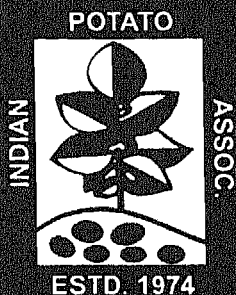


ISSN 0970-8235  
J. Indian Potato Assoc. 30 (3 - 4) : 117-242, 2003

# JOURNAL OF THE INDIAN POTATO ASSOCIATION

Volume 30, No. 3 - 4  
(July-December, 2003)  
(Issued January, 2004)



*Official Journal of*  
The Indian Potato Association  
Central Potato Research Institute, Shimla - 171 001

# INDIAN POTATO ASSOCIATION

## EXECUTIVE COUNCIL (2002-2003)

Chief Patron	Dr Mangala Rai
Patron	Dr G Kalloo
President	Dr SM Paul Khurana
Immediate Past President	Dr GS Shekhawat
Vice President	

<b>Region I</b>	Dr Shiv Kumar
<b>Region II</b>	Dr Kamla Singh
<b>Region III</b>	Dr DS Uppal
<b>Region IV</b>	Dr Raj Pal Singh
<b>Region V</b>	Dr BK De
<b>Region VI</b>	Dr TA Joseph

Secretary	Dr KC Sud
Joint Secretary	Dr NK Pandey
Treasurer	Dr JS Minhas

### Regional Councillors

<b>Region I</b>	<b>Region II</b>	<b>Region III</b>
Dr PH Singh	Dr VK Gupta	Dr SC Khurana
Dr MC Sood	Dr Surender Singh	Dr RD Bhutani
Dr VK Dua	Dr Shantanu Kumar	Dr SK Roy
Dr K Mukherjee	Dr Mrs. Uma Shah	Sh JS Jassal
Dr D Pattanayak		<b>Region V</b>
Dr Vinay Bhardwaj	<b>Region IV</b>	Dr Barsati Lal
Sh Shashi Rawat	Dr Ram Kishore	Dr M Mohasin
Sh JP Uniyal	Dr SBS Parihar	Sh Dhruv Kumar
Sh Praveen Chandla	Sh RN Sharma	<b>Region VI</b>
Sh Ranjeet Singh	Dr Dinesh Kumar	Sh G Ravichandran

### Editorial Board (2002-2005)

<b>Editor-in-Chief</b>	Dr SK Pandey	
<b>Business Editor</b>	Dr Brajesh Singh	
<b>Members</b>	Dr R Ezekiel	Dr VK Chandla
	Dr ID Garg	Dr PS Naik
	Dr Jai Gopal	Dr PM Govindkrishnan

**THE INDIAN POTATO ASSOCIATION**  
(Registered under the Societies Registration Act, XXII, 1860)

Honorary & Distinguished fellows of IPA

183

The Society was founded in 1974 with following objectives:

- (1) To advance the cause of potato research and development, culture and utilization.
- (2) Provide opportunity for personal contact and fellowship among workers in different fields embracing the potato.
- (3) Hold periodical conferences, symposia, workshops.
- (4) Publishing books, reports, summaries of paper and other forms of scientific and technical literature, Newsletter and the Journal of the Indian Potato Association.
- (5) Promote exchange of scientific and other information and develop other means of communication between the potato agriculture and industry.
- (6) Foster regional and international cooperation/collaboration in attainment of the objectives outlined.

Journal of the Indian Potato Association is published quarterly. The annual membership in the country is Rs. 100.00, (Rs. 75.00 for students) and US \$ 20.00 or equivalent for members abroad (inclusive of sea mail) and payable in advance. Life membership is Rs. 1000.00 or US \$ 100.00 (for foreign members). The annual subscription, payable in advance, is Rs. 800.00 in India and US \$ 40.00 or equivalent for other countries, post free (sea-mail). US \$ 15.00 will be charged extra (in advance) if copies are wanted by air mail. The membership/subscription dues should be sent in the form of bank draft (or through M.O.) in favour of the Indian Potato Association, Central Potato Research Institute, Shimla 171001 (H.P.), India and for exchange programme please contact the Sr. Librarian, Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh) India.

A limited amount of space is available for insertion of the advertisements of interest to the potato research workers, universities/State departments of agriculture and progressive farmers. The advertisers may write for details and rate tariff to the Secretary, IPA.

----- ✂ -----  
**INDIAN POTATO ASSOCIATION**  
**MEMBERSHIP FORM**

To  
The Secretary/Treasurer,  
Indian Potato Association,  
Central Potato Research Institute,  
Shimla-171 001 (India)

I ..... wish to enrol myself as Associate Member/Annual Member/Life Member/Annual Substanting Member of the Indian Potato Association.

I am sending the prescribed fee of Rs. ....  
by Money Order/Indian Postal Order No./Demand Draft No. ....  
.....

Kindly acknowledge the receipt.

Yours faithfully

## Contents

Invertase and sucrose synthase activity and carbohydrate status during sink to source transition in developing potato leaves — J.S. Minhas, V.K. Rai and H.S. Saini	217
Chemical maturity of potato processing cultivars grown in western Uttar Pradesh — Dinesh Kumar, S.V. Singh and S.K. Pandey	225
Relationship between under water weight and specific gravity, dry matter and starch content of potatoes grown in India — R. Ezekiel, Brajesh Singh and J. Gopal	233
Immuno electron microscopic diagnosis of potato virus M — I.D. Garg, Shiv Kumar and S.M. Paul Khurana	241
Effect of location, season and cultivar on the processing quality of potatoes — Dinesh Kumar, R. Ezekiel and S.M. Paul Khurana	247
Yield and processing attributes of indigenous and exotic potato varieties for processing in late planted crop in NW plains — S.V. Singh, Dinesh Kumar and S.K.Pandey	253
A reference chart for potato chip colour for use in India — R. Ezekiel, Brajesh Singh and Dinesh Kumar	259
Micropropagation in potato seed production: Need to revise seed certification standards — Prakash S. Naik and S.M. Paul Khurana	267
Development and evaluation of plain and profiled roller type of potato grader — B.B. Saxena, Manjit Singh, Sunil Gulati and R.C. Sharma	277
Soil and plant N as influenced by furrow and trickle irrigation in potatoes — J.K. Chawla and N.K. Narda	285
Evaluation of non-refrigerated storage methods for short term on-farm storage of potatoes — Ashiv Mehta and R. Ezekiel	291
Management of stem necrosis disease in early planted potato crop with varying fertilizer levels — A.K. Somani, V.S. Kushwah and S.P. Singh	301

Studies on potato based crop sequences in West Bengal — M. Chettri, S.K. Mukhopadhaya, A. Konar and A. Basu	305
Marketing and assessment of post-harvest losses in potato in Bihar — N.K. Pandey, Prem S. Dahiya, Anshuman Karol and Nalini Ranjan Kumar	309
Response of potato to soil moisture and temperature as affected by different mulches — S.P. Uniyal and A.C. Mishra	315
Potato intercropping with garlic in rainfed mid hills of Uttaranchal — R.V. Singh, S. Johri, Y.N. Tripathi and A.C. Mishra	319
Influence of different N and P levels with and without bio-fertilizer on N, P content, uptake and yield of potato cv. Kufri Jyoti — S.S. Kushwah and R.N.S. Banafar	321
Effect of different fertility levels on spectral characteristics, growth and yield of potato cv., Kufri Bahar — U.P. Shahi, Suman Kumar, N.P. Singh and A.K. Tiwari	325
Incidence of cutworm on potato in different locations of West Bengal — A. Konar and Md. Mohasin	329
Effectiveness of synthetic insecticides, bio-pesticides and <i>Azadirachtin</i> against potato aphids — A. Konar and M. Chettri	331
Wart disease of potato in India - Present scenario — P.H. Singh and I.D. Garg	335
Book Review	341
Acknowledgement to the referees (2003)	342
Honorary & Distinguished fellows of IPA	343

# INVERTASE AND SUCROSE SYNTHASE ACTIVITY AND CARBOHYDRATE STATUS DURING SINK TO SOURCE TRANSITION IN DEVELOPING POTATO LEAVES

J.S. Minhas<sup>1</sup>, V.K. Rai<sup>2</sup> and H.S. Saini<sup>3</sup>

**ABSTRACT:** Potato plants grown under tuber inducing and non-inducing conditions were used to study the activities of invertases, sucrose synthase and carbohydrate status in developing potato leaves. Plants grown under non-inducing conditions continued to grow vegetatively and there was starch accumulation in the leaves, and roots. However, under tuber-inducing conditions, vegetative growth slowed down considerably and there was very little starch accumulation in the leaves and roots, indicating that developing tubers acted as strong sinks for photoassimilates. Invertases were the major enzymes acting on the imported sucrose in the young leaves while sucrose synthase was of minor importance. Of the invertases, cell wall invertase activity was 44-110% higher than the soluble invertase in young leaves, indicating apoplastic unloading of imported sucrose as the major route. Reduced growth and leaf expansion under tuber inducing conditions was supported by 27% reduction in the activity of cell wall invertase. As the leaves developed to become net exporters of carbohydrates, the activity of sucrose degrading enzymes declined by 90%.

## INTRODUCTION

Carbohydrate metabolism changes profoundly during leaf development. Young leaves are heterotrophic; they depend in part on carbohydrate imported from other regions of the plant. Mature leaves on the other hand, are autotrophic; they produce excess of photoassimilate and act as plant's major sources of transport sugar. This conversion from sink to source status marks a fundamental transition in physiology of the leaf, and a considerable amount of study has gone into understanding its biochemical and structural characteristics (12, 17).

Structure and function do not develop homogeneously in the developing leaves, but develop significant spatial gradients that change dynamically (13, 33). Cell division and

elongation ceases first in the leaf tip. This allows the tip to mature several days before the leaf base. This coincides with the maturation of xylem and phloem elements in the acropetal direction (31). As a result, the lamina tip stops importing and begins to export while transport of photoassimilate from other leaves into the relatively immature leaf base continues (1). In most dicotyledenous plants the transition from photoassimilate sink to source occurs when leaves are 50-60% expanded (12)

Acid invertase and sucrose synthase are the two main enzymes acting on the imported sucrose in the sink tissues. Growing plant organs often exhibit a positive correlation between acid invertase activity and rate of cell expansion (21). During growth, carbon

---

<sup>1</sup> Central Potato Research Institute, Shimla 171 001 (Himachal Pradesh)

<sup>2</sup> Himachal Pradesh University, Shimla 171 005 (Himachal Pradesh)

<sup>3</sup> Institut de recherche en biologie végétale, Université de Montréal, Montréal, Canada H1X 2B2.

substrates are required for energy, synthesis of cell wall and cytoplasmic constituents. The hydrolysis of imported sucrose to hexose sugars by invertase during expansion growth may be the principal source of such carbon substrates (25). By lowering osmotic potential, the conversion of sucrose to hexoses in cell vacuoles may also contribute to the turgor driving force for cell expansion (15). In majority of the cases, acid invertase is the dominant sucrose cleaving enzyme in developing leaves (12,28), however, Claussen *et al.* (5) have suggested that sucrose synthase plays a major role in the import activity of developing egg plant leaf.

Many studies on the import-export conversion have been done to distinguish the preparatory events from the causal events of export. Turgeon and Webb (32) established in *Cucurbita pepo* that no one system in the development specifically regulated the onset of export but instead the import-export conversion resulted from the integrated maturation of many structural and physiological systems. In this study, the leaf import-export conversion was investigated at biochemical level not with the intent of determining the causal event(s) of export but rather to elucidate carbohydrate metabolism in sink and source leaf.

## MATERIALS AND METHODS

**Plant growth, treatments and tissue sampling:** Potato (*Solanum tuberosum* L. cv. Niska) plants were grown in 20 cm diameter plastic pots containing 50:50 mixture of sand and Pro-mix (Les Tourbieres Premier, Canada). Two uniformly chitted tubers were planted in each pot and initially kept in a temperature-controlled greenhouse with average day/night

temperature of 23/21°C and a minimum 16 h photoperiod-the conditions that inhibited tuberization. Pots were watered on alternate days and were fertilised weekly with a 3 g l<sup>-1</sup> solution of N-P-K (15-16-17) and once during the 4th week of growth with 0.6 g l<sup>-1</sup> solution of chelated micro-nutrients. After 30 days of growth (0 day of treatment), 10 pots were transferred to the tuber-inducing conditions (TI) in a controlled environment chamber (Model E-15, Conviron, Winnipeg, Canada) with 23/16°C day/night temperature, a canopy level average PPFD of 350  $\mu$  mol m<sup>-2</sup> s<sup>-1</sup>, and 10 h photoperiod. A matching set of 15 pots was left under the non-inductive conditions (NTI) in the greenhouse to serve as the control. In these experiments, all the plants from a pot represented one replicate. Plants from three pots for each treatment (inducing and non-inducing) were harvested at the time of transfer (day-0) and 5, 10 and 20 days after the transfer date. As carbohydrate content and enzyme activities in potato leaves and tubers show diurnal fluctuation (3, 18), all samples were collected between 1100 and 1130 hrs to minimise variation.

Plant height, number of leaves, number of stolons/tubers and size of tubers were recorded. Leaves were harvested and separated into the following categories according to size and age: young (blade length 20-40 mm), expanding (70-90 mm), fully expanded (140-160mm) and mature (8th to 10th leaf from top). Five leaves from each category were chopped into small pieces, mixed, and a random sample was drawn and frozen immediately with liquid nitrogen. Samples were stored at -80° C until they were ground to a fine powder under liquid nitrogen and subjected to the following analyses.

**Total and reducing sugars:** Tissue powder (15-20 mg) was extracted three times with 500  $\mu$ l of 80% ethanol at 80° C. The supernatant was pooled, dried under vacuum, dissolved in 500  $\mu$ l of distilled water and used for estimation of total sugars and reducing sugars according to the methods of Yemm and Willis (36) and Nelson (24), respectively. To estimate starch, the sugar-free pellet from the above extraction was washed twice with distilled water and then hydrolyzed with 500  $\mu$ l of 35% perchloric acid. The glucose released was quantified by the method of Yemm and Willis (36), and the starch content was expressed as glucose equivalents.

**Activities of soluble acid invertase and sucrose synthase:** Eighty to 100 mg of tissue powder was extracted with 1 ml extraction buffer (50 mM HEPES-KOH, pH 7.4, 5 mM  $MgCl_2$ , 1 mM EDTA, 5 mM DTT and 2% insoluble PVP) by vigorously shaking with vortex for 10 min. The extract was centrifuged for 10 minutes at 16,000  $\times$  g at 4°C. Twenty microliters of the supernatant (enzyme extract) was used to assay soluble acid invertase by the method of Tsai *et al.* (30). To determine sucrose synthase activity, 50  $\mu$ l of the supernatant was desalted with a sephadex G-25 microspin column (Pharmacia, Sweden, and 20  $\mu$ l of desalted extract was used to assay the enzyme activity by the method of Dancer *et al.* (6)

**Cell wall invertase:** Eighty to 100 mg tissue powder was extracted as described for acid invertase but without PVP and DTT in the extraction buffer. The pellet was washed three times with the extraction buffer and once with distilled water, and was then incubated overnight at 4°C in 1 ml of 20 mM MES-KOH

buffer pH 6.0 containing 1 M NaCl to dislodge invertase protein from the cell wall (2). The incubation mix was centrifuged at 16,000  $\times$  g at 4°C for 10 minutes, and 20  $\mu$ l of supernatant was used for the assay of released cell wall invertase by the method described above for soluble invertase.

## RESULTS

**Plant growth:** When long day grown plants were shifted to short days, the increase in their height slowed down. Control plants (NTI) left under long days and high night temperature continued to grow and were 89.2 cm tall compared to 60.3 cm for growth chamber (TI) plants. Short days and lower night temperature stimulated tuberization and stolons showed visible swelling after just 5 days and by 20 days the tubers had grown to an average diameter of 26 mm while control plants did not form any tubers (Table 1).

**Starch content:** Control plants continued to accumulate starch in their leaves and its amount increased as the leaves developed. Young leaves had 25-29  $\mu$ mol glc equivalent  $g^{-1}$  fr.wt. and it increased to 60-65  $\mu$ mol in mature leaves. Plants shifted to tuber inducing conditions accumulated less starch in their leaves. Although young leaves had the similar amount of starch as control plants but the amount of accumulated starch was less in later stages of leaves and mature leaves had only 30-33  $\mu$ mol glc equivalent  $g^{-1}$  fr.wt. In fully expanded leaves of the (TI) plants the amount of starch showed a reducing trend (from 39.8  $\mu$ mol to 27.4  $\mu$ mol glc equivalent  $g^{-1}$  fr.wt.) as the time under these conditions increased from 5 to 20 days. Mature leaves of tuberizing plants had almost half the amount of starch compared to control plants (Table 2).

Table 1. Plant height and tuber dia. of control potato plants and plants shifted to tuber inducing conditions after 30 days

Days of growth	Plant height (cm)		Tuber diameter (mm)	
	TI	NTI	TI	NTI
25	40.3	40.1	0	0
30*	49.1	50.2	0	0
35	52.4	64.6	8.0	0
40	57.3	77.0	14.5	0
50	60.3	89.5	26.0	0

NTI Control plants grown in glass house at 23/21 °C day/night temperature 16 h photoperiod

TI Plants grown in growth chambers at 23/16 °C day/night temperature 10 h photoperiod

\* Time when half of the plants were shifted to growth chambers

**Total sugars:** Total sugars also increased in the leaves during development from young to mature in control plants as well as in tuberizing plants. The trend was similar to starch but the quantum of reduction under tuberizing conditions was not as much as for starch. Reduction was clearly visible from 57-67  $\mu\text{mol glc equivalent g}^{-1}$  fr.wt. in control plants to 46-50  $\mu\text{mol}$  in fully expanded and mature leaves after 10-20 days under tuber inducing conditions (Table 2).

**Reducing sugars:** The amount of reducing sugars was about half the amount of total sugars in the leaves under both treatments. There was not much change in the amount of reducing sugars during leaf development although mature leaves showed slightly higher amounts of it. Fully expanded leaves after 20 days under tuberizing conditions had 25.2

$\mu\text{mol glc equivalent g}^{-1}$  fr.wt compared to 32.3 for control leaves (Table 2).

**Soluble acid invertase:** Soluble acid invertase activity was highest in the young leaves and it declined as the leaves developed. In the control plants, enzyme activity reduced by 5% in expanding leaves and by 47% in fully expanded leaves compared to young leaves. In the plants shifted to tuber inducing conditions the enzyme activity was lower compared to control leaves and was highest in the plants that had been shifted to the growth chambers for 5 days and reduced as the time under tuber inducing conditions increased in all leaves. Mature leaves had negligible enzyme activity (Fig. 1).

### Cell wall invertase

Cell wall form of invertase was much more

Table 2. Starch, total and reducing sugars content ( $\mu\text{mol glc equivalent g}^{-1}$  fr.wt) of potato leaves under tuber inducing (TI) and non tuber inducing conditions (NTI)

	Starch				Total Sugars				Reducing sugars			
	Young	Expan- ding	Expan- ded		Young	Expan- ding	Expan- ded		Young	Expan- ding	Expan- ded	Mature
0 day NTI	25.8	38.4	50.0	36.0	51.0	56.4		16.0	19.1	18.6		
5 day NTI	26.6	39.8	51.8	38.3	51.4	50.2		17.0	19.6	20.1		
10 day NTI	29.5	45.1	50.1	61.5	36.7	60.1	57.2	62.8	22.8	22.3	29.0	33.8
20 day NTI	26.2	39.3	50.3	65.6	37.2	60.4	62.3	67.4	18.6	23.6	32.3	36.8
5 day TI	29.4	34.7	39.8		39.2	48.5	52.2		20.4	18.9	19.9	
10 day TI	24.8	30.6	33.1	29.9	38.9	47.3	50.4	46.1	23.5	25.7	21.6	23.5
20 day TI	24.8	33.6	27.4	33.6	37.7	41.3	46.9	48.6	24.0	24.9	25.2	28.4

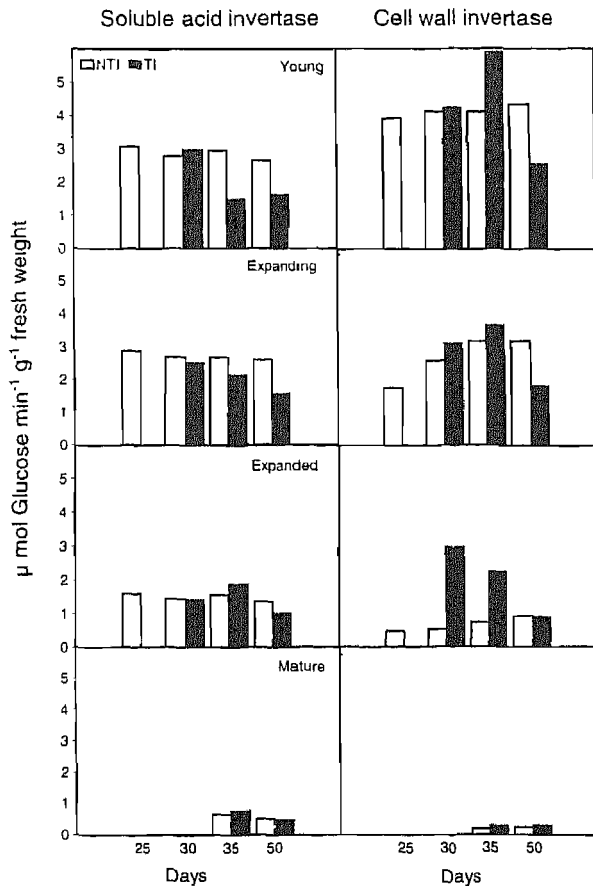


Fig 1. Activity of soluble acid invertase and cell wall invertase in leaves under tuber inducing (TI) and non tuber inducing (NTI) conditions

active in the leaves compared to soluble form and was 44% higher in young leaves of control (NTI) plants while it was 110% higher in the young leaves of (TI) plants. Maximum enzyme activity was found in young leaves of 10 day (TI) plants. Activity of cell wall form of the enzyme also declined rapidly as the leaves developed and was negligible in the mature leaves (Fig. 1).

### Sucrose synthase

Activity of sucrose synthase was negligible compared to total invertase activity and it plays a minor role in sucrose breakdown in the developing leaves (Fig. 2).

## DISCUSSION

**Plant growth:** Short days and low night temperatures constitute conditions that strongly stimulate tuberisation in potato (4, 23). When potato plants grown under non tuber inducing conditions (long days and high night temperature) were shifted to tuber inducing conditions, their vegetative growth

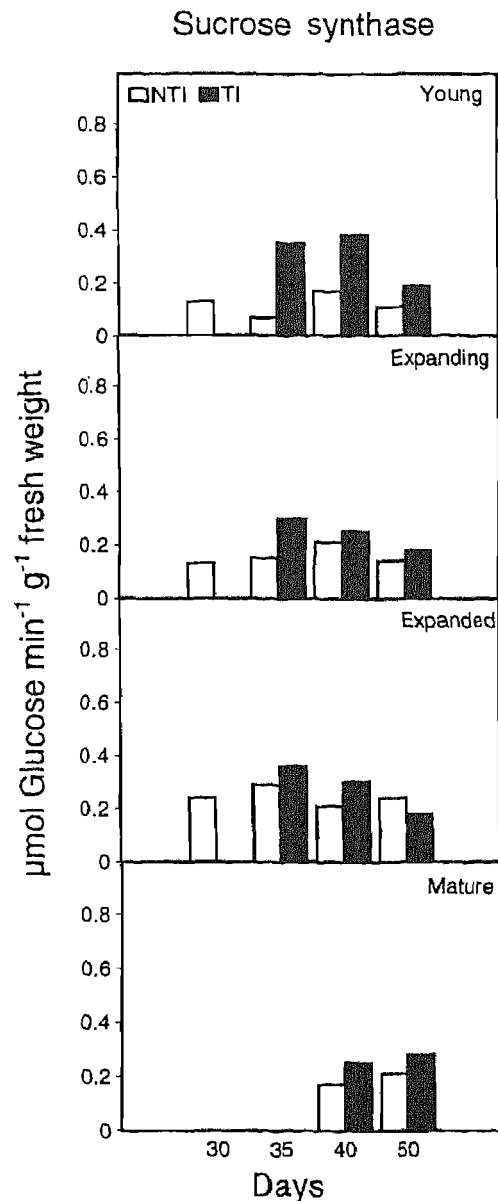


Fig 2. Activity of sucrose synthase in leaves under tuber inducing (TI) and non tuber inducing (NTI) conditions

slowed down as the tubers started developing. Leaves became broader and larger under tuber inducing conditions while they remained small and narrow under non tuber inducing conditions (data not shown). Developing tubers are a dominant sink for carbohydrates (19) and compete with haulms for the available assimilates resulting in slower haulm growth under strong tuberizing conditions. Our data support this view.

*Sink-to-source transition in leaves:* Carbohydrate metabolism in the leaves changes profoundly during development as they turn from net importers of carbohydrates to net exporters. This topic has been reviewed (31) and most of the work on sink to source transition has been descriptive in its analysis of changing physiology and structure. As the leaves develop, their photosynthetic capacity increases (34) and after becoming autotrophic, they begin to export photoassimilates. During the period of active photosynthesis, excess carbohydrates produced are stored as starch in the leaves which are later translocated to other developing tissues during the period of little or no photosynthesis (3). Tuberized plants under favourable conditions have low amounts of starch in their leaves as under such conditions rapidly growing tubers act as strong sinks and up to 90% of the carbohydrates produced in the leaves are translocated to the tubers within 24 hours (10, 20, 35). This is evident from the 20 day old (TI) leaves in which starch content increases very little from young to mature leaves (Table 2). However, under non tuber inducing conditions excess photosynthate is stored as starch in the leaves (Table 2) and roots (data not shown). Increased sink demand (rapidly growing tubers) result in an increased source output and mobilization

of reserve carbohydrates (27) resulting in lower starch content in roots and leaves compared to plants under non tuber inducing conditions.

Total sugars increase with leaf development and plants growing under non tuber inducing conditions show a higher concentration of total sugars as compared to control plants. High sucrose content has been reported in mature potato leaves (16) and also in leaves under high temperature when tuber sink demand is low. Our data is in conformity with these results.

Since sucrose is the main translocated sugar, we studied the enzymes that first act on it *i.e.* acid invertases and sucrose synthase. Our study has indicated that invertases are the main enzymes that act on the imported sucrose in young leaves while sucrose synthase is of only minor importance. Very high activity of cell wall form of acid invertase (44-110% more than soluble acid form in young leaves) indirectly indicates towards apoplastic unloading of sucrose along with simplastic route in very young potato leaves. Although Turgeon (31) has argued in favour of simplastic unloading of sucrose in young leaves on the basis of available reports (7, 11, 34) but has not ruled out the possibility of apoplastic unloading. Many workers have reported that soluble invertase in the main enzyme acting on the imported sucrose in the developing leaves (15, 22, 25, 26), however, our results indicate that cell wall invertase is the major enzyme acting on the imported sucrose in developing leaves in potato. Cell wall invertase is highly active in rapidly growing plant tissues like extension zones of root tips, elongating inter-nodes, emerging secondary roots and developing tap roots (8). The importance of extracellular cleavage of sucrose for assimilate

partitioning and source sink relations is indicated by the induction of sink metabolism in source leaves where extracellular yeast cell wall invertase has been over-expressed in source leaves (29). Rapid decline in invertase activity with leaf development is in line with the observation in many plants that net import of carbon declines with leaf development and ceases when the leaves are one sixth to one half fully grown (9, 14, 19, 31). Reduced growth and leaf expansion under tuber inducing conditions is supported by 27% reduction in the activity of cell wall invertase in young leaves under tuber inducing conditions.

It can be concluded from this study that the absence of a strong sink under non tuber inducing conditions in potato, results in distribution of photoassimilates in other vegetative parts resulting in increased haulm growth and starch deposition in leaves and roots. Cell wall invertase is the major sucrose cleaving enzyme in young leaves which indicates apoplastic unloading of imported sucrose and that the activity of invertase declines as the leaves become autotrophic and start exporting excess photoassimilates.

## LITERATURE CITED

1. Anderson, L.S. and J.E. Dale. 1983. The source of carbon for developing leaves of barley. *J. Exp. Bot.* **34**: 405-14.
2. Appeldoorn, N.J.G., S.M. de Bruijn, E.A.M. Koot-Gronsveld, R.G.F. Visser, D. Vreugdenhil and L.H. W. van der Plas. 1997. Developmental changes of enzymes involved in conversion of sucrose to hexose-phosphate during early tuberization of potato. *Planta* **202**: 220-26.
3. Basu, P.S. and J.S. Minhas. 1991. Heat tolerance and assimilate transport in different potato genotypes. *J. Exp. Bot.* **42**: 861-66.
4. Chapman, H.W. 1958. Tuberization in the potato plant. *Physiol. Plant.* **11**: 215-24.
5. Claussen, W., B.R. Loveys, and J.S. Hawker. 1985. Comparative investigations on the distribution of sucrose synthase activity and invertase activity within growing, mature and old leaves of some C<sub>3</sub> and C<sub>4</sub> plant species. *Physiol. Plant.* **65**: 275-80.
6. Dancer, J.E., W.D. Hatzfeld and M. Stitt. 1990. Cytosolic cycles regulate the turnover of sucrose in heterotrophic cell-suspension cultures of *Chenopodium rubrum*. *Planta* **182**: 223-51.
7. Ding, B., M.V. Parthasarathy, K. Niklas and R. Turgeon. 1988. A morphometric analysis of the phloem unloading pathway in developing tobacco leaves. *Planta* **176**: 307-18.
8. Eschrich, W. 1980. Free space invertase, its possible role in phloem unloading. *Berichte der Deutschen Botanischen Gesellschaft* **93**: 363-78.
9. Fellows, R.J. and D.R. Geiger. 1974. Structural and physiological changes in sugar beet leaves during sink to source conversion. *Plant Physiol.* **54**: 877-85.
10. Frommer, W. and U. Sonnewald. 1995. Molecular analysis of carbon partitioning in solanaceous species. *J. Exp. Bot.* **46**: 587-607.
11. Giaquinta, R. 1977. Sucrose hydrolysis in relation to phloem translocation in *Beeta vulgaris*. *Plant Physiol.* **60**: 339-43.
12. Giaquinta, R. 1978. Source and sink leaf metabolism in relation to phloem translocation-carbon partitioning and enzymology. *Plant Physiol.* **61**: 380-85.
13. Heckenberger, U., U. Roggatz, and U. Schurr. 1998. Effect of drought stress on the cytological status in *Ricinus communis*. *J. Exp. Bot.* **49**: 181-89.
14. Ho, L. C., R. G. Hurd, L. J. Ludwig, A. F. Shaw and J. H. M. Thornley. 1984. Changes in photosynthesis, carbon budget and mineral content during the growth of the first leaf of cucumber. *Ann. Bot.* **54**: 87-101.

15. Katsumi, M. and H. Kazama. 1978. Gibberellin control of cell elongation in cucumber hypocotyl sections. *Bot. Mag. Tokyo* **1**: 141-58.
16. Kolbe, H. and S. Stephan-Beckmann. 1997. Development, growth and chemical composition of the potato crop (*Solanum tuberosum* L.). II. Tuber and whole plant. *Potato Res* **40**: 135-53.
17. Larson, P. R. and R. E. Dickson. 1973. Distribution of imported <sup>14</sup>C in developing leaves of eastern cottonwood according to phyllotaxy. *Planta* **111**: 95-112.
18. Misra, J. B., E. V. Daniel, and Premchand. 1994. Sucrose synthase and sucrose phosphate synthase in potato: distribution of activities and variations in leaves. *Pl. Phy. Biochem. (Paris)* **32**: 131-36.
19. Moorby, J. 1968. The influence of carbohydrates and mineral nutrient supply on the growth of potato tubers. *Ann. Bot.* **32**: 57-68.
20. Moorby, J. 1978. In: *The potato crop* (P.M. Harris, Ed.), pp. 153-95, Chapman and Hall, London.
21. Morris, D.A. 1982. In: *Plant growth substances 1982, Proceedings of the 11th international conference on plant growth substances.* (P.F. Wareing, Ed.), pp. 659-68, Academic Press, New York.
22. Morris, D. A. and E. D. Arthur. 1984. An association between acid invertase activity and cell growth during leaf expansion in *Phaseolus vulgaris* L. *J. Exp. Bot.* **35**: 1369-79.
23. Nagarajan, S. and K. C. Bansal. 1990. Growth and distribution of dry matter in a heat tolerant and a susceptible potato cultivar under normal and high temperature. *J. Agron. Crop Sci.* **165**: 306-11.
24. Nelson, N. 1944. A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* **153**: 375-80.
25. Ricardo, C. P. P. and T. ap Rees. 1970. Invertase activity during the development of carrot roots. *Phytochemistry* **9**: 239-47.
26. Roberts, D. W. A. 1953. Physiological and biochemical studies in plant metabolism.VIII. The distribution of invertase in the first leaf of *Khapli* wheat. *Can. J. Bot.* **31**: 367-82.
27. Sale, P. J. M. 1974. Productivity of vegetative crops in a region of high solar input. III. carbon balance of potato crops. *Aust. J. Plant Physiol.* **1**: 283-96.
28. Schaffer, A. A., O. Sagee, E. E. Goldschmidt and R. Goren. 1987. Invertase and sucrose synthase activity, carbohydrate status and endogenous IAA levels during *Citrus* leaf development. *Physiol. Plant.* **69**: 151-55.
29. Stitt, M. and U. Sonnewald. 1995. Regulation of metabolism in transgenic plants. *Ann. Rev. Plant Physiol. Plant Mol. Biol.* **46**: 341-68.
30. Tsai, C. Y., F. Salamini and O. E. Nelson. 1970. Enzymes of carbohydrate metabolism in the developing endosperm of maize. *Plant Physiol.* **46**: 299-306.
31. Turgeon, R. 1989. The sink source transition in leaves. *Ann. Rev. Plant. Physiol. Plant Mol. Biol.* **40**: 119-38.
32. Turgeon, R. and J. A. Webb. 1975. Leaf development and phloem transport in *Cucurbita pepo*: carbon economy. *Planta* **123**: 53-62.
33. Walter, A. and U. Schurr. 1999. The modular character of growth in *Nicotiana tabacum* plants under steady state nutrition. *J. Exp. Bot.* **50**: 1169-77.
34. Wolf, S. 1993. Effect of leaf age on photosynthesis, carbon transport and carbon allocation in potato plants. *Potato Res.* **36**: 253-62.
35. Wolf, S., A. Marani and J. Rudich. 1990. Effect of temperature and photoperiod on assimilate partitioning in potato plants. *Ann. Bot.* **66**: 513-20.
36. Yemm, E. W. and A. J. Willis. 1954. The estimation of carbohydrates in plant extracts by anthrone. *Biochem. J.* **57**: 508-14.

---

MS Received: 31.10.2002

## CHEMICAL MATURITY OF POTATO PROCESSING CULTIVARS GROWN IN WESTERN UTTAR PRADESH\*

Dinesh Kumar<sup>1</sup>, S.V. Singh<sup>1</sup> and S.K. Pandey<sup>2</sup>

**ABSTRACT:** Six potato cultivars including four Indian and two exotic were evaluated for chemical maturity at three dates of harvest. Minimum reducing sugar level was achieved at 80 days of harvest in cvs. Atlantic and FL-1533, at 90 days in cv. Kufri Chipsona-1 and at 100 days in cvs. Kufri Chipsona-2, Kufri Jyoti and Kufri Lauvkar. The lowest sucrose content was obtained at 90 days in cv. Kufri Chipsona-1 and at 100 days harvest in rest of the five cultivars. The sucrose content of <150 mg/100g fresh weight was not obtained in any of the cultivars at any stage. Acceptable chip color was attained in cvs. Kufri Chipsona-1 & Chipsona-2 at 90 days of harvest while in Atlantic it was 80 days. Except for cvs. Kufri Jyoti and Kufri Lauvkar, all other four cultivars had dry matter content of more than 20 percent at 80 days of harvest.

### INTRODUCTION

For making good quality potato chips, the content of reducing sugars in potatoes is required to be low (10). The principal reason for the critical role of hexose reducing sugars in potato quality is the fact that frying at high temperature results in a typical Maillard reaction between these sugars and the amino acid groups of nitrogenous compounds, resulting in a dark colored, bitter tasting product (17). Sucrose, another disaccharide, does not participate directly in Maillard reaction, but several workers have tried to relate post-storage reducing sugar content to sucrose content at harvest (16, 21). Sugar contents in potato are complex, and the concentration levels vary according to the maturity of the harvested crop as well as the environment in which the crop is grown (2, 6, 12). Burton (1) states that apart from cultivar differences, maturity may be one of the

principle factors affecting sugar content in potatoes. The initial level of sugars-reducing sugars as well as sucrose- at the time of harvesting is affected by maturity (5). There is considerable variation among cultivars with regards to their susceptibility to the degree of maturation and related physiological processes (5).

Potatoes are physically mature when wines have senesced and tubers have obtained a degree of skin-set, while physiological maturity of tubers occurs when a peak of dry matter is attained, which usually coincides with a minimum sugar content (3). However, tuber may be physically mature without being chemically mature (i.e. low sugar concentration), the level of sucrose in chipping potatoes should be 150 mg./100g or less at harvest to minimize accumulation of reducing sugars (glucose and fructose) over long-term storage (22).

---

<sup>1</sup>Central Potato Research Institute Campus, Modipuram-250 110 (Uttar Pradesh)

<sup>2</sup>Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh)

\*CPRI Publication No.-1752

The North-central plains comprising western Uttar Pradesh and Madhya Pradesh in Indian plains are major growing areas for chipping potatoes. The major potato cultivars used for chipping include Kufri Jyoti, Kufri Lauvkar, Kufri Chipsona-1 and Kufri Chipsona-2 besides occasionally used exotic cultivar Atlantic and Fritolay-1533 (FL-1533). The information on chemical maturity of these cultivars was lacking with respect to western Uttar Pradesh. The present study was, therefore, undertaken with the aim to investigate the sugar levels at different harvest dates so that the information generated can help the growers and processors to take decisions as per the intended use of potatoes.

## MATERIALS AND METHODS

Potatoes were grown for two seasons i.e. 1999-2000 and 2000-2001 at the Central Potato Research Institute Campus, Modipuram. Six cultivars, viz., Kufri Chipsona-1, Kufri Chipsona-2, Kufri Jyoti, Kufri Lauvkar, Atlantic and Fritolay-1533 were planted in third week of October in Randomized Complete Block Design with three replications. The crop was raised as per the recommended cultural practices for the region (150N: 80P<sub>2</sub>O<sub>5</sub>: 100K<sub>2</sub>O). The haulms were cut at 80, 90 and 100 days after planting. Tubers were harvested ten days after haulm cutting and graded into processable and non-processable grades. Tubers more than 40 mm in diameter were taken as processing grade and used for further analyses. Fifteen tubers were selected randomly from each replication and analysed for reducing sugars (13), sucrose (24), chip color and dry matter content. Chip colour was determined by frying 1.75 mm thick slices in

sunflower oil at 180°C till bubbling stopped, and the colour score was given to chips on a scale of 1 to 10 (1 being the lightest and highly acceptable and 10 the darkest and unacceptable) (9). Dry matter content was determined by drying more than 50 g finely chopped and mixed tuber pieces initially at 80 °C and then at 65 °C till constant weight. Five tubers were used each for sugar, chip colour and dry matter analysis. All analysis were carried out in triplicate and the data were analyzed in a two factor randomized complete block design combined over locations (or combined over years) using the statistical software MSTAT-C.

## RESULTS AND DISCUSSIONS

The analysis of variance showed that the main effects of the cultivar and days after planting were significant ( $P \leq 0.01$ ) for all the processing parameters studied (Table 1). Two-way interaction between the cultivar × days after planting was significant ( $P \leq 0.01$ ) only for reducing sugars and sucrose. This suggested that the effects of days after planting was not uniform over the cultivars tested for reducing sugars and sucrose.

**Reducing sugars:** The mean values of reducing sugar content decreased with crop maturity, but the decrease from 90 days harvest to 100 days harvest was not significant (Table 2). At 80 days harvest Atlantic tubers had significantly lower reducing sugars as compared to cvs. Kufri Chipsona-1, Kufri Jyoti and Kufri Lauvkar, and there was no significant decline in reducing sugars at subsequent dates of harvest. This is expected since the cv. Atlantic is considered to be an early maturing variety with average number of tubers in the range of 4 to 6. Reducing

Table 1. Sources of variation and their effect on sugar content and processing quality of potatoes

Source of Variation	Degree of Freedom	Mean squares			
		Reducing sugars	Sucrose	Chip color	Dry matter
Date of harvest (D)	2	33894.096**	133150.954**	7.108**	31707**
Cultivar (C)	5	43746.634**	32228.596**	18.003**	66.382**
DC	10	5935.307**	6085.642**	0.574	1.060
Error	68	2114.621	1788.512	0.604	1.246

\*\* Significant at 0.01 levels

Table 2. Sugars, chip color and dry matter content in potato processing cultivars at different dates of harvest

Cultivar	Days after planting			Means
	80	90	100	
<b>(a) Reducing Sugars (mg/100g fresh weight)</b>				
Kufri Chipsona-1	142.80	62.02	63.31	89.38
Kufri Chipsona-2	116.74	102.73	62.71	94.06
Kufri Jyoti	244.27	180.22	143.69	189.39
Kufri Lauvkar	246.77	106.13	158.06	170.32
Atlantic	69.13	65.49	60.77	65.13
Fritolay-1533	106.87	105.44	106.55	106.28
Means	154.43	103.67	99.18	
<b>(b) Sucrose (mg/100g fresh weight)</b>				
Kufri Chipsona-1	292.40	180.83	175.68	216.30
Kufri Chipsona-2	440.98	290.83	220.91	317.58
Kufri Jyoti	251.34	190.90	161.31	201.18
Kufri Lauvkar	257.92	232.47	178.15	222.85
Atlantic	312.55	203.27	172.83	229.55
Fritolay-1533	247.05	211.76	180.62	213.14
Means	300.37	218.34	181.58	
<b>(c) Chip color</b>				
Kufri Chipsona-1	2.80	1.98	2.47	2.42
Kufri Chipsona-2	3.52	2.58	2.48	2.86
Kufri Jyoti	5.41	4.15	4.18	4.58
Kufri Lauvkar	4.45	3.92	4.32	4.22
Atlantic	2.80	1.88	1.59	2.09
Fritolay-1533	3.20	3.13	2.45	2.93
Means	3.70	2.94	2.91	
<b>(d) Dry matter (%)</b>				
Kufri Chipsona-1	20.87	21.86	22.14	21.62
Kufri Chipsona-2	21.81	22.47	24.05	22.77
Kufri Jyoti	17.63	18.23	20.12	18.66
Kufri Lauvkar	19.16	19.22	19.87	19.42
Atlantic	22.20	23.46	24.52	23.39
Fritolay-1533	21.31	22.51	23.50	22.44
Means	20.50	21.29	22.37	

## CD VALUES:

	Date of harvest (D)	Cultivar (C)	D x C
Chip color (CC)	0.487**	0.689**	NS
Dry matter (DM)	0.700**	0.990**	NS
Reducing sugars (RS)	28.83**	40.77**	70.62**
Sucrose (Suc)	26.52**	37.50**	64.95**

sugars decreased significantly in cv. Kufri Chipsona-1 up to 90 days harvest only, while

in cv. Kufri Chipsona-2, the lowest levels were achieved at 100 days harvest, though the

decrease was not significant. Based on the results, it appears that cv. Kufri Chipsona-2 may require further maturity to achieve still lower reducing sugars. The present trial was conducted with NPK levels that are now considered as sub-optimum and Singh *et al.* (19) have recommended higher doses of NPK for Chipsona varieties and harvesting at 100-120 days. Both fertilizer and maturity stages may affect the reducing sugar content of Chipsona varieties. Among the varieties, lowest mean reducing sugar content was achieved in cv. Atlantic, but the difference in reducing sugars content was not significant when compared with either cv. Kufri Chipsona-1 or Kufri Chipsona-2. Both Kufri Jyoti and Kufri Lauvkar had significantly higher reducing sugars contents as compared to other four varieties. The leaves of Kufri Jyoti started showing signs of senescence at an early stage; hence it is also speculated that the fertilizer requirements of this variety may also be slightly higher. Surprisingly, Fritolay-1533, which otherwise is known to be a low reducing sugar cultivar, had significantly higher reducing sugar contents than cv. Atlantic. As sugar content in potato tubers is influenced by several factors including tuber temperature, crop maturity besides the genotype (20), such kind of variations can be expected. This is corroborated by higher value of coefficient of variation obtained for reducing sugars. The concentration and relative proportions of the individual sugars are variable both between tubers on the same plant and between plants growing in close proximity (4). As both day-length and temperatures in Indo-Gangetic plains are in contrast to European or American conditions, there is a need to quantify the different factors

affecting reducing sugars content in processing varieties specifically for sub-tropical Indian conditions. Given that the optimum reducing sugars for making potato chips are below 0.1% (15), except cvs. Kufri Jyoti and Kufri Lauvkar, all other four cultivars were suitable at 100 days, Kufri Chipsona-1 at 90 days and Atlantic at all three stages of harvest.

**Sucrose:** A significant and steady decline in mean sucrose levels occurred from 80 days to 100 days harvest (Table 2). In five out of six cultivars, lowest sucrose levels were obtained at 100 days harvest. In case of cv. Kufri Chipsona-1, decrease in sucrose content was not significant from 90 to 100 days stage. Sucrose levels decreased in cv. Kufri Lauvkar from 90 to 100 days harvest with simultaneous increase in reducing sugar content. This may be possible because of sucrose breakdown, i.e. invertase action, as Kufri Lauvkar is also an early maturing variety. Taking varietal means Kufri Chipsona-2 had highest sucrose contents. Again, as discussed earlier, the sucrose contents may further decrease in Kufri Chipsona-2 and even in Kufri Chipsona-1, if the growing period is further extended by using latest recommended fertilizer doses. Marwaha (9) reported decrease in sucrose contents after 70 days of planting. The values of sucrose obtained are less as reported earlier (7), possibly because of estimation method.

**Chemical maturity in processing varieties:** Chemically mature potato tubers are those that have reached their lowest levels of sucrose (15). As per this definition, cv. Kufri Chipsona-1 at 90 days, and rest of five varieties became chemically mature at 100 days harvest. But according to Marwaha (9) minimum reducing sugar content should be taken as the basis for

chemical maturity of potatoes under short day conditions, and this should be considered in conjunction with optimum tuber yield and specific gravity or dry matter content of tubers in determining the optimum maturity of potatoes for chipping. This seems to be optimum criteria if potatoes are to be used for immediate processing after harvest or after short-term storage. cv. Kufri Chipsona-1 accordingly was suitable at 90 days maturity and cv. Kufri Chipsona-2 at 100 days while cv. Atlantic even at 80 days. (dry matter data presented in Table 2). Mazza (11) studied the correlation between quality parameters of potatoes during growth and long-term storage, and stated that quality parameters of potatoes are not sufficiently stable to serve as a general measure of prediction under all conditions. This means that each potato production area of the world may have to develop relationships which best reflects its environmental conditions and production, storage and utilization practices.

Although sucrose does not participate in the unfavourable non-enzymic browning of processed products directly, it serves as a substrate for reducing sugar production via the storage activated enzyme invertase (16). According to Sowokinos (21), potatoes capable of reaching low sucrose levels prior to harvest demonstrate superior processing quality for chipping directly from intermediate temperature storage (11.7 °C). The levels of sucrose in chipping potatoes should be 1.5 mg/g (150 mg/100g fresh wt.) or less at harvest to minimize accumulation of reducing sugars over long-term storage (22). None of the varieties investigated in the present study achieved these sucrose levels. Nevertheless, the values of sucrose were below 200mg/100g

fresh wt. in cvs. Kufri Chipsona-1 and Kufri Jyoti at 90 days and in all varieties at 100 days, except in cv. Kufri Chipsona-2. In India, the Indo-Gangetic plains experience a hot summer after potato harvest, necessitating potato storage at lower temperatures to make round the year availability of potatoes. Potato storage at low temperatures of 2-4°C accumulates excessive reducing sugars making potatoes unacceptable for processing into chips (1). In India, storage at 10-12°C with CIPC is being practiced to make available processing grade tubers to the industry during off-season. Except for the small quantity of fresh harvests at different times of the year and from different regions, major chunk of potatoes is grown in Indo-Gangetic plains which are harvested in February-March. Therefore, it is essential that varieties being stored at elevated temperatures should maintain low reducing sugar contents for as long as possible. It is essential that the pre- and post-harvest management factors should be standardized in such a manner that the potatoes should have low reducing sugars and sucrose levels at the time of storage. The sugar balance of the potato tuber is governed by many inter-related metabolic pathways and is subject to significant genetic and environmental control (4). Tuber initiation, growth and development and post-harvest physiology are characterized by significant modifications in hexose and sucrose concentrations and in the ratios of hexose: sucrose and glucose: fructose (4). This standardization is essential for each variety under a particular geographical location. It has been shown that quantitative relationships between chip colour and specific compositional or environmental factors determined for one cultivar cannot be used to predict the color of chips made from other cultivars (8) Sowokinos

(23) suggested that the clones may vary in their ability to form reducing sugars in storage, and this variability is defined as Glucose Forming Potential (GFP). GFP is influenced by, in part, by differences in invertase activity and/or compartmentalization of sucrose among the clones.

**Chip colour:** Taking mean values of at different dates of harvest, chip colour improved with crop maturity, but the improvement from 90 to 100 days stage was not significant (Table 2). Among varietal means, best chip colour was obtained in cv. Atlantic followed by Chipsona varieties and Fritolay-1533. If colour score of 3 is taken as upper limit of acceptability, cvs. Kufri Chipsona-1 and Atlantic yielded acceptable chips at all three dates of harvest. In cv. Kufri Chipsona-2 a colour score of < 3 was obtained at 90 and 100 days maturity, while in cv. Fritolay-1533, it was at 100 days only. The results of Fritolay 1533 and Kufri Chipsona-1 are different from that reported earlier (7). This could again be due to the year-to-year variations in climatic conditions. The higher values of coefficient of variation obtained both in case of chip colour and reducing sugar contents validates this assumption. The chip colours in case of cvs. Kufri Jyoti and Kufri Lauvkar were not acceptable at any date, and the varietal means were also significantly higher than rest of four varieties. Both cvs. Kufri Jyoti and Kufri Lauvkar are suitable for chips making when grown in Malwa region of Madhya Pradesh (18 and unpublished data). This again shows the effect of location and climatic conditions besides genotypes on potato processing quality. In a study conducted at Modipuram -location in which free sugars were monitored in cv. Kufri Lauvkar and cv.

Atlantic during development, it has been shown that both reducing sugars and sucrose contents were higher in cv. Kufri Lauvkar as compared to cv. Atlantic (3). Nelson and Sowokinos (14) observed that the effect of harvest date on chip colour depends to a great extent on potato variety; in their study six potato varieties did not show any relation to harvest date. In case of cvs. Kufri Jyoti and Kufri Lauvkar the chip colour decreased from 80 to 90 days, but was not in acceptable range. In cv. Kufri Lauvkar chip colour increased from 90 to 100 days, which may be due to the increase in reducing sugars content. Marwaha (9) reported improvement in chip colour with maturity, and Kufri Lauvkar yielded acceptable chips at 90 days harvest.

**Dry matter:** The means of dry matter values at different dates of harvest showed significant increase in dry matter content from 80 to 100 days maturity (Table 2). Taking varietal means of dry matter, cvs. Atlantic and Kufri Chipsona-2 had significantly higher dry matter than cvs. Kufri Chipsona-1, Kufri Jyoti and Kufri Lauvkar. A desirable dry matter content of 20% or more could be obtained in cvs. Kufri Chipsona-1, Kufri Chipsona-2, Atlantic and Fritolay-1533 even at 80 days of harvest. An increase in dry matter content was observed in cvs. Kufri Jyoti and Kufri Lauvkar only at 90 to 100 days. This could most probably be due to the water loss, as both the varieties are early maturing and temperature rise as date of harvest is advanced (along with 10 days of curing under such temperatures). A dry matter content of 24 per cent or above was achieved in cvs. Kufri Chipsona-2 and Atlantic at 100 days harvest. Higher dry matter is an index of better processing quality, as it

Table 3. Total and percent process grade tuber yields at different dates of harvest

Cultivar	Dates of harvest							
	80		90		100		Means	
	TY*	PPG**	TY	PPG	TY	PPG	TY	PPG
Kufri Chipsona-1	43.97	60.44	47.86	64.54	52.86	76.24	48.23	67.07
Kufri Chipsona-2	31.43	40.18	33.89	60.94	39.60	75.36	34.97	58.82
Kufri Jyoti	36.52	64.33	46.04	77.69	46.42	83.68	42.99	75.23
Kufri Lauvkar	40.35	81.90	43.28	86.68	43.28	91.89	42.30	86.66
Atlantic	32.51	85.63	36.53	88.52	40.22	92.39	36.42	88.85
Fritolay-1533	36.13	73.83	43.94	80.47	45.68	86.40	41.96	80.23
Means	36.82	67.72	41.92	76.47	44.67	84.24		

CD Values:		
	Total yields (TY)	Percent process grade (PPG)
Cultivar (C)	6.42**	9.45**
Date of Harvest (D)	7.60**	11.18**
CD	9.63	14.18

\*TY= Total yield (Kg/ 12.86 m<sup>2</sup> plot); \*\*PPG= Percentage of processing grade

results in lesser oil absorption and less frying time (15).

**Process grade percentage:** Mean values of percent process grade tubers increased with maturity, but the increase was significant only at 100 days of harvest (Table 3). In case of individual cultivars increase in percentage was observed upto 100 days in cvs. Kufri Chipsona-2, Kufri Jyoti and Fritolay-1533, and there was no significant increase in cvs. Atlantic and Kufri Lauvkar. Highest total yield (mean) was achieved in cv. Kufri Chipsona-1, which was significantly higher than cvs. Kufri Chipsona-2 and Atlantic. Increase in total tuber yields was non-significant in cv. Kufri Lauvkar beyond 80 days of harvest.

**Overall performance:** As suggested by Marwaha (9), the minimum reducing sugar contents in tubers in conjunction with optimum specific gravity, dry matter content and tuber yield should be considered as the basis for determining optimum processing maturity of cultivars under short days. In that respect processing varieties, except cvs. Kufri Jyoti and Kufri Lauvkar (because of poor chip

colour) required 100 days for optimum maturity. Cultivar Kufri Chipsona-1 achieved low reducing sugars and optimum dry matter at 90 days harvest also, but due to increase in process grade yields, the 100 days have been mentioned. The lowest sucrose levels were also obtained at 100 days in all the cultivars except cv. Kufri Chipsona-1. Depending upon the requirement of material, the varieties can be harvested at early dates also, by compromising certain yields. That way cv. Kufri Chipsona-1 yields good dry matter and chip color at 90 days, while Atlantic at 80 days. But the higher values of sucrose at early dates may pose problems during storage at elevated temperatures.

## ACKNOWLEDGEMENTS

The authors are grateful to the Director, Central Potato Research Institute and Joint-Director, Central Potato Research Institute Campus, Modipuram for providing all the facilities. Thanks are also due to the Head of the Division, Crop Physiology and Post-harvest Technology for interest in the work and Mrs. Vineet Sharma and Sh. Dinesh Kumar for

excellent technical and statistical help, respectively.

## LITERATURE CITED

1. Burton, W.G. 1966. *The potato*. H. Veenman and Zonen, Wageningen, the Netherlands.
2. Burton, W.G and A.R. Wilson. 1978. The sugar content and sprout growth of tubers of potato cultivar Record, grown in different localities when stored at 10, 2 and 20°C *Potato Research* 21: 145-50.
3. CPRI. 2002. Annual Report, CPRI, Shimla. pp. 34.
4. Davies, H.V and R. Viola. 1994. Control of sugar balance in potato tubers. In: *The molecular and cellular biology of the potato* (W.R Belknap and M.E. Vayda, Eds.) pp. 67-80. CAB International, Wallingford, U.K.
5. Es, A.V and K.J. Hartmans. 1987. Starch and sugars during tuberization, storage and sprouting. In: *Storage of potatoes*. (Rastovski *et al.*, Eds.), pp. 79-113 Pudoc, Wageningen, the Netherlands.
6. Iritani, W.M and L.D. Weller. 1977. Changes in sucrose and reducing sugar content of Kennebec and Russet Burbank tubers during growth and post-harvest holding temperatures. *Am. Potato J.* 54: 395-404.
7. Kumar, D., S.V. Singh and S.K. Pandey. 2001. Potato processing quality as influenced by date of haulm cutting. *J. Indian Potato Assoc.* 28: 167-68.
8. Loiselle, F., G.C.C.Tai and B.R. Christie. 1990. Genetic components of chip color evaluated after harvest, cold storage and reconditioning. *Am. Potato J.* 67: 633-46.
9. Marwaha, R.S. 1998. Factors determining processing quality and optimum processing maturity of potato cultivars grown under short days. *J. Indian Potato Assoc.* 25: 95-102.
10. Marquez, G. and M.C. Anon. 1986. Influence of reducing sugars and amino acids in the color development of fried potatoes. *J. Food Sci.* 51: 157-60.
11. Mazza, G. 1983. Correlations between quality parameters of potatoes during growth and long-term storage. *Am. Potato J.* 60: 145-59.
12. Miller, R.A., J.D. Harrington and G.D. Kuhn. 1975. Effect of variety and harvest date on tuber sugars and chip color. *Am. Potato J.* 52: 379-86.
13. Nelson, N. 1944. A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* 153: 375-80.
14. Nelson, D.C. and J.R. Sowokinos. 1983. Yield and relationships among tuber size, sucrose and chip color in six potato cultivars on various harvest dates. *Am. Potato J.* 60: 949-58.
15. Pavlista, A.D. and J.C. Ojala. 1997. Potatoes: Chips and French fry Processing. In *Processing vegetables-science and technology* (O. Smith *et al.*, Eds.), pp 287-84. Technomac Publishing Co. Lancaster, U.S.A.
16. Pressey, R. 1969. Role of invertase in the accumulation of sugars in cold stored potatoes. *Am. Potato J.* 46: 291-97.
17. Shallenberger, R.S., O. Smith and R.H. Treadway. 1959. Role of the sugars in the browning reaction in potato chips. *J. Agric. Food Chem.* 7: 274-77.
18. Singh, S.V., D. Kumar and S.K. Pandey. 2001. Scope of new processing varieties Kufri Chipsona-1 and -2 in Malwa region of Madhya Pradesh. *J. Indian Potato Assoc.* 28: 21-23.
19. Singh, S.V., S.K. Pandey, D. Kumar, P. Kumar and S.M.Paul Khurana. 2002. *Production of potatoes for processing*. Exten. Bull. No. 33. CPRI, Shimla. 6 pp.
20. Smith, O. 1975. Potato Chips In: *Potato processing*. 3<sup>rd</sup>Ed. pp. 305-402. The Avi Publishing Co., Inc. Westport, Conn (USA).
21. Sowokinos, J.R. 1978. Relationship of harvest sucrose content in processing maturity and storage life of potatoes. *Am. Potato J.* 55: 333-45.
22. Sowokinos, J.R. and D.A. Preston. 1988. Maintenance of potato processing quality by chemical maturity monitoring (CMM). Station Bulletin 586, University of Minnesota, St. Paul (USA).
23. Sowokinos, J., B. Morgan, M. Sleeper and I. Shea. 1989. Glucose forming potential (GFP). A tool to screen for superior processing potato clones. *Am. Potato J.* 66:545.
24. Van Handell, E.V. 1968. Direct microdetermination of sucrose. *Anal. Biochem.* 22: 280-83.

---

MS Received: 12.08.2003

# RELATIONSHIP BETWEEN UNDER WATER WEIGHT AND SPECIFIC GRAVITY, DRY MATTER AND STARCH CONTENT OF POTATOES GROWN IN INDIA\*

R. Ezekiel, Brajesh Singh and J. Gopal<sup>1</sup>

**ABSTRACT:** The under water weight (UWW), specific gravity (SG), dry matter (DM) and starch content of potatoes were determined in tubers grown at Kufri, Jalandhar, Modipuram and Patna. Linear regression equations and correlation coefficients were worked out for different pairs of values, for each location. The regression equation for Kufri (hills) was different from those for other locations in the plains. Regression equations for the relationship of UWW with SG, DM and starch content are presented in this paper. Based on these equations, a conversion table has been developed for the first time for potatoes grown in India, for the benefit of the potato processing industry.

## INTRODUCTION

Measurement of specific gravity of potatoes has been widely used as a tool for quick estimation of dry matter and starch content in potato tuber lots. For specific gravity determination, methods like brine solution (13), hydrometer (9) and weight of potatoes in air and water (2) have been used. On the basis of estimation of a large number of samples, relation between specific gravity and dry matter content of potatoes has been developed in the form of regression equations by several workers in Europe (14), America (5) and India (13). However, this relationship has been found to vary with the variety, location, season as well as the year of cultivation (1, 12). One of the reasons for such differences was suggested as the variation in the intercellular space in the tuber tissue (1). Besides, the temperature of potatoes and of the water in which the potatoes are weighed may also influence specific gravity.

Since the dry matter content of tubers is one of the important considerations for potato processors, it is important to know about the variability in dry matter content in Indian potato varieties grown at different locations. Verma *et al.* (13) determined specific gravity in some Indian potato varieties and cultures following the brine solution method and worked out a relationship between specific gravity and dry matter content of potatoes for these locations. Starch content in Indian potato varieties is also important as many potential potato starch manufacturers in India are interested in this. No information is available on the relationship between under water weight and starch content in Indian potato varieties.

Relationship between under-water weight and specific gravity, dry matter and starch content has been worked out in developed countries and conversion charts are available (11) for use by the potato processing industry

---

\*CPRI Publication No. 1708

<sup>1</sup>Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh)

in those countries. Such a chart is not available in India and charts developed in Europe or America can not be used in India because as already pointed out the relationship varies with location, variety, soil type and cultural conditions. Therefore, an attempt has been made here to work out the relationship between under water weight and specific gravity, dry matter and starch content of potatoes grown in India and to develop a conversion table that can be used by the potato processing industry in India.

## MATERIALS AND METHODS

Potatoes were grown at four different locations and used in this experiment.

**Kufri:** The potato crop of Indian potato varieties and advanced hybrids was grown during long-day summers in 2000 and 2001 at Central Potato Research Station, Kufri (32°N, 77°E, 2501m amsl), following the recommended package of practices. Fertilizer was applied at the rate of 120 kg nitrogen (100 kg at planting and 20 kg at the time of earthing up), 100 kg P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O per hectare in the form of calcium ammonium nitrate (CAN), single super phosphate (SSP) and muriate of potash (MOP), respectively. Seed tubers were planted at a spacing of 60 cm x 20 cm. Planting was done in the last week of April and the tubers were harvested in the 3<sup>rd</sup> week of September after full maturity during both the years and required quantity of tuber samples was collected. A total of 47 varieties/ advanced hybrids were used for the experiment.

**Modipuram:** Six varieties, viz., Kufri Chandramukhi, Kufri Badshah, Kufri Lalima, Kufri Bahar, Kufri Sindhuri and Kufri Jyoti

were grown at Central Potato Research Institute Campus, Modipuram (29°N, 76°E, 222m amsl) during 1999-2000 following recommended package of practices. Fertilizer was applied @ 200 kg N (half at planting in the form of CAN and half at earthing up in the form of urea), 100 kg P<sub>2</sub>O<sub>5</sub> in the form of SSP and 100 kg K<sub>2</sub>O/ha in the form of MOP. The spacing followed was 60 cm x 20 cm. Planting was done during the 2<sup>nd</sup> week of October and the crop was harvested during the 3<sup>rd</sup> week of February. Tuber samples of these varieties were collected for the experiment.

**Jalandhar:** At Central Potato Research Station, Jalandhar (31°N, 75°E, 237m amsl), four varieties, viz., Kufri Badshah, Kufri Sindhuri, Kufri Jyoti and Kufri Chandramukhi were grown during 1999-2000 following the recommended package of practices. Fertilizer was applied @ 150 kg N (half at planting in the form of CAN and half at earthing up in the form of urea), 80 kg P<sub>2</sub>O<sub>5</sub> in the form of SSP and 120 kg K<sub>2</sub>O/ha in the form of MOP, and the spacing followed was 60 cm x 20 cm. The crop was planted in the 1<sup>st</sup> week of October and harvested in the 1<sup>st</sup> week of February. Required quantity of samples was collected for the experiment.

**Patna:** Six potato varieties, viz., Kufri Jyoti, Kufri Ashoka, Kufri Lalima, Kufri Chandramukhi, Kufri Badshah and Kufri Sindhuri were grown at Central Potato Research Station, Patna (25°N, 85°E, 53m amsl) during 1999-2000, following the recommended package of practices. Fertilizer was applied at the rate of 180 kg N (half at planting in the form of CAN and half at earthing up in the form of urea), 60 kg P<sub>2</sub>O<sub>5</sub> in the form of SSP

and 120 kg K<sub>2</sub>O/ha in the form of MOP, and the spacing followed was 60 cm x 20 cm. The crop was planted during the 2<sup>nd</sup> week of November and harvested during the 1<sup>st</sup> week of March 2000. Required quantity of tuber samples was collected for the experiment.

Tubers grown at Kufri, Modipuram, Jalandhar and Patna were brought to Shimla and all the determinations were made at CPRI, Shimla.

**Measurement of specific gravity:** For specific gravity determination, the normal procedure followed by the potato processing industry was used. Tubers were weighed in air and then under water using a triple beam specific gravity balance (Sky Light Industries, Ghaziabad, UP). The sample size used was 5 kg and the specific gravity was calculated using the following formula:

**Specific gravity:**  $5000/5000-UWW$  (5000 is the wt of potatoes in air in grams)

**Estimation of dry matter and starch content:** The dry matter content was determined in three replicated samples by the oven-drying method. Tuber samples were diced, mixed thoroughly and 50 g was weighed and dried at 80°C to obtain dry weight. Starch content was determined by the method of Hodge and Hofreiter (4) on dry weight basis and the values were converted to percent starch content on fresh weight basis. Dried tuber samples were treated with 80% alcohol to remove sugars and then the starch was extracted with perchloric acid. After extraction the starch was hydrolyzed to glucose and the colour was developed with anthrone, which was compared with the standard graph of glucose.

The values of correlation coefficient and regression equations were obtained using MSTAT 4.0C package of computers following the method of Gomez and Gomez (3). The conversion table was prepared using Fox Pro data base system.

## RESULTS AND DISCUSSION

The pooled data of two years from hills showed a significant positive correlation between UWW and specific gravity, UWW and percent dry matter content as well as UWW and percent starch content. However, the coefficient of correlation was low between specific gravity and dry matter content ( $r = 0.45$ ).

Potatoes harvested from the plains showed considerable variability over locations for a given variety and therefore, the regression equations for individual locations were different from one another (Table 1). This agrees with the work of Verma *et al.* (13) who showed that the regression equation varied with location. After pooling all the values for the plains, significant positive relations were obtained between the UWW and dry matter content, starch content and specific gravity as well. Unlike hills harvest, the coefficient of correlation between specific gravity and dry matter content was higher in this case ( $r = 0.81$ ). Verma *et al.* (13) had also noticed variations in the equations obtained between the specific gravity and dry matter content over locations. They had suggested that it might be desirable to use the individual regression equations to estimate the dry matter content of potatoes grown at different locations. Since they had determined specific gravity directly, they got a better relationship

Table 1. Relationship between UWW and specific gravity, dry matter and starch content of potatoes grown in hills and plains

Location & Year	Parameters		Regression equation	Coefficient of correlation
	X	Y		
Hills (2000 & 2001 pooled)	UWW	DM	$Y = 6.28 + 0.047x$	+0.85
	UWW	Starch	$Y = 2.93 + 0.036x$	+0.75
	UWW	SG	$Y = 1.01 + 0.0002x$	+0.58
	SG	DM	$Y = -64.23 + 80.73x$	+0.45
Verma <i>et al.</i> (1972)	SG	DM	$Y = -178.66 + 183.24x$	+0.91
Plains (all locations pooled for 2000)	UWW	DM	$Y = 4.60 + 0.068x$	+0.85
	UWW	Starch	$Y = -1.63 + 0.053x$	+0.52
	UWW	SG	$Y = 0.99 + 0.0002x$	+0.99
Modipuram (2000)	SG	DM	$Y = -302.39 + 307.77x$	+0.85
	SG	DM	$Y = -221.31 + 230.96x$	+0.81
Jalandhar (2000)	SG	DM	$Y = -269.98 + 276.77x$	+0.65
Verma <i>et al.</i> (Jalandhar)	SG	DM	$Y = -57.24 + 70.87x$	+0.76
Patna (2000)	SG	DM	$Y = -251.49 + 259.12x$	+0.86
Verma <i>et al.</i> (Patna)	SG	DM	$Y = -50.69 + 65.53x$	+0.76

UWW = Under water weight of 5 kg tubers; DM = Dry matter (%); SG = Specific gravity; Starch = Starch content (%).

between SG and DM with a higher r-value of 0.91. Since SG values in our case were derived from UWW, we did not get a better relationship between SG and DM and the r-value was also low. It has been found that both the specific gravity and the dry matter content vary with the variety and the location (8, 10, 12). Variations have been observed in under water weight as well from year to year and location to location (11).

On the basis of the regression equations obtained between different parameters (Table 1) a conversion table for dry matter, starch content and specific gravity from UWW of 5 kg potatoes (harvested from hills) was developed (Table 2). The minimum value obtained for UWW in the samples was 200 and the maximum was 445, therefore, the range of UWW in conversion table is given between 200 and 449. Several authors have derived this kind of relationship between specific gravity and dry matter/starch content from time to time under different conditions

(6, 7, 13). This work differs from the work of Verma *et al.* (13) in two ways. (i) Verma *et al.* followed brine solution method, while we determined the weight in air and water using a specific gravity balance, as per the normal method followed in potato processing factories. (ii) They had worked out the relationship between specific gravity and dry matter content, so that dry matter content can be derived from specific gravity values. Whereas, we have worked out the relationship between under water weight and, specific gravity, dry matter and starch content so that using under water weight, values for other three parameters can be derived.

The conversion table on the basis of equations obtained between these parameters has been prepared for the Dutch potatoes (11). When compared to the conversion table available for potatoes grown in the Netherlands, for a given under water weight, the specific gravity values (Table 2) are slightly lower by 0.001 to 0.006. But the values for dry

Relationship between UWW & sp. gravity, dry matter & starch

Table 2. Conversion table for specific gravity (SG), dry matter content (DM) and starch content from the under water weight (UWW) of 5 kg of potatoes. Soil type was brown acidic hill soils of Kufri

UWW (g)	SG	DM (%)	Starch (%)	UWW (g)	SG	DM (%)	Starch (%)	UWW (g)	SG	DM (%)	Starch (%)
200	1.047	15.648	10.179	250	1.056	17.991	11.991	300	1.065	20.334	13.804
201	1.047	15.695	10.215	251	1.056	18.038	12.028	301	1.065	20.381	13.841
202	1.047	15.742	10.251	252	1.056	18.085	12.064	302	1.065	20.428	13.877
203	1.047	15.789	10.287	253	1.056	18.132	12.100	303	1.065	20.475	13.913
204	1.047	15.836	10.324	254	1.056	18.179	12.136	304	1.065	20.521	13.949
205	1.048	15.882	10.360	255	1.057	18.225	12.173	305	1.065	20.568	13.986
206	1.048	15.929	10.396	256	1.057	18.272	12.209	306	1.066	20.615	14.022
207	1.048	15.976	10.432	257	1.057	18.319	12.245	307	1.066	20.662	14.058
208	1.048	16.023	10.469	258	1.057	18.366	12.281	308	1.066	20.709	14.094
209	1.048	16.070	10.505	259	1.057	18.413	12.318	309	1.066	20.756	14.131
210	1.048	16.117	10.541	260	1.057	18.460	12.354	310	1.066	20.803	14.167
211	1.049	16.164	10.577	261	1.058	18.507	12.390	311	1.067	20.849	14.203
212	1.049	16.210	10.614	262	1.058	18.553	12.426	312	1.067	20.896	14.239
213	1.049	16.257	10.650	263	1.058	18.600	12.463	313	1.067	20.943	14.276
214	1.049	16.304	10.686	264	1.058	18.647	12.499	314	1.067	20.990	14.312
215	1.049	16.351	10.722	265	1.058	18.694	12.535	315	1.067	21.037	14.348
216	1.050	16.398	10.759	266	1.058	18.741	12.572	316	1.067	21.084	14.384
217	1.050	16.445	10.795	267	1.059	18.788	12.608	317	1.068	21.131	14.421
218	1.050	16.492	10.831	268	1.059	18.835	12.644	318	1.068	21.177	14.457
219	1.050	16.538	10.867	269	1.059	18.881	12.680	319	1.068	21.224	14.493
220	1.050	16.585	10.904	270	1.059	18.928	12.717	320	1.068	21.271	14.529
221	1.050	16.632	10.940	271	1.059	18.975	12.753	321	1.068	21.318	14.566
222	1.051	16.679	10.976	272	1.060	19.022	12.789	322	1.069	21.365	14.602
223	1.051	16.726	11.012	273	1.060	19.069	12.825	323	1.069	21.412	14.638
224	1.051	16.773	11.049	274	1.060	19.116	12.862	324	1.069	21.459	14.674
225	1.051	16.820	11.085	275	1.060	19.163	12.898	325	1.069	21.506	14.711
226	1.051	16.866	11.121	276	1.060	19.209	12.934	326	1.069	21.552	14.747
227	1.052	16.913	11.157	277	1.060	19.256	12.970	327	1.069	21.599	14.783
228	1.052	16.960	11.194	278	1.061	19.303	13.007	328	1.070	21.646	14.819
229	1.052	17.007	11.230	279	1.061	19.350	13.043	329	1.070	21.693	14.856
230	1.052	17.054	11.266	280	1.061	19.397	13.079	330	1.070	21.740	14.892
231	1.052	17.101	11.303	281	1.061	19.444	13.115	331	1.070	21.787	14.928
232	1.052	17.148	11.339	282	1.061	19.491	13.152	332	1.070	21.834	14.964
233	1.053	17.194	11.375	283	1.062	19.537	13.188	333	1.070	21.880	15.001
234	1.053	17.241	11.411	284	1.062	19.584	13.224	334	1.071	21.927	15.037
235	1.053	17.288	11.448	285	1.062	19.631	13.260	335	1.071	21.974	15.073
236	1.053	17.335	11.484	286	1.062	19.678	13.297	336	1.071	22.021	15.110
237	1.053	17.382	11.520	287	1.062	19.725	13.333	337	1.071	22.068	15.146
238	1.053	17.429	11.556	288	1.062	19.772	13.369	338	1.071	22.115	15.182
239	1.054	17.476	11.593	289	1.063	19.819	13.405	339	1.072	22.162	15.218
240	1.054	17.522	11.629	290	1.063	19.865	13.442	340	1.072	22.208	15.255
241	1.054	17.569	11.665	291	1.063	19.912	13.478	341	1.072	22.255	15.291
242	1.054	17.616	11.701	292	1.063	19.959	13.514	342	1.072	22.302	15.327
243	1.054	17.663	11.738	293	1.063	20.006	13.550	343	1.072	22.349	15.363
244	1.055	17.710	11.774	294	1.064	20.053	13.587	344	1.072	22.396	15.400
245	1.055	17.757	11.810	295	1.064	20.100	13.623	345	1.073	22.443	15.436
246	1.055	17.804	11.846	296	1.064	20.147	13.659	346	1.073	22.490	15.472
247	1.055	17.851	11.883	297	1.064	20.193	13.695	347	1.073	22.536	15.508
248	1.055	17.897	11.919	298	1.064	20.240	13.732	348	1.073	22.583	15.545
249	1.055	17.944	11.955	299	1.064	20.287	13.768	349	1.073	22.630	15.581

(Continued)

Table 1. (Continued)

UWW (g)	SG	DM (%)	Starch (%)	UWW (g)	SG	DM (%)	Starch (%)	UWW (g)	SG	DM (%)	Starch (%)
350	1.074	22.677	15.617	383	1.079	24.223	16.814	416	1.085	25.770	18.010
351	1.074	22.724	15.653	384	1.080	24.270	16.850	417	1.086	25.817	18.046
352	1.074	22.771	15.690	385	1.080	24.317	16.886	418	1.086	25.863	18.083
353	1.074	22.818	15.726	386	1.080	24.364	16.922	419	1.086	25.910	18.119
354	1.074	22.864	15.762	387	1.080	24.411	16.959	420	1.086	25.957	18.155
355	1.074	22.911	15.798	388	1.080	24.458	16.995	421	1.086	26.004	18.191
356	1.075	22.958	15.835	389	1.081	24.504	17.031	422	1.086	26.051	18.228
357	1.075	23.005	15.871	390	1.081	24.551	17.067	423	1.087	26.098	18.264
358	1.075	23.052	15.907	391	1.081	24.598	17.104	424	1.087	26.145	18.300
359	1.075	23.099	15.943	392	1.081	24.645	17.140	425	1.087	26.191	18.336
360	1.075	23.146	15.980	393	1.081	24.692	17.176	426	1.087	26.238	18.373
361	1.075	23.192	16.016	394	1.081	24.739	17.212	427	1.087	26.285	18.409
362	1.076	23.239	16.052	395	1.082	24.786	17.249	428	1.087	26.332	18.445
363	1.076	23.286	16.088	396	1.082	24.833	17.285	429	1.088	26.379	18.481
364	1.076	23.333	16.125	397	1.082	24.879	17.321	430	1.088	26.426	18.518
365	1.076	23.380	16.161	398	1.082	24.926	17.357	431	1.088	26.473	18.554
366	1.076	23.427	16.197	399	1.082	24.973	17.394	432	1.088	26.519	18.590
367	1.077	23.474	16.233	400	1.082	25.020	17.430	433	1.088	26.566	18.626
368	1.077	23.520	16.270	401	1.083	25.067	17.466	434	1.089	26.613	18.663
369	1.077	23.567	16.306	402	1.083	25.114	17.502	435	1.089	26.660	18.699
370	1.077	23.614	16.342	403	1.083	25.161	17.539	436	1.089	26.707	18.735
371	1.077	23.661	16.379	404	1.083	25.207	17.575	437	1.089	26.754	18.771
372	1.077	23.708	16.415	405	1.083	25.254	17.611	438	1.089	26.801	18.808
373	1.078	23.755	16.451	406	1.084	25.301	17.647	439	1.089	26.847	18.844
374	1.078	23.802	16.487	407	1.084	25.348	17.684	440	1.090	26.894	18.880
375	1.078	23.848	16.524	408	1.084	25.395	17.720	441	1.090	26.941	18.916
376	1.078	23.895	16.560	409	1.084	25.442	17.756	442	1.090	26.988	18.953
377	1.078	23.942	16.596	410	1.084	25.489	17.793	443	1.090	27.035	18.989
378	1.079	23.989	16.632	411	1.084	25.535	17.829	444	1.090	27.082	19.025
379	1.079	24.036	16.669	412	1.085	25.582	17.865	445	1.091	27.129	19.062
380	1.079	24.083	16.705	413	1.085	25.629	17.901	446	1.091	27.175	19.098
381	1.079	24.130	16.741	414	1.085	25.676	17.938	447	1.091	27.222	19.134
382	1.079	24.176	16.777	415	1.085	25.723	17.974	448	1.091	27.269	19.170
								449	1.091	27.316	19.207

UWW=Under water weight of 5 kg tubers; DM = Dry matter (%), SG = Specific gravity; Starch = Starch content (%)

matter and starch content are higher by 3.91 to 4.17% and 1.00 to 2.21% respectively. This clearly shows that conversion tables available in the developed countries can not be used for potatoes grown in India.

The results of this study show that UWW, dry matter content, starch content and specific gravity show considerable variation over different locations. Such variations are known to exist and hence an equation developed for a given location may not hold good for another

location. It would, therefore, be desirable to obtain regression equations for individual locations on the basis of a large number of samples as has been done for the hills in this study. The conversion table proposed for the hills may be applicable to potatoes grown under similar conditions but may not be applicable to potatoes grown in the plains. It is hoped that the conversion table given in Table 2 would be useful to the potato processors in the country as it can give an

idea about the specific gravity, dry matter and starch content of potatoes for a given under water weight.

## ACKNOWLEDGEMENTS

The authors are thankful to Dr. GS Shekhawat, former Director, CPRI, Shimla for providing the necessary facilities to carry out this work. Special thanks are due to Mr. Islam Ahmad for his help in the data analysis and preparation of conversion table. The authors are grateful to Dr. (Mrs.) A. Mehta, PS, CPRS, Jalandhar, Dr. Dinesh Kumar, Scientist SS, CPRIC, Modipuram and Dr. Manish Das, Scientist SS, CPRS, Patna for their help in sending the tubers. The authors thank the Joint Director, CPRIC, Modipuram, Heads of CPRS, Jalandhar and Patna and Dr. Vinod Kumar, Scientist (germplasm), CPRS, Kufri for providing the material used in the present investigation. The authors also wish to thank Mr. Subhash Chand, Ms. Asha Thakur and Ms. Manju Rani for their technical assistance.

## LITERATURE CITED

- Burton, W.G. 1966. *The potato*. 2<sup>nd</sup> edition. H. Veenman and Zones, Wageningen, the Netherlands.
- Fitzpatrick, T.J., W.L. Porter and G.V.C. Houghland. 1969. Continued studies of the relationship of specific gravity to total solids of potatoes. *Am. Potato J.* 46: 120-27.
- Gomez, A.A. and K.A. Gomez. 1976. *Statistical procedures for agricultural research*. IRRI, Manila, Philippines.
- Hodge, J.E. and B.T. Hofreiter. 1962. *Methods in carbohydrate chemistry* (R.L. Whistler and J.N. Be Miller, Eds.) Academic Press, New York, USA.
- Houghland, G.V.C. 1966. New conversion table for specific gravity, dry matter and starch in potatoes. *Am. Potato J.* 43: 138.
- Porter, W.L., T.J. Fitzpatrick and E.A. Talley. 1964. Studies of the relationship of specific gravity to total solids of potatoes. *Am. Potato J.* 41: 329-36.
- Simmonds, N.W. 1977. Relations between specific gravity, dry matter content and starch content of potatoes *Potato Res.* 20: 137-40.
- Staub, J. and R.H. Cole. 1980. Specific gravity relationship among potato varieties in five regions of Pennsylvania. *Hort. Science* 15: 439.
- Sukumaran, N.P. and C. Ramdass. 1980. A simple variable load hydrometer. *J. Indian Potato Assoc.* 7: 32-7
- Vakis, N.J. 1978. Specific gravity, dry matter content and starch content of 50 potato cultivars grown under Cyprus conditions. *Potato Res.* 21: 171-81.
- van Es, A. and K.J. Hartmans. 1987. Structure and chemical composition of the potato. In: *Storage of potatoes, post-harvest behaviour, store design, storage practice and handling* (A. Rastovski and A. van Es et al., Eds.), PUODOC, Wageningen, the Netherlands. 15-78 pp.
- Verma, S.C. 1991. *Potato processing in India-an appraisal*. Tech. Bull. No. 34, CPRI, Shimla, India. 24 pp.
- Verma, S.C., K.C. Joshi, T.R. Sharma and V.P. Malhotra. 1972. Relation between specific gravity and dry matter content of potato (*Solanum tuberosum* L.). *Indian J. Agric. Sci.* 42: 709-12.
- von Scheele, C., G. Svensson and J. Rasmussen. 1937. Die Bestimmung des starkegehalts und der Trockensubstanz der kartoffel mit Hilfe des spezifischen Gewichts. *Landw. Ves. Sta.* 127: 67-96. (original not seen).

---

MS Received: 17.12.2002



# IMMUNO ELECTRON MICROSCOPIC DIAGNOSIS OF POTATO VIRUS M

I.D. Garg, Shiv Kumar and S.M. Paul Khurana<sup>1</sup>

**ABSTRACT:** Solid and liquid phase immuno electron microscopy (SPIEM and LPIEM) for PVM detection were tried on clarified virus-extract (CVE) and clarified virus concentrate (CVC) preparations. CVC preparation through polyethylene glycol (PEG) precipitation was found satisfactory when clarification did not employ  $\text{Ca}_3(\text{PO}_4)_2$  or solvents. CVE preparations revealed plenty of virions both in SPIEM and LPIEM. Maximum trapping was found when pH of the extraction buffer and trapping antiserum, respectively, were 6 and 7 or 8 while best decoration was obtained with antiserum at pH 6. The best clumping of virions was observed with pH 7 of extraction buffer and pH 6 of the antiserum. The present investigations appear to be the first report for optimum IEM diagnosis of PVM.

## INTRODUCTION

Potato virus M has worldwide distribution except Andean region of South America (8). It is economically important in eastern Europe and Russia where some cultivars may be 100% infected causing yield losses of 15-45% (5). It was reported in India in 1980 (6). It is often symptomless, but may cause mottle, mosaic, crinkling and rolling of leaves and stunting of shoots depending on the potato cultivar and the virus strain. It has been found associated with other potato viruses, viz. PVX, PVA and PVY in potato cv. Kufri Ashoka and other hybrids which exhibited severe paracrinkle and stunting at Hissar (4). The virus is routinely detected with ELISA. For quarantine purposes, it is often desirable that the material may also be tested with yet another sensitive and reliable method like IEM. Perusal of literature, to the best of our knowledge, did not reveal any report on the IEM diagnosis of PVM. Present investigations were, therefore, undertaken to develop an IEM procedure for the optimum diagnosis of PVM to fill this gap.

## MATERIALS AND METHODS

A pure culture of PVM maintained in potato cvs. Saco and Green Mountain, was used. Older leaves having higher virus titre were excised and used for the preparation of clarified virus extracts (CVE) and clarified virus concentrates (CVC) as follows:

**CVE:** Four types of CVE were prepared by employing four different buffers for extraction, namely 0.1M Sorenson phosphate, pH 7 (PB), 0.1M phosphate containing 0.1M EDTA, pH 7 (PBE) and citrate-phosphate buffer, pH 9 (PBC) used earlier by Tavantzis (9) and the buffer used by Cavileer *et al.* (1). The last mentioned two buffers comprised, respectively, 0.165M  $\text{Na}_2\text{HPO}_4$ , 0.018M trisodium citrate, 0.1% diethyldithio carbamic acid (sodium salt), 0.5mM EDTA and 0.5% 2-mercaptoethanol (PBC), and 100mM sodium borate, pH 8.2 containing 100mM EDTA, 2% PVP-40 and 0.1% 2-mercaptoethanol (SBB). In each case, 1g of infected leaf tissue was ground with 2ml of the buffer using a mortar and pestle. The slurry was passed through a cotton wool plug

---

<sup>1</sup>Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh)

to obtain sap which was diluted 20 fold with the same buffer in case of PB or PBE but with PB in case of the other two buffers followed by spinning at 10,000g for 15 minutes. The supernatant served as the CVE. CVEs were also prepared in 0.1M PB pH 6 and 8.

**CVC:** CVCs were prepared employing following procedure:

- a) Two g of leaf tissue was ground with 6ml of each of the above mentioned buffers. Slurry passed through cheese cloth followed by clarification either with hydrated  $\text{Ca}_3(\text{PO}_4)_2$  as described earlier by Tavantzis (9) or with n-butanol: chloroform (1:1 V/V). To the clear supernatant obtained after spinning, PEG and NaCl were added to a final concentration of 6% and 0.125 M, respectively. The contents were stirred gently for 15 min and then allowed to stand at 4°C for 2 h. Precipitated virus was pelleted by spinning at 12,000 g for 15 min and the precipitate was resuspended in 0.1M PB, pH 7 overnight at 4°C. It was then spun at 10,000 g for 10 min. The supernatant served as CVC.
- b) Two g of leaf tissue was triturated with 6 ml of each of the buffer mentioned above and slurry passed through cheesecloth as described above. The sap so obtained was clarified by spinning at 12,000 g for 15 min. Further processing of the clarified sap was in the same way as described in the preceding paragraph.
- c) The CVC was made by the same procedure as described under (b) above except that buffer was 0.1M citrate buffer containing 0.75%  $\text{Na}_2\text{SO}_4$ , 5mM Na EDTA, 1% 2-mercaptoethanol and 0.325% ascorbic acid (CAB), pH 7 adjusted with NaOH.

**Trapping :** Collodion film covered grids were coated with antiserum to PVM by floating them on microdrops of the antiserum diluted 600 fold with 0.86% NaCl or the PB pH 6, 7 or 8 for 5 minutes at room temperature. They were then washed, drained and again floated, this time, on microdrops of the CVCs and CVEs placed over parafilm fixed on glass slides kept in humid Petri-dishes. They were incubated at 37°C for 1 h followed by washing, draining and staining with 2% aqueous uranyl acetate.

**Decoration :** The grids with trapped virions, without staining, were washed, drained and again floated, this time, on microdrops of the 1:1000 diluted antiserum for another 1h at 37°C. They were then washed, drained and negatively stained as above.

**Clumping:** Micro-drops of the CVCs and CVEs, placed on parafilm fixed on slides and kept in humid Petri-dish(es) were mixed with microdrops of the diluted antiserum followed by incubation at 37°C for 1 h to allow cross-linking (clumping) of virions with the help of homologous antibodies in the antiserum. Collodion-film covered grids were coated with protein A (5 ug/ml), washed and then floated on the above said drops containing clumps of the virions for 1h at 37°C. Then the grids were washed, drained and stained as above.

Three grids were prepared for each variation or treatment. A total of 90 counts per treatment were recorded from 9 holes of three grids at 21,000 x through 10x binocular per 20cm<sup>2</sup> screen area. Mean of 10 counts per hole followed by grand mean of the 9 means was worked out.

## RESULTS AND DISCUSSION

PVM virions were observed in the CVEs prepared using PB or PBE (Fig.3). In case of PBC or SBB, there was formation of brown coloured precipitate in the virus extract drop during incubation of the copper grid if the virus extract had previously not been diluted 20 fold with PB. The precipitate interfered with the trapping of the virus on the grid. This problem was overcome by diluting the leaf sap, prepared in PBC or SBB, with the PB 1:19 before spinning. Number of virions trapped was about 30% higher in case of extraction buffers earlier used by Tavantzis (9) and Cavileer *et al.* (1) (Figs. 1, 2) than in case of PB or PBE (data not shown). No virions were detected in the CVCs made by clarification of sap with hydrated  $\text{Ca}_3(\text{PO}_4)_2$  or n-butanol:chloroform. Virus was also absent in the CVC made by using CAB. Good concentration of virus was observed in CVCs made without any solvent or hydrated  $\text{Ca}_3(\text{PO}_4)_2$  clarification using PBC or SBB (Fig.4). Thus, there was loss of virus during solvent or hydrated  $\text{Ca}_3(\text{PO}_4)_2$  clarification. Non detection of virus with CAB may probably be due to disintegration of virions in this buffer. Results of the studies on the effect of pH of the extraction buffer and the trapping antiserum are given in Table 1. Trapping was the best when pH of the extraction buffer and

the antiserum was 6 and 8, respectively. Other good combinations of pH of buffer/antiserum were 8/7, 8/8 or 7/6.

The best decoration observed was with the combination of pH of extract/antiserum of 7/6 (Fig.5) followed by 8/6. Best clumping was observed with a combination of pH of extract/antiserum of 7/6 (Fig. 6).

Trapping of virions was greatly improved if the grids were first coated with protein A and then with the antiserum (data not shown). Similarly trapping of clumps of virions was also markedly enhanced by first coating the grid with protein A and then using it for trapping the clumps (data not shown).

Pronounced effect of pH of the antiserum and that of the extraction buffer on trapping of virions was earlier reported for PVX, PVS and PVY (3). A combination of pH 6 of antiserum and 8 of the extraction buffer as observed in the present studies (Table 1) was also observed to be the best earlier for another carlavirus PVS (3).

There was enhanced trapping of the virions when they were trapped on a grid coated first with protein A and then with the antiserum. This may be due to the fact that protein-A has got high affinity towards IgG produced in rabbit (7). Coating of the grid with protein A allowed preferential binding of IgG over other

Table 1. Effect of pH of extraction buffer and the antiserum on trapping of PVM virions

pH of virus extract <sup>a</sup>	No. of virions <sup>b</sup> trapped with PVM antiserum <sup>c</sup> at pH		
	6	7	8
6	1.5	3.2	3.6
7	3.0	1.0	1.0
8	1.5	3.1	3.0

a: Leaf sap was extracted in citrate-phosphate (PBC) buffer and then diluted 1:19 with 0.1M phosphate buffer (PB) of pH 6,7 or 8

b: Grand mean of 9 means from 90 counts at 21,000 x per 20cm<sup>2</sup> screen area

c: Antiserum was diluted 1:599 with 0.1M PB pH 6,7 or 8.



## ACKNOWLEDGEMENTS

Authors are grateful to Dr. A. Kowalska, Poland for the supply of PVM antiserum and to Shri Ranjeet Singh, Technical Officer, CPRI, Shimla for technical help.

## LITERATURE CITED

1. Cavileer, T.D., R.C. Clarke, D.L. Corsini and P.H. Berger. 1998. A new strain of potato carlavirus M. *Plant Dis.* **82**: 98-102.
2. Garg, I.D. and S.M. Paul Khurana. 1991. Protein-A supplemented electron microscopy for diagnosis of potato viruses X, S, Y and leafroll. In: *Horticulture: New technologies and applications* (J. Prakash and R.L.M. Pierik, Eds). pp. 329-336. Kluwer Academic, Dordrecht, the Netherlands.
3. Garg, I.D. and S.M. Paul Khurana. 1992. Factors influencing immune electron microscopy of flexuous potato viruses. *Acta Virologica* **36**: 435-42.
4. Garg, I.D., Shiv Kumar, S.M. Paul Khurana and B.S. Lakra. 2001. Virus spectrum in potato showing paracrinkle. *Proc: Annual Meeting Indian Phytopathol Soc. (NZ)*, Dec.12-13, 2001, HAU, Hisar, pp. 43 (abstr.).
5. Jeffries, C.J. 1998. Potato, FAO/IPGRI Technical Guidelines for the Safe Movement of Germplasm No.19, pp. 59-60. Food and Agriculture Organisation of the United Nations, Rome/International Plant Genetic Resources Institute, Rome.
6. Khurana, S.M. Paul and M.N. Singh. 1980. Occurrence of potato virus M in Shimla hills. *Indian J. Mycol. Pl. Path.* **10**: 179-81.
7. Langone, J.J. 1978. Protein-A: A tracer for general use in immunoscience. *J.Immunol. Methods* **24**: 269-85.
8. Salazar, L.F. 1990. Main virus diseases of potato. In: *Control of Virus and Virus-like Diseases of Potato and Sweet Potato*. Report of the 3<sup>rd</sup> Planning Conference, 20-22, Nov. 1989, pp.9-12. International Potato Center (CIP), Lima, Peru.
9. Tavantzis, S.M. 1983. Improved purification of two potato carlaviruses. *Phytopathology* **73**: 190-94.

---

MS Received: 11.02.2003



## EFFECT OF LOCATION, SEASON AND CULTIVAR ON THE PROCESSING QUALITY OF POTATOES

Dinesh Kumar<sup>1</sup>, R. Ezekiel and S.M. Paul Khurana<sup>2</sup>

**ABSTRACT :** The effect of location, season and cultivar on the processing quality of potatoes was studied for five years (1997-2002) using three cultivars. The crops were raised at eleven locations of All India Coordinated Potato Improvement Project representing most of the potato growing regions in the country and the tubers were analysed for processing quality parameters. An average dry matter content of 20% and above was observed at Deesa, Dholi, Jorhat, Kota, Chindwara and Faizabad. The reducing sugar content was less than 100 mg/100g tuber f. wt at Deesa, Dholi, Jorhat and Kota and the low level of reducing sugars resulted in an average chip colour score of 4 and below at these four places. The sucrose content was below 200 mg/100g tuber f. wt at Jorhat, Kota and Chindwara. The results reported here provide experimental evidence to show that potatoes grown in warmer areas contain higher dry matter content and lower level of reducing sugars resulting in higher yield of good quality chips, and these parameters vary considerably from season (year) to season in the same location. Amongst cultivars, Kufri Jyoti gave higher dry matter content at several locations.

### INTRODUCTION

Potato chips are one of the most popular processed products from potato in India. The yield of potato chips depends upon the solid or dry matter content of potatoes. A dry matter content of 20% and more is considered ideal for making chips. High dry matter containing potatoes produce chips which take less time during drying and frying, absorb less oil, are crispier in texture and returns to the processors are more (4). Further, the reducing sugar content of potatoes has very important bearing on chip colour, especially in case of fried potato chips. High reducing sugar content (i.e. > 100 mg/100 g fresh wt) results in brown and bitter chips (8). Both dry matter and reducing sugar content are variety specific characters but environmental interactions greatly influence the final chipping quality of potatoes. Besides reducing sugars and dry matter, sucrose content was also included in

this study, as it plays important role during storage. High sucrose content means potatoes will be more prone to development of reducing sugars during storage. Several factors affect the processing quality of potatoes and location, season (year) and cultivar are the three major factors that influence the processing quality. In India potatoes are grown in several agro climatic zones and hence it is important to determine the processing quality of potatoes of different varieties grown at different places. Therefore, this study was carried out with the aim of determining the processing quality of potatoes grown in different parts of the country and the variations due to season and cultivar.

### MATERIALS AND METHODS

Three cultivars were grown at eleven different locations of All India Coordinated Potato Improvement Project (AICPIP). The study was carried out for five years, from

---

1. Central Potato Research Institute Campus, Modipuram-250110 (Uttar Pradesh)

2. Central Potato Research Institute, Shimla-171001 (Himachal Pradesh)

1997 to 2002. The design followed was RBD. Seed tubers were planted at a spacing of 60 x 20 cm (At Deesa and Jorhat the spacing was 50 x 20 cm). The date of planting varied with the location, but the haulms were cut 90 days after planting at all the locations to eliminate variations due to crop maturity. Recommended doses of fertilizers and cultural practices were followed. Tuber samples were brought to CPRIC, Modipuram for analysis. Samples of Kufri Pukhraj and Kufri Sutlej were collected from 11 locations and samples of Kufri Jyoti were collected from 7 locations. The tubers were analysed for chip colour, dry matter, reducing sugars and sucrose. One half of each tuber was used for chip colour and the other half was diced, mixed thoroughly and used for the estimation of dry matter content, reducing sugars and sucrose. For chip colour 1.75 mm thick slices were prepared, washed in cold water, dried quickly and fried in refined sunflower oil at 180°C. The chip colour was scored on a scale of 1-9 with a score of 1 for the lightest colour and a score of 9 for the darkest colour. Dry matter content was determined by oven drying at 80°C. Reducing sugars were analyzed by Nelson's method (6) and sucrose by van Handel's (11) method. The results of each year were treated as a replication for statistical analysis of the data.

## RESULTS AND DISCUSSION

**Dry matter content:** The dry matter content varied from 17.5 to 20.7% in Kufri Jyoti, from 13.9 to 20% in Kufri Pukhraj and from 17 to 22.6% in Kufri Sutlej (Tables 1-3). In most European and North American cultivars, the dry matter in potato tubers falls in the range of 18-26% (2). An average dry matter content of  $20 \pm 1\%$  was obtained at Deesa, Dholi,

Jorhat, Kota, Chindwara and Faizabad. Even for the same variety and season there was considerable variation in the dry matter content depending upon the location. Season to season (year) variation was also observed for a given variety and location. The seasonal variation was higher at Jorhat and Dholi, and lower at Modipuram and Hisar. Smith (7) has reported striking differences in dry matter content of a potato cultivar grown in various localities during the same season. The dry matter content also varied from season to season in the same locality. In a study conducted in India covering four locations, the specific gravity and dry matter content of three varieties were higher at Rajgurunagar and lower at Jalandhar (14). A similar trend has been observed by us in this study. Maximum dry matter content was obtained in tubers grown at Kota. Several advanced hybrids grown at Kota were found to have higher dry matter content (9). Amongst the cultivars Kufri Jyoti had higher dry matter content at several locations.

**Reducing sugars and sucrose:** The reducing sugars content varied from 33.6 to 141.2 mg/100g tuber f.wt in Kufri Jyoti, from 18 to 246.2 mg/100 g tuber f.wt in Kufri Pukhraj and 74.7 to 338.6 mg/100 g f.wt in Kufri Sutlej (Tables 1-3). In an earlier study, the reducing sugar content in five Indian potato varieties ranged from 110 to 570 mg/100 g tuber f.wt (10). The reducing sugar content in British potato varieties range from 60 mg to 450 mg/100 g f. wt (1). Dutch cultivar Bintje is reported to contain 60 mg of reducing sugars/ 100 g tuber f.wt at harvest (12). Processing potato varieties like Atlantic (96 mg/100 g f.wt) and Frito Lay variety FL-1533 (51 mg/100 g f.wt) contain

low level of reducing sugars when grown at Modipuram in U.P. (3). An average reducing sugar content of less than 100 mg/100 g tuber f.wt was obtained at Deesa, Dholi, Jorhat and Kota (Tables 1-3). At Jorhat, the season to season variation was quite high. This could be attributed to differences in environmental conditions during the crop growth period. For example, cool and wet weather can lead to higher sugar levels (5). The seasonal variation was lower at Faizabad. Amongst cultivars, Kufri Jyoti had lower reducing sugars content at several locations.

Sucrose content ranged from 117.5 mg to 266 mg/100 g tuber f.wt in Kufri Jyoti, from 145.6 mg to 285.8 mg/100 g tuber f.wt in Kufri Pukhraj and from 108.9 mg to 290.4 mg/100g f.wt in Kufri Sutlej (Tables 1-3). A sucrose content of 490 mg/100 g f.wt has been

reported for Kufri Sindhuri (13). An average sucrose content of less than 200 mg/100 g f.wt was observed only at Jorhat, Kota and Chindwara. All the three cultivars were harvested at 90 days. Further decrease in sugar content could be expected if harvested 10-15 days later. Seasonal variation in sucrose content was maximum at Deesa and Dholi and minimum at Kota. Sucrose content was lower in Kufri Jyoti as compared to other two cultivars.

**Chip colour:** An average chip colour score of less than 4 was observed at Deesa, Jorhat and Kota (Fig.1). Chips with a score of 1-2 are considered excellent and a score of 3-4 is considered good. When the chip colour score exceeds 5, it is unacceptable. Potatoes from Jorhat gave most consistent results. In some years good chip colour was observed at

Table 1. Processing quality of cv. Kufri Jyoti grown at different locations in India

Location	Chip colour	Dry matter (%)	Reducing sugars (mg/100g f. wt)	Sucrose (mg/100g f. wt)
Deesa	3.4±1.07	19.1±1.45	33.6±19.00	266.1±120.08
Dharwar	6.1±3.01	17.8±1.27	127.5±91.91	190.6±12.89
Dholi	3.7±1.04	20.5±1.59	86.9±50.84	197.2±22.42
Jorhat	3.5±1.50	20.7±2.89	66.1±68.80	188.3±44.28
Hisar	5.1±0.84	17.5±0.51	141.2±68.80	243.1±18.41
Kota	3.0±0.01	20.3±0.71	68.6±42.11	117.5±11.25
Modipuram	4.2±0.27	18.3±0.55	140.8±26.50	168.1±39.71

Table 2. Processing quality of cv. Kufri Pukhraj grown at different locations in India

Location	Chip colour	Dry matter (%)	Reducing sugars (mg/100g f. wt)	Sucrose (mg/100g f. wt)
Deesa	2.8±1.35	18.2±1.68	18.1±11.56	285.8±103.59
Dharwar	5.4±2.27	18.8±1.58	111.5±41.42	251.0±77.88
Dholi	4.5±1.32	19.1±0.07	133.9±15.90	262.8±78.23
Jorhat	3.0±1.00	19.6±2.51	87.5±68.19	150.9±64.99
Hisar	6.4±2.09	13.9±0.87	169.9±23.43	169.0±63.39
Kota	4.4±0.63	20.0±2.15	90.2±46.08	145.6±29.70
Modipuram	5.3±0.58	17.6±0.77	192.0±27.94	276.1±73.95
Chindwara	5.0±2.65	19.1±2.13	220.7±175.31	178.7±42.19
Faizabad	5.2±1.59	18.5±0.66	143.9±9.22	236.2±51.23
Pantnagar	4.7±1.11	17.6±1.02	246.2±24.23	183.0±21.93
Bhubaneshwar	3.6±1.49	17.1±1.45	98.7±92.94	246.8±52.54

Table 3. Processing quality of cv. Kufri Suttlej grown at different locations in India

Location	Chip colour	Dry matter(%)	Reducing sugars (mg/100g f. wt)	Sucrose (mg/100g f. wt)
Deesa	5.7±2.31	19.4±1.20	154.5±105.16	290.4±96.59
Dharwar	7.1±2.66	17.0±0.21	151.4±42.47	217.6±18.26
Dholi	4.7±1.47	20.1±1.26	122.3±41.49	233.7±50.99
Jorhat	3.8±0.76	18.3±0.63	74.7±104.83	108.9±24.15
Hisar	5.3±1.53	15.3±0.52	250.2±50.18	209.6±28.34
Kota	3.7±0.71	22.6±1.52	117.2±30.15	126.8±6.23
Modipuram	5.5±0.50	18.6±0.23	152.2±83.52	216.8±25.95
Chindwara	3.6±0.68	19.2±0.71	142.4±52.93	179.2±11.06
Faizabad	5.2±1.01	18.5±1.33	93.2±20.93	244.7±39.90
Pantnagar	5.7±2.21	17.6±0.46	338.6±135.31	242.7±21.80
Bhubaneshwar	5.2±1.62	17.1±0.83	195.2±78.91	183.6±6.02

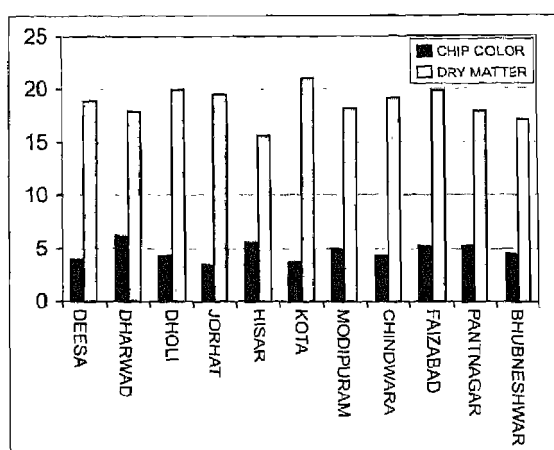


Fig. 1: Chip color and dry matter content of potato grown at different locations in India

Chindwara, Dholi, Dharwar and Bhubaneshwar, but seasonal and cultivar variations were considerable resulting in poor average chip colour score. The seasonal variation was maximum at Dharwar and minimum at Modipuram (Tables 1-3).

According to Burton (2), in this type of study, it is impossible to make any general statement that a particular cultivar gives higher yield or tubers with a high percentage dry matter content. Such attributes are the result of the interaction between the cultivar and its environment, and the results in one locality may be completely different from the other.

The results of our study aptly fit in this statement. Both location and season (year) affected the processing quality of a given cultivar and this could be attributed to the environmental factors. Although several factors are involved, temperature is the single most important determinant of dry matter content of potatoes. (4,7). While trying to relate the dry matter content of potatoes to air temperature during crop growth, Ezekiel *et al.* (4) have shown that a dry matter content of 18-20% can be expected when the average minimum temperature is between 10 and 12°C and when the average minimum temperature is more than 12°C, we can expect a dry matter content of 20% and more, and a low level of reducing sugars. In the present study, taking average minimum and maximum temperatures during crop season at the locations studied, Hisar with a minimum temperature of 5.5°C recorded lowest dry matter and the places having a minimum temperature of 10°C and above had reasonably good dry matter content. Furthermore, the results of this present study spread over eleven locations provided experimental evidence to the projections made by Ezekiel *et al.* (4) and

gave a clear indication that by and large they hold good. For example, they had projected that the dry matter content in Punjab and Haryana will be least due to lower temperatures and as we proceed towards East or South the dry matter content will increase and reducing sugars content decrease. The results showed that the dry matter content was least at Hisar (max. 20.5°C; min. 5.5°C) and increased towards east i.e. Faizabad (max. 22°C; min. 8.9°C) and Jorhat (max. 25.7°C; min. 10.9°C) or towards South i.e. Deesa (max. 26.6°C; min. 8.7°C) and Chindwara (max. 23.9°C; min. 12.8°C). The dry matter content from Dharwar (max. 30.2°C; min. 20.3°C) was not as high as expected because the samples were from *Kharif* crop and potatoes from rainfed crop generally contain lower dry matter.

Taking all the four parameters of the present study into consideration, it may be concluded that Rajasthan, Gujarat, Central India and North-east regions are more suitable for producing potatoes with higher dry matter content and lower level of reducing sugars. Although season to season variations and cultivar differences could be considerable, for a given cultivar and season, potatoes grown in the above region may be expected to have higher dry matter content and lower level of reducing sugars.

#### ACKNOWLEDGEMENTS

The authors are thankful to the Scientists-in-charge of all AICPIP centers for sending tuber samples and to the Joint Director, CPRIC, Modipuram for providing necessary facilities.

#### LITERATURE CITED

1. Burton, W.G. 1965. The sugar balance in some British potato varieties during storage. I. Preliminary observations. *Eur. Potato J.* 8: 80-91.
2. Burton, W.G. 1989. *The potato*. Longman Scientific and Technical, New York. pp. 142-143.
3. CPRI. 2000. *Annual Sci. Report, 1999-2000*. Central Potato Research Institute, Shimla. pp. 99-100.
4. Ezekiel, R., S.C. Verma, N.P. Sukumaran and G.S. Shekhawat. 1999. *A guide to potato processors in India*. Tech. Bull. No. 48. CPRI, Shimla. 39 pp.
5. Miller R.A., J.D. Harrington and G.D. Kuhn. 1975. Effect of variety and harvest date on tuber sugars and chip colour. *Am. Potato J.* 52: 379-86.
6. Nelson, A. 1944. A photometric adaptation of Somogyi method for determination of glucose. *J. Biol. Chem.* 153: 375-80.
7. Smith, O. 1987. Effect of cultural and environmental conditions on potatoes for processing. In: *The potato crop* (W.F. Talburt and O. Smith, Eds.), pp. 73-147.
8. Storey, R.M.J. and H.V. Davies. 1992. Tuber quality. In: *The potato crop* (P.M. Harris, Ed.), pp. 507-69. Chapman and Hall, London.
9. Uppal, D.S. and S.M. Paul Khurana. 2001. Chipping performance of potato varieties grown at different locations. *J. Indian Potato Assoc.* 28: 233-36.
10. Uppal, D.S. and S.C. Verma. 1990. Changes in the sugar content and invertase activity in tubers of some Indian potato varieties stored at low temperatures. *Potato Res.* 33: 119-23.
11. van Handel, E. 1968. Direct micro-determination of sucrose. *Anal. Biochem.* 22: 280-83.
12. van Es, A. and K.J. Hartmans. 1987. Starch and sugars during tuberization, storage and sprouting. In: *Storage of potatoes* (A. Rastovski et al., Eds.), pp 79-113, Pudoc, Wageningen, the Netherlands.
13. Verma, S.C. 1991. *Potato processing in India*. Technical Bulletin No. 34. CPRI, Shimla. 24 pp.
14. Verma, S.C., K.C. Joshi, T.R. Sharma and V.P. Malhotra. 1975. Dry matter content of potato varieties grown at different locations. *J. Indian Potato Assoc.* 2: 15-17.



## YIELD AND PROCESSING ATTRIBUTES OF INDIGENOUS AND EXOTIC POTATO VARIETIES FOR PROCESSING IN LATE PLANTED CROP IN NW PLAINS

S.V. Singh, Dinesh Kumar<sup>1</sup> and S.K.Pandey<sup>2</sup>

**ABSTRACT:** Eight Dutch and two American varieties along with newly developed indigenous processing varieties, Kufri Chipsona-1 and Kufri Chipsona-2 and 5 others were evaluated over two years (1999 and 2000) at CPRI Campus, Modipuram in NW plains in late planted crop to assess their potential in producing raw material for industry for a longer time. The highest total and processing grade yields in a crop of 100 days were recorded in cv. Kufri Anand followed by Kufri Sutlej, the two newly released varieties for table consumption and suitable for plains of India. The per cent dry matter was lowest (17.09%) in Morfona (Dutch) and highest (22.67%) in Kufri Chipsona-2 followed by in Chipsona-1 (22.22%), while reducing sugars ranged from 35.43 to 363.17mg/100g fr.wt with minimum in Atlantic followed by Kufri Chipsona-1 (45.60mg/100g fr.wt). The acceptable chip colour (grade-3) was observed only in Kufri Chipsona-1 followed by nearly acceptable chips in cv. Atlantic (grade 3.5). Sucrose varied from 143.82 in FTL-1533 to 328.49mg/100gm fr.wt. in Kufri Chipsona-1. Kufri Chipsona-1, the only variety meeting all the processing requirements, was found suitable for growing in late planted crop in NW plains and its cultivation in paddy-potato rotation can provide processing potatoes for a longer period by staggered planting starting optimally from 1st week of October. However, amount of high sucrose in cv. Kufri Chipsona-1 in late planted crop indicated its unsuitability for long term storage.

### INTRODUCTION

The work on development of high yielding indigenous potato varieties was earnestly started with the establishment of Central Potato Research Institute (CPRI) in 1949 and the Institute till 1990 developed 26 varieties suitable for different agro-climatic regions of the country (3). All of these varieties were bred/developed for consumption as fresh potatoes with tuber yield and disease resistance as the major characters of concern in their development. However with the increase in urbanization, need for development of high dry matter and low sugar varieties was felt for use by the processing industry mainly for production of chips in the country.

The concerted efforts initiated in 1990 resulted in development of country's first processing varieties, viz. Kufri Chipsona-1 and Kufri Chipsona-2 in 1998 (2, 4, 5). During this period several exotic varieties were also brought by MNCs in the country mainly from Holland and America with a view of introducing them for producing potatoes for processing. However, round the year availability of fresh potatoes for processing remained a problem for industry in spite of suitable varieties. This was mainly because bulk of the potatoes from northern plains, the main potato bowl of the country, are available only between December to February/March from autumn/winter harvest. The present study was conducted to evaluate the indigenous and exotic varieties

---

<sup>1</sup>Central Potato Research Institute Campus, Modipuram-250 110, Meerut (Uttar Pradesh)

<sup>2</sup>Central Potato Research Institute, Shimla 171 001 (Himachal Pradesh)

meant for processing to assess their potential for producing raw material for industry for longer duration by planting and harvesting late in the season in NW plains

## MATERIALS AND METHODS

Seventeen potato varieties including eight Dutch (Agria, Ajex, Anosta, Cardinal, Diamant, Fresco, Morfona and Sante), two American (Atlantic and Frito-Lay-1533), two old Indian varieties hitherto used in processing (Kufri Jyoti and Kufri Lauvkar), two new processing varieties (Kufri Chipsona-1 and Kufri Chipsona-2) and three popular table varieties of the northern plains (Kufri Bahar, Kufri Sultej and Kufri Anand) were grown during 1999-2000 and 2000-2001 crop seasons using randomized complete block design at experimental farm of CPRI Campus, Modipuram, Meerut (UP) in North western plains. The experiment was laid out on 10<sup>th</sup> November in each year following recommended cultural and manurial practices of the region. The inter and intra row distances of 60 and 20 cms were maintained within the three replications. The crop was dehaulmed at 100 days after planting and was harvested after another 10 days allowing curing of tuber skin.

At harvest, data on total and processing grade (>35g tubers) yields was recorded. Dry matter (DM) was determined by oven drying properly chopped 100g composite samples at 80°C till complete dry. Chip colour (CC) was determined visually on 1-10 scale (where 1 was white and 10 was dark brown and a score up to 3 being acceptable) by frying 1.4 mm slices at 180°C in refined oil till bubbling in the oil completely stopped. Reducing sugars (RS) were determined following the method

of Nelson (6). Sucrose was determined by van Handel's method (8). The data for two years were pooled and statistically analysed.

## RESULTS AND DISCUSSION

The data on total tuber and processed grade yields, reducing sugars (mg/100g/fr.wt.) and sucrose (mg/100g/fr.wt.) is presented in Table 1. Total tuber yield ranged from 276.3 q/ha in cv. Kufri Lauvkar to 457.3 q/ha in cv. Kufri Anand, the recently released Indian table variety for northern plains. The processing grade tuber yield ranged from 243.2 q/ha in cv. Atlantic (Table 1) to 401.1 q/ha in cv. Kufri Anand. The exotic and Indian processing varieties except Anosta (Dutch), Atlantic and FTL-1533 (American) and Kufri Lauvkar (Indian) gave total tuber yield of more than 300 q/ha. However, popular Indian table variety Kufri Sultej released for cultivation in northern plains and Kufri Jyoti (another table variety hitherto used for processing) along with Dutch varieties Cardinal and Diamant were at par and gave processing grade yield of more than 300 q/ha. All other exotic and indigenous varieties yielded less than 300 q/ha of processing grade tubers in the late planted crop in North western plains (Table 1).

Dry matter in the Indian and exotic varieties ranged from 17.09% to 22.67% (Fig.1). Tubers of cv. Kufri Chipsona-1 gave the highest dry matter (22.67%) followed by cv. Kufri Chipsona-2 (22.22%) indicating that both the indigenous processing varieties are capable of giving high dry matter even in the late planted crop in NW plains, an area known for producing low dry matter potatoes (1).

Reducing sugars varied from 35.43 to 363.3

Table 1. Total and processing grade yield (q/ha) and processing characters in Indian and exotic potato varieties

Sr. No.	Variety	Total tuber yield	Processing grade yield	Reducing sugars (mg/100g/fr.wt.)	Sucrose (mg/100g/fr.wt.)
1	Agria	356.0	311.0	363.3	195.0
2	Ajex	371.7	325.0	274.0	171.0
3	Anosta	292.5	261.2	128.0	241.5
4	Cardinal	397.3	345.0	219.2	233.4
5	Diamant	379.2	323.3	197.0	285.5
6	Fresco	328.0	290.4	209.4	253.0
7	Morfona	318.0	255.0	338.2	194.5
8	Sante	305.3	253.0	88.3	148.0
9	Kufri Anand	457.3	401.1	285.0	187.0
10	Kufri Bahar	374.1	327.1	329.0	307.0
11	Kufri Chipsona-1	336.0	271.5	46.0	328.5
12	Kufri Chipsona-2	362.1	314.0	99.4	196.0
13	Kufri Jyoti	334.1	278.5	81.4	146.0
14	Kufri Lauvkar	276.0	252.0	117.0	196.0
15	Kufri Sutlej	410.0	369.4	130.0	193.3
16	Atlantic	279.3	243.2	35.4	164.0
17	Frito-Lay 1533	299.4	257.0	77.0	144.0
	SE +_	13.4	13.0	12.0	8.0
	CD(0.05)	38.7	37.0	34.0	23.0

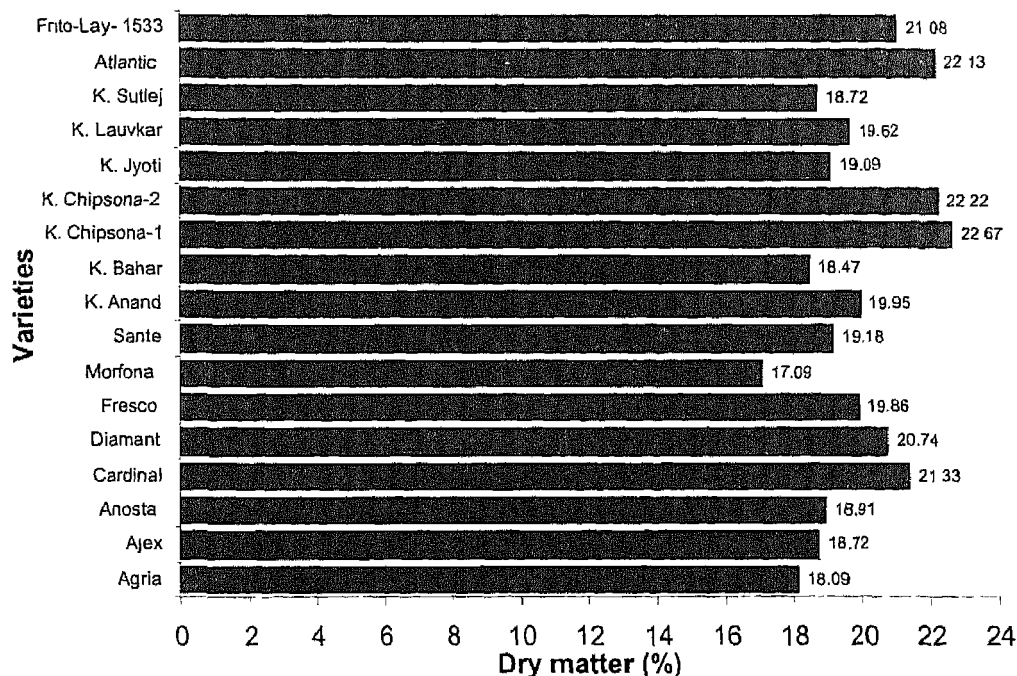


Fig. 1 Percent tuber dry matter in indigenous and exotic potato varieties

mg/100 g fresh weight with minimum in cv. Atlantic followed by cv. Kufri Chipsona-1 (46 mg/100 g fr.wt.). The other varieties that gave low levels of reducing sugars (below 150 g/100 fr.wt.) were cvs. Kufri Chipsona-2, Kufri

Jyoti, Kufri Lauvkar and Kufri Sutlej from India and Sante and Anosta from the Netherlands. Despite the relatively low levels of reducing sugars, in the Dutch and Indian varieties under test, desirable chip colour was

not observed except in cv. Kufri Chipsona-1. Sucrose content varied from 144 mg/100g fresh wt. in cv. Frito Lay (FTL)-1533 (American) to 328.5 mg/100gm fresh weight in cv. Kufri Chipsona-1. Low dry matter and high reducing sugars in Dutch potato varieties were earlier observed by Gaur *et al.* (3) and Singh *et al.* (7) as well at Modipuram in NW plains in normal planted (15<sup>th</sup> Oct) crop.

The acceptable chips (grade 3 or <3) were observed only in cv. Kufri Chipsona-1 followed by nearly acceptable chips in cv. Atlantic (grade 3.5). Rest of the varieties gave unacceptable chip colour on frying (Fig. 2). Singh *et al.* (7) earlier obtained acceptable (< grade 3) and light colour chips both in cvs. Kufri Chipsona-2 and Frito Lay-1533 in normal (15<sup>th</sup>Oct.) autumn planted crop. The deterioration in chip colour can be explained due to differences in temperatures during normal and late planted crop (Table 2). None

Table 2. Average weekly minimum and maximum temperatures at Modipuram during 2000 and 2001.

Month/Week	Temperature°C			
	Year 1999-2000		Year 2000-01	
	Minimum	Maximum	Minimum	Maximum
October				
1	26.10	34.00	21.20	36.50
2	26.30	36.00	17.70	36.50
3	23.70	34.10	17.50	34.10
4	23.40	33.50	16.50	33.00
November				
1	13.50	29.00	15.70	31.20
2	9.70	26.70	13.50	32.00
3	9.80	22.00	11.16	29.20
4	9.70	26.00	8.90	26.90
December				
1	8.00	24.00	5.40	26.40
2	9.00	27.00	6.30	25.90
3	8.60	23.30	5.90	25.90
4	5.00	21.50	4.00	24.00
January				
1	8.00	19.00	5.00	16.70
2	4.00	20.00	2.30	17.30
3	6.00	21.00	3.90	21.60
4	6.50	21.00	5.30	24.10
February				
1	7.00	22.00	4.00	24.00
2	8.00	24.00	7.20	25.50
3	8.50	25.00	10.20	27.90
4	11.50	26.00	9.20	27.80

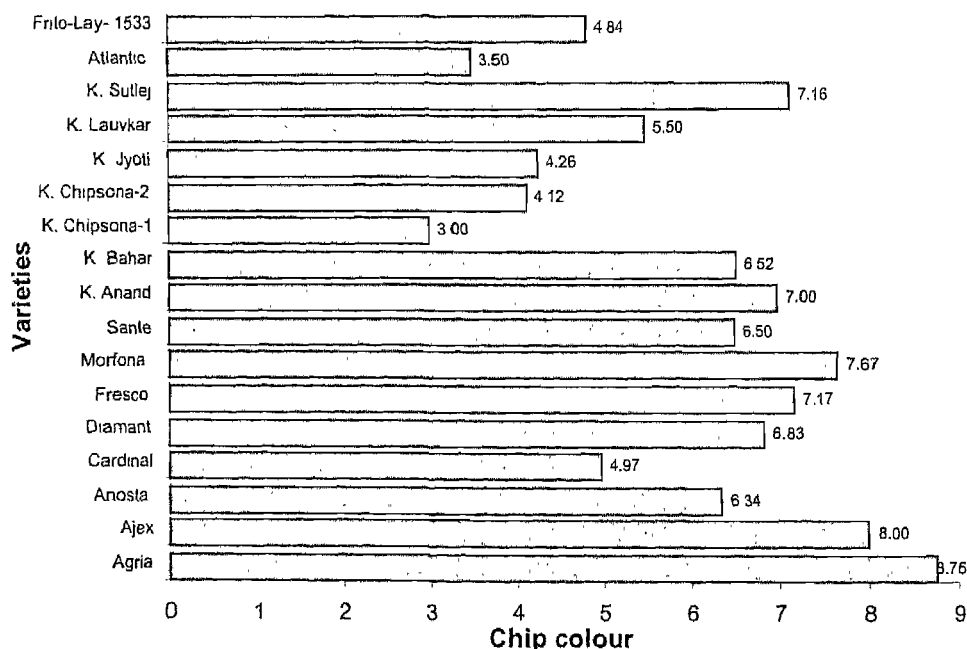


Fig 2. Chip colour in indigenous and exotic potato varieties

of the other Indian varieties meant for cultivation in NW plains and Dutch varieties produced acceptable chips and were found suitable for processing.

Potatoes having high dry matter (>20%), low reducing sugars (<250 mg/100 g fr.wt.) and thus capable of giving quality chips (grade <3) are suitable for processing. The results in the present study indicated that both Kufri Anand and Kufri Sutlej produced very high yields but had low dry matter and high reducing sugars in tubers and were, therefore, suitable only for table consumption and not fit for processing. This was also evident from the dark unacceptable chips produced by them on frying (Fig. 2). Kufri Chipsona-1, on the other hand, produced tubers with high dry matter and low reducing sugars meeting the processing requirements and, therefore, appeared to be most suitable for processing in the late planted crop. Both Kufri Chipsona-1 and Kufri Chipsona-2 also produced high dry matter (>20%) and low reducing sugars in North-western, central and eastern plains and yielded high recovery of light colour chips on industrial frying (2, 5).

Potatoes grown in cooler climate particularly in the areas where night temperatures remain below 10°C during last one month before harvest are not suitable for processing (1). Potatoes grown in NW plains in the states of Punjab, Haryana and western UP where winter is severe and night temperatures drop below 10°C before harvest in January (Table 2), accumulate large amount of sugars. Such potatoes are, therefore, not suitable for processing. Presently, potatoes for processing are procured from warmer areas of the country mainly from *kharif* crop in

Karnataka, winter crop in Malwa region of M.P and summer crop in Nagrota region of H.P. In a large area in NW plains, paddy-potato crop rotation is followed where potato follows *kharif* rice in autumn/winter. However in areas where scented *basmati* rice varieties which have relatively longer maturity period, rice is followed by wheat. However in these *basmati* rice growing areas in NW plains, cultivation of processing variety Kufri Chipsona-1 will be ideal. The variety can be planted in November and continued up to end of February or early March for harvest under warmer conditions and thereby making available fresh potatoes for processing industry. However, amount of high sucrose in cv. Kufri Chipsona-1 in late planted crop (Table 1) indicated that such potatoes can not be stored for long and have to be processed immediately after harvest.

The results of the present investigation clearly indicated that indigenous processing variety Kufri Chipsona-1 can be grown in late planted crop in paddy (scented)-potato rotation in NW plains, an area unsuitable for processing potatoes. The processing industry, thus can be fed with fresh potatoes for longer duration by staggered planting starting optimally from 1st week of October.

#### LITERATURE CITED

1. Ezekiel, R., S. C. Verma, N. P. Sukumaran and G. S. Shekhawat. 1999. *A guide to potato processors*. Tech. Bull. No. 48. Central Potato Research Institute, Shimla. 39pp.
2. Gaur, P.C., S.K. Pandey, S.V. Singh, Devendra Kumar, R.S. Marwaha and Dinesh Kumar. 1998. Kufri Chipsona-1: A potato variety for processing. *J. Indian Potato Assoc.* 25: 115-18.

3. Gaur, P.C., P.S. Naik, S.K. Kaushik and S.K. Chakrabarti. 1999. *Indian potato varieties*. Tech. Bull. No.51. Central Potato Research Institute, Shimla . 38pp.
  4. Gaur, P.C., S.K. Pandey, S.V. Singh and Dinesh Kumar. 1999. *Indian potato varieties for processing*. Tech. Bull. No.50. Central Potato Research Institute, Shimla. 25pp.
  5. Gaur, P.C., S.V. Singh, S.K. Pandey, R.S. Marwaha, Devendra Kumar and Dinesh Kumar. 1999. Kufri Chipsona-2: A new potato variety for chipping. *Current Science* 76: 722-24.
  6. Nelson, N. 1944. A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* 153: 375-80.
  7. Singh, S.V., Dinesh Kumar, P.C. Gaur, S.K. Pandey and Jagpal Singh. 1999. Performance of Indian and Dutch processing varieties for chipping in North-western Plains. *J. Indian Potato Assoc.* 26: 65-66.
  8. van Handel, E.V, 1968. Direct micro-determination of sucrose. *Anal. Biochem.* 22: 280-83.
- 

MS Received: 09.06.2003

## A REFERENCE CHART FOR POTATO CHIP COLOUR FOR USE IN INDIA

R. Ezekiel, Brajesh Singh<sup>1</sup> and Dinesh Kumar<sup>2</sup>

**ABSTRACT:** Fresh and stored potatoes varying in their sugar levels were used to prepare chips of different colours and photographs of these chips have been used to develop a 10 point colour chart with colour scores of 1-10 of increasing dark colour. Chip colour score showed a significant positive correlation ( $r = 0.77^{**}$ ) with reducing sugar content of tubers and the relationship between these two parameters was exponential ( $R^2 = 0.75$ ). Use of this reference colour chart will give uniformity in the evaluation of chip colour in India.

### INTRODUCTION

Potato is an important crop not only of the developed countries but also of the developing countries. Large portions of potatoes produced are consumed in processed form in developed countries. For example, in the United States of America about 57% of the total produce is processed (6). Whereas in India less than 0.3% of the total produce is processed (4). Increased production has resulted in frequent gluts in India. However, not all the potatoes produced in the country can be utilized for processing since for processing, potatoes should have certain minimum requirements such as shape, size, texture, dry matter and reducing sugars (5). For processing into potato chips, it is desirable to have potato varieties with round or oval tubers with fleet eyes. The dry matter content should be around 20% and the reducing sugar content should be less than 0.25% (14). While dry matter content influences the yield of the processed product, sugar content determines the colour of the fried product (5). Potato chips prepared from potatoes containing large amounts of sugars

turn brown and become unacceptable to the consumers. Generally the colour of the chips is scored with a reference chart and this varies with the country. For example, in USA a colour score of 1-10 of increasing dark colour is used (3), while in the Netherlands, a colour score of 1-9 of decreasing dark colour is used (1). In India, no such colour chart has been developed so far. Therefore, an attempt was made to develop a reference colour chart, which can be used by potato researchers and processors in India.

### MATERIALS AND METHODS

The work was carried out at CPRI, Shimla during 2001-2002. Potatoes grown in the plains and hills were used for preparing potato chips. Both fresh and stored tubers were used in order to get tubers of different sugar levels and chips of different colours. Potatoes stored in cold store (2-4°C) were used for getting darker colour chips, as the sugar accumulation is high when stored at lower temperatures. The potatoes were peeled, sliced, dried and fried using a mini-potato processing unit

<sup>1</sup>Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh)

<sup>2</sup>Central Potato Research Institute Campus, Modipuram-250 110 (Uttar Pradesh)

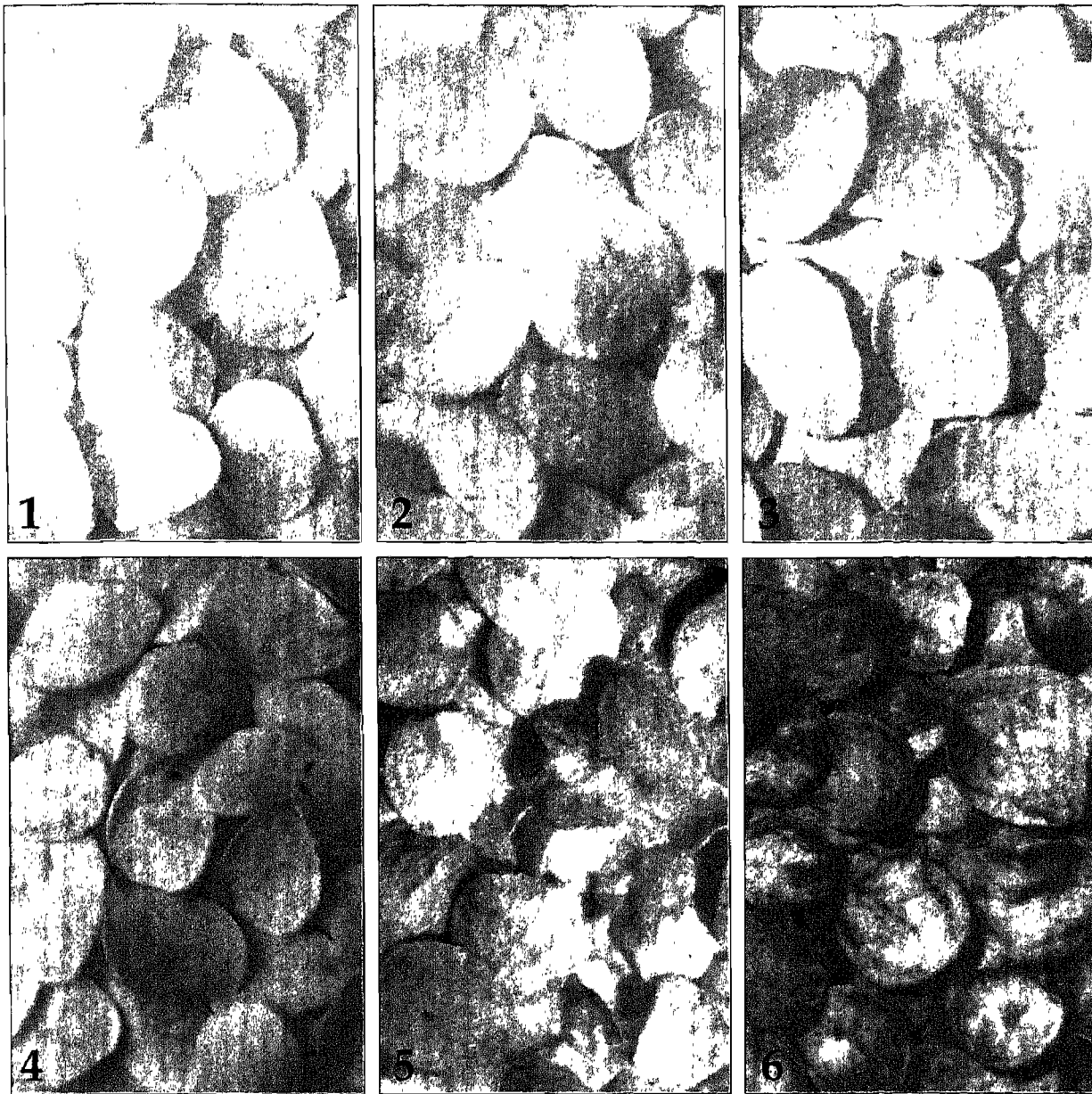
(Wintech Taparia, Indore). Peeling was done using an abrasive peeler and slicing was done using a rotary type slicer to get slices of 1.5-1.8 mm thickness. The slices were blanched for 1 min at 60°C and cooled in water at room temperature. Surface moisture from potato slices was removed using a spin dryer before frying the slices. Frying was done using a fryer for about 2 minutes and cottonseed oil was used for the purpose. The temperature of the oil in the fryer at the time of entry of the slices was 180°C and the final temperature after the completion of frying was 165°C. The fried chips were cooled and packed in a polythene bag. The chips were photographed the next day using a digital camera (Model Kodak DC 265). The light conditions were similar for all the photographs. Visual colour scoring was done on a scale of 1-10 of increasing dark colour with 1 denoting the lightest colour and 10 denoting the darkest colour, by a panel of seven persons. This reference colour chart was evaluated using chips prepared from 80 samples. Chip colour was also determined objectively using a MiniScan XE Plus spectrophotometric colour measurement system (Hunter Lab, Reston, USA) standardized with white reference disc at Yellow Index (YI) = 1.6 and Hunter colour L value (HC-L)= 93.36 (Higher the HC-L value better the colour). The chip colour was scored and was related to reducing sugar content of tubers. Care was taken to include tuber samples with distinctly different levels of *reducing sugar by storing at different temperatures*, so that chip colours of all the ten grades were obtained. Each lot of sample contained 8-10 tubers. The tubers were cut longitudinally and one half of each tuber was used for the preparation of chips, and the

other half was used for reducing sugar estimation. Chips were prepared as described above. For reducing sugar determination, tubers were cut longitudinally, diced and mixed thoroughly, and 50g of diced tubers were used for determining reducing sugar by Arsenomolybdate method (9). Correlation coefficient and regression equation were obtained using MSTAT 4.0C software.

## RESULTS AND DISCUSSION

From the photographs shown in figures 1-10, it can be said that photograph with colour score of 1 can be considered excellent and photograph with colour score of 2 can be considered very good, and therefore, highly acceptable. Photograph with colour score of 3 can be considered good and photograph with colour score 4 can be considered acceptable. Photograph with colour score of 5 is not acceptable because of higher percentage of browning and photographs with colour score ranging from 6-10 are increasingly darker in colour, therefore, unacceptable.

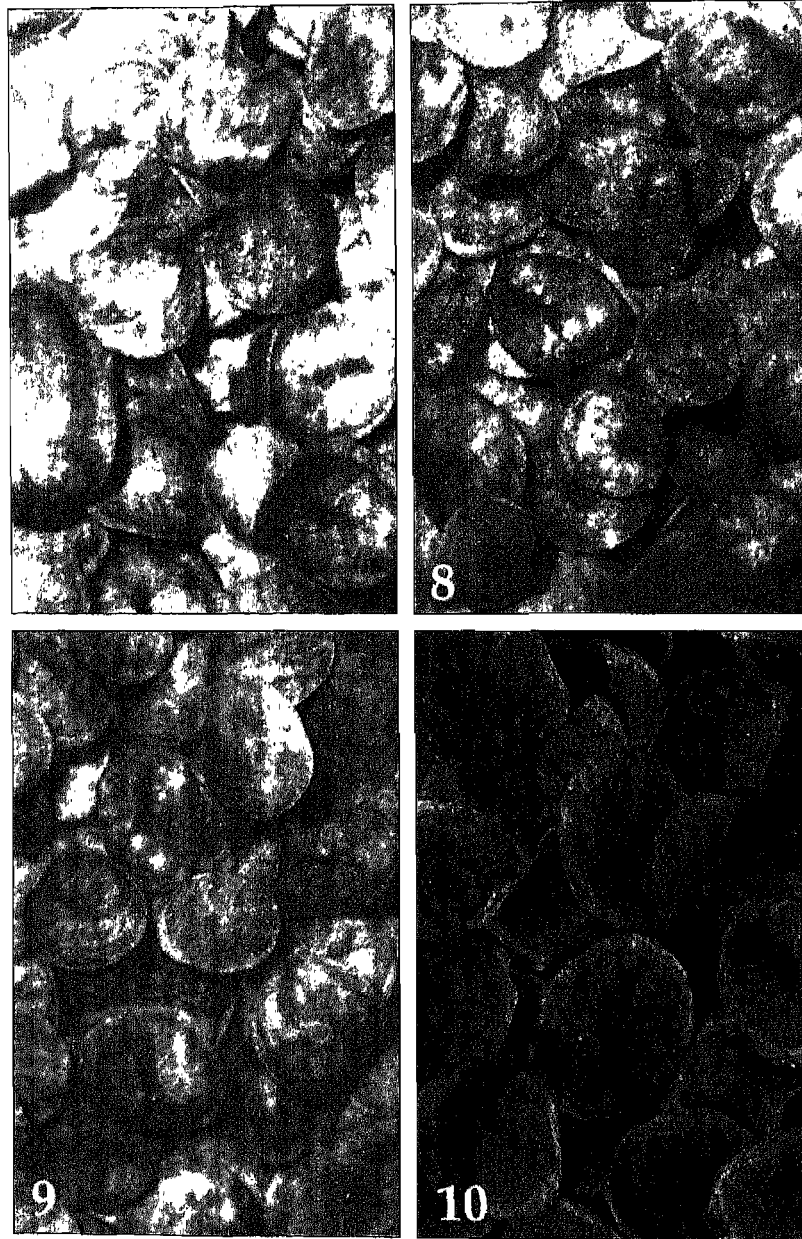
We have used colour score of 1-10 of increasing dark colour. Agriculture Canada standard potato chip colour chart uses 100-point visual scale ranging from very dark at 10 to very light at 100 (2). Visual scale of 10 and 100 can be compared to colour score 10 and 1 respectively, of our reference colour chart. In the colour cards developed by the Institute for Storage and Processing of Agricultural Produce, Wageningen, the Netherlands, colour numbers 1-9 of increasing light colour are used wherein No. 1 denotes darkest colour and No. 9 denotes lightest colour (1). The colour number 9 corresponds to colour score 1 of our colour chart and colour number 1 corresponds to colour score



Figs. 1-6. Reference chart for potato chip colour; colour score 1-6.

10 of our colour chart. The snack food association (SFA) colour standards for potato chips developed recently uses chip colour score of 1-3 with chip colour designation 1 corresponding to Agtron readings of 65 and higher, 2 corresponding to reading of 55-64 and 3 corresponding to reading of 45-54 (6). In the SFA colour standard, chip colour

designation 1 is considered highly acceptable and 3 as acceptable. Colour designations 1 and 2 of SFA colour standards are comparable to our colour scores of 1 and 2, and colour designation 3 of SFA colour standards is comparable to our colour score of 4. In the potato chip colour reference standards developed by Potato Chip Institute



*Figs. 7-10. Reference chart for potato chip colour; colour score 7-10.*

International, Cleveland, Ohio, USA, a scale of 1 to 10 is used where 1 indicates light golden colour chips and 10 indicates dark colour, therefore, unacceptable chips (3). The colour scores given in our reference chart is on the lines of colour score used in USA. The mean and range of HC-L value and YI value

obtained for each chip colour score are given in Table 1. The HC-L value for chips with colour score of 1 considered excellent ranged from 80 to 82 and for chips with colour score of 4 considered acceptable it ranged from 60 to 66. HC-L values above 60 are considered acceptable (10). Rodriguez and Wrolstad (11)

Table 1. Hunter colour L (HC-L) and Yellow index (YI) values corresponding to different chip colour scores

Chip colour score	HC-L value		YI value	
	Mean*	Range	Mean	Range
1	81.0	80-82	42.7	36-46
2	77.3	75-79	43.0	35-50
3	69.3	67-74	57.0	54-61
4	62.0	60-66	67.7	63-71
5	55.7	53-60	78.3	71-85
6	51.7	51-53	87.0	79-95
7	48.3	45-51	93.7	90-96
8	40.1	39-44	96.0	93-99
9	37.7	36-39	102.7	101-105
10	30.0	25-35	110.0	103-116

\*Mean of three values

observed a HC-L value of 58.4 for acceptable chip colour and a HC-L value of 49 for dark chip colour.

#### Relationship between chip colour score and reducing sugar content of tubers

There was considerable variation in the reducing sugar content. Tubers with reducing sugar content ranging from 30-54 mg/100 g f. wt produced chips of colour score 1 and the variation in reducing sugar content between tuber samples was 80% (Table 2). Tubers with reducing sugar content of 44-239 mg/100g f. wt produced chips of colour score 5 and the variation in reducing sugar content between tuber samples was 443%. Tubers with reducing sugar content of 232 to 1496 mg/100g f. wt produced chips of colour score 10 and the variation in reducing sugar content between tuber samples was 645%. There was not much difference in the minimum values of reducing sugars observed for chip colour scores of 1 and 4, although the maximum values varied considerably (Table 2). However, the mean values were different for different colour scores. A reducing sugar content of up to 250 mg/100 g f. wt is considered acceptable for processing (5). But the results reported here show that for producing chips of acceptable

colour, the reducing sugar content of potatoes should not exceed 160 mg/100 g f. wt. Reducing sugar content of tubers has been found to be highly variable. For example, we observed a reducing sugar content range of 30-54mg/100g tuber f. wt for chip colour score of 1. A reducing sugar content range of 16-78mg/100g tuber f. wt (8) and 58-85mg/100g tuber f. wt (7) have been reported for corresponding chip colour score of 1. Similarly, tubers producing chips with colour score of 10 have been reported to have a reducing sugar content of 2218 mg/100g tuber f. wt (13), which is much higher than the figure of 1496 reported by us.

Table 2. Reducing sugar content of tubers corresponding to different chip colour scores

Chip colour score	Reducing sugar content (mg/100g tuber f. wt)	
	Mean*	Range
1	42.5	30-54
2	50.0	33-62
3	64.2	37-102
4	85.0	31-163
5	112.0	44-239
6	175.6	58-375
7	252.1	95-464
8	804.6	116-1205
9	975.6	228-1239
10	1001.6	232-1496

\*Mean of eight values

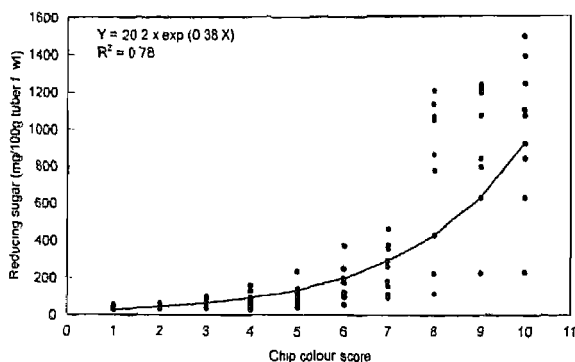


Fig.11. Relationship between chip colour and reducing sugar content of tubers

The reducing sugar content showed significant ( $p=0.01$ ) positive correlation with potato chip colour ( $r=0.77$ ;  $n=80$ ) and the relationship between these two parameters was exponential ( $R^2=0.78$ ) (Fig. 11). When chip colour was determined by Hunter-Color Quest and Agron Instruments, where higher score denotes lighter chip colour, a negative association of glucose ( $r=-0.7$ ) and fructose ( $r=-0.7$ ) with chip colour has been reported (11). Using Agron E-10 colorimeter for colour determination, Sinha *et al.* (12) observed significant negative correlation ( $r=-0.84$ ) between glucose content and chip colour. Using Agriculture Canada standard potato chip colour chart, Coleman *et al.* (2) observed negative correlation ( $r=-0.72$ ) between reducing sugars and chip colour. Since we have used a 1 to 10 scale of increasing dark colour with colour score 1 corresponding to lower reducing sugar level and colour score 10 corresponding to higher reducing sugar level, we observed a positive correlation between reducing sugar and chip colour. The results reported here indicate that reducing sugar content cannot fully explain the differences in chip colour, especially at lower concentrations. Rodriguez and Wrolstad (11) also concluded that reducing sugar concentration did not completely explain

chip colour quality when it was present in low concentration. Other reactants present in potato tubers may also play an important role in colour quality of potato chips.

This reference chart we hope, will be useful to potato researchers in the country. Though this is a subjective system, it is easy to use and potato researchers in the country can have a common reference chart throughout the country, which will give uniformity in the evaluation of chip colour.

## ACKNOWLEDGEMENTS

The authors are grateful to Dr. SM Paul Khurana, Director, CPRI, Shimla for the facilities and encouragement. The technical assistance of Smt. Asha Thakur and Smt. Manju Rani and the assistance of Mr. S.K. Dey in photography is thankfully acknowledged.

## LITERATURE CITED

1. Anonymous. 1974. *Colour cards for the quality evaluation of potato chips*. The Institute for storage and processing of agricultural produce, Wageningen, the Netherlands.
2. Coleman, W.K., G.C.C. Tai, S. Clayton, M. Howie and A. Pereira. 1993. A portable monitor for the rapid assessment of processing quality of stored potato tubers. *Am. Potato J.* 70: 909-23.
3. Douches, D.S. and R. Freyre. 1994. Identification of genetic factors influencing chip colour in diploid potato (*Solanum spp.*). *Am. Potato J.* 71: 581-90.
4. Ezekiel, R. and G.S. Shekhawat. 2002. Potato processing in developing countries with special reference to India. In: *Potato, global research & development*, Volume-II, (SM Paul Khurana *et al.*, Eds.), pp. 1010-20, Indian Potato Association and Central Potato Research Institute, Shimla.

5. Ezekiel, R., S.C. Verma, N.P. Sukumaran and G.S. Shekhawat. 1999. *A guide to potato processors in India*. Technical Bulletin No. 48, CPRI, Shimla. 39 pp.
  6. Gould, W.A. 1999. *Potato production, processing and technology*. CTI publications Inc. Maryland, USA. 259 pp.
  7. Gaur, P.C., S.K. Pandey, S.V. Singh and Dinesh Kumar. 1999. *Indian potato varieties for processing*. Tech. Bull. No. 50. CPRI, Shimla. 25 pp.
  8. Marwaha, R.S. 2000. Processing quality of low and high sugar potato cultivars as influenced by storage temperatures. *J. Indian Potato Assoc.* 27: 5-11.
  9. Nelson, N. 1944. A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* 153: 375-80.
  10. Pandey, S.K., Dinesh Kumar, S.V. Singh, R. Ezekiel and T.P.S. Tomar. 2001. On-line performance of potato varieties Kufri Chipsona-1 and 2 for processing as chips. *J. Indian Potato Assoc.* 28: 156-58.
  11. Rodriguez-Saona, L.E. and R. E. Wrolstad. 1997. Influence of potato composition on chip color quality. *Am. Potato J.* 74: 87-106.
  12. Sinha, N.K., J. N. Cash and R.W. Chase. 1992. Differences in sugars, chip color, specific gravity and yield of selected potato cultivars grown in Michigan. *Am. Potato J.* 69: 385-89.
  13. Uppal, D.S. and R. Ezekiel. 2002. Effect of traditional storage methods on sugar concentrations and chip quality of potatoes. In: *Potato, global research and development*. Vol. II (S.M. Paul Khurana *et al.*, Eds), pp. 1091-95. Indian Potato Association and Central Potato Research Institute, Shimla.
  14. Verma, S.C. 1991. *Potato processing in India*. Tech. Bull. No. 34, CPRI, Shimla, India. 34 pp.
- 

MS Received: 29.05.2003



## MICROPROPAGATION IN POTATO SEED PRODUCTION: NEED TO REVISE SEED CERTIFICATION STANDARDS

Prakash S. Naik and S.M. Paul Khurana<sup>1</sup>

**ABSTRACT:** In a vegetatively propagated crop like potato, use of healthy seed is the most important component for harnessing maximum benefits. The seed requirement for potato crop is very high due to high seed rate (3-4 t/ha). With continuous increase in the area under potato cultivation and possibilities of seed export, a proportional increase in seed requirement is envisaged in the future. The advent of tissue culture, in which plants are grown in artificial media under sterile conditions in the laboratory, has revolutionized potato seed production world over. In addition to quality assurance, the technique ensures enhanced multiplication rate in initial stages of seed production. These characteristics fit well in the latest international developments emerging through WTO (World Trade Organization). Minimum commercial quality requirements fall under the WTO-TBT (WTO-Technical Barriers to Trade) agreement. According to the International Plant Protection Convention (IPPC) under the WTO/SPS (WTO/ Sanitary and Phytosanitary) agreement, presence and/or absence of the pathogens are major quality criteria. Therefore, there is an urgent need to introduce micropropagation in potato seed production and revise seed certification standards for various categories of seed potatoes in such a way that these are aligned, as far as possible, with the international standards. A "Limited Generation System" wherein the planting of each seed class is limited as per the eligibility by compliance with established disease tolerance levels and the number of field multiplications is proposed and discussed.

A short duration crop like potato (*Solanum tuberosum* L.), which produces more dry matter, edible energy and edible protein per unit land and time than many other major crops is an important constituent of Indian agriculture. Short duration, high yields and wide flexibility in planting and harvesting time are potato's valuable traits that help in adjusting this crop in various intensive-cropping systems without putting much pressure on scarce resources such as land, water and fertilizers. In India, the impact of extensive potato research and development during the period 1949-50 to 2000-2001 resulted in 5.2 fold increase in area, 13.3 fold increase in production and 2.6 fold increase in productivity of this crop. In 2001-2002, India produced 24.08 million t of potatoes from 1.22 million ha with productivity of 19.77 t/ha (1). Based on the last five years (1997-2001)

averages, globally India ranks 4<sup>th</sup> in area and 3<sup>rd</sup> in potato production (2).

**Potato seed production scenario:** In a vegetatively propagated crop like potato, use of healthy seed is most important component for harnessing benefits of modern crop husbandry. With the development of "Seed Plot Technique" (6), a National Potato Seed Production Program (NPSPP) was initiated at the Central Potato Research Institute (CPRI) in the year 1967. CPRI, at present, is the only organization in India engaged in Breeders' Seed production. The Breeders' Seed production method consists in selection of virus-free tubers by indexing and their field multiplication in four stages under strict management practices to protect the crop from infiltration of degenerative pathogens (3, 8). The Breeders' Seed produced by CPRI is

---

<sup>1</sup>Central Potato Research Institute, Shimla 171 001 (Himachal Pradesh)

supplied to State Departments of Agriculture/Horticulture, National Seeds Corporation (NSC) and State Farms Corporation of India (SFCI) for further multiplication as Foundation-I, Foundation-II and Certified Seed.

**Domestic seed requirement:** The seed requirement for potato crop is very high due to high seed rate (3-4 t/ha). There are different views as to after how many years farmers should replace their seed stocks. This replacement depends upon agro-climatic conditions, variety and crop management practices. However, the authors feel that to get economic yields, farmers should replace their seed stocks at least once in every four years. Based on these assumptions, the current annual Certified Seed requirement is about 0.9 million tonnes. Although reliable data on production of Certified Seed by the State Departments of Horticulture/Agriculture and other seed producing agencies are not available, it is expected that the Breeders' Seed supplied by the CPRI is multiplied 216 times (6 times each in Foundation-I, Foundation-II and Certified Seed stages). CPRI annually produces about 2500 t Breeders' Seed which, after three field multiplications can give rise to 0.54 million t and can meet about 60% requirement of the country.

With continuous increase in the area under potato cultivation, a proportional increase in seed requirement is envisaged in the future. Thus, there is an urgent need to integrate micropropagation and related technologies to enhance potato seed production to meet domestic requirement and also enhance seed export.

**Micropropagation: An aid to quality seed production:** In conventional seed production

programmes, tubers from individual plants that appear to be visually free of disease problems are indexed and used for subsequent multiplications. The selected tubers of a single plant are planted together as a "clone". If a pathogen is detected even in any one plant of a clone, the entire clone is rejected. In this procedure, however, a number of disease-causing pathogens can remain latent or below detectable limits within a seed tuber and go undetected during inspection and indexing process. This led to the development and adoption of many new laboratory testing and seed stock multiplication techniques that have dramatically influenced the quality of certified seed potatoes. Today, nearly all certified potato seed stocks in many countries originate from the mericlones (meristem derived tissue cultured plantlets) produced under strict aseptic laboratory conditions.

The advent of tissue culture, in which plants are grown in artificial media under sterile conditions in the laboratory, has revolutionized nuclear seed stock development. Most seed producing agencies currently operate tissue culture laboratories that produce the initial stocks of pathogen-free planting material. The tissue culture procedure involves removal of the small growing point or meristem, approximately 0.1-0.3 mm in size, from a tuber sprout or stem of a potato plant. The meristem is placed in a test tube or other vessel with media containing all necessary macro- and micronutrients, carbohydrates, and growth regulators required for growth and development into a plantlet. The grown mericlone (plantlet developed from meristem) is ready for nodal cutting and pathogen testing. A nodal cutting from a tissue culture plantlet is a stem segment containing 1-2 leaves with axillary growing points. Each

plant yields about 3 nodal cuttings after 20-25 days. Therefore, theoretically  $3^{15}$  (14 million) microplants can be obtained from a single virus-free microplant in a year after 15 sub-cultures. Large number of *in vitro* plants thus obtained are hardened and used for direct planting for production of minitubers on nursery beds in greenhouses or in soil-less medium. These plants can also be used for production of microtubers in the laboratory. Like hardened *in vitro* plants, sprouted microtubers can be used to produce minitubers on nursery beds. These techniques have been described in details elsewhere (4, 5) and some of the stages are shown in Figure 1.

Minitubers, microtubers or tissue culture plantlets are the initial source for production of quality potato seed. These propagules are multiplied and increased until a sufficient quantity becomes available for commercial use. During the increase process, the seed lots are subjected to rigorous pathogen testing in laboratories and also visual field inspections.

**Need for revision of seed certification standards:** Minimum commercial quality requirements fall under the WTO-TBT agreement. According to the International Plant Protection Convention (IPPC) under the WTO/SPS agreement, presence and/or absence of the pathogens are major quality criteria. In line with this, recently, several countries revised certification schemes for seed potatoes. These schemes focus on micropropagation as the recommended method of initial seed production (nuclear stock).

Therefore, there is an urgent need to revise certification standards for various categories of seed potatoes in such a way that these are

aligned, as far as possible, with the international standards and aim at:

- (a) harmonizing with international standards/trends,
- (b) facilitating fair international trade by avoiding technical barriers,
- (c) encouraging production of high quality seed to ensure farmer's profitability,
- (d) protecting consumer's interests, and
- (e) gaining confidence of importing countries that the imported seed lots have been monitored through international procedures.

For harmonizing seed certification in the country and promoting seed export there is also a need for an "National Accreditation Body". Potato Development Council was set up in 1977 under the Ministry of Agriculture, Govt. of India to formulate new policies for potato development and to monitor seed production and distribution. However, this council was never re-constituted after the expiry of its first term. It is now necessary that this council or a "Potato Board" be constituted at national level to take care of the interests of this important crop. This may organize, coordinate and supervise seed certification both for national and export requirements. Besides, it may also serve as the "Accreditation Body" at National level.

**Seed certification system for micropropagation based potato seed production:** Limited Generation System wherein the planting of each seed class is limited as per the eligibility by compliance with established disease tolerance levels and the number of field multiplications is proposed. During potato production, the plant is constantly exposed to sources of contamination. The probability of a

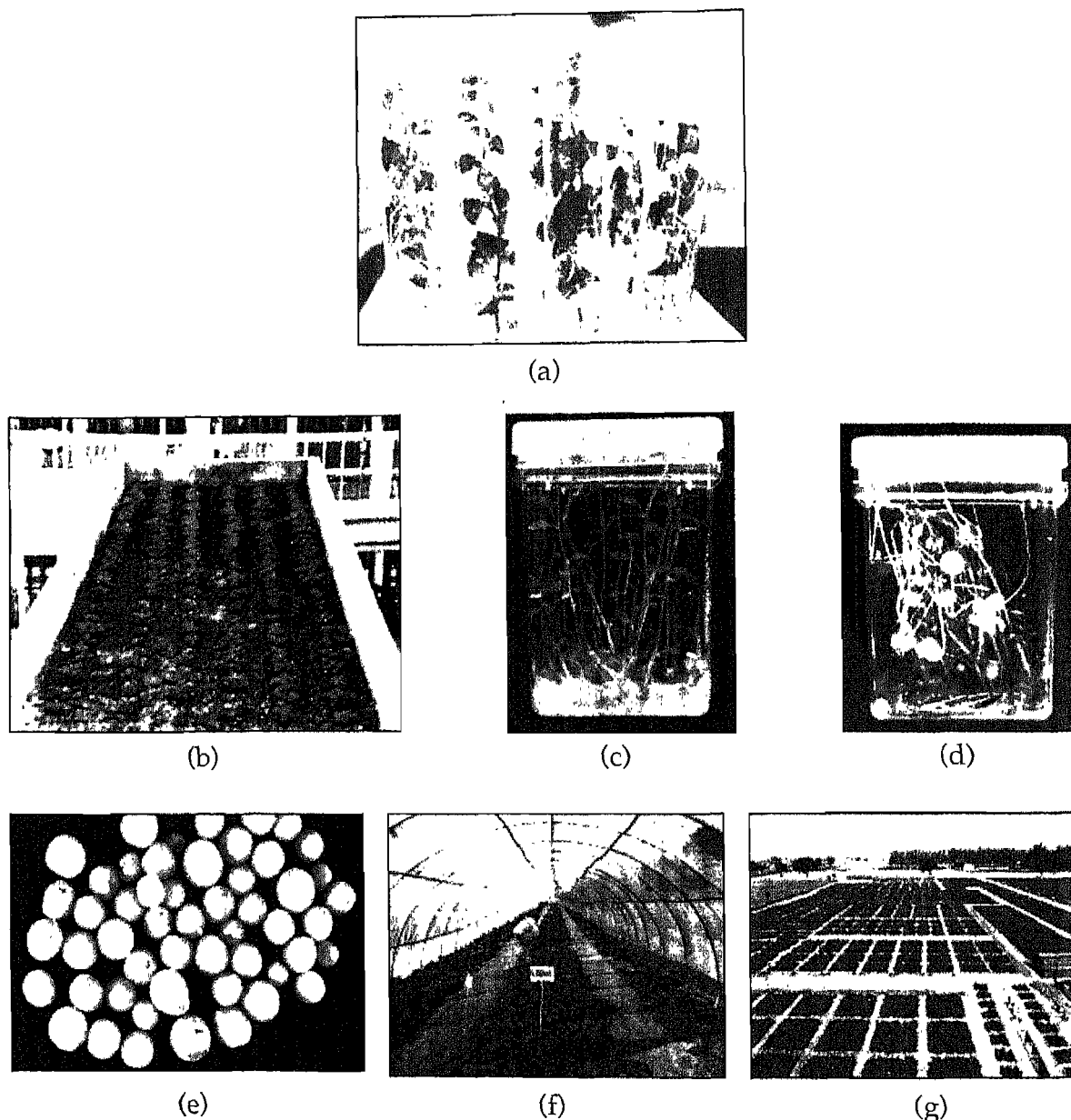


Fig. 1. Use of micropropagation in potato seed production. (a) Virus-free in vitro plants. (b) In vitro plants can be directly transplanted in nursery beds for production of minitubers. (c) These in vitro plants can also be used for microtuber production. The picture shows 1<sup>st</sup> step in microtuber production i.e. mass micropropagation on liquid culture medium. (d) Production of microtubers in special medium under dark. (e) Harvested microtubers. (f) Nursery bed crop raised from microtubers. (g) Normal seed crop raised from minitubers harvested from nursery beds

seed tuber or seed lot becoming infected with pathogens progressively increases every year. To minimize this, seed certification agencies have enacted regulations to basically restrict or limit the number of years the seed lot can be eligible for the seed certification process.

The proposed system is summarized in figure-2 and its salient features are given below.

1. All seed potatoes must be limited to a maximum of seven multiplications. Of which first two are confined to

laboratories/greenhouse and remaining 5 are open field multiplications.

2. The classes of the limited generation system are; Pre-nuclear, Nuclear, Generation 1, Generation 2 (Breeders'/ Basic Seed), Generation 3 (Foundation-I), Generation 4 (Foundation-II) and Generation 5 (Certified Seed); where Pre-nuclear is essentially from the laboratory, Nuclear Seed is produced in a greenhouse, while Generations 1 to 5 are the first and subsequent multiplications in the field.
3. Pre-nuclear seed stocks must originate from tissue cultured plantlets, minitubers or microtubers.
4. Except for varietal mixtures, seed lots may be downgraded or advanced in generation if they do not meet the disease tolerances for that generation. Such seed lots, if meet standards of Certified Seed, can be sold as Certified Seed.
5. The Certified Seed class is not eligible for re-certification. However, if seed availability is low for a specific potato variety, seed lots with more than 5 field multiplications may be eligible for re-certification but only after prior approval of the Seed Certification Authority.

The proposed system and minimum quality requirements at each stage are given below.

### Laboratory and Greenhouse Facility Requirements

- i. All micropropagation and greenhouse facilities must be got approved from the Seed Certification Authority. Scorecard for assessing tissue culture and greenhouse facilities already developed (7) can be used for this purpose.
- ii. Laboratory and greenhouse facilities used for production of plantlets/microtubers or

minitubers shall be maintained free of potato pests or vectors of potato pathogens.

- iii. All potting or growth media shall be sterile or free from pathogens, pests and volunteers. Water sources used in a laboratory or greenhouse operation shall also be free of potato pathogens and pests.
- iv. Suitable precautions shall be taken in micropropagation practices and in the potting, planting, irrigating, movement and use of equipment, and other laboratory and greenhouse practices to guard against the spread of diseases or pests within the facilities.
- v. All details of the material propagated must be maintained for inspection by seed certification authority. These may include inventory of all plant material in the laboratory, origin of initial material, individual records for each line showing step-by-step flow through various multiplication stages, number of plants/ microtubers /minitubers on inventory, test reports etc.

### Farm Requirements

- (a) For nuclear seed production in greenhouses, the growing medium/soil must be free from fungal and bacterial pathogens, nematodes, volunteers and also from weeds.
- (b) Seed potatoes can not be grown in areas/ fields having history of wart (*Synchytrium endobioticum*), bacterial wilt (*Ralstonia solanacearum*) and nematodes (*Globodera rostochiensis* and *G. pallida*)
- (c) Boundaries of seed potato fields must be clearly defined.
- (d) Adequate separation (isolation) from uncertified fields must be maintained.

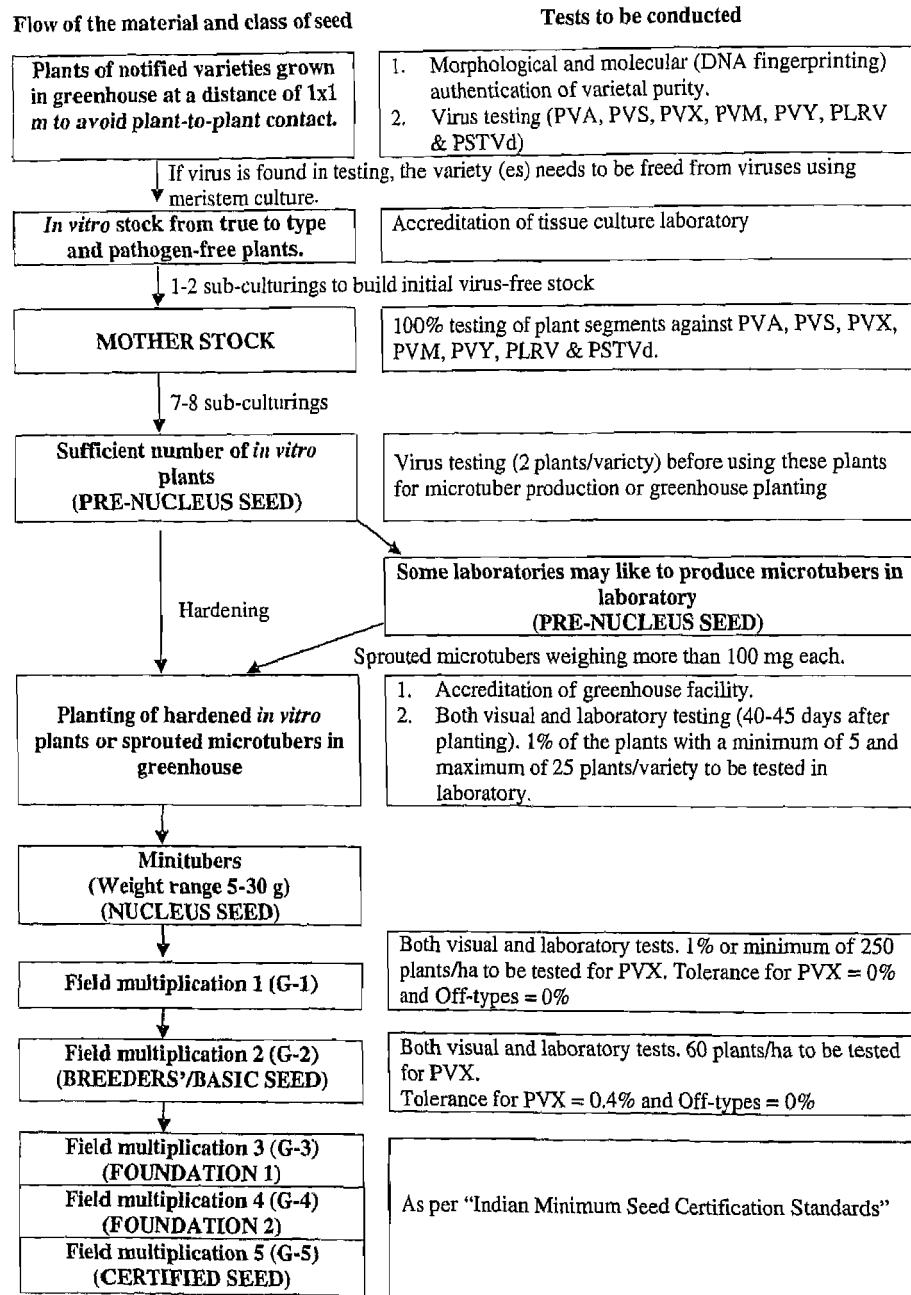


Fig. 2. Proposed micropropagation based potato seed certification system

- (e) Seed potatoes will not be planted on the farm that was cropped with potatoes the previous year, unless the farm is fumigated.
- (f) There must be clear demarcation between different varieties and classes of seed potatoes.

- (g) All equipment and storage facilities in the potato operation must be used only for the field entered for certification. In case these have been used on other farms, before reuse in seed plot, they need to be properly disinfected.

- (h) Equipment and stores must be clean and disinfected periodically but at least once annually.

## MINIMUM QUALITY REQUIREMENTS

### Pre-Nuclear (*In vitro* Production)

**Initiation of Pre-Nuclear Stock:** Any potato material can be used to initiate Pre-Nuclear Stock, provided the following requirements are met:

1. The material being initiated must be of a known varietal/clonal identity and must be duly documented with respect to origin.
2. All samples of a potato variety/clone being initiated must be tested by an accredited laboratory and found free from the following:  
PVA, PVS, PVM, PVY, PVX, PLRV, PSTVd, endophytic/epiphytic bacteria and fungi and also nematodes.
3. The initiating facility uses recognized aseptic initiation and propagation procedures (i.e. follows procedures and uses equipment, which will maintain sterile conditions).
4. The initiating facility must maintain information on variety/clone identification, date of initiation, origin and testing results from accredited laboratory for each variety/clone for review and audit by the Seed Certification Authority.
5. Pre-Nuclear Stocks need to be developed every year from certified *in vitro* plants after subjecting them to "Grow Out" test in greenhouse and authentication of varietal purity and pathogen-freedom. Varietal purity needs to be established by an accredited organization using morphological characters and DNA fingerprinting.

**Certification of Pre-Nuclear Stock:** On application for inspection, the Pre-Nuclear *in vitro* Stocks as developed above are eligible for certification. The micropropagation facility to be inspected must have been approved by the Seed Certification Authority. Each variety/clone must have a valid disease-testing report at any time during multiplication process. Tests must be carried out on a minimum of two plantlets for each variety/clone by an accredited laboratory. Such tests will be valid for a period of one year. No plant should contain PVA, PVS, PVM, PVY, PVX, PLRV, PSTVd, endophytic/epiphytic bacteria and fungi and nematodes.

Valid disease testing results are required prior to the initiation of microtuber production cycle.

Every container showing visual evidence of bacterial or fungal contamination must be removed from the micropropagation facility.

### Nuclear (Greenhouse or Controlled Environment) Seed Production

The following requirements must be met for the multiplication of Nuclear Stock in a protected environment:

1. The grower must notify the Seed Certification Authority of his production plans well in advance of the planting.
2. The crop must be grown from certified Pre-Nuclear *in vitro* plants or microtubers, which were produced, in an aseptic environment. Small minitubers of certified Nuclear stage produced previous year, which are too small for field planting can also be used for planting. But these minitubers must be planted in a separate greenhouse.

3. If pathogen testing is required, it must be carried out at 40-45 days after planting on a representative sample, which consists of 1% of the plants/tubers with a minimum of 5 and a maximum of 25 plants/tubers sampled for each variety/clone.
4. The protected environment must be "aphid proof" and be equipped with a double-door entrance, provision for footwear disinfecting prior to entering the protected environment and aphid proof ventilation screening on intakes and exhaust openings
5. Effective sanitation practices including insect and disease monitoring and prevention must be adhered to.
6. Nuclear Stock can be planted in commercially available medium, which has not been recycled. If nursery beds are used, a new or clean physical barrier from the growing medium must separate the underlying soil. If containers are used, they must be new or clean.
7. The facility must be free from all potato and solanaceous plant debris before planting.
8. No field-produced seed potatoes (including pathogen tested clonal selections), non-seed potatoes, nor any other solanaceous species of plants can be grown in the protected environment while used to produce Nuclear Stock.
9. Varieties/clones must be separated by physical barriers, which will prevent varietal mixture.
10. The crops and the facility must be got inspected from the Seed Certification Authority, at least once during the growing cycle. The inspection must take place at about 40–45 days after planting. Depending on the condition of the crop, the inspector may take leaf samples for laboratory testing to determine if the crop is free of pathogens.
11. If testing reveals the presence of PVA, PVS, PVM, PVY, PVX, PLRV or PSTVd the crop will be assigned the next appropriate class but will not be certified as Nuclear Stock.
12. If testing performed by an accredited laboratory reveals the presence of banned virus(s), fungus or bacteria all the crops in the protected environment will be ineligible for certification.
13. In the eventuality of detection of insect vectors by Seed Certification Authority, the grower must provide post harvest test results to this authority. A representative sample, representing each variety/clone grown in the protected environment must be post harvest tested and if the results are negative for PVS, PVM, PVA, PVY and PLRV, the crop will be assigned a Nuclear Stock status. Any crop testing positive for one of the above mentioned pathogens will be assigned appropriate seed class and allowed to be grown for the next generation by the owner only.

**Transfer of Pre-Nuclear and Nuclear Stock:**

An official Nuclear Stock Certificate issued by the certifying agency must accompany pre-Nuclear or nuclear stock, which is transferred to a new owner. The certificate may contain information on the date and number of certificate, name of the variety, type of propagules transferred (i.e. micro-tubers, micro-cuttings, or mini-tubers), amount of

Table 1. Proposed tolerance levels for visual inspection-I and II in G-1 and G-2

Factor	Generation-1		Generation-2	
	I	II	I	II
<i>Isolation distance</i>	5 m		5 m	
Off-types	0	0	0.10	0
PSTVd	0	0	0	0
Wilts	0	0	0	0
Total visible viruses/ mosaics	0	0	0.25	0.10
Bacterial wilt	0	0	0	0
Nematodes	0	0	0	0
Wart	0	0	0	0

propagules transferred, grower's name and address and consignee's name and address.

Nuclear Stock, though was produced in a protected environment, once transferred to a new owner, cannot be re-used to produce nuclear stock again.

**Field Inspections and Certification of G1 to G5 Stocks:** In G-1 and G-2 (Breeders'/Basic Seed) stages both visual inspections will be carried out twice during the season (at 35-45 and 60-75 days after planting depending upon crop duration) for pathogen freedom. In G-1 stage a minimum of 250 leaves collected from separate plants or 1% of the hills will be tested for PVX by an accredited laboratory. Tolerance for PVX in this stage shall be 0%. In G-2, 60 plants per ha shall be tested for PVX in the laboratory and the permissible tolerance should be 0.4%. The possible tolerance limits for G-1 and G-2 are given in table 1.

Field inspections for seed crops in G-3 (Foundation-I), G-4 (Foundation-II) and G-5 (Certified Seed) may be conducted as detailed under Indian Minimum Seed Certification Standards (9).

## LITERATURE CITED

- DES. 2003. Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, New Delhi.
- FAOSTAT. 1997-2001. Food and Agriculture Organization. Statistical Database.
- Khurana, S.M. Paul, G.S. Shekhawat, B.P. Singh and S.K. Pandey (Eds). 2002. *Potato: global research and development*, Volume-I, Indian Potato Association, Shimla. 733 pp.
- Naik, P.S. and D. Sarkar. 2001. Use of microtubers in potato for production of virus-free planting material. In: *Role of resistance in intensive agriculture*. (Nagrajan, S. and D.P. Singh, Eds.). Kalyani Publishers, New Delhi. pp. 12-28.
- Naik, P.S and D. Sarkar. 1998. *In vitro* approaches to propagation and conservation of genetic resources in potato. In: *Biotechnology in horticultural and plantation crops*. (K.L. Chadha, P.N. Ravindran and L. Sahijram, Eds.), pp. 369-406, Malhotra Publishing House, New Delhi.
- Pushkarnath. 1967. Seed potato production in the sub-tropical plains of India. *Am. Potato J.* 44: 429-441.
- Singh, H.P. and J. Samuel. 2002. Prospective of high tech horticulture and precision farming. In: *Souvenir-National Seminar cum Workshop on Hi. Tech. Horticulture and Precision Farming*. July 26-28, 2002. Lucknow. pp. 1-17.
- Singh, Sarjeet, V.K. Garg, Shiv Kumar and G.S. Shekhawat. 2000. *Seed potato production manual*. Central Potato Research Institute, Shimla. 91 pp.
- Tunwar, N.S. and S.V. Singh. 1988. *Indian minimum seed certification standards*. The Central Seed Certification Board, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India, New Delhi. pp. 171-175.

MS Received: 15.09.2003



## DEVELOPMENT AND EVALUATION OF PLAIN AND PROFILED ROLLER TYPE OF POTATO GRADER

B.B. Saxena<sup>1</sup>, Manjit Singh, Sunil Gulati<sup>2</sup> and R.C. Sharma<sup>3</sup>

**ABSTRACT:** The rubber roller type of Potato Grader for small farmers and hill regions was developed. The main components of the grader were feed conveyor, frame, grading unit, collecting chutes and power transmission unit. The grader required electric motor of 0.746 KW to drive various component of grader at full load with reduction gear box of 13:1. The grader was tested with potato of three varieties viz. Kufri Chandramukhi, Kufri Sindhuri and Kufri Jyoti to see the average size and sphericity of potato. It was found that grading of potato was very uniform irrespective of variety of potato. The maximum separation efficiency at optimum of conveyor speed (7.5 m/min) was found to be 93% for the out put capacity of about 45 q/h.

### INTRODUCTION

The potato is one of the most important crop in India. The Uttar Pradesh is one of the highest potato producing state in the country. The second highest potato producing state is West Bengal and the rest is cultivated in Bihar, Punjab, Madhya Pradesh and Gujarat. The grading of potato is an important operation in preparing potato for seed and commercial purposes. The grading or sorting out of seed potato in to desired grades for seed purpose is a skilled operation. The grading operation is basically done by counting manually. The manual grading operation i.e. picking by hand is very slow, labour intensive and costly. More over the manual grading of potato is not very accurate. It mostly depends on the attention of the manual labour and his sincerity.

The different types of graders have been developed in different places. Central Potato Research Institute, Shimla has developed

simple hand and power operated mechanical size graders on the conventional principal of sieving. It needs to and fro operations, which invites more wear and tear on moving parts and also time and labour consuming.

The efficient grading operation on the basis of physical dimensions of the potato can be developed with the help of mechanical potato grader. In India, different type of oscillating sieves (2,3), V-belt type (1), differential belt speed expanding pitch type (4) and expanding pitch rubber spool types (5) were developed earlier to grade potato in three grades. Shyam, *et al.* (2,3) developed an oscillating sieves seed potato size-grader. The sizing efficiency ranged from 80 to 90% and average tuber damage was with in 2%. Garg and Rai (1) developed V-belt expanding pitch type potato grader. The maximum separation efficiency of 80% was obtained for grader shaft speed of 40 rpm.

---

<sup>1</sup> NRC for Soybean, Indore-452 017 (Madhya Pradesh)

<sup>2</sup> Central Potato Research Station, Model Town, Jalandhar-144 003 (Punjab)

<sup>3</sup> Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh)

Singh (4) developed a differential belt speed expanding pitch type potato grader. The maximum separation efficiency at optimum speed (35 rpm of grader shaft, 4.4 m/min of belt speed) was found to be 87%.

Verma and Kalkat (5) developed an expanding pitch rubber spool potato sizer. The potatoes are not separated in to desired sizes as over riding occurs during the grading process. The out put of graders developed in USA and other European countries (hexagonal opening screen type potato grader) is very high but the disadvantages of this machine were the tedious construction, high losses due to bruising, skinning and cutting during grading process.

About 18% potato is cultivated in hills. The use of mechanical potato graders in hills is very limited because of non availability of suitable grader. The design considerations for hill grader are handy, compact, easy to move from one place to another place, light weight and needs very less repair and maintenance. Therefore, the efforts have been put to develop rotary rubber roller type of grader specially suitable for hills.

## MATERIALS AND METHODS

The grader consist of conveyor, frame, ground wheels, rotating shaft along with rubber rollers and plain PVC pipes. These PVC pipes work as conveyor in the grading system and the gap between the plain PVC pipes and round rubber roller helps in grading. The main component of the grader is rubber roller. The dimension of the roller is 96 mm on top and 40 mm at bottom. The rubber roller is made from synthetic rubber with natural colour so that there may not be any

possibility of colouring the potato while in contact with rubber roller. The motor as primemover used of 0.746 kw with a reduction gear box of 13:1 (speed ratio). The speed of motor is 1400 rpm, which is reduced with the help of reduction gear and V-belt and pulley to 70 rpm.

The main components of the grader are feed conveyor, frame, grading unit, collection chutes and power transmission unit. The conveyor consists of iron frame, wooden strip, conveyor belt and wooden roller to move the conveyor in the forward motion. The total size of the conveyor is 226 x 81 cm. The conveyor is divided in to 11 strips each of 71 x 17 cm size, which carry about 10-15 kg. potatoes in one instance. At the lower end of the conveyor, a feed tray is provided at an angle of 20° with the horizontal. At the end of the tray, a small rubber plate is hinged which helps to carry small tubers of potato (Fig. 1).

The grading unit is mounted on a (106.0 x 100.5 cm) angle iron frame. At the feeder end, the three plain hollow PVC pipes are mounted on a round shaft at ends with the help of wooden bush. These rods are moving with the help of chain and sprocket. The potatoes from the conveyor are discharged in small lots and are spread well with the help of PVC pipes. The movement of the PVC pipes helps the potatoes to the grading space. The different grading space is provided between the plain rollers and rubber rollers. The rubber rollers of (96 mm max. dia x 40 mm length and hollow within having square hole of 21 mm in the centre) are mounted on all square shaft of 21 mm size. The plain pipes of PVC are provided in between each grades. The potato of particular grade is dropped within the space

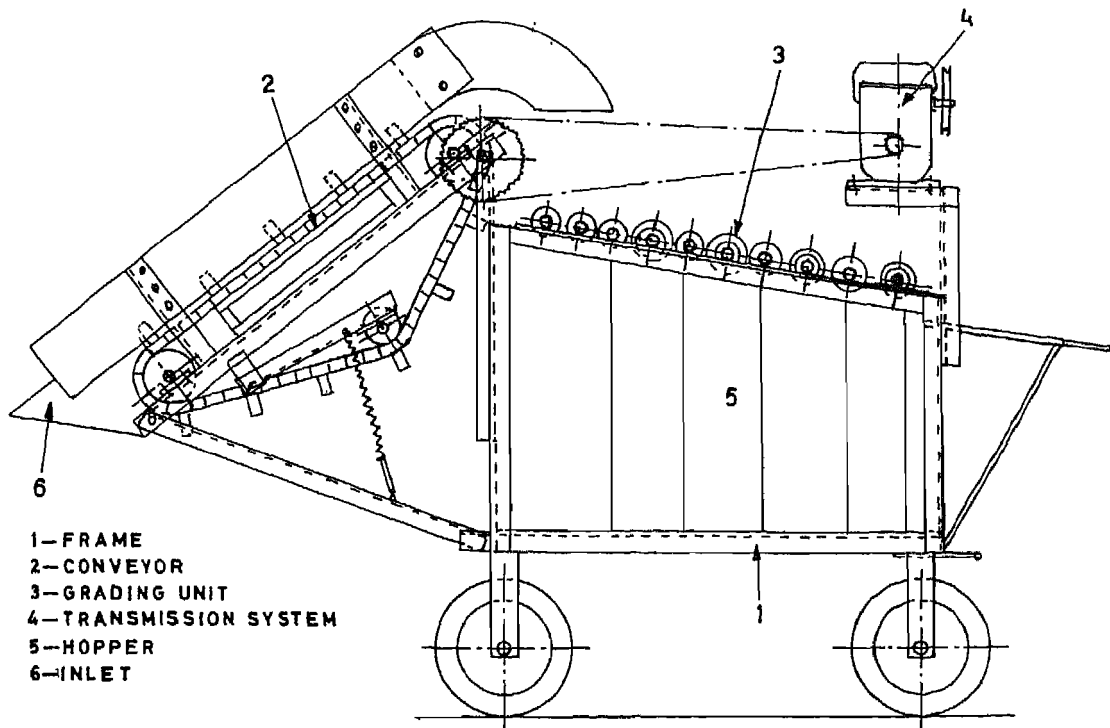


Fig. 1. Rubber roller type potato grader for hills

provided between plain roller and rubber rollers. The potato of remaining grades move with the help of plain pipes' 12 pairs of rubber rollers are mounted on one square and the shaft is rotating with the help of chain and sprocket.

The potato of particular grade is collected in the chutes provided on both the sides of the grader. The chutes are provided with rubber cushion so that the potato after grading should not get damaged and is collected in baskets or bags. The grader is providing four grades and the over size potato goes in the last. The slope from feeding end to the last grading end is provided about 16 percent (Fig. 2).

The transmission unit consists of electric motor, speed reducing gear box (13:1) V-belt and pulley and chain and sprocket. The electric motor of 0.746 kw to 1.01 kw is provided and

with the help of V-belt and pulley, the revolution is reduced from 1440 rpm to 900 rpm and finally with the help of reduction gear box, the revolution is reduced to 70 rpm on the reduction gear. With the help of chain and sprocket, the speed of feeding conveyor was kept as 8.5 m/min at 18 rpm. The revolution of rubber roller shaft as well as plain pipes was kept at about 100 rpm. The peripheral speed of rubber roller was kept at 31.5 m/min. The grader was also operated with 3.73 kw (5 hp) diesel engine and the speed of conveyor and grading unit is changed and it was used for testing purpose. Fig.1 shows the diagramme of rubber roller type potato grader for hills and Fig. 2 shows its photograph.

The samples were taken from each grade and the average size was computed by

measuring three perpendicular dimensions X, Y and Z of each potato from the samples. The following formula was used to calculate average size.

$$\text{Average size} = (X.Y.Z)^{1/3}$$

$$\text{Sphericity} = \frac{(X.Y.Z)^{1/3}}{Z}$$

Where,

X = smallest dimensions along X - axis

Y = middle dimensions along Y - axis

Z = largest dimensions along Z - axis

The separation efficiency of each grade at a particular conveyor speed was calculated. The over all separation efficiency at particular speed of the machine was calculated by dividing the total weight of correct size of graded potato of all the samples with the total weight of all the sample. The separation efficiency was calculated by using following formula:

$$E_s = \frac{W_t - W_u - W_o}{W_t} \times 100$$

Where,

$E_s$  = percentage separation efficiency of that grade.

$W_t$  = total weight of the sample.

$W_u$  = weight of the under size in that sample.

$W_o$  = weight of the over size in that sample.

## RESULTS AND DISCUSSION

The potato grader designed for hills and small farmers was tested at Central Potato Research Station (CPRS), Jalandhar farm during 2001-2002. The varieties of potato, viz. Kufri Chandramukhi, Kufri Sindhuri and Kufri Jyoti were used to test the average size and sphericity of the graded potato. The samples were taken from graded potato lots to determine the average size and sphericity.

The average size was calculated for all the four grades of three potato varieties and the data is presented in Table 1. The potato grader was designed to obtain four different grades i.e. A, B, C and D. As per Table 1, the average size of A grade varied between 2.98, 3.08 and 3.16 cm and for B grade 3.84, 3.99 and 4.14 cm for C grade 5.25, 5.13 and 5.38 cm and for D grade 6.73, 6.05, 6.27 cm, respectively for cvs. Kufri Chandramukhi, Kufri Sindhuri and Kufri Jyoti varieties of potato. The data of average size was analysed statistically. The critical difference between treatment means were calculated. The difference with in the same grade of potato irrespective of potato variety was found non-significant at 5% level. It shows that the grader was maintaining good uniformity in grading the potato irrespective of potato varieties. The data were analysed statistically and the critical difference and

Table 1. The details of mean of average tuber size of different potato cultivars (Kufri Chandramukhi), Kufri Sindhuri and Kufri Jyoti) of four different grades (A, B, C and D)

S.No.	Grade	Kufri Chandramukhi Average size in cm	Kufri Sindhuri Average size in cm	Kufri Jyoti Average size in cm	CD
1.	A	2.98	3.08	3.16	0.20(NS)
2.	B	3.84	3.99	4.14	0.28(NS)
3.	C	5.25	5.13	5.38	0.09(NS)
4.	D	6.73	6.05	6.28	0.16(NS)
Average Mean :		4.70	4.56	4.74	
Standard Error :		0.12	0.10	0.10	
C.D. (0.05):		0.33	0.27	0.28	
C.V. (%)		12.06	9.77	9.04	

coefficient of variance were calculated. It was found that the difference was significant at 5% level from one grade to another grade, showing that the grader was performing satisfactorily irrespective of the potato variety.

The graded samples of cv. Kufri Jyoti variety at different conveyor speed were taken and average size of the samples were calculated (Table 2). The least significant difference at 5% level (CD) and coefficient of variance between treatment means were calculated and it was found that the coefficient of variance was less at 7.5 m/min conveyor speed than at 3.5 m/min and 5.4 m/min. It showed that the quality of grading was better at 7.5 m/min conveyor speed than the lower speeds. It was also found that as the conveyor speed was increased, the output of the grader was increased. The capacity or out put of the grader was found, 35 q/h, 40 q/h and 45 q/h at 3.5 m/min, 5.4 m/min and 7.5 m/min conveyor speeds, respectively. Therefore, it could be concluded that at conveyor speed of 7.5 m/min the output of grader was 45 q/h without sacrificing the quality of the grading of potato.

The grader was used for grading 400 q. of potatoes of cv. Kufri Jyoti variety. It grader

was run at 3.5 m/min, 5.4 m/min, 7.5 m/min and 8.5 m/min conveyor speeds. Potatoes obtained in different grades in one minute run of the machine were weighed and the feed rate was calculated. This was repeated three times for each speed and sample.

The separation efficiency of each grade was calculated at different conveyor speed (Table 3). The separation efficiency at 3.5 m/min conveyor speed varied from A, B, C and D grade at the rate of 93%, 96%, 96% and 93%, respectively whereas the separation efficiency of each grade at 8.5 m/min of conveyor speed varied from A, B, C and D grade at the rate of 82%, 87%, 88% and 80%, respectively. It showed that as the conveyor speed was increased the separation efficiency of each grade was reduced as shown in Fig.3. The output at each conveyor also samples and it was found that the output or capacity of grader increased linearly with the increase of conveyor speed. The over all separation efficiency at different conveyor speeds i.e. 3.5 m/min, 5.4 m/min, 7.5 m/min and 8.5 m/min was calculated and was found 95%, 92%, 93% and 85.2%, respectively. It show that the over all separation efficiency decreased as the conveyor speed was increased. The over all

Table 2. Average size of Kufri Jyoti at different conveyor speed

S.No.	Grade	Conveyor speed 3.5 m/min (output 35 q/h)	Conveyor speed 5.4 m/min (output 40 q/h)	Conveyor speed 7.5 m/min (output 45 q/h)
1.	A	2.75 cm	2.80 cm	2.93 cm
2.	B	3.76 cm	4.20 cm	3.68 cm
3.	C	5.44 cm	5.31 cm	4.87 cm
4.	D	6.25 cm	6.94 cm	6.18 cm
Mean :		4.55	4.81	4.42
S. Error		0.11	0.11	0.08
Critical difference (0.05) :		0.31	0.32	0.22
Coefficient of variance :		12.35%	12.17%	8.66%

Table 3. The average weight of samples of each grade at different conveyor speed to calculate the separation efficiency of each grade

S. No.	Conveyor Speed m/min.	Outputq/ha	Grade	Mass of the sample kg.		Seperation efficiency	
				Total	Over & undersize wt	Grade wise	Overall
1.	3.5	36.00	A	22.50	1.56	93%	95%
			B	62.40	2.25	96%	
			C	57.60	2.04	96%	
			D	37.50	2.40	93%	
2.	5.4	39.90	A	24.00	2.64	89%	92%
			B	72.00	5.04	93%	
			C	66.00	3.30	95%	
			D	37.50	3.75	90%	
3.	7.5	44.40	A	25.50	2.55	90%	93%
			B	78.00	3.90	95%	
			C	72.00	4.32	94%	
			D	46.50	4.20	91%	
4.	8.5	48.00	A	30.00	5.40	82%	85.2%
			B	84.00	11.04	87%	
			C	78.00	9.36	88%	
			D	48.00	9.60	80%	

separation efficiency was recorded at 7.5 m/min conveyor speed and the output was also calculated to be about 45 q/h at this speed. Therefore, it could be concluded that the grader need to be operated at 7.5 m/min conveyor speed to obtain 93% over all separation efficiency and output of 45 q/h.

The bruising of potato during grading operation was found negligible and there was no wear and tear observed during the operation of the machine. The operational view of Rubber roller type grader is shown in Fig. 2.

The power requirements at no load and full load are shown in Fig.4. It shows that the power requirement increased with increase in speed of conveyor and grading unit. The power requirement varied from 0.373 kw to 0.56 kw and 0.45 kw to 0.7 kw at no load and at full load respectively at different conveyor speed.



Fig.2. Rubber roller type of potato grader in operation

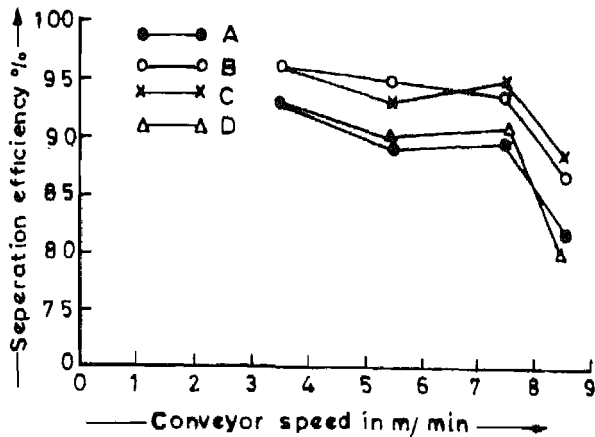


Fig.3. Effect of conveyor speed on separation efficiency on each grade

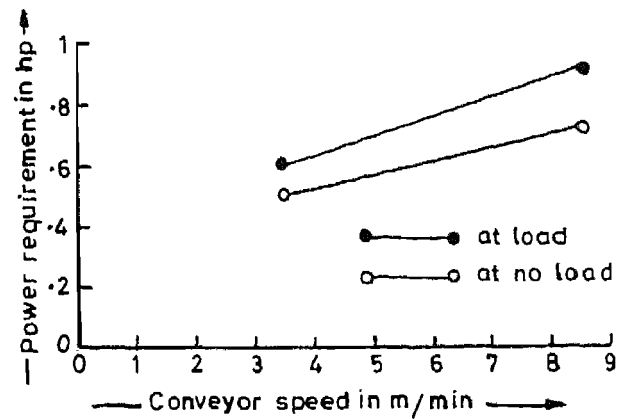


Fig.4. Effect of conveyor speed on power requirement of grader (at load and no load)

### ACKNOWLEDGEMENTS

Authors are grateful to Dr. G.S. Kang, Head, C.P.R.S., Jalandhar and Dr. R.N. Khanna, Retd. Principal Scientist for their encouragement and valuable suggestions from time to time during the period of development of grader and its testing.

### LITERATURE CITED

- Garg, B.K. 1974. *Design, development and testing of belt type potato grader*. B. Tech. Thesis, Department of Agril. Engineering, G.B. Pant University of Agril. and Tech., Pantnagar.

- Shyam, M., R. Singh and V. Singh. 1988. Simple indigenous machines for seed potato size grading. *Seeds and Farms* 14(2): 38-39.
- Shyam, M., R. Singh and V. Singh. 1991. Development of oscillating sieves seed potato size - grader. *J. Indian Potato Association* 18: 61-67.
- Singh, Bachachan. 1980. Development and performance of differential belt speed expanding pitch type potato grader. *J. of Agril. Engg.* 17(2)
- Verma, S.R. and H.S. Kalkat. 1975. Design and development of expanding pitch rubber spool potato sizer. *J. of Agril. Engg.* 12: 35-40.

MS Received: 31.10.2002



# SOIL AND PLANT N AS INFLUENCED BY FURROW AND TRICKLE IRRIGATION IN POTATOES

J.K. Chawla and N.K. Narda<sup>1</sup>

**ABSTRACT :** The study of soil and plant N as influenced by furrow method of irrigation and trickle fertigation on potatoes revealed highest concentration of NO<sub>3</sub>-N in the soil in the 30-45 cm layer after 2 days of first irrigation in the furrow method. After second irrigation, NO<sub>3</sub>-N content that was maximum in the surface layer was reduced to the minimum after 10 days. In the trickle fertigated plot, NO<sub>3</sub>-N was maximum in the 15-30 cm layer irrespective of the number of days after irrigation. Total plant N under trickle treatments was higher than furrow irrigated crop. The high fertilizer use efficiency resulted in higher crop yield in the trickle fertigated crop.

## INTRODUCTION

With the introduction of high yielding crop varieties having high water and fertilizer needs, farmers are confronted with the challenge of providing crops with optimal quantities of water and nutrients in the most effective manner so as to have high yields. Trickle irrigation coupled with its ability of fertigation offers an alternative to conventional method of irrigation because it is highly efficient and thus economizes greatly on fertilizer and water use and also ensures better crops.

Many researchers (1, 2, 5) have established that fertilizer use efficiency using trickle irrigation is quite high but data on availability of nutrients in soil and plant by using this method on vegetable crops has been lacking.

The present research was thus aimed at investigating the status of available soil and plant N under furrow and trickle irrigation methods under different fertigation options in potato crop with urea as the source of N.

## MATERIALS AND METHODS

The study was undertaken at the Research Farm of the Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana for two seasons during the years 2001 and 2002 on potato cv. Kufri Chandramukhi using trickle and conventional furrow irrigation methods of irrigation. The area of the trickle plot was 414 m<sup>2</sup> in which laterals of 23-m length were laid. The lateral lines had in-line type of emitters spaced 30 cm apart having an average emitter discharge of 2 l h<sup>-1</sup>. The area of furrow plot was 360 m<sup>2</sup> in which the furrows were also of the same length but were constructed as per the farmers' practice.

Three variables, viz. fertilizer application rate (N); frequency of fertigation (F) and wetted soil volume (V) each having three levels were studied. Basal dose of urea ( $\frac{1}{4}$ N= 103 kg/ha) along with whole of P (62.5 kg/ha) and K (125 kg/ha) was applied to both the trickle and furrow plots at planting time. The post planting dose of urea (309 kg/ha) was applied in the furrows as per the recommended

---

<sup>1</sup>Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana-141 004 (Punjab)

practices of PAU while in the trickle plot, this dose was applied in splits as per frequency of fertigation. Urea was applied to the crop @ 30 ( $N_1$ ), 60 ( $N_2$ ) and 100 ( $N_3$ ) per cent of the recommended post-planting dose (309 kg/ha) with 3 frequencies of fertigation, viz. 8 ( $F_1$ ), 12 ( $F_2$ ) and 16 ( $F_3$ ) days combined with 3 wetted soil volumes of 50 ( $V_1$ ), 75 ( $V_2$ ) and 100 ( $V_3$ ) per cent of the wetted depth. The 27 treatments were laid out in a split plot design with 2 replications. Additional irrigations (besides that applied with fertigations) based on IW/CPE ratio of 0.8 were given as advocated by Singh and Sood (8) where IW denotes the irrigation water requirement and CPE is the cumulative pan evaporation. Irrigation was applied at weekly intervals when CPE equalled 25mm and the irrigations did not interfere with the treatment fertigations. The planting was done in the second week of October and recommended plant protection measures were undertaken. The crop was harvested in the first week of January during both the years.

In the trickle plot, the post-planting dose of urea was split into 6, 4 and 3 parts corresponding to 8, 12 and 16 days' frequencies of fertigation. First fertigation was done on 31 DAP and the entire set of fertigations was completed within 48 days so as that the applied nutrients were utilized by the crop before its harvest. The wetted soil volume beneath the emitter was calculated by assuming it to be ellipsoidal shaped (4).

From the trickle fertigated plot, soil samples for  $NO_3$ -N analysis were taken from 3 depths (0-15, 15-30 and 30-60 cm) before each fertigation and 48 hours after fertigation for total plant N determination.

In the furrow irrigated plot, soil and plant sampling for  $NO_3$ -N analysis was started with the application of remaining  $\frac{3}{4}$  dose of urea band placed 30 DAP before earthing up. Soil and plant samples at random were taken before every irrigation and then after 2, 4, 6, 8 and 10 days of each irrigation. Soil samples were analyzed for  $NO_3$ -N analysis using an Auto Analyzer model SKALAR PLUS. Dried and ground plant samples were taken for total plant N determination by Kjeldahl digestion method (6).

## RESULTS AND DISCUSSION

### *Nitrate dynamics in the furrow irrigated plot*

Depthwise distribution of  $NO_3$ -N in the soil profile of furrow irrigated but conventionally fertilized crop is shown in Fig.1 (a and b) for two periods: i) after 2 and 10 days of first irrigation and (ii) after 3 and 10 days of second irrigation. After 2 days of first irrigation, the  $NO_3$ -N concentration was highest in the 15-30 cm layer which may be due to nitrification of accumulated  $NH_4$ -N in this depth. Similar were the results at 10 days irrigation.

The dynamics of nitrate in the soil profile after 3 and 10 days of second irrigation reveals a significant change in its distribution between the two periods (Fig.1b). Nitrate N content was maximum in the surface layer at 3 days which thereafter, decreased with depth and at 10 days, it dropped to the minimum in the top layer and increased with depth. The movement of water front and that of  $NO_3$ -N from the top layer to the bottom layer is well known.

From Fig.1, it is evident that the peak of nitrate concentration in the furrow irrigated crop was within 15-30 cm soil layer irrespective

of the time interval. Singh and Sood (8) had observed similar phenomenon. This was also observed by Beri *et al.* (3) who opined that in free flooding, significant quantity of urea moved along with the wetting front in an unhydrolysed form to give a peak of  $\text{NO}_3^-$ -N in the surface layer of soil profile.

**$\text{NO}_3^-$ -N dynamics in trickle fertigated crop:** A careful perusal of the values for  $\text{NO}_3^-$ -N in trickle fertigated crop showed its maximum concentration in the 15-30 cm layer (Table 1). However, the peak of  $\text{NO}_3^-$ -N in furrow method of irrigation shifts to deeper layers after II irrigation owing to greater mobility of

$\text{NO}_3^-$ -N ions with water. In trickle fertigated crop, since the quantity of water applied was limited to 30-60 cm soil depth, hence the  $\text{NO}_3^-$ -N ions remained confined to this zone only. This may be one of the reason for better performance of the crop under trickle fertigation since the roots which proliferate heavily in this very zone, were able to take up  $\text{NO}_3^-$ -N (available in readily available form and in the desired quantities) easily leading to higher fertilizer use efficiency.

**Total plant N vs stage of growth :** There was a build up of total plant N in potato plant for all the frequencies of fertigation upto certain

Table 1. Observed values of  $\text{NO}_3^-$ -N (ppm) for three frequencies of fertigation around maturity stage of potato crop

Set $F_1$ *	$\text{NO}_3^-$ -N	Set $F_2$	$\text{NO}_3^-$ -N	Set $F_3$	$\text{NO}_3^-$ -N
	26.0		20.1		21.5
$N_1F_1V_1$ **	29.4	$N_1F_2V_1$	13.5	$N_1F_3V_1$	25.0
	26.6		19.5		15.0
	27.2		10.8		18.4
$N_1F_1V_2$	11.2	$N_1F_2V_2$	18.4	$N_1F_3V_2$	27.0
	10.7		20.1		10.6
	13.9		16.2		16.8
$N_1F_1V_3$	12.0	$N_1F_2V_3$	20.1	$N_1F_3V_3$	15.1
	17.6		26.0		20.5
	19.5		16.5		20.9
$N_2F_1V_1$	21.7	$N_2F_2V_1$	32.1	$N_2F_3V_1$	21.2
	19.2		16.5		17.9
	37.5		22.3		23.5
$N_2F_1V_2$	52.5	$N_2F_2V_2$	31.0	$N_2F_3V_2$	32.0
	26.5		23.5		23.0
	20.8		15.7		22.5
$N_2F_1V_3$	37.8	$N_2F_2V_3$	17.6	$N_2F_3V_3$	19.8
	44.1		38.5		28.0
	39.5		30.5		33.0
$N_3F_1V_1$	37.8	$N_3F_2V_1$	46.0	$N_3F_3V_1$	44.0
	16.8		17.3		10.7
	37.8		27.0		35.1
$N_3F_1V_2$	51.9	$N_3F_2V_2$	37.0	$N_3F_3V_2$	31.1
	20.8		11.2		13.0
	37.8		30.0		31.5
$N_3F_1V_3$	55.3	$N_3F_2V_3$	23.4	$N_3F_3V_3$	39.0
	52.4		48.5		28.4

\* $F_1$  = crop fertigated at 8 days interval,  $F_2$ = fertigation interval 12 days and  $F_3$  = fertigation interval 16 days

\*\* Against each treatment NFV- the three listed values of  $\text{NO}_3^-$ -N pertain to the three depth increments from top to bottom, viz. 0-15, 15-30 & 30-60 cm depth respectively.

$V_1$  = for 50% wetted soil volume,  $V_2$  = 75 % wetted soil volume and  $V_3$  =100% wetted soil volume. For more details, refer to (4)

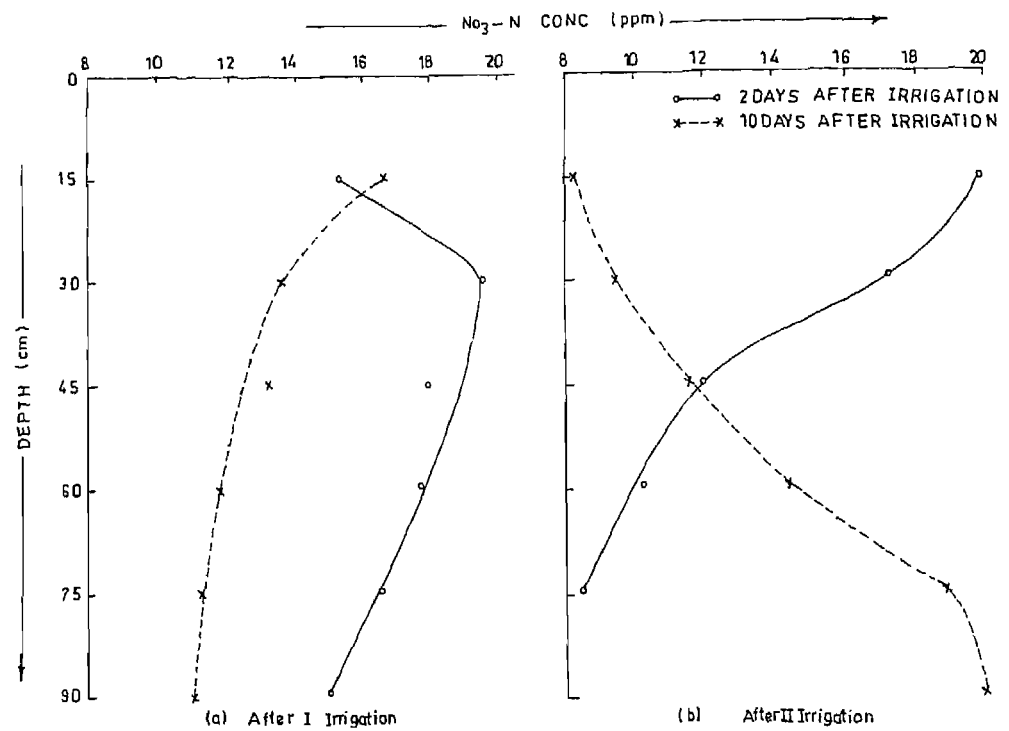


Fig. 1. Nitrate distribution in soil profile in furrow plots

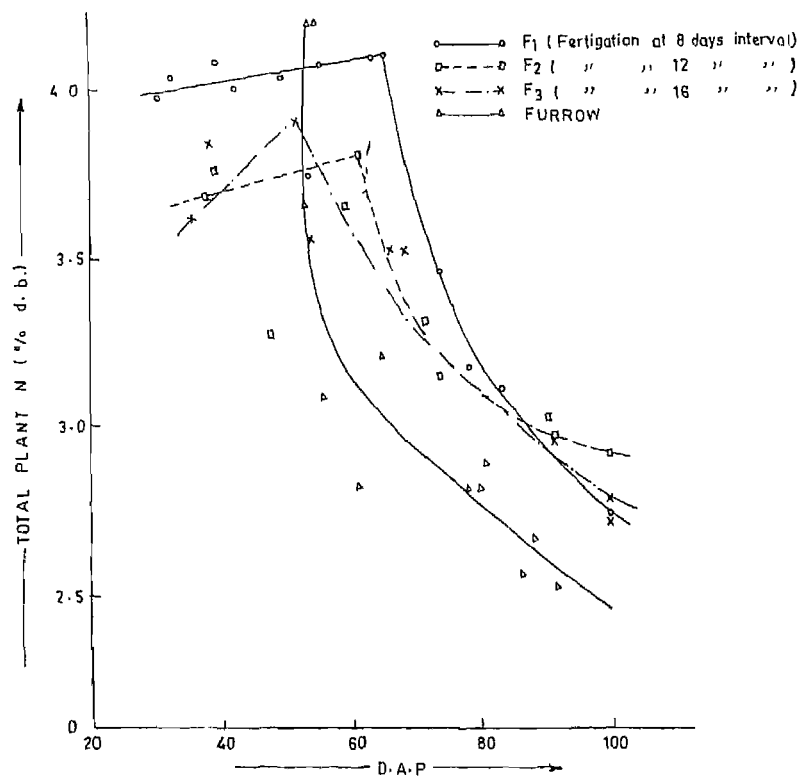


Fig. 2. Total plant N vs DAP showing the effect of split nutrition on trickle fertigated vs furrow irrigated potato crop

stage after which there was a steep fall in the N-content (Fig. 2). The initial increase in plant N content in the leaves may be due to the continuous uptake of nutrients during tuberisation phase (40-50 DAP). The steepness of the slope points to the high rate of transfer of carbohydrates from the leaves to the tubers. Total plant N content decreased after certain stage in all the frequencies of fertigation including furrow irrigated crop. The order of rate of decrease was  $F_1 > F_2 > F_3 >$  furrow meaning thereby that in furrow irrigated plants, the N-content of plant was always lower than trickle fertigated crop, a factor which ultimately led to larger tuber size and

hence increased yield and improved efficiency of N use by potatoes under trickle fertigation. Phene *et al.* (7) had also observed high petiole  $\text{NO}_3\text{-N}$  content in trickle fertigated potatoes.

**Fresh tuber yield:** The yield data of fresh tubers for potato crop for the two seasons along with their means is given in Table 2. The highest yield of  $36.29 \text{ t ha}^{-1}$  (mean of two years) was obtained for the treatment  $\text{N}_3 \text{ F}_1 \text{ V}_3$  i.e. when 100 per cent dose of N was applied at an interval of 8 days and the soil volume was wetted to the extent of 100 per cent as compared to an average yield of  $21.5 \text{ t ha}^{-1}$  realized for the conventionally grown crop registering an increase of 68.8 per cent while the overall mean yield (based on 27 treatments) was  $30.13 \text{ t ha}^{-1}$  which was 40.14 per cent higher than the control. Even the lowest yield of  $22.58 \text{ t ha}^{-1}$  ( $\text{N}_1 \text{ F}_3 \text{ V}_1$ ) was more than the control. Thus it is evident that when same dose of N is applied to potato crop using fertigation technique, it leads to higher yield as compared to furrow method of irrigation indicating its better use efficiency in the former.

On the basis of this experiment, it can be concluded that after urea application in potato crop,  $\text{NO}_3\text{-N}$  concentration in furrow irrigated crop increased in the top layer after first irrigation and decreased with depth thereafter while after second irrigation, the peak of  $\text{NO}_3\text{-N}$  shifted to deeper soil layers. In trickle fertigated crop, the maximum concentration of  $\text{NO}_3\text{-N}$  remained confined to 30-60 cm soil depth. Total plant N content in the above ground parts was always more in trickle fertigated crop than furrow irrigated crop. These factors resulted into higher crop yield and better fertilizer use efficiency in the trickle fertigated crop of potatoes.

Table 2. Fresh tuber yield data for potato crop (t/ha)

Treatment	I Season	II Season	Pooled
$\text{N}_1 \text{ F}_1 \text{ V}_1^*$	26.48	26.40	26.44
$\text{N}_1 \text{ F}_1 \text{ V}_2$	29.41	30.87	30.14
$\text{N}_1 \text{ F}_1 \text{ V}_3$	34.37	33.81	34.09
$\text{N}_2 \text{ F}_1 \text{ V}_1$	27.18	27.43	27.30
$\text{N}_2 \text{ F}_1 \text{ V}_2$	31.62	31.95	31.78
$\text{N}_2 \text{ F}_1 \text{ V}_3$	35.11	35.28	35.20
$\text{N}_3 \text{ F}_1 \text{ V}_1$	28.90	27.70	28.30
$\text{N}_3 \text{ F}_1 \text{ V}_2$	32.19	33.00	32.60
$\text{N}_3 \text{ F}_1 \text{ V}_3$	36.23	36.35	36.29
$\text{N}_1 \text{ F}_2 \text{ V}_1$	24.32	22.49	23.40
$\text{N}_1 \text{ F}_2 \text{ V}_2$	29.25	27.87	28.56
$\text{N}_1 \text{ F}_2 \text{ V}_3$	32.98	31.25	32.12
$\text{N}_2 \text{ F}_2 \text{ V}_1$	26.87	24.32	25.60
$\text{N}_2 \text{ F}_2 \text{ V}_2$	31.45	29.40	30.42
$\text{N}_2 \text{ F}_2 \text{ V}_3$	35.10	33.60	34.35
$\text{N}_3 \text{ F}_2 \text{ V}_1$	27.90	27.40	27.65
$\text{N}_3 \text{ F}_2 \text{ V}_2$	31.86	30.32	31.09
$\text{N}_3 \text{ F}_2 \text{ V}_3$	36.28	36.10	36.24
$\text{N}_1 \text{ F}_3 \text{ V}_1$	23.11	22.05	22.58
$\text{N}_1 \text{ F}_3 \text{ V}_2$	29.07	25.97	27.52
$\text{N}_1 \text{ F}_3 \text{ V}_3$	32.41	31.09	31.75
$\text{N}_2 \text{ F}_3 \text{ V}_1$	26.61	24.00	25.30
$\text{N}_2 \text{ F}_3 \text{ V}_2$	30.37	28.38	29.37
$\text{N}_2 \text{ F}_3 \text{ V}_3$	34.57	33.04	33.80
$\text{N}_3 \text{ F}_3 \text{ V}_1$	27.40	25.64	26.52
$\text{N}_3 \text{ F}_3 \text{ V}_2$	31.65	29.28	30.46
$\text{N}_3 \text{ F}_3 \text{ V}_3$	35.61	33.35	34.48
Average (Trickle)	30.70	29.55	30.13
Average (Furrow)**	23.70	19.30	21.50

\* Subscript 1, 2 and 3 refer to the three levels of respective factor

\*\* Based on the average produce of 8 rows.

## LITERATURE CITED

1. Black, J.D.F. 1976. Trickle Irrigation: A review. *Hort. Abst.* **46**: 69-74.
2. Bar Yosef, B. 1991. In: *Fluid fertilizer technology*, (Derek A. Palgrave, Ed.), pp. 285-330. Marcel Dekkar Inc., USA.
3. Beri, V., S.S. Brar, G.S. Sekhon and B.S. Ghuman. 1978. Extent of urea leaching in soils and its biochemical control. *J. Ind. Soc. Soil Sci.* **26**: 116-24.
4. Chawla, J.K. and N.K. Narda. 2001. Economy in water and fertilizer use in trickle fertigated potato. *Irrigation and Drainage* **50**: 129-37.
5. Haynes, R.J. 1985. Principles of fertilizer use for trickle irrigated crops. *Fert. Res.* **6**: 235-55.
6. Page, A.L. 1982. *Methods of soil analysis*. Part 2, 2<sup>nd</sup> edition. American Society of Agronomy and Soil Science Society of America, Madison (USA).
7. Phene, C.J., J.L. Fauss and D.C. Sanders. 1979. Water, nutrient and herbicides management of potatoes with trickle irrigation. *Am. Potato J.* **56**: 51-59.
8. Singh, N. and M.C. Sood . 1994. Water and nitrogen needs of potato under modern irrigation methods In: *Potato - Present and Future* (G. S. Shekhawat *et al.*, Eds.), Indian Potato Assoc., Shimla.

---

MS Received: 22.05.2003

## EVALUATION OF NON-REFRIGERATED STORAGE METHODS FOR SHORT TERM ON-FARM STORAGE OF POTATOES\*

Ashiv Mehta<sup>1</sup> and R. Ezekiel<sup>2</sup>

**ABSTRACT:** Evaluation of traditional methods of potato storage viz. pit and heap and an evaporatively cooled store (ECS) was done during 1999-2001 with the use of sprout inhibitor isopropyl 3- chlorophenyl carbamate (CIPC). Maximum temperatures in the pit storage remained 5 – 15° C lower than the ambient during March – June. Temperatures in ECS and heap storage were about 2-3° C higher than pit storage. Relative humidity in the three storage systems remained consistently high (60.0- 95.8%). Total loss in weight of untreated potatoes remained low (7.4- 9.4%) up to 12 weeks of storage. Potatoes could be safely stored up to the first week of June and the performance of pit storage was better than heap and at par with ECS storage. Double treatment with sprout inhibitor isopropyl 3- chlorophenyl carbamate (CIPC) could further extend the storage life of potatoes up to 16 weeks by reducing physiological weight loss (by 39.8%), sprouting (by 83.7%) and sprout growth (by 93.3%) in tubers. The efficiency of CIPC was more pronounced under pit storage where even the single treatment of CIPC showed significant sprout suppression and reduction in weight loss of tubers up to 16 weeks.

### INTRODUCTION

About 90 per cent of potato in India is produced in North-western plains where the crop is harvested at the beginning of hot summer in February-March. Storing untreated potatoes under ambient conditions results in higher losses from sprouting, moisture loss and rotting. Seasonal production pattern, limited alternative market outlets (e.g. processing) and inadequate cold storage capacity often results in market gluts and heavy price reductions during the main harvesting months. Potato prices rapidly increase in April-May and are almost double in July-August (3). To overcome the problem and get remunerative prices, short term non-refrigerated storage of potatoes has been recommended in northern plains of India in a potato store (ECS) cooled by passive

evaporative cooling (8). Evaluation of two such storage structures of 20 tonne capacity each, revealed that potatoes could be safely stored in them till June, when the market prices are quite high (7). However their adoption by farmers remained restricted mainly due to high initial investment on construction. Farmers also use indigenous storage practices like pits, heaps, trenches and basements to hold some of their produce for short term (2 - 3 months) to fetch better prices (4, 5). A recent field survey in Punjab revealed that heap storage of ware potatoes is the only on-farm storage method in use to avoid distress sale at harvest (11). In heaped potatoes though the physiological losses were much reduced, sprouting of potatoes remained the main problem, which involves additional expenditure on labour for desprouting of tubers before sending them to market.

---

\*CPRI Publication No.1716

<sup>1</sup>Central Potato Research Station, Jalandhar-144 003 (Punjab)

<sup>2</sup>Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh)

The sprout suppressant isopropyl 3-chlorophenyl carbamate (CIPC) has been shown to effectively reduce physiological losses, sprouting and sprout growth of potatoes and extend the storage life of potatoes up to 14 weeks in ECS (9). However, the efficacy of CIPC under the indigenous storage methods has not been studied so far. This investigation was, therefore, designed to study physiological losses under on-farm storage methods and to assess the comparative efficacy of CIPC during storage of potatoes in heap and pit in comparison to ECS in order to improve the efficiency of these potato storage methods keeping in view the farmers' need to store potatoes on-farm for 3-4 months.

## MATERIALS AND METHODS

Healthy crop of cv. Kufri Chandramukhi was raised in sandy loam soils at the farm of Central Potato Research Station, Jalandhar during 1999-2001. N, P and K were applied @ 180, 80 and 120kg ha<sup>-1</sup>, respectively. Up to 10 irrigations were given during crop-growth but irrigation was stopped 10 days before haulm cutting. The harvested tubers were kept in the field in heaps for 15-20 days for proper curing of skin. Well cured, undamaged and apparently healthy tubers were used for storage studies.

A thatched roof made of straw (*Sarkanda*) and bamboos supported on a wooden beam at a height of 10 ft. was raised to prevent the entry of rain water. A pit (10 ft. deep, 5 ft. diameter) with an inside lining of bricks in cement was dug under the thatched roof. Pit was provided with a platform made of bamboos placed 2" apart and 2 ft. above the base to improve aeration. Two perforated PVC

pipes (4" dia) were lowered in the pit and heap up to the base for recording temperatures and relative humidity. Fourteen and five quintals of potatoes respectively, were stored in pit and heap under the thatched roof by the 1<sup>st</sup> of March and then covered with >1 ft thick rice straw (Figs. 1 & 2).

Pure CIPC (Sigma Chemical Co.) diluted to 1% with talcum powder was applied uniformly @ 2.5g kg<sup>-1</sup> tuber weight as immediate post-harvest dust treatment and the tubers were then kept under airtight conditions for 48 hr. The second treatment (CIPC-II) was given one month after the first treatment. The concentration of CIPC used was equal to that found effective earlier (9). The treated and control tubers in lots of 5 kg in *jute* bags with 4 replications per treatment were placed in pit storage, heap storage and in ECS in the first week of March. A daily record of maximum and minimum temperatures and relative humidity was maintained during the storage period.

Respiration rate (fresh weight basis) was measured using the standardized method (15) by an infrared gas analyzer (CD-301, CID, Inc., USA) at monthly intervals. Weight loss was recorded from 20 marked tubers. Weight of carbon loss (mg of C present in CO<sub>2</sub>) during storage was calculated from rate of respiration (12). The difference between weight loss and carbon loss was assumed to be transpiration loss even though the ultimate source of some water loss was probably generated during respiration. Weight loss was expressed in milligrams (C or total) lost per gram of tuber fresh weight. Sprouting and rotting was recorded in 4 replications of 100 tubers each for 16 weeks. Tubers having at least one sprout

of 0.5 cm or more in length were recorded as sprouted. Sprout weight was recorded in undisturbed separate lots and data was statistically analysed (6).

A confirmatory trial was conducted during 2001, where 25 kg each of treated and untreated potatoes in *jute* bags with 3 replications per treatment were stored undisturbed up to 16 weeks of storage under the three storage systems. Final observations on weight loss, sprouting, sprout weight and rotting in tubers were recorded.

## RESULTS AND DISCUSSION

**Storage environment:** The three storage systems allowed the daily range of variation in temperatures to be reduced while maintaining a high relative humidity (RH). Effective protection against solar radiation provided by the thatched roof reduced the maximum temperatures during storage by 1-2° C as compared to the ambient, besides providing a protection from the rain. The minimum-maximum temperatures in the three storage systems during March to June ranged between 13-29°C, 13-32°C and 10-32°C in pit, heap and ECS, respectively as compared to 8-44°C in the ambient. Thick covering of rice straw in the pit helped in maintaining the daily maximum temperatures 5 to 15° C lower than the ambient (23 to 44°C). Temperatures in ECS and heap were about 2-3°C higher than the pit. Relative humidity inside the three storage environments remained consistently high (71.0-95.8% in ECS, 76.0-94.8% in pits and 60.0 – 93.3% in heaps) compared to wide variation and lower levels of 27 to 87% in the ambient.

**Physiological weight loss:** Physiological

weight loss under the three storage conditions increased progressively during storage. Mean of overall total weight loss ranged from 13.4 mg g<sup>-1</sup> at 4 weeks to 114.0 mg g<sup>-1</sup> tuber weight at 16 weeks (Table 1), a progression in accordance with earlier findings (14). Weight loss was minimum under pit storage and maximum under heap storage at all the dates of observation. The higher losses under heap storage may be attributed to relatively low levels of humidity during the storage period. The loss in weight in excess of 10% reduces the marketability of potatoes because of their shrivelled appearance (1). Total loss in weight of potatoes stored in the three storage systems remained well below this level up to 12 weeks (June, 1<sup>st</sup> week) even in untreated control tubers.

Respiration rates at any one storage time were similar during both years of study. Mean of overall respiratory carbon loss under the three storage conditions also increased during storage from 0.82 mg g<sup>-1</sup> at 4 weeks to 3.71 mg g<sup>-1</sup> tuber weight at 16 weeks (Table 1). Increase in respiratory losses during storage is concurrent with sprouting and advanced sprout growth of tubers. Respiration rate of sprouted tubers is high because it includes the respiration of tubers and the sprouts (2). Weight loss during storage was mainly due to evaporation and contribution of respiratory carbon loss to total weight loss was slight (3.2-6.1%) which supports an earlier report (10). Respiratory losses were also significantly higher under heap storage than the other two storage conditions.

Treatment mean values showed that only CIPC-II treatment significantly reduced the

Table 1. Effect of CIPC on total weight loss (T) and respiratory carbon loss (C) in potato tubers during storage under different conditions (mean data of 2 years)

Storage condition	Treatment	Storage period (weeks)							
		4		8		12		16	
		T*	C*	T	C	T	C	T	C
Pit	CIPC-I	10.6	0.91	28.2	1.62	68.4	2.99	107.6	3.82
	CIPC-II	10.2	1.10	24.5	1.26	40.9	2.25	66.0	2.31
	Control	14.0	0.91	32.1	1.81	73.6	3.92	121.0	4.50
	Mean	11.6	0.97	28.3	1.56	61.0	3.05	98.2	3.54
ECS**	CIPC-I	12.8	0.55	32.5	1.55	69.1	2.75	118.0	3.93
	CIPC-II	8.5	0.80	33.8	0.97	58.0	2.36	77.0	2.38
	Control	11.2	0.60	37.5	1.31	74.2	1.98	126.9	4.38
	Mean	10.9	0.65	34.6	1.28	67.1	2.36	107.3	3.56
Heap	CIPC-I	18.0	0.68	56.3	1.95	115.6	3.36	161.4	3.67
	CIPC-II	17.6	1.03	43.6	1.89	77.2	2.57	96.3	2.82
	Control	17.5	0.79	49.4	2.32	94.4	3.57	151.5	5.54
	Mean	17.7	0.83	49.7	2.05	95.7	3.17	136.4	4.01
Treatment mean	CIPC-I	13.8	0.71	39.0	1.71	84.4	3.03	129.0	3.81
	CIPC-II	12.1	0.98	34.0	1.38	58.7	2.39	79.8	2.50
	Control	14.2	0.77	39.7	1.81	80.7	3.16	133.1	4.81
CD (0.05)	Stores	2.0	0.09	4.9	0.15	4.3	0.48	6.0	0.24
	Treatment	2.0	0.09	4.9	0.15	4.3	0.48	6.0	0.24
	S x T	NS	NS	NS	0.24	7.4	0.87	10.3	0.42

\* mg g<sup>-1</sup> tuber weight; \*\* ECS = Evaporatively cooled store.

total as well as the respiratory carbon loss (Table 1) during storage as compared to control (no treatment). Respiratory loss was significantly reduced in CIPC-I treatment also after 16 weeks of storage. Interaction between storage and treatment was significant after 12 weeks.

In the pit storage where CIPC treatment showed maximum effect, both the single and the double treatments significantly reduced the total loss in weight after 16 weeks (by 11.1 and 45.5%, respectively) as compared to control. Tubers appeared firm with less shriveling. Final weight loss after 16 weeks of storage for both the CIPC treatments was significantly lower than each corresponding figure from heap and ECS storage. Final weight loss in control being at par with ECS was also significantly lower than heap storage.

**Sprouting and Sprout weight:** Sprouting of tubers started after 4 weeks of storage. All untreated (control) tubers had sprouted by 8

weeks and by 16 weeks even those treated with CIPC-I (Table 2). Mean percentage of sprouted tubers was significantly reduced in CIPC-I and CIPC-II treatments until 12 and 16 weeks, respectively. Lesser effectiveness of CIPC-I treatment after 16 weeks of storage is perhaps because the efficiency of CIPC is temperature dependent, which decreases with the increase of temperature (13). However, the sprout growth remained remarkably suppressed till the last observation even in CIPC-I treatment (Table 3). Treatment mean values showed a significant reduction in sprout weight of tubers in both the single and double treatment with CIPC (by 44.2 and 93.3%, respectively) as compared to control up to 16 weeks of storage. Interaction between storage and treatment was significant. There was no need to desprout the tubers in case of CIPC double treatment up to 16 weeks of storage and the labour used for desprouting of CIPC-I treated tubers was also significantly reduced.

Table 2. Effect of CIPC on sprouting (%) in potato tubers on storage under different conditions (mean data of 2 years)

Storage condition	Treatment	Storage period (weeks)			
		4	8	12	16
Pit	CIPC-I	11.00	58.33	72.00	95.66
	CIPC-II	0	0	0	7.34
	Control	51.33	99.33	100.0	100.0
	Mean	20.78	52.56	57.33	67.66
ECS*	CIPC-I	7.67	85.99	89.33	99.99
	CIPC-II	0	3.34	11.83	13.67
	Control	62.33	100.0	100.0	100.0
	Mean	23.34	63.11	67.05	71.22
Heap	CIPC-I	10.67	73.00	89.66	98.33
	CIPC-II	0	17.00	26.67	28.00
	Control	50.67	100.0	100.0	100.0
	Mean	20.45	63.33	72.11	75.44
Treatment means	CIPC-I	9.78	72.44	83.66	97.99
	CIPC-II	0	6.78	12.84	16.33
	Control	54.78	99.77	100.0	100.0
CD (0.05)	Stores	NS	4.88	4.86	3.28
	Treatment	4.91	4.88	4.86	3.28
	S x T	NS	8.45	8.40	5.66

\*ECS = Evaporatively cooled store.

Table 3. Effect of CIPC on per cent sprout wt. and rottage in tubers on storage under different conditions (mean data of 2 years)

Storage condition	Treatment	Sprout weight (%)			Rottage (%)
		Storage period (weeks)			
		8	12	16	16
Pit	CIPC-I	0.55	0.78	1.01	1.00
	CIPC-II	0	0	0.14	4.00
	Control	0.76	2.04	2.86	3.00
	Mean	0.44	0.94	1.34	2.67
ECS*	CIPC-I	0.36	1.19	2.88	0.34
	CIPC-II	0.06	0.24	0.24	2.67
	Control	0.52	1.74	4.53	0.34
	Mean	0.31	1.06	2.55	1.12
Heap	CIPC-I	0.29	1.29	1.88	0.34
	CIPC-II	0.09	0.27	0.30	3.67
	Control	0.49	1.72	2.93	1.34
	Mean	0.29	1.09	1.70	1.78
Treatment means	CIPC-I	0.40	1.09	1.92	0.56
	CIPC-II	0.05	0.17	0.23	3.45
	Control	0.59	1.83	3.44	1.56
CD (0.05)	Stores	0.06	NS	0.29	1.17
	Treatment	0.06	0.11	0.29	1.17
	S x T	0.11	0.23	0.46	NS

\*ECS = Evaporatively cooled store.

Sprout suppression effect of CIPC under the three storage conditions is clearly depicted in Fig. 3.

**Loss due to rots:** Tuber rotting was not detected until 12 weeks of storage under the

three storage conditions. At the end of storage period, the overall mean percentage of rotted tubers in ECS at 1.12% was significantly lower than 2.67% in the pit storage (Table 3). Rottage under heap storage (1.78%) was not different

Table 4. Effect of CIPC on sprouting behaviour and storage losses in potatoes after 16 weeks of storage under different conditions (March to July, 2001)

Storage condition	Treatment	Total weight loss (%)	Sprouting (%)	Sprout weight (%)	Rottage (%)
Pit	CIPC-I	8.2 (10.8)	13.4 (95.7)	0.22 (1.01)	1.8 (1.0)
	CIPC-II	5.1 (6.6)	4.5 (7.3)	0.11 (0.14)	3.9 (4.0)
	Control	10.7 (12.1)	100 (100)	4.22 (2.86)	0.5 (3.0)
	Mean	8.0 (9.8)	39.3 (67.7)	1.52 (1.34)	2.1 (2.7)
ECS*	CIPC-I	9.1 (11.8)	20.3 (100)	1.07 (2.88)	4.0 (0.3)
	CIPC-II	6.9 (7.7)	5.9 (13.7)	0.23 (0.24)	1.8 (2.7)
	Control	11.0 (12.7)	100 (100)	4.86 (4.53)	1.6 (0.3)
	Mean	9.0 (10.7)	42.1 (71.2)	2.05 (2.55)	2.5 (1.1)
Heap	CIPC-I	15.3 (16.1)	32.7 (98.3)	0.19 (1.88)	1.8 (0.3)
	CIPC-II	9.0 (9.6)	11.4 (28.0)	0.06 (0.30)	2.4 (3.7)
	Control	14.3 (15.2)	100 (100)	2.44 (2.93)	2.6 (1.3)
	Mean	12.9 (13.6)	48.0 (75.4)	0.90 (1.70)	0.9 (1.8)
Treatment mean	CIPC-I	10.9 (12.9)	22.1 (98.0)	0.49 (1.92)	2.5 (0.6)
	CIPC-II	7.0 (8.0)	7.3 (16.3)	0.13 (0.23)	2.7 (3.5)
CD (0.05)	Control	12.0 (13.3)	100 (100)	3.84 (3.44)	1.6 (1.6)
	Stores	0.72 (0.60)	1.97 (3.28)	0.14 (0.29)	0.35 (1.17)
	Treatment	0.72 (0.60)	1.97 (3.28)	0.14 (0.29)	0.35 (1.17)
	S x T	1.25 (1.03)	3.39 (5.66)	0.23 (0.46)	0.61 (NS)

Figures within parentheses are for mean of 1999, 2000; \* ECS = Evaporatively cooled store.

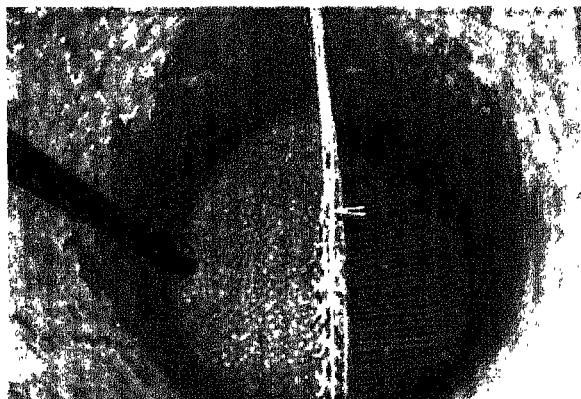


Fig. 1. Potatoes stored in pit

from the two storage conditions. Though significantly higher percentage of rotted tubers were recorded in CIPC double treatment (3.45) as compared to control (1.56), practically the values were not very high as only 3.45% of total number of tubers stored were lost up to 16 weeks of storage.

In the confirmatory experiment during 2001, where the potatoes after CIPC treatment were stored undisturbed under the three

storage conditions the sprout suppression effect of CIPC was more pronounced till 16 weeks of storage as compared to previous years' results (Table 4). A significant reduction in per cent sprouting and sprout weight of tubers was recorded in both the single and double treatments of CIPC. Weight loss in tubers was also much reduced as compared to previous years even in control tubers which may be because the stored potatoes remained



Fig. 2. Potatoes stored in heap

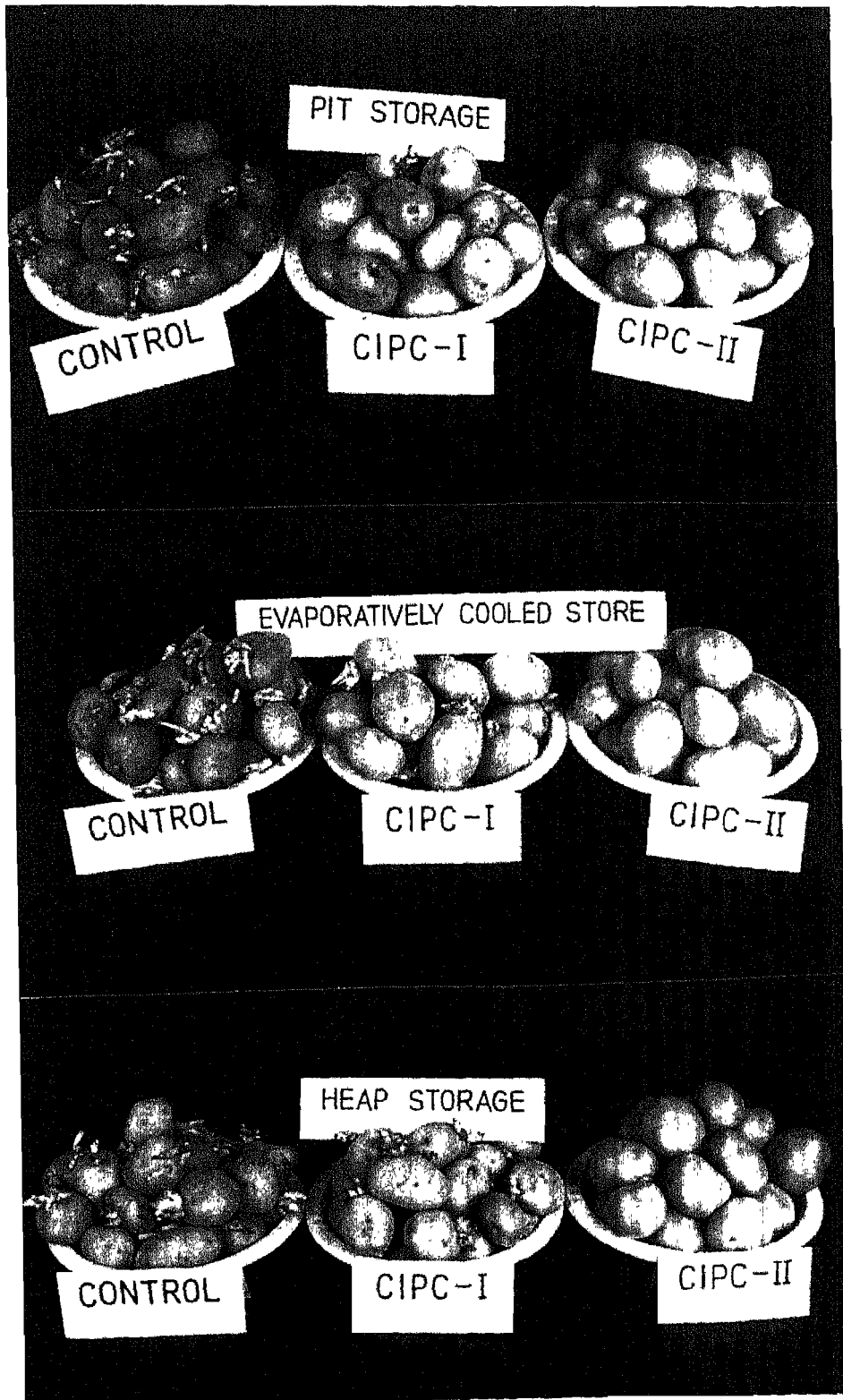


Fig. 3. Sprout suppression in potatoes with CIPC after 16 weeks of storage under different conditions

undisturbed under the cool and humid environments till 16 weeks. Whereas, during the previous years the rice straw covering on pit and heap was disturbed and the stored potatoes were brought every month for one day at higher ambient temperatures and low humidity to record observations.

Thus it can be concluded that it is feasible to store potatoes up to the first week of June by traditional methods in heaps and pits in North-western plains of Punjab. The performance of pit storage was better than heap and at par with ECS storage. Further storage in heaps and pits is much cheaper than in ECS. A 20 tonne capacity ECS could cost about Rs. 1 lakh, whereas for making a 20 tonne heap the cost is not more than Rs. 5000 and for a 15 tonne pit it is around Rs. 15000. Treatment with sprout inhibitor CIPC could further extend the storage life of potatoes up to 16 weeks under the three storage conditions by reducing physiological weight loss, sprouting and sprout growth in tubers. The efficiency of CIPC was more pronounced under pit storage where even the single treatment of CIPC showed significant sprout suppression and reduction in weight loss of tubers. Experiments are being conducted (including tuber quality) to determine the commercial potential of CIPC for use as sprout inhibitor of potatoes under traditional methods of storage.

#### ACKNOWLEDGEMENTS

The authors are thankful to Dr. G. S. Kang, Head CPRS, Jalandhar for providing facilities, to Mr Yogesh Gupta and Mr Raj Kumar for the assistance in experimentation and statistical analyses, respectively.

#### LITERATURE CITED

1. Booth, R.H. and R.L. Shaw. 1981. *Principles of potato storage*, International Potato Centre, Lima, Peru.
2. Burton, W.G., van A. Es and K.J. Hartmans. 1992. In: *The potato crop-scientific basis for improvement*. (P.M. Harris, Ed.), pp. 608-27. Chapman and Hall, London.
3. Dahiya, P.S. and H.C. Sharma. 1994. *Potato marketing in India : Status, issues and outlook*. Social Science Department Working Paper No. 1994 - 2, International Potato Center, Lima, Peru.
4. Dahiya, P.S., V.S. Khatana, and S.G. Ilangantileke. 1997. *Producer storage practices for potatoes in Malwa region, Madhya Pradesh, India*. Social Science Department Working Paper No. 1997 -10, International Potato Centre, Lima, Peru.
5. Dahiya, P.S., V.S. Khatana, S.G. Ilangantileke and J.P.S. Dabas. 1997. *Potato storage patterns and practices in Meerut district, U.P., India*. Social Science Department Working Paper No. 1997 -2, International Potato Centre, Lima, Peru.
6. Gomez, K.A. and A.A. Gomez. 1984. *Statistical Procedures for Agricultural Research*. John Wiley and Sons, New York (USA).
7. Kaul, H.N. and Ashiv Mehta. 1988. Evaluation of passive evaporative cooling for storage of potatoes. *Indian J. Agric. Sci.* 58: 928-31.
8. Kaul, H.N. and N.P. Sukumaran. 1984. *A Potato store run on passive evaporative cooling*. Tech. Bull. 11 , Central Potato Research Institute, Shimla. 14 pp.
9. Mehta, Ashiv and H.N. Kaul. 1991. Effect of sprout inhibitors on potato tubers (*Solanum tuberosum* L.) stored at ambient or reduced temperatures. *Potato Res.* 34: 443-50.
10. Mehta, Ashiv and H.N. Kaul. 1997. Physiological weight loss in potatoes under non-refrigerated storage : Contribution of respiration and transpiration. *J. Indian Potato Assoc.* 24: 106-13.
11. Mehta, Ashiv, H.N. Kaul and R. Ezekiel. 2001. Farmers' storage practices for potatoes in North-western plains. *J. Indian Potato Assoc.* 28: 149-51.
12. Picha, David N. 1986. Weight loss in sweet potatoes during curing and storage : Contribution of transpiration and respiration. *J. Amer. Soc. Hort. Sci.* 111: 889-92.

13. Rama, M.V. and P. Narasimham. 1987. Comparative efficacies of chemical sprout inhibitors and vapour heat treatments on the control of sprouting in stored potatoes. *J. Food Sci. Tech.* 24: 40-44.
14. Schippers, P.A. 1971. The influence of storage conditions on various properties of potatoes. *Amer. Potato J.* 48: 234-45.
15. Singh, J.P., Ashiv Mehta and H.N. Kaul. 1995. A simple scheme to measure respiration rate of potato tubers with CO<sub>2</sub> gas analyser. *J. Indian Potato Assoc.* 22: 70-73.

---

MS Received: 17.12.2002



# MANAGEMENT OF STEM NECROSIS DISEASE IN EARLY PLANTED POTATO CROP WITH VARYING FERTILIZER LEVELS\*

A.K. Somani, V.S. Kushwah and S.P. Singh

**ABSTRACT:** Both stem necrosis disease incidence and index were lowest when crop was not fertilized with inorganic fertilizers while it was highest when NPK was applied maximum @ 180 kg N, 80 kg P<sub>2</sub>O<sub>5</sub> and 120 kg K<sub>2</sub>O/ha in a study conducted at CPRS, Gwalior during four years i.e. 1997-98 to 2000-01. The maximum yields were also observed with the above NPK dose. However disease could be managed in a significant manner with judicious application of NPK @ 150 kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O/ha.

## INTRODUCTION

Stem necrosis disease in potato, first reported in 1989 (2, 5) is caused by a tospovirus (3) and is a serious problem in Central India. The problem is severe in early planted crops (6). Field studies were carried out to study its management under varying doses of nitrogen, phosphorus and potassium fertilizers in potato crop.

## MATERIALS AND METHODS

The field trial was conducted in randomized complete block design with potato cv. Kufri Chandramukhi for four successive potato seasons from 1997-98 to 2000-01 at Central Potato Research Station, Gwalior (Madhya Pradesh). There were 9 treatments having different levels of nitrogen, phosphorus and potassium fertilizers in (Table 1). Treatments were replicated three times. Gross plot size was 4.0 m x 4.2 m and net plot was 4.0 m x 3.0 m. The sources of nitrogen were calcium ammonium nitrate (+ urea at earthing up), phosphorus as single super phosphate

and potassium as muriate of potash. Half dose of N and full doses of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O were applied at planting. The plantings were done between 8 and 11 October. Plant emergence was normal during all the seasons. Disease incidence (DI) and intensity i.e. disease index (DX) of stem necrosis were recorded twice – first at 40 days after planting (DAP) and second at 55-60 DAP. The scale used for recording the disease in net plots and computing index is given below:

- 1 = up to 4 lesions (5%)
- 2 = up to 10 lesions (30%)
- 3 = above 30 to 50% plant area affected
- 4 = above 50 to 80% plant area affected
- 5 = plant died due to infection

$$\text{Disease Index (\%)} = \frac{\text{Sum of all numerical rating} \times 100}{\text{Total no. of plants} \times \text{maximum rating no. observed}}$$

The % disease incidence and index were calculated and analysed statistically, first for individual seasons and then pooled over for last three seasons (1998-99 to 2000-01) as the disease incidence and index were unusually

high during first season (1997-98). However, the trend of disease incidence and index remained the same. Tuber yield was recorded at the time of harvest. Yield data of three seasons (1998-99 to 2000-01) were pooled and analysed statistically.

## RESULTS AND DISCUSSION

**Disease incidence and index:** The incidence and index were lowest (12.6% and 2.95%, respectively) in plots where fertilizer was not applied (Table 1). The incidence and index were highest (41.1% and 8.96%, respectively) with maximum dose of fertilizer (180 kg N, 80 kg P<sub>2</sub>O<sub>5</sub> and 120 kg K<sub>2</sub>O/ha). Besides, it was significantly higher when compared to other treatments during individual seasons and after pooled analysis as well. Among the fertilizer treatments, disease incidence and index were lower (20.4% and 4.45% , respectively) with minimum levels of fertilizer application i.e. 150 kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O/ha during individual seasons. It was significantly lower as compared to all other treatments in pooled analysis as well. In general, there was no significant difference in stem necrosis disease incidence and index amongst other levels of fertilizer treatments. Thus, application of 150 kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O/ha was found to restrict the disease in early crop of potato.

Higher nitrogen levels resulted in succulent, vegetative growth and delayed maturity thus making the plant more susceptible to disease (1). Potassium increases resistance by improving the balance of nutrients (1, 4) and phosphorus accelerates the maturity of the crop (1). However, in present study, increase in stem necrosis disease was encountered in potato with increased

levels of nitrogen.

**Potato tuber yield:** The perusal of three seasons pooled data revealed that in general, potato tuber yield increased from 223 q/ha to 268 q/ha with the increase in levels of NPK fertilizers from 150 : 60 : 100 to 180 : 80 : 120 kg/ha, respectively. The lowest tuber yield of 114 q/ha was recorded under control where no NPK was applied during all the years on the fixed site of experimentation. Highest tuber yield (268 q/ha) was obtained with the highest dose of NPK (180 kg N, 80 kg P<sub>2</sub>O<sub>5</sub> and 120 kg K<sub>2</sub>O/ha) which was significantly higher than all other treatments. It was followed by 253 q/ha in treatment with 180 kg N, 80 kg P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O/ha.

**Interaction of fertilizers with disease and yield:** Though, the stem necrosis disease incidence as well as index was highest with the highest dose of fertilizer application, the yield of crop was also highest. The higher levels of available nutrition might have nullified the adverse effect of the disease in this case. Levels of 150 kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O/ha were best in the management of disease. However, at this level of fertilization, the yield was significantly lower (223 q/ha) in early potato crop. On increasing the level of fertilization from 150: 60 : 100 : to 180 : 80 : 120 kg NPK/ha, though the disease increased significantly, but the yield also increased significantly. It shows that the higher incidence of disease due to higher levels of fertilizers does not have an adverse effect on yield because of better nutrition.

It could be concluded from the present study that in early planted potato crop, the disease can be restricted by application of lower levels of fertilizers, viz., 150 kg N, 60 kg

Table 1. Stem necrosis disease and tuber yield in potato crop with different levels of NPK

Treatment	1997-98	1998-99	1999-2000	2000-01	Pooled*	Tuber yield (q/ha) pooled*
<i>Disease incidence (per cent)</i>						
T1 : N 150 P 60 K 100	77.2	16.2	12.4	32.7	20.4	223
T2 : N 150 P 60 K 120	88.2	25.6	17.1	33.8	25.5	234
T3 : N 150 P 80 K 100	92.2	20.8	23.5	41.2	28.5	248
T4 : N 150 P 80 K 120	89.8	20.8	20.7	43.7	28.4	240
T5 : N 180 P 60 K 100	88.0	20.4	22.8	51.4	31.5	251
T6 : N 180 P 60 K 120	79.9	19.7	23.7	42.9	28.7	250
T7 : N 180 P 80 K 100	88.9	22.2	18.9	43.6	28.2	253
T8 : N 180 P 80 K 120	92.6	30.0	29.3	64.1	41.1	268
T9 : N 0 P 0 K 0	46.6	12.7	4.2	20.9	12.6	114
SE <sub>m</sub> ±	5.23	3.04	4.74	4.50	1.86	6
CD @ 5%	11.09	6.44	10.06	9.54	3.94	13
<i>Disease index (per cent)</i>						
T1 : N 150 P 60 K 100	22.21	3.92	2.57	6.87	4.45	
T2 : N 150 P 60 K 120	28.29	7.07	3.56	6.91	5.83	
T3 : N 150 P 80 K 100	30.59	5.32	4.77	8.59	6.24	
T4 : N 150 P 80 K 120	24.11	5.31	4.48	9.50	6.43	
T5 : N 180 P 60 K 100	27.05	5.92	5.28	10.55	7.25	
T6 : N 180 P 60 K 120	23.90	4.81	5.12	9.26	6.40	
T7 : N 180 P 80 K 100	26.04	6.03	4.07	9.60	6.57	
T8 : N 180 P 80 K 120	31.31	7.37	6.01	13.49	8.96	
T9 : N 0 P 0 K 0	14.43	3.70	0.97	4.19	2.95	
SE <sub>m</sub> ±	1.39	0.86	1.07	1.05	0.45	
CD @ 5%	2.95	1.83	2.27	2.23	0.96	

\*Pooled data for three seasons -1998-99, 1999-2000 and 2000-01.

P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O/ha. But for higher yields of potato, the levels of N need to be increased to 180 kg/ha while P<sub>2</sub>O<sub>5</sub> may be applied @ 60 to 80 kg and K<sub>2</sub>O 100 to 120 kg/ha for nullifying the adverse effect of higher incidence and intensity of stem necrosis disease.

## LITERATURE CITED

- Agrios, G.N. 1988. Environmental effects on infectious plant disease development. In: *Plant Pathology* (3<sup>rd</sup> Ed.) Academic Press Inc, California, 803 pp.
- Khurana, S.M. Paul, S.G. Phadtare, I.D. Garg, M.N. Singh and V.P. Bhardwaj. 1989. Potato stem necrosis epidemic due to tomato spotted wilt virus in India (Abst.). In: *Proc. IV Int. Pl. Virus Epidemiol. Workshop*, Montpellier, France, Sept. 3-8, 1989. pp. 301.
- Khurana, S.M. Paul, R.B. Singh, R.A. Naidu and M. Krishnareddy. 1998. Potato stem necrosis disease is caused by a possibly distinct tospovirus species belonging to serogroup. In: *Proc. 4<sup>th</sup> Int. Symp. on tospovirus and thrips in floral and vegetable crops*. Wageningen, May 2-6, 1998, pp. 44-45.
- Patricia Imas and S.K. Bansal. 1999. Potassium and integrated nutrient management in potato. In: *Potato, global research and development* Vol. II (S.M. Paul Khurana et al., Eds.), pp. 744-54, CPRI, Shimla.
- Phadtare, S.G., S.M. Paul Khurana, I.D. Garg and V.P. Bhardwaj. 1989. Stem necrosis - a virus disease of potatoes in Central India. *J. Indian Potato Assoc.* 16: 164-65.
- Somani, A.K., V.S. Kushwah and R.A. Singh. 1999. Stem necrosis disease of potato as influenced by varying planting dates, irrigation intervals and insecticides. In: *Abstracts - Global Conference on Potato*, New Delhi, Dec. 6-11, 1999. pp. 212.

MS Received: 03.10.2002



## STUDIES ON POTATO BASED CROP SEQUENCES IN WEST BENGAL

M. Chettri<sup>1</sup>, S.K. Mukhopadhaya<sup>2</sup>, A. Konar and A. Basu<sup>1</sup>

**ABSTRACT** : Four cropping system, viz. potato-groundnut-paddy, potato-sesame(*til*)-paddy, potato-okra (*bhindi*)-paddy and potato-jute-paddy were compared at Adisaptagram Block Seed Farm, Hooghly over three years. The yields of potato were not affected by the systems. Potato-okra-paddy system was found to be most economical with highest potato yield equivalent (498 q/ha). Improvement of nutrient status of the soil (organic carbon, P and K) was also observed after three years of experimentation and maximum improvement was observed by potato-groundnut-paddy system.

### INTRODUCTION

Potato, a short duration crop can be adjusted in various cropping systems. Potato based multiple cropping thus provides scope for maintaining high productivity by utilizing the available resources most efficiently. In West Bengal, potato is emerging as an important crop. Thus, an attempt has been made to assess various potato based cropping systems for higher productivity under the agro-climatic conditions of alluvial plains of West Bengal.

### MATERIALS AND METHODS

The experiment was conducted at Adisaptagram Block Seed Farm, Hooghly, West Bengal during 1998-99 to 2001-2002. Four cropping systems with 300% crop intensity were tested under upland situation. They were potato-groundnut-paddy (C<sub>1</sub>), potato-sesame-paddy (C<sub>2</sub>), potato-okra-paddy (C<sub>3</sub>) and potato-jute-paddy (C<sub>4</sub>). Crops of different seasons and their respective varieties including spacing and fertilizer doses have been given in Table 1. The soil of the experimental site was sandy

loam in texture having 0.48% organic carbon, 21.4 kg/ha available P, 238.5 kg/ha available K and pH of 6.6. The experiment was laid out in RBD with four replications. The sources of N, P and K were urea, single super phosphate and murate of potash, respectively. The initial and final soil nutrient status such as organic carbon, available P, available K and pH were estimated using standard methods (3).

Potato yield equivalent\* (q/ha) and the economics of different crop rotations were computed based on local market prices.

Total selling price of all crops of a particular sequence in 1 ha.

\*Potato yield equivalent =  $\frac{\text{Total selling price of all crops of a particular sequence in 1 ha.}}{\text{Price of one quintal of potato tubers}}$

### RESULTS AND DISCUSSION

**Crop yield:** The tuber yield of potato did not differ significantly under the different potato based cropping systems which varied from 266 to 279 q/ha. Groundnut, sesame, okra and jute as second crop after potato gave relatively better production. Paddy yield was higher when grown after groundnut and jute

<sup>1</sup> AICPIP, Bidhan Chandra Krishi Viswavidyalaya, Kalyani-741235 (West Bengal)

<sup>2</sup> NARP, NAZ, Gayeshpur, BCKV, Nadia-741 252 (West Bengal)

Table 1. Details of cultural practices

Crop	Variety	Spacing (cm)	Seed rate (q/ha)	Fertilizer (q/ha)			Date of planting/sowing	Date of harvesting
				N	P	K		
Potato	K. Jyoti	60 X 20	25.00	1.80	1.50	1.50	9.12.1998	15.3.1999
	K Jyoti	60 X 20	25.00	1.80	1.50	1.50	4.12.1999	12.3.2000
	K. Jyoti	60 X 20	25.00	1.80	1.50	1.50	6.12.2000	18.3.2001
Groundnut	AK-12-24	60 X 20	1.00	0.20	0.30	0.50	22.3.1999	19.7.1999
	AK-12-24	60 X 20	1.00	0.20	0.30	0.50	19.3.2000	21.7.2000
	AK-12-24	60 X 20	1.00	0.20	0.30	0.50	25.3.2001	23.7.2001
Paddy	IET 4094	20 X 15	0.60	1.00	0.50	0.50	26.7.1999	28.11.1999
	IET 4094	20 X 15	0.60	1.00	0.50	0.50	24.7.2000	25.11.2000
	IET 4094	20 X 15	0.60	1.00	0.50	0.50	28.7.2001	30.11.2001
Sesame	Rama	30 x 10	0.08	0.50	0.25	0.25	22.3.1999	19.7.1999
	Rama	30 x 10	0.08	0.50	0.25	0.25	19.3.2000	21.7.2000
	Rama	30 x 10	0.08	0.50	0.25	0.25	25.3.2001	23.7.2001
Okra	Arka Abhaya	48 x 25	0.12	0.60	0.50	0.50	22.3.1999	19.7.1999
	Arka Abhaya	48 x 25	0.12	0.60	0.50	0.50	19.3.2000	21.7.2000
	Arka Abhaya	48 x 25	0.12	0.60	0.50	0.50	25.3.2001	23.7.2001
Jute	JRO - 524	20 x 05	0.05	0.60	0.30	0.30	22.3.1999	19.7.1999
	JRO - 524	20 x 05	0.05	0.60	0.30	0.30	19.3.2000	21.7.2000
	JRO - 524	20 x 05	0.05	0.60	0.30	0.30	25.3.2001	23.7.2001

Table 2. Cost of cultivation and local market prices of different crops

Name of crop	Cost of seed (Rs./ha)	Cost of fertilizers (Rs./ha)	Cost of cultivation (Rs./ha)	Total cost of cultivation (Rs/ha)	Market price (Rs./q)
Potato	17500	5822	21298	44620	270
Groundnut	2300	1160	3090	6550	1600
Sesame	160	1172	2820	4152	1500
Okra	240	1940	4600	6780	320
Jute	275	1407	11615	13297	800
Paddy	600	2345	8890	11835	800

Cost of seed (Rs/quintal) : Potato- 700/-; Groundnut - 2300/-; Sesame - 2000/-; Okra - 2000/-; Jute - 5500/-; Paddy - 1000/-.

when compared with okra and sesame (Table 3). Addition of higher organic matter and better physical condition of soil after the harvest of groundnut and jute might have resulted in higher grain yield of paddy in  $C_1$  and  $C_4$  systems by improving the yield attributing characters. The result is in agreement with the observation of Chatterjee and Mondal (2). The potato yield equivalent varied with the crop sequences. The highest potato yield equivalent was recovered from potato - okra - paddy system while lowest potato equivalent yield was obtained from potato - sesame - paddy system (Table 3).

The highest potato yield equivalent in potato - okra - paddy ( $C_3$ ) system was mainly due to higher returns from okra in comparison to sesame, jute, and groundnut.

**Economics:** Economics of different systems showed that the cost of cultivation (Table 2) was highest in potato-jute-paddy ( $C_4$ ) and was minimum in potato-sesame-paddy ( $C_2$ ) in all the years (Table 3). The highest gross income was obtained from the potato-okra-paddy ( $C_3$ ) sequence followed by potato-groundnut-paddy ( $C_1$ ), potato-jute-paddy ( $C_4$ ) and potato-sesame-paddy ( $C_2$ ) sequences. Maximum net

Table 3. Crop yield and economics of various potato based cropping systems (average of 3 years)

Rotation/ Crop	Crop yield (q/ha)	Potato equivalent (q/ha)	Gross income ('000 Rs./ha)	Cost of Cultivation ('000 Rs./ha)	Net returns ('000 Rs./ha)	Net returns from rotation ('000 Rs./ha)
C <sub>1</sub> : Potato	279.15	449.11	75.37	44.62	30.75	58.26
Groundnut	11.18		17.89	6.55	11.34	
Paddy	35.00		28.00	11.83	16.17	
Total			121.26	63.00	58.26	
C <sub>2</sub> : Potato	266.29	425.00	71.90	44.62	27.28	54.15
Sesame	11.08		16.62	4.15	12.47	
Paddy	32.79		26.23	11.83	14.40	
Total			114.75	60.60	54.15	
C <sub>3</sub> : Potato	273.29	498.22	73.79	44.62	29.17	71.12
Okra	107.06		34.26	6.78	27.48	
Paddy	32.87		26.30	11.83	14.47	
Total			134.52	63.23	71.12	
C <sub>4</sub> : Potato	270.04	467.33	72.91	44.62	28.29	56.43
Jute	32.50		26.00	13.30	12.70	
Paddy	34.09		27.27	11.83	14.47	
Total			126.18	69.75	56.43	
CD (0.05)						
Potato	NS					
Paddy	NS					

Table 4. Nutrient status before and after rotation

Rotation	Nutrient status before rotation				Nutrient status after rotation			
	pH	OC (%)	Av. P (Kg/ha)	Av. K (Kg/ha)	pH	OC (%)	Av. P (Kg/ha)	Av. K (Kg/ha)
C <sub>1</sub> = Potato-groundnut-paddy	6.6	0.48	21.42	238.52	6.7	0.51	32.00	255.07
C <sub>2</sub> = Potato-sesame-paddy	6.6	0.48	21.42	238.52	6.6	0.49	25.90	246.90
C <sub>3</sub> = Potato-okra-paddy	6.6	0.48	21.42	238.52	6.7	0.50	30.75	250.97
C <sub>4</sub> = Potato-jute-paddy	6.6	0.48	21.42	238.52	6.5	0.52	28.45	249.02
CD (0.05)						NS	NS	6.40

profit (Rs. 71120/- per ha.) was realised in potato – okra – paddy system followed by potato – groundnut – paddy (Rs.58260/- per ha) and potato – jute – paddy (Rs.56430/- per ha.) rotation. Though potato – jute – paddy system ranked second in respect of gross income, higher cost of cultivation of this system put it into third position in respect of total net returns from the system. The minimum gross income and net profit (Rs. 54150/- per ha.) was obtained from potato – sesame – paddy system.

**Nutrient status of soil:** No remarkable change in soil pH was recorded after the

completion of three cycles of crop sequences (Table 4). However, a slight fall in soil pH was recorded in potato – jute – paddy sequence. Sadanandan and Mahapatra (4) also observed a fall in pH in cropping patterns where jute was one of the crops in sequence. A build up of organic carbon, available P and available K was observed as compared to its initial status after three years in all the crop sequences as all the crops were raised with recommended dose of fertilizers. The effect of crop sequences on organic carbon and available P of the soil was not significant, however, potato – groundnut – paddy and

potato – jute – paddy showed some improvement in organic carbon and available P content in the soil. This is in conformity with the observation of Chatterjee *et al.* (1). K status of the soil increased in all the crop sequences after three years, however, potato – groundnut – paddy system increased the K status of the soil significantly as compared to potato – sesame – paddy sequence.

#### ACKNOWLEDGEMENT

The authors are grateful to Dr. S.M. Paul Khurana, Director, CPRI and Project Coordinator, AICPIP, Shimla for his keen interest and kind cooperation in the investigation.

#### LITERATURE CITED

1. Chatterjee, B.N., N.C. Banerjee, D.C. Ghosh and P.K. Debnath. 1978. Response to P K and FYM in multiple cropping with potato. *J. Indian Potato Assoc.* 5: 9-12.
2. Chatterjee, B.N. and S.S. Mondal. 1987. Potato based cropping system in West Bengal. *J. Indian Potato Assoc.* 14: 1-8.
3. Jackson, M.L. 1973. *Soil chemical analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.
4. Sadanandan, N. and I.C. Mahapatra. 1972. Effect of various cropping patterns on pH of upland alluvial rice soils. *Indian J. Agron.* 18: 41-44.

---

MS Received: 08.07.2003

## MARKETING AND ASSESSMENT OF POST-HARVEST LOSSES IN POTATO IN BIHAR\*

N.K. Pandey, Prem S. Dahiya\*\*, Anshuman Karol<sup>1</sup> and Nalini Ranjan Kumar<sup>2</sup>

**ABSTRACT:** This study focuses both on the marketing system and estimation of post-harvest losses in terms of physical and economic in Nalanda district, the leading potato growing district in Bihar and the major terminal market of Patna. Two marketing channels i.e (i) producer-cold store-wholesaler-retailer-consumer and (ii) producer-wholesaler's field agent /wholesaler-retailer-consumer accounted for 46.8 % potato disposal in Biharsharif block and 91.3% potato disposal in Noorsarai block respectively. The significant post-harvest losses were found on weight basis at farm level (12.84%), wholesale level (12.40%) and retail level (9.45%) due to cut, crack and diseases. The post-harvest losses on weight and number basis were observed to be 26.84%. Total economic loss was worked out to be 5.67% only.

### INTRODUCTION

In India, the potato crop is grown in more than 1.3 million hectares of land with a production of around 25 million tonnes. The Indo-Gangetic plains account for about 81 percent of the area under potato crop. There are many causes for the losses to occur during different stages of the post-harvest handling of the produce from production point to the ultimate consumers. The study report (4) estimated that the degree of damage depends upon the method of harvesting, distance of planting, nature of soil and the skill of labour. The extent of damage is greater when the tubers are dug out by ploughing than by other methods. The estimated damage in harvesting of potato varies from 0.5 percent to 10.0 percent (4). The high range of variation is due to the difference in the methods of harvesting (manual/tractor), distance of planting and types of soil. Post-harvest losses in potato reduce the per capita availability significantly

as they are estimated to be 15-20% that occur during harvesting, wholesale level, retail level, transportation and storage, etc. (2). The post-harvest losses like rottage, cut and damaged tubers also result in increase in the transport cost and add to the marketing cost. This affects both producers and the consumers by reducing the availability of potato on the one hand and through higher prices paid because of the increase in the transport cost on the other hand. The researchers have mainly focused on marketing of potato but very few studies have been conducted on post-harvest losses on potato and most of them do not reflect the real situation prevailing in the market and the factors responsible for such losses. Keeping the above facts in view, the present study was conducted to estimate post-harvest losses both in physical and economic terms at different stages of handling of potato produce in Nalanda district in Bihar and the major terminal markets of Patna.

---

\*Publication No. 1733, CPRI, Shimla

<sup>1</sup> Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh)

<sup>2</sup> Central Potato Research Institute Campus, Modipuram, Meerut-250 110 (Uttar Pradesh)

\*\*Center for Development & Agricultural Research, House # 212, Sector 1, Rohtak-124 001 (Haryana)

## METHODOLOGY

The present study was undertaken under the ICAR Network Project on Marketing and Assessment of Post-harvest losses in Fruits and Vegetables in India. The post-harvest data from 30 farmers from two blocks i.e. Biharsharif and Noorsarai of Nalanda district were collected. The requisite data from 15 wholesalers comprising 10 from Patna market and 5 from Biharsharif wholesale market and 19 retailers in Patna market and 5 retailers in Biharsharif town were also collected.

The post-harvest losses have been estimated both in physical and economic terms. The losses at the farmers, wholesalers and retailers levels were observed on account of the tubers being cut during harvesting, various diseases and cracking. Variety-wise post-harvest losses were also determined. On weight basis, a sample of 5 kg was taken from ungraded produce from each farmer, wholesaler or retailer as the case may be. The cut, diseased and cracked tubers were collected and weighed. Then the total number of tubers constituting the sample of 5 kg was counted and similarly the number of tubers suffering from different kind of post losses such as due to cut, disease and cracking were weighed. The post-harvest losses (PHL) on number basis were also assessed. For working out the gross economic loss, the value of the produce affected by PHL was worked out on the basis of harvest price of potatoes. This was done for each farmer, wholesaler and retailer and then it was added up for the sample size at block level. The gross economic loss was divided by the total value of the produce again for working out the economic loss in percentage terms. Even the PHL affected potatoes do

carry certain value by fetching low price. In other words, the loss is, by and large, partial in economic terms and it is not total economic loss. A simple tabular analysis method has been used to arrive at the results.

## RESULTS AND DISCUSSION

### Production and disposal pattern of potato

**Disposal pattern:** The results (Table 1) indicated that 50 per cent farmers of Nalanda district disposed off 60.6 per cent of total potato production in the market. But only 26.4 per cent of the production was cold stored by 16.7 per cent farmers. Farmers of Biharsharif block stored maximum portion of their produce (46.8%) in cold stores and did not sell at farm levels while the farmers of Noorsarai block cold stored only very negligible portion of their produce (4.4%) and sold 20% of the produce at the farm itself.

**Marketing Channels:** The marketing of potato in the state of Bihar starts from village level. There is no village trader involved in the marketing process. A number of marketing channels for potato disposal were identified in the district. In Biharsharif block four important channels were identified such as: (i) Producer- Wholesaler's field agent / wholesaler- Retailer-Consumer, (ii) Producer-Commission agent/wholesaler-Retailer-Consumer, (iii) Producer-Cold store-Wholesaler-Retailer-Consumer, and (iv) Producer-Retailer-Consumer, but out of these four channels the most important marketing channel was: **Producer-Cold store-Wholesaler-Retailer-Consumer**. Over 46.8 per cent of the total production in Biharsharif was disposed off through this popular channel. But in the case of Noorsarai block, the five

Table 1. Disposal pattern of potatoes in Nalanda district of Bihar

(Percentages of farmers &amp; total disposal)

Block	No. of farmers & total quantity disposed of (q)	Disposal pattern at harvesting time							
		Stored at home		Sold in markets		Cold stored		Sold at farm	
		% of farmers	% of quantity sold	% of farmers	% of quantity sold	% of farmers	% of quantity sold	% of farmers	% of quantity sold*
Bihar Sharif	15 (598.9)*	26.7	21.2	53.3	32.0	20.0	46.8	0.0	0.0
Noorsarai	15(562.0)	20.0	4.3	46.7	91.3	13.3	4.4	20.0	NR
Nalanda district	30(1160.9)	23.3	13.0	50.0	60.6	16.7	26.4	10.0	NR

\*Figures in parentheses indicate quantity of potatoes disposed off; NR= Not reported

important marketing channels were identified such as (i) Producer-Itinerant trader/*Bania*-Retailer-Consumer, (ii) Producer-Wholesaler's field agent/Wholesaler-Retailer-Consumer, (iii) Producer-Commission agent/Wholesaler-Retailer-Consumer, (iv) Producer- Cold store-Wholesaler-Retailer-Consumer, and (v) Producer- Retailer-Consumer, but the channel *Producer-Wholesaler's field agent/Wholesaler-Retailer-Consumer* accounted for 91.3 percent of the total disposal of production of the block.

**Packing practices and transportation for potato disposal:** Both gunny bags (50 kg size) and baskets (30 kg size) are used for packing of potatoes. Only 63 per cent farmers used some kind of packing material. Basket packing (66.7%) appeared to be popular in Bihar Sharif, perhaps, because of shorter transportation

distance required (home or cold store). But in the other block of Noorsarai the use of gunny bags (60%) was popular (Table 2). In Nalanda district in Bihar, the farmers used baskets for packing because, the cold storages have a practice of storing potatoes in loose form locally called, "*Khattal*". As for the transport of produce is concerned, 76.2% produce was transported by bullock cart in Bihar Sharif, but in Noorsarai block tractor was used to transport 91.3% of potato (Table 3)

**Post-harvest losses at farmers' level:** On overall basis, the total post-harvest loss at farmers level on weight and number basis in the two blocks of Nalanda district under the study were 12.84 and 12.72%, respectively. In economic terms these losses worked out to 10.24 and 5.04%, respectively. On weight and number basis, the maximum post-harvest

Table 2. Packing practices in Nalanda district of Bihar

Blocks	Sample size	Packaging done by farmers	Material used for Packaging		
			Gunny bag	Basket	Gunny bag & Basket
Bihar Sharif	15	60.0	22.2	66.7	11.1
Noorsarai	15	66.7	60.0	30.0	10.0
Bihar state	30	63.3	42.1	47.4	10.5

Capacity of packing material: Gunny bag- 50 kg; Basket - 30 kg

Table 3. Share of different modes of potato transport in Nalanda district of Bihar

Block	No. of farmers	Mode of transport used			Quantity transported		
		Bullock cart	Tractor	No transport used (sold at farm)	Bullock cart	Tractor	Total quantity transported (q)
Biharsharif	15	46.7	53.3	0.0	76.2	23.8	598.9
Noorsarai	15	26.7	53.3	20.0	8.7	91.3	562.0
Nalanda district	30	36.7	53.3	10.0	43.5	56.5	1160.9

losses (5.21 and 6.0%) were due to cut tubers during harvesting in Biharsharif block, while in the case of Noorsarai the loss was low as 3.37 and 4.82%. The gross economic loss was higher in Biharsharif (11.0%) than Noorsarai block (9.73%) (Table 4).

*Post-harvest losses at wholesaler's level:* On weight and number basis, the post-harvest losses at wholesaler's level were 12.40% and 9.37%, respectively in these two markets of Biharsharif and Patna. The higher PHL at wholesaler's level vis-à-vis at farmer level

Table 4. Post-harvest losses in potato at farmer's level in Biharsharif and Noorsarai block in Nalanda district of Bihar

Block	Total number of samples	Weight & average number of tuber per sample		Post-harvest losses in percentages									
				Losses due to cut tubers		Losses due to diseased tubers		Losses due to cracking in tubers		Total PHL		Total economic loss*	
				Weight basis	No. basis	Weight basis	No. basis	Weight basis	No. basis	Weight basis	No. basis	Gross loss	Net loss
				(kg)	No. of tubers	(kg)	No. of tubers	(kg)	No. of tubers	(kg)	No. of tubers	%	%
Biharsharif	15	5	117	5.21	6.00	2.44	2.12	5.83	4.27	13.48	12.39	11.00	4.03
Noorsarai	15	5	131	3.37	4.82	3.71	3.91	5.35	4.57	12.43	13.30	9.73	5.69
Bihar state	30	5	124	4.26	5.35	3.00	2.94	5.58	4.43	12.84	12.72	10.24	5.04

\*Worked out as percentages of the total value of the total quantity of the sample

Table 5. Post-harvest losses in potato at wholesaler's level in Biharsharif market and Patna market in Bihar during 2001

Market	Total number of samples	Weight & average number of tuber per sample		Post-harvest losses in percentages									
				Losses due to cut tubers		Losses due to diseased tubers		Total PHL		Total economic loss*			
				Weight basis	No. basis	Weight basis	No. basis	Weight basis	No. basis	Gross loss	Net loss		
				(kg)	Number of tubers	(kg)	Number of tubers	(kg)	Number of tubers	%	%		
Biharsharif	5	5	115	3.70	3.31	2.10	0.48	5.80	5.40	5.80	3.14		
Patna	6	5	146	14.34	11.50	3.58	0.46	17.92	11.96	14.74	7.58		
Bihar state	11	5	132	9.50	8.26	2.90	1.10	12.40	9.37	10.54	5.50		

\*Worked out as percentages of the total value of the total quantity of the sample

could be attributed to the fact that the farmers did not sort out the cut and diseased tubers effectively and fully. But in Patna market, the losses were significantly higher being 17.92 and 11.96 per cent. This could also be probably due to distant transportation from other districts and cultivation of Kufri Sindhuri variety having small tubers. The gross and net economic losses were 10.54 and 5.50 per cent in the two markets of Biharsharif and Patna (Table 5).

**Post-harvest losses at Retailer's level:** The post-harvest losses (PHL) at retail level are presented in Table 6. The post-harvest losses have been worked out on the basis of a sample of 19 retailers (15 samples for Kufri Sindhuri variety and only 4 samples for Kufri Jyoti variety) in Patna market and only 5 retailers (Kufri Jyoti variety) in Biharsharif market (Nalanda district). The losses at retail level were 9.45 and 17.58 % on weight and number basis, respectively. The post-harvest losses on number basis in Patna market were much higher (almost double) because of the smaller tuber size of cv. Kufri Sindhuri while losses were less in cv. the Kufri Jyoti, which is mainly cultivated in Nalanda district, having larger tuber size relative to Kufri Sindhuri and long

distance transportation from Biharsharif to Patna market.

**Overall Post-harvest losses in Potato:** The highest percentage of post-harvest losses on over all basis in potatoes takes place due to the tubers being subjected to cuts during harvesting. Overall post harvest losses were 13.16 per cent on weight basis and 11.75 per cent on number basis due to cut tubers at farmers, wholesaler and retailer levels. Disease incidence also caused losses to the tune of 8.10 per cent on weight basis and 10.65 per cent on number basis respectively at farmers, wholesaler and retailer levels. Mandal and Dasgupta (6) also worked out post harvest losses in 3 markets of West Bengal for potato and found that, on an average, total post harvest losses were 12.21 percent. Post harvest losses due to cracking of tubers have also been estimated to be 5.58 % on weight and 4.43 % on number basis at all three levels. Economic losses were also estimated due to all kind of losses at all three level and it came to be 5.6%.

Potatoes also suffer from post-harvest losses during storage in cold stores for longer periods. Martinez and Martinez (7) estimated post-harvest losses in Irish potatoes between

Table 6. Post-harvest losses in potato at retailers' level in Patna and Biharsharif market in Bihar during 2001

Market	Total number of samples	Weight & average number of tuber per sample		Post-harvest losses in percentages							
		Weight (kg)	Average Number of tubers	Losses due to cut tubers		Losses due to diseased tubers		Total PHL		Total economic loss*	
				Weight basis	No. basis	Weight basis	No. basis	Weight basis	No. basis	Gross loss	Net loss
Patna	19	5	132	7.34	15.13	2.44	4.36	9.78	19.49	9.40	6.20
Biharsharif	5	5	117	5.20	3.09	3.00	7.23	8.20	10.32	7.61	5.53
Bihar State	24	5	129	6.90	12.70	2.55	4.88	9.45	17.58	8.95	6.03

\*Worked out as percentages of the total value of the total quantity of the sample

27 and 54 % depending on the storage period during the marketing process. They observed major losses at the farm level especially when storage is required. The study report (4) estimated the cold storage losses are approximately 5 percent of the total quantity stored and may go up to 50 percent if the power supply is disrupted for 10 to 15 days. Dahiya *et al.* (1) reported post-harvest losses in indigenous storage methods, which were 8.6% for *katchi hodi* (pit), 9.1% for *pakki hodi*, 8.5% for field heaps, 6.5% for *kotha* (room) storage and 5.1% for *talghar* (basement) store relative to the total quantity of potatoes stored. Subrahmanyam (8) reported 5.40 percent post-harvest losses in potatoes in developing countries. The post-harvest losses in vegetables also result in increase in the transportation cost and hence the price paid by consumers. Gauraha (3) reported that the maximum post harvest loss was observed to be in tomato (32.64%) followed by cauliflower (22.36%) and potato (19.79%). The causes of losses were the practices followed in post harvest handling, the standards of materials, facilities used for storage, packing and transportation that were outdated and were contributing directly to the post harvest losses. Mani (5) discussed the factors which influenced the post-harvest losses as: i) improper handling and storage led physical damage due to tissues breakdown, ii) mechanical losses include bruising, cracking, cuts, etc.

## CONCLUSIONS

Nalanda district of Bihar stands first in area under potato and potato production in the Bihar state. Studies conducted on the estimation of post harvest losses in potato showed that the major quantity (60.0 %) was

sold in the market at the hands of wholesalers due to inadequate cold storage capacity in the area. In all, the significant post-harvest losses were found at farmers level, wholesaler and retail level due to cuts and cracking of tubers. A number of concerted measures at research level and improvement of harvesting techniques as well as storage facilities need to be undertaken for reduction of post-harvest losses and improvement of potato crop in Bihar.

## LITERATURE CITED

1. Dahiya, P.S., V.S. Khatana and S.G. Illangantileke. 1997. *Producer Storage practices in the Malwa region, Madhya Pradesh*. Working Paper No. 10. International Potato Center (CIP), Lima, Peru and CPRI, Shimla. 23 pp.
2. FAO. 1981. *Food loss prevention in perishable crops*. Agricultural Service. Bulletin No. 43. Rome.
3. Gauraha, A.K. 1997. Economic assessment of post-harvest losses in vegetable crops. *Indian Journal of Agril. Marketing* 11: 38-39.
4. Govt. of India. 1984. *Marketing of potato in India*. MRPC-17, Directorate of Marketing and Inspection, Ministry of Rural Development, Faridabad. 349 pp.
5. Maini, S.B. 1997. Present status and future prospects of post-harvest technology of vegetables. *Agricultural Marketing* Oct-Dec, 1997: 21-24.
6. Mandal, N.C. and M.K. Dasgupta. 1981. Post-harvest diseases of perishables in West Bengal. *Annals of Agricultural Research* 2: 73-85.
7. Martinez, E.A. and J.F. Martinez. 1981. *Post-harvest losses of cassava, tomato, Irish potato and rice in Dominican Republic*. Report of post-harvest losses in the Caribbean. London (UK) Commonwealth Secretariat 2: 215-26.
8. Subrahmanyam, K.V. 1986. Post-harvest losses in horticultural crops: An appraisal. *Agricultural situation in India* 41: 339-43.

---

MS Received: 5.05.2003

# RESPONSE OF POTATO TO SOIL MOISTURE AND TEMPERATURE AS AFFECTED BY DIFFERENT MULCHES

S.P. Uniyal and A.C. Mishra<sup>1</sup>

**ABSTRACT:** Five locally available mulch materials, viz., wheat straw, green twigs, FYM, *Piltu* (dry leaves of *Pinus roxburghii*) and forest litter were applied in potato cv. Kufri Jyoti. It was found that the mulches had significant influence on soil moisture, soil temperature, plant height, fresh shoot weight, tuber weight, number of tubers per plant and tuber yield. Mulching with FYM was found most efficient to increase the soil moisture, soil temperature, plant height, fresh shoot weight, tuber weight and tuber yield followed by forest litter. Cutworm incidence in tubers was low in plots mulched with green twigs, *piltu*, forest litter and wheat straw. Correlation coefficients indicated that higher tuber yield in plots mulched with FYM and forest litter was due to their ability to conserve high soil moisture and reduce maximum soil temperature favouring plant growth and tuber bulking, respectively.

## INTRODUCTION

In hills, potato is grown as rainfed crop in summer from March to September. The rainfall in hills, although is more than evaporation yet the potato crop suffers from water stress during early stages of its growth and excess water during later stages of plant growth. In mid hills of Uttaranchal, there is surplus of about 120 cm annual rainfall, which could be harvested and conserved for its effective use. Mulching of crop is one of the efficient means to conserve the moisture. In addition, it reduces the soil temperature and increases the tuber yield (4,5,6,7,8). Although, irrigation of crop gave better results in terms of tuber yield (1,6) yet mulching is one of the methods to supplement conserved moisture of rains to the crop plants in rainfed areas. Evaluation of some mulch materials with good soil moisture conservation and soil temperature regulation ability is thus imperative. Some earlier works (2,3,9) have been done in potato with same

objective but the information under rainfed conditions of Uttaranchal is lacking.

## MATERIALS AND METHODS

The experiment was conducted during summer seasons of 1998, 1999 and 2000 in mid hill conditions of Uttaranchal (2000 m altitude, 30°15'N longitude and 78°52'E latitude) with five locally available mulch materials, viz., wheat straw, green twigs of non-fodder tree species, FYM, *Piltu* (dried pine needles) and forest litter using potato cv. Kufri Jyoti. The crop was raised in randomized complete block design with three replications. The sprouted healthy tubers were planted in first week of March at a spacing of 60 x 20 cm following recommended cultural practices. Different mulch materials were applied in furrows in a thickness of about 8-10 cm, just after planting the tubers along with control (no mulching). Data recorded in three successive years were pooled and analyzed to

---

<sup>1</sup>G.B. Pant University of Agriculture and Technology, Hill Campus, Ranichauri-249 199 (Uttaranchal)

estimate the efficacy of different mulch materials for soil moisture conservation, decrease in soil temperature, emergence (after 35 days of planting), plant growth and various plant and yield parameters (after 121 days of planting). Soil temperature was noted between 10 to 11 a.m. from about 10 cm soil depth and the soil samples were taken between 11 to 12 noon to determine the soil moisture content.

## RESULTS AND DISCUSSION

Analysis of variance and mean values of treatments for different characters indicated that mulching had pronounced effects on soil moisture, soil temperature, emergence, plant growth and tuber yield characters (Table 1). It was found that all the mulches had comparable influence on soil moisture and temperature, tuber weight and tuber yield but mulching with FYM was found to be the most favourable for tuber yield (313.83 q/ha), tuber weight (61.51 g), fresh shoot weight (310.00 g), plant height (44.64 cm), soil moisture and soil temperature in May (19.40% and 18.20 °C, respectively), while being second most favourable influence on soil moisture and soil temperature in April (22.21% and 15.73 °C, respectively) after mulching with forest litter

(22.56% and 15.30 °C, respectively). Maximum number of tubers per plant was recorded in plots mulched with *Piltu* (7.63) whereas, mulching with green twigs, *piltu*, and wheat straw drastically reduced the cutworm incidence in tubers (Table 1). High soil moisture conservation by FYM and forest litter could be due to high percolation of rainwater through their partially decomposed materials and less evaporation as compared to other intact mulches. Moreover it is likely that, decomposed matters may have released some nutrients resulting in good plant growth and tuber yield. Mulch materials increased the soil moisture by 6.33-7.41% in April and 5.24-6.36% in May and decreased the soil temperature by 3.05-4.73 °C in April and 2.63-4.34 °C in May under rainfed mid hill conditions. Mulches, viz., FYM, forest litter, green twigs, *Piltu* and wheat straw increased the per hectare tuber yield by 65.29%, 57.67%, 49.72%, 48.51% and 40.02%, respectively over control. Beneficial effects of mulching were also reported by Sood and Sharma (10), Sood (8) and Sood and Singh (9) on plant growth and tuber yield and Sood (7) and Sharma and Upadhyay (2) on soil moisture and temperature.

Table 1. Effect of different mulch materials on soil moisture, soil temperature and plant performance in potato cv. Kufri Jyoti (pooled over three years)

Mulch materials	Soil moisture in April (%)	Soil moisture in May (%)	Soil Temp. in April (°C)	Soil Temp. in May (°C)	Emergence (%)	Plant height (cm)	Fresh shoot weight (g)	Cutworm damaged tubers (%)	No. of tubers/plants	Tuber weight (g)	Tuber yield /ha. (q)
Wheat straw	21.61	18.31	16.98	19.81	78.75	36.45	135.08	17.17	7.39	51.80	265.86
Green twigs	21.50	18.49	16.24	19.97	73.66	43.33	208.92	9.14	6.85	51.01	284.26
FYM	22.21	19.40	15.73	18.20	79.49	44.64	310.00	29.16	5.83	61.51	313.83
Pine needles	21.48	18.28	16.58	19.91	84.24	41.58	200.00	9.94	7.63	53.98	281.98
Forest litter	22.56	19.31	15.30	18.45	83.12	40.96	266.58	11.85	5.20	58.84	299.35
Control	15.15	13.04	20.03	22.54	81.16	33.62	96.66	72.39	5.08	32.42	189.86
SEm±	1.15	1.02	0.83	1.16	1.65	2.65	6.72	5.19	0.5	4.43	33.13
C.D. (0.05)	2.55	2.26	1.86	2.58	3.76	5.10	21.18	16.36	1.20	9.89	73.87

Table 2. Correlation coefficients among different soil and plant characters as influenced by mulches in cv Kufri Jyoti

Mulch materials	Soil moisture in May (%)	Soil Temp. in April (°C)	Soil Temp. in May (°C)	Emergence (%)	Plant height (cm)	Fresh shoot weight (g)	Cutworm damaged tubers (%)	No. of tubers/plants	Tuber weight (g)	Tuber yield/plant (g)	Tuber yield/ha. (q)
Soil moisture in April (%)	0.997**	-0.973**	-0.928**	-0.083	0.764	0.736	-0.923**	0.371	0.962**	0.893*	0.959**
Soil moisture in May (%)		-0.982**	-0.948**	-0.102	0.803*	0.784	-0.897*	0.329	0.980**	0.926**	0.978**
Soil Temp. In April (°C)			0.957**	0.063	-0.838*	-0.850*	0.871*	-0.232	-0.979**	-0.939**	-0.981**
Soil Temp. in May (°C)				-0.029	-0.782	-0.895*	0.725	-0.016	-0.989**	-0.923**	-0.966**
Germination (%)					-0.211	0.037	0.127	-0.423	-0.066	-0.208	-0.072
Plant height (cm)						0.890*	-0.668	0.257	0.834*	0.951**	0.834*
Fresh shoot weight (g)							-0.511	-0.162	0.878*	0.919**	0.890*
Cutworm damaged tubers (%)								-0.636	-0.797	-0.742	-0.822*
No. of Tubers/ plant									-0.156	0.206	0.224
Tuber weight (g)										0.957**	0.991**
Tuber yield/ plant (g)											0.977**

\*, \*\* Significant at 5% and 1%, respectively.

Differential response of mulches on different soil and plant characters necessitated to find out the relationships between them and causes of influences of the mulches. Correlation coefficient values indicated that tuber yield was positively and significantly associated with soil moisture, plant height, fresh shoot weight and tuber weight whereas, soil temperature and cutworm damaged tubers established significantly negative relationship (Table 2). Positive correlation of soil moisture with tuber weight, plant height and fresh shoot weight was due to increased plant growth and photosynthetic efficiency resulting in accumulation of more foods in tubers and latter appeared as principal factors for high tuber yield. Negative correlation between soil temperature and soil moisture led to conclude that low soil temperature was due to cooling effect of high moisture in soil.

The study revealed that organic manures such as FYM, forest litter, etc. with high moisture conservation efficiency could be recommended as mulch in potato crop under rainfed mid hill conditions of Uttaranchal.

#### LITERATURE CITED

1. Anonymous, 1978. *Annual Scientific Report*, ICAR Research Complex for NEH Region, Shillong, pp. 110-14.
2. Sharma, R.C. and N.C. Upadhyay. 1990. Nitrogenous fertilizers for potato and their transformation in soils. *Annual Scientific Report*, CPRI, Shimla, pp. 36-40.
3. Singh, K. and K.S. Sethi. 1966. Effect of different mulching materials on various responses of potatoes (*Solanum tuberosum* L.). *Punjab Hort. J.* 6: 169-76.
4. Singh, M., L.C. Sikka and B.B. Nagaich. 1977. Changing concepts and practices for production of seed potato in India. *J. Indian Potato Assoc.* 4: 54-63.

5. Singh, M., R.C. Sharma, J.S. Grewal and L.C. Sikka. 1975. Water management for potato crop in Shimla hills. *Indian J. Agric. Sci.* 45:116-23.
6. Sood, M.C. 1986. Effect of supplemental irrigation, mulching and nitrogen levels on growth, yield and nutrient uptake of potato in Shimla hills. *Indian J. Agric. Sci.* 56: 47-55.
7. Sood, M.C. 1988. Water optimization and its requirement in potato crop. *Annual Scientific Report*, CPRI, Shimla, pp. 87-99.
8. Sood, M.C. 1983. Soil, water and NP&K losses and their control in Shimla hills. In: *Potato production, storage and utilization*. (B.B. Nagaiah, Ed.), pp. 232-42, Central Potato Research Institute, Shimla.
9. Sood, M.C. and N. Singh, 1990. Water optimization and requirement of potato crop. *Annual Scientific Report*, CPRI, Shimla, pp. 52-55.
10. Sood, M.C. and R.C. Sharma. 1985. Effect of pine needle mulch on tuber yield and fertilizer economy of potato. *J. Indian Soc. Soil Sci.* 33: 141-44.

---

MS Received: 27.09.2002

## POTATO INTERCROPPING WITH GARLIC IN RAINFED MID HILLS OF UTTARANCHAL

R.V. Singh, S. Johri, Y.N. Tripathi and A.C. Mishra<sup>1</sup>

Potato is grown as rainfed crop in mid hills of Uttaranchal during summer. It is planted in March and remains in field up to August. There is no other crop that can be harvested in February-March to vacate the field for potato planting. Because of this, field for planting the potato is rendered fallow throughout the winter. This is uneconomical for the farmers of this region. Therefore, intercropping practices become indispensable. No compatible inter-cropping systems have been evaluated so far in this region. October planted garlic gives a standing crop during March for intercropping with potato. Suitability of potato in intercropping has been proved (1, 2, 3, 4, 5). Keeping this in view the present investigation was carried out to observe the suitability of inter cropping of potato with garlic in the region.

The experiments were conducted during *rabhi* 2001 and 2002 at Ranichauri, the mid hill conditions of Uttaranchal (2000 m altitude) with potato cv. Kufri Giriraj and a local cultivar of garlic. The experiment was laid out in randomised complete block design with six replications. The garlic was planted on 16 October at a spacing of 30 x 10 cm and potato was planted on 10 March at spacing of 60 x 20 cm in such a way that one and two rows of garlic could be adjusted in between two rows

of potato. Intercrops were grown along with pure cultures of these crops following recommended cultural operations for both the crops, separately. For raising the garlic crop, 20 tonnes FYM and a basal dose of NPK @ 40: 60: 80 kg/ha was applied in form of urea, SSP and MOP, respectively. During the planting of potato, NPK through same sources were applied @ 100:60:80 kg/ha, respectively. Data of two years on different parameters of both the crops were pooled. The economics of the cropping systems were calculated considering usual market rate of produce (i.e. potato @ Rs 300/per quintal and garlic @ Rs 1000/per quintal) and inputs.

Results indicated that the treatments did not differ significantly for the most of parameters except >75 g tuber yield in potato and garlic yield. Maximum total tuber yield and yield of large tubers (>75 g) were recorded in pure culture of potato. Similarly, garlic produced significantly higher yield of bulbs (87.97 q/ha) in pure culture as compared to intercropping. Yield of tubers of <25 g, 25-50 g, 50-75 g, total tuber yield and percentage of emergence in potato did not differ significantly however, pure culture of the crop gave the best results for these parameters except yield of tubers of 25-50 g i.e. 55.83 q/ha as compared to 62.94 q/ha in one row of garlic between

<sup>1</sup> Department of Vegetable Science, G.B. Pant university of Agriculture and Technology, Hill Campus, Ranichauri-249 199 (Uttaranchal)

Table 1. Performance of potato and garlic in intercropping

Treatments	Potato Emergence (%)	Tuber yield (q/ha)				Total tubers yield	Garlic bulb yield	Net monetary return (Rs/ha)
		<25 g tubers	25-50 g tubers	50-75 g tubers	>75 g tubers			
Pure potato	91.50	42.21	55.83	76.93	63.31	238.87	-	31661
Pure garlic	-	-	-	-	-	-	87.97	37970
2 rows of potato + 1 row of garlic	90.17	39.90	62.94	72.71	60.87	236.42	29.84	45766
2 rows of potato + 2 rows of garlic	89.67	34.72	60.61	68.37	50.25	213.95	42.60	26075
S.Em. ( $\pm$ )	0.75	7.62	6.82	7.35	5.30	19.36	12.66	-
C.D (0.05)	NS	NS	NS	NS	16.71	NS	32.01	-

two rows of potato and 60.61 q/ha in two rows of garlic between two rows of potato. Decreased tuber yield in potato under intercropping were also reported by Verma and Yadav (6). Slight reduction in performance of potato under intercropping might be due to inadequate tith for the crop and increased competition for the nutrients. Maximum bulb yield in pure garlic could be due to more plant population. Although, in 2 rows of potato + 2 rows of garlic system the plant population of garlic was equal but the bulb and tuber yields in garlic and potato, respectively were drastically decreased due to increased competition for nutrients and space. The performance of garlic in intercropping system of one row of garlic between two rows of potato could be due to less number of plants accommodated in an unit area. Incidence of cut worm, *Epilachna* beetle and white grubs was also observed in intercropped potato. This might have happened due to insecticidal effect of garlic.

The economics of the cropping systems indicated that net monetary return was highest Rs 45766/- when one row of garlic was grown in between two rows of potato (Table 1). The potato yield was more or less equal in both of intercropping systems however, 1 row of garlic

between 2 potato rows, garlic yield was higher with marginal expenditure. Single row of garlic between two rows of potato proved to be suitable intercropping practice in rainfed mid hills of Uttaranchal with respect to integrated use of nutrients, land, moisture, better performance of the crops, less incidence of insect-pests and high remunerative yield.

#### LITERATURE CITED

1. Grewal, J.S., S.S. Saini and P.M. Govindakrishnan. 1991. *Potato based cropping systems*. Tech. Bull. No. 30, CPRI, Shimla, 24 pp.
2. Hooda, R.S., G. Kallou and V. P. Singh. 1985. *J. Indian Potato Assoc.* 12: 98-101.
3. Sharma, S.N., R. Prasad and S. Singh. 1989. *Indian J. Agric.Sci.* 59: 431-34.
4. Sidhu, M.S., T.S. Sahota and B.D. Sharma. 1988. *Indian Fmg.* 38 (5): 25-26, 39.
5. Singh, M. 1989. Changing concept in cropping system and input management. In: *Current facets in potato research* (J. S. Grewal, G. S. Shekhawat, S. K. Bhattacharya and R. A. Singh, Eds.). CPRI, Shimla, pp. 10-26.
6. Verma, R.S. and R.L. Yadav. 1986. *J. Agric. Sci., Cambridge* 107: 125-31.

MS Received: 07.06.2002

## INFLUENCE OF DIFFERENT N AND P LEVELS WITH AND WITHOUT BIO-FERTILIZER ON N, P CONTENT, UPTAKE AND YIELD OF POTATO CV. KUFRI JYOTI

S.S. Kushwah<sup>1</sup> and R.N.S. Banafar<sup>2</sup>

Malwa region of Madhya Pradesh particularly Indore and Ujjain districts have distinguished place in production of potato (*Solanum tuberosum* L.). The region produces two crops of potato i.e. an early crop from middle of September to middle of December and main season crop from October to January/February. Kufri Jyoti is the predominant variety occupying nearly 90% of the potato area. Potato is a heavy feeder of nutrients and requires large quantity of fertilizers. Varying yield responses to fertilizer application have been reported by Sharma and Grewal (7) and Sharma (6). Chemical fertilizer besides being costly poses serious threat to the soil and environmental health. Bio-fertilizers are eco-friendly and cheap source of nutrients (3) and need to be evaluated for potato crop in this region. Hence, present experiment was undertaken to study the effect of different N, P levels with and without bio-fertilizer on potato cv. Kufri Jyoti.

A field experiment was conducted during Rabi 1994-95 at Research Farm, College of Agriculture, Indore. The soil of the experimental site was clayey in texture

(vertisols). Initial status of experimental soil had pH 7.5, EC 0.5 dsm<sup>-1</sup>, organic carbon 0.55%, available N - 220 kg/ha, P - 9.6 kg/ha and K 520 kg/ha. The following eight treatments were laid out in randomized block design with four replications.

- T<sub>1</sub> - Control (no fertilizer)
- T<sub>2</sub> - *Azotobacter* + Phosphate solubilising bacteria
- T<sub>3</sub> - 150 kg N ha<sup>-1</sup> + PSB
- T<sub>4</sub> - 80 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + *Azotobacter*
- T<sub>5</sub> - 75 kg N ha<sup>-1</sup> + 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + *Azotobacter* + PSB culture
- T<sub>6</sub> - 150 kg N ha<sup>-1</sup> + 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + PSB culture
- T<sub>7</sub> - 75 kg N ha<sup>-1</sup> + 80 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + *Azotobacter* culture
- T<sub>8</sub> - 150 kg N ha<sup>-1</sup> + 80 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>

Healthy and sprouted potato tubers treated with Mancozeb (0.2%) solution were planted at an inter and intra row spacing of 60 and 20 cm respectively. Fifty percent of N and 100% of P<sub>2</sub>O<sub>5</sub> was applied at planting and remaining N was top dressed on 40<sup>th</sup> day after planting. Bio-fertilizers, viz. *Azotobacter* and Phosphate Solubilising Bacteria (PSB) culture each @ 3 kg/ha were mixed with 50kg well sieved FYM as per treatment and applied to the root zone of the crop at 20 days after planting. The same

<sup>1</sup>Department of Vegetable Crops & Floriculture, JNKVV, Jabalpur-482 004 (Madhya Pradesh)

<sup>2</sup>Department of Horticulture, College of Agriculture, Indore-452 001 (Madhya Pradesh)

quantity of FYM i.e. 50 kg/ha was also incorporated with  $T_1$  and  $T_8$  treatments to ensure the uniformity. A basal dose of 120 kg  $K_2O$ /ha was applied with each treatment. Nitrogen, phosphorus and potassium were given in the form of urea, single super phosphate and muriate of potash respectively. Composite soil sample was collected before planting for analyzing initial nutrients status of the soil. Potato haulm and tuber were collected at harvesting stage from each treatment. These haulm and tuber were washed, dried in oven and grounded in stainless steel Wiley mill then passed through 40 mesh sieve and there after used for analysis as per standard procedure. The total nutrients uptake was calculated by multiplying N and P concentration of haulm and tuber with their dry matter yield, respectively.

**Dry Matter Production:** The data presented in Table 1 showed significant difference for dry matter production under various treatments at harvesting stage. Use of 150 kg N + 80 kg  $P_2O_5$  ha<sup>-1</sup> produced maximum dry matter of haulm (26.72 q ha<sup>-1</sup>) and tuber (59.51 q ha<sup>-1</sup>) at harvest stage. It was significantly superior over other combinations. The treatment  $T_6$ ,  $T_7$  and  $T_5$  were comparable which produced 23.16 qha<sup>-1</sup>, 22.41 q ha<sup>-1</sup> & 20.85 q ha<sup>-1</sup> haulm dry matter at harvest stage respectively. Tuber dry matter production at harvest stage under  $T_6$  (53.48 qha<sup>-1</sup>) and  $T_7$  (51.88 qha<sup>-1</sup>) were at par, it decreased significantly under  $T_5$  (44.07 qha<sup>-1</sup>). The latter ( $T_5$ ) exhibited non-significant difference with  $T_4$  and  $T_3$  for haulm and tuber dry matter production. Soil inoculation with *Azotobacter* and PSB culture also registered markedly higher haulm and tuber dry matter over control. Shanmugasundaram and Savithri (4)

and Mahendran and Kumar (3) have also reported the increased dry matter production with the application of bio-fertilizer and increasing levels of fertilizers.

**Tuber Yield:** Potato tuber yield as depicted in Table 1 was markedly influenced by different fertilizer doses. Application of 150 kg N + 80 kg  $P_2O_5$  ha<sup>-1</sup> gave significantly higher yield (278.14 q ha<sup>-1</sup>) over other combinations. Tuber yield obtained under  $T_6$  (265.30 q ha<sup>-1</sup>) and  $T_7$  (259.18 q ha<sup>-1</sup>) were at par. Whereas, use of 75 kg N + 40 kg  $P_2O_5$  along with *Azotobacter* and PSB culture (228.38 q ha<sup>-1</sup>), 150 kg N + PSB culture (223.92 qha<sup>-1</sup>) and 80 kg  $P_2O_5$  + *Azotobacter* culture did not differ significantly. Dual inoculation of soil with *Azotobacter* and PSB culture showed pronounced improvement in yield (151.95 q ha<sup>-1</sup>) as compared to control (133.58 q ha<sup>-1</sup>). This increase in yield may be attributed to increased availability of N and P in the soil, which led to their enhanced absorption resulting in increased yield. These findings are in conformity with the findings of Mahendran and Chandramani (2) and Shanmugasundaram and Savithri (4).

**Nitrogen content and uptake:** A perusal of the data (Table 1) revealed that N content and uptake of haulm as well as tuber differed significantly in different treatments at harvest stage. The nitrogen content of haulm and tuber increased with increasing level of nitrogen fertilizers. Highest N concentration of haulm (2.36%) and tuber (1.89%) at harvest stage was found with the application of 150 kg N+ 80 kg  $P_2O_5$  ha<sup>-1</sup>. It was followed by  $T_6$ ,  $T_7$ ,  $T_5$ ,  $T_3$ ,  $T_4$  and  $T_2$ . Lowest N content of haulm as well as tuber was recorded in control. Similarly highest uptake of N in haulm (63.06 kg ha<sup>-1</sup>) and tuber (112.47 kg ha<sup>-1</sup>) at harvest stage was

Table 1. Effect of different treatments on N, P content, uptake and dry matter and tuber yield in potato

Treatment	Dry matter (q ha <sup>-1</sup> )			Tuber yield (q ha <sup>-1</sup> )	N-Content (%)		N-uptake (kg ha <sup>-1</sup> )		P-content (%)		P-uptake (kg ha <sup>-1</sup> )	
	haulm	tuber	total		haulm	tuber	haulm	tuber	haulm	tuber	haulm	tuber
T <sub>1</sub>	11.45	22.73	34.18	133.58	1.64	1.02	18.77	23.18	0.24	0.14	2.75	3.18
T <sub>2</sub>	15.68	28.85	44.53	151.95	1.81	1.34	28.38	38.66	0.29	0.20	4.55	5.77
T <sub>3</sub>	19.74	43.05	62.79	223.92	2.07	1.58	40.86	68.02	0.30	0.22	5.92	9.47
T <sub>4</sub>	18.35	42.52	60.87	221.74	1.98	1.41	36.33	59.95	0.36	0.26	6.60	11.05
T <sub>5</sub>	20.85	44.07	64.92	228.38	2.08	1.61	43.37	70.95	0.32	0.25	6.67	11.02
T <sub>6</sub>	23.16	53.48	76.64	265.30	2.20	1.76	50.95	94.12	0.43	0.26	9.96	13.90
T <sub>7</sub>	22.41	51.88	74.29	259.18	2.15	1.68	48.18	87.16	0.45	0.28	10.08	14.53
T <sub>8</sub>	26.72	59.51	86.23	278.14	2.36	1.89	63.06	112.47	0.47	0.31	12.56	18.45
SEm ±	1.05	1.83	-	3.95	0.05	0.03	2.08	3.25	0.01	0.01	0.53	0.86
CD <sub>0.05</sub>	3.08	5.38	-	11.63	0.14	0.08	6.11	9.56	0.04	0.03	1.55	82.53
Mean	19.11	43.26	-	220.27	2.03	1.51	39.67	68.11	0.36	0.23	7.18	10.80

recorded with the use of 150 kg N+ 80 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> which was more than other combinations. It was observed that treatments with same level of N dose showed increased N content and uptake with increased P application. Sharma and Sharma (5) have reported positive interaction between P and N on N uptake. Earlier workers (1, 4) have reported increased N content and uptake with increasing fertilizer levels.

**Phosphorus content and uptake:** The haulm and tuber of potato collected at harvest stage were analyzed for P content and uptake (Table 1). The concentration of P in potato haulm and tuber varied significantly and showed increasing trend with increasing level of P fertilizers. Highest P content in haulm (0.47%) and tuber (0.31%) was observed with the application of 150 kg N + 80 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> followed by 75 kg N + 80 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + *Azotobacter* (T<sub>7</sub>) and 150 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> + PSB (T<sub>6</sub>). Lowest P content was recorded in control. Increasing level of P fertilizer resulted in improved uptake of P by haulm and tuber. Maximum P uptake by haulm (12.56 kg ha<sup>-1</sup>) and tuber (14.17 kg ha<sup>-1</sup>) at harvest stage was recorded with 150 kg N + 80 kg P<sub>2</sub>O<sub>5</sub>, which

was significantly more than the other treatments. Soil inoculation with *Azotobacter* and PSB culture also increased P uptake significantly compared to the control having lowest P uptake of 2.75 kg ha<sup>-1</sup> (haulm) and 3.18 kg ha<sup>-1</sup> (tuber) at harvest stage. The treatments with same level of P applied with higher N dose had enhanced P concentration and P uptake by both haulm and tubers. Similar observation was made by Sharma and Sharma (5). Phosphorus applied at higher levels might have made nutrients easily available to the plant roots and resulted in higher P contents in haulm and tuber. This coupled with high dry matter production may be attributed to higher P uptake by haulm and tuber of potato. These results are in agreement with the results obtained by earlier workers (1, 4).

It may be concluded that higher potato yield could be obtained with the application of 150 kg N + 80 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>, and application of *Azotobacter* and PSB culture is beneficial in increasing dry matter, N and P content and uptake by haulm and tuber and tuber yield of potato.

### LITERATURE CITED

1. Chaurasia, S.N.S. and K.P. Singh. 1993. *J. Indian Potato Assoc.* 20: 169-71.
2. Mahendran, P.P. and P. Chandramani. 1998. *J. Indian potato Assoc.* 25: 50-52.
3. Mahendran, P.P. and N. Kumar. 1998. *South Indian Hort.* 46: 97-98.
4. Shanmugasundaram R. and P. Savithri. 2000. *J. Indian Potato Assoc.* 27: 127-31.
5. Sharma, R.C. and H.C. Sharma. 1990. *J. Indian Potato Assoc.* 17: 24-29.
6. Sharma, U.C. 1992. *J. Indian Potato Assoc.* 19: 77-88.
7. Sharma, V.C. and J.S. Grewal. 1991. *J. Indian Potato Assoc.* 18: 43-47.

---

MS Received: 07.06.2002

## EFFECT OF DIFFERENT FERTILITY LEVELS ON SPECTRAL CHARACTERISTICS, GROWTH AND YIELD OF POTATO CV., KUFRI BAHAR

U.P. Shahi, Suman Kumar<sup>1</sup>, N.P. Singh and A.K. Tiwari<sup>2</sup>

Ground based radiometric measurements have been successfully used to assess crop condition over various crops. The low reflectance and transmittance of visible radiation is attributed to the high absorption by leaf pigments, primarily the chlorophyll. However, these pigments are highly transparent to infrared radiation and the internal cellular structure of leaf appears to determine the high reflectance at these wavelengths. Accurate assessment of growth and condition for spectral measurement will require further understanding of the relationship between crop development and spectral response (4). The present study was aimed to observe the spectral characteristics, growth and yield response of potato to the applied nitrogen and phosphorus doses.

A field experiment was conducted on sandy loam soil at Vegetable Research Center of G.B. Pant University of Agric. & Tech., Pantnagar, during *rabi* season of 1998-99. The treatment consisted three levels of nitrogen (75, 150 and 225 kg N ha<sup>-1</sup>) and three levels of phosphorus (50, 100 and 150 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) in potato variety Kufri Bahar with randomized block design. Spectral reflectance was measured using a multi-band ground truth

radiometer (model/041) in four bands of spectral region, *viz.*, 450-520, 520-590, 620-680 and 770-860 nm blue, green, red and infra-red, respectively after 6,8,10 and 12 weeks after planting.

### Spectral characteristics

The general trend showed that under the treatment N<sub>225</sub>P<sub>100</sub> (225Kg N and 100Kg P<sub>2</sub>O<sub>5</sub>/ha), the percent blue reflectance (PBR) value was minimum and under the treatment N<sub>75</sub>P<sub>50</sub> (75Kg N and 50Kg P<sub>2</sub>O<sub>5</sub>/ha) it was maximum. It clearly indicated that the PBR value decreased almost significantly with increasing levels of fertilizer dose.

From the Table 1 it can be inferred that at high doses of fertilizer application, reflectance was less, but at low dose of fertilizer more reflectance was found. Increase in reflectance could be attributed to the fact that light absorbance in this spectral region is greatly affected by pigment concentration which depends on the nitrogen concentration. Lowering the nitrogen content leads to decrease in the chlorophyll and consequently a reduced absorbance of radiation (hence an increase of reflectance) (1). The percent green reflectance (PGR) also decreased with

<sup>1</sup> Department of Soil Science, G.B. Pant University of Agriculture & Technology, Pantnagar-263 145 (Uttaranchal)

<sup>2</sup> Department of Vegetable Science, G.B. Pant University of Agriculture & Technology, Pantnagar-263 145 (Uttaranchal)

**Table 1.** Percent blue reflectance (PBR) and percent green reflectance (PGR) of potato (cv. K. Bahar) as influenced by different fertility levels at various growth stages

Treatments	Weeks after planting							
	6		8		10		12	
	PBR	PGR	PBR	PGR	PBR	PGR	PBR	PGR
NP <sub>75-50</sub>	22.47	25.14	21.45	26.00	22.34	33.17	23.83	36.27
NP <sub>75-100</sub>	23.87	26.13	21.25	27.26	21.85	28.43	23.89	27.45
NP <sub>75-150</sub>	20.00	24.67	20.46	26.56	21.40	28.00	23.40	26.00
NP <sub>150-50</sub>	19.78	24.00	20.29	24.96	21.55	27.72	22.79	26.18
NP <sub>150-100</sub>	19.00	23.02	20.18	23.18	20.00	24.96	22.45	25.93
NP <sub>150-150</sub>	18.92	23.47	20.27	23.13	21.00	24.00	22.00	25.82
NP <sub>225-50</sub>	18.15	21.47	18.61	22.08	19.83	23.37	21.37	24.11
NP <sub>225-100</sub>	17.00	22.15	17.29	22.00	19.45	23.00	20.17	24.73
NP <sub>225-150</sub>	18.04	22.25	18.30	23.25	18.30	23.80	21.00	23.00
S.Em. ±	0.75	0.67	0.42	0.88	0.36	0.81	0.65	0.48
CD = 0.05	2.25	2.00	1.25	2.40	1.08	2.43	1.96	1.44

increasing levels of fertilizer (Table 2). The values observed for PGR over plant canopy on each of observation were higher in comparison to value obtained for per cent blue reflectance (PBR) and per cent red reflectance (PRR), because in the visible portion of the spectrum, most of the energy striking a green leaf is absorbed and very little is transmitted through the leaves. The low reflectance in blue and red reflectance region is due to much absorption by leaf (3).

Table 2 shows that the application of N<sub>150</sub>P<sub>100</sub>, N<sub>150</sub>P<sub>150</sub>, N<sub>225</sub>P<sub>50</sub>, N<sub>225</sub>P<sub>100</sub> and N<sub>225</sub>P<sub>150</sub> levels of fertilizers significantly decreased PRR

of potato at all growth stages except 10 weeks after planting as compared to lowest dose of fertilizer (N<sub>75</sub>P<sub>50</sub>). It was also observed that PRR values of potato decreased at increasing levels of fertilizer doses. At the same time, the value of leaf area index, and chlorophyll content showed increasing values with increasing levels of fertilizer that was in accordance to the above results. Similar results were reported by Mahey *et al.* (5) in maize crop.

The percent infra-red reflectance (PIRR) values increased with increasing doses of fertilizer but statistically non-significant

**Table 2.** Percent red reflectance (PRR) and percent infra red reflectance (PIRR) of potato (cv. K. Bahar) as influenced by different fertility levels at various growth stages

Treatments	Weeks after planting							
	6		8		10		12	
	PRR	PIRR	PRR	PIRR	PRR	PIRR	PRR	PIRR
NP <sub>75-50</sub>	21.71	41.63	18.36	47.00	19.95	44.76	21.13	43.00
NP <sub>75-100</sub>	20.00	41.86	17.61	46.91	19.00	45.01	21.00	43.05
NP <sub>75-150</sub>	18.47	42.73	17.20	47.70	19.83	45.11	20.00	44.00
NP <sub>150-50</sub>	19.82	42.51	17.61	48.69	18.76	46.00	20.97	43.71
NP <sub>150-100</sub>	17.68	42.86	16.97	47.90	18.05	46.36	19.50	45.03
NP <sub>150-150</sub>	18.00	43.20	15.31	49.63	17.82	47.00	19.00	45.05
NP <sub>225-50</sub>	14.93	43.50	15.00	49.00	17.15	47.11	18.00	45.36
NP <sub>225-100</sub>	16.36	43.82	14.91	50.07	16.11	48.00	18.87	45.53
NP <sub>225-150</sub>	14.52	44.00	14.78	50.03	16.10	47.50	17.61	46.00
S.Em. ±	0.57	-	0.65	-	-	-	0.69	-
CD = 0.05	1.72	NS	1.96	NS	NS	NS	2.06	NS

differences were found among different treatments (Table 2).

Fertilizer deficiency caused increasing reflectance in the visible wave length and reduced the infrared reflectance of canopies with adequate nitrogen and phosphorus fertilization. The changes in reflectance could be attributed to lower levels of chlorophyll in the leaves and less leaf area and ground cover. The blue and red reflectance decreased rapidly with time, due to an increase in chlorophyll concentration and LAI. After that it started increasing continuously due to senescence as crop matured. Chlorophylls absorb energy strongly in ultra violet, blue and red region of the electromagnetic radiations. The absorbed energy of this part of the spectrum is utilized for photosynthetic activity. The temporal variation of spectral parameter during the life cycle of the crop can represent the growth and development of the crop (8). For spectral variables the separation between a lowest and highest fertilized crop was found to be at maximum during a period of maximum

vegetative development. At early dates, when the percentage soil cover was low, the effect of stress was less recognizable because the spectral response of the soil dominated the canopy response. Late in season, senescence caused the difference to decrease. Spectral parameters can be used to distinguish between fertilized and deficient crop.

**Growth parameters:** Significantly increased the dry weight of shoot, leaf area index (LAI) and chlorophyll content of leaves at all the growth stages. Application of  $N_{225}P_{150}$  dose showed the highest mean dry weight, LAI and chlorophyll content in comparison to application of  $N_{75}P_{50}$ . Which showed lowest dry weight, LAI and chlorophyll content. From the analysis of data (Table 3), it was revealed that there was an upward trend in the value of dry weight, LAI and chlorophyll content from 6<sup>th</sup> to 10<sup>th</sup> weeks after sowing but it decreased later on. Higher growth rate at higher level of fertilizer seems to have led to more synthesis and translocation of photosynthates to the tuber by the plants.

Table 3. Percent shoot dry matter per plant, leaf area index (LAI), total chlorophyll content (mg/g fresh weight) and tuber yield of potato (cv. K.Bahar) as influenced by different fertility levels at various growth stages

Treatments	Weeks after planting										Yield (q/ha)		
	6		8		10		12		LAI	Chlorophyll content			
	Dry matter (%)	LAI Chlorophyll content (mg/g fresh weight)	Dry matter (%)	LAI Chlorophyll content (mg/g fresh weight)	LAI Chlorophyll content (mg/g fresh weight)	LAI Chlorophyll content (mg/g fresh weight)							
$N_{75}P_{50}$	6.80	2.50	1.85	8.25	4.00	1.91	9.52	4.70	1.26	8.89	4.00	1.10	207.7
$N_{75}P_{100}$	7.00	2.80	1.89	8.68	4.30	1.99	9.75	4.80	1.78	9.00	4.00	1.43	210.3
$N_{75}P_{150}$	7.20	3.00	1.92	8.60	4.40	2.02	10.22	5.00	1.80	9.22	4.50	1.45	201.3
$N_{150}P_{50}$	7.70	3.30	1.95	9.10	4.70	2.09	10.53	5.40	1.85	9.85	4.80	1.50	262.7
$N_{150}P_{100}$	8.10	3.36	2.05	9.70	4.90	2.14	11.25	5.60	1.90	10.50	5.00	1.52	286.3
$N_{150}P_{150}$	8.40	3.40	1.98	10.00	5.00	2.20	11.80	5.60	2.01	11.20	5.20	1.55	265.6
$N_{225}P_{50}$	9.50	3.50	2.10	11.30	5.00	2.30	13.11	6.10	2.04	12.03	5.30	1.60	247.0
$N_{225}P_{100}$	10.10	3.65	2.13	11.90	5.32	2.35	13.80	6.21	2.06	13.00	5.30	1.64	289.3
$N_{225}P_{150}$	10.60	3.70	2.10	12.70	5.50	2.41	13.70	6.25	2.05	13.20	5.50	1.60	274.7
S.Em. $\pm$	0.13	0.14	-	0.15	0.14	0.08	0.10	0.12	0.06	0.27	0.16	0.09	12.5
CD = .05	0.39	0.42	NS	0.44	0.43	0.25	0.31	0.38	0.19	0.80	0.47	0.27	37.9

Patel *et al.* (6) also reported higher dry matter with higher dose of nitrogen.

The values showed that chlorophyll content increased with increasing rate of fertilizers. This has been due to the fact that nitrogen is a constituent of chlorophyll and has a major role in its synthesis. Cieccko *et al.* (2) reported higher chlorophyll content at higher dose of fertilizer application. The maximum tuber yield (289.33 q ha<sup>-1</sup>) was recorded under application of N<sub>225</sub>P<sub>100</sub> dose of fertilizer while minimum yield (201.33 q ha<sup>-1</sup>) under the application of N<sub>75</sub>P<sub>150</sub> dose of fertilizer (Table 3). Singh and Raghav (7) have also reported that increasing levels of nitrogen produced significantly higher tuber yield.

#### ACKNOWLEDGEMENT

Authors are grateful to Dr. A.K. Sharma, Professor and Head, Department of Agrometeorology, G.B. Pant University of Agriculture & Technology, Pantnagar, for making useful suggestions and providing field radiometer for the work.

#### LITERATURE CITED

1. Al-Abbas, A.H., R. Barr, J.D. Hall, F.L. Crane and M.F. Baumgardner. 1974. *Agron. J.* 66: 16-20.
2. Cieccko, Z., M. Wyszowski, A. Zolnowski and J. Zabielska. 2000. Proceedings of conference "Table and food processing potato-agrotechnical and storage factors conditioning quality", Radzikow, Poland, 23-25. Feb. 1999. *Biuletyn-Institutu-Hodowli-I-Aklimatyzacji-Roslin.* 213: 131-36.
3. Hoffer, R.M. 1978. In: *Remote Sensing. The quantitative approach.* (P.H. Swain, S.M. Davis, Eds.), pp. 227-90, Mc Graw Hill International Book Co., New York.
4. Leamer, R.W., V.I. Myers and L.F. Silva. 1973. *Rev. Sci. Instrum.* 44: 611-14.
5. Mahey, R.K., R. Singh, S.S. Sidhu and R.S. Narang. 1990. *Indian J. Agron.* 35: 153-58.
6. Patel, J.C., L.R. Patel, A.U. Amin and J.K. Patel . 2000. *J. Indian Potato Assoc.* 27: 51-53.
7. Singh, N.P. and Manoj Raghav. 2000. *J. Indian Potato Assoc.* 27: 47-48.
8. Singh, T.P., N.K. Patel, R.R. Navalgund and B. Sahai. 1982. *ISRO Technical Report, ISRO-SRC-TR-22-82*, Indian Space Research Organization, Bangalore.

---

MS Received: 02.02.2002

## INCIDENCE OF CUTWORM ON POTATO IN DIFFERENT LOCATIONS OF WEST BENGAL

A. Konar and Md. Mohasin<sup>1</sup>

Potato is an important food crop in Indo-gangatic plains of West Bengal due to its high production potentiality and good returns. This crop is attacked by many insects which reduce the yield of potato tubers and also destroy the plant. The seedlings of potato are more susceptible to cutworm, *Agrotis ipsilon* (Hufner) than well established plants (2). Population build up of insect and its control was studied by many workers (2, 4, 5 and 6) in various parts of the country. Present investigation was undertaken for recording the intensity of infestation of cutworm, *Agrotis ipsilon* (Hufner) on potato in three districts of West Bengal.

This field investigation was conducted on potato cv. Kufri Jyoti at four locations of three districts at farmers field/ Govt. farm of West Bengal, viz, Memari and Kalna (Burdwan), Kalyani (Nadia) and Boinchee (Hooghly) during rabi seasons between 1989 - 1999 on the incidence of cutworm on potato. Observation was taken 45 to 30 days after planting on percent plant damage and at the time of harvesting on number and weight of tuber damage from a compact plot of 100 plants. The crop was raised as per recommended package and practices.

The results are presented in Table 1 and fig. 1 & 2. At Memari, plant damage and tuber

damage on number and weight basis from 100 plants were found to vary from 3.5 to 14%, 4.5 to 24.0 and 0.275 to 1.250%, respectively, where as these were recorded from 4.0 to 16.0%, 3 to 22 and 0.12 to 1.350%, respectively, at Kalna. Total tuber yield per 100 plants were recorded to vary from 9 to 22.1 kg at Memari and 10.2 to 23.1 kg at Kalna. Plant damage and number and weight of the damage tubers from 100 plants were recorded to vary from 2 to 11%, 3 to 23 and 0.13 to 1.45%, respectively, at Kalyani where as these were observed between 2.5 to 16.5%, 3.5 to 25.0 and 0.225 to 1.40%, respectively, at Boinchee. Total tuber yield from 100 plants were found 10.6 to 21.5 kg at Kalyani and 12.1 to 22.3 kg at Boinchee. The highest percent of plant damage was found at Boinchee (16.5) followed by Kalna (16.0), Memari (14.0) and Kalyani (11.0), respectively. Maximum number of damaged tubers were recorded at Boinchee and minimum at Kalna, where the average minimum and maximum temperature was found to vary from 16.7 to 20.8° C and 31.3 to 36.1° C and average minimum and maximum relative humidity ranged from 49.3 to 73.0% and 83.7 to 98.0%, respectively. Yield of damaged tuber was found to be highest at Kalyani and it was recorded lowest at Memari. Maximum total number of tubers was noted

<sup>1</sup>Department of Agril. Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, Nadia (West Bengal)

Table 1. Incidence of cutworm on potato in West Bengal

Year	Memari (Burdwan)			Kalna (Burdwan)			Kalyani (Nadia)			Boinchee (Hooghly)		
	Plant damage (%)	Tuber damage Numbers (%)	Tuber damage Weight (%)	Plant damage (%)	Plant damage Numbers (%)	Plant damage Weight (%)	Plant damage (%)	Tuber damage Numbers (%)	Tuber damage Weight (%)	Plant damage (%)	Tuber damage Numbers (%)	Tuber damage Weight (%)
1989-90	4.5	7.5	0.600	4.0	5.5	0.450	4.0	8.5	0.850	8.5	13.0	1.400
1990-91	10.5	10.0	0.750	7.0	6.5	0.300	10.5	19.5	1.450	16.5	25.0	1.100
1991-92	6.5	5.0	0.320	6.0	5.0	0.425	4.5	6.5	0.200	6.0	4.5	0.300
1992-93	7.5	6.5	0.350	4.5	3.0	0.120	3.5	3.0	0.280	5.5	3.5	0.225
1993-94	6.0	4.5	0.275	4.0	4.0	0.150	2.0	5.5	0.225	2.5	5.0	0.250
1994-95	3.5	6.0	0.330	4.0	5.0	0.175	2.8	3.5	0.130	3.0	7.0	0.350
1995-96	8.5	10.0	0.630	12.5	14.5	0.990	6.0	8.0	0.375	14.5	15.5	0.950
1996-97	12.0	13.0	0.800	15.0	21.5	1.350	7.5	8.5	0.460	10.0	18.5	1.125
1997-98	10.0	18.5	1.100	9.5	20.5	1.100	4.0	21.0	1.200	7.5	16.0	0.980
1998-99	14.0	24.0	1.250	16.0	22.0	1.150	11.0	23.0	1.350	9.0	19.5	0.950

at Boinchee followed by Kalna, Memari and Kalyani, respectively, where as the maximum total tuber yield from 100 plants was found at Kalna followed by Boinchee, Memari and Kalyani, respectively. Plant damage by cutworm appeared first during 3<sup>rd</sup> week of December and increased thereafter until 2<sup>nd</sup> week of January. Tuber damage was recorded first during late December and increased till harvest and cutworms were not found one week after harvest (1). Persistent dry weather and high temperature favour the infestation of cutworm on potato (3).

#### ACKNOWLEDGEMENTS

The authors are grateful to Dr. S.M. Paul Khurana, Director, CPRI and Project Coordinator, AICPIP, Shimla, HP for his

valuable suggestions. The results presented are compilation of data collected under AICPIP, for the period mentioned.

#### LITERATURE CITED

1. Das, B.B. and G. Ram. 1988. *Indian J. Agric. Sci.* 58: 650-51.
2. Kishore, R. and S.S. Misra. 1984. *Indian J. Ent.* 46(3): 366-68.
3. Kishore, R. and S.S. Misra. 1988. *Bull. Ent.* (New Delhi). 29: 223-25.
4. Kishore, R. and S.S. Misra. 2001. *J. Ent. Res.* 25(1): 31-35.
5. Parihar, S.B.S. and O.P. Singh. 1992. *Nat. Aca. Sci. Letters.* 15: 57-58.
6. Ram, G., S.S. Misra and K.P.M. Damayanathi. 2001. *J. Ent. Res.* 25(3): 183-87.

MS Received: 08.07.2002

## EFFECTIVENESS OF SYNTHETIC INSECTICIDES, BIO-PESTICIDES AND *AZADIRACTIN* AGAINST POTATO APHIDS

A. Konar and M. Chettri<sup>1</sup>

Potato is an important crop in West Bengal due to its high production potentiality. It occupies a significant position in the national production because of congenial climatic condition. The green peach aphid, *Myzus persicae* (Sulzer) is widely distributed all over the world on a large number of host plants. Its virus spreading ability results in the quick degeneration of seed stocks and yield reduction in potato (1). Number of reports are available (2, 3, 4, 5) on the appearance of aphid, population build up and their control from different parts of the country. However, the use of synthetic insecticides to control the aphids need to be minimized as their continuous application not only leads to development of resistance in insects but also disturb the ecosystem. In the present study various bio-pesticides along with synthetic insecticides have been evaluated for effective control of aphids resulting in less disturbance of ecosystem.

The field study was carried out at Adisaptagram Block Seed Farm, Hooghly district, West Bengal during *rabi* seasons of 1997-98 and 1998-99 for the effective

management of aphids using different bio-pesticides and synthetic insecticides. Seven treatments including untreated check plot were taken in randomized block design with four replications, having a plot size 3 m x 2.5 m. All the recommended agronomic practices were applied. Potato cv. Kufri Chandramukhi was planted during late November to early December at 50 cm. x 20 cm. inter and intra spacings. Phorate 10 G was applied once at earthing up, while other treatments were sprayed four weeks after planting followed by two more sprays at 15 days interval. The untreated check plots were sprayed with the same volume of water. Count on the aphid number was taken on one upper, one middle and one lower leaf of ten plants in each plot before spraying. Thereafter the counts were taken at 7 and 15 days after each spraying. The data recorded were statistically analysed for evaluating the effectiveness of different bio-pesticides and botanicals along with synthetic insecticides against aphids *Myzus persicae* and *Aphis gossypii* on potato.

The data on population of aphids in the field before and after the application of

---

<sup>1</sup> All India Coordinated Potato Improvement Project, Bidhan Chandra Krishi Viswavidyalaya, Kalyani-741 235, Nadia, (West Bengal)

Table 1. Efficacy of different treatments against *Myzus persicae* (Ia) and *Aphis gossypii* (Ib) on potato during rabi season of 1997-98

Treatments	Pre-treatment population		Ist spraying				II nd spraying				III rd spraying				Tuber yield (q/ha)
	Ia	Ib	7 DAP		15 DAP		7 DAP		15 DAP		7 DAP		15 DAP		
			Ia	Ib	Ia	Ib	Ia	Ib	Ia	Ib	Ia	Ib	Ia	Ib	
Phorate 10 G 1.5 kg a.i./ha	54.33 (7.40)	32.33 (5.72)	8.33 (2.97)	7.33 (2.79)	4.33 (2.19)	6.33 (2.61)	4.00 (2.12)	4.33 (2.19)	3.50 (2.00)	2.50 (1.73)	14.00 (3.80)	12.33 (3.58)	18.0 (4.30)	16.33 (4.10)	228.73
Azadirachtin 1500 ppm 1.8 lit./ha	49.20 (7.04)	39.10 (6.29)	9.30 (3.13)	8.30 (2.96)	30.33 (5.55)	26.33 (5.17)	20.00 (4.52)	18.00 (4.30)	35.33 (5.89)	32.00 (5.70)	13.00 (3.67)	9.33 (3.13)	9.33 (3.73)	7.33 (2.79)	219.52
Lindane 6.5 WP 3 kg/ha	47.10 (6.89)	40.20 (6.37)	23.00 (4.84)	21.33 (4.67)	31.33 (5.64)	25.33 (5.08)	19.00 (4.41)	17.66 (4.26)	12.33 (3.58)	11.33 (3.49)	11.00 (3.39)	8.33 (2.97)	6.33 (2.61)	4.00 (2.12)	231.66
Chlorpyrifos 20 EC 2.4 lit./ha	50.20 (7.12)	37.10 (6.13)	18.00 (4.30)	15.00 (3.93)	15.33 (3.97)	11.33 (3.43)	10.00 (3.24)	8.00 (2.91)	6.33 (2.61)	5.33 (2.41)	5.33 (2.41)	3.33 (1.95)	3.0 (1.87)	2.66 (1.77)	238.19
Acceptate 75 SP 600 ml./ha	45.00 (6.74)	43.00 (6.59)	11.00 (3.39)	9.33 (3.13)	9.00 (3.08)	7.00 (2.73)	7.30 (2.79)	6.33 (2.61)	6.00 (2.54)	4.33 (2.19)	4.66 (2.27)	3.00 (1.87)	3.0 (1.87)	1.33 (1.35)	235.26
Bt 10 <sup>6</sup> spore count/ml 750 gm/ha	47.20 (6.90)	41.10 (6.44)	24.00 (4.94)	21.33 (4.67)	18.00 (4.30)	14.33 (3.85)	16.00 (4.06)	12.00 (3.53)	11.00 (3.39)	10.33 (3.29)	8.33 (2.97)	6.00 (2.54)	5.0 (2.34)	3.33 (1.95)	224.81
Control	46.30 (6.84)	42.30 (6.54)	52.00 (7.24)	43.33 (6.62)	63.00 (7.96)	49.00 (7.03)	72.33 (8.53)	55.33 (7.47)	55.00 (7.44)	48.00 (6.96)	47.00 (6.89)	42.00 (6.51)	29.33 (5.46)	27.33 (5.27)	209.47
SEM +	5.357	5.365	3.047	2.372	1.921	1.587	1.936	1.855	1.623	1.343	2.018	3.460	1.240	1.089	
C.D. (1 %)	NS	NS	13.165	10.248	8.30	6.857	8.368	8.018	7.013	5.803	8.993	14.95	5.361	4.709	
C.D. (5 %)	NS	NS	9.388	7.308	5.919	4.889	5.967	5.718	5.001	4.138	6.413	10.66	3.823	3.358	

Figures in the parenthesis are transformed value =  $\sqrt{X + 0.5}$

Table 2. Efficacy of different treatments against *Myzus persicae* (Ia) and *Aphis gossypii* (Ib) on potato during rabi season of 1998-99

Treatments	Pre-treatment population		Ist spraying		II nd spraying		III rd spraying		Tuber yield (q/ha)				
	Ia	Ib	7 DAP	15 DAP	7 DAP	15 DAP	7 DAP	15 DAP					
Phorate 10 G 1.5 kg a.i./ha	70.33 (8.41)	51.00 (71.7)	13.00 (3.67)	11.33 (3.43)	8.00 (2.91)	7.33 (2.79)	6.33 (2.61)	5.00 (2.34)	18.33 (4.45)	17.33 (4.22)	232.66		
Azadirachtin 1500 ppm 1.8 lit./ha	64.33 (8.05)	55.33 (7.47)	28.00 (5.33)	24.66 (5.01)	21.00 (4.63)	19.33 (4.45)	18.66 (4.37)	22.66 (4.81)	16.33 (4.10)	11.33 (4.43)	226.98		
Lindane 6.5 WP3 kg/ha	74.00 (8.63)	48.33 (6.98)	27.66 (5.30)	22.33 (4.77)	20.33 (4.56)	19.00 (4.41)	16.66 (4.14)	17.33 (4.45)	14.33 (3.85)	11.33 (4.43)	234.62		
Chlorpyrifos 20 EC 2.4 lit./ha	67.00 (8.21)	53.00 (7.31)	19.33 (4.45)	13.00 (3.67)	10.33 (3.29)	11.33 (3.43)	7.00 (2.73)	4.33 (2.19)	6.33 (2.61)	3.33 (1.95)	241.27		
Acephate 75 SP600 ml./ha	76.0 (8.74)	45.0 (6.74)	15.0 (3.93)	11.00 (3.39)	9.33 (3.13)	10.33 (3.29)	6.00 (2.54)	4.33 (2.19)	5.33 (2.41)	3.00 (1.87)	239.48		
Bt 10 <sup>6</sup> spore count/ml 750 gm/ha	71.33 (8.47)	49.33 (7.05)	26.33 (5.17)	20.33 (4.56)	19.33 (4.45)	18.00 (4.30)	17.33 (4.22)	15.00 (3.93)	11.33 (3.43)	8.33 (2.97)	229.75		
Control	68.00 (8.27)	54.00 (7.38)	77.00 (8.80)	81.00 (9.02)	67.33 (8.23)	82.33 (9.10)	68.33 (8.29)	73.00 (8.57)	65.33 (8.11)	53.0 (7.31)	43.00 (6.59)	213.16	
SEM +	3.269	3.553	3.461	3.144	3.590	2.129	1.757	2.487	2.091	2.374	1.729	1.861	
C.D. (1 %)	NS	NS	14.955	13.584	15.511	9.200	7.594	13.069	10.747	9.035	10.258	7.470	8.128
C.D. (5 %)	NS	NS	10.664	9.687	11.061	6.560	5.415	7.664	6.443	7.315	5.327	5.796	

Figures in the parenthesis are transformed value =  $\sqrt{X + 0.5}$

different treatments have been shown in Tables 1 and 2. It is evident from the results of both the years that all the treatments, viz. phorate 10 G @ 1.5 kg a.i./ha ; azadirachtin 1500 ppm @ 1.8 lit./ha; lindane 6.5 WP @ 3.5 kg/ha; chlorpyrifos 20 EC @ 2.4 lit./ha; acephate 75 SP @ 600 ml./ha and *Bacillus thuringiensis* (Bt) 10<sup>4</sup> spore count /ml. @ 750 gm/ha were significantly superior against both the species of aphids, i.e. *Myzus persicae* (Sulzer) and *Aphis gossypii* (Glover) over untreated control. However, phorate 10 G @ 1.5 kg a.i./ha was most effective insecticide for controlling both the aphids, followed by acephate, chlorpyrifos, *Bacillus thuringiensis* (Bt), lindane and azadirachtin, respectively, during first and second spraying i.e. upto 45 days. But after third spraying, acephate 75 SP @ 600 ml./ha was found most effective insecticide in reducing the population of both species of aphids followed by chlorpyrifos, *Bacillus thuringiensis* (Bt), lindane, azadirachtin and phorate 10 G respectively. Single application of phorate 10 G was at par with two applications of acephate and chlorpyrifos against both the species of potato aphids. Phorate 10 G @ 1.5 kg a.i./ha was found to be the most effective insecticide against aphids if applied at earthing (5). Single application of foliar or granular systemic insecticide (phorate 10 G) did not protect the crop from the attack of these aphids for the entire crop

season as was earlier reported by Misra and Agarwal (4). Maximum tuber yield (238.19 q/ha and 241.27 q/ha during 1997-98 and 1998-99, respectively) was recorded in chlorpyrifos treated plots followed by those treated with acephate, lindane, phorate 10 G, *Bacillus thuringiensis* (Bt) and azadirachtin, respectively. The minimum tuber yield (209.47 q/ha and 213.16 q/ha during 1997-98 and 1998-99) was recorded from untreated (control) plots.

#### ACKNOWLEDGEMENT

The authors are grateful to Dr. S.M. Paul Khurana, Director, CPRI, Shimla for his valuable suggestion during writing of this manuscript. The results given here are compilation of data collected under AICPIP, BCKV, funded by I.C.A.R. for the period mentioned.

#### LITERATURE CITED

1. Khurana, S.M. Paul. 1999. *Potato viruses and viral diseases*. CPRI, Shimla. Tech. Bull. No 35. 94 pp.
2. Konar, A. 1998. *J. Indian Potato Assoc.* 25: 76-78.
3. Konar, A. 2001. *J. Indian Potato Assoc.* 28: 123-24.
4. Misra, S.S. and H.O. Agrawal. 1990. *Indian J. Plant Prot.* 18(1): 11-16.
5. Trivedi, T.P. and S.S. Misra. 1989. *Indian J. Plant Prot.* 17: 109-11.

---

MS Received: 08.07.2002

## WART DISEASE OF POTATO IN INDIA - PRESENT SCENARIO

P.H. Singh and I.D. Garg<sup>1</sup>

Potato wart, caused by a fungus, *Synchytrium endobioticum* (Schilb) Perc, a dreaded disease of the crop was first reported in 1896 from Trentachen in Hungary (1,6), now a part of Czechoslovakia. The disease is known to occur in central and western Germany, Czechoslovakia, Scandinavia, British Isles; to a lesser extent in Holland, Belgium, Finland, France, northern Italy and in few pockets of South Africa, Central Andes and some mining districts of USA. Isolated outbreaks were reported from Canada, Portugal, Algeria and New Zealand (2,4,6).

In India, potato wart was introduced in 1953 in Darjeeling hills of West Bengal (3,5). Due to this an internal quarantine regulation act was imposed in 1959 and Darjeeling hills lost its importance as seed producing area (5). The disease is both soil and tuber borne and the pathogen can survive in the soil for 20-25 years or more, even if the land is kept fallow (7). The disease renders potatoes unfit for seed. Badly infected tubers rot in the field causing considerable losses and release numerous resting spores. The present paper reports the latest status of wart disease in Darjeeling hills, based on surveys conducted in 2000 and 2002.

In May 2000, 15 localities of Sukhiapokhri Development Block and 23 of Bijanbari

Development Block were surveyed by the Department of Agriculture, Govt. of West Bengal, Directorate of Plant Protection, Quarantine and Storage, Govt. of India and Central Potato Research Institute, Shimla. Altogether, 540 plants from 134 terraces in Sukhiapokhri Development Block and 454 plants from 190 terraces in Bijanbari Development Block were uprooted at crop maturity stage and examined. Wart was detected on only one tuber of Darjeeling Red Round (DRR) at Rajahatta village of Sukhiapokhri block whereas 8 villages, viz. Namla, Sangbogaon, Rimbick forest, Manaydara, Palmazoa, Dhotrey, Srikhola and Musakherka of Bijanbari block showed light to heavy wart incidence. Disease incidence was 60% at Musakherka, upto 100% at Rimbick forest and Palmazoa, 66.5% at Manaydara, 50% at Namla, 45% at Srikhola, 40% at Dhotrey and 25% at Sangbogaon (Table 1). Varieties under cultivation were B-2, Kufri Jyoti, Pimpernel, Bhanjang White Long, Sangdorje and DRR (on small scale or as mixture). Disease was observed only in DRR and B-2 (unreleased clone of potato probably from Nepal and Bhutan) (8,10).

In June, 2002, survey was conducted jointly by Department of Agriculture, Govt. of West Bengal and Directorate of Plant Protection,

---

<sup>1</sup>Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh)

Table 1. Results of joint wart survey, 2000

<i>Development Block/ Localities surveyed</i>	<i>Varieties under cultivation</i>	<i>% fields infested</i>	<i>% Plants infected</i>
<b>Bijanbari block</b>			
Bloom field	Pimp, KJ, B-2	0.0	A
Rajbari	Pimp	0.0	A
Gairigaon	B-2, Pimp	0.0	A
Namla	B-2, DRR	40.0	50.0
Lingsaybong	DRR, B-2	0.0	A
Sangbogaon	B-2, DRR	33.3	25.0
Rimbick Forest	B-2, DRR, Pimp	25.0	100.0
Manaydara	B-2, DRR	100.0	65.5
Rimbick	B-2, DRR	0.0	A
Dilpa	B-2	0.0	A
Palmazoa	B-2, DRR, Pimp	37.5	100.0
Dhotrey	B-2	66.7	40.0
Majua	B-2	0.0	A
Barahatta	B-2, SD, Pimp	0.0	A
Bansbotay	B-2, Pimp	0.0	A
Srikhola	B-2, DRR, KJ, Pimp	44.0	45.0
Musakherka	DRR, Pimp	60.0	60.0
Daragaon	Pimp, B-2	0.0	A
Shepi	B-2, Pimp	0.0	A
Rajabir	B-2, DRR	0.0	A
Jaubari	B-2	0.0	A
Newargaon	B-2, KJ, Pimp	0.0	A
Phedikhola	B-2, KJ	0.0	A
<b>Sukhiapokhri Block</b>			
Rajahatta	B-2, DRR as mix	5.0	P
Magargaon	B-2, DRR as mix	0.0	A
Gairigaon	B-2, KJ	0.0	A
Jungle Busty	B-2, Pimp, BWL	0.0	A
Rangbul	KJ, Pimp, BWL	0.0	A
Upper Sonada	B-2, KJ	0.0	A
Lower Sonada	KJ, B-2	0.0	A
Ghoom Bhanjang	B-2, DRR	0.0	A
Pubong Fatak	BWL	0.0	A
Chataidhura	-	-	-
Lepcha jagat	BWL, KJ, B-2	0.0	A
Majhidhura	B-2, Pimp	0.0	A
Simana	B-2, DRR as mix	0.0	A
Rangbhang	B-2	0.0	A
Batasia	B-2, KJ	0.0	A

A=Wart absent; P = Wart present; - = No potato crop; Pimp=Pimpernel; KJ=Kufri Jyoti; DRR=Darjeeling Red Round; SD=Sangdorje; BWL=Bhanjang White Long.

Quarantine and Storage, Govt. of India. In all, 11 localities of Sukhiapokhri Development Block and 23 localities of Binajbari block were surveyed (Table 2). Altogether 442 plants from 203 terraces in Sukhiapokhri Development Block and 868 plants from 361 terraces in Bijanbari Development Block were uprooted

at crop maturity stage and examined. Wart infection from 2.9 to 96.5% was recorded in 13 out of 23 localities of Bijanbari block, whereas the disease was not noticed in any locality of Sukhiapokhri block. Percentage plants infected were 96.5 at Dhotrey, 90.0 at Majua, 73.5 at Palmazoa, 40.0 at Rimbick forest, 31.0 at

Table 2. Results of joint wart survey, 2002

<i>Development Block/ Localities surveyed</i>	<i>Varieties under cultivation</i>	<i>% fields infested</i>	<i>% Plants infested</i>
<b>Bijanbari block</b>			
Majua	B-2	100.0	90.0
Dhotrey	DRR, B-2	100.0	96.5
Palmazoa	DRR, B-2	77.8	73.5
Lingsaybong	DRR, B-2	60.0	23.1
Gairigaon	B-2	100.0	20.0
Namla	B-2	100.0	23.5
Sangbogaon	B-2	0.0	A
Manaydara	B-2	100.0	31.0
Rimbick Forest	B-2	100.0	40.0
Rimbick	B-2	100.0	27.6
Dilpa	B-2	6.7	2.9
Jaubari	B-2, KJ	28.6	13.3
Barahatta	B-2, DRR, KJ	20.0	8.7
Fedikhola	B-2, KJ	0.0	A
Bansbotay	B-2, KJ	0.0	A
Shepi	B-2, KJ, Pimp	62.5	11.3
Srikhola	B-2, Pimp, KJ	0.0	A
Ramam	B-2, Pimp, KJ	0.0	A
Daragaon	B-2, Pimp, KJ	0.0	A
Newargaon	B-2, Pimp	0.0	A
Rajabir	B-2, DRR	0.0	A
Rajbari	B-2, Pimp	0.0	A
Bloomfield	Pimp, KJ	0.0	A
<b>Sukhiapokhri Block</b>			
Jungle Busty	Pimp, KJ, B-2	0.0	A
Upper Sonada	KJ, Pimp, B-2	0.0	A
Lower Sonada	KJ, Pimp, Voran, B-2	0.0	A
Rangbul/Bangaladara	KJ, Pimp, B-2	0.0	A
Ghoom Bhanjang	Pimp, KJ	0.0	A
Pubong Fatak	-	-	-
Chataidhura	-	-	-
Majhidhura	B-2	0.0	A
Simana	B-2	0.0	A
Upper Tarsing	B-2	0.0	A
Batasia	B-2, KJ	0.0	A

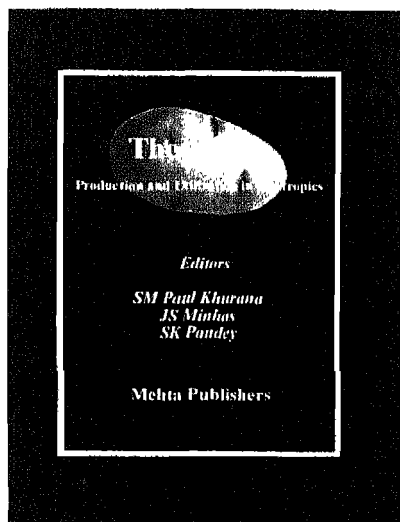
A=Wart absent; - = No potato crop; Pimp=Pimpernel; KJ=Kufri Jyoti, DRR=Darjeeling Red Round

Manaydara, 27.6 at Rimbick, 23.5 at Namla, 23.1 at Lingsaybong, 20.0 at Gairigaon and 13.3 at Jaubari. Three localities, *viz.* Dilpa, Barahatta and Shepi had very light infection (2.9, 8.7 and 11.3%, respectively, Table 2). Varieties under cultivation in Sukhiapokhri block were Kufri Jyoti, Pimpernel and B-2, whereas in Bijanbari block, B-2 was the predominant cultivar followed by Darjeeling Red Round, Kufri Jyoti and Pimpernel.

It was alarming to note that farmers in Bijanbari block and to some extent in Sukhiapokhri block have again switched over to the cultivation of wart susceptible varieties like DRR and unreleased clone B-2. Srivastava *et al.* (11,12) have reported wart incidence in about 42% of the fields inspected in 1962 survey whereas, Singh (9) reported the presence of wart disease in only three small pockets of Bijanbari block in 1995 survey. This



## BOOK REVIEW



**The Potato: Production and Utilization in Sub Tropics**, Eds., Drs. SM Paul Khurana, JS Minhas, SK Pandey; 2003, Mehta Publishers, A-16 (East) Naraina II, New Delhi 110 028, India, x+446, ISBN: 81-88039-19-7, Price: Rs.595/-

The Potato (*Solanum tuberosum* sub sp.) was introduced to this sub-continent nearly 400 years ago. It quickly spread from hills to the plains and now potato is grown in almost all parts of the country. Today India produces nearly 25 million tonnes of potato from 1.3 million hectares, and has emerged as the third largest potato producer in the world. Potato production in India is projected to double by 2020. During the later part of 20th century, agriculture became a predominantly technological vocation and the boom in potato cultivation in this period primarily came as a result of scientific crop husbandary and innovative and hard working farming community of India. Therefore, the success of potato in India is a reflection of the indigenous technological advances and competence available in this field. Technology is information driven; and the quality and volume of information presented in this book

shows credibility of the scientists in the field of potato research.

The book is organized under 43 chapters contributed by 65 authors. The chapters are arranged in a well thought out plan starting with fascinating journey of potato, the systematics, input management, production constraints, emerging threats, seed certification, marketing, genetic modification, etc. Despite the fact that some of the research information presented in these chapters is from secondary/tertiary sources, style of their presentation reflects masterly and experienced treatment by the authors/editors and a textbook style has been maintained throughout. The chapters covered in this book provide an outline of contemporary research themes not only in the field of agriculture but also in the area of botany in general. Therefore, it is expected to serve as an important reference book not only for the students of agriculture but even for those of botany. In fact there is something for all kinds of readers in this 'all-potato' book.

The editors have done a commendable job in maintaining uniform presentation style and keeping it nearly error-proof. Yet a few typographical mistakes, particularly in the chapter on morphology and some botanical terminologies have crept in. The precise subject index included would be of great help to the readers. A list of complete address of all the 65 contributors is also appropriately placed with their e-mail addresses for any interaction between the readers and authors. It is hoped that this book will serve as an excellent textbook for the students and as a reference book for the teachers, planners and policy makers.

K.L. Chadha  
(K.L. Chadha)

## ACKNOWLEDGEMENT TO THE REFEREES (2003)

Following is the list of learned referees who helped the Editorial Board by way of giving valuable advice about suitability of the manuscripts for publication in the Journal.

Arora, RP, New Delhi	Lal, SS, Shimla
Ahlawat, YS, New Delhi	Lal, Laxman, Lucknow
Basu, PS, Kanpur	Mishra, SS, Shimla
Bhargava, R, Bikaner	Manival, P, Shimla
Chandel, RS, Shimla	Nath, N, Pantnagar
Chakraborti, SK, Shimla	Rai, RP, Patna
Ezekiel, R, Shimla	Sharma, RC, Shimla
Govindakrishnan, PM, Shimla	Sukumaran, NP, Shimla
Garg, ID, Shimla	Singh, JP, Jalandhar
Gaur, PC, Panchkula	Shyam, Murari, Bhopal
Gogoi, AK, Jabalpur	Singh, Manjit, Jalandhar
Gopal, Jai, Shimla	Singh, BP, Meerut
Kushwah, VS, Gwalior	Singh, Sarjeet, Shimla
Kadam, SS, Rahuri	Singh, DB, Meerut
Kapoor, HC, New Delhi	Sharma, SS, Shimla
Kadian, MS, New Delhi	Sud, KC, Shimla
Kaushik, BD, New Delhi	Singh, VP, Jabalpur
Kaushik, SK, Shimla	Thakur, KC, Shimla
Kashyap, RK, Hissar	Trehan, SP, Jalandhar
Kaul, HN, Jalandhar	Tyagi, PD, New Delhi

## INDIAN POTATO ASSOCIATION, SHIMLA (HP)

### HONARARY FELLOWS

Bhargava, SN*	Pal, BP*
Chadha, KL	Pushkarnath*
Dhillon, IS	Ramanujam, S*
Grewal, JS	Shekhawat, GS
Gupta, PK	Sikka, LC
Horvath, J (Hungary)	Singh, Kirti
Hawkes, JG (UK)*	Singh, RP (Canada)
Kishore, Hari*	Singh, Mukhtar*
Nayar, NM	Upadhyaya, MD (Canada)
Nagaich, BB	

### DISTINGUISHED FELLOWS

Bhattacharyya, SK (1994)	Sharma, RC (1995)
Barua, BL (1999)	Sharma, UC (1996)
Chandla, VK (2002)	Shekhawat, GS (1994)
Dubey, KC (1994)	Shivalli, SS (1994)
Gaur, PC (1996)	Singh, AK (1997)
Khurana, SM Paul (1994)	Singh, BP (2001)
Kang, GS (1998)	Singh, Jagpal* (1999)
Lal, SS (2000)	Singh, RA (1994)
Nankar, JT (1994)	Singh, RP (1994)
Nayar, NM (1994)	Srivastava, SNS (1997)
Pandey, SK (2001)	Sud, KC (2002)
Pandita, ML (1994)	Sukumaran, NP (1998)
Prasad, KSK (2000)	Verma, KD (1995)
Rana, MS (1994)	Verma, SC (1994)
Sharma, KP* (1994)	Verma, SM (1999)

\* Since deceased

*Hurry to avail the 2-in-1 offer*

*Potato, Global Research & Development*

*- 2 volumes at 50% discount*

**NOT ONLY FOR LIBRARIES BUT EVEN FOR INDIVIDUALS\***

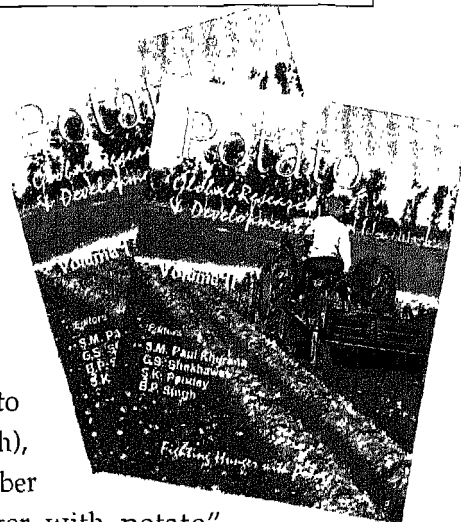
Hard back cover

Total pages 1304

Publication Price Rs. 3,000/-

Special offer price Rs. 1,500/- +

Packing & postage charges



## About the book

The Indian Potato Association (IPA) and the Central Potato Research Institute (Indian Council of Agricultural Research), Shimla organized a Global Conference on potato during December 6-11, 1999 under a thematic platform of "Fighting hunger with potato".

Subsequently, the IPA compiled the proceedings of this conference and brought out two volumes entitled 'Potato, Global Research and Development'. The first volume (733 pp) contains a total of 102 articles covering disciplines like Genetic Research, Crop Improvement, Application of Biotechnology, Management of late blight and other diseases/pests of potato and their eco-friendly management and non-conventional methods of Seed Production. This volume also includes key note addresses from leading agricultural scientists/experts/policy makers, viz. Dr. M.S. Swaminathan, Chairman Swaminathan Foundation and former DG, ICAR; Dr. Hubert Zandstra, DG, International Potato Center, Lima, Peru; Dr. R.S. Paroda, former DG, ICAR, besides the thought provoking inaugural address from Nitish Kumar, former Minister of Agriculture and Co-operation, Government of India. The second volume (571 pp) deals with disciplines like Crop Production, Cropping Systems and Crop Modelling and Storage, Processing and Marketing in 95 articles.

***Hurry up limited copies available***

### CONTACT:

The Secretary  
Indian Potato Association  
Central Potato Research Institute  
Shimla-171 001, HP  
Fax No. : +91(0177) 2624460

or

M/s Malhotra Publishing House  
B-6 DSIDC Complex  
Kirti Nagar, New Delhi-110 015  
Fax No. +91 (011) 25934597

\* In special cases of demand, we may offer one volume each for Rs. 1,000/- only.

## SUGGESTIONS TO THE CONTRIBUTORS\*

1. The Journal of the Indian Potato Association publishes reviews (by invitation), full length papers and short notes. Manuscripts should be sent to the Editor-in-Chief, Indian Potato Association, Central Potato Research Institute, Shimla-170 001, India. At least one of the authors should be a member of the Association.
2. All manuscripts submitted for publication will guide the Editor as to the acceptability and any necessary modification required. A paper already published or under consideration for publication, wholly or substantially elsewhere, cannot be accepted.
3. Manuscripts must be in English, type-written double spaced with at least 4 cm margin, on one side of good quality paper and should be submitted in duplicate along with the floppy version in MS word\*. A short running title be provided on a separate sheet in addition to the full title of the paper. Full names(s) and address(es) should be included on the first page. The name of author, with complete address, responsible for correcting the proof should be clearly indicated on a separate sheet.
4. Full length paper should consist of Abstract, Introduction, Materials and Methods, Results and Discussion, Acknowledgement and Literature Cited.
5. A paper not exceeding 4-5 pages in length may be submitted as a 'Short Note' in which the Abstract is omitted. It is not necessary in the case of short notes to divide the text into sections except for Acknowledgement and Literature cited.
6. Due to the high cost of production, only essential information should be included in the paper. Numerical results should be presented either as tables or diagrams. Only essential tables, diagrams and 12 typed pages including tables, figures, references and abstract will normally be accepted. Manuscripts must conform to the typographic usage of the Journal in all respects. Manuscripts requiring more than minor corrections will be returned to the authors for modification.
7. Abstracts not exceeding 150 words will be published in English.
8. Diagrams should be drawn with black India ink either on pale blue lined graph paper, transparent paper or white card sheets about twice the size of the finished block. Shading must be indicated by lines or dots. All lettering should be inserted in pencil outside the diagrams. Photographs must be black and white with adequate contrast printed on white, glossy paper to allow for 1/4 to 1/2 reduction. Each table, diagram and photograph must have a caption. Diagrams and photographs are taken together as figures and are numbered serially as Fig. 1 and Fig. 2 etc. Tables and figures with their captions should be submitted separately from the text in which only their eventual position should be indicated.
9. Literature cited must be listed alphabetically at the end of the article, according to the Harvard System as follows : Serial number, name and initial(s) of the author, year of publication (further distinguished by the addition of a small a, b, c, to the date where more than one paper published by the same author(s) in the same year is cited), full title of paper (to be omitted in case of short notes), abbreviated title of periodical as used in 'Biological Abstracts', volume number in arabic numerals and first and last page number of the article.

The Style for citation of journals (1), books (2), and multi authored books (3) is given below:

1. Khurana, S.M. Paul, G.S. Shekhawat and B.B. Nagaich. 1983. Light microscopy of potato plants for detection of three mycoplasmal diseases. *J. Indian Potato Assoc.* 10: 60-63.
2. Dixon, M. and E.C. Webb. 1964. *Enzymes*, 2nd Edn. pp. 562-64. Longmans Green, London.
3. Burton, W.C. 1963. In : *The growth of the potato* (J.D. Ivins and E.L. Milthorpe, Eds.), pp. 17-40. Butterwoths, London.

In the text references should be indicated by giving the serial number. In references with more than two authors, quoted in the text, the first name is followed by '*et al*'. References to publications other than periodicals, e.g. books, should include the name of the publishers, place of publication. Authors may receive the galley proofs for correction. Twenty five reprints are supplied free to the author(s).

---

\* Important for the contributors to note.