indicated that these plants were capable to put forth sufficient assimilatory apparatus unit^{-1} land area at the very early stage of tuberisation. These characteristics are very ideal for sizeable tuber production in short winters of West Bengal.

4.3.1.2 Dry matter accumulation:

4.3.1.2.1 Dry weight of leaves:

Dry weight of leaf was significantly influenced by the Dutch and Indian potato cultivars at all the crop growth stages during two years of trial (Table 4.3.2). The dry weight of leaf increased with the age of the crop till 70 DAP and then at 80 DAP the leaf dry weight reduced considerably irrespective of cultivars. During the active growth period (50-70 DAP), the plant rapidly accumulated dry matter (DM) and thereafter it slowed down due to senescence of leaves and slowness of growth activities.

Dry weight of leaf of potato cultivars varied and it ranged between 48.12-108.00; 54.32-120.33; 56.70-133.54 and 52.68-124.00 gm^{-2} at 50, 60, 70 and 80 DAP among the different cultivars during two successive crop seasons. Pooled data reveal that the leaf dry weight was highest in the Dutch cultivar Cardinal at 50 DAP (92.66 gm^{-2}) whereas Marfona recorded the highest dry matter of leaves at all other stages of crop growth (102.78, 114.06 and 107.67 gm^{-2} at 60, 70 and 80 DAP, respectively) and remained statistically at par with Cardinal. The Dutch cultivar Fresco recorded the minimum dry weight of leaves at 50 DAP (57.93 gm^{-2}) while during 60, 70 and 80 DAP, Indian cultivar Kufri Chipsona-2 produced the minimum values (67.27, 72.03 and 68.23 gm^{-2}, respectively). Marwaha (1998 a) reported similar higher dry matter content in exotic cultivars as compared to Indian cultivars.

Table 4.3.2 : Dry weight production of leaves (g m^{-2}) of Dutch and Indian potato cultivars at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Ajax	76.10	63.32	69.71	81.12	76.13	78.63	94.31	83.18	88.75	82.33	77.51	79.92
Cardinal	98.23	87.08	92.66	105.24	98.22	101.73	112.44	102.41	107.43	109.33	99.53	104.43
Diamant	89.12	77.22	83.17	101.32	88.51	94.92	108.22	92.23	100.23	103.30	90.24	96.77
Fresco	59.41	56.44	57.93	77.25	62.74	70.00	82.56	66.25	74.41	78.63	63.10	70.87
Marfona	108.00	73.25	90.63	120.33	85.22	102.78	133.54	94.57	114.06	124.00	91.34	107.67
Sante	81.33	48.12	64.73	94.58	54.32	74.45	99.50	56.70	78.10	94.21	52.68	73.45
K.Chipsona-1	83.34	76.80	80.07	88.21	80.57	84.39	92.36	81.20	86.78	87.25	78.52	82.89
K.Chipsona-2	68.08	57.79	62.94	73.31	61.23	67.27	78.52	65.54	72.03	74.24	62.21	68.23
K. Jyoti	71.52	73.53	72.53	78.14	78.10	78.12	86.68	83.21	84.95	79.21	77.64	78.43
S.Em(±)	3.69	3.73	3.57	3.13	3.46	3.08	5.09	2.48	3.18	3.96	3.42	3.16
C.D.(P=0.05)	11.09	11.19	10.70	9.41	10.37	9.23	15.27	7.46	9.54	11.88	10.27	9.49

Plate 4.3.1 : Potato plants of Ajax, Cardinal and Diamant at 60 days after planting

Plate 4.3.2 : Potato plants of Fresco, Marfona and Sante at 60 days after planting

Plate 4.3.3 : Potato plants of Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti at 60 days after planting

4.3.1.2.2 Dry weight of stems:

It is evident from Table 4.3.3 that the dry weight of stems increased steadily with the crop age irrespective of cultivars up to 70 days and declined thereafter. Significant variations in the DM accumulation in stem among the cultivars were noted and it ranged between 43.91-93.54; 47.24-98.25; and 49.12-109.23 gm^{-2} at 50, 60 and 70 DAP, respectively and declined thereafter with a range from 48.08-105.87 gm^{-2} at 80 DAP during both the years. The pooled data show that dry weight of stem was maximum in the Dutch cultivar Cardinal (84.81, 93.38 and 94.60 gm^{-2} at 50, 60 and 80 DAP respectively), which remained statistically at par with Marfona whereas during 70 DAP Marfona exhibited the maximum value (96.41 gm^{-2}) and no statistical differences prevailed with Cardinal. Growth of robust stems might have contributed higher DM accumulation in these cultivars that was also observed by Shaheen *et al.* (1995) and Marwaha (2001). Despite having higher leaf area indices, Kufri Chipsona-1 and Kufri Chipsona-2 produced significantly lower DM accumulation in stems in comparison to Dutch cultivar Cardinal at all the dates of observation during consecutive years of experimentation due to growth of medium thick stems in these cultivars. However, dry weight of stem was minimum in the Dutch cultivar Fresco (50.43, 60.40, 63.78 and 60.77 gm^{-2} at 50, 60, 70 and 80 DAP, respectively).

4.3.1.2.3 Dry weight of tubers:

The Dutch and Indian cultivars imparted significant effect on the DM accumulation of tubers at different stages of growth till harvest (Table 4.3.4). The dry weight of tubers progressively increased with the age of the crop irrespective of cultivars up to harvest. However, the rate of DM accumulation in tuber was slightly higher between 60-70 DAP which might be due to maximum tuber bulking that took place during this stage. Pooled data of two years reveal that the Indian cultivar Kufri Chipsona-1 accounted for significantly maximum dry weight of tubers (182.83, 283.06, 439.83 and 583.01 gm^{-2} at 50, 60, 70 and

Table 4.3.3 : Dry matter production of stems (g m^{-2}) of Dutch and Indian potato cultivars at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Ajax	64.38	56.11	60.25	76.42	63.40	69.91	82.97	68.68	75.83	76.24	65.89	71.07
Cardinal	86.62	83.00	84.81	97.11	89.65	93.38	101.15	91.06	96.11	99.75	89.44	94.60
Diamant	81.44	70.05	75.75	92.80	74.60	83.70	99.57	76.67	88.12	95.52	75.40	85.46
Fresco	51.91	48.94	50.43	64.94	55.85	60.40	67.63	59.93	63.78	65.37	56.16	60.77
Marfona	93.54	69.43	81.49	98.25	75.94	87.10	109.23	83.58	96.41	105.87	82.32	94.10
Sante	71.07	43.91	57.49	81.03	47.24	64.14	91.60	49.12	70.36	88.39	48.08	68.24
K.Chipsona-1	72.62	66.50	69.56	77.08	68.87	72.98	80.10	68.50	74.30	78.11	67.42	72.77
K.Chipsona-2	73.22	60.51	66.87	77.55	62.41	69.98	81.27	65.92	73.60	79.79	62.53	71.16
K. Jyoti	60.90	62.75	61.83	63.80	65.09	64.45	69.30	68.01	68.66	65.84	66.28	66.06
S.Em(±)	2.10	3.18	2.39	3.58	3.20	2.86	3.80	2.59	2.17	3.09	2.85	2.31
C.D.(P=0.05)	6.30	9.56	7.16	10.74	9.62	8.58	11.41	7.77	6.52	9.26	8.54	6.93

Table 4.3.4 : Dry weight production of tubers (g m^{-2}) of Dutch and Indian potato cultivars at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled	1999-00	2000-01	Pooled
Ajax	132.62	129.00	130.82	211.09	195.34	203.22	327.22	312.47	319.85	430.46	415.60	423.03 (17.86)
Cardinal	146.77	143.17	144.97	251.10	239.64	245.37	429.43	417.71	423.57	581.57	565.04	573.31 (18.78)
Diamant	126.17	158.10	142.14	229.74	263.90	246.82	393.64	435.14	414.39	551.31	590.27	570.79 (19.18)
Fresco	120.05	115.62	117.83	179.55	176.75	178.15	285.28	276.82	281.05	384.61	369.38	377.00 (18.32)
Marfona	110.27	114.43	112.35	181.83	173.29	177.57	306.10	296.83	301.47	404.57	398.39	401.48 (16.81)
Sante	106.12	134.19	120.16	167.25	197.42	182.34	280.79	320.16	300.48	367.62	407.82	387.72 (17.74)
K.Chipsona-1	187.33	178.32	182.83	290.56	275.55	283.06	446.03	433.62	439.83	594.29	571.72	583.01 (21.98)
K.Chipsona-2	175.21	170.51	172.87	266.68	256.21	261.45	399.78	389.95	394.87	516.01	487.71	501.86 (20.85)
K. Jyoti	153.35	140.25	146.80	239.79	221.81	230.80	376.82	359.35	368.09	492.85	465.31	479.08 (18.87)
S.Em(±)	5.30	4.31	2.78	5.18	4.52	2.81	5.36	4.50	2.80	5.50	4.66	2.97
C.D.(P=0.05)	15.89	12.92	8.36	15.54	13.56	8.42	16.08	13.50	8.40	16.51	13.99	8.93

Values in parentheses are dry weight ($cent^{-1}$) of tubers at 80 DAP

80 DAP, respectively). This was followed by Kufri Chipsona-2 at 50 and 60 DAP (172.87 and 261.45 gm^{-2}, respectively) while during 70 and 80 DAP Dutch cultivar Cardinal followed Kufri Chipsona-1 (423.57 and 573.31 gm^{-2}, respectively). Gaur *et al.* (1999 b), Kumar *et al.* (1999 b) and Singh *et al.* (1999) reported significantly higher tuber DM of Kufri Chipsona-1 and 2 at various locations. The Dutch cultivar Marfona produced the minimum tuber DM (112.35 and 177.57 gm^{-2} at 50 and 60 DAP, respectively) but Fresco showed the minimum values afterwards (281.05 and 377.00 gm^{-2} at 70 and 80 DAP, respectively).

Ezekiel *et al.* (1999) opined that when the average minimum temperature is more than 12^0C especially during the last 30 days of crop growth, a DM content of 20 $cent^{-1}$ or more could be expected. The Indian cultivars Kufri Chipsona-1 and 2 and Dutch cultivar Diamant recorded up to 3.11 $cent^{-1}$ higher DM content of tubers than Kufri Jyoti (control) at 80 DAP, while the other Dutch cultivars exhibited lower values. The meteorological data in Table 3.2 show that the mean minimum temperature is above 10^0C during the crop growth period and above 14^0C particularly at the time of maturity that resulted in higher tuber DM in all the cultivars. These cultivars particularly the Indian ones, Kufri Chipsona-1 and 2 having more than 20 $cent^{-1}$ DM, can therefore, be considered good for processing into chips as proposed by Brody (1969).

4.3.1.2.4 Total dry matter production:

A significant variation in DM production of plants was observed among the cultivars at all the crop growth stages during consecutive years of study (Table 4.3.5; Fig. 4.3.2). The total DM accumulation increased gradually with the advancement of crop age up to harvest, which might be due to continuous translocation of photosynthates from source to sink till harvest of the crop. The total DM production of potato cultivars varied and it ranged between 221.00-343.29, 298.98-455.85, 403.00-643.02 and 488.64-790.65 gm^{-2} at 50, 60, 70 and 80 DAP, respectively during two years of experimentation. Similar varietal differences in DM content of Indian and exotic potato cultivars have

Table 4.3.5 : Total dry matter production (g m^{-2}) of Dutch and Indian potato cultivars at different stages of growth

Treatments	50 DAP			60 DAP			70 DAP			80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Ajax	273.10	248.43	260.77	368.63	334.87	351.75	504.50	464.33	484.42	589.03	559.00	574.02
Cardinal	331.62	313.25	322.44	453.45	427.51	440.48	643.02	611.18	627.10	790.65	754.01	772.33
Diamant	296.73	305.37	301.05	423.86	427.01	425.44	601.43	604.04	602.74	750.13	755.91	753.02
Fresco	231.37	221.00	226.19	321.74	295.34	308.54	435.47	403.00	419.24	528.61	488.64	508.63
Marfona	311.81	257.11	284.46	400.41	334.45	367.43	548.87	474.98	511.93	634.44	572.05	603.25
Sante	258.52	226.22	242.37	342.86	298.98	320.92	471.89	425.98	448.94	550.22	508.58	529.40
K.Chipsona-1	343.29	321.62	332.46	455.85	424.99	440.42	618.49	583.32	600.91	759.65	717.66	738.66
K.Chipsona-2	316.51	288.81	302.66	417.54	379.85	398.70	559.57	521.41	540.49	670.04	612.45	641.25
K. Jyoti	285.77	276.53	281.15	381.73	365.00	373.37	532.80	510.57	521.68	637.90	609.23	623.57
S.Em(±)	5.19	3.55	3.26	5.11	3.60	3.02	5.13	6.19	4.02	5.03	3.94	3.17
C.D.(P=0.05)	15.56	10.66	9.77	15.34	10.80	9.08	15.39	18.56	12.06	15.09	11.83	9.52

been reported by Verma *et al.* (1971) and Marwaha and Kumar (1987). Pooled analysis of data reveal that during the early growth stage (50 DAP), total DM accumulation was highest in the Indian cultivar Kufri Chipsona-1 (332.46 gm^{-2}) indicating its early bulking nature and significantly superior to the rest of the cultivars. However, during 60, 70 and 80 DAP, Dutch cultivar Cardinal showed the maximum values of 440.48, 627.10 and 772.33 gm^{-2}, respectively. This was closely followed by Kufri Chipsona-1 at 60 DAP (440.42 gm^{-2}) but at 70 and 80 DAP interacted significantly with Diamant (602.74 and 753.02 gm^{-2}, respectively). The Indian cultivar Kufri Chipsona-2 also produced significantly higher DM (302.66, 398.70, 540.49 and 641.25 gm^{-2} at different growth stages till harvest) than Kufri Jyoti (control). The above finding confirm the results of Kumar *et al.* (1999 c). However, at all the dates of observation Dutch cultivar Fresco computed the minimum values of total DM accumulation (226.19, 308.54, 419.24 and 508.63 gm^{-2}) at 50, 60, 70 and 80 DAP, respectively.

4.3.1.3 Crop growth rate:

The cultivars varied significantly with respect to crop growth rate (CGR) at all the dates of observation during 1999-2000 and 2000-2001 (Table 4.3.6; Fig. 4.3.3). CGR attained its maximum value at 70 DAP, thereafter biomass production decreased in all the cultivars. It was also noted that the highest CGR of potato plant was achieved during the period between 60-70 DAP in all the cultivars. Pooled data show that the Dutch cultivar Diamant accrued the highest CGR between 50-60 DAP (12.44 $gm^{-2}d^{-1}$) and 70-80 DAP (15.03 $gm^{-2}d^{-1}$), followed by Cardinal (11.80 and 14.52 $gm^{-2}d^{-1}$ during respective growth intervals) while during 60-70 DAP the effect was just reversed and Cardinal fetched the highest CGR values (18.66 $gm^{-2}d^{-1}$) followed by Diamant (17.73 $gm^{-2}d^{-1}$). The Indian cultivar Kufri Chipsona-1 also resulted in significantly superior CGR values (10.80, 16.05 and 13.78 $gm^{-2}d^{-1}$ at respective time intervals) over Kufri Jyoti. During the period between 50-60 DAP and 70-80 DAP, the Dutch cultivar Sante accounted for the lowest CGR values (7.86 and 8.05 $gm^{-2}d^{-1}$, respectively), however during the interval 60-70 DAP,

Table 4.3.6 : Crop growth rate (g $m^{-2}d^{-1}$) of Dutch and Indian potato cultivars during different growth intervals

Treatments	50-60 DAP			60-70 DAP			70-80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Ajax	9.55	8.64	9.10	13.59	12.95	13.27	8.45	9.47	8.96
Cardinal	12.18	11.43	11.80	18.96	18.37	18.66	14.76	14.28	14.52
Diamant	12.71	12.16	12.44	17.76	17.70	17.73	14.87	15.19	15.03
Fresco	9.04	7.43	8.24	11.37	10.77	11.07	9.31	8.56	8.94
Marfona	8.86	7.73	8.30	14.85	14.05	14.45	8.56	9.71	9.14
Sante	8.43	7.28	7.86	12.90	12.70	12.80	7.83	8.26	8.05
K.Chipsona-1	11.26	10.34	10.80	16.26	15.83	16.05	14.12	13.43	13.78
K.Chipsona-2	10.10	9.10	9.60	14.20	14.16	14.18	11.05	9.10	10.07
K. Jyoti	9.60	8.85	9.22	15.11	14.56	14.83	10.51	9.87	10.19
S.Em(±)	0.04	0.07	0.02	0.04	0.06	0.03	0.19	0.04	0.05
C.D.(P=0.05)	0.12	0.21	0.07	0.12	0.19	0.10	0.58	0.13	0.16

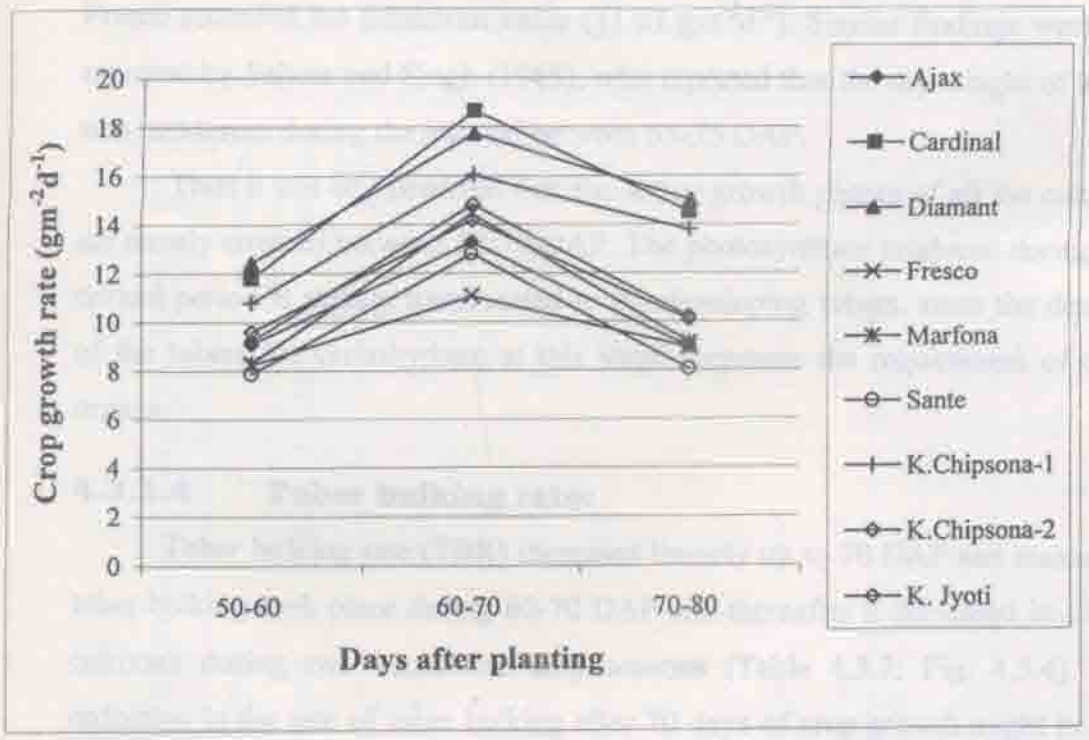


Fig.4.3.3:Effect of Dutch and Indian potato cultivars on crop growth rate.

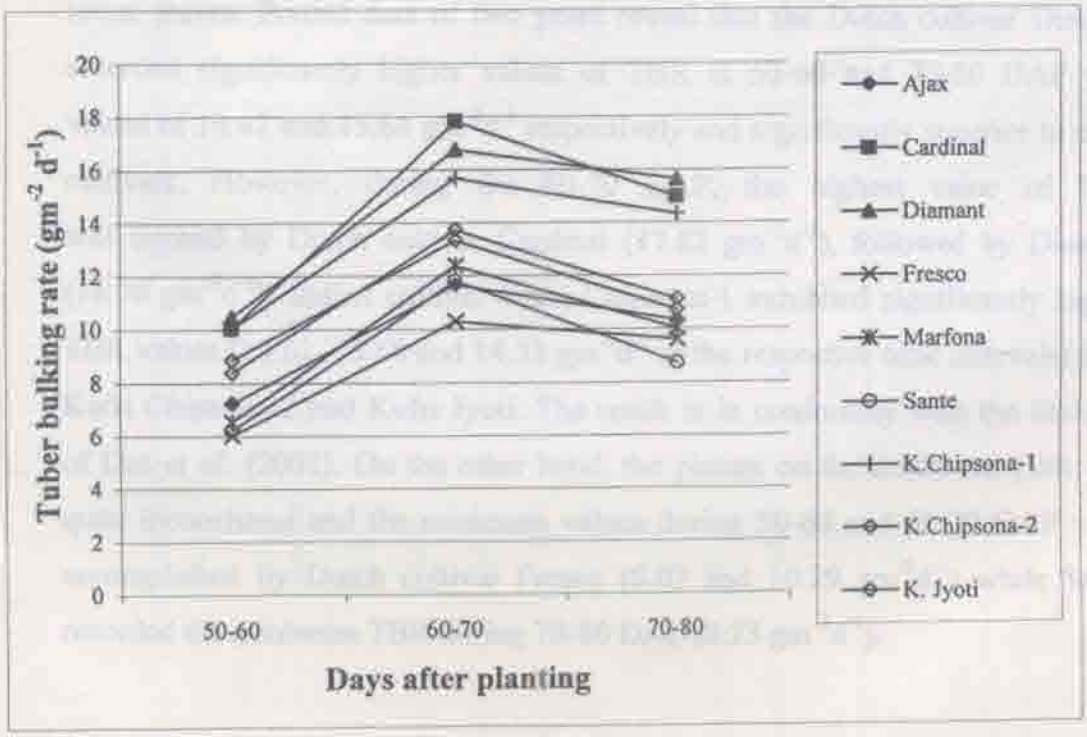


Fig.4.3.4:Effect of Dutch and Indian potato cultivars on tuber bulking rate.

Fresco recorded the minimum value (11.07 $gm^{-2}d^{-1}$). Similar findings were also reported by Sahota and Singh (1985), who reported that the dry weight of leaves was maximum during the interval between 55-75 DAP.

Thus it can be visualized that the active growth phases of all the cultivars are mostly covered between 60-70 DAP. The photosynthate produced during this critical period is mainly translocated to the developing tubers, since the demand of the tubers for carbohydrate at this stage surpasses the requirement of other organs.

4.3.1.4 Tuber bulking rate:

Tuber bulking rate (TBR) increased linearly up to 70 DAP and maximum tuber bulking took place during 60-70 DAP and thereafter it decreased in all the cultivars during two successive crop seasons (Table 4.3.7; Fig. 4.3.4). The reduction in the rate of tuber bulking after 70 days of crop growth might be due to lesser efficiency of photosynthetic perceptive organ and consequently lower accumulation of photosynthate to the harvesting organ and senescence of the lower leaves. Pooled data of two years reveal that the Dutch cultivar Diamant recorded significantly higher values of TBR at 50-60 and 70-80 DAP with values of 10.47 and 15.64 $gm^{-2}d^{-1}$ respectively and significantly superior to other cultivars. However, during the 60-70 DAP, the highest value of TBR was fetched by Dutch cultivar Cardinal (17.82 $gm^{-2}d^{-1}$), followed by Diamant (16.76 $gm^{-2}d^{-1}$). Indian cultivar Kufri Chipsona-1 exhibited significantly higher TBR values (10.02, 15.68 and 14.32 $gm^{-2}d^{-1}$ at the respective time intervals) over Kufri Chipsona-2 and Kufri Jyoti. The result is in conformity with the findings of Das *et al.* (2001). On the other hand, the picture on the minimum TBR was quite inconsistent and the minimum values during 50-60 and 60-70 DAP were accomplished by Dutch cultivar Fresco (6.03 and 10.29 $gm^{-2}d^{-1}$) while Sante recorded the minimum TBR during 70-80 DAP (8.73 $gm^{-2}d^{-1}$).

Table 4.3.7 : Tuber bulking rate (g $m^{-2}d^{-1}$) of Dutch and Indian potato cultivars during different growth intervals

Treatments	50-60 DAP			60-70 DAP			70-80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Ajax	7.85	6.63	7.24	11.61	11.71	11.66	10.32	10.31	10.32
Cardinal	10.43	9.65	10.04	17.83	17.81	17.82	15.21	14.73	14.97
Diamant	10.36	10.58	10.47	16.39	17.12	16.76	15.77	15.51	15.64
Fresco	5.95	6.11	6.03	10.57	10.01	10.29	9.93	9.26	9.60
Marfona	7.16	5.89	6.53	12.43	12.35	12.39	9.85	10.16	10.01
Sante	6.11	6.32	6.22	11.35	12.27	11.81	8.68	8.77	8.73
K.Chipsona-1	10.32	9.72	10.02	15.55	15.81	15.68	14.83	13.81	14.32
K.Chipsona-2	9.15	8.57	8.86	13.31	13.37	13.34	11.62	9.78	10.70
K. Jyoti	8.64	8.16	8.40	13.70	13.75	13.73	11.60	10.60	11.10
S.Em(±)	0.04	0.08	0.06	0.07	0.07	0.05	0.16	0.06	0.09
C.D.(P=0.05)	0.13	0.24	0.19	0.21	0.22	0.17	0.50	0.20	0.28

4.3.1.5 Net assimilation rate:

The capacity of potato cultivars to increase dry weight in terms of their assimilatory surface varied significantly at different stages of crop growth (Table 4.3.8). Net assimilation rate (NAR) increased gradually up to 70 DAP and afterwards it decreased in all the cultivars. The NAR was found to be higher during the initial growth period (being maximum during 60-70 DAP) compared to later period, which might be due to the mutual shading effect of leaves at the later stages (70-80 DAP) of plant growth. These results are in conformity with the findings of Watson (1958) who reported that owing to the mutual shading of leaves LAI tends to be negatively correlated to NAR.

Dutch cultivars in general maintained conspicuously higher NAR values than the Indian potato cultivars. Pooled data of two years show that the maximum NAR was resorted to Diamant during the early (50-60 DAP) and later stages (70-80 DAP) of crop growth with values of 7.40 and 7.50 $gm^{-2}d^{-1}$, respectively and significantly superior to other cultivars. Cardinal (6.81 and 7.19 $gm^{-2}d^{-1}$) followed this at respective time intervals. Likewise, Cardinal recorded the maximum NAR values during the period of 60-70 DAP (9.62 $gm^{-2}d^{-1}$), followed by cultivar Diamant (9.16 $gm^{-2}d^{-1}$). However, Indian cultivar Kufri Chipsona-2 maintained the lowest NAR (5.27, 6.79 and 4.65 $gm^{-2}d^{-1}$ at the respective growth stages).

4.3.1.6 Leaf area duration:

The Dutch and Indian potato cultivars significantly influenced the leaf area duration (LAD) during consecutive two years (Table 4.3.9 Fig. 4.3.5). The Indian cultivar Kufri Chipsona-1 reckoned the longest LAD (64.47 and 60.84 days) in both the years and remained statistically at par with Kufri Chipsona-2 (61.52 days) and Dutch cultivar Diamant (58.27 days) in the first and second year, respectively. Pooled analysis of two years data reveal that among the Dutch cultivars, Cardinal exhibited the longest LAD of 54.46 days. The minimum

Table 4.3.8 : Net assimilation rate (g $m^{-2}d^{-1}$) of Dutch and Indian potato cultivars during different growth intervals

Treatments	50-60 DAP			60-70 DAP			70-80 DAP		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Ajax	6.06	6.12	6.09	7.47	7.75	7.61	4.39	5.43	4.91
Cardinal	6.69	6.92	6.81	9.11	10.13	9.62	6.63	7.74	7.19
Diamant	8.35	6.45	7.40	10.14	8.19	9.16	8.17	6.83	7.50
Fresco	6.87	5.72	6.29	7.27	6.99	7.13	5.50	5.28	5.39
Marfona	5.43	5.51	5.47	7.82	8.66	8.24	4.27	5.73	5.00
Sante	6.42	6.19	6.30	8.23	8.96	8.60	5.07	5.64	5.36
K.Chipsona-1	5.41	5.25	5.33	6.97	7.09	7.03	5.86	5.85	5.86
K.Chipsona-2	5.08	5.45	5.27	6.36	7.22	6.79	4.80	4.49	4.65
K. Jyoti	5.27	5.87	5.57	7.23	7.94	7.58	4.87	4.99	4.93
S.Em(±)	0.05	0.11	0.06	0.07	0.11	0.08	0.04	0.07	0.03
C.D.(P=0.05)	0.17	0.34	0.19	0.22	0.33	0.24	0.13	0.22	0.10

value of LAD was obtained in the Dutch cultivar Sante (38.78 and 36.50 days) during two years.

It is evident from the results that the ground cover duration of leaves of hybrid potato cultivars was very fast and consequently the hybrid tubers perform well to maintain the higher LAD values.

Table 4.3.9 : Leaf area duration (days) of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	50.16	44.24	47.20
Cardinal	58.57	50.34	54.46
Diamant	47.52	58.27	52.90
Fresco	42.95	41.11	42.03
Marfona	51.78	44.06	47.92
Sante	38.78	36.50	37.64
Kufri Chipsona-1	64.47	60.84	62.66
Kufri Chipsona-2	61.52	51.78	56.65
Kufri Jyoti	56.44	48.92	52.68
S.Em(±)	3.30	4.16	2.91
C.D.(P=0.05)	9.91	12.50	8.73

4.3.2 Yield components:

4.3.2.1 Tubers hill^{-1}:

Dutch and Indian potato cultivars displayed significant variations for number of tubers hill^{-1} during both the years (Table 4.3.10; Fig. 4.3.6). The maximum number of tubers hill^{-1} was recorded in Indian cultivar Kufri Chipsona-1 (9.11 and 9.37) which remained statistically at par with Dutch cultivar Cardinal (8.74) and Marfona (8.77) in the first and second year, respectively. Indian cultivar Kufri Chipsona-1 produced 15.61 and 28.18 cent^{-1}

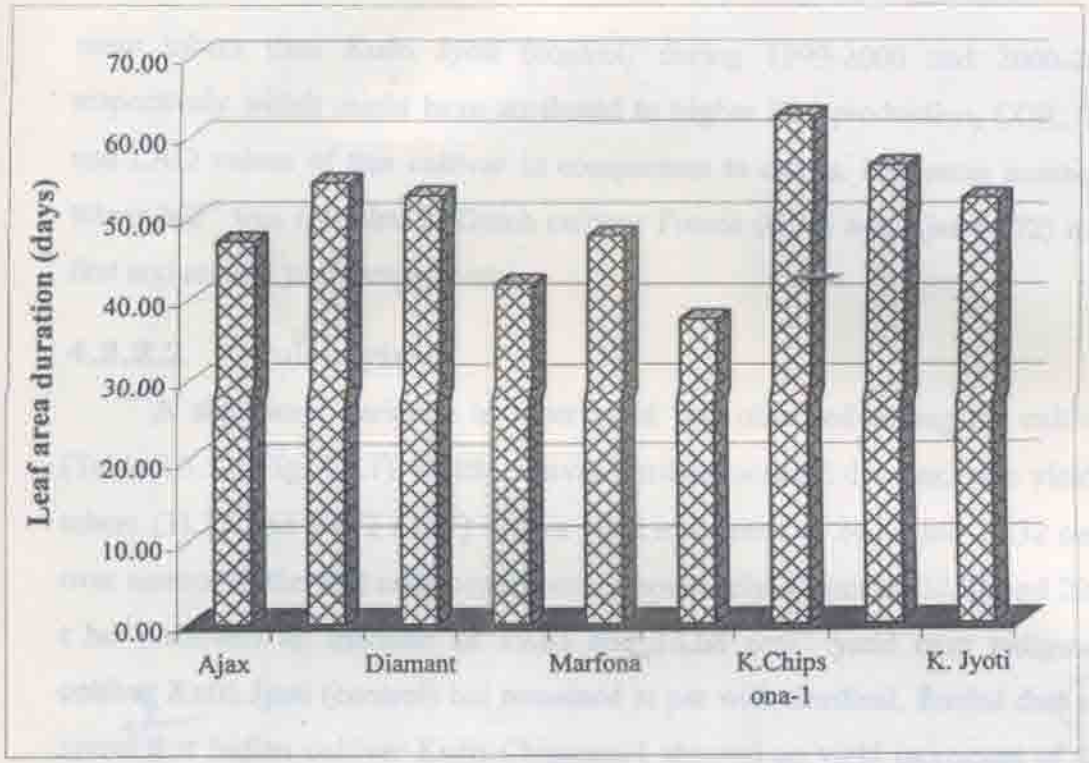


Fig.4.3.5: Effect of Dutch and Indian potato cultivars on leaf area duration.

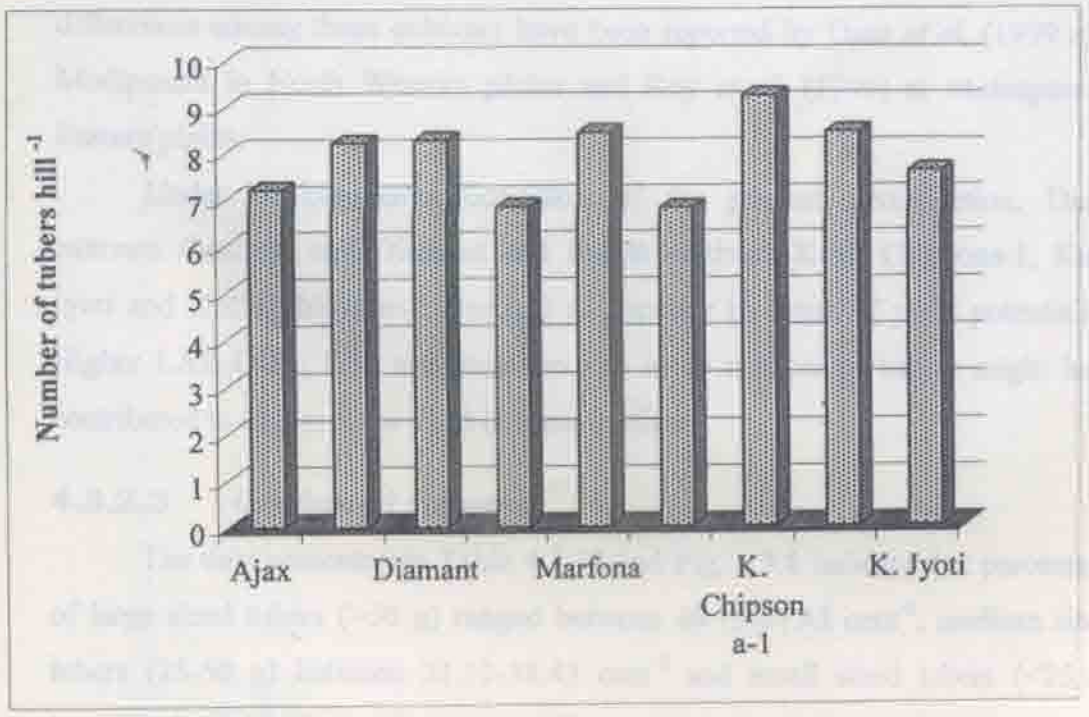


Fig.4.3.6:Effect of Dutch and Indian potato cultivars on number of tubers hill $^{-1}$

more tubers than Kufri Jyoti (control) during 1999-2000 and 2000-2001, respectively which might have attributed to higher DM production, CGR, TBR and LAD values of this cultivar in comparison to others. Minimum number of tubers hill^{-1} was recorded in Dutch cultivar Fresco (6.31) and Ajax (6.72) in the first and second year, respectively.

4.3.2.2 Tuber yield:

A significant variation in tuber yield was observed among the cultivars (Table 4.3.11; Fig. 4.3.7). Dutch cultivar Cardinal accrued the maximum yield of tubers (31.33 and 29.72 t ha^{-1}) with a yield increment of 24.23 and 16.32 cent^{-1} over control in the first and second year, respectively. Diamant (30.22 and 29.30 t ha^{-1}) showed an increase of 19.83 and 14.68 cent^{-1} yield over indigenous cultivar Kufri Jyoti (control) but remained at par with Cardinal. Pooled data also reveal that Indian cultivar Kufri Chipsona-1 showed an yield increment of 4.49 cent^{-1} over control. Dutch cultivar Fresco recorded the lowest yield of tubers (20.33 and 20.83 t ha^{-1} in the first and second year, respectively). Similar differences among these cultivars have been reported by Gaur *et al.* (1999 a) at Modipuram in North Western plains and Roy *et al.* (1999) at Midnapore in Eastern plains.

Under environmental condition of the present investigation, Dutch cultivars Cardinal and Diamant and Indian cultivars Kufri Chipsona-1, Kufri Jyoti and Kufri Chipsona-2 emerged as superior in terms of yield potentiality. Higher LAI, CGR, DM accumulation and more number of tubers might have contributed to higher tuber yield in these cultivars.

4.3.2.3 Grades of tubers:

The data presented in Table 4.3.12 and Fig. 4.3.8 indicate that percentage of large sized tubers (>50 g) ranged between 46.15-67.43 cent^{-1}, medium sized tubers (25-50 g) between 21.12-38.43 cent^{-1} and small sized tubers (<25 g) between 7.82-18.33 cent^{-1} among different cultivars during both the years of study. Similar differences in different grades of tubers among these cultivars

Table 4.3.10 : Number of tubers hill^{-1} of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	7.71	6.72	7.22
Cardinal	8.74	7.71	8.23
Diamant	8.55	8.05	8.30
Fresco	6.31	7.38	6.85
Marfona	8.13	8.77	8.45
Sante	6.58	7.06	6.82
K. Chipsona-1	9.11	9.37	9.24
K. Chipsona-2	8.61	8.30	8.46
K. Jyoti	7.88	7.31	7.60
S.Em(±)	0.32	0.46	0.23
C.D.(P=0.05)	0.97	1.40	0.71

Table 4.3.11 : Tuber yield (t ha^{-1}) of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	23.89	23.47	23.68
Cardinal	31.33	29.72	30.53
Diamant	30.22	29.30	29.76
Fresco	20.33	20.83	20.58
Marfona	24.44	23.33	23.89
Sante	20.78	22.91	21.85
K. Chipsona-1	25.55	27.50	26.53
K. Chipsona-2	22.44	25.69	24.07
K. Jyoti	25.22	25.55	25.39
S.Em(±)	1.18	1.07	0.77
C.D.(P=0.05)	3.56	3.23	2.32

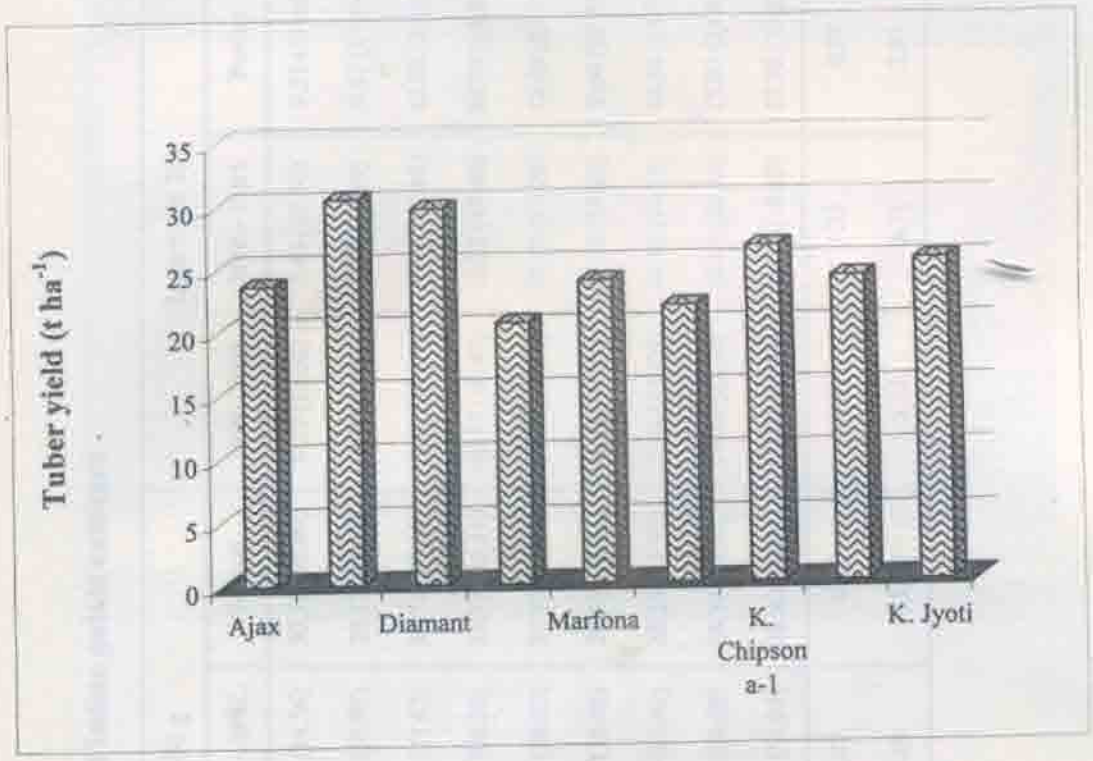


Fig.4.3.7:Effect of Dutch and Indian potato cultivars on tuber yield.

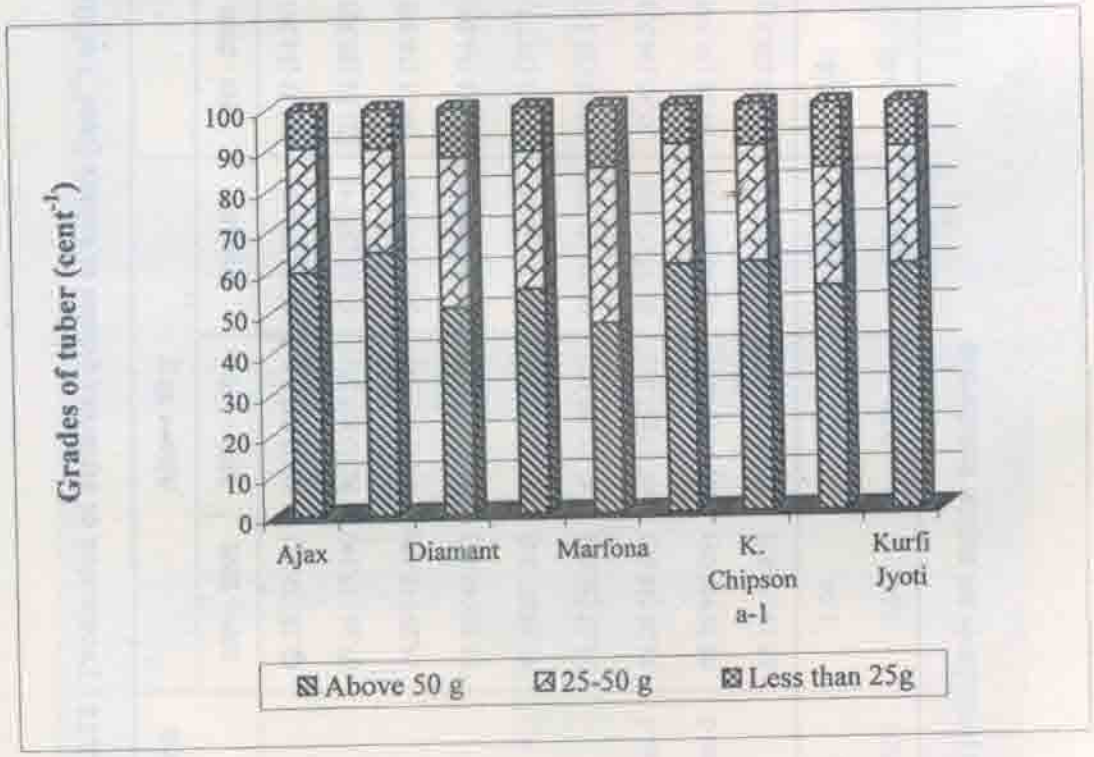


Fig.4.3.8: Effect of Dutch and Indian potato cultivars on the production of different grades of tubers.

Table 4.3.12 : Production of different grades of tubers (cent^{-1}) of Dutch and Indian potato cultivars

Treatments	Above 50 g			25-50 g			Less than 25g		
	1999 - 2000	2000 – 2001	Pooled	1999 - 2000	2000 – 2001	Pooled	1999 - 2000	2000 – 2001	Pooled
Ajax	62.28 (52.12)	58.35 (49.81)	60.32 (50.97)	28.53 (32.24)	32.22 (34.56)	30.37 (33.40)	9.19 (17.52)	9.43 (17.80)	9.31 (17.66)
Cardinal	67.36 (55.19)	62.55 (52.28)	64.96 (53.74)	21.12 (27.32)	29.63 (32.96)	25.37 (30.14)	11.52 (19.81)	7.82 (16.15)	9.67 (17.98)
Diamant	54.29 (47.47)	48.12 (43.92)	51.21 (45.70)	36.21 (36.98)	37.28 (37.62)	36.74 (37.30)	9.50 (17.89)	14.60 (22.45)	12.05 (20.17)
Fresco	57.20 (49.14)	53.67 (47.10)	55.44 (48.12)	32.43 (34.69)	35.11 (36.33)	33.77 (35.51)	10.37 (18.43)	11.22 (19.46)	10.79 (18.95)
Marfona	47.39 (43.50)	46.15 (42.79)	46.77 (43.15)	37.53 (37.77)	38.43 (38.31)	37.98 (38.04)	15.08 (22.75)	15.42 (23.06)	15.25 (22.91)
Sante	58.67 (50.00)	63.11 (52.60)	60.89 (51.30)	33.21 (35.17)	25.73 (30.45)	29.47 (32.81)	8.12 (16.25)	11.16 (19.29)	9.64 (17.77)
K. Chipsona-1	55.26 (48.02)	67.43 (55.21)	61.35 (51.62)	35.45 (36.53)	21.25 (27.41)	28.35 (31.97)	9.29 (17.42)	11.32 (19.35)	10.30 (18.39)
K. Chipsona-2	50.15 (45.09)	60.17 (50.89)	55.16 (47.99)	31.52 (34.14)	26.22 (30.78)	28.87 (32.46)	18.33 (25.30)	13.61 (21.61)	15.97 (23.46)
K. Jyoti	65.19 (53.85)	55.28 (48.03)	60.24 (50.94)	23.19 (28.71)	34.41 (35.91)	28.80 (32.31)	11.62 (19.88)	10.31 (18.69)	10.96 (19.29)
S.Em (±)	1.00	0.93	0.76	1.01	1.09	0.85	1.71	1.23	0.98
C.D.(P=0.05)	3.01	2.79	2.28	3.03	3.29	2.59	5.15	3.71	2.95

Values in parentheses are angular transformed

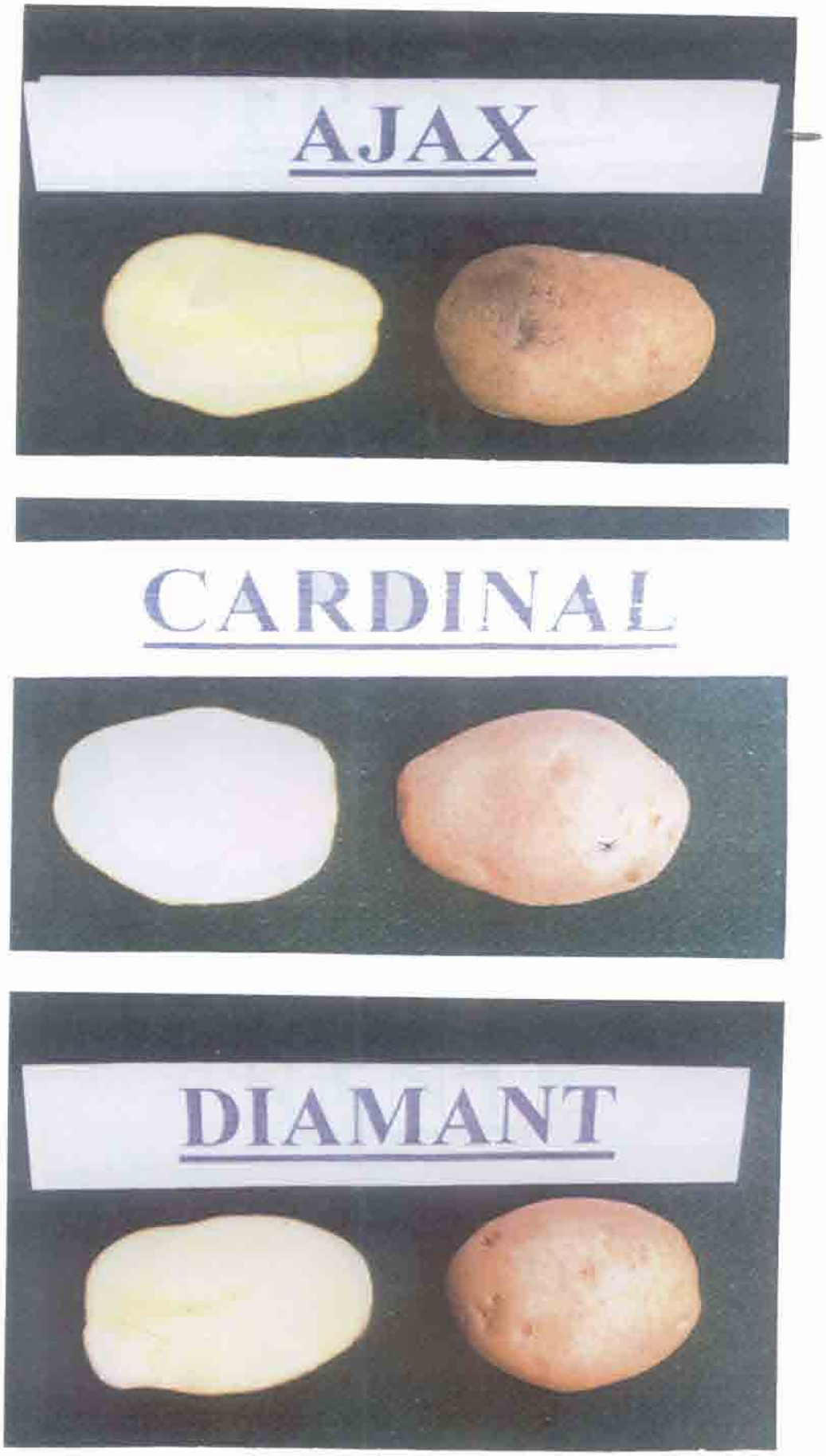


Plate 4.3.4 : Cut and whole tubers of Ajax, Cardinal and Diamant

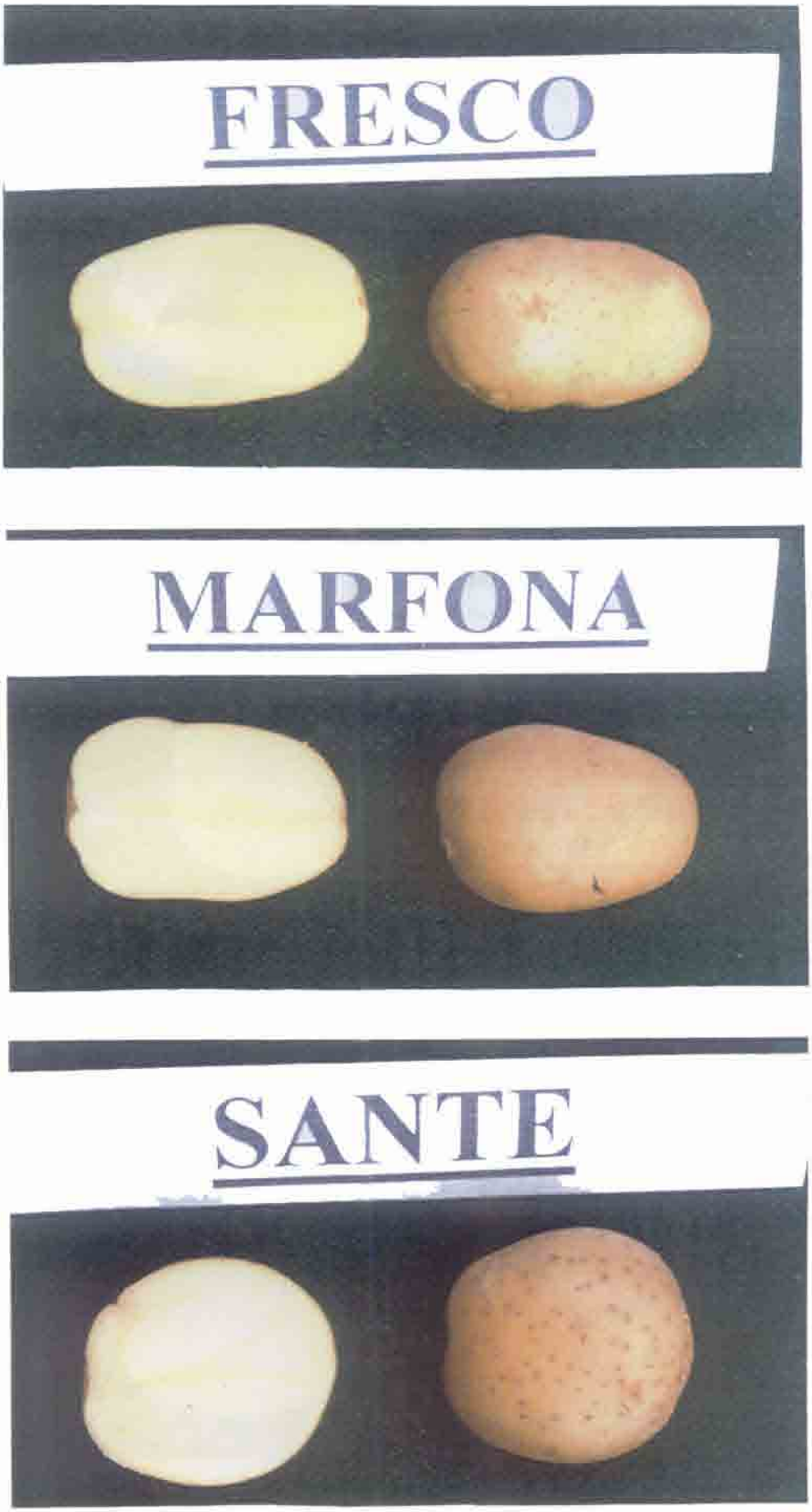


Plate 4.3.5 : Cut and whole tubers of Fresco, Marfona and Sante

Plate 4.3.6 : Cut and whole tubers of Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti

were reported by Gaur *et al.* (1999 a) for Modipuram in North Eastern plains, Roy *et al.* (1999) for Midnapore and Chettri *et al.* (2001) for Hooghly in West Bengal. Pooled data show that when yield comprising the large and medium sized tubers (>25 g) was considered, the maximum percentage of large sized tubers was recorded in Dutch cultivar Cardinal (64.96 $cent^{-1}$), closely followed by Indian cultivar Kufri Chipsona-1 (61.35 $cent^{-1}$), while maximum yield of medium sized tubers was obtained in Dutch cultivar Marfona (37.98 $cent^{-1}$), closely followed by Diamant (36.74 $cent^{-1}$). The percentage of tuber yield containing small sized tubers (<25 g) was highest in Kufri Chipsona-2 (15.97 $cent^{-1}$), closely followed by Marfona (15.25 $cent^{-1}$).

From the results, it is evident that both the cultivars Cardinal and Kufri Chipsona-1, which produced more than 89 $cent^{-1}$ large and medium sized tuber yield, have potential for large-scale cultivation in West Bengal. However, Cardinal is susceptible to late blight and produces red-coloured tubers. Considering that white-coloured potatoes are preferred in West Bengal except in a few-pockets and late blight appears almost every year, cultivation of Kufri Chipsona-1 and Kufri Chipsona-2 will be successful for replacement of Kufri Jyoti in future, which has now gone susceptible to late blight. Moreover, with cultivation of Kufri Chipsona-1 in West Bengal, processing potatoes from the state can be provided to the processors both to organized and unorganized sectors.

4.3.3 Physical characters:

4.3.3.1 Specific gravity:

Specific gravity of tubers differed significantly among Dutch and Indian potato cultivars during two consecutive years of study (Table 4.3.13; Fig. 4.3.9). Differences in specific gravity of tubers of potato cultivars were observed and the values ranged between 1.050 and 1.082 in both the years. Tubers of Indian potato cultivar Kufri Chipsona-2 exhibited the highest specific gravity (1.082 and 1.079), closely followed by Kufri Chipsona-1 (1.078 and 1.075), while

Table 4.3.13 : Specific gravity of tubers of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	1.073	1.069	1.071
Cardinal	1.074	1.069	1.072
Diamant	1.074	1.070	1.072
Fresco	1.052	1.050	1.051
Marfona	1.067	1.063	1.065
Sante	1.069	1.060	1.065
K. Chipsona-1	1.078	1.075	1.077
K. Chipsona-2	1.082	1.079	1.081
K. Jyoti	1.076	1.072	1.074
S.Em(±)	0.002	0.002	0.002
C.D.(P=0.05)	0.007	0.008	0.006

Table 4.3.14 : Peeling loss (cent^{-1}) of tubers of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	10.25 (3.28)	10.72 (3.35)	10.49 (3.32)
Cardinal	9.61 (3.18)	10.19 (3.27)	9.90 (3.23)
Diamant	12.10 (3.55)	12.82 (3.65)	12.46 (3.60)
Fresco	11.89 (3.52)	11.82 (3.51)	11.86 (3.52)
Marfona	13.94 (3.80)	14.78 (3.91)	14.36 (3.86)
Sante	11.68 (3.49)	11.54 (3.47)	11.61 (3.48)
K. Chipsona-1	11.54 (3.47)	11.61 (3.48)	11.58 (3.48)
K. Chipsona-2	12.74 (3.64)	12.96 (3.67)	12.85 (3.66)
K. Jyoti	13.56 (3.75)	13.26 (3.71)	13.41 (3.73)
S.Em(±)	0.07	0.08	0.05
C.D.(P=0.05)	0.21	0.24	0.15

Values in parentheses are angular transformed

Dutch cultivar Fresco attained the lowest value (1.052 and 1.050) in 1999-2000 and 2000-2001, respectively. The observation showed a positive correlation between specific gravity and dry matter content of tuber, which was also reported by Marwaha and Kumar (1987). It is reported that potatoes with specific gravity less than 1.075 can be canned without disintegration even without the use of calcium salts (Talburt, 1987). Based on this, Kufri Jyoti and all the Dutch cultivars containing dry matter less than 20 $cent^{-1}$ and specific gravity less than 1.075 may be considered suitable for canning.

Table 4.3.15 : Tuber characters of Dutch and Indian potato cultivars after harvest

Cultivars	Tuber characters			
	Shape	Skin type/ colour	Eyes	Flesh
Ajax	Oval	Smooth/ yellow	Fairly shallow	Pale yellow to yellow
Cardinal	Oval and slightly tapering	Rough/ red	Fairly shallow	Pale yellow
Diamant	Oval and slightly tapering	Rough/ yellow	Fairly shallow	Pale yellow
Fresco	Short oval	Smooth/ yellow	Fairly shallow	Pale yellow
Marfona	Short oval	Smooth/ pale yellow	Medium depth	Pale yellow
Sante	Oval	Smooth/ pale yellow	Shallow	Pale yellow
Kufri Chipsona-1	Oval to oblong	Smooth/ white cream	Fleet	Cream
Kufri Chipsona-2	Round to oval	Smooth/ cream	Fleet	Yellow
Kufri Jyoti	Oval	Smooth/ white	Shallow	Dull white

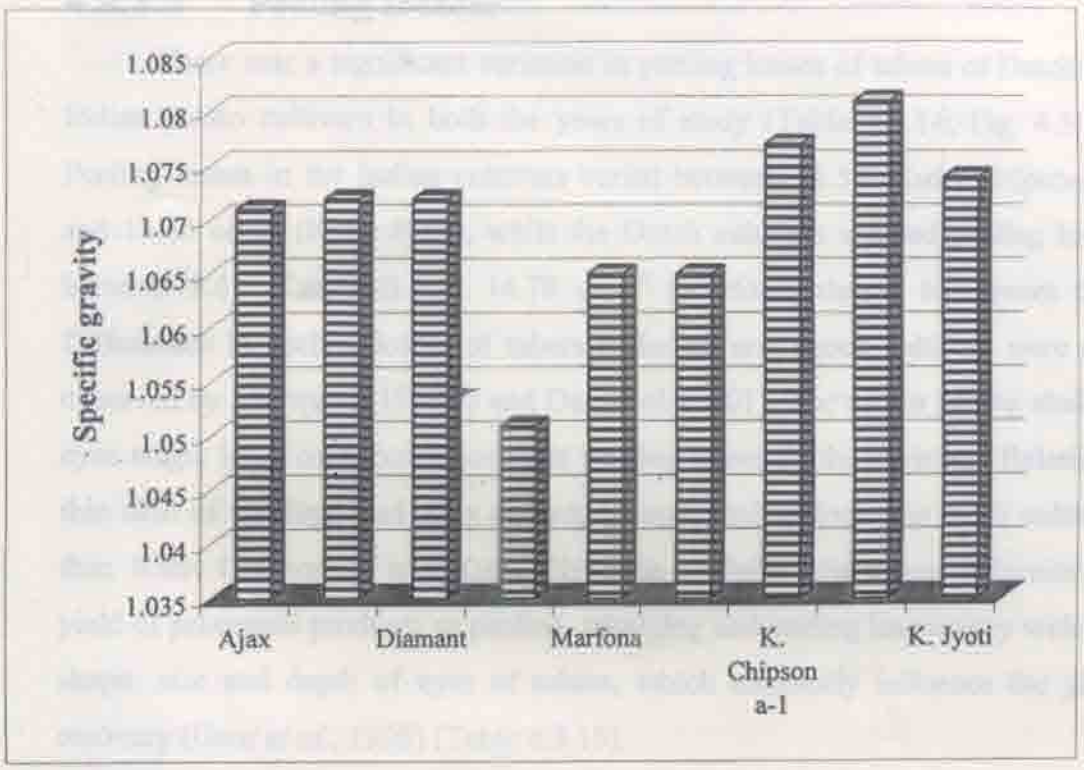


Fig.4.3.9:Effect of Dutch and Indian potato cultivars on specific gravity of tubers.

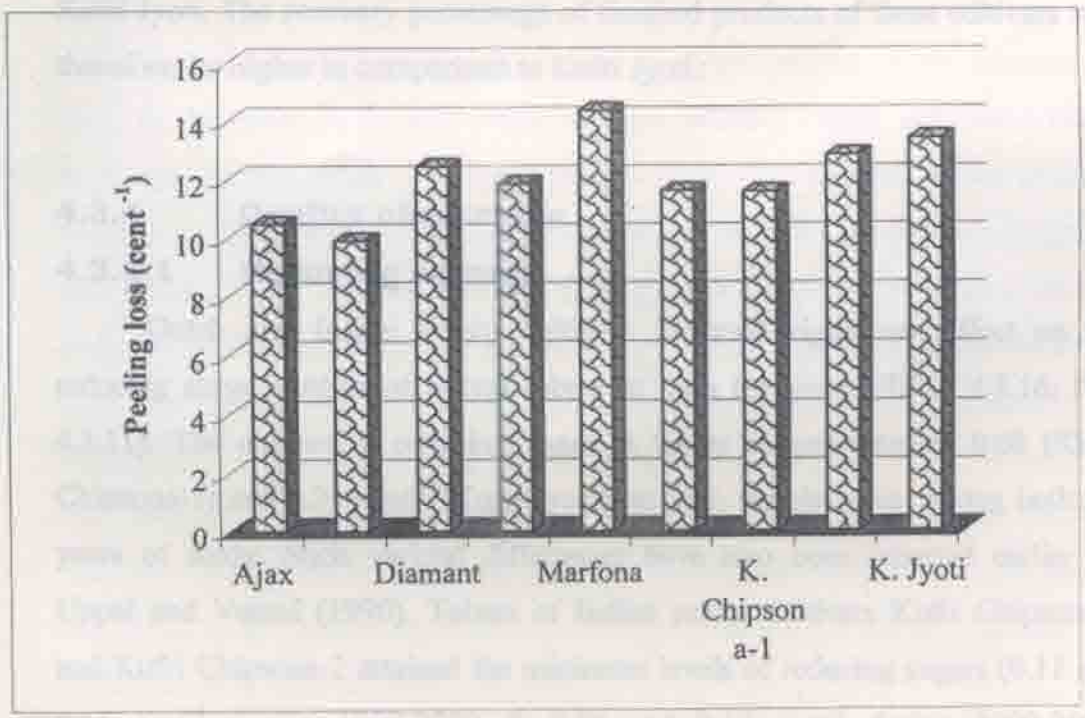


Fig.4.3.10:Effect of Dutch and Indian potato cultivars on peeling loss of tubers.

4.3.3.2 Peeling losses:

There was a significant variation in peeling losses of tubers of Dutch and Indian potato cultivars in both the years of study (Table 4.3.14; Fig. 4.3.10). Peeling losses in the Indian cultivars varied between 11.54 (Kufri Chipsona-1) and 13.56 $cent^{-1}$ (Kufri Jyoti), while the Dutch cultivars showed peeling losses between 9.61 (Cardinal) and 14.78 $cent^{-1}$ (Marfona) during two years trial. Differences in peeling losses of tubers of Indian and exotic cultivars were also observed by Marwaha (1998 a) and Das *et al.* (2001). The tubers having shallow eyes might have contributed to lower peeling losses in the varieties. Relatively thin skin of Cardinal and Ajax recorded lesser peeling losses in these cultivars than Kufri Chipsona-1 and Kufri Chipsona-2. Tuber characters influence the yield of processed products as peeling, trimming and cutting losses vary with the shape, size and depth of eyes of tubers, which ultimately influence the yield recovery (Gaur *et al.*, 1998) (Table 4.3.15).

The results show that processing losses in the cultivars Kufri Chipsona-1 and Kufri Chipsona-2 and all Dutch cultivars except Marfona were less than in Kufri Jyoti. The recovery percentage of finished products of these cultivars will, therefore, be higher in comparison to Kufri Jyoti.

4.3.4 Quality characters:

4.3.4.1 Reducing sugars:

Dutch and Indian potato cultivars imparted significant effect on the reducing sugar content of potato tubers in both the years (Table 4.3.16; Fig. 4.3.11). The content of reducing sugar in tubers ranged between 0.08 (Kufri Chipsona-1) and 0.29 $cent^{-1}$ (Kufri Jyoti) on fresh weight basis, during both the years of study. Such varietal differences have also been reported earlier by Uppal and Verma (1990). Tubers of Indian potato cultivars Kufri Chipsona-1 and Kufri Chipsona-2 attained the minimum levels of reducing sugars (0.11 and 0.14 $cent^{-1}$ during 1999-2000 & 0.08 and 0.10 $cent^{-1}$ during 2000-2001,

respectively). Singh *et al.* (1999) observed that the Indian varieties Kufri Chipsona-1 and Kufri Chipsona-2 contained low amount of reducing sugars (below 150 mg 100 g^{-1} fresh weight), which not only compare well with exotic varieties but perform better in processing and keeping quality. The maximum levels of reducing sugar were achieved by potato cultivars Kufri Jyoti (0.29 $cent^{-1}$) and Sante (0.24 $cent^{-1}$) during 1999-2000 and 2000-2001, respectively.

It is also interesting to note that in Hooghly the average reducing sugar content of the cultivars was low as compared to north Indian conditions, which might be because of relatively warmer temperature, which rarely went below 10^0C during growth and curing of potatoes. Temperature below 10^0C triggers high ratio of conversions of sucrose to reducing sugar due to increased invertage activity (Pressey and Shaw, 1966 and Davies and Viola, 1992). Reducing sugars of potato tubers determines the suitability of tubers for processing into fried products and tubers containing large amounts of reducing sugars produced unacceptable dark coloured chips and french fries (Burton, 1966 and Roe *et al.*, 1990).

Under long day conditions, sucrose has been reported as the predominant sugar in the tubers at the time of harvest and reducing sugars were either absent or present in very small quantities (Mazza, 1983). Tubers with lowest levels of sucrose were considered chemically mature and suitable for processing (Iritani and Weller, 1977). In contrast to the above, under short day conditions, we find high accumulation of reducing sugars in the tubers, which may be attributed to high invertase activity associated with low soil temperatures (Yamaguchi *et al.*, 1964). However, with the adoption of Kufri Chipsona-1 and Kufri Chipsona-2, the Gangetic Alluvial plains will be able to produce potatoes for processing. Introduction of these cultivars will help in diverting part of the potato produce of the region to the processing factories, thereby, reducing fluctuations and the glut situations, which occur every few years.

Table 4.3.16 : Reducing sugar content (cent^{-1} fresh weight) of tubers of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	0.25 (0.87)	0.20 (0.84)	0.23 (0.86)
Cardinal	0.16 (0.81)	0.20 (0.84)	0.18 (0.83)
Diamant	0.19 (0.83)	0.16 (0.81)	0.18 (0.82)
Fresco	0.20 (0.83)	0.22 (0.85)	0.21 (0.84)
Marfona	0.18 (0.82)	0.18 (0.82)	0.18 (0.82)
Sante	0.27 (0.88)	0.24 (0.86)	0.26 (0.87)
K. Chipsona-1	0.11 (0.78)	0.08 (0.76)	0.10 (0.77)
K. Chipsona-2	0.14 (0.80)	0.10 (0.77)	0.12 (0.79)
K. Jyoti	0.29 (0.89)	0.23 (0.85)	0.26 (0.87)
S.Em(±)	0.02	0.02	0.01
C.D.(P=0.05)	0.06	0.07	0.03

Values in parentheses are angular transformed

Table 4.3.17 : Total sugar content (cent^{-1} fresh weight) of tubers of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	1.06 (1.25)	1.20 (1.30)	1.13 (1.28)
Cardinal	0.96 (1.21)	1.06 (1.25)	1.01 (1.23)
Diamant	0.99 (1.22)	1.23 (1.32)	1.11 (1.27)
Fresco	0.89 (1.18)	1.31 (1.35)	1.10 (1.27)
Marfona	0.84 (1.16)	1.16 (1.29)	1.00 (1.23)
Sante	1.11 (1.27)	1.17 (1.29)	1.14 (1.28)
K. Chipsona-1	0.79 (1.14)	0.89 (1.18)	0.84 (1.16)
K. Chipsona-2	0.81 (1.14)	0.96 (1.21)	0.89 (1.18)
K. Jyoti	1.01 (1.23)	1.29 (1.34)	1.15 (1.29)
S.Em(±)	0.02	0.03	0.01
C.D.(P=0.05)	0.08	0.10	0.03

Values in parentheses are angular transformed

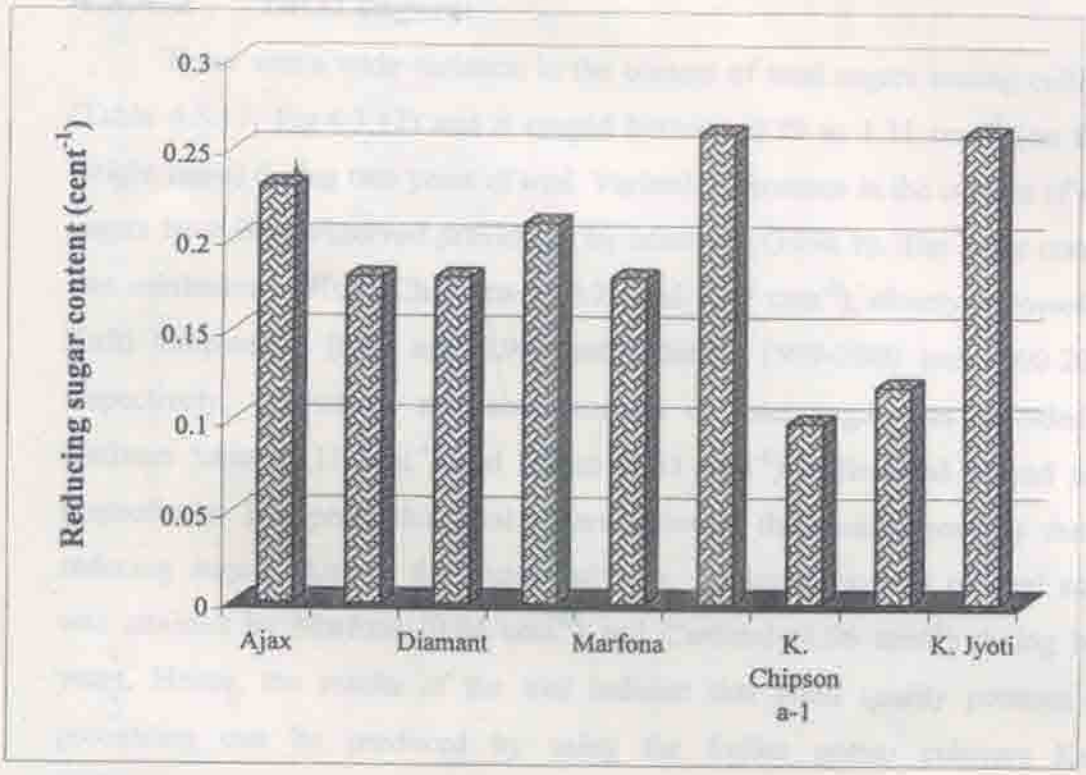


Fig. 4.3.11: Effect of Dutch and Indian potato cultivars on reducing sugar content of tubers

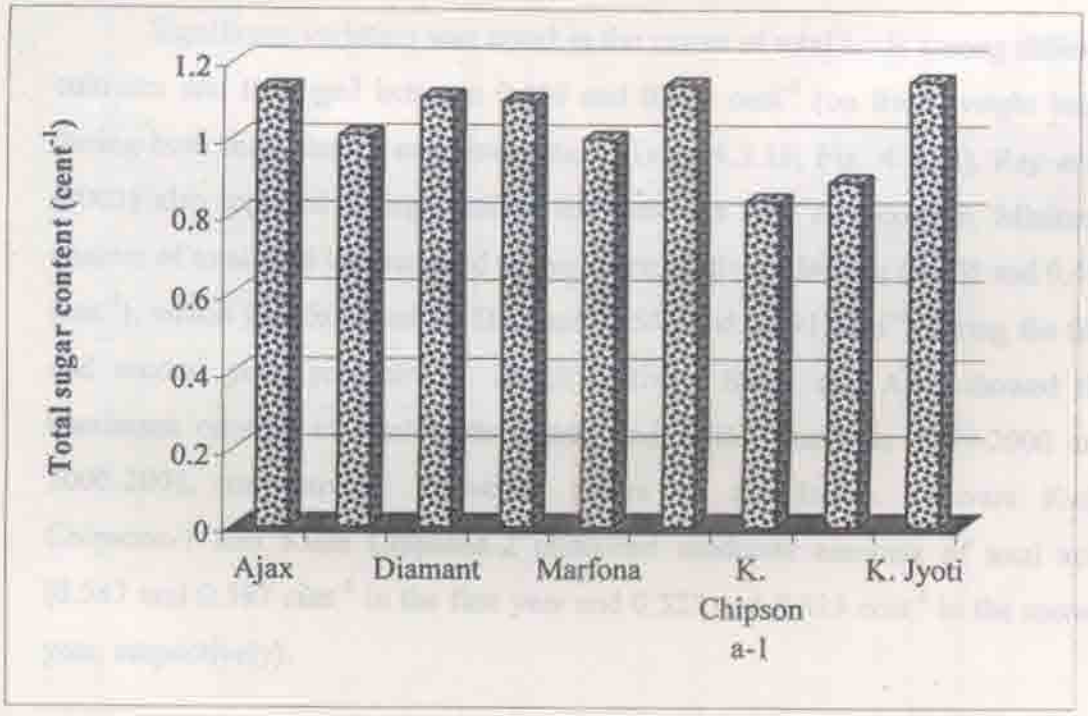


Fig.4.3.12: Effect of Dutch and Indian potato cultivars on total sugar content of tubers.

4.3.4.2 Total sugars:

There was a wide variation in the content of total sugars among cultivars (Table 4.3.17; Fig.4.3.12) and it ranged between 0.79 to 1.31 $cent^{-1}$ (on fresh weight basis) during two years of trial. Varietal differences in the content of total sugars have been observed previously by Marwaha (1998 b). The sugar content was minimum in Kufri Chipsona-1 (0.79 and 0.89 $cent^{-1}$), closely followed by Kufri Chipsona-2 (0.81 and 0.96 $cent^{-1}$) during 1999-2000 and 2000-2001, respectively. However, maximum content of total sugar was recorded in cultivars Sante (1.11 $cent^{-1}$) and Fresco (1.31 $cent^{-1}$) in first and second year, respectively. It appears that total sugars followed the similar trend as that of reducing sugars. Among the Dutch cultivars, minimum content of total sugar was attained by Marfona (0.84 $cent^{-1}$) and Cardinal (1.06 $cent^{-1}$) during both years. Hence, the results of the trial indicate that good quality potatoes for processing can be produced by using the Indian potato cultivars Kufri Chipsona-1 and Kufri Chipsona-2.

4.3.4.3 Total acids:

Significant variation was noted in the extent of total acids among different cultivars and it ranged between 0.459 and 0.693 $cent^{-1}$ (on fresh weight basis) during both the years of experimentation (Table 4.3.18; Fig. 4.3.13). Ray *et al.* (2002) also reported a large varietal difference in total acid content. Minimum content of total acid was resorted to the Dutch cultivar Marfona (0.555 and 0.459 $cent^{-1}$), which was followed by Diamant (0.565 and 0.491 $cent^{-1}$) during the first and second year, respectively. Dutch cultivars Sante and Ajax showed the maximum content of total acids (0.693 and 0.661 $cent^{-1}$) in 1999-2000 and 2000-2001, respectively. However, tubers of the Indian cultivars Kufri Chipsona-1 and Kufri Chipsona-2 contained moderate amounts of total acid (0.587 and 0.597 $cent^{-1}$ in the first year and 0.523 and 0.523 $cent^{-1}$ in the second year, respectively).

Table 4.3.18 : Total acid content (cent^{-1} fresh weight) of tubers of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	0.651 (1.073)	0.661 (1.078)	0.656 (1.076)
Cardinal	0.651 (1.073)	0.629 (1.063)	0.640 (1.068)
Diamant	0.565 (1.032)	0.491 (0.995)	0.528 (1.014)
Fresco	0.576 (1.037)	0.533 (1.016)	0.555 (1.027)
Marfona	0.555 (1.027)	0.459 (0.979)	0.507 (1.003)
Sante	0.693 (1.092)	0.597 (1.047)	0.645 (1.070)
K. Chipsona-1	0.587 (1.042)	0.523 (1.011)	0.555 (1.027)
K. Chipsona-2	0.597 (1.047)	0.523 (1.011)	0.560 (1.029)
K. Jyoti	0.661 (1.078)	0.533 (1.016)	0.597 (1.047)
S.Em(±)	0.014	0.018	0.011
C.D.(P=0.05)	0.043	0.056	0.033

Values in parentheses are angular transformed

Table 4.3.19 : Total soluble solids (^{0}Brix) of tubers of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	7.8	6.8	7.3
Cardinal	6.8	6.9	6.9
Diamant	7.6	6.5	7.1
Fresco	6.1	6.0	6.1
Marfona	7.1	6.7	6.9
Sante	8.0	8.1	8.1
K. Chipsona-1	6.6	6.2	6.4
K. Chipsona-2	7.7	7.1	7.4
K. Jyoti	5.0	5.6	5.3
S.Em(±)	0.08	0.06	0.03
C.D.(P=0.05)	0.25	0.19	0.11

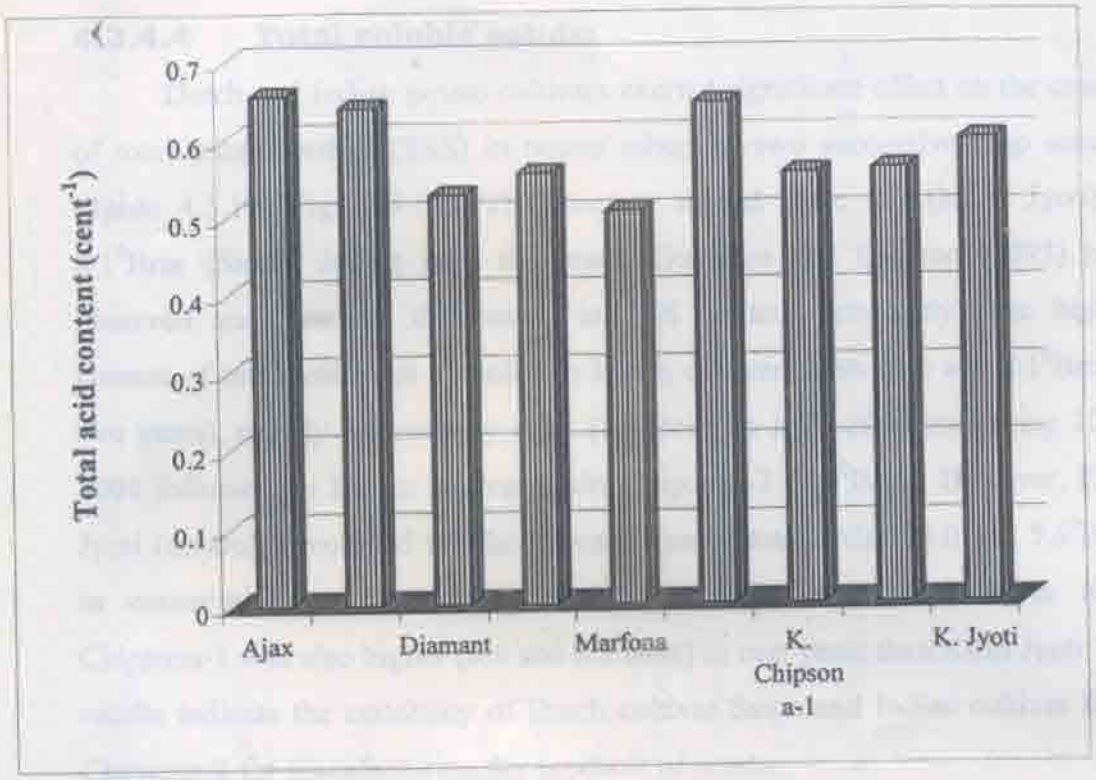


Fig. 4.3.13: Effect of Dutch and Indian potato cultivars on total acid content of tubers.

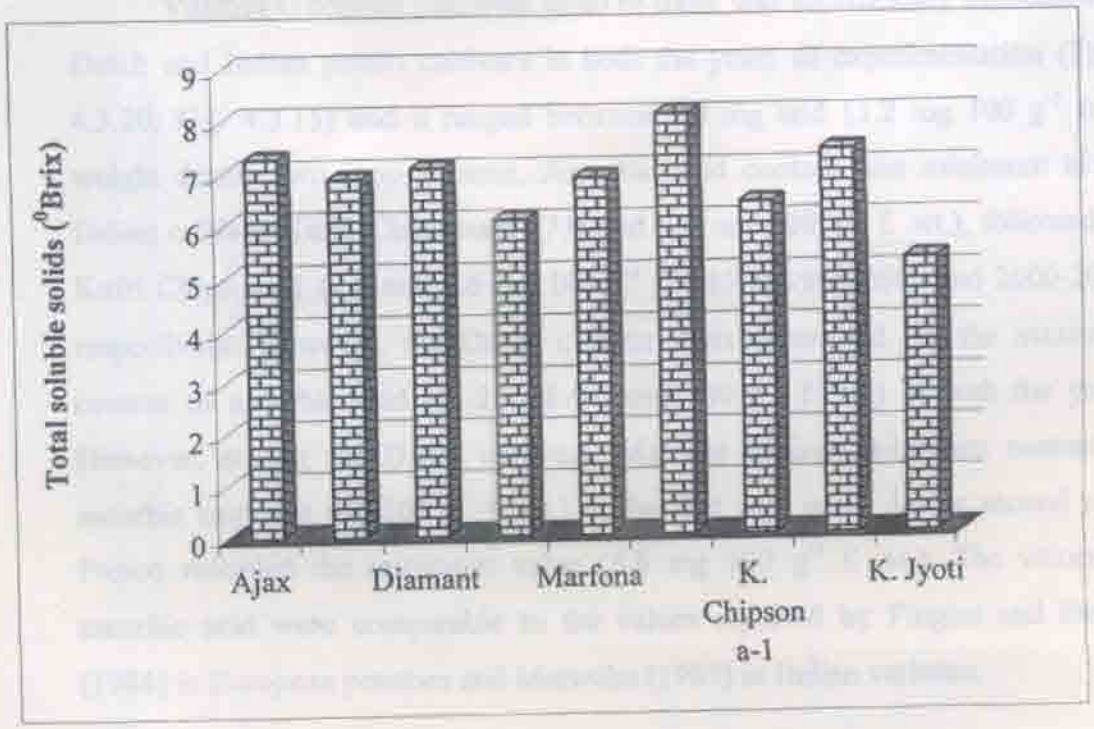


Fig.4.3.14: Effect of Dutch and Indian potato cultivars on total soluble solids of tubers.

4.3.4.4 Total soluble solids:

Dutch and Indian potato cultivars exerted significant effect on the content of total soluble solids (TSS) in potato tubers in two successive crop seasons (Table 4.3.19; Fig. 4.3.14). TSS content ranged from 5.0 (Kufri Jyoti) to 8.1^{0}Brix (Sante) during both the years. Gonzalez and Carreno (1993) have observed such varietal differences in TSS content previously. The highest content of total solid was recorded in Dutch cultivar Sante (8.0 and 8.1^{0}Brix in two years), closely followed by Ajax (7.8^{0}Brix) in 1999-2000 but during 2000-2001 followed by Indian cultivar Kufri Chipsona-2 (7.1^{0}Brix). However, Kufri Jyoti (control) accounted for the lowest value of total solids (5.0 and 5.6^{0}Brix) in consecutive two years. The content of TSS in Indian cultivar Kufri Chipsona-1 was also higher (6.6 and 6.2^{0}Brix) in two years than Kufri Jyoti. The results indicate the suitability of Dutch cultivar Sante and Indian cultivar Kufri Chipsona-2 for manufacturing dry products of potato.

4.3.4.5 Vitamin C content:

Vitamin C content (ascorbic acid) of tuber was significantly influenced by Dutch and Indian potato cultivars in both the years of experimentation (Table 4.3.20; Fig. 4.3.15) and it ranged between 4.0 mg and 11.2 mg 100 g^{-1} fresh weight during two crop seasons. Ascorbic acid content was minimum in the Indian cultivar Kufri Chipsona-2 (7.0 and 4.0 mg 100 g^{-1} f. wt.), followed by Kufri Chipsona-1 (7.8 and 5.6 mg 100 g^{-1} f. wt.) in 1999-2000 and 2000-2001, respectively. However, the Dutch cultivar Ajax accounted for the maximum content of ascorbic acid (11.2 and 9.0 mg 100 g^{-1} f. wt.) in both the years. However, among the Dutch cultivars, Marfona attained minimum content of ascorbic acid (8.4 mg 100 g^{-1} f. wt.) in the first year while during second year, Fresco recorded the minimum value (5.6 mg 100 g^{-1} f. wt.). The values of ascorbic acid were comparable to the values reported by Finglas and Faulks (1984) in European potatoes and Marwaha (1987) in Indian varieties.

Table 4.3.20 : Vitamin C content (mg 100 g^{-1} fresh weight) of tubers of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Pooled
Ajax	11.2	9.0	10.1
Cardinal	10.4	7.6	9.0
Diamant	10.8	7.6	9.2
Fresco	9.4	5.6	7.5
Marfona	8.4	6.2	7.3
Sante	9.2	7.4	8.3
K. Chipsona-1	7.8	5.6	6.7
K. Chipsona-2	7.0	4.0	5.5
K. Jyoti	9.6	7.8	8.7
S.Em(±)	0.29	0.34	0.27
C.D.(P=0.05)	0.87	1.04	0.83

Table 4.3.21 : Chip colour score of tubers of Dutch and Indian potato cultivars

Treatments	1999-2000	2000-2001	Mean
Ajax	6	5	5.5
Cardinal	5	5	5.0
Diamant	6	5	5.5
Fresco	5	4	4.5
Marfona	5	3	4.0
Sante	5	4	4.5
K. Chipsona-1	2	1	1.5
K. Chipsona-2	3	3	3.0
K. Jyoti	5	4	4.5

On 1-10 scale where 1 is the lightest and 10 the dark brown colour

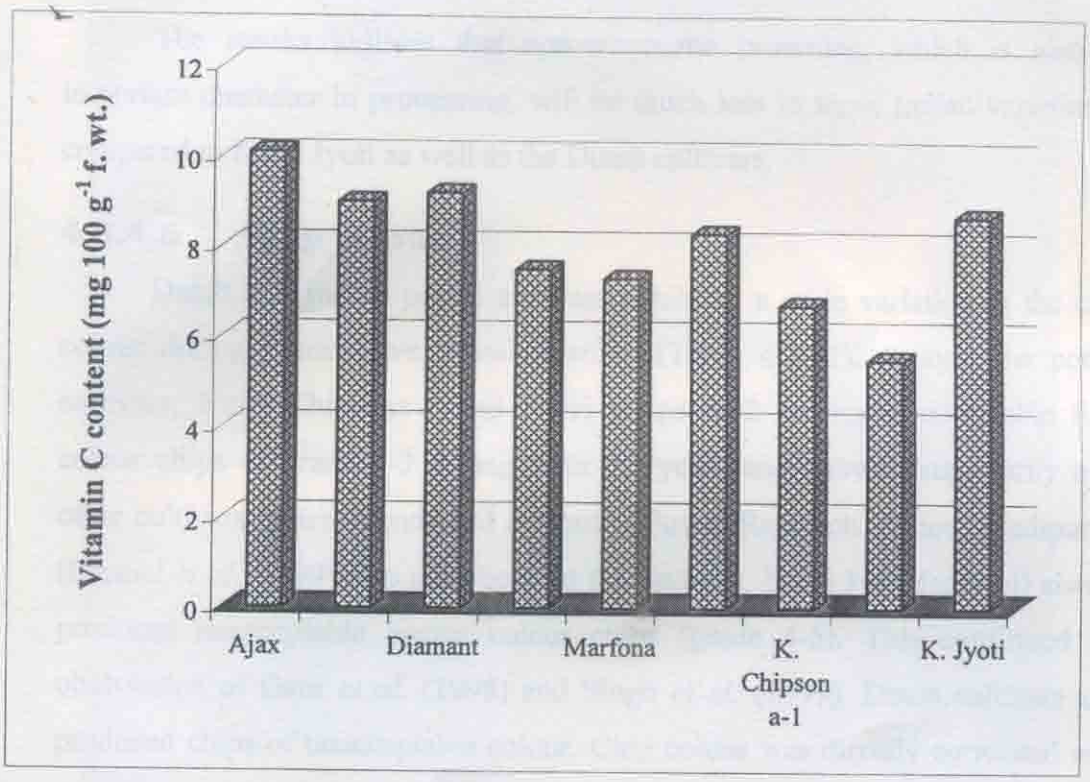


Fig. 4.3.15: Effect of Dutch and Indian potato cultivars on vitamin C content of tubers.

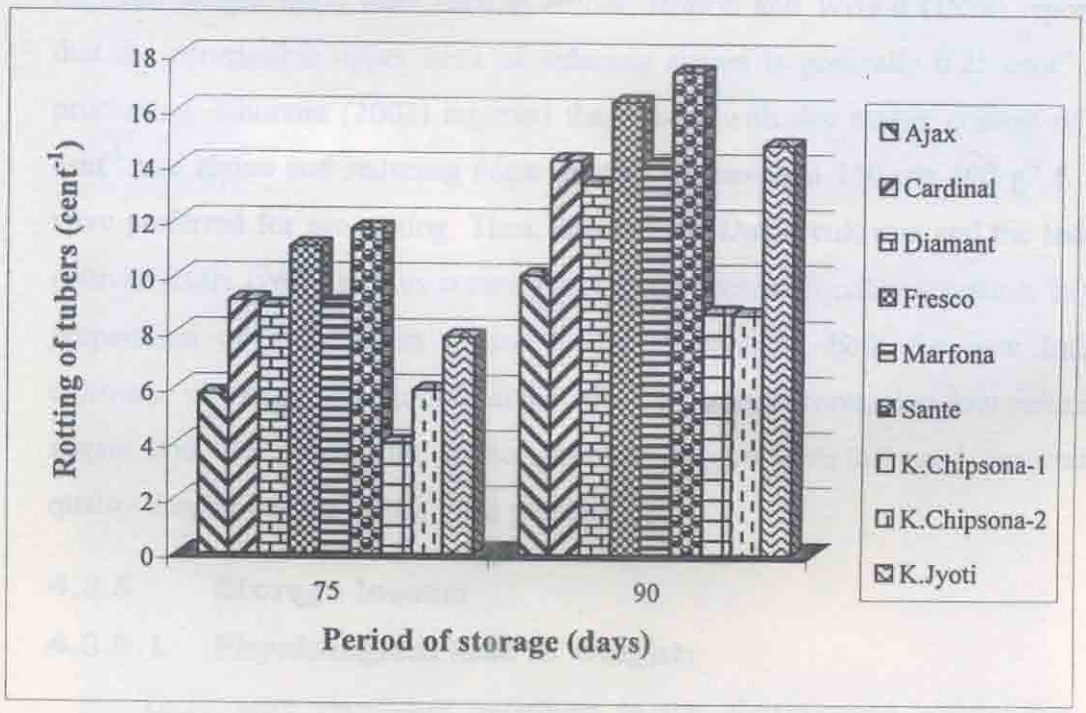


Fig.4.3.16: Effect of Dutch and Indian potato cultivars on rotting of stored potato tubers.

The results indicate that non-enzymatic browning, which is also an important character in processing, will be much less in these Indian varieties as compared to Kufri Jyoti as well as the Dutch cultivars.

4.3.4.6 Chip colour:

Dutch and Indian potato cultivars exhibited a wide variation in the chip colour during consecutive years of study (Table 4.3.21). Among the potato cultivars, Kufri Chipsona-1 and Kufri Chipsona-2 produced acceptable light colour chips of grade 1-3 during both the years and showed superiority over other cultivars. A trial conducted at Central Potato Research Station, Modipuram (Ezekiel *et al.*, 1999) also corroborated the findings. Kufri Jyoti (control) always produced unacceptable brown colour chips (grade 4-5). This confirmed the observation of Gaur *et al.* (1998) and Singh *et al.* (1999). Dutch cultivars also produced chips of unacceptable colour. Chip colour was directly correlated with the content of reducing sugars in the tubers (Marwaha, 1998 b) and the chips prepared from potato cultivars containing more than 0.39 $cent^{-1}$ reducing sugars on fresh weight basis were dark in colour. Burton and Wilson (1978) reported that the permissible upper limit of reducing sugars is generally 0.25 $cent^{-1}$ for processing. Khurana (2002) reported that tubers with dry matter content of 20 $cent^{-1}$ and above and reducing sugar content of less than 150 mg 100 g^{-1} f. wt. were preferred for processing. Thus, none of the Dutch cultivars and the Indian cultivar Kufri Jyoti (used as control) met the processing quality standards in the preparation of the lightest colour chips. In contrast, both the new Indian cultivars, *viz.* Kufri Chipsona-1 and Kufri Chipsona-2 containing low reducing sugars and high tuber dry matter met the requirements of good processing quality despite having better yield potential.

4.3.5 Storage losses:

4.3.5.1 Physiological loss in weight:

There were significant variations in the physiological weight loss of stored potato tubers at room temperature of Dutch and Indian cultivars during

Plate 4.3.7 : Starch and chips of Ajax, Cardinal and Diamant

Plate 4.3.8 : Starch and chips of Fresco, Marfona and Sante

Plate 4.3.9 : Starch and chips of Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti

Table 4.3.22 : Physiological loss in weight (cent^{-1}) of stored Dutch and Indian potato cultivars under normal room condition at fortnightly intervals

Treatments	Period of storage (days)																	
	15			30			45			60			75			90		
	1999 - 2000	2000 - 2001	Pooled	1999 - 2000	2000 - 2001	Pooled	1999 - 2000	2000 - 2001	Pooled	1999 - 2000	2000 - 2001	Pooled	1999 - 2000	2000 - 2001	Pooled	1999 - 2000	2000 - 2001	Pooled
Ajax	1.37 (1.36)	0.83 (1.15)	1.10 (1.26)	2.13 (1.62)	1.73 (1.49)	1.93 (1.56)	2.77 (1.80)	2.80 (1.82)	2.79 (1.81)	4.27 (2.18)	4.07 (2.13)	4.17 (2.16)	7.60 (2.85)	7.33 (2.80)	7.47 (2.83)	11.77 (3.50)	10.83 (3.37)	11.30 (3.44)
Cardinal	0.77 (1.12)	1.13 (1.27)	0.95 (1.20)	1.67 (1.47)	2.17 (1.63)	1.92 (1.55)	2.70 (1.78)	3.43 (1.98)	3.07 (1.88)	4.27 (2.18)	4.30 (2.19)	4.29 (2.19)	7.73 (2.87)	7.70 (2.86)	7.72 (2.87)	12.20 (3.56)	11.33 (3.44)	11.77 (3.50)
Diamant	0.87 (1.16)	1.30 (1.33)	1.09 (1.25)	1.90 (1.55)	2.67 (1.78)	2.29 (1.67)	3.03 (1.88)	3.90 (2.09)	3.47 (1.99)	5.17 (2.38)	4.83 (2.31)	5.50 (2.35)	9.00 (3.08)	8.03 (2.92)	8.52 (3.00)	13.83 (3.79)	12.27 (3.57)	13.05 (3.68)
Fresco	1.07 (1.25)	0.90 (1.18)	0.99 (1.22)	1.70 (1.48)	1.83 (1.53)	1.77 (1.51)	2.90 (1.84)	3.07 (1.89)	2.99 (1.87)	4.57 (2.25)	5.17 (2.38)	4.87 (2.32)	8.17 (2.94)	8.57 (3.01)	8.37 (2.98)	13.13 (3.69)	13.00 (3.67)	13.07 (3.68)
Marfona	1.23 (1.31)	1.37 (1.35)	1.30 (1.33)	2.43 (1.71)	2.03 (1.59)	2.23 (1.65)	3.03 (1.88)	3.33 (1.96)	3.18 (1.92)	4.43 (2.22)	5.33 (2.42)	4.88 (2.32)	8.00 (2.92)	9.10 (3.10)	8.55 (3.01)	12.47 (3.60)	13.17 (3.70)	12.82 (3.65)
Sante	1.77 (1.50)	1.57 (1.42)	1.67 (1.46)	2.50 (1.73)	2.50 (1.73)	2.50 (1.73)	3.43 (1.99)	4.03 (2.13)	3.73 (2.06)	5.27 (2.40)	5.53 (2.46)	5.40 (2.43)	9.27 (3.12)	9.57 (3.17)	9.42 (3.15)	14.07 (3.82)	13.53 (3.74)	13.80 (3.78)
K.Chipsona-1	1.13 (1.27)	1.03 (1.23)	1.08 (1.25)	1.97 (1.57)	2.03 (1.59)	2.00 (1.58)	2.63 (1.77)	3.53 (2.00)	3.08 (1.89)	4.13 (2.15)	4.23 (2.18)	4.18 (2.17)	7.13 (2.76)	7.50 (2.83)	7.32 (2.80)	11.37 (3.45)	11.07 (3.40)	11.22 (3.43)
K.Chipsona-2	1.53 (1.42)	1.43 (1.38)	1.48 (1.40)	2.20 (1.64)	2.30 (1.67)	2.25 (1.66)	3.27 (1.94)	3.53 (2.00)	3.40 (1.97)	4.77 (2.29)	4.47 (2.23)	4.62 (2.26)	8.47 (2.99)	7.83 (2.89)	8.15 (2.94)	13.43 (3.73)	11.73 (3.50)	12.58 (3.62)
K. Jyoti	1.63 (1.45)	1.93 (1.55)	1.78 (1.50)	2.33 (1.68)	2.37 (1.69)	2.35 (1.69)	3.17 (1.91)	3.67 (2.04)	3.42 (1.98)	4.93 (2.33)	5.07 (2.36)	5.50 (2.35)	8.63 (3.02)	8.47 (2.99)	8.55 (3.01)	13.57 (3.75)	12.67 (3.63)	13.12 (3.69)
S.Em(±)	0.06	0.06	0.04	0.05	0.04	0.03	0.01	0.04	0.03	0.04	0.04	0.02	0.03	0.04	0.03	0.04	0.03	0.02
C.D.(P=0.05)	0.20	0.20	0.12	0.17	0.12	0.10	0.04	0.13	0.09	0.13	0.12	0.07	0.11	0.13	0.10	0.12	0.10	0.07

Values in parentheses are angular transformed

both the years of experimentation (Table 4.3.22). Physiological loss in weight of different cultivars increased with increasing period of storage in all the cultivars. The losses varied from 0.77-1.93 cent^{-1} (15 days of storage), 1.70-2.67 cent^{-1} (30 days of storage), 2.63-4.03 cent^{-1} (45 days of storage), 4.13-5.53 cent^{-1} (60 days of storage) which increased drastically from 7.13-9.57 cent^{-1} (75 days of storage) and 11.37-14.07 cent^{-1} (90 days of storage) during two successive crop seasons. Verma and Jha (1991) and Kumar *et al.* (1995) have also reported variation in weight loss in different genotypes during storage at ambient temperature. Pooled data of two years reveal that the potato cultivars Kufri Chipsona-1, Ajax, Cardinal and Kufri Chipsona-2 exhibited minimum weight loss (11.22, 11.30, 11.77 and 12.58 cent^{-1}, respectively) after 90 days of storage and showed better keeping quality than control, Kufri Jyoti (13.12 cent^{-1}). In contrast, Dutch cultivar Sante exhibited very poor keeping quality with maximum weight losses of 9.42 and 13.80 cent^{-1} after 75 and 90 days of storage, respectively.

4.3.5.2 Rotting of tubers:

The percentage of rotting in stored potato tubers varied from 3.40 and 13.93 cent^{-1} (75 days of storage) to 7.83 and 20.53 cent^{-1} (90 days of storage) among the Dutch and Indian cultivars during two years of observation (Table 4.3.23; Fig. 4.3.16). Verma *et al.* (1974) and Verma and Jha (1991) have also observed a wide range in spoilage of tubers among Indian potato varieties and hybrids. Pooled data show that the rotting of tuber was minimum in Indian potato cultivars, Kufri Chipsona-2 (8.67 cent^{-1}) and Kufri Chipsona-1 (8.75 cent^{-1}); and Dutch cultivar Ajax (10.07 cent^{-1}) after 90 days of storage. On the other hand, maximum rotting of potato tuber was recorded in Dutch cultivar Sante (11.73 and 17.45 cent^{-1} after 75 and 90 days of storage, respectively).

Results thus indicate that good keeping quality of hybrids, Kufri Chipsona-1 and Kufri Chipsona-2 would ensure their wider acceptability and greater utilization. Such hybrids, which can be stored for three months at room

Table 4.3.23 : Rotting (cent^{-1} by weight) of stored Dutch and Indian potato cultivars under normal room condition

Treatments	Period of storage (days)					
	75			90		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
Ajax	6.10 (2.56)	5.43 (2.41)	5.77 (2.49)	9.43 (3.15)	10.70 (3.33)	10.07 (3.24)
Cardinal	10.77 (3.34)	7.53 (2.52)	9.15 (2.93)	15.73 (3.98)	12.73 (3.63)	14.23 (3.81)
Diamant	7.83 (2.86)	10.03 (3.23)	8.93 (3.05)	13.33 (3.69)	13.43 (3.73)	13.38 (3.71)
Fresco	12.40 (3.59)	9.80 (3.20)	11.10 (3.40)	18.90 (4.40)	13.80 (3.76)	16.35 (4.08)
Marfona	6.73 (2.68)	11.33 (3.43)	9.03 (3.06)	13.57 (3.75)	14.60 (3.87)	14.09 (3.81)
Sante	9.53 (3.16)	13.93 (3.78)	11.73 (3.47)	14.37 (3.85)	20.53 (4.58)	17.45 (4.22)
K.Chipsona-1	3.40 (1.97)	4.67 (2.06)	4.04 (2.02)	7.83 (2.87)	9.67 (3.17)	8.75 (3.02)
K.Chipsona-2	5.37 (2.39)	6.50 (2.61)	5.94 (2.50)	8.33 (2.97)	9.00 (2.72)	8.67 (2.85)
K.Jyoti	8.50 (2.98)	7.20 (2.75)	7.85 (2.87)	13.93 (3.79)	15.67 (4.01)	14.80 (3.90)
S.Em(±)	0.18	0.34	0.23	0.21	0.31	0.17
C.D.(P=0.05)	0.56	1.02	0.69	0.65	0.94	0.52

Values in parentheses are angular transformed

temperature after harvest without much weight loss, would be highly useful for farmers for slow and successive release of their produce in the market.

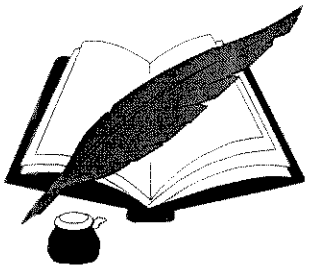
4.3.6 Economics:

The average economics of cultivation of two years (Table 4.3.24) show higher gross return in the Dutch cultivars Cardinal (Rs. 91,575 ha^{-1}) and Diamant (Rs. 89,280 ha^{-1}) and Indian cultivar Kufri Chipsona-1 (Rs. 79,575 ha^{-1}), which was 20.25, 17.23 and 4.49 $cent^{-1}$ more against the control (Kufri Jyoti) that recorded a gross return of Rs. 76,155 ha^{-1}. The corresponding increases in the net profit in these cultivars were 42.68, 36.33 and 9.47 $cent^{-1}$ over Kufri Jyoti. The net profit $rupee^{-1}$ invested was also higher in the cultivars Cardinal (1.29), Diamant (1.23) and Kufri Chipsona-1 (0.99), while Dutch cultivar Fresco fetched the minimum benefit : cost ratio (0.54).

Table 4.3.24 : Economics of cultivation of Dutch and Indian potato cultivars

Treatment	Cost of cultivation (Rs. ha^{-1})			Gross return (Rs. ha^{-1})			Net profit (Rs. ha^{-1})			Benefit : Cost (Rs.)		
	1999-00	2000-01	Mean	1999-00	2000-01	Mean	1999-00	2000-01	Mean	1999-00	2000-01	Mean
Ajax	39,268	40,778	40,023	71,670	70,410	71,040	32,402	29,632	31,017	0.83	0.73	0.77
Cardinal	39,268	40,778	40,023	93,990	89,160	91,575	54,722	48,382	51,552	1.39	1.19	1.29
Diamant	39,268	40,778	40,023	90,660	87,900	89,280	51,392	47,122	49,257	1.31	1.16	1.23
Fresco	39,268	40,778	40,023	60,990	62,490	61,740	21,722	21,712	21,717	0.55	0.53	0.54
Marfona	39,268	40,778	40,023	73,320	69,990	71,655	34,052	29,212	31,632	0.87	0.72	0.79
Sante	39,268	40,778	40,023	62,340	68,730	65,535	23,072	27,952	25,512	0.59	0.69	0.64
K.Chipsona-1	39,268	40,778	40,023	76,650	82,500	79,575	37,382	41,722	39,552	0.95	1.02	0.99
K.Chipsona-2	39,268	40,778	40,023	67,320	77,070	72,195	28,052	36,292	32,172	0.71	0.89	0.80
K.Jyoti	39,268	40,778	40,023	75,660	76,650	76,155	36,392	35,872	36,132	0.93	0.88	0.90

Chapter-5



Summary and Conclusion

5. SUMMARY AND CONCLUSION

The research programme comprising three separate field experiments were conducted at Block Seed Farm, Adisaptagram, Hooghly, West Bengal during *rabi* 1999-2000 and 2000-2001 with the objective of formulating an appropriate schedule of NPK nutrients for better efficiency while utilizing the beneficial effects of different biofertilizers and identifying suitable high yielding potato processing varieties for the Gangetic Alluvial Zone of West Bengal. Storage behaviour of tubers under normal room condition of all the cultivars was evaluated for processing and the effect of potassium on this aspect was also studied for two years.

The soil of the experimental field was sandy loam (Entisol) having pH 5.9, organic carbon 0.87%, available nitrogen 223.17 kg N, available phosphorus 8.39 kg P and available potassium 169.15 kg K ha^{-1}. Well-sprouted healthy seed tubers were planted at a spacing of 60 cm x 20 cm following the normal fertilizer schedule of the region (180 kg N, 150 kg P_2O_5 and 150 kg K_2O ha^{-1}) during the last week of November each year.

The first experiment has been undertaken to study the fertilizer economy in potato (cv. Kufri Jyoti) by the use of biofertilizers (*Azotobacter* + Phosphobacteria and *Bacillus cereus* + *Bacillus subtilis*). The experiment was laid out in a randomized block design with eight treatment combinations replicated thrice. Treatments containing 100% N and P + 1% urea + 1% sodium bicarbonate + *Azotobacter* + Phosphobacteria produced the highest LAI, DM accumulation, CGR and TBR at different stages of observation with the exception in TBR during 70-80 DAP when tubers treated with 75% N and P + *Bacillus* spp. recorded the highest value. The treatment comprising 100% N and P + 1% urea + 1% sodium bicarbonate + *Azotobacter* + Phosphobacteria also exhibited the longest LAD

(71.92 days), maximum number of tubers hill^{-1} (7.11), percentage of large sized (>50g) tubers (62.73 cent^{-1}) and highest tuber yield (32.50 t ha^{-1}) but there was no significant yield variation among the treatments comprising 100 and 75% N and P along with *Bacillus* spp. and uninoculated control of 100% N and P and only significantly superior to the uninoculated treatment of 75% N and P. Maximum uptake of NPK by potato plants (155.40 kg N, 18.59 kg P and 158.58 kg K ha^{-1}) and soil available NPK was also registered with the same treatment. The economics of cultivation indicated that net return rupee^{-1} invested was higher with tubers containing 100% N and P + 1% urea + 1% sodium bicarbonate + *Azotobacter* + Phosphobacteria (1.40), 100% N and P + *Bacillus* spp. (1.31) and 75% N and P + 1% urea + 1% sodium bicarbonate + *Azotobacter* + Phosphobacteria (1.29) as compared to uninoculated controls (1.18 and 1.06 at 100% and 75% N and P, respectively). It visualizes that biofertilizer inoculation increased the efficiency of applied N and P and reduced the extent of N and P fertilizer requirement of the crop by 25 cent^{-1}.

In the second experiment efforts have been made to find out the effects of levels and methods of potassium application (0, 50, 100, 150 and 200 kg K_2O ha^{-1} as basal and in splits) for increasing its efficiency in potato (cv. Kufri Jyoti) and its role on storage behaviour of tubers under normal room condition. It was a factorial experiment conducted in RBD with three replications and altogether there were seventeen treatment combinations. The maximum LAI, DM production, CGR and LAD were recorded at 200 kg K_2O ha^{-1}. However maximum LAI and LAD values were attained when potassium was applied full as basal while split application of potassium (½ as basal + ½ as top dressing at 30 DAP) gave rise to the highest DM production, CGR and TBR at all the dates of observation except at later stages (70-80 DAP) in CGR and TBR where potassium applied $^2/_3$ rd as basal + $^1/_3$ rd as top dressing at 30 DAP recorded the highest value. The maximum

number of tubers hill^{-1} (9.00) was obtained with 150 kg K_2O ha^{-1} but potassium applied at 200 kg K_2O ha^{-1} accrued the maximum percentage of large sized tubers (65.34 cent^{-1}) and highest tuber yield (29.00 t ha^{-1}). Moreover split application of potassium $^2/_3$ rd as basal + $^1/_3$ rd as top dressing at 30 DAP recorded the highest number of tubers hill^{-1} (8.58) whilst tuber yield (29.42 t ha^{-1}) and percentage of large sized tubers (58.46 cent^{-1}) were maximum when potassium was applied in two equal splits. The NPK uptake by leaf, stem and tuber was also higher at 200 kg K_2O ha^{-1} when applied ½ as basal + ½ at 30 DAP. However, all the levels of potassium maintained their distinct superiority to control. There was a build up in available soil N and P after the completion of the experiment at all the levels. However, except the levels of 100, 150 and 200 kg K_2O ha^{-1}, in rest levels of potassium there was a decline in available K during both the years. Regarding storage behaviour, the minimum physiological loss in weight (11.10 cent^{-1}) and rotting of tubers (8.42 cent^{-1}) after 90 days of storage was recorded at 200 kg K_2O ha^{-1}. However among the methods, potassium applied full as top dressing at 30 DAP showed minimum physiological loss in weight (12.16 cent^{-1}) and rotting of tubers (11.86 cent^{-1}) after 90 days of storage. The response curve indicated the economic optimum and physical optimum level of potassium at 157.8 and 216 kg K_2O ha^{-1} with corresponding yields of 28.29 and 28.94 t ha^{-1}, respectively. The gross return and benefit : cost ratio increased with the increase in potassium levels and exhibited maximum value at 200 kg K_2O ha^{-1}. Keeping in mind the yield parameters and NPK uptake pattern of potato, split application of potassium (½ as basal + ½ as top dressing at 30 DAP) at 150 kg K_2O ha^{-1} proved to be effective for achieving higher production of potato.

The trial to evaluate the Dutch and Indian potato cultivars (Ajax, Cardinal, Diamant, Fresco, Marfona, Sante, Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti) for processing on the basis of yield, chip colour and keeping

quality was carried out in a RBD with three replications. The Indian cultivar Kufri Chipsona-1 accounted for maximum LAI and DM production at all the crop growth stages and also recorded the longest LAD. The Dutch cultivar Diamant accrued the highest CGR, TBR and NAR between 50-60 and 70-80 DAP while during 60-70 DAP Cardinal exhibited the highest values of these parameters. Kufri Chipsona-1 and Kufri Chipsona-2 attained higher number of tubers hill^{-1} (9.24 and 8.46, respectively), but the highest tuber yield (30.53 t ha^{-1}) and maximum percentage of large sized tubers (64.96 cent^{-1}) were obtained by Cardinal. Kufri Chipsona-1 and Kufri Chipsona-2 also produced higher tuber yields (26.53 and 24.07 t ha^{-1}) with low reducing sugars (0.10 and 0.12 cent^{-1} on fresh weight basis) and total sugars (0.84 and 0.89 cent^{-1}), respectively and gave acceptable light colour chips (grade 1-3). Dutch cultivar Cardinal achieved the minimum peeling loss of tubers (9.9 cent^{-1}) while Kufri Chipsona-1 showed 11.58 cent^{-1} losses. Specific gravity was highest in Kufri Chipsona-2 (1.081) while Ajax recorded the maximum content of total acids (0.656 cent^{-1}) and vitamin C (10.1 mg 100 g^{-1} f. wt.). The maximum content of total soluble solids was recorded in Sante (8.1^{0}Brix), which remained at par with Kufri Chipsona-2 (7.4^{0}Brix). Regarding keeping quality, Kufri Chipsona-1 showed minimum physiological loss in weight (11.20 cent^{-1}) while Kufri Chipsona-2 resulted in minimum rotting of tubers (8.67 cent^{-1}) after 90 days of storage. The highest net return (Rs. 51,552 ha^{-1}) and maximum benefit : cost ratio (1.29) was recorded with Cardinal while the corresponding values in Kufri Chipsona-1 were Rs. 39,552 ha^{-1} and 0.99, respectively. Thus Indian cultivars Kufri Chipsona-1 and Kufri Chipsona-2 yielded higher, and met the requirement of processing quality standards of high dry matter content, specific gravity and low reducing sugars to give light colour chips for commercial adoption by the farmers. Moreover, they were susceptible to late blight.

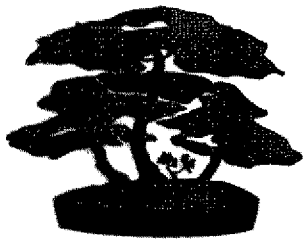
CONCLUSION:

Biofertilizer inoculation increased the efficiency of applied N and P in potato crop and reduced the extent of N and P fertilizer requirement of the crop by 25 $cent^{-1}$. Thus, a fertilizer schedule of 75% of existing doses of N and P and soaking of seed tubers in solution containing 1% urea and 1% sodium bicarbonate for five minutes followed by inoculation with *Azotobacter* + Phosphobacteria or *Bacillus* spp. may be advocated for achieving higher production of potato.

Levels and methods of potassium application influenced growth and yield of potato. The economic optimum dose of potassium was worked out to be 157.8 kg K_2O ha^{-1}. Split application of potassium (½ as basal and ½ as top dressing at 30 DAP) proved to be effective for achieving higher production of potato than its full basal application, which is usually recommended and conventionally practiced by the farmers.

Kufri Chipsona-1 and Kufri Chipsona-2 met the requirements of processing cultivars. Besides, it was observed that they had yield potential comparable to the most popular cultivar Kufri Jyoti and showed good resistance to late blight. Hence, introduction of these cultivars in West Bengal may help in diverting part of potato produce of the state to the processing factories, thereby reducing price fluctuations and the glut situations that occur every few years.

Chapter-6



Future Scope of Research

6. FUTURE SCOPE OF RESEARCH

The results of the experiments revealed that biofertilizer application appreciably affected not only the productivity of potato (cv. Kufri Jyoti) but also economized the requirement of N and P by about 25 $cent^{-1}$. It is, therefore, essential to study the effect of different sources of biofertilizers and their methods of application on the productivity and keeping quality of tubers of other existing potato cultivars.

The role of levels and methods of potassium on yield and keeping quality of tubers of Kufri Jyoti was studied and optimum dose was also worked out. However, it is not known whether different cultivars differ in their potassium requirement. Hence, this aspect needs investigation. Different sources of potassium on growth and yield of potato cultivars should also be investigated. The effect of micronutrients on potato and their role on storage behaviour of tubers may be studied.

The results also revealed that the cultivation of the traditional potato cultivar Kufri Jyoti can be substituted by the new promising cultivars Kufri Chipsona-1 and 2, which not only yielded comparable to Kufri Jyoti but superior in terms of quality standards for processing into chips. Hence, intensive research studies on these varieties are needed to be carried out at various locations of the state. Experiment can also be laid out with different combinations of N, P, K and organic sources of nutrients on the yield and processing quality of these promising cultivars.

Only nine cultivars were studied for their chipping quality and the yields were compared. However, at present number of potato hybrids released from CPRI are under the process of evaluation in West Bengal. These varieties should also be studied for yield and suitability of producing various processing products.

Biochemical parameters of potato tubers were studied just after harvest. It was, however, not possible to study the biochemical changes in tuber during storage. This study is essential to assess the availability of suitable raw material for processing in the later part of the year.

Bibliography

BIBLIOGRAPHY

A.O.A.C. 1984. *Official methods of Analysis*. Association of official agricultural chemists. 14th ed., Washington DC. pp. 16.

Bansal, S.K. and Maibaum, W. 1999. Potato (cv. Kufri Bahar) yield and quality response to potassium application on different sites in Uttar Pradesh and Haryana. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 122.

Baskar, D. 1975. Centigrade scale temperature corrections for the specific gravity of potatoes. *Potato Res.* **18** : 123-125.

Bhattarcharyya, P.; Jain, R.K. and Paliwal, M.K. 2000. Biofertilizers for vegetables. *Indian Hort.* **44** (2) : 12-13.

Brody, J. 1969. Pointers on potatoes. *Food Engineering.* **41** : 124-132.

Burton, W.G. 1966. *The Potato.* 2nd Edn. *(Veenman, H. and Zonen, N.V. eds.)* Wageningen, Holland. pp. 128-130.

Burton, W.G. and Wilson, A.R. 1978. The sugar content and sprout growth of tubers of potato cultivar Record, grown in different localities when stored at 10, 12 and 20^{0}C. *Potato Res.* **21** : 145-150.

Chadachan, R.B.; Nalawadi, U.G. and Madalageri, B.B. 1993. Nitrogen and potassium nutrition of rainfed potatoes on vertisols of north Karnataka. *J. Indian Potato Assoc.* **20** (3-4) : 265-266.

Chetri, M.; Mukhopadhyay, S.K.; Ray, D.; Basu, A. and Konar, A. 2001. Yield performance of some Indian and exotic cultivars of potato for processing in West Bengal. *J. Indian Potato Assoc.* **28** (1) : 68-69.

Das, M.; Ezekiel, R. and Shekhawat, G.S. 2001. Quality of dehydrated potato chips produced from fresh and heap stored tubers. *J. Indian Potato Assoc.* **28** (1) : 174-175.

Davies, H.V. and Viola, R. 1992. Regulation of sugar accumulation in stored potato tubers. *Post-harvest News and Information.* **3** (5) : 97-100.

Ezekiel, R.; Verma, S.C.; Sukumaran, N.P. and Shekhawat, G.S. 1999. A guide to potato processors in India. *Tech. Bull. 48*, CPRI, Shimla. p. 3-22.

Finglas, P.M. and Faulks, R.M. 1984. Nutritional composition of UK retail potatoes, both raw and cooked. *J. Sci. Food Agric.* **35** (12): 1347-1356.

Fisher, R.A. and Yates, F. 1979. *Statistical Tables for Biological, Agricultural and Medical Research,* Longmann Group Ltd., London.

Gaur, A.C. 2002. Production and role of organic manures in sustainable agriculture and organic farming. In : *Proceedings : National Seminar on development and use of biofertilizers, biopesticides and organic manures,* BCKV, West Bengal, 10-12 Nov., 2000. pp. 62-80.

Gaur, P.C.; Pandey, S.K.; Singh, S.V. and Kumar, D. 1999 a. Indian potato varieties for processing. *Tech. Bull. 50,* CPRI, Shimla. p. 9-20.

Gaur, P.C.; Pandey. S.K.; Singh, S.V.; Kumar, D.; Marwaha, R.S. and Kumar, D. 1998. Kufri Chipsona-1: A potato variety for processing. *J. Indian Potato Assoc.* **25** (3-4) : 113-118.

Gaur, P.C.; Singh, S.V.; Pandey, S.K.; Marwaha, R.S.; Kumar D. and Kumar, D. 1999 b. Kufri Chipsona-2 : A new high dry matter potato variety for chipping. *Current Sci.* **76** (6) : 722-724.

Ghimbasan, R. 1997. Potato cultivation (growing) conditions, varieties and productions (crops). *Bull. Transilvania Univ. Brasov.* **4** (39) : 31-34.

Gomez, K.A. and Gomez, A.A. 1983. *Statistical Procedures for Agricultural Research.* 2nd ed., Philippines. pp. 633-645.

Gonzalez, M. and Carreno, R. 1993. Evaluation of quality in potato cultivars Kennebec and Sebago in relation to their processing. *Agronomia Tropical Maracay.* **43** (5-6) : 287-303.

Gould, W.A.; Hair, B. and Baroudi, A. 1979. Evaluation of potato cultivars before and after storage regimes for chipping. *Am. Potato J.* **56** : 133-144.

Heady, E.O. and Dhillon, J.N. 1966. Agricultural production function. *Iowa State Univ. Press A.* Iowa. pp. 31-107.

Hooda, R.S. and Pandita, M.L. 1978. Effect of split application of potassium levels on growth, yield and chemical composition of potato. *Indian Potash J.* **3** (4) : 10-11.

Hossain, M.J.; Bhuiyan, M.K.R.; Zakaria, M. and Rashid, M.M. 1995. Evaluation of some British potato varieties for keeping quality under natural storage conditions in Bangladesh. *Tropical Sci.* **35** (2) : 113-120.

Humadi, F.M. 1986. Influence of potassium rates on growth and yield of potato. *Iragvi J. Agric. Sci. Zanco.* **4** (2) : 69-73.

Imas P. and Bansal, S.K. 1999. Integrated nutrient management in potato. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 105.

Iritani, W.M. and Weller, L.D. 1977. Changes in sucrose and reducing sugar contents of Kennebec and Russet Burbank tubers during growth and post harvest holding temperatures. *Am. Potato J.* **54** : 395-404.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall India Pvt. Ltd., New Delhi.

Jaiswal, V.P. 1995. Effect of cost reduction schedules on yield and economics of potato production. *J. Indian Potato Assoc.* **22** (3-4) : 162-165.

Jekic, M. and Stojanov, S. 1992. The effect of fertilizers on yields of 5 Dutch potato cultivars. *Savremena Poljoprivreda.* **40** (1-2) : 205-210.

Kang, G.S. and Gopal, J. 1993. Differences among potato genotypes in storability at high temperature after different periods of storage. *J. Indian Potato Assoc.* **20** (2) : 105-110.

Kang, G.S.; Kumar, R.; Pandey, S.K. and Khurana, S.M.P. 2001. Keeping quality of some advanced potato hybrids at room temperature storage. *J. Indian Potato Assoc.* **28** (1) : 137-138.

Khan, J. 1993. Effect of different levels of NPK fertilizers on potato tuber yield. *Sarhad J. Agri.* **9** (6) : 543-550.

Khan, M.S.; Islam, M.S.; Saha, U.K. and Kabir, H. 1992. Effect of irrigation on yield and water relations of some exotic and indigenous potato varieties. *J. Indian Potato Assoc.* **19** (1-2) : 1-4.

Khurana, S.M.P. 2002. Possible R & D linkages and strategies for sustainable potato production in India. *J. Indian Potato Assoc.* **29** (1-2) : 1-18.

Krishnamurthy, N.; Khalak, A. and Sujith, G.M. 2001. Response of potato grown from TPS to integrated use of organic manures and fertilizers in alfisols of eastern dry zone of Karnataka. *South Indian Hort.* **49** (Special) : 165-167.

Krishnappa, K.S. and Gowda, M.C. 1988. NPK uptake by Kufri Jyoti potato (*Solanum tuberosum* L.) in sandy loam soil. *J. Indian Potato Assoc.* **15** (3-4) : 153-158.

Krishnappa, K.S. and Muddappagowda, P. 1979. Effects of soil and foliar application of potassium on gradewise and total yield of potato. *Madras Agric. J.* **66** (11) : 747-751.

Kumar, D.; Ezekiel, R. and Jame, K. 1999 a. Chipping quality of some Indian and exotic potato cultivars grown at Modipuram. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 75.

Kumar, D.; Gaur, P.C.; Pandey, S.K.; Singh, J. and Singh, S.V. 1999 b. Effect of storage and reconditioning on recently released Indian potato processing varieties. *J. Indian Potato Assoc.* **26** (1-2) : 71-73.

Kumar, D.; Kaul, H.N. and Singh, S.V. 1995. Keeping quality in advanced potato selections during non-refrigerated storage. *J. Indian Potato Assoc.* **22** : 105-108.

Kumar, D.; Praharaj, C.S.; Sharma, R.C. and Khurana, S.M.P. 2001 a. Response of potato varieties to fertility levels in Indo-Gangetic plains of Bihar. *J. Indian Potato Assoc.* **28** (1) : 56-57.

Kumar, D.; Singh S.K.; Gaur, P.C. and Pandey, S.K. 1999 c. Chipping quality of potatoes grown at different locations in India. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 76.

Kumar, D.; Singh, S.V. and Pandey, S.K. 2001 c. Potato processing quality as influenced by date of haulm cutting. *J. Indian Potato Assoc.* **28** (1) : 167-168.

Kumar, V.; Jaiswal, R.C. and Singh, A.P. 2001 b. Effect of biofertilizers on growth and yield of potato. *J. Indian Potato Assoc.* **28** (1) : 60-61.

Mahendran, P.P. and Chandramani, P. 1998. NPK uptake, yield and starch content of potato cv. Kufri Jyoti as influenced by certain biofertilizers. *J. Indian Potato Assoc.* **25** (1-2) : 50-52.

Mahendran, P.P. and Kumar, N. 1998. Effect of biofertilizers on tuber yield and certain quality parameters of potato cv. Kufri Jyoti. *South Indian Hort.* **46** (1-2) : 97-98.

Marwaha, B.C. 1995. Biofertilizer : A supplementary source of plant nutrition. *Fert. News.* **40** (7) : 39-50.

Marwaha, R.S. 1987. Evaluation of some potato cultivars for processing on basis of their chemical composition. *J. Indian Potato Assoc.* **14** : 9-16.

Marwaha, R.S. 1998 a. Evaluation of Indian and exotic potato cultivars for processing into French fries. *J. Indian Potato Assoc.* **25** (1-2) : 61-65.

Marwaha, R.S. 1998 b. Factors determining processing quality and optimum processing maturity of potato cultivars grown under short days. *J. Indian Potato Assoc.* **25** (3-4) : 95-102.

Marwaha, R.S. 2001. Evaluation of potato cultivars for desirable processing traits before and after storage at higher temperatures. *J. Indian Potato Assoc.* **28** (1) : 162-163.

Marwaha, R.S. and Kumar, R. 1987. Relationship between specific gravity and dry matter content of potato tubers. *Intern. J. Trop. Agri.* **5** : 227-230.

Mazza, G. 1983. Correlations between quality parameters of potatoes during growth and long term storage. *Am. Potato J.* **60** : 145-159.

Muhr, G.R.; Datta, N.P.; Sankrasubramoney, H.; Laley, U.K. and Donahue, R.S. 1965. *Soil Testing in India.* 2nd edn. United States Aid for International Department. pp. 39-46.

Nandekar, D.N.; Dubey, K.C. and Upadhyay, P.C. 1993. Stability analysis of tuber yield in potato. *Indian J. Hort.* **50** (1) : 80-83.

Nandekar, D.N.; Khandwe, N. and Sharma, B.R. 1999. Response of potato to phosphorus and potassium in Satpura Zone of Madhya Pradesh. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 129.

Pandey, S.K.; Gaur, P.C.; Singh, S.V. and Kumar, D. 1999. Potential of processing potato varieties in different agro-climatic regions. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 85.

Panse, V.G. and Sukhatme, P.V. 1995. *Statistical Methods for Agricultural Workers*, ICAR, New Delhi. pp. 342-343.

Peixoto, J.R.; Garcia, C.A.P. and Martins, J.F. 1996. Yield of potatoes cv. Achat as a function of rates of NPK and B. *Horticultura Brasileira.* **14** (2) : 232-235.

Piper, C.S. 1966. *Soil and Plant analysis.* Hans Publishers, Bombay.

Praharaj, C.S.; Kumar, D. and Sharma, R.C. 1999. Fertilizer economy in potato (*Solanum tuberosum* L.) production through use of biofertilizers. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 142.

Pressey, R. and Shaw, R. 1966. Effect of temperature on invertase, invertase inhibitors and sugars in potato tubers. *Plant Physiol.* **41** : 1657-1661.

Ray, D. and Mukhopadhyay, S.K. 2002. Fertilizer economy in potato by the use of biofertilizers. In : *Proceedings : National Seminar on development*

and use of biofertilizers, biopesticides and organic manures, BCKV, West Bengal, 10-12 Nov., 2000. pp. 156-161.

Ray, D.; Mukhopadhyay, S.K. and Chettri, M. 2002. Performance of some Indian and Dutch potato processing varieties under West Bengal condition. In : *Abstracts : National Symposium on Agriculture in Changing Global Scenario*, IARI, New Delhi, 21-23 Feb., 2002. pp. 178-179.

Roe, M.A.; Faulks, R.M. and Belsten, J.L. 1990. Role of reducing sugars and amino acids in fry colour of chips from potatoes grown under different regimes. *J. Sci. Food Agric.* **52** : 207-214.

Roy, S.K.B.; Chakraborty, A.K.; Kumar, D. and Gaur, P.C. 1999. Evaluation of potato varieties for processing in West Bengal. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 95.

Sahota, T.S. and Singh, M. 1985. Levels and methods of application of P, K and FYM to potato grown on the alluvial soils of Punjab. *Indian J. Agric. Sci.* **55** (1) : 28-32.

Satyanarayana, V. and Arora, P.N. 1985. Effect of nitrogen and potassium on yield and yield attributes of potato (cv. Kufri Bahar). *Indian J. Agron.* **30** (3) : 292-295.

Saxena, A.K. and Tilak, K.V.B.R. 1994. Interaction among beneficial soil micro-organism. *Indian J. Microbiol.* **34** (2) : 91-106.

Shaheen, G.H.; Ahmed, A.; Baber, S.; Khan, A.R.; Malik, I.A. and Hussain, A. 1995. Studies on the processing and quality evaluation of potato varieties. In : *Proceedings : National Seminar on Research and Development of potato production in Pakistan,* NARC, Islamabad, Pakistan, 23-25 April, 1995. pp. 335-343.

Sharma, A.K.; Garg, V.K. and Singh, S. 2001. Storage behaviour of some advanced potato hybrids in north-western hill conditions under room temperatures. *J. Indian Potato Assoc.* **28** (1) : 139-140.

Sharma, R.C.; Sood, M.C.; Patricia, I.; Khan, M.A. and Bansal, S.K. 1999. Nitrogen and potassium interaction on the tuber yield and soil parameters at Shimla. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 134.

Sharma, R.C.; Sunaina, V.; Upadhyay, N.C. and Kumar, M. 1996. Effect of green manuring, organics and biofertilizers on tuber production in potato on a typic ustochrept. In : *Proceedings : XIV National Symposium on*

Agronomy, Environment and Food Security for 21st century, CCSHAU, Hisar, 10-14 Dec., 1996. pp. 183-184.

Sharma, R.C.; Trehan, S.P.; Roy, S.K. and Kumar, D. 1999. Nutrient management in potato. *Indian Fmg.* **49** (9) : 152-154.

Sharma, R.P. and Ezekiel, R. 1993. Influence of potassium on the chemical composition and storage behaviour of potato. *J. Indian Potato Assoc.* **20** (3-4) : 275-278.

Sharma, U.C. 1989. Potato yield and nutrient uptake as influenced by fertility levels at different locations in Meghalaya. *J. Indian Potato Assoc.* **16**: 91-95.

Sharma, U.C. 1992. Effects of levels of N, P and K and their interactions on yield and nutrient uptake of potato in acid soils. *J. Indian Potato Assoc.* **19** : 77-80.

Sharma, U.C. and Arora, B.R. 1988. Calcium content of potato (*Solanum tuberosum* L.) plant as affected by potassium application . *Indian J. Agric. Sci.* **58** (1) : 69-71.

Shekhawat, G.S. 1999. Potato for food and nutrition security. *J. Indian Potato Assoc.* **26** (3-4) : 77-84.

Shekhawat, G.S. 2001. Potato production, utilization and marketing in India. *J. Indian Potato Assoc.* **28** (2-4) : 185-193.

Shukla, D.N. and Singh, S. 1976. Effect of split application of potassium levels on the yield and grade of potato varieties. *Haryana J. Hort. Sci.* **5** (1-2) : 43-48.

Sidorenko, O.; Storozhenko, V. and Kukharenkova, O. 1996. The use of bacterial preparation in potato cultivation. *Mezhdunarodngi-sel. Skokhozyaist-vennyi Zhuranal.* **6** : 36-38.

Singh, J.; Singh, M.; Saimbhi, M.S. and Kooner, K.S. 1993. Growth and yield of potato cultivars as affected by plant density and potassium levels. *J. Indian Potato Assoc.* **20** (3-4) : 279-282.

Singh, J.P. and Grewal, J.S. 1987. Response of potato to potassium under intensive cropping and changes in soil potassium with time. *J. Potassium Res.* **3** (3) : 107-114.

Singh, J.P.; Marwaha, R.S. and Grewal, J.S. 1996. Effect of sources and levels of potassium on potato yield, quality and storage behaviour. *J. Indian Potato Assoc.* **23** (3-4) : 153-156.

Singh, K. 1999 a. Effect of seed rates and fertilizer levels on the yield and economics of potato (*Solanum tuberosum*) under north-eastern hill conditions. *Indian J. Agric. Sci.* **69** (3) : 182-184.

Singh, K. 1999 c. Role of biofertilizers in increasing the efficiency of nitrogen to potato crop under north-east hill conditions. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 150.

Singh, K. 2001. Response of potato (*Solanum tuberosum*) to biofertilizer and nitrogen under north-eastern hill conditions. *Indian J. Agron.* **46** (2) : 375-379.

Singh, K.; Singh, Y. and Sarangi, S.K. 2002. Potential of problem soils in augmenting food production in India. *Fert. News.* **47** (11) : 41-53.

Singh, L. 1996. A potato ideotype for the Indo-Gangetic plains. *J. Indian Potato Assoc.* **23** (3-4) : 112-120.

Singh, N.P. and Raghav, M. 2000. Response of potato to nitrogen and potassium fertilization under U.P. tarai conditions. *J. Indian Potato Assoc.* **27** (1-2) : 47-48.

Singh, S. and Singh, K. 1964. Studies on effect of soil moisture conditions and potassium application on the growth behaviour of rice plant. *J. Scientific Res.* **15** : 8-18.

Singh, S.K. 1999 b. Combination of phosphate solubilizing biofertilizer (bacteria) with phosphorus on tuber yield of potato. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 132.

Singh, S.K. and Sharma, R.C. 2002. Effect of inoculation, nitrogen and phosphorus on yield and nutrient uptake of potato and their residual effect on radish. *J. Indian Potato Assoc.* **29** (1-2) : 41-45.

Singh, S.M. and Grewal, J.S. 1979. Dry matter production and NPK uptake by the potato variety Kufri Chandramukhi in alluvial soil. *J. Indian Potato Assoc.* **6** (2) : 78-86.

Singh, S.V.; Kumar, D.; Gaur, P.C.; Pandey, S.K. and Singh, J. 1999. Performance of Indian and Dutch processing potato varieties for chipping in north-western plains. *J. Indian Potato Assoc.* **26** (1-2) : 65-66.

Singh, S.V.; Kumar, D.; Pandey, S.K. and Gaur, P.C. 1997. Evaluation of advanced stage potato hybrids for processing. *J. Indian Potato Assoc.* **24** (3-4) : 124-127.

Singh, S.V.; Pandey, S.K. and Khurana, S.M.P. 2001 a. Storage behaviour of some advanced potato hybrids in plains of western U.P. at ambient temperatures. *J. Indian Potato Assoc.* **28** (1) : 135-136.

Singh, V.N. and Singh, S.P. 1995 a. Effect of levels and methods of potassium application on vegetative growth and yield of potato cv. Kufri Badshah. *J. Indian Potato Assoc.* **22** (3-4) : 118-121.

Singh, V.N. and Singh, S.P. 1995 b. Effect of potassium application on yield and yield attributes of potato. *J. Potassium Res.* **11** (3-4) : 338-343.

Sood, M.C. and Sharma, R.C. 2001. Value of growth promoting bacteria, vermicompost and *Azotobacter* on potato production in Shimla hills. *J. Indian Potato Assoc.* **28** (1) : 52-53.

Sunaina, V.; Kishore, V.; Shekhawat, G.S. and Kumar, M. 1999. Effect of specific strains of *Bacillus* spp. on growth and yield of potato. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 224.

Talburt, W.F., 1987. Canned white potatoes. In : *Potato Processing* (Taburt, W.F. and Smith, O. eds.) Van Nostrand Reinhold Co., New York, USA. pp. 684-685.

Trehan, S.P. and Grewal, J.S. 1991. Effect of time and level of potassium application on tuber yield and K composition of plant tissues and tubers of two potato cultivars. *J. Indian Potato Assoc.* **18** (3-4) : 115-121.

Trehan, S.P. and Sharma, R.C. 1998. Soil and foliar application of potassium for increasing its efficiency in potato. *J. Indian Potato Assoc.* **25** (1-2) : 42-45.

Umar, S.; Majumdar, K.; Bansal, S.K. and Imas, P. 1999. Effect of potassium and sulphur on yield and quality parameters of potato (*Solanum tuberosum* L.) cv. Kufri Chandramukhi. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 124.

Upadhyay, N.C.; Sharma, R.C. and Chand, P. 1994. Efficiency of *Azotobacter* culture as influenced by method of its application in potato crop. *J. Indian Potato Assoc.* **21** (1-2) : 83.

Uppal, D.S. 1999. Quality traits and chipping performance of newly released potato varieties. *J. Indian Potato Assoc.* **26** (3-4) : 139-142.

Uppal, D.S. and Verma, S.C. 1990. Changes in sugar content and invertase activity in tubers of some Indian potato varieties stored at low temperature. *Potato Res.* **33** (1) : 119-123.

Veeranna, H.K. and Khalak, A. 1997. Effect of spacing and fertilizer levels on growth parameters and dry matter production of potato crop raised from TPS seedlings. *Crop Res.* **14** (1) : 119-126.

Veeranna, H.K.; Khalak, A. and Sridhara, S. 1997. Uptake and recovery of N, P and K in potato crop raised from TPS seedlings at different spacing and fertilizer levels. *Mysore J. Agric. Sci.* **31** (2) : 149-154.

Verma, S.C.; Malhotra, V.P.; Joshi, K.C. and Sharma, T.R. 1971. *Potato Res.* **14** : 94-95.

Verma, S.C.; Sharma, T.R. and Verma, S.M. 1974. Effect of extended high temperature storage on weight losses and sugar content of potato tubers. *Indian J. Agric. Sci.* **44** : 702-706.

Verma, V.S. and Jha, V.B. 1991. Evaluation of potato genotypes for their storability under room temperature. *J. Indian Potato Assoc.* **17** : 152-161.

Walkley, A. and Black, C.A. 1934. An examination of Degtjarff methods for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sci.* **37** : 29-34.

Watson, D.J. 1956. The dependence of net assimilation rate on leaf area index (LAI). *Ann. Bot.* N.S. London. **22** : 36-54.

Watson, D.J. 1958. The influences of NAR on LAI. *Ann. Bot.* **22** : 37-54.

Welbank, P.J. 1962. *Ann. Bot.* N.S. Lond. **26** : 361.

Yadav, K.S.; Singh, N.; Malik, Y.S.; Nehra, B.K.; Narula, N. and Lakshminarayana, K. 1999. *Azotobacter* biofertilizer – A potential nitrogen supplement in potato (*Solanum tuberosum* L.) cv. Kufri Sutlej. In : *Abstracts : Global Conference on Potato*, IARI, New Delhi, 6-11 Dec., 1999. pp. 123.

Yamaguchi, M.; Timm, H. and Spurr, A.R. 1964. Effects of soil temperature on growth and nutrition of potato plants and tuberization, composition and periderm structure of tubers. *Proc. Am. Soc. Hort. Sci.* **84** : 412-423.

Zahir, Z.A. and Arshad, M. 1996. Effectiveness of *Azotobacter* inoculation for improving potato yield under fertilized conditions. *Pakistan J. Agric. Sci.* **33** (1-4) : 1-5.