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INFLUENCE OF METEOROLOGICAL FACTORS ON POTATO LATE BLIGHT DEVELOPMENT IN NORTH-WESTERN PLAINS OF INDIA*

K.K. Sharma¹

ABSTRACT : The analysis of 7 years meteorological data on blight development in NW Plains of India revealed that late blight severity was positively correlated with maximum relative humidity ($r=0.467$), rain, dew and cloudy days and negatively with minimum temperatures ($r=0.630^*$). Late blight occurrence was normally associated with drop in air temperatures ($<26.0^{\circ}\text{C}$) and rise in the morning relative humidity ($\text{RH}>85\%$). Blight could appear in absence of rains also. The multiple regression analysis revealed that maximum temperatures and minimum (afternoon) RH had high influence on disease severity.

INTRODUCTION

Late blight (*Phytophthora infestans* (Mont.) de Bary) is one of the most devastating diseases of potato throughout the world. Its appearance and development in relation to weather parameters has been reported by several workers (3, 5, 8). In India, though disease prediction system has been worked out for hills (4), little work has been done on this aspect for plains. The present studies were, therefore, conducted to find out the influence of important weather parameters on late blight development in North-western plains for working out relationship between weather and disease development.

MATERIALS AND METHODS

Field experiments were conducted at Central Potato Research Station, Jalandhar farm, for 7 years (1986 to 1992). Apparently healthy tubers of cv. Kufri Chandramukhi were planted in experimental nursery during 2nd-3rd week of October. The nursery was observed daily for blight appearance. The growers fields in the vicinity of the farm were also surveyed for blight occurrence.

Late blight was recorded on BMS scale (1) till crop maturity. Meteorological data on

minimum and maximum temperature, relative humidity and dew were collected for November to January from the Meteorological observatory. The other parameters measured were total rainfall and number of cloudy days over the week. Correlation analysis of individual meteorological factors with disease severity and also stepwise multiple regression analysis of 7 years pooled data were performed. For correlation and regression analysis average temperatures (Av. of min. and max.) and av. relative humidity were also considered. Significance of coefficient of determination (R^2) was worked out at 5 per cent level of probability.

RESULTS AND DISCUSSION

Seven years data on weather parameters and blight severity was pooled and regression and correlation analyses performed to study the influence of weather on disease progress.

Late blight normally appeared in the month of December. However, disease once appeared early in November (1992-93) and once quite late in January (1990-91). Late blight onset was associated with the drop in maximum air temperatures ($<26^{\circ}\text{C}$) and rise in maximum (morning) relative humidity ($>85\%$) and partly

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¹Central Potato Research Station, Jalandhar - 144003 (Pb.)

Table 1. Correlation matrix of late blight severities with meteorological factors

Y	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	Y
(X ₁)	1.000	-	-	-	-	-	-	-	-	-
(X ₂)	.691	1.000	-	-	-	-	-	-	-	-
(X ₃)	.884	.94	1.000	-	-	-	-	-	-	-
(X ₄)	-.117	-.759	-.540	1.000	-	-	-	-	-	-
(X ₅)	-.594	-.914	-.850	.714	1.000	-	-	-	-	-
(X ₆)	-.263	-.851	-.664	.979	.841	1.000	-	-	-	-
(X ₇)	-.172	-.527	-.416	.634	.384	.600	1.000	-	-	-
(X ₈)	-.759	-.803	-.851	.498	.816	.621	.547	1.00	-	-
(X ₉)	-0.177	-.790	-.587	.869	.751	.889	.440	.412	1.000	-
(Y)	-.630	-.499	-.599	-.030	.467	.111	.056	.450	.105	1.000

Critical Value (p<.05) = .629; Critical Value (p<.01) = .764

X₁ : Min. Temperature; X₂ : Max. Temperature; X₃ : Av. Temperature; X₄ : Min. RH; X₅ : Max. RH;
X₆ : Av. RH; X₇ : Rain (mm); X₈ : Dew (mm); X₉ : No. of cloudy days and Y : Predicted disease severity.

cloudy days. The disease did develop in absence of rains as dew remained through out the season in varying amounts providing free moisture for sporulation and infection. Correlation of the meteorological variables with disease (Table 1) revealed that the disease severity (Y) had a positive correlation with maximum (morning) relative humidity ($r_{YX_5}=+0.467$), rainfall, dew and cloudy days and had significant negative correlation with minimum temperature ($r_{YX_1}=-0.630^*$). All the weather parameters contributed towards disease development, though to a varying extent.

Rotem *et al* (6) had also reported that the effects of biological parameters on the pathogen are relative rather than absolute and the contribution of each being conditioned by the state of other.

Stepwise multiple regression analyses were performed to find out the subset of environmental variables that predicted disease severity satisfactorily. The blight severity prediction equations with all the important possible combinations of meteorological variables alongwith value of coefficient of determination (R²) are presented in table 2. It

Table 2: Values of coefficient of determination (R²) and partial regression co-efficient for different functional equations

	R ²
$Y=731.56+(-19.35X_2) +(-5.63X_4^*)$	0.64*
$Y =-.609.43+(-19.03X_3^*)+(-4.61X_6)$	0.50
$Y=1259.48+(19.54X_1)+(38.27X_2^*)+(-10.38X_4^*)$	0.74*
$Y=1954.91(14.40X_1)+(-39.69X_2)+(-16.88X_6)$	0.66
$Y=1099.70+(19.23X_1)+(-36.70X_2)+(-10.34X_4^*)+(1.44X_5)$	0.74
$Y=1753.84+(41.48X_1^*)+(-63.71X_2^*)+(-11.57X_4^*)+(1.43X_5)+(-74.81X_9)$	0.88*
$Y=1608.75+(38.52X_1)+(-65.54X_2^*)+(-10.55X_4^{**})+(5.85X_5)+(-821.12X_8)+(-94.27X_9)$	0.91

*Significant at P < 0.05; **Significant at P<0.01

X₁ : Min Temperature; X₂ : Max. Temperature; X₃ : Av. Temperature; X₄ : Min. RH;
X₅ : Max. RH; X₆ : Av. RH; X₇ : Rain; X₈ : Dew; X₉ : No. of cloudy days and Y : Predicted disease severity.

is evident from the equation that combined effect of even only two variables could explain more than 50 per cent variation in disease severity. The analysis of multiple regression equations showed that among the various factors which could influence the disease severity, maximum temperature (X_2) and minimum relative humidity (X_4) had very high influence on the disease progress. However, the prediction equation with six variables (max. and min. temperatures, max. and min RH, dew and cloudy days) gave the best fit as it could explain maximum variation (91%) in disease development. This suggests that though blight development depends on many meteorological factors, the influence of even two to three factors could be taken into consideration for predictive purposes as most of the factors have been shown to be interrelated. In another study (2) though RH > 80 and 90 per cent and cloudy days revealed significant correlation with late blight progress, temperature hrs > 20°C were consistently correlated negatively with the disease. The two meteorological variables temperature and rainfall accounted for 56% of the variation of epidemic progress (7, 8).

It could be concluded from the present studies that late blight development in the region was positively correlated with maximum RH, rainfall, dew and cloudy days and negatively with minimum temperature. Drop in air temperatures (< 26.0°C) and rise in maximum relative humidity (> 85%) favoured blight occurrence. A sharp fall in minimum temperature was responsible for delaying blight outbreaks.

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PROCESSING QUALITY OF LOW AND HIGH SUGAR POTATO CULTIVARS AS INFLUENCED BY STORAGE TEMPERATURES*

R.S. Marwaha¹

ABSTRACT : Five low sugar exotic cultures and three high sugar Indian varieties grown under short day conditions were evaluated for chip colour and processing related characteristics before and after storage in a refrigerated store (3-4°C, RH 90-95%) for 28 days and in a high temperature farm store (Max temp 24-38°C, Min temp 16-26°C RH 30-75%) up to 75 days. Before storage, fresh fried chips prepared from exotic cultivars were far superior in colour in comparison to Indian varieties. The dry matter content of exotic cultivars was also higher than the Indian cultivars, while free amino acids and total phenols were significantly lower in the exotic cultivars at the time of storage. However, chip colour score and the contents of reducing sugars, sucrose and free amino acids increased in both the exotic and Indian cultivars after 28 days of refrigerated storage.

High temperature storage up to 75 days was found to be suitable for producing chips of acceptable light colour from all the exotic cultivars, while only one Indian variety, Kufri Lauvkar, performed well under these conditions. The average contents of reducing sugars, free amino acids and total phenols dropped by approx. 50%, 8% and 25% respectively, while that of sucrose increased by 13% after 75 days of farm storage.

INTRODUCTION

In India, more than three-quarters of the area under cultivation for producing potatoes is in the North-western plains, where crop is harvested at the beginning of summer in February-March. This is followed by a period of hot and dry weather till June-July. In this region, potatoes cannot be normally stored in good condition without refrigerated store for a long time. Low temperature storage, although provides the best conditions for long term storage of potatoes by reducing respiration and the need for sprout inhibitors, but is not suitable for processing, as it induces the accumulation of high levels of reducing sugars in a short time (3, 17). Therefore, potatoes destined for chipping must be stored at a comparatively high temperature. However, high temperature storage has its own limitations as it causes shrinkage, rottage, and sprouting resulting in high total weight losses (9, 20). A weight loss in excess of 10% leads to shrivelling of tubers, poses difficulty in peeling and reduces the marketability of potatoes (9).

Potato processing industries require potatoes round the year to run the plant and for this they have to depend upon the stored potatoes. Although, there are some reports on the processing behaviour of cold stored potatoes of popularly used Indian varieties, Kufri Jyoti and Kufri Lauvkar (1, 12); but the information on the performance of recently introduced exotic cultivars after storage under different conditions is lacking. Particularly, there is no report on the effect of high temperature storage on the chipping quality of these popular processing potato cultivars. Hence, there is an urgent need to determine the performance of these cultivars under different storage temperatures and to identify ideal storage conditions for the regular supply of desired raw material to the industries. Keeping these specific objectives in view, the present investigation was carried out. Besides the effects of storage temperatures on some associated processing characteristics of tubers such as sugars, free amino acids and phenols which influence chipping quality were also examined.

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MATERIALS AND METHODS

Five exotic cultivars, viz. Atlantic, and Frito Lay (FL) 1291, 1533, 1584 and 1625 and three Indian varieties namely Kufri Chandramukhi, Kufri Jyoti and Kufri Lauvkar were grown in sandy loam soil at the Central Potato Research Station, Jalandhar during October, 1994 to January, 1995 following recommended cultural practices and the crop was harvested at full maturity.

Well cured uniform size tubers (70-80g) of each cultivar were stored in the refrigerated store (3-4°C, RH 90-95%) for 28 days and in the farm store at ambient temperatures (Max temp 24-38°C, Min temp 16-26°C, RH 30-75%) for 75 days beginning first of March. Tubers were taken out from the cold store at weekly interval up to 4 weeks, while two samplings were made from the tubers stored in the farm store, 45 days and 75 days after storage. Fresh fried chips were prepared on each date of sampling and the chemical analysis was done simultaneously. For preparation of chips, 8-10 tubers were hand peeled and bisected perpendicularly from stem to bud end. The exposed centre of each tuber was used to collect tissue for chip colour and chemical analysis. One half of the tuber was used to collect 4 chips approximately of 1.4 mm thickness, while the other half was finely diced, mixed thoroughly and used for different chemical estimations. Chip slices were rinsed in cold water to remove free starch, air dried and immediately fried in the groundnut oil at 180°C for 2-3 min. The fresh fried chips were subjectively scored for colour and assigned a value according to the 1-10 scale (Lower number-better colour) of the PC/SFA chart (4). Chips up to score 5 were acceptable. Tubers were cut into small pieces and oven dried at 70°C to a constant weight for the determination of dry matter content. Reducing sugars were determined according to the procedure of

Nelson (11), while sucrose was determined by the method of Van Handel (18). Total phenols were determined by the method of Swain & Hillis (15) and free amino acids were determined by the method of Moore (10). Four replicates for each estimation were taken and the data were statistically analyzed.

RESULTS AND DISCUSSION

Dry matter content of exotic and Indian cultivars: Dry matter content of the exotic cultivars varied between 20.2% (FL 1625) to 23.2% (FL 1533), while the Indian cultivars showed a dry matter content from 18% (Kufri Jyoti) to 20.5% (Kufri Chandramukhi) (Table 1).

Dry matter content is one of the major factors which determines the yield and texture of the processed products and decides the suitability of a potato cultivar for processing besides other factors such as contents of sugars, phenolic compounds, shape, size and colour of tubers. Potatoes having high dry matter are considered ideal for chipping and high dry matter content has been associated with mealiness, crispness and reduced oil uptake in chips (5). At the time of storage, all the exotic cultures, viz. Atlantic, FL 1291, FL 1533,

Table 1. Dry matter content of some exotic and Indian potato cultivars used for chipping

<i>Cultivar</i>	<i>Dry matter (%)</i>
Exotic cultivars	
Atlantic	20.8
FL 1291	21.4
FL 1533	23.2
FL 1584	20.4
FL 1625	20.2
Indian varieties	
Kufri Chandramukhi	20.5
Kufri Jyoti	18.0
Kufri Lauvkar	19.2
CD (0.05)	0.6

FL 1584 and FL 1625 having dry matter content more than 20% produced light coloured chips of very superior quality. However, among Indian varieties, only Kufri Lauvkar, a medium dry matter variety produced chips of good colour, while the other two varieties produced chips which were on the border line of acceptance (Table 2).

Changes in processing quality under refrigerated storage : Changes in chip colour and some chemical constituents influencing processing were studied at an interval of one week up to 70 days of storage. However, the results are reported only up to 28 days, being

more relevant, since after this stage all the cultivars produced dark coloured unacceptable chips and became unfit for chipping.

Chip colour and sugar content of potatoes:

Before storage, fresh fried chips prepared from all the exotic cultivars were very light in colour and far superior in comparison to Indian varieties (Table 2). Among Indian varieties, chips prepared from Kufri Lauvkar were acceptable in colour, while Kufri Chandramukhi and Kufri Jyoti produced chips which were on the border line of acceptance. The reducing sugar content of the exotic cultivars was very low (64-80 mg/100 g fr wt) as compared to the Indian cultivars

Table 2. Chip colour score, reducing sugar (mg/100 g fr wt) and sucrose (mg/100 g fr wt) content of potato tubers during low temperature storage

Cultivar (C)	Constituent	Days of storage (DS)					Mean
		0	7	14	21	28	
Atlantic	CCS*	1	2	4	5	7	3.8
	RS	76	88	196	240	383	197
	S	176	209	428	671	2251	747
FL 1291	CCS	1	5	6	6	8	5.2
	RS	78	258	278	307	714	327
	S	203	304	838	1134	2301	956
FL 1533	CCS	2	2	3	4	6	3.4
	RS	80	121	187	218	388	199
	S	158	162	600	1381	2286	917
FL 1584	CCS	1	3	4	4	6	3.6
	RS	69	140	214	235	295	191
	S	189	368	675	1422	2412	1013
FL 1625	CCS	1	1	2	4	5	2.6
	RS	64	72	95	125	160	103
	S	221	403	607	1543	2389	1033
K. Chandramukhi	CCS	5	6	8	8	10	7.4
	RS	285	308	533	1370	1767	853
	S	205	323	684	831	908	590
K. Jyoti	CCS	5	6	7	7	9	6.8
	RS	203	304	617	1412	1810	869
	S	213	314	786	998	1316	725
K Lauvkar	CCS	3	4	8	8	9	6.4
	RS	158	224	346	836	990	571
	S	167	334	405	445	1110	492
Mean	CCS	2.4	3.6	5.3	5.8	7.5	
	RS	127	189	308	593	813	
	S	192	302	628	1053	1872	
CD (0.05)	DS		C	DSxC			
	RS	12	16	31			
	S	17	21	43			

CCS = Chip colour score, RS = Reducing sugar, S = Sucrose

*On a 1-10 scale of increasing dark colour, chip colour score > 5 was unacceptably dark

(158-285 mg/100 g fr wt) (Table 2). A positive correlation of reducing sugars to the chip colour was obtained by us which is also reported earlier (13).

Reducing sugar content of potato tubers is of considerable importance in relation to processing, especially for fried products. Potatoes containing high content of reducing sugars are not suitable for chips and French fries (7, 8). All the exotic cultivars contained lower amounts of reducing sugars and produced light coloured chips at the time of storage, while two Indian cultivars, Kufri Chandramukhi and Kufri Jyoti, having high content of reducing sugars produced chips which were just acceptable. There were not much differences in the range of sucrose content among exotic and Indian cultivars before storage (Table 2).

Irrespective of the cultivar, chip colour score increased significantly up to 28 days of refrigerated storage. All the Indian cultivars and FL 1291 proved unfit for chipping after 2

weeks of storage, while an exotic cultivar, FL 1625, produced nearly acceptable chips after 28 days of storage (Table 2). The content of reducing sugar increased significantly in all the cultivars, but the increase was tremendous in Indian cultivars. FL 1625 accumulated lowest content of reducing sugars during storage. Sucrose accumulation was exceptionally high in exotic cultivars in comparison to the Indian cultivars after the end of storage (Table 2). An increase in the content of reducing sugars and sucrose at 3-5°C with about 60% of sugar accumulation during the first 30 days of storage is reported by Uppal & Verma (17). Genotypic differences in sugar accumulation during low temperature storage are also reported by several other workers (2, 21).

Free amino acids and phenolic content of potatoes : Before storage, the contents of free amino acids and total phenols were significantly lower in the exotic cultivars in comparison to Indian cultivars (Table 3). Among the exotic cultivars, FL 1625 had minimum content of

Table 3. Free amino acid (mg N/100 g fr wt) and total phenol (mg/100 g fr wt) content of potato tubers during low temperature storage

Cultivar (C)	Days of storage (DS)					
	0		28		Mean	
	FAA*	TP*	FAA	TP	FAA	TP
Atlantic	65.3	43.4	72.8	27.1	69.1	35.3
FL 1291	72.0	34.0	72.3	28.6	72.2	31.3
FL 1533	72.9	42.9	65.3	28.6	69.1	35.8
FL 1584	68.5	37.3	69.6	26.4	69.1	31.9
FL 1625	60.9	34.9	74.4	28.0	67.7	31.5
K. Chandramukhi	88.3	51.1	96.3	40.0	92.3	45.6
K. Jyoti	73.1	60.7	84.4	48.8	78.8	54.8
K. Lauvkar	89.0	49.1	91.1	36.2	90.1	42.7
Mean	73.8	44.2	78.3	33.0		
CD (0.05)	Free amino acid				Total phenol	
Days of storage (DS)	1.4				1.1	
Cultivar (C)	1.8				1.4	
DSxC	3.6				2.8	

*FAA = Free amino acid, TP = Total phenol

free amino acids, while FL 1291 contained minimum total phenols.

Tubers of exotic cultivars showed no enzymic discoloration during peeling, slicing or drying operations prior to chip frying, due to low content of total phenols. However, it was observed in Kufri Jyoti which contained maximum content of total phenols (Table 3). Phenolic compounds have been associated with enzymic discoloration which occurs due to the oxidation of these compounds by polyphenoloxidase (14).

Mean free amino acid content increased significantly, while a reduction was noticed in total phenols after 4 weeks of refrigerated storage. Decrease in phenolics after 30 days of storage at 0°C is reported in some varieties by Workman *et al.* (21), while Uppal *et al.* (16) observed an increase in the content of phenolic compounds during long term storage, irrespective of the storage condition.

Changes in processing quality during high temperature storage : Changes in chip colour and some important chemical constituents of tubers influencing processing were studied after 45 and 75 days of storage under high temperature. The results after 75 days are not reported because total weight losses of the cultivars exceeded more than 10% at this stage. The peeling also became difficult due to shrinkage of potatoes and the cultivars were unfit for processing after 75 days.

Chip colour and sugar content of exotic and Indian cultivars : Light coloured and acceptable chips were prepared from all the exotic cultivars up to 75 days of storage in a farm store, while only one Indian variety, Kufri Lauvkar, performed better for chipping at this stage (Table 4). The average content of reducing sugars dropped by approx. 50%, while that of sucrose increased by 13% after 75 days of farm storage (Table 4 & 5). Mehta & Kaul (9) also reported a decrease in reducing sugar content in 3 Indian varieties after 14 weeks of high

Table 4. Chip colour score and reducing sugar content (mg/100 g fr wt) of potato tubers during high temperature storage

Cultivar (C)	Days of storage (DS)							
	0		45		75		Mean	
	CCS*	RS*	CCS	RS	CCS	RS	CCS	RS
Atlantic	1	76	1	74	2	50	1.3	67
FL 1291	1	78	1	49	1	27	1.0	51
FL 1533	2	80	1	66	1	34	1.3	60
FL 1584	1	69	1	42	1	16	1.0	42
FL 1625	1	64	2	63	2	61	1.7	63
K. Chandramukhi	5	285	6	234	6	156	5.7	225
K. Jyoti	5	203	5	152	6	74	5.3	143
K. Lauvkar	3	158	2	116	3	84	2.7	119
Mean	2.4	127	2.4	100	2.8	63		
CD (0.05)	Reducing sugar							
Days of storage (DS)	6							
Cultivar (C)	10							
DSxC	19							

*CCS = Chip colour score, RS = Reducing sugar

On a 1-10 scale of increasing dark colour, chip colour score >5 was unacceptably dark

Table 5. Sucrose content (mg/100 g fr wt) of potato tubers during high temperature storage

Cultivar (C)	Days of storage (DS)			Mean
	0	45	75	
Atlantic	176	193	187	185
FL 1291	203	169	201	191
FL 1533	158	167	193	173
FL 1584	189	173	198	187
FL 1625	221	181	191	198
K. Chandramukhi	205	174	236	205
K. Jyoti	213	182	288	228
K. Lauvkar	167	150	239	185
Mean	192	174	217	

CD (0.05)	
Days of storage (DS)	8
Cultivar (C)	12
DSxC	23

temperature storage and envisaged the feasibility of using high temperature stored potatoes for processing. Increase in sucrose content during high temperature storage is reported earlier (6, 19).

Free amino acids and phenolic content of exotic and Indian cultivars : The content of free amino acids and total phenols were lower in the exotic cultivars at both the stages of farm storage. The average contents of free amino acids and total phenols dropped by approx. 8% and 25% respectively after 75 days of farm storage (Table 6).

The results indicated that, excepting FL 1625, tubers of all the other cultivars stored in the refrigerated store even for a short period of 4 weeks were unfit for processing into chips. Both, reducing sugar and sucrose content, increased manifold during refrigerated storage, but the increase in reducing sugars was tremendous in Indian varieties. The exotic cultivars were far superior for chipping in comparison to the Indian varieties. The study, further, concludes that all the 5 exotic cultivars and one Indian variety, Kufri Lauvkar can be stored at ambient temperature up to 75 days for producing chips of good quality.

Table 6. Free amino acid (mg N/100 g fr wt) and total phenol (mg/100 fr wt) content of potato tubers during high temperature storage

Cultivar (C)	Days of storage (DS)							
	0		45		75		Mean	
	FAA*	TP*	FAA	TP	FAA	TP	FAA	TP
Atlantic	65.3	43.4	68.2	28.0	65.6	28.2	66.4	33.2
FL 1291	72.0	34.4	68.4	31.0	54.3	22.4	64.9	29.3
FL 1533	72.9	42.9	63.8	28.3	67.3	28.0	68.0	33.1
FL 1584	68.5	37.3	58.1	31.5	58.7	27.7	61.8	32.2
FL 1625	60.9	34.9	58.6	32.2	65.6	28.3	61.7	31.8
K. Chandramukhi	88.3	51.1	69.1	44.4	71.8	44.4	76.4	46.6
K. Jyoti	73.1	58.7	74.2	52.0	82.0	42.9	76.4	51.2
K. Lauvkar	89.1	49.2	75.1	45.3	74.2	36.7	79.5	43.7
Mean	73.8	44.0	66.9	36.6	67.4	32.3		

CD (0.05)		Free amino acid	Total phenol
Days of storage (DS)		1.3	1.0
Cultivar (C)		1.7	1.3
DSxC		3.5	2.6

*FAA = Free amino acid, TP = Total phenol

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EFFECT OF LOW TEMPERATURE, DESPROUTING AND GIBBERELIC ACID TREATMENT ON LITTLE TUBER FORMATION ON POTATOES DURING STORAGE*

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ABSTRACT : Effect of low temperature, desprouting and GA treatment on the initiation and development of little tubers on physiologically old mother tubers during storage was investigated during 1995-98. In tubers stored at 20°C and desprouted thrice, little tuber initiation occurred 214 days after harvest. But in tubers subjected to high temperature (20°C) with desproutings for different periods followed by low temperature treatment (4°C) for different periods, it took at least 325 days for initiation of little tubers. When the tubers were subjected to low temperature (4°C) treatment for 197 days followed by storage at 20°C with desprouting twice, little tuber initiation occurred after 315 days. The number of little tubers produced per mother tuber ranged from 2 to 9 depending upon the cultivar. The proportion of little tubers weighing less than 0.5 g was as high as 75% in Kufri Sutlej. Cultivars differed in their response to treatments. While Kufri Chandramukhi produced on an average nine little tubers per mother tuber, Kufri Jyoti and Kufri Badshah produced only two little tubers per mother tuber. When the dormancy of mother tubers was broken by treatment with GA and thiourea, sprout growth started early but little tuber formation was severely affected. Total sugars, reducing sugars, soluble protein, free amino acids and total phenols were determined periodically in the mother tubers. There was no evidence of threshold level of these biochemical constituents at which little tuber formation would occur.

INTRODUCTION

When potato seed tubers are stored for a long time, they become physiologically old and produce little tubers. The formation of "little tubers" could be the result of the mother tubers actually becoming old or may be due to hastening of their life-cycle by storage conditions (4). Formation of little tubers on physiologically old potato seed tubers was also observed by Bodlaender *et al.* (2). Storage temperature is reported to have a strong influence on the formation of "little potatoes" (10). Little potatoes have been produced on physiologically old seed tubers either by subjecting sprouted tubers to low temperature treatment or by repeated desprouting of tubers stored at 20°C (7). An attempt has been made to produce little tubers by prolonged storage of seed tubers at room temperature in North Indian hills and it has been suggested that this technique can be developed into a rapid

multiplication technique (21). In North Indian plains, potatoes are harvested in February and the next crop is planted in October. Thus, almost seven months are available between the harvesting of one crop and the planting of another crop. Therefore, a series of experiments were conducted at controlled temperature conditions to explore the possibility of producing "little potatoes" on physiologically old mother tubers and the results of these experiments are reported here. The aim of this research work was to see whether it would be feasible to multiply the seed tubers, during storage i.e. in the time gap between the harvest and planting of the succeeding crop.

MATERIALS AND METHODS

The experiments 1-5 were conducted at Central Potato Research Station, Modipuram (AMSL 222 m, 29°N, 76°E) during the years 1995-96, 1996-97 and 1997-98 to study little

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tuber formation during storage in the plains while the experiments 6 and 7 were conducted at Central Potato Research Institute, Shimla (AMSL 2202 m, 31 °N, 77°E) during the years 1996-97 and 1997-98 to study little tuber formation in the hills. In all the experiments, 40 to 60g size seed was used and the recommended practices followed for raising the crop. After the harvest, tubers weighing 75-120g were used in the storage experiments. At Modipuram, walk-in-chambers were used for storing tubers at 18-20°C with 80-85% RH and cold store was used for storing tubers at 2-4°C with 90-95% RH. At Shimla, BOD incubators were used for storing the tubers at different temperatures. In all cases, the tubers were treated before storage by dipping in 0.25% mancozeb solution for 15 minutes and then air drying them to prevent fungal infection during storage.

Experiment 1 : Six potato cultivars, viz. Kufri Chandramukhi, Kufri Jyoti, Kufri Bahar, Kufri Badshah, Kufri Lalima and Kufri Sindhuri were used in this experiment. The experimental details are given in table 1. Haulms were cut at different times for different varieties, depending upon the maturity period. Two

batches of 100 tubers for each variety were stored at 20°C. The little tubers were graded into three grades i.e. <0.5g, 0.5-1.0g and >1.0g and their number and weight recorded grade-wise.

Experiments 2 and 3 : Experiments 2 and 3 were designed to study development of little tubers on mother tubers of cultivar Kufri Bahar harvested when immature (haulms cut at 90 days after planting (90 DAP)) and after full maturity (haulms cut at 110 DAP), respectively. All the treatments had three replicates. The experimental details are given in table 2.

Experiments 4 : This experiment was conducted to evaluate the response of three potato cultivars, viz. Kufri Sutlej, Kufri Chandramukhi and Kufri Bahar. Haulms were cut at different times depending on varietal maturity. The experimental details are given in table 1.

Experiment 5 : The effect of GA and thiourea treatment on break of dormancy and subsequent ageing process during storage at different temperatures was studied in this experiment. Tubers of Kufri Bahar were treated with 1ppm GA and 1% thiourea for 1 hour to break the dormancy. Before treatment, two 1" superficial incisions were made on the tubers to facilitate entry of GA and thiourea. The experimental details are given in table 1.

Experiments 6 and 7 : These two experiments were conducted at Shimla, during 1996-97 and 1997-98. Tubers of Kufri Chandramukhi were used in these two experiments and the tubers were treated with 1ppm GA and 1% thiourea for breaking dormancy. Experimental details upto storage at room temperature are given in table 3. In experiment 6, The tubers were shifted to 20°C on 11.12.96 and there were two treatments. In treatment T₁, the tubers were stored at 20°C continuously and during the storage period, the tubers were desprouted six times i.e. on 13.1.97, 10.2.97, 15.3.97, 16.4.97,

Table 1. Experimental details for experiments 1, 4 & 5

	<i>Expt 1</i>	<i>Expt 4</i>	<i>Expt 5</i>
Year	1995-96	1996-97	1996-97
Planting date	17.10.95	18.10.96	18.10.96
Harvesting date	22.2.96	15.2.97	17.1.97
Date of storage	30.3.96 (at 20°C)	22.3.97 (at 4°C) 07.10.97 (at 20°C)	17.1.97 23.3.97 (at 4°C) 30.9.97 (at 20°C)
Desprouting date	1st 1.5.96 2nd 9.7.96 3rd 7.10.96	10.11.97 10.12.97 —	20.11.97 — —

Table 2. Experimental details for experiments 2 and 3

	Expt 2		Expt 3	
Year :	1996-97		1996-97	
Planting date :	18.10.96		18.10.96	
Harvesting date :	27.1.97		15.2.97	
Date of storage T ₁ :	27.1.97 to	22.3.97 (at 20°C)	27.1.97 to	15.5.97 (at 20°C)
Desprouting date :	22.3.97 to	21.3.97 30.9.97 (at 4°C) 30.9.97 (at 20°C)	15.5.97 to	8.5.97 30.9.97 (at 4°C) 30.9.97 (at 20°C)
Desprouting date :	20.11.97		20.11.97	
T ₂ :	27.01.97 to	25.04.97 (at 20°C)	27.1.97 to	15.6.97 (at 20°C)
Desprouting date :	1st :	2.4.97	8.5.97	
	2nd :	25.4.97	15.6.97	
		25.4.97 to 30.9.97 (at 4°C) 30.9.97 (at 20°C)	15.6.97 to	30.9.97 (at 4°C) 30.9.97 (at 20°C)
Desprouting date	20.11.97		20.11.97	
T ₃ :	27.1.97 to	25.5.97 (at 20°C)	—	
Desprouting date	1st :	2.4.97	—	
	2nd :	25.4.97	—	
	3rd :	21.5.97	—	
		25.5.97 to 30.9.97 (at 4°C) 30.9.97 (at 20°C)	—	
Desprouting date	20.11.97			

Table 3. Experimental details of experiments 6 and 7

	Expt 6	Expt 7
Year	1996-97	1997-98
Planting date	15.4.96	15.4.97
Dehaulming date	16.8.96	20.8.97
Harvesting date	15.9.96	20.9.97
Storage at room temperature	20.9.96 to 11.12.96	24.9.97 to 9.10.97
Temperature	Max. : 25.2°C Min. : 8.2°C	23.1°C 13.6°C

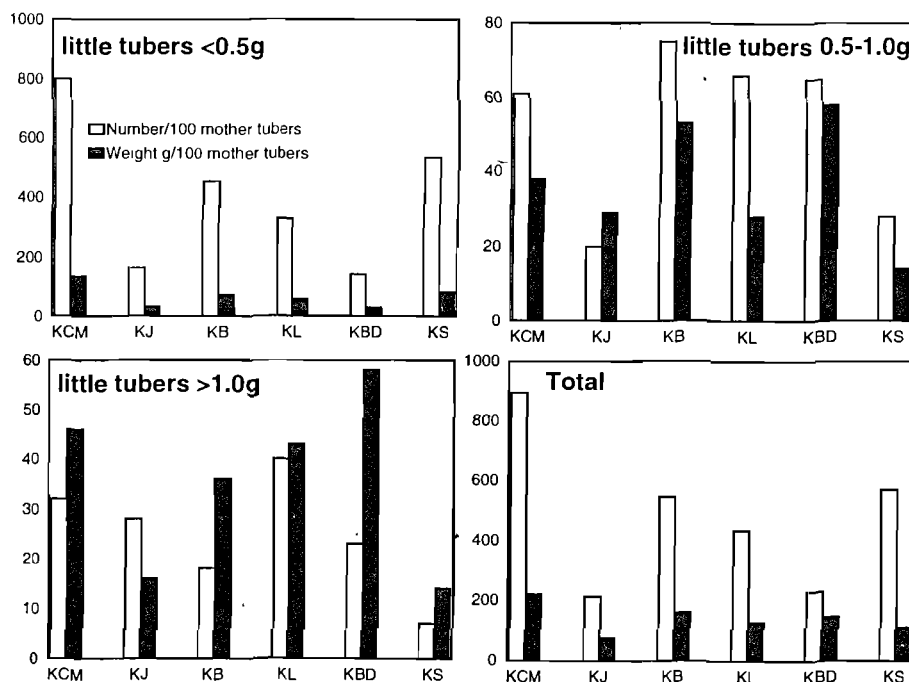
17.5.97 and 16.6.97. A few little tubers were seen initiating on 7.7.97 i.e. 295 days after harvest. In treatment T₂, the tubers were stored at 20°C for 94 days and desprouted twice on 13.1.97 and 10.2.97 during storage. The desprouted tubers were shifted to 6°C on 15.3.97. Initiation of little tubers occurred after 125 days of storage at 6°C. During the storage, tuber samples were drawn at monthly intervals and analysed for total sugars, soluble protein and total phenols. For each sample, 10g of diced tubers were used for analysis. Sugars

were extracted with 80% isopropanol by refluxing for 1h and the extracts were clarified. Reducing sugars were estimated by the arsenomolybdate method (17). Total sugars were determined by the anthrone method (22). Soluble protein content was determined by the method of Lowry *et al.* (16) and total phenols were determined by AOAC methods (1). In experiment 7, tubers stored at room temperature were shifted to three different shifting temperature regimes. In treatment T_1 , the tubers were stored at 27°C for 25 days and then shifted to 18°C on 3.11.97. After 180 days of storage at 18°C, i.e. on 18.6.98, initiation of a few little tubers was observed. During the storage, the tubers were desprouted seven times i.e. on 3.12.97, 12.1.98, 12.2.98, 11.3.98, 15.4.98, 15.5.98 and 18.6.98. In treatment T_2 , the tubers were stored at 6°C for 25 days and then shifted to 18°C on 3.11.97. During storage at 18°C, the tubers were desprouted six times i.e. on 12.1.98, 12.2.98, 11.3.98, 15.4.98, 15.5.98 and 18.6.98. In treatment T_3 , the tubers were stored at 27°C for 25 days and shifted to 18°C on 3.11.97. After

30 days i.e. on 3.12.97, the tubers were shifted to 6°C. During the storage period, samples were drawn periodically and analysed for total sugars, soluble protein and free amino acids. For each sample, 10g of diced tubers were used for analyses. For the determination of total sugars and soluble proteins, the methods followed were as in experiment 6 while free amino acids were determined following the method of Lee & Takahashi (14).

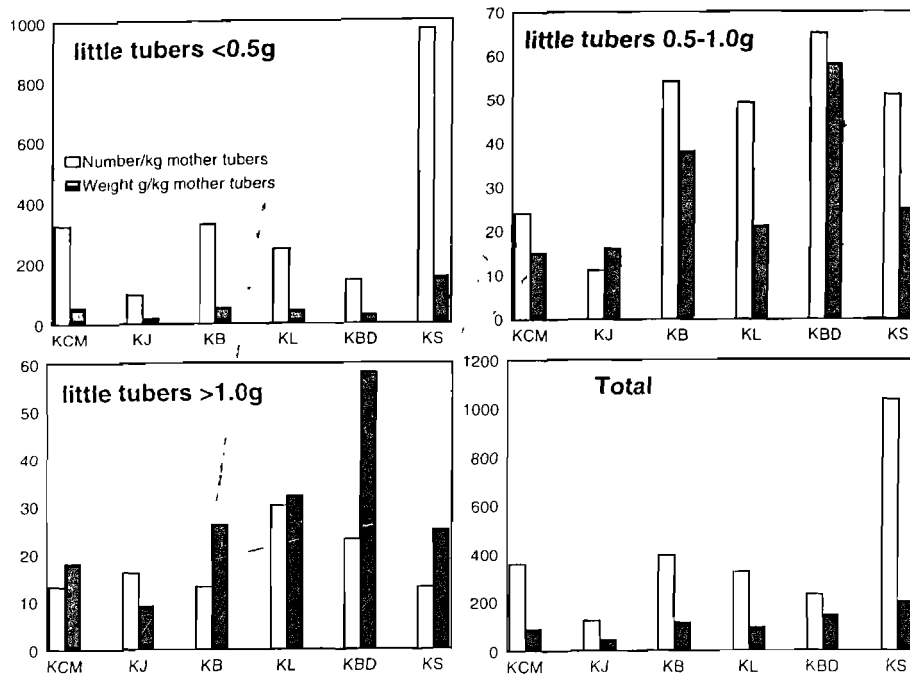
RESULTS AND DISCUSSION

In experiment 1, when tubers were stored at 20°C and desprouted thrice, little tuber initiation occurred after 214 days after harvest. The number and weight of little tubers produced are shown in Figs. 1 and 2. Cultivar Kufri Chandramukhi produced maximum number of little tubers. Kufri Badshah and Kufri Jyoti were less responsive compared to the other four. More than 90% little tubers weighed less than 0.5g in Kufri Chandramukhi and Kufri Sindhuri.



KCM: Kufri Chandramukhi, KJ: Kufri Jyoti, KB : Kufri Bahar, KL : Kufri Lalima, KBD :Kufri Badshah and KS : Kufri Sindhuri

Fig. 1. Effect of repeated desprouting during storage at 20°C of mother tubers on little tuber production in six potato cultivars [Number and weight (g) of little tubers per 100 mother tubers]



KCM : Kufri Chandramukhi, KJ : Kufri Jyoti, KB : Kufri Bahar, KL : Kufri Lalima, KBD : Kufri Badshah and KS : Kufri Sindhuri

Fig 2. Effect of repeated desprouting during storage at 20°C of mother tubers of little tuber production in six potato cultivars [Number and weight (g) of little tubers per kg mother tubers]

In experiment 2, immature tubers (90 days after planting) were used and a combination of high temperature (20°C) storage coupled with desproutings and subsequent low temperature treatment were tried. Irrespective of the number of desproutings during initial storage at 20°C and subsequent low temperature treatment, it took 325-327 days from the date of harvest of the mother tuber for initiation of little tubers. Three harvests of little tubers were done i.e. on 9.1.98, 20.1.98 and 27.2.98. The total number of little tubers produced was maximum upon three desproutings coupled with 128 days of low temperatures treatment (Fig. 3). Further increase in period of low temperature treatment did not increase little tuber production. The number of little tubers produced weighing more than 1 g were only 3-6% and out of the remaining little tubers nearly half weighed less than 0.5g (Fig. 3).

In experiment 3, mature tubers from crop dehaulmed after maturity at 110 days, were

used and it took 317-332 days for the initiation of little tubers. Three harvests of little tubers were done on 12.2.98, 5.3.98 and 19.3.98. The total number of little tubers produced were less compared to that in the second experiment and 65-80% of the little tubers weighed less than 0.5g (Fig. 4).

In experiment 4, three cultivars were evaluated regarding their relative efficiency for little tuber production. Little tubers were harvested thrice, viz. on 13.2.98, 27.2.98 and 16.3.98. Kufri Chandramukhi produced maximum number of little tubers while Kufri Bahar had the minimum (Fig. 5). Further, in this experiment the mother tubers were subjected to low temperature (4°C) immediately after harvest followed by ageing at 20°C. Though the change in sequence of treatments did not alter the time required for little tuber initiation still the number of little tubers produced was less.

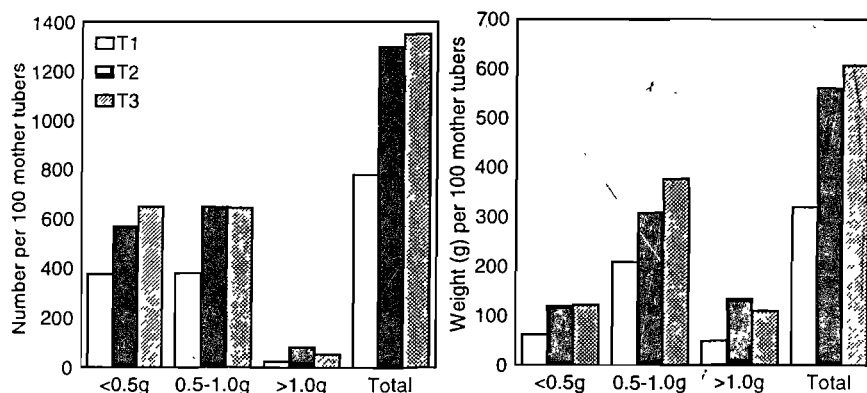


Fig. 3. Effect of desprouting at high temperature followed by low temperature treatment of mother tubers (harvested 90 days after planting) on little tuber production, in Kufri Bahar
 T1 : 64 days at 20°C with one desprouting followed by 190 days at 4°C
 T2 : 98 days at 20°C with two desproutings followed by 158 days at 4°C
 T3 : 128 days at 20°C with three desproutings followed by 128 days at 4°C

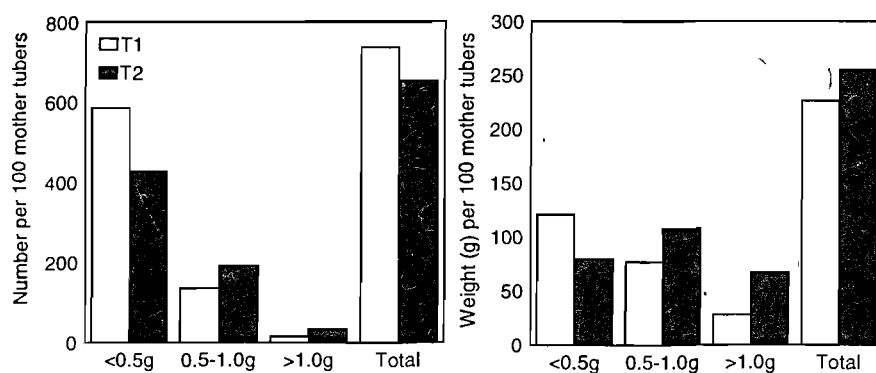


Fig. 4 : Effect of desprouting at high temperature followed by low temperature treatment of mother tubers (harvested 10 days after planting) on little tuber production, in Kufri Bahar
 T1 : 89 days at 20°C with one desprouting followed by 138 days at 4°C
 T2 : 120 days at 20°C with two desproutings followed by 107 days at 4°C

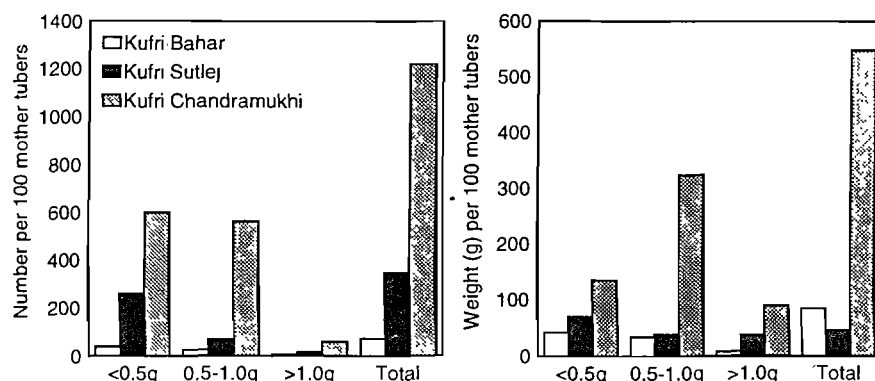


Fig. 5 : Effect of low temperature treatment followed by desprouting at high temperature storage of mother tubers on little tuber production in three potato cultivars

In experiment 5, where the tubers were treated with GA and thiourea to break the dormancy, initiation of little tubers occurred after 395 days of harvest, i.e. 70 days later than the untreated tubers and even after 10 days of initiation, only 20 little tubers were harvested, after which there was no further production of little tubers.

In experiment 6, when the tubers were stored continuously at 20°C and desprouted six times, initiation of little tuber was observed 295 days after harvest whereas, in tubers stored at 20°C for 90 days and subsequently at 6°C, little tuber initiation occurred after 308 days after harvest. In the first treatment, only 30% tubers had little tuber formation with only one or two little tubers on each mother tuber, that too weighing less than 100mg each. In the second treatment, only about 5% tubers had

single little tubers on each mother tuber and these weighed 50 mg or less.

Total sugars in the mother tuber increased with increase in its age (Fig. 6). Sugar content continued to increase even after formation of the little tubers. The reducing sugars also showed a slight increase upto first five months of storage but declined thereafter. The levels of both reducing sugars and total sugars were higher in tubers stored at 6°C (Fig. 6). The soluble protein content increased upto the formation of little tubers and then declined. Total phenol content continued to increase throughout at the higher storage temperature of 20°C whereas in tubers stored at 6°C, it declined after formation of the little tubers.

In experiment 7, in the first treatment where the tubers were stored at 27°C for 25 days and subsequently at 18°C, it took 271 days after the

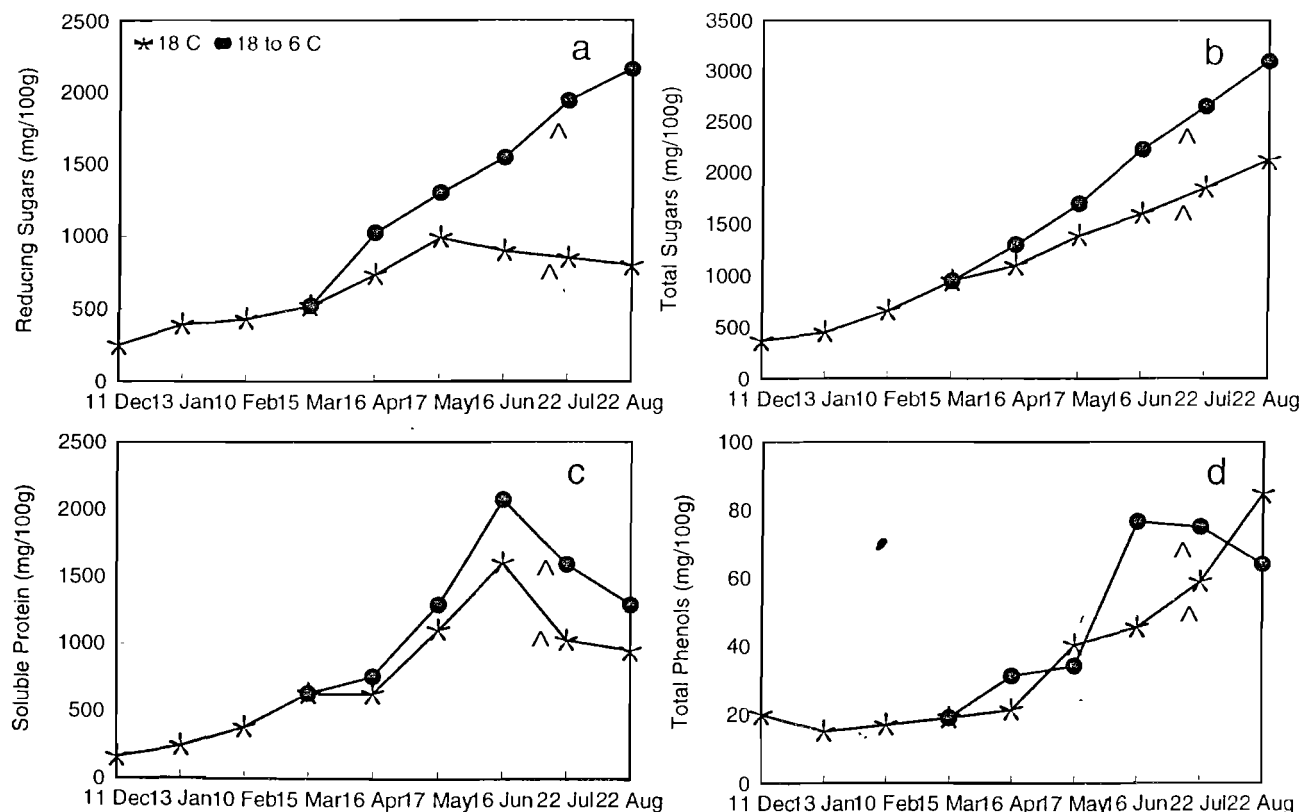


Fig 6 : Changes in the levels of (a) reducing sugars, (b) total sugars, (c) soluble protein content and (d) total phenols during storage at different temperatures during 1996-97 (^ indicates little tuber initiation).

harvest, for the initiation of little tubers. Only 5% of the mother tubers showed little tuber initiation and none of them developed further. In the second treatment also, where the tubers were stored at 6°C for 25 days and subsequently at 18°C, initiation of little tubers was observed after 271 days. Only 10% of the mother tubers showed little tuber initiation while none of them developed further. In the third treatment, where the tubers were first stored at 27°C for 25 days followed by storage at 18°C for 30 days and subsequently at 6°C, little tuber initiation did not occur until the end of the experiment i.e. upto 300 days after harvest. The levels of total sugars increased with increase in the storage period in all the three treatments. The soluble protein content also increased with storage period but began to decline at the last stage. However, the total free amino acids continued to increase (Fig. 7). During 1998, initiation of little tubers was observed on June 18, 1998.

The initiation of little tubers is considered to be the culmination of a developmental sequence leading to tuberization. This happens when storage conditions hasten the life cycle of mother tubers (4). Conditions that accelerate physiological ageing of tubers such as repeated sprout removal and prolonged storage under warm conditions are reported to induce little tuber formation (10). Both storage at higher temperature coupled with repeated desproutings or storage at higher temperature followed by low temperature treatment were found effective in inducing little tuber formation in 214 days after harvest in all the varieties studied. However, about 75 days were required for development of little tubers. Repeated desprouting at higher storage temperature of 20°C prior to low temperature treatment or increasing the period of low temperature treatment from 128 days to 190 days did not hasten little tuber formation. Desprouting

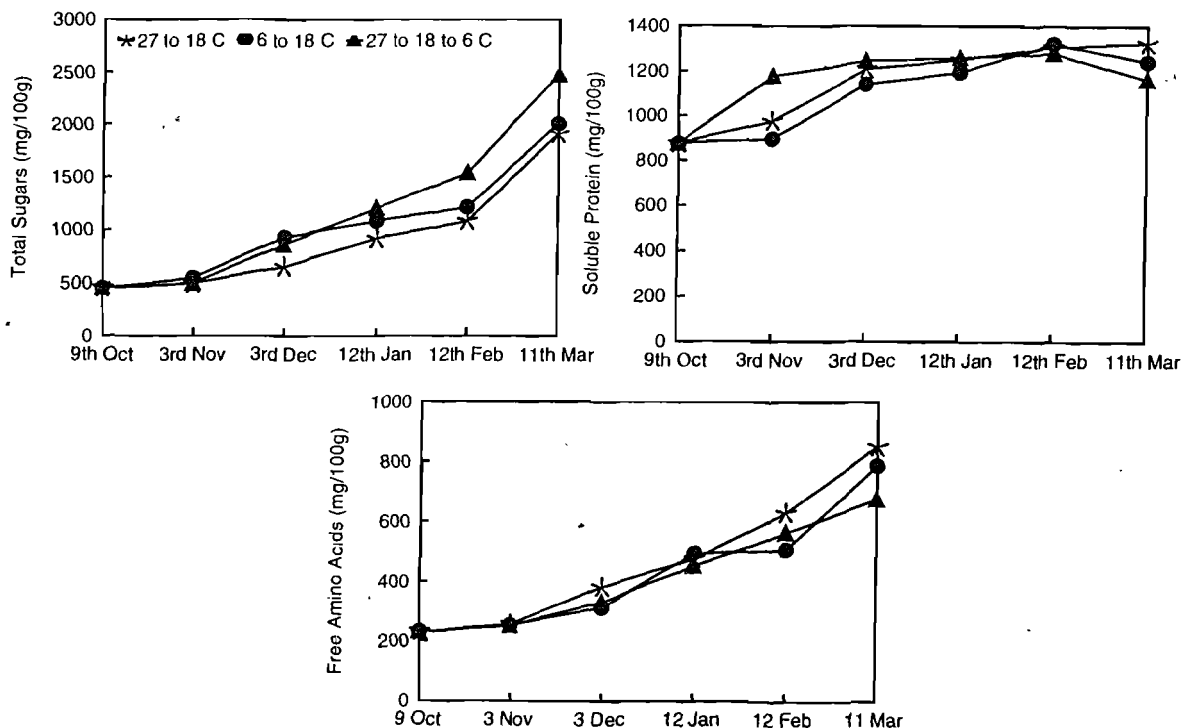


Fig. 7 : Changes in the levels of (a) total sugars, (b) soluble protein content and (c) free amino acids during storage at different temperatures during 1997-98

during higher storage temperature followed by low temperature treatment were complementary i.e. longer the storage at 20°C with repeated desproutings, shorter is the duration of low temperature treatment required to induce little tuber formation. Ageing of the tubers however, enhances the efficiency of little tuber production than the low temperature treatment. Maturity of the mother tubers used did not have any effect on the time required for little tuber formation.

Both high temperature and repeated desproutings hasten the ageing process and this leads to the formation of little tubers as the final step in the ageing process of the mother tuber. Senile tubers are known to contain more of ABA and less of GA (5, 6). Low temperature is also known to decrease GA content in leaves and shoots of potato plants (12, 18). It appears that both ageing and low temperature treatments lead to the same effect i.e. lowering the level of GA, and thus cause initiation of little tubers on the physiologically old mother tubers.

In order to reduce the time period from harvest to little tuber initiation, seed tubers were treated with GA and thiourea to break the dormancy of mother tubers which led to early sprout development. But it badly affected the formation of little tubers as reflected by the negligible number of little tubers harvested. Tuber initiation in a potato plant is regulated by the level of endogenous growth substances. Thiourea is reported to delay senescence because of its cytokinin-like activity (8). While gibberellic acid is known to inhibit tuberization in potato plants (13) and a higher level of abscisic acid in ageing mother tubers may also be responsible for the initiation and development of little tubers. In mother tubers treated with gibberellic acid and thiourea for artificially breaking the dormancy, the gibberellic acid level might have been higher. Further, the

incisions made on the mother tubers during the breaking of dormancy might have also resulted in increased level of GA since any injury or incision made is reported to increase the endogenous level of GA in tubers (19), which could have upset the ABA/GA balance leading to poor efficiency of little tuber formation. Besides, thiourea might have resulted in delaying senescence which is necessary for the production of little tubers.

The reducing sugars content of mother tubers showed an increase during the first five months of storage period but declined thereafter. Increase in reducing sugars content during storage at 20°C with repeated desprouting has been reported (11). After about 45 weeks of storage, at 20°C, Coleman & King (5) found that the reducing sugars content was less than 0.3% in three American potato varieties. But we found that at the time of little tuber formation, which was after about 39 weeks, the reducing sugars content in mother tubers was about 0.8%. Probably, Indian potato varieties have a tendency to accumulate more reducing sugars during storage and hence this difference in the reducing sugar content.

The total sugars increased with an increase in storage period of mother tubers in all the treatments during both the years. Isherwood & Burton (11) observed that accumulation of sugars was much higher when the tubers were desprouted manually and total sugars increased four fold when the tubers were stored at 20°C for several months, subsequent to storage at 10°C for 70 days. The total sugars content reached a maximum of 1.6% in sprouted tubers and 3% in the tubers which were desprouted repeatedly. We observed 5.7 times increase when the tubers were stored at 20°C and 4.4 times when the tubers were stored at 18°C. The total sugars content was about 2% in our experiments, when the tubers were desprouted repeatedly at about monthly intervals. The sugar

content was higher at about 3% when the tubers were stored at 6°C. Linneman *et al.* (15) also reported an increase in total sugars during prolonged storage at 7, 16 and 28°C. Sugar accumulation at low temperature is attributed to "low temperature sweetening" and sugar accumulation in ageing tubers during prolonged storage at higher temperature is attributed to 'senescent sweetening'(3). Reust & Aerny (20) observed that when tuberization occurred on sprouts, the tuber sucrose content was between 0.85 and 2%. In our experiments the levels of sugar accumulation at the time of little tuber formation was different at different storage temperatures. During 1997-98, the total sugar content was above 1.5% by March 11, but little tuber formation did not take place at this time, it took place about three months later. Thus, there was no evidence of a threshold level of sugar accumulation at which little tuber formation would occur. This shows that probably little tuber formation is not related to sugar accumulation in mother tubers.

Soluble protein content of tubers increases when the dormancy is over. This increase was higher if the tubers were transferred from 3 to 26°C (9). An increase in soluble proteins was also seen with increase in the storage period. However, the soluble proteins declined after 185 days of storage, irrespective of little tuber formation. The total free amino acids were also found to increase with increase in storage period. Free amino acids are reported to increase especially in sprouted tubers (9). Total phenols in tubers continued to increase when stored at 6°C but at 20°C there was a decline after 220 days of storage. As in the case of sugars, there was no evidence of a threshold level of soluble protein and total phenols accumulation at which little tuber formation would occur since at the time of little tuber formation the level of sugars, soluble proteins and total phenols was different in different treatments. Biochemical analysis of

the ageing potato tubers, during prolonged storage has enabled us to show the levels of total sugars, reducing sugars, soluble protein and total phenols in mother tubers at the time of little tuber formation. However, it can not be said for sure whether formation of little tubers is a consequence of such biochemical changes in the mother tuber.

It has been suggested that production of little tubers may be developed into a rapid seed multiplication technique (7, 21). Based on the results reported here the following conclusions can be drawn. 1. Not all cultivars respond well to the treatments. 2. The rate of seed multiplication is low. It should be increased to atleast 10 times to make this a viable technique. 3. To be able to plant directly in the field, the little tubers should weigh at elast 500 mg. A large proportion of the little tubers weigh less than 500mg and therefore unsuitable for planting in the field. 4. The time required for the initiation of little tubers after the harvest is very long and by the time sizeable little tubers are harvested, it is almost 12 months. 5. The time gap from harvesting of the mother tuber to the initiation of little tubers can not be reduced by breaking dormancy with GA and thiourea treatment because of the inhibitory effect of GA or/and thiourea on little tuber formation. Further studies are required to help develop this method into a viable rapid multiplication technique and it is essential to induce little tuber formation earlier so that little tubers could be harvested in about 6-7 months time.

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JHULSACAST : A COMPUTERIZED FORECAST OF POTATO LATE BLIGHT IN WESTERN UTTAR PRADESH*

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ABSTRACT : JHULSACAST has three components, viz. i) late blight prediction models for western Uttar Pradesh, ii) a computer programme to forecast late blight (*Phytophthora infestans*) using the models developed for this purpose and, iii) an 'interface' to utilize weather data from an automatic weather station. All the three components were specifically developed for predicting late blight in western Uttar Pradesh. The models were developed by utilizing the weather data for 9 years collected at the Central Potato Research Instt. Campus, Modipuram. However, before constructing these models, some of the most popular late blight prediction models developed world over were also tested for their accuracy. Results revealed that none of them was fit enough to predict late blight accurately in western Uttar Pradesh. Two models developed one each for rainy and non rainy years are: Model 1 (Rainy year): i) measurable rain (0.1-0.5 mm) for a minimum of 2 consecutive days, ii) 5-day moving >85% RH periods ≥ 50 hrs and iii) 5-day moving congenial temperature (7.2-26.6°C) ≥ 105 hrs, Model 2 (non rainy years) : i) 7-day moving > 85% RH period ≥ 60 hrs and ii) 7-day moving congenial temperature (7.2-26.6°C) ≥ 120 hrs. If any of the above conditions prevail for 7-consecutive days, blight would appear within 10 days.

A computer programme was written in Fox Pro to predict late blight using the above two models. The disease was successfully predicted for three consecutive years (1997-98, 1998-99, 1999-2000) using the computer programme and the above two models. An interface was also developed in Fox Pro for utilizing weather data directly from an automatic weather station.

INTRODUCTION

Late blight caused by a fungus *Phytophthora infestans* (Mont.) de Bary is one of the most destructive diseases of potato crop world over, including India. Its severity however, varies from region to region, being more severe in temperate highlands than in the sub-tropical plains (3). This is primarily due to differences in weather prevalent in these regions. In the Indian hills, be it southern, eastern or western hills, potato crop is grown mostly during rainy season (Feb-Oct) when the temperatures are moderate (10-20°C) and rains are plenty which raises the ambient relative humidity above 80% for the most part of the crop season. Consequently, weather conditions become congenial for appearance of late blight very early in the crop season which lead to late blight outbreaks every year. However, such situation does not exist in the sub-tropical plains. Most of the times, weather remains dry

and moderately cool which does not favour late blight outbreak. But in some years, sky remains overcast with lot of morning fog and dew, besides frequent irrigations which raise the ambient relative humidity to above 80%. This may, at times, be coupled with intermitant rains as has happened during the last few years (1997-1998). Such a weather favours the late blight outbreak (9). Since weather does not follow any definite trend, prediction of late blight in the sub-tropical plains is difficult. Weather conditions, viz. temperature, relative humidity, rainfall, dew, sunshine hours have a direct effect on *P. infestans* (7, 13) and consequently on the disease. Van Everdingen (22) utilized all the above weather parameters in developing a late blight prediction system, commonly known as "Dutch rules". Beaumont & Staniland (1, 2), however, found only two factors i.e. minimum temperature of 50°F or above and relative humidity not below 75% for at least two days, important in forecasting the

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disease. Several other workers (6, 17, 24) also relied on these two weather parameters, but their regimes varied from place to place and, country to country. Cook (10, 11) evolved the concept of 'moving days' to determine the critical "Blight Favourable Periods" using 7-day moving total rain fall and 7-day moving average mean temperature charts. Hyre (14, 15), Hyre & Bonde (16) and Choudhary & Pal (8) used the concept of moving days in developing late blight forecasting systems for various regions. Bhattacharyya, *et al.* (4) also utilized this approach for constructing forecasting systems for Darjeeling, Ooty and Shimla hills. Wallin (23) developed a specific relationship between duration of relative humidity periods $\geq 90\%$ and the average temperature during those periods. This relationship has been utilized by several workers for developing computerized need-based spray schedules for controlling late blight (5, 19, 20, 21). Linear discriminant and logistic regression analyses have also been used for predicting potato late blight (18). It is now well established that different methods and weather criteria are required for forecasting potato late blight in different regions. Sub-tropical plains in India represent diverse agro-ecological zones where 80% of potatoes are grown in the country. Since no late blight forecasting system has so far been developed for this region, studies were undertaken to develop/construct suitable late blight forecasting system for western Uttar Pradesh using disease and weather data collected over a decade.

MATERIALS AND METHODS

Field experiments : Late blight trap nurseries were raised with susceptible cultivars Kufri Chandramukhi and Kufri Bahar at Central Potato Research Station, Modipuram experimental farm since 1986 to 1998. Ten plot, each consisting of 50 plants of both the cultivars were planted between 15 and 20 October each

year near the observatory. Hygrothermograph housed in Stevenson screen was adjusted periodically so as to keep the hygrothermograph just below the canopy level. Temperature and relative humidity were recorded daily from 20th October till disease appearance using the hygrothermograph. Other weather parameters, viz. rainfall, leaf wetness, sunshine hours, wind velocity and speed were recorded in the observatory. Appearance of first late blight symptom was recorded in the trap nursery and in other fields at the farm and adjoining farmers fields. Since, 1991-92, late blight infected tubers (artificially inoculated) were planted in the centre of each plot of the nursery for ensuring the availability of the inoculum.

The temperature and relative humidity data was computed on hourly basis whereas rainfall, leaf wetness and sunshine hours were computed on daily basis. The temperature, RH, rainfall and sunshine hours data were interpolated with the actual date of disease appearance using computer programmes developed in Fox Pro. The forecasting systems tested were:

- i) Dutch rules (22)
- ii) Beaumont rules (2)
- iii) Cook's (10) and Hyre's method (14) of moving graphs
- iv) Bhattacharya *et al* IInd forecast (4)
- v) Wallin's relative humidity and temperature method (23)

Besides, several other new combinations of relative humidity and temperature were evaluated for their fitness to predict late blight by using computer programmes developed for this purpose.

Data acquisition : Temperature and relative humidity data from hygrothermographs was converted to digital form on hourly basis,

whereas rainfall data was collected on daily basis. For utilizing the weather data from the automatic weather station, an 'INTERFACE' was developed in Fox Pro to convert the temperature and relative humidity data on hourly basis and rainfall data on daily basis for utilization in the JHULSACAST.

Computer Programme : The current version of JHULSACAST was developed in Fox Pro. The main MENU of the programme are:

- i) Late blight forecasting model(s)
- ii) Data entry and modification, and
- iii) Model execution

The programme will read the weather data from the base and would decide which of the two models will be operationalized for disease forecasting. The weather data is updated daily by entering it manually or by an automatic weather station 'INTERFACE' programme and the models are executed for knowing the status of late blight. Depending on the weather conditions, any of the following two late blight status will be displayed.

Status-1 : Conditions for non rainy model fulfilled/not fulfilled.

Status-2 : Conditions for rainy model fulfilled/not fulfilled.

In case the conditions for any of the two model are fulfilled, a warning is flashed stating, "The Late Blight is Expected to Appear Within Seven to Ten Days"

RESULTS

Fitness of some of the most popular late blight forecasting systems used world over was tasted for predicting late blight in western Uttar Pradesh. Their performance is discussed below:

Dutch Rules : The weather data collected at CPRS Modipuram did not fulfil the Dutch

Rules. In none of the years all the four criteria were fulfilled. There were years (1987-88, 1990-91, 1991-92, 1996-97) when minimum temperature remained below 10°C and there was no rainfall at all but, late blight still appeared within the same week. The results showed that rain is not a pre-requisite for outbreak of late blight in western parts of Uttar Pradesh and, therefore, any criterion/model which has a component of rainfall will not be suitable for predicting late blight in this region.

Beaumont Rules : Out of nine years, Beaumont rules were successful in forecasting late blight in five years, viz. 1986-87, 1988-89, 1989-90, 1991-92 (Table 1). In these years blight appeared within 7-8 days of fulfilment of Beaumont Rules. In 1987-88, Beaumont rules were fulfilled on 13th December but late blight did not appear in this year. In 1990-91, 1992-93, 1993-94 and 1994-95 Beaumont rules were not fulfilled but late blight was recorded in all these years. Overall success rate of Beaumont rules was only 55.5%.

Table 1. Fitness of models based on temperature and relative humidity in predicting late blight in western Uttar Pradesh

Year	Expected date of appearance		Actual date of appearance
	Bhattacharyya et al (1982) 2nd forecast	Beaumont Rules	
1986-87	13-17 Dec	8-22 Dec	15 Dec
1987-88	—	13-27 Dec	No LB
1988-89	10-17 Jan	8-22 Jan	12 Jan
1989-90	28 Dec-4 Jan	28 Dec - 11 Jan	30 Dec
1991-92	2-9 Dec	17-31 Dec	24 Dec
1992-93	-	-	16 Dec
1993-94	-	-	14 Jan
1994-95	-	-	15 Dec
1996-97	-	-	No LB

(-) = Late blight not predicted

Bhattacharya *et al* (4) 2nd Forecast : The model developed by Bhattacharya *et al* (4) consisted of two forecast. First forecast was based on rainfall and mean temperature. Since late blight often appears in the region even in absence of rainfall, the first forecast is not valid for this region. Second forecast of their model which is based on temperature and relative humidity was tested for its accuracy. The model predicted late blight appearance accurately only in five years viz. 1986-87, 1987-88, 1988-89 and 1989-90 and 1996-97 (Table 1) indicating that accuracy of this model was 55.5%.

Hyre's (14) Model : As per the conditions of the forecast, 5-day mean temperature should be <25.5°C and 10 days cumulative total rainfall should not be less than 3cm. If these conditions prevail for 10 consecutive days, late blight would appear within 7-14 days time. This model predicted late blight accurately only in 3 years (1987-88, 1989-90 and 1996-97) out of 9 years (Table 2) indicating that the accuracy of this model was 33.3%, which is not within the acceptable limits.

Cook's (10) Method : This model is based on weekly mean temperature and weekly cumulative rainfall. Weekly mean temperature should be <25.5°C and cumulative rainfall should be more than critical rainfall. The disease

is forecast after two consecutive favourable weeks. The critical rainfall, which is the mean of blight and non blight years could be predicted accurately in 4 out of 9 years indicating that the accuracy of this model was 44.4% (Table 2).

Wallin's (23) Method : This method forecasts the initial occurrence and subsequent spread of late blight based on relative humidity and temperature. The system is based on accumulation of "severity values" which are numbers arbitrarily assigned to specific relationship between duration of relative humidity periods $\geq 90\%$ and the average temperature during those periods (23). The first occurrence of late blight is predicted 7-14 days after 18-20 severity values have been accumulated. The results revealed that this model could not predict late blight in any one out of 12 years for which data was analysed. The cumulative severity values did not cross 7 in any of the years as against the required 18-20 severity values. This model, therefore, is not suited to western Uttar Pradesh conditions where rain is not a recurring feature in the crop season.

In absence of any reliable method which could forecast late blight in western Uttar Pradesh accurately, the weather and disease appearance data from this region were interpolated for identifying weather conditions which are essential for the initial appearance of late blight in this region. Factors tried were (i) minimum and maximum temperatures, (ii) minimum and maximum relative humidity, (iii) 5 and 7-day moving $\geq 75\%$ relative humidity and congenial temperature (7.2-26.6°C) periods, (iv) 5 and 7-day moving $\geq 80\%$ relative humidity and congenial temperature (7.2-26.6°C) periods, (v) 5 and 7-day moving $> 85\%$ relative humidity and congenial temperature (7.2-26.6°C) periods, (vi) 7-days moving $\geq 90\%$ relative humidity and congenial temperature (7.2-26.6°C) periods, (vii) rainfall, (viii) cloudiness and (ix) dew.

Table 2. Fitness of temperature and rainfall based models in predicting late blight in western Uttar Pradesh

Year	Expected date of appearance		Actual date of appearance
	Cook (1947) model	Hyre (1954) model	
1986-87	-	-	15 Dec
1987-88	-	-	No LB
1988-89	7 Jan	-	12 Jan
1989-90	31 Dec	30 Dec-13 Jan	30 Dec
1991-92	31 Dec	7-21 Jan	24 Dec
1992-93	-	-	16 Dec
1993-94	-	-	14 Jan
1994-95	-	25 Jan-9 Feb	15 Dec
1996-97	-	-	No LB

(-) = Late blight not predicted.

No correlation was observed between minimum temperature, maximum temperature, minimum relative humidity, maximum relative humidity, cloudiness, dew and the disease, appearance and were, therefore, discarded. Data on 5 and 7-day moving relative humidity and congenial temperature (7.2-26.6°C) periods revealed that their efficacy varied with relative humidity regimes.

7-day moving $\geq 90\%$ relative humidity (≥ 50 hrs) and congenial temperature (7.2 -26.6°C) periods (≥ 150 hrs) : This method predicted late blight accurately only in four (1997-88, 1991-92, 1992-93, 1996-97) out of nine years indicating that its accuracy is only 44.4%. In some of the years (1987-88, 1988-89, 1989-90 and 1994-95) late blight was not predicted at all although the disease appeared in all these years. On the other hand, in 1986-87 and 1993-94 the disease appeared well before the predicted date (Fig. 1).

5 and 7-day moving $\geq 80\%$ relative humidity and congenial temperature (7.2-26.6°C) periods : 5 and 7-day moving relative humidity periods (70 and 80 hrs respectively) and congenial temperature periods (120 and 150 hrs respectively) were tested. 5-day moving graph method was comparatively better over 7-day moving graph. Accuracy of 5-day moving graph was 66.6% as against 44.4% of 7-day moving graph. (Figs. 2, 3) but still it fell short of the desired level of accuracy.

5 and 7-day moving $\geq 75\%$ relative humidity and congenial temperature (7.2 - 26.6°C) periods : 5 and 7-day moving relative humidity periods (80 and 90 hrs. respectively) and congenial temperature periods (120 and 150 hrs respectively) were tested. Results revealed that 7-day moving graph was comparatively better (55.5% accuracy) over 5-day moving graph (44.4% accuracy) but both of them fell below the expected level of accuracy (Figs. 4, 5).

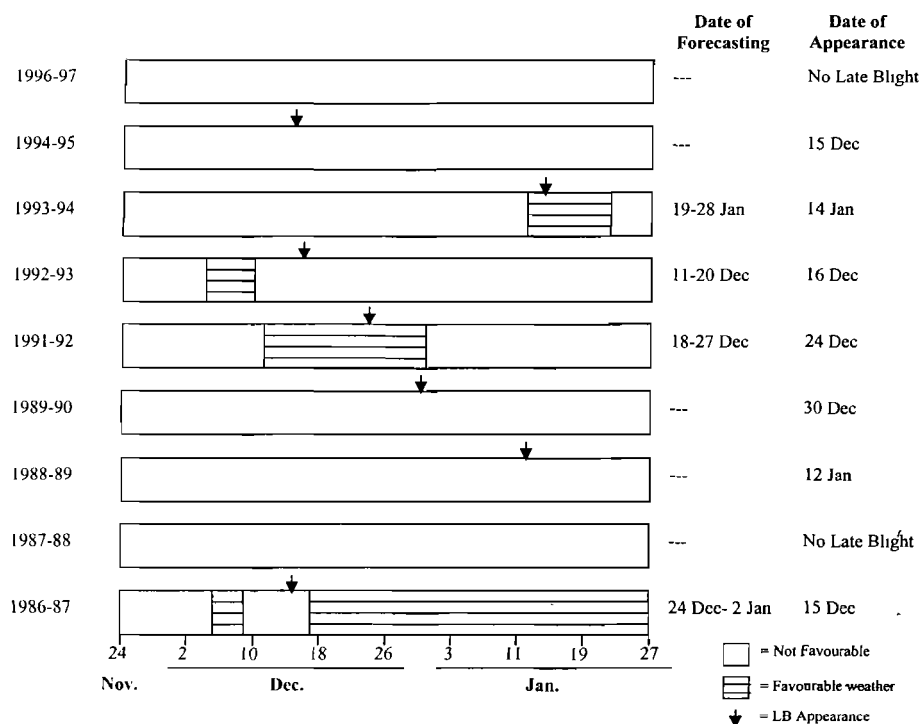


Fig 1. Fitness of 7-day moving relative humidity $\geq 90\%$ (≥ 50 hrs) and congenial temperature (7.2-26.6°C) periods (≥ 150 hrs) in predicting late blight in western Uttar Pradesh

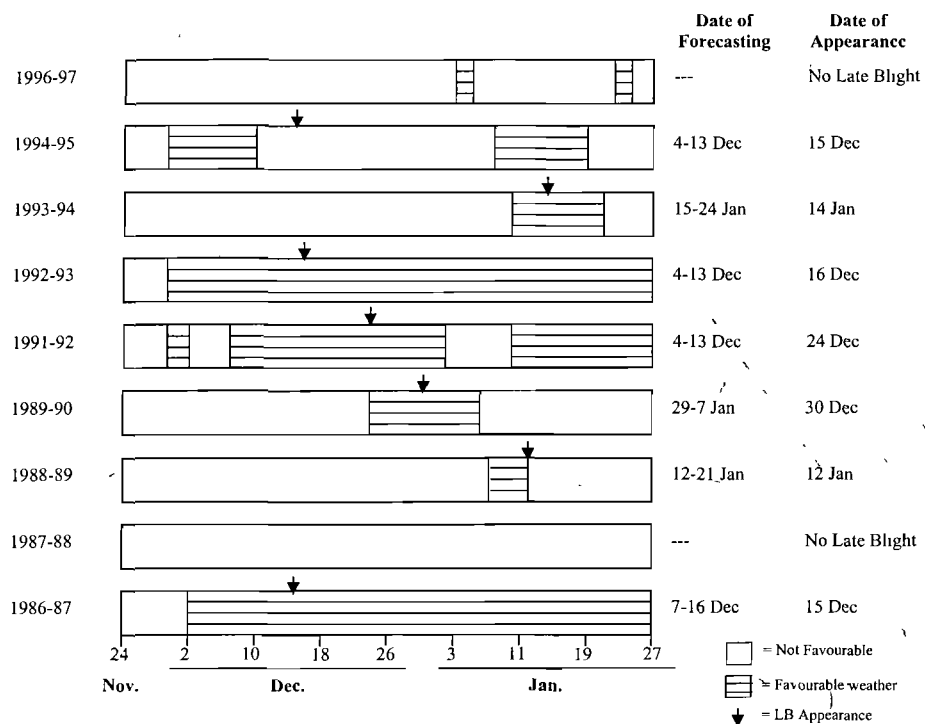


Fig 2. Fitness of 5-day moving relative humidity $\geq 80\%$ (≥ 70 hrs) and congenial temperature 7.2-26.6°C periods (≥ 120 hrs) in predicting late blight in western Uttar Pradesh

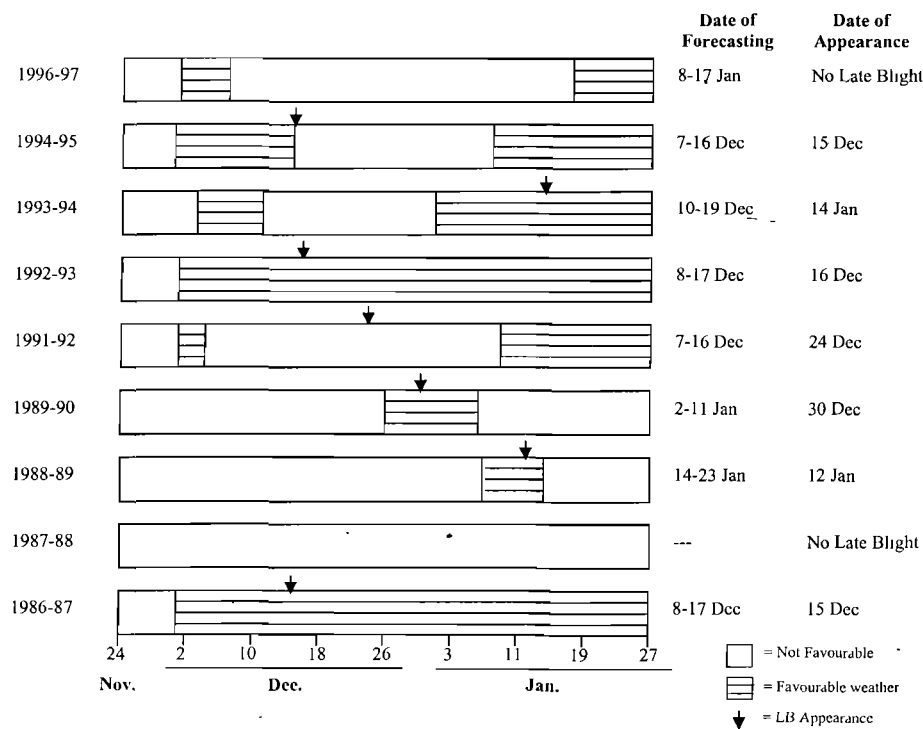


Fig. 3. Fitness of 7-day moving relative humidity $\geq 80\%$ (≥ 80 hrs) and congenial temperature 7.2-26.6°C periods (≥ 150 hrs) in predicting late blight in western Uttar Pradesh

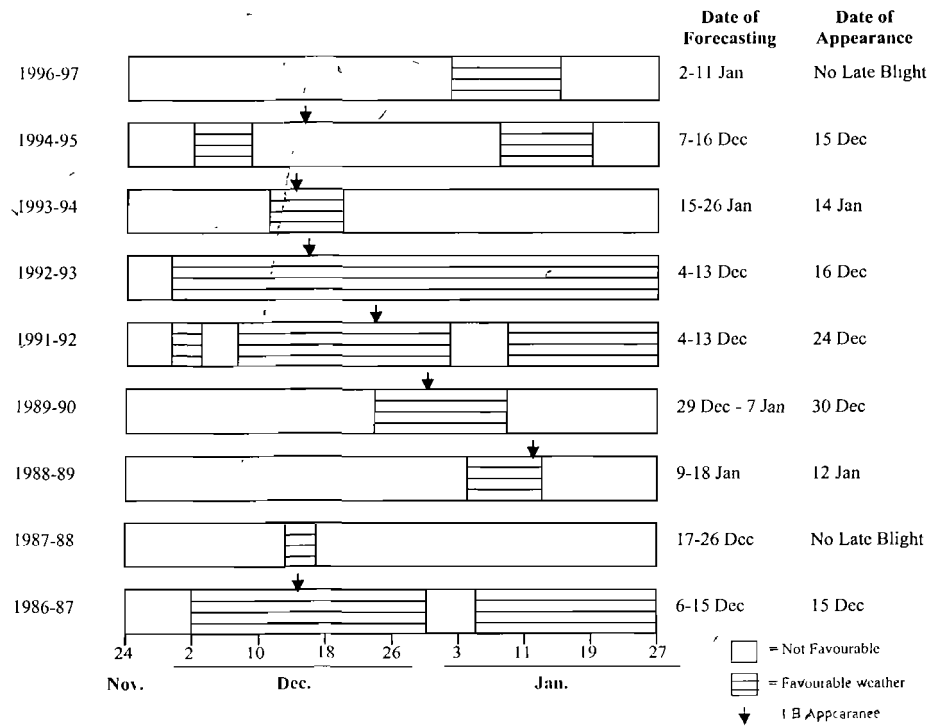


Fig. 4. Fitness of 5-day moving relative humidity $\geq 75\%$ (≥ 80 hrs) and congenial temperature (7.2-26.6°C) periods (≥ 120 hrs) in predicting late blight in western Uttar Pradesh

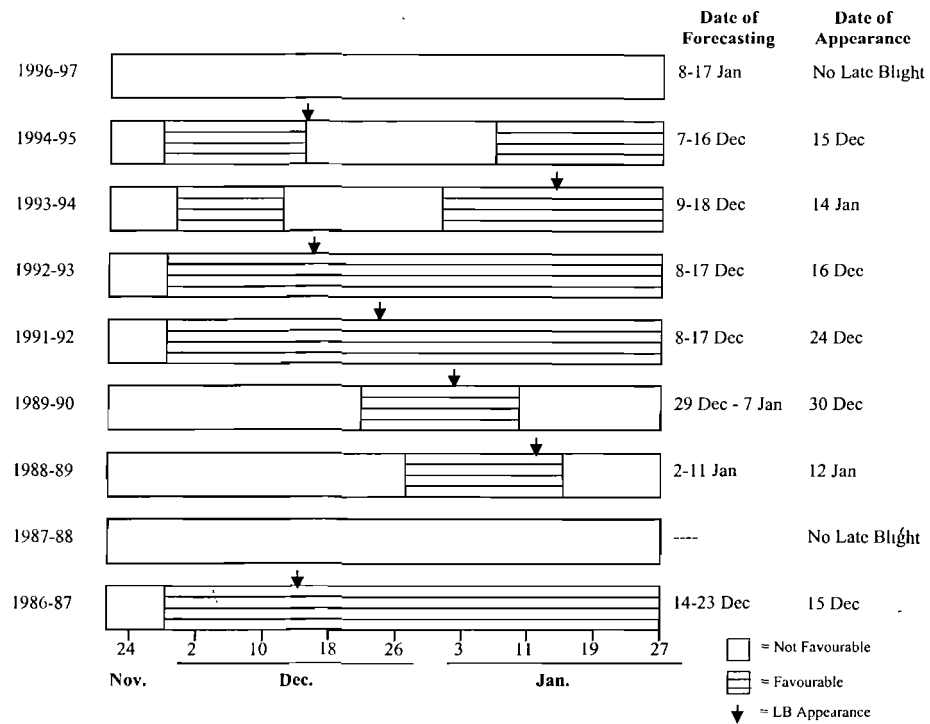


Fig. 5. Fitness of 7-day moving relative humidity $\geq 75\%$ (≥ 90 hrs) and congenial temperature (7.2-26.6°C) periods (≥ 150 hrs) in predicting late blight in western Uttar Pradesh

7-day moving $\geq 85\%$ relative humidity (≥ 50 hrs) and congenial temperature (7.2 - 26.6°C) periods (≥ 105 hrs) : This model predicted late blight accurately in 7 out of 9 years i.e. its accuracy was 77.7 per cent. The two years (1988-89 and 1989-90) in which the model failed to predict the disease were rainy years which indicated that this model may not be suitable for rainy years (Fig. 6).

5-day moving $\geq 85\%$ relative humidity (≥ 60 hrs) Congenial temperature (7.2-26.6°C) periods (≥ 120 hrs) coupled with measurable rainfall (0.1 - 0.5 mm) for two consecutive days : This model forecast the disease accurately in three out of nine years. All the three years, viz. 1988-89, 1989-90 and 1993-94 in which forecast was successful received minimum rainfall (0.1-0.5 mm) for two consecutive days. This indicated that this model is suitable only for those years which get measurable rainfall for two consecutive days (Fig. 6).

DISCUSSION

Indian sub-tropical plains consist of several agro-climatic zones and, therefore, weather during the crop season varies greatly from region to region. Expectedly, no single late blight prediction model/system would work for the entire plains. Present studies were aimed at developing suitable late blight prediction system(s) for the western parts of Uttar Pradesh which is one of the most important potato growing regions in the country. Evaluation of six well established models based on temperature and rainfall (10, 11, 14, 22) and temperature and relative humidity (2, 4, 23) using 9 year weather data from Central Potato Research Station, Modipuram revealed that none of these models worked under western Uttar Pradesh conditions. Out of all of them, Beaumont rules were the best but even their accuracy was only 55.5%. It indicated that none of the existing models were suitable for predicting the disease in western Uttar Pradesh.

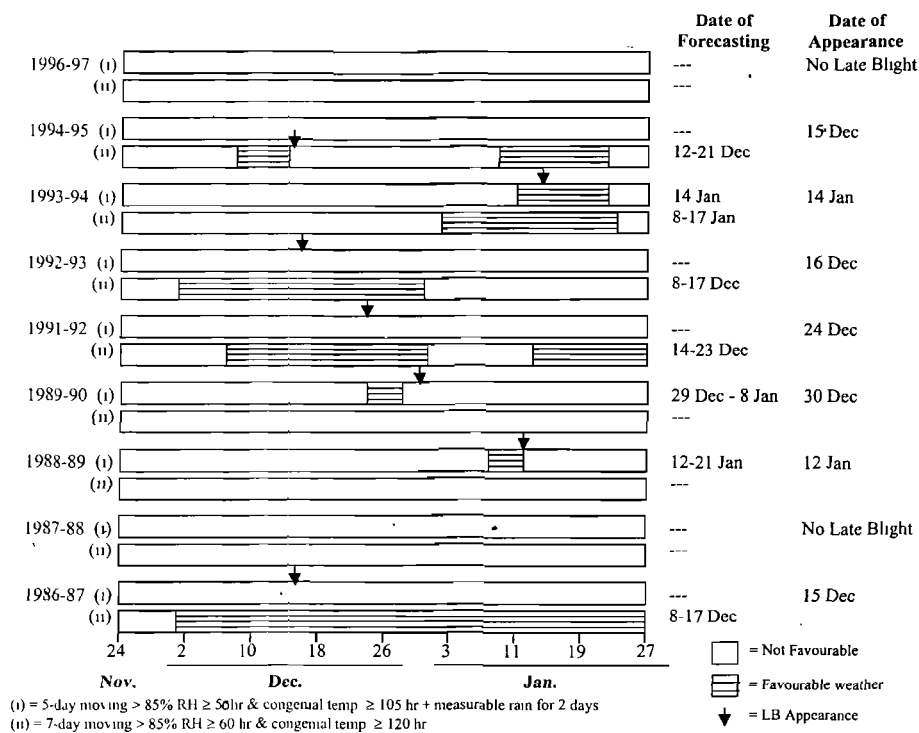


Fig. 6. Proposed models and their accuracy in predicting potato late blight in western Uttar Pradesh

Perusal of the weather data revealed that late blight appeared at Modipuram, Meerut, under two distinct weather conditions, viz. rainy and non rainy conditions. Therefore, any model based on temperature and relative humidity or temperature and rainfall alone will not work in this region. Keeping this in view, two separate weather conditions, one each for rainy and non rainy years, were standardized. They were:

- i) measurable rain (0.1-0.5 mm) for 2 consecutive days.
- ii) 5-day moving >85% relative humidity period \geq 50 hrs.
- iii) 5-day moving congenial temperature (7.2-26.6°C) period \geq 120 hrs. for rainy years and,
- i) 7-day moving > 85% relative humidity period \geq 60 hrs.
- ii) 7-day moving congenial temperature *7.2 - 26.5°C) period \geq 120 hrs. for non rainy years.

These two set of conditions were able to forecast late blight within 10 days of their occurrence (Fig. 6). Weather conditions standardized for rainy and non rainy years were able to predict late blight accurately in all the years.

The above two models were successfully validated for three consecutive years, viz. 1997-98, 1998-99 and 1999-2000 (Table 3) using computer software developed for these models indicating suitability of these models as well as of the software for predicting late blight in western Uttar Pradesh.

Table 3. Validation of the proposed models

Year	Expected date of late blight appearance	Date of appearance of late blight
1997-98	8-18 Nov	9 & 12, Nov
1998-99	13-23 Nov	24 Nov
1999-2000	9-18 Nov	14 Nov

The software can be utilized by the scientists as well as the farmers/associations for

predicting late blight in this region. Farmers can send their daily weather data (temp. & RH) to nearby CPRIC, Modipuram for verifying the status of late blight in their locality. JHULSACAST is almost similar to BLITECAST developed by Krause *et al* (19) except that it has its own forecasting models and that it is meant for forecasting the initial appearance of late blight.

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PRICE SPREAD AND MARKETING PROBLEMS OF POTATO IN BASTI DISTRICT, U.P.

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ABSTRACT : Basti is the major potato-producing district of Gorakhpur division of eastern Uttar Pradesh where the study was carried out. Three different marketing channels were being operated in the study area. The pattern of disposal revealed that marginal farmers were selling higher produce, i.e. 61.94 per cent of total sale, to consumer and retailers, while small and other farmers were found to be selling 84.57 and 93.84 per cent, respectively, to the wholesaler. Substantial amount of consumer rupee (i.e. 93.68 per cent) was finally realized by the producer selling directly to consumer. However, producer's share in consumer rupee was recorded as 56.35 per cent when only one intermediary was involved in marketing process. When two intermediaries were involved, the producer's share was 44.10 per cent. Storage was found to be the important marketing function, which when done by the producer accrued 49.98 per cent of consumer rupee to producer, however, when this function was performed by wholesaler, it accrued only 22.49 per cent to producer. The major marketing problems identified were lack of storage, transportation and marketing knowledge.

INTRODUCTION

District Basti occupies a prominent place in Gorakhpur division, which is the highest potato producing division in eastern Uttar Pradesh. It accounted for an area of 7,496 hectare and recorded a production of 80,856 metric ton in the year 1995-96. The production alone is not responsible for the good economic returns unless and until it is matched with efficient marketing process. In efficient marketing, the prices not only ensure good returns to producer but also imparts ideal return to functionaries so that they do not leave the marketing process and thus marketing system does not collapse. The situation for marketing of potato, however has not been that bright due to several reasons. Potato is a bulky and semi-perishable commodity containing about 80% water. Almost the whole crop is removed from the field in just three months from January to March which has to withstand rising temperature of the coming summer months during storage (1). Therefore, cold storage conditions are required. Storage is also important from the view point of regular supply throughout the year. Another important component of marketing, namely processing, may also open new opportunities of income and

employment. Besides, post-harvest operations namely packing, storage, and marketing create employment opportunities. Taking into account the above facts on the marketing study looks imperative and an attempt, therefore, has been made to study the marketing aspects of potato in Basti district of U.P.

MATERIALS AND METHODS

Concentration of acreage under potato was prime consideration for selecting a block namely Kaptanganj in district Basti where this study was carried out. Six villages having reasonably larger area under potato were selected from Kaptanganj block for this study. The farmers of the selected villages were classified as follows :

1. Below 1 ha. (Marginal)
2. 1-2 ha (Small)
3. 2 ha and above (Others)

Probability-proportionate random sampling technique was used for the selection of farmers. In this way, 38 marginal farmers, 33 small farmers and 19 other farmers were selected for the study. In all, 90 farmers i.e. 15 from each villages were selected. The primary data were

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collected by survey method and relates to the agricultural year, 1996-97.

Methods & technique of analysis : Descriptive statistics, whereby average value was calculated for different parameters, was used. Simple tabular analysis was used.

RESULTS AND DISCUSSION

Pattern of disposal of potato by different size group of farmers : Three different channels were prevalent for the disposal of potato. The different channels of marketing were identified as follows :

- Channel-I : Producer-Consumer
- Channel-II : Producer-Retailer-Consumer
- Channel-III : Producer-Wholesaler-Retailer-Consumer

Under Channel III, following three systems were observed :

- System-I : Without storage
- System-II : Storage by producer
- System-III : Storage by wholesaler

The patterns of disposal of potato by different size group of farmers is presented in table 1.

It is apparent from table 1, that small and other farmers sell higher proportion of their produce to wholesaler. On the contrary marginal farmers, sell major percentage of the produce to consumers and retailers. It is evident from

Table-1 that none of the farmers of other size group sell their produce directly to the consumers. The percentage of the produce sold to wholesaler has proportional relationship with the farm size. The marginal and small size of farmers marketed their produce through Channel-I and Channel-II (i.e. through consumer and retailers), whereas small and other farmers marketed through Channel-II and Channel-III (i.e. retailers and wholesalers).

Price-spread of potato : The term of price spread has been variously defined and understood according to its usage. Generally, it refers to the difference between the two prices, i.e., the price paid by the consumer and the price received by the producer. A study of the price spread involves not only the ascertainment of the actual prices at various stages of the marketing channel, but the costs incurred in the process of the movement of the produce from the farm to the consumer and the margin of various intermediaries². The marketing cost, market margin and price spread per quintal of potato for cited three channels are displayed in Table 2, 3, and 4.

In Channel-I, net price per quintal received by the producers for potato came to Rs. 154.57. Producer's share in consumer's rupee was 93.68%. Marketing cost per quintal incurred by the producer was Rs. 10.43 and the percentage share in consumer's rupee was 6.32. In Channel-I, transportation cost and losses were major factors responsible for widening marketing cost.

Table 1. Pattern of disposal of Potato by different size group of farmers

Channels/ Size group (ha)	Below 1 (marginal)		1-2 (small)		2 & above (other)		Total	
	No. of farmers	% age	No. of farmers	% age	No. of farmers	% age	No. of farmers	% age
Channel-I	16	28.26	2	3.14	-	-	18	20.00
Channel-II	13	33.68	7	12.29	1	6.16	21	23.33
Channel-III	9	38.06	24	84.57	18	93.84	51	56.67
Total	38	100	33	100	19	100	90	100

Table 2. Price spread of potato in Basti vegetable market for Channel-I & Channel-II

S No	Particulars Channel-I		Potato Channel-II	
	Rs./q.	% Share in consumer (Rs)	Rs./q	% Share in consumer (Rs.)
1. Net price received by the producer	154.57	93.68	104.95	56.35
2. Marketing cost incurred by producer	10.43	6.32	17.83	9.57
3. Producer sale price/retailers purchase price.	-	-	122.78	65.92
4. Marketing cost incurred by the retailer	-	-	18.49	9.93
5. Retailers net margin	-	-	44.98	24.15
6. Total marketing cost	10.43	6.32	36.32	19.50
7. Total marketing margin	-	-	44.98	24.15
8. Consumers purchase price	165.00	100.00	185.25	100.00

Table 3. Price spread of potato in Basti vegetable market for Channel-III (Producer-Wholesaler-Retailer-Consumer)

S Particulars No.	System-I		System-II		System-III		Average	
	Rs./q	% share in consumer (Rs.)	Rs./Q.	% share in consumer (Rs.)	Rs./q.	% Share in consumer (Rs.)	Rs./q	% Share in consumer (Rs.)
1. Net price received by the producer	74.05	37.73	165.25	49.98	74.13	22.49	129.50	44.10
2. Marketing cost incurred by the producer	26.05	13.27	84.65	25.60	25.87	7.85	61.65	20.99
3. Producer sale price/ Wholesalers purchase price	100.10	51.00	249.90	75.58	100.00	30.34	191.14	65.09
4. Marketing cost incurred by wholesaler	12.30	6.27	12.42	3.76	71.27	21.63	19.31	6.58
5. Wholesaler net margin	31.89	16.25	24.50	7.41	113.64	34.49	37.01	12.60
6. Wholesaler sale price/ Retailer's purchase price.	144.29	73.52	286.82	86.75	284.91	86.47	247.47	84.28
7. Marketing cost incurred by the Retailer	13.24	6.75	13.39	4.05	13.24	4.02	13.33	4.54
8. Reatiler's margin	38.72	19.73	30.44	9.20	31.35	9.51	32.82	11.18
9. Consumers price	196.25	100	330.65	100.00	329.50	100.00	293.62	100.00

In Channel-II, net price received by the producer for potato came to Rs. 104.94, producer's share in consumer's rupee came to 56.35%. Marketing cost incurred by the producer was Rs. 17.83 and the percentage share in consumer rupees was 9.57. Producer sale price/retailer purchase price was Rs. 122.78 (65.92%). Retailer's margin (Rs. 44.98) and percentage share in consumer's rupee was 24.15. Marketing cost incurred by the retailer was Rs. 18.49 (9.93%).

In Channel-III, producer's sale price/wholesaler's purchase price and net price received by the producer (Wholesaler's

purchase price minus marketing cost incurred by the producer) was highest in case of potato under system-II (49.98%) followed by system-I (37.73%) and lowest in case of system-III (22.49%). Wholesaler's net margin in term of percentage share in consumer's rupee was highest (34.49%) for system-III followed by system-I (16.25%) and lowest (7.41%) in system-II. Retailer's net margin in terms of percentage share in consumer's rupee was highest for system-I (19.73%) followed by system-III (9.51%) and lowest in system-II (9.20%) in case of potato under Channel-III.

Table 4. Interchannel comparison as a whole

S. No.	Particulars	Channel-I		Channel-II		Channel-III	
		Rs./q	% share in consumer (Rs.)	Rs./q.	% share in consumer (Rs.)	Rs./q.	% share in consumer (Rs.)
1.	Net price received by the producer	154.57	93.68	104.94	56.35	129.50	44.10
2.	Marketing cost incurred by the producer	10.43	6.32	17.83	9.57	61.65	20.99
3.	Producer sale price/Retailers purchase price	-	-	122.78	65.92	-	-
4.	Producer sale price/whole saler purchase price.	-	-	-	-	191.14	65.09
5.	Marketing cost incurred by wholesaler	-	-	-	-	19.31	6.58
6.	Wholesaler net margin	-	-	-	-	37.01	12.60
7.	Whole-saler sale price/Retailer purchase price	-	-	-	247.47	84.28	-
8.	Marketing cost incurred by the Retailer	-	-	18.49	9.93	13.33	4.54
9.	Retailer margin	-	-	44.98	24.15	32.82	11.18
10.	Consumer price	165.00	100.00	186.25	100.00	293.62	100.00

It is evident from Table-3 that over all cost paid under Channel-III was highest, i.e., system-I Rs. 51.59 (26.29%), system-II Rs. 110.46, system-III Rs. 110.38 and overall average Rs. 94.29 (32.11%) followed by Channel-II, Rs. 36.32 (19.50%) per quintal and Channel-I, Rs. 10.43 (6.32%) per quintal. It is also evident that marketing cost increased with increase in size of holding and was found highest for large farmers. Increasing trend of marketing cost reveals the involvement of number of middlemen, which resulted in the increase in cost of marketing.

Inter Channel comparison : Interchannel comparison of price spread, marketing costs and margins in Basti market is displayed in Table-4.

Interchannel comparison revealed that the net price received by the producer was maximum in Channel-I (Rs. 154.57) followed by Channel-III (Rs. 129.50) and Channel-II (Rs. 104.95). The marketing cost incurred by

the producer was maximum in Channel-III (Rs. 61.65 per quintal) followed by Channel-II (Rs. 17.83) and Channel-I (Rs. 10.43). By comparing Channel-II, and Channel-III, marketing cost incurred by the retailer in Channel-II was higher in comparison to Channel-III.

Problems in the marketing of potato : Potato is an important vegetable crop enterprise. It is a cash crop and sometimes its cultivation suffers from many problems. Some of the problems are listed below:

1. Desirable and cheaper rates of transportation are not readily available to the producers during the season.
2. Farmers are being compelled to dispose off their produce at lower price in market, due to unavailability of sufficient storage facilities and weak financial structure.
3. Producers are compelled to sell their produce at lower price due to lack of proper knowledge about market intelligence.

Pattern of disposal reveals that marginal farmers sell majority of their produce to consumers and retailers, while small and other farmers sell majority of their produce to wholesalers. With the increase in number of intermediaries, the producer's share in consumer rupee is reduced; while at the same time consumers pay more. This can be avoided with the help of cooperative marketing leaving less room for intermediaries to exploit both producer and consumer.

A glut in market is created during peak harvesting season when the supply is more and this resulted into the situation of imbalances between demand and supply. This results in lowering down the prices, which is directly proportional to the demand. Hence, surplus quantity, if stored, can reduce to some extent the fluctation in potato price in the market. Storage can also restore regular supply of potato throughout the year. Storage, when performed

by producer, accrued 49.98 per cent of consumer's rupee to producer while when performed by wholesaler accrued 22.49 per cent to producer. Hence, cooperative marketing can be effective in providing enough scope for storage by the producer himself. Lack of cheaper transportation, sufficient storage and no knowledge of market are the major constraints significantly reducing the producer's price.

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ROOT WATER UPTAKE AS INFLUENCED BY MULCHED AND UNMULCHED TREATMENTS IN POTATO*

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ABSTRACT : Field experiments were conducted on a silty clay loam soil, classified as Alfisol, Typic Hapludulf, during 1992-93 and 1993-94, to study the effect of mulching on water uptake and overall return of potato crop. Root water uptake (r_2) and water extraction was maximum under pine needle mulched treatments. Mulched treatments maintained higher values of xylem water potential as compared to unmulched treatments. Potato leaf area index (LAI) and tuber yield were also higher under mulched treatments. The mulching saved 60 kg N/ha in addition to 4cm of water.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important cash crop in hills of HP, India. The average yield of potato is 12.18 t ha⁻¹. The major reason for low yield is the lack of assured irrigation facility and dependence on rains, which are erratic. The crop prefers wet moisture regime not only for adequate moisture supply but also for maintenance of low soil strength, which are conducive for development and enlargement of tuber (1, 3). Mulching helps conserve moisture and maximizes its use efficiency. Availability of materials for mulching is a constraint. In hilly areas, however, there are many organic wastes which can be used for mulching. Pine needle is one such material which is a waste from the pine forests. The present study was undertaken to evaluate the effect of mulched and unmulched treatments on root water uptake and crop growth.

MATERIALS AND METHODS

The experiment was conducted on a silty clay loam Typic Hapludulf, during 1992-93 and 1993-94 at the experimental farm of Himachal Pradesh Agricultural University, Palampur (1290 m above mean sea level). The physico-chemical characteristics of the soils (0-15 cm) of the experimental site were pH 5.6, organic carbon 0.94%, CEC 14.0 cmol (p+) kg⁻¹. Available N, P

and K were 381, 19 and 220 kg ha⁻¹, respectively. The treatments included were (i) conventional cultivation (with 20 t ha⁻¹ FYM), (ii) conventional cultivation (with 20 t ha⁻¹ FYM) + pine needle mulch @ 10 t ha⁻¹ and (iii) cultivation with 10t ha⁻¹ FYM + 10t ha⁻¹ compost prepared from *Eupatorium adenophorum*. These treatments were combined with two N levels of 60 and 120 kg ha⁻¹. Fifty per cent of N was applied at planting and rest in two equal split, at stolonization and tuber bulking stages. Phosphorus and potash were applied as basal doses with 60 kg ha⁻¹ of P₂O₅ as single super phosphate and 40 kg ha⁻¹ K₂O as muriate of potash, respectively. Treatments were replicated four times in a randomized block design. Potato (cv. Kufri Jyoti) was planted in 0.5m apart ridges at 0.2 m plant to plant distance on January 14, 1992 and December 28, 1993, respectively.

Eupatorium adenophorum is a widely growing weed but can not be used as fodder. This was used for composting and as substitute of farmyard manure. For preparation of the compost a pit of the size 1.5 x 1.5 x 1.5 m was dug in the month of August. A layer of succulent *Eupatorium* (0.3 m) leaves/plants, was spread at the bottom of the pit. A layer of less rotten farmyard manure along with 40 g of urea was spread over this layer. Likewise four more layers of succulent *Eupatorium* were spread

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in the pit with a layer of farmyard manure and urea in between two layers. In the month of September and November the compost in the pit was worked up for proper mixing to ensure proper decomposition. The compost so prepared contained 1.8% N, 0.05% P and 0.45% K as compared to FYM containing 1.62% N, 0.08% P and 0.32% K.

The different parameters, Xylem water potential (XWP) and leaf area index (LAI) were evaluated at stolonization and tuber enlargement stages of crop growth. XWP was recorded by using portable chamber apparatus. Observations were taken during mid-day (1200-1400 hrs) under full sunlight. LAI was calculated by dividing leaf area by ground area. Mercury water tensiometers at different depths (15, 30, 45 and 60 cm) were installed in one of the replications to monitor the changes in hydraulic gradients and to use them in the calculations of hydraulic flux and root water uptake. The changes in soil water content were determined gravimetrically. Soil moisture data were analysed using Darcy's law. The rates and pattern of water uptake by roots at any given depth were computed from the rate of change of soil water content ($-d\theta/dt$) and water flux divergence (dv_z/d_z) using the known procedure (2).

$$d\theta/dt = dv_z / d_z + r_z \dots\dots\dots (i)$$

$$-r_z = (d\theta/dt) + dv_z / d_z \dots\dots\dots (ii)$$

Where \bar{V}_z (the flux) is positive downward and r_z (cm^3 of water cm^{-3} of soil d^{-1}) is the water uptake by roots at depth Z. Being a negative quantity, r_z is considered as sink. Integration of r_z over a given depth interval in the root zone yields R_z (cm d^{-1}), the sum of water extraction by roots and evaporation i.e.

$$R_z = \int_0^z r_z d_z \dots\dots\dots (iii)$$

By the use of these equations (ii) and (iii), changes in water content ($d\theta/dt$) for selected time intervals were determined. Potato was harvested on June 6, 1993 and May 13, 1994, respectively. The tuber yield was recorded and expressed on per hectare basis.

RESULTS AND DISCUSSION

The water uptake by potato roots under different treatments during drying period from 71 to 84 days after planting (Fig. 1) has shown that r_z (including evaporation) from 0-15 cm soil layer was maximum under mulched treatment (PNN_2) being 0.02 d^{-1} and minimum under unmulched treatment, CCN_1 ($r_z = 0.014 \text{ d}^{-1}$) at the stolonization stage. Similarly, the mulched treatments PNN_1 and PNN_2 showed higher total water extraction rate (R_z) values of 9.21 and 9.12 mm d^{-1} over unmulched treatments CCN_1 , CCN_2 , EN_1 and EN_2 with values of 6.91, 7.48, 7.47 and 7.52 mm d^{-1} , respectively. As the dry period progressed after rain or irrigation, the matric potential decreased under all treatments. For example on 74 days after planting of crop matric potential values observed in treatments PNN_1 , PNN_2 , EN_1 , EN_2 , CCN_1 and CCN_2 at 0.15 m depth were -5.92, -3.81, -3.91, -3.82, -3.46 and -4.35 kPa. And on 84 days after planting, these values dropped to -26.99, -27.21, -29.33, -28.43, -29.91 and 28.22 k Pa in respective treatments. The decrease in the matric potential was primarily as a result of evapotranspiration losses from the soil as also aberved by Sharma & Acharya (4).

The mulched treatments (PNN_1 and PNN_2) maintained higher value of plant water potential expressed as XWP than unmulched treatments (CCN_1 , CCN_2 , EN_1 and EN_2) at stolonization and tuber bulking stages, respectively (Table 1). This may be due to better hydrothermal regimes under mulched treatments, resulting in better plant growth and higher uptake of water.

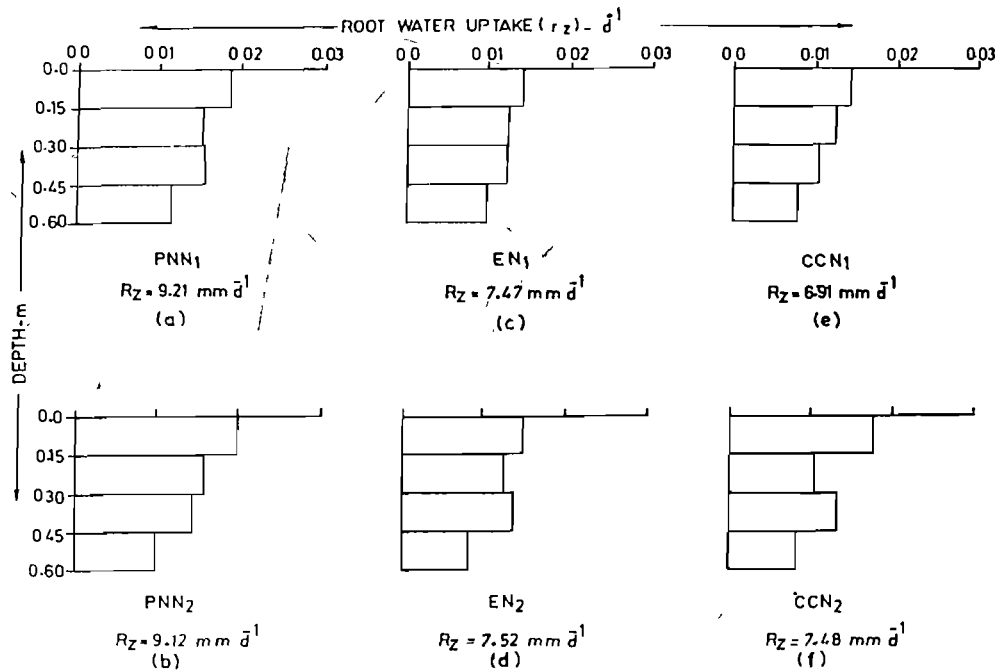


Fig. 1. Water uptake by crop roots under different treatments during a typical drying period from 71 to 84 days after sowing in the year 1992-93

Table 1. Effect of different treatments on xylem water potential (-kpa), leaf area index and potato tuber yields (t ha⁻¹)

Treatments	1992-93					1993-94				
	ST*		TE		Yield	ST		TE		Yield
	XWP	LAI	XWP	LAI		XWP	LAI	XWP	LAI	
PNN ₁	960.0	1.04	1001.0	1.41	12.23	713.0	1.34	780.0	1.81	18.79
PNN ₂	940.0	1.29	970.0	1.44	14.67	658.0	1.59	760.0	1.97	20.17
EN ₁	1090.0	0.88	1280.0	1.31	10.23	840.0	1.19	870.0	1.72	13.83
EN ₂	1050.0	1.01	1180.0	1.34	11.34	790.0	1.41	810.0	1.89	17.09
CCN ₁	1110.0	1.00	1320.0	1.37	10.81	830.0	1.27	950.0	1.79	14.92
CCN ₂	1060.0	1.03	1190.0	1.42	12.67	800.0	1.50	830.0	1.92	18.09
CD (P=0.05)	29.0	0.03	46.0	0.06	2.26	56.0	0.13	42.0	0.12	2.52

*ST - Stolonization, T.E. - Tuber enlargement

PNN₁ - Pine needle mulch and 60 kg N/ha + 20 t FYM/ha;

PNN₂ - Pine needle mulch and 120 kg N/ha + 20 t FYM/ha;

EN₁ - 10 t Compost/ha from *Eupatorium* and 60 kg N/ha + 10 t FYM/ha;

EN₂ - 10 t Compost/ha from *Eupatorium* and 120 kg N/ha + 10 t FYM/ha;

CCN₁ - No mulch and 60 kg N/ha + 20 t FYM/ha; and

CCN₂ - No mulch and 120 kg N/ha + 20 t FYM/ha

The LAI was higher under mulched treatments in comparison to unmulched treatments. The mulched treatment PNN₂ gave significantly higher LAI values (1.29 and 1.44, 1.59 and 1.97) over unmulched treatment CCN₂ (1.03 and 1.42, 1.50 and 1.92) at stolonization and tuber bulking stages of potato growth during first and second year. Similarly mulched treatments gave higher tuber yields over unmulched treatments during both the years (Table 1). *Eupatorium* compost was found as effective as FYM in influencing potato productivity. Mulched + 60 kg N ha⁻¹ resulted in yield similar to that produced by unmulched treatment + 120 kg N ha⁻¹, which resulted in saving of 60 kg N/ha. Mulching also resulted

in higher water use efficiency i.e. only three irrigations (4 cm each) were given as compared to four irrigations in unmulched treatments.

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EFFECT OF SPACING ON WARE CROP OF POTATO RAISED FROM SEEDLINGS

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Seed is the costliest input in potato production. Besides, seed tubers also lead to perpetuation of some diseases. However, pathogens are not carried by true potato seed (TPS) and only few grams of TPS is enough to raise nursery for transplanting. Spacing is an important component of cultural requirement and therefore, present experiment was conducted to find out the optimum spacing for transplants under Haryana conditions.

Experiment consisting of combinations of three each of row (45, 50 and 55 cm) and plant spacing (5, 10 and 15 cm) was laid out in randomized block design at Vegetable Research Farm of Department of Vegetable Crops, CCS Haryana Agricultural University, Hisar. Seedlings of family HPS I/13 were raised in nursery beds. Furrows were lightly irrigated 2-3 days before transplanting. 50 days old seedlings were transplanted on one side of the ridge on 14th and 15th December during 1991 and 1992, respectively in plots measuring 3.0x3.6 m. Crop was supplied with N, P₂O₅ and K₂O at the rate of 150, 50 and 60 kg/ha, respectively. Crop was irrigated immediately after transplanting and later on as and when required. First earthing up was done at 35 days after transplanting and second at 60 days after transplanting, when seedlings were brought in the centre of the ridge. Plant protection measures and other cultural practices were followed as per need of the crop.

Due to short days and low temperature, plant height increased at very slow rate upto 90 days after transplanting (DAT). It was 8.9,

11.3 and 23.9 cm at 30, 60 and 90 DAT, respectively. As the day length and temperature increased, foliage growth also increased at faster speed and plant height reached 46.1 cm at 120 DAT. Plant height, however, was not influenced by inter-row and intra-row spacing. Mortality of seedlings *per se* continued upto harvest (Table 1). But increase in plant to plant spacing from 5-10 & 10-15 cm decreased the mortality of seedlings. Number of branches/plant was not influenced by row to row spacing but increased with increase in plant to plant spacing (Table 2). Number of leaves per plant increased significantly with increase in row as well as plant spacing (Table 2). Dry weight of foliage was highest at closer spacing (45 cm row and 5 cm plant to plant spacing). This may be due to more number of plants at closer spacing and thus higher interception of light. Similar results were obtained by Sarkar & Kabir (3) while working with the progenies of Serranne x DTO-28. The number of tubers per plant, however was highest with wider spacing but yield was highest with closer spacing (45 x 5 cm).

Highest yield at closer plant spacing is due to increase in number of plants per unit area which must have increased light interception and, therefore, resulted in higher tuber yield: Results are in accordance with the findings of other workers (1, 2, 5, 6, 7).

With increase in row spacing from 45 to 55 cm, and intra-row spacing from 5 to 15 cm., there was significant increase in the proportion of >50 and 40-50 mm size tubers on weight as well as number basis. However, the proportion

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Table 1. Effect of plant spacing on establishment of seedlings (%) at different stages (mean of two years)

Stages	Row spacing (cm)											
	45				50				55			
	Plant spacing (cm)				Plant spacing (cm)				Plant spacing (cm)			
	5	10	15	Mean	5	10	15	Mean	5	10	15	Mean
Two Weeks	83	85	89	86	78	89	89	85	73	91	90	85
Four Weeks	71	72	79	74	63	78	79	73	62	77	78	72
Eight Weeks	47	53	67	56	41	53	63	52	43	53	65	54
At harvest	34	42	53	43	31	40	49	40	30	39	50	40
Mean	59	63	72	65	53	65	70	63	52	65	71	63

C.D. at 5%

Row spacing

2 Plant spacing

2

Stages x row spacing

3 Stages

2

Row spacing x plant spacing

3 Plant spacing x stages

3

Stages x row spacing x plant spacing : 5

Table 2. Effect of row and plant spacing on yield and growth of potato (mean of two years)

Row spacing (cm)	Number of branches/plant	Number of leaves per plant	Haulm dry wt. kg/sq. m	Yield kg/sq. m.	Tuber number per plant
45	2.6	8.5	286	1.579	10.8
50	2.7	9.5	266	1.509	11.9
55	2.9	10.9	260	1.449	12.4
C.D. at 5%	N.S.	0.7	6	N.S.	0.7
Plant spacing (cm)					
5	2.6	8.7	288	1.666	10.0
10	2.7	9.9	259	1.488	12.1
15	2.9	10.3	243	1.386	12.8
C.D. at 5%	0.2	0.7	6	0.150	0.7

of small sized tubers decreased with increased plant spacing. The results are in accordance with other-workers (2, 4).

These findings show that there is possibility of raising ware potato crop from transplants, however, before adopting it for commercial production, a lot of research work need to be carried out on different aspects of its cultivation.

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RESPONSE OF POTATO TO NITROGEN AND POTASSIUM FERTILIZATION UNDER U.P. TARAI CONDITIONS

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Potato is grown on an area of about 20,000 hectare in U.P. *tarai* conditions. Supply of nutrients plays an important role in growth and yield. Nitrogen is an essential constituent of protein and chlorophyll whereas potassium helps in translocation of carbohydrates and enhances plant resistance to withstand stresses against drought and frost. Meager information is available regarding nutrient requirement of potato cv. Kufri Ashoka in *tarai* belt of Uttar Pradesh. Therefore, the present investigation was conducted at Pantnagar.

Experiments were laid out at the Vegetable Research Centre of G.B.P.U.A.&T., Patharchatta, Pantnagar, taking four levels of both nitrogen (40, 80, 120 and 160 kg/ha) and potassium (30, 60, 90 and 120 kg/ha) with sixteen combinations over a common dose of phosphorus at 100 kg/ha. The design was R.B.D. factorial with three replications. Soils had pH 6.7 and 7.1, organic carbon 1.49 and 1.46%, available N 143 and 145 kg/ha, P 147 and 143 kg/ha, K 220 and 218. kg/ha during 1997-98 and 1998-99, respectively. The entire quantity of P and K and half dose of N were applied at planting time and remaining N dose was top dressed at the time of earthing up. Pre-sprouted tubers of potato cv. Kufri Ashoka were planted on October 15 and October 20 at 60 x 20 cm inter & intra row spacing in 1997-98, and 1998-99, respectively. Urea, single super phosphate and muriate of potash were the source of nitrogen, phosphorus and potassium fertilization. Recommended agronomic practices and plant protection measures were adopted for raising the healthy crop.

Effect of N and K on plant growth : Plant height were significantly affected by various doses of nitrogen in both the years of experimentation (Table 1). Maximum height was recorded with 160 kg N/ha. These results are also supported by Singh *et al.* (3). Maximum height was recorded by application of 120 kg K₂O/ha. Similar findings have also been reported by Gupta (1).

Effect of N and K on yield : The data on tuber yield presented in table 1, revealed that increasing levels of nitrogen produced significantly higher yield of tubers. The maximum tuber yield was recorded under highest level of nitrogen fertilization (160 kg/ha) which was 78% higher than lowest dose and the minimum was observed in 40 kg/ha. Similar findings have also been reported by Singh *et al.* (3). The increase in tuber yield may be ascribed to higher number of stolons, more plant height and the better assimilation of carbohydrates and their translocation to the tubers which ultimately helped in enlargement of tuber weight. Potassium behaved similarly. This might be due to catalytic involvement of potassium in increasing large size tuber yields. These findings are in conformity with the results of Maity & Arora (2).

Combined effect of N and K: Interaction between nitrogen and potassium was found significant (Table 2). The pooled analysis of data revealed that the highest tuber yield of 274 q/ha was obtained with N 160 x K 120 kg/ha and was followed by 255 q/ha obtained with N 160 x K 90 kg/ha. This might be explained due to better absorption of nitrogen and potassium

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Table 1. Effect of different levels of N and K on plant height and tuber yield

Treatments	Plant height (Cm)			Yield (Q/Ha)		
	1997-98	1998-99	Mean	1997-98	1998-99	Mean
N ₄₀	39.8	39.1	39.4	120	118	119.0
N ₈₀	50.6	47.2	48.9	175	177	176.0
N ₁₂₀	57.2	50.8	54.0	250	247	248.5
N ₁₆₀	60.0	50.3	55.1	255	253	254.0
C.D. (0.05%)	3.9	2.7	2.3	24.7	29.3	22.9
K ₃₀	47.6	46.2	46.9	130	127	128.5
K ₆₀	50.8	47.1	48.9	170	168	169.0
K ₉₀	44.5	49.3	46.9	245	251	248.0
K ₁₂₀	55.0	50.1	52.5	265	269	267.0
C.D. (0.05%)	2.9	4.1	3.1	NS	NS	NS

Table 2. Interaction effect of N x K on tuber yield of potato (pooled analysis)

N\K	30	60	90	120	Mean
40	125.5	135.5	144.5	151.5	139.2
80	169.5	173.5	181.0	190.0	178.5
120	202.0	208.0	216.0	229.5	213.8
160	223.0	241.5	255.0	274.0	248.3
Mean	180.0	189.6	199.1	211.2	-

C.D. (0.5) Nitrogen = 5.6; Potassium = 6.2; N x K = 8.2

from the soil, perhaps due to good rooting behaviour of cv Kufri Ashoka. Similar findings have also been reported by Singh *et al.* (3). Therefore, a fertilizer dose of N 160 x K 120 kg/ha for potato crop was found to be more responsive for the soils of tarai belt of U.P.

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EFFECT OF IRRIGATION AND NITROGEN ON GROWTH, BIOMASS YIELD AND NUTRIENT UPTAKE OF POTATO IN LAHAUL VALLEY OF HIMALAYAS*

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Seed potato is major cash crop. The judicious usage of water and nitrogen fertilizer are important components to realize high tuber yield in Lahaul Valley of Himachal Pradesh. A strong and positive interaction exists between soil water supply and nitrogen fertilization (1). However, information with respect to the optimum levels of irrigation, nitrogen and their interaction is scanty for this region. The present study was aimed at optimising levels of irrigation, nitrogen and their interaction on crop growth, biomass yield and nutrient uptake.

A field experiment was laid out in a factorial randomized block design with three replications at Regional Research Station, Kukumseri. The soil was sandy loam in texture having bulk density (1.40 Mg/m³), hydraulic conductivity (0.74 cm/hr), the field capacity (28.8% W/W) and permanent wilting point being 7.0% W/W. The soil was neutral in reaction (pH 6.8) with organic carbon content (0.81%), available N (267/kg/ha), P (31 Kg/ha) and K (324 kg/ha). The treatment consisting of 4 levels of irrigation, viz. IW/CPE ratio (1.4, 1.2, 1.0 and 0.8) and 4 levels of N (75, 100, 125 and 150 kg N/ha) were taken in plot size of 3x2m (gross). A basal dose of 100 kg P₂O₅/ha and 50 kg K₂O/ha was applied at the time of planting. The depth of irrigation applied was 5 cm. The potato cv. Kufri Chandramukhi was planted at 40x15 cm spacing on 10th June 1994 and harvested on 2nd Oct. 1994. Tuber numbers/hill and total

biomass (tuber+haulms) were recorded. Total (tuber+haulms) uptake of N, P, and K was calculated as per standard methods.

Tuber/hill : The perusal of data (Table 1) showed that tuber numbers/hill differed significantly among different irrigation and nitrogen levels. The treatment combinations of 1.4 IW/CPE ratio with 150 kg/N ha gave the highest (7.0) number of tuber/hill and 0.8 IW/CPE ratio with 75kg N/ha gave the least (3.0) number of tuber/hill. Similar was the results for N levels.

Biomass yield : Irrigation and N treatments has a significant effect on total biomass (tuber+haulms) yield. Interaction effect of irrigation and nitrogen was found to be significant. Treatment combination of 1.4 IW/CPE ratio with 150 kg N/ha gave the highest (31.1 t/ha) biomass yield and 0.8 IW/CPE ratio with 75 kgN/ha gave the lowest (18.8 t/ha) biomass yield (Table 1.) Zbiec *et al.* (3) also reported that irrigation increased the average tuber yield and reduced the adverse effect of nitrogen application causing nitrate accumulation.

Nutrient uptake : Total (tuber+haulms) N, P and K uptake differed significantly among different irrigation and nitrogen levels. There was consistent and substantial increase in N, P and K uptake under different irrigation and nitrogen levels (Table 2). The interaction effect

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Table 1. Effect of irrigation and nitrogen on tuber no./hill and total biomass (tuber+haulms) yield

Treatment Irrigation	Nitrogen kg/ha									
	75	100	125	150	Mean	75	100	125	150	Mean
	Tuber/hill					Biomass (Tuber+haulms) yield (t/ha)				
IW/CPE=1.4	5.7	6.0	6.3	7.0	6.3	26.7	27.5	29.8	31.1	28.8
IW/CPE=1.2	5.3	5.0	5.0	5.0	5.1	25.4	25.7	25.8	25.8	25.7
IW/CPE=1.0	3.3	3.7	3.7	4.0	3.7	23.5	23.9	24.8	25.9	24.5
IW/CPE=0.8	3.0	3.0	3.0	3.3	3.1	18.8	19.5	21.6	22.6	20.6
Mean	4.3	4.4	4.5	4.8	-	23.6	24.1	25.5	26.4	-
	Irrigation	Nitrogen	Irri. x Nitrogen			Irrigation	Nitrogen	Irri. x Nitrogen		
CD (P=0.05)	0.30	0.30	N.S.			0.96	0.96	1.96		

Table 2. Effect of irrigation and nitrogen on total nutrient uptake (Kg/ha) by potato

Treatment Irrigation	Nitrogen kg/ha														
	75	100	125	150	Mean	75	100	125	150	Mean	75	100	125	150	Mean
	Nitrogen					Phosphorus					Potassium				
IW/CPE=1.4	177.8	188.7	204.4	216.0	196.7	22.6	24.5	28.1	30.1	26.3	184.0	189.6	203.7	213.3	197.6
IW/CPE=1.2	150.8	157.2	163.8	168.4	160.1	16.5	18.2	19.3	20.4	18.6	164.3	168.2	173.3	177.2	170.8
IW/CPE=1.0	119.2	126.6	136.0	145.1	131.7	13.0	13.9	15.3	16.2	14.6	140.2	148.4	156.2	162.1	151.7
IW/CPE=0.8	85.9	87.8	101.6	110.3	94.6	6.9	8.1	10.0	11.6	9.1	103.3	107.7	122.1	131.4	116.1
Mean	133.4	140.1	151.5	160.0	-	14.8	16.2	18.2	19.6	-	147.9	153.5	163.8	171.0	-
	Irri.	Nitro.	Irri. x Nitro.			Irri.	Nitro.	Irri. x Nitro.			Irri.	Nitro.	Irri. x Nitro.		
CD (P=0.05)	2.18	2.18	4.36			0.31	0.31	0.62					11.6	1.16	2.33

of irrigation and nitrogen was found to be significant on uptake of all the three nutrients. The treatment combination of 1.4 IW/CPE ratio with 150 kg N/ha gave the highest (216.0 kg N/ha, 30.1 kg P₂O₅/ha and 213.3 kg K₂O/ha) N, P and K uptake, while the 0.8 IW/CPE ratio with 75 kg N/ha gave the lowest (85.9 kg N/ha, 6.9 kg P₂O₅/ha and 103.3 kg K₂O/ha) N, P and K uptake. It could be attributed to the better soil moisture conditions during plant growth which helped in better utilization of nutrients by the

plant, thereby resulting in highest yield and nutrient uptake. Similar results have been reported by Roy & Tripathi (2).

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EFFECT OF IRRIGATION AND NITROGEN LEVELS ON GROWTH AND YIELD OF POTATO

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Irrigation and nitrogen application have great bearing on the growth and yield of potato. Adequate and timely supply of irrigation water with optimum dose of nitrogen to potato contribute maximum to the growth of crop. Although much work has been done on these aspects, the information on recently released TPS population C-3 is meagre. Hence the present investigation was carried out to study the effect of irrigation and nitrogen levels on various growth parameters and yield of potato varieties.

The experiment was conducted at Regional Research Station, Gujarat Agricultural University, Sardarkrushinagar during *rabi* season of 1995 and 1996 on loamy sandy soil. The experimental plot soil was having 7.8 pH and contained 0.32 % organic carbon, 189 kg/ha available nitrogen, 56 kg/ha available phosphorus and 240 kg/ha available potash. The experiment was laid out in split plot design replicated four times with four irrigation levels as main plot treatment (1.00, 1.25, 1.50 and 1.75 IW:CPE ratio) and combination of varieties (Kufri Badshah and TPS C-3) and nitrogen levels (180, 220 and 260 kg/ha) as sub plot treatments. Variety Kufri Badshah was raised from cutting of tubers while TPS C-3 was raised from tuberlets in which whole tubers were used as planting material. Dry weight of shoots was recorded at 30, 60 and 90 DAP (days after transplanting) and of tubers at 60 and 90 DAP. Leaf area was determined by Leaf Area Meter immediately after sampling. Data obtained on leaf area were used for the determination of

Leaf Area Index (LAI), Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR).

Frequent irrigation at higher ratio favoured profuse plant growth. Up to 30 DAP the difference in LAI was not significant. The significant differences were recorded at 60 DAP. At this stage, LAI increased with increase in irrigation level up to 1.50 IW:CPE ratio. With advance in age at 90 DAP, the maximum LAI was recorded with 1.75 IW:CPE ratio. LAI in all the irrigation levels increased up to 60 DAP (Table 1) thereafter declined at maturity due to senescence of leaves (1). Kufri Badshah recorded significantly higher LAI at 30, 60 and 90 DAP as compared to TPS C-3. Similarly, LAI increased significantly with increase in level of nitrogen at 60 and 90 DAP, while at 30 DAP the increase in LAI was registered up to 220 kg/ha. Higher dose of nitrogen application favoured vegetative growth resulting into higher LAI. Singh (5) also recorded similar results.

No significant difference was observed due to irrigation levels on dry weight of shoots/plant up to 30 DAP. Thereafter at 60 and 90 DAP, increase in dry weight of shoots and tubers/plant was obtained due to irrigation up to 1.50 IW: CPE ratio. Adequate supply of irrigation water kept leaves in turgid condition which coupled with higher LAI resulted in higher rate of photosynthesis and translocation of photosynthate into tubers resulting in increased dry matter/plant. The findings are corroborative of Misra & Singh (4).

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Table 1. Effect of irrigation and nitrogen levels on dry biomass/plant, LAI RGR, CGR and NAR on potato varieties

Treatment	Laf Area Index			Dry weight of shoots/plant(g)			Dry weight of tubers/plant (g)		CGR (g/day)	RGR g/g/day	NAR g/cm ² /day	Tuber yield (q/ha)
	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	60 DAP	90 DAP				
IW:CPE ratio												
1.00	0.87	1.40	0.91	1.87	5.04	7.42	11.39	21.47	6.47	7.23	6.98	182.46
1.25	0.90	1.56	1.01	1.89	5.59	8.18	12.66	23.91	7.26	7.56	7.33	203.94
1.50	0.90	1.72	1.13	1.92	6.15	8.89	14.05	26.71	8.13	7.83	7.61	229.76
1.75	0.92	1.78	1.19	1.96	6.30	9.16	14.59	26.32	8.41	7.88	7.78	235.14
CD (0.5)	NS	0.07	0.04	NS	0.34	0.49	1.25	1.47	0.42	0.26	0.45	12.12
Varieties												
Kufri Badshah	0.98	1.66	1.09	2.05	6.00	8.63	13.81	25.49	7.89	7.52	7.33	219.72
TPS C-3	0.82	1.57	1.02	1.77	5.55	8.20	12.54	23.72	7.25	7.72	7.51	205.93
CD (0.5)	0.03	0.05	0.03	0.07	0.17	0.25	0.67	0.69	0.25	0.14	NS	6.73
N level (kg/ha)												
180	0.84	1.45	0.98	1.81	5.12	7.54	11.47	21.66	6.60	7.38	7.15	190.09
220	0.91	1.64	1.07	1.91	5.84	8.50	13.34	25.05	7.67	7.67	7.46	215.88
260	0.95	1.75	1.12	2.02	6.36	9.20	14.71	27.11	8.47	7.82	7.66	232.53
CD (0.5)	0.04	0.05	0.03	0.08	0.20	0.31	0.51	0.84	0.30	0.18	0.21	5.50

Dry weight of shoots and tubers/plant was higher with Kufri Badshah as compared to TPS C-3 at all growth stages. As Kufri Badshah had a better vigour of plants with higher leaf index, it resulted in greater biological yield.

Each increase in nitrogen levels significantly increased the dry weight of shoots and tubers/plant at all growth stages. Higher growth rate at higher level of nitrogen seems to have led to more synthesis and translocation of photosynthates to the developing tubers by the plants. Misra & Singh (4) also reported higher dry matter with higher dose of nitrogen.

CGR and RGR increased with increase up to irrigation at 1.50 IW: CPE ratio. This indicated that higher ratio (1.75 IW: CPE) did not show beneficial effect on CGR and RGR (Table 1).

Higher plant growth and translocation of photosynthate from source to sink at adequate supply of water (1.50 IW:CPE ratio) produced more biological yield as a result of more leaf area which induced higher CGR. Increase in each level of nitrogen, significantly increased CGR, though, RGR and NAR increased only up to 220 kg N/ha. Dry weight of whole plant increased linearly with increasing level of nitrogen (Table 2). These results are in agreement with findings of Kumar *et al.* (2).

Variety Kufri Badshah recorded significantly higher dry weight of shoots and tubers/plant when it received 260 kg N per ha, while at same level of nitrogen variety TPS C-3 did not show its potential to produce dry matter/plant at 60 and 90 DAP. Similar trend was observed in CGR also (Table 2).

Table 2. Interaction effect of varieties and nitrogen on dry weight of shoots and tubers/plant and CGR

Nitrogen levels (kg/ha)	Dry weight of shoot/plant(g).				Dry weight of tubers/plant (g)				CGR (g/day)	
	60 DAP		90 DAP		60 DAP		90 DAP		Kufri Badshah	TPS C-3
	Kufri Badshah	TPS C-3	Kufri Badshah	TPS C-3	Kufri Badshah	TPS C-3	Kufri Badshah	TPS C-3		
180	5.17	5.07	7.48	7.61	11.65	11.30	22.03	21.29	6.62	6.51
220	5.99	5.70	8.58	8.41	13.76	12.91	25.42	24.68	7.86	7.48
260	6.84	5.88	9.82	8.57	16.01	13.40	29.02	25.20	9.18	7.75
CD (.05)		0.29		0.44		0.72		1.19		0.43

Tuber yield increased with an increase in IW:CPE ratio from 1.25 to 1.75 but increase was significant up to 1.50 ratio. Adequate soil moisture condition favoured higher LAI, dry weight of shoots and tubers/plant, CGR, RGR and NAR which resulted in higher growth and ultimately higher yield. Variety Kufri Badshah produced significantly higher tuber yield than TPS C-3. It might be due to significantly higher value of plant growth attributes observed in Kufri Badshah. Tuber yield of potato increased with each successive increase in nitrogen levels. High fertility favoured profuse vegetative growth resulting in higher rate of photosynthesis and increased translocation of photosynthates into tubers with higher yield.

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GROWTH ANALYSIS OF POTATO IN RELATION TO BIODYNAMIC PACKAGE AND ORGANIC MANURES WITH CHEMICAL FERTILISERS

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Growth analysis techniques have been used in manipulation of different combinations of organic manures and inorganic fertilisers. Influence of various factors on the rate and time of dry matter accumulation and its distribution in different plant part is helpful in improving the productivity through combined use of organic manures and inorganic fertilisers. Therefore, growth rhythms of potato under different levels of organic manures and inorganic fertilisers and biodynamic package were worked out.

The field experiment was conducted at the Research Farm, JNKVV, College of Agriculture, Indore (M.P.), during *rabi* season of 1997-98 on medium black soil (pH-7.6) having organic carbon (0.24%), available N (160 kg/ha), available P (11.20 kg/ha) and available K (663 kg/ha). The experiment was laid out in a Randomised Block Design comprising 10 treatments with 4 replications. The Potato cultivar 'Kufri Jyoti' was planted on 8th November 1997 and harvested on 16th February, 1998.

The required quantities of manures, viz. Poultry manure (PM), Nadep compost (NC), Biogas slurry (BGS) and Farmyard manure (FYM) and 50% and 75% N, P₂O₅ and K₂O/ha of the recommended dose (150 kg N, 120 kg P₂O₅ and 80 kg K₂O/ha) were applied to the respective plots. Before using the organic manures they were analysed chemically for

their N, P₂O₅ and K₂O composition. FYM contained 0.7%, 0.5% and 0.8%; NC-0.9%, 0.6% and 0.9%; BGS-1.4%, 0.8% and 1.0%; PM-2.17%, 1.5% and 1.2% and biodynamic package contained 1.65%, 1.5% and 1.2% of N, P₂O₅ & K₂O, respectively. Manures were applied in furrows immediately before planting. Half amount of nitrogen with full doses of P₂O₅ and K₂O were applied as basal and the remaining amount of nitrogen was top dressed at 35 days after planting (DAP). Biodynamic package consisted of biodynamic compost @ 40t/ha, Cowpit pat (CPP) manure @ 6.25 kg/ha, Preparation 500 (P500) @ 75 g/ha, Preparation 501 (P501) @ 2.5 g/ha and Preparation 504 (P504) @ 2.5 lit/ha. Biodynamic compost was applied in furrows just prior to planting of the tubers and thoroughly mixed in soil. CPP was sprayed two times according to the schedule of "Planting Calendar". Likewise four mist sprays of P500 and three foliar sprays of P504 were applied.

Five plants were sampled randomly at 25, 45, 65 and 85 DAP. The plants were separated into shoots, roots and tubers and their dry weights recorded. Leaf area was measured using a planimeter to compute the leaf area index. From these data, crop growth rate (CGR = g.m⁻² day⁻¹), net assimilation rate (NAR = g.g⁻² day⁻¹) were computed as described by Watson & Wilson (5) and later relative growth rate (RGR = mg. cm⁻² day⁻¹) was calculated (1). Harvest index (HI) was calculated by dividing

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economic yield (tuber yield) by the biological yield and then multiplied by 100.

A. Total Dry Matter accumulation (TDM) :

The total dry matter accumulation in the plants increased gradually with time. The data at 65 DAP (Table 1) were statistically analysed. There were significant differences in total dry matter accumulation among various treatments. The highest value (133.68 g/plant) was recorded with 6.5 t PM + 75% NPK followed by 10.2 t BGS + 75% NPK (121.95 g/plant) whereas, the lowest was with 12.9 t BGS ha⁻¹ + 50% NPK (110.20 g/plant). Though the nitrogen level in all the treatments was constant, increasing trend of dry matter accumulation was observed which may be due to different levels of P₂O₅ and K₂O in the organic manures. Sharma & Ezekiel (4) reported the effect of K₂O with increasing trend of dry matter accumulation. Jenkins & Nelson (2) also reported highest dry matter accumulation at 240 kg N/ha. The performance of different manures in dry matter accumulation was in the order: PM>BGS>FYM>NC.

B. Leaf Area Index (LAI) : The LAI increased with time and was highest at 65 DAP (Table 1) and later declined at the time of dehauling. Significant differences were observed amongst various treatments with respect to LAI. The highest LAI (4.84) was recorded with 6.5 t PM ha⁻¹ + 75% NPK followed by 10.2 t BGS + 75% NPK ha⁻¹. The differential response in LAI of the plants was apparently due to variation in content of P₂O₅ and K₂O in the organic manures.

C. Net Assimilation Rate (NAR) : Various treatments showed significant differences (Table 1) pertaining to NAR. The highest NAR (3.38 mg. cm⁻² day⁻¹) was associated with 6.5 t PM/ha + 75% NPK followed by 10.2 t BGS ha⁻¹ + 75% NPK (2.92 mg. cm⁻² day⁻¹), while the lowest NAR was recorded in case of 20.08 t NC ha⁻¹ + 50% NPK which was found to be

at par with 15.9 t NC ha⁻¹ + 75% NPK (1.86. cm⁻² day⁻¹). Initially the NAR was low since LAI was very less. Later it increased upto 65 DAP and reached senescence phase at 85 DAP. Watson & Wilson (6) corroborated well with the present finding that the additional N had no effect on NAR in potatoes.

D. Crop Growth Rate (CGR) : CGR increased gradually and attained peak during tuber development period and later on decreased. This increase in CGR may be attributed to decrease in NAR and also to reduced leaf area. Different treatments had significant influence on the average CGR of potato. The highest CGR (4.74 g.m⁻² day⁻¹) was associated with biodynamic package followed by 75% NPK+6.5 t PM ha⁻¹ (4.20 g.m⁻² day⁻¹), both being at par. The lowest CGR was measured with 50% NPK + 20.08 t NC/ha (2.37 g.m⁻² day⁻¹). This is contrary to the finding of Khalak & Kumaraswamy (3) who had reported increase in LAI with increasing fertiliser levels.

E. Relative Growth Rate (RGR) : The RGR of potato increased with time and reached maximum at 65 DAP, thereafter it declined owing to concomitant decrease in NAR and CGR. Significant differences were observed amongst various treatments. The maximum RGR was measured with biodynamic treatment (0.121 g.g⁻¹ day⁻¹) followed by 75% NPK + 6.5 t PM ha⁻¹ (0.114 g.g⁻¹ day⁻¹). Whereas, the minimum RGR was obtained with 50% NPK + 20.08 t NC ha⁻¹ (0.087 g.g⁻¹.day⁻¹).

The increasing trend of all these parameters was observed upto 65 DAP and a declining trend afterwards may be ascribed to the growth curve. The senescence phase of potato plant started after 65 days of planting, resulting into lower values of the studied growth parameters. The differential response of various treatments provided may be due to different levels of P₂O₅ and K₂O contents in the organic manure.

Table 1. Influence of various treatments on growth parameters of potato

Treatments	Total Dry Matter accumulation/ Plant (g)			Leaf Area Index (LAI)			Crop Growth Rate (g m. ⁻² Day ⁻¹)			Relative Growth Rate (g g ⁻¹ day ⁻¹)			Net Rate Assimilation (mg cm ⁻² day ⁻¹)				
	25	45	65	25	45	65	25-45	45-65	65-85	25-45	45-65	65-85	25-45	45-65	65-85		
	DAP	DAP	DAP	DAP	DAP	DAP	DAP	DAP	DAP	DAP	DAP	DAP	DAP	DAP	DAP		
50% NPK+25.8 t FYM*/ha	21.47	57.48	111.47	0.25	1.69	4.28	3.88	3.09	5.54	2.44	0.100	0.129	0.105	6.023	5.31	2.65	81.35
50% NPK+20.08t NC*/ha	19.87	55.05	112.19	0.32	1.70	4.38	3.99	2.85	4.71	2.37	0.096	0.119	0.087	5.467	4.28	1.76	84.95
50% NPK+12.9t BGS*/ha	20.65	56.30	110.20	0.29	1.50	4.35	3.97	2.75	4.93	3.61	0.094	0.123	0.108	5.288	4.71	2.60	83.65
50% NPK+8.3t PM*/ha	21.42	61.70	120.01	0.37	1.79	4.50	4.66	2.99	5.41	4.00	0.098	0.128	0.113	5.564	5.11	2.88	86.55
75% NPK+20.4t FYM/ha	20.99	70.26	119.57	0.29	1.65	4.56	4.15	3.07	5.66	3.81	0.099	0.130	0.110	5.737	5.33	2.62	82.30
75% NPK+15.9t NC/ha	21.90	64.12	116.62	0.34	1.87	4.75	4.20	3.29	5.36	2.41	0.103	0.127	0.088	6.074	5.01	1.86	83.75
75% NPK+10.2t NC/ha	24.79	68.80	121.95	0.40	2.11	5.08	4.50	3.56	7.30	3.23	0.107	0.130	0.083	6.640	5.24	2.92	85.95
75% NPK+6.5t PM/ha	30.20	74.45	133.68	0.50	2.38	5.40	4.84	4.20	6.15	4.20	0.115	0.134	0.114	7.445	5.59	3.38	88.25
Biodynamic package	24.06	65.78	119.25	0.34	1.75	4.61	4.61	3.64	6.19	4.74	0.108	0.135	0.121	6.776	5.83	2.60	86.05
100%NPK+15t FYM/ha	19.62	56.95	113.53	0.32	1.70	4.46	3.89	3.20	4.82	3.12	0.101	0.122	0.098	5.880	4.49	2.13	84.65
SEm±			2.386				0.057		0.217				0.004			0.838	NS
CD (5%)			6.924				0.17		0.629				0.012			0.26	

FYM : Farmyard Manure, NC : Nadep Compost, BGS : Biogas Slurry, PM : Poultry Manure.

F. Harvest Index (HI) : Treatments had non-significant influence on harvest index of potato. Nevertheless, the highest HI of 88.25% was recorded with 75% NPK+ 6.5 t PM ha⁻¹ followed by 50% NPK+8.3 t PM ha⁻¹ (86.55%), while the lowest HI was associated with 50% NPK + 25.8 t FYM ha⁻¹ (81.35%). Non-significant difference may be ascribed to proportionate vegetative growth with the tuber yield.

Application of poultry manure excelled in performance of all the growth parameters reflected in to highest tuber yield followed by BGS. On the basis of investigation, it could be concluded that 25% of NPK can be saved by the application of either poultry manure or by biogas slurry in conjunction with 75% NPK, which resulted in net returns of Rs. 51,012.50/ha and Rs. 49,490.00/ha with C:B ratio of 3.14

& 3.19, respectively. The only limitation associated with the use of biodynamic package is adoption of entirely chemical free environment which might have been major cause of lower values of growth parameters and also lower yield due to uncontrollable severe infestation of blights.

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EFFECT OF ROW SPACING AND PLANTING SYSTEM ON GROWTH AND YIELD OF POTATO UNDER SURFACE AND DRIP IRRIGATION*

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Potato is a highly input intensive crop. Among various inputs, irrigation plays a dominant role in potato tuber production.

In the present day context, due to water scarcity, the efficient and economic utilization of irrigation water is very essential. Thus, there is a need to develop a technology which increase the production by involving efficient irrigation water application method such as drip system.

The experiment was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri during *rabi* 1996-97. The treatment consisting of 2 row spacings (60 and 45 cm), 2 planting systems (normal and paired row) and 2 irrigation methods (drip and surface) which were laid out in a Factorial Randomised Block Design with 3 replications. Seed tubers were planted on 25th November, 1997. A fertilizer dose of 150 kg N, 60 kg P₂O₅/ha and 80 kg K₂O were applied in which half of N and all P₂O₅ and K₂O were applied at the time of planting and remaining half N at earthing up i.e. after one month of planting.

The irrigation were scheduled on the basis of cumulative pan evaporation at every alternate day for drip irrigation and at 50 mm CPE in furrow method of irrigation with 50 mm irrigation depth. The entire data have been presented in table 1.

Effect of irrigation method : The drip irrigation system produced significantly higher number of tubers per plant (5.58), size of tubers (16.08 cm), weight of tubers per plant (145.5g) and tuber yield (20.43 tonnes/ha) as compared to surface irrigation. Similar trend was also noticed in case of biometric characters. The better plant characters and higher tuber yield may be attributed to optimum soil moisture under drip system in the surface soil throughout the period of crop growth, which helped in better root growth and tuber development. Drip irrigation saved 46 per cent irrigation water over surface irrigation. Gorantiwar & Pampattiwar (1) also reported that weight of tuber per plant was maximum in drip irrigation system as compared to furrow irrigation system at Rahuri.

Effect of row spacing : Wider spacing of 60 cm significantly increased tuber yield over narrower spacing of 45 cm. This increase was due to favourable effect of wider spacing on number of tubers per plant, size of tubers, weight of tuber per plant and yield of tuber at harvest. Similar trend was also noticed in yield contributing characters. Singh (3) reported higher number of tuber per plant in 60 cm row spacing than 50 cm spacing in potato.

Effect of planting system : The normal planting produced significantly higher growth and yield

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Table 1. Effect of row spacing and planting system on growth and yield of potato under surface and drip irrigation

Treatments	Mean plant height (cm)	Mean plant spread (cm)	No. of leaves/plant	No of branches/plant	No. of tuber/plant	Mean size of tuber (cm)	Mean tuber/plant (g)	Yield of tubers (t/ha)
A. Irrigation system								
Drip	44.05	42.07	30.98	5.79	5.58	16.08	145.50	20.43
Surface	41.86	40.22	29.53	4.42	4.33	14.57	140.75	17.73
CD at 5%	0.79	0.93	0.82	0.77	0.67	0.77	2.16	0.86
B. Planting system								
Normal	43.54	41.83	30.75	5.59	5.33	15.79	144.50	19.66
Paired	42.40	40.45	29.77	4.62	4.58	14.86	141.75	18.49
CD at 5%	0.79	0.93	0.82	0.77	0.67	0.77	2.16	0.86
C. Row spacing								
45 cm	42.08	40.08	29.10	4.05	4.00	14.24	140.25	17.86
60 cm	43.85	42.20	31.42	6.16	5.92	16.21	146.00	20.29
CD at 5%	0.79	0.93	0.82	0.77	0.67	0.77	2.16	0.86

components, viz. number of tubers per plant, size of tubers, weight of tubers per plant and tuber yield at harvest as compared to paired row planting. The higher tuber yields in normal planting might be due to improvement in vegetative growth and yield parameters over paired row planting. Singh (2) also reported higher weight of tubers in single row planting than double row planting system in potato in Punjab.

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WEED MANAGEMENT IN POTATO UNDER DIFFERENT FERTILITY LEVELS IN THE NORTH-WESTERN HILLS*

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Weeds cause enormous losses in crop yield. The yield losses in potato crop due to weeds range from 10 to 80% (4). The problem of weeds may vary with fertility levels since the elevated soil fertility due to farm yard manure (FYM) or fertiliser application usually stimulate the growth of the weeds much earlier than the growth of the crop, thus reducing the crop yield (1, 6). Keeping the above in view, the present study was undertaken to examine the role of two herbicides (alachlor and paraquat) in potato crop under varying fertility levels on weed growth and the yield of potato crop grown in the North-western hills.

Field experiments were conducted at the Lower Laboratory Farm of the Central Potato Research Institute, Shimla during 1994 and 1995 on a sandy loam soil, slightly acidic (pH 6.1) in reaction. The soil contained 1.1% organic carbon, 2397 kg total nitrogen/ha and was high in available phosphorus (133 kg/ha) and available potassium (632 kg/ha). The treatments consisted of combination of four fertility levels and four weed control methods (Table 1). Alachlor was applied at 1.5 kg/ha as pre-emergence (immediately after potato planting) and paraquat was applied at 0.5 kg/ha as early post-emergence (when about 5% of potato plants had emerged) using 800 litres of water per hectare. The experiment was laid out in factorial randomised block design with three replications. The medium sized tubers of potato cv. Kufri Jyoti at 50 x 20 cm spacing were planted in the second fortnight of April, during both the years. Half of the nitrogen and whole

of FYM, P and K were applied at the time of planting in furrows and remaining nitrogen was applied at 45 days after planting (DAP).

Manual weeding was done at 45 DAP and was immediately followed by earthing up in the manual weeding+earthing up treatment. The crop was harvested in first week of September and yield was recorded in three different grades i.e. small (< 30 g), medium (30-60 g) and large (> 60 g) size tubers. The observation on number of main stems per hill and plant height (cm) of potato crop was also recorded 20 days before harvesting. Weeds were collected randomly from a quadrat of 0.50 m x 0.50 m at one place in each plot at harvest. The N, P and K in weeds and tuber samples were determined by the standard procedures (3). Weed control efficiency was calculated using the following formula:

$$\text{Weed control efficiency} = \frac{\text{Weed dry matter yield in control} - \text{weed dry matter yield in a treatment}}{\text{weed dry matter yield in control}} \times 100$$

The data obtained were pooled over the years for analyses using standard statistical procedures (2).

Weed flora : The predominant weed flora in experimental plots were *Echinochloa crusgalli* (L.) Beauv, *Setaria glauca* (L.) Beauv, *Oxalis corniculata* L., *Amaranthus viridis* L., *Polygonum* spp., *Chenopodium murale* L., *Melilotus indica* L and *Digitaria sanguinalis* (L) Scop.

Effect on weeds : The interaction effect of fertility levels and weed control methods was not significant on weed dry matter yields, hence

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Table 1. Effect of different fertility levels and weed control methods on weed dry matter yield, weed control efficiency and total tuber yield (Pooled over 1994 & 1995)

Treatments	weed dry matter yield (g/m ²)			Weed control efficiency (%)	Total tuber yield (q/ha)
	Dicot	Monocot	Total		
Fertility levels (per ha)					
1. 150 kg N+100 kg P ₂ O ₅ + 100 kg K ₂ O	46.7 (6.139)	159.3 (12.093)	206.0 (13.721)	—	120.0
2. 30 t FYM	46.9 (6.455)	139.8 (11.334)	186.7 (13.127)	—	119.8
3. 15t FYM + 150 kg N+ 50 kg P ₂ O ₅ +50 kg K ₂ O	42.3 (6.095)	157.3 (11.807)	199.6 (13.478)	—	131.5
4. 30t FYM+150 kg N	51.0 (6.502)	168.7 (12.376)	219.7 (14.109)	—	129.0
C.D. (at 5%)	NS	NS	NS		NS
Weed control methods					
1. Weedy check	97.9 (9.745)	257.4 (15.786)	355.2 (18.632)	—	94.0
2. Manual weeding+ earthing up	42.1 (6.357)	169.4 (12.553)	211.5 (14.219)	40.5	124.0
3. Alachlor 1.5kg/ha	15.2 (3.662)	76.8 (8.535)	92.0 (9.415)	74.9	134.7
4. Paraquat 0.5 kg/ha	31.7 (5.427)	121.5 (10.696)	153.2 (12.169)	56.9	147.6
C D (at 5%)	(0.820)	(1.681)	(1.463)		15.7

Figures in parentheses are square root (x+1) transformed values

main effect of the treatments are reported (Table 1). The monocot weeds dominated the total weed dry matter yield. The maximum total weed dry matter was recorded in plots which received 30t FYM+150 kg N/ha. The effect of different fertility levels on the dry matter yield of dicot, monocot as well as total weeds was found to be non-significant. Among the weed control treatments, alachlor @ 1.5 kg/ha resulted in the significantly lowest dry matter yields of dicot, monocot and total weeds. This treatment gave 84.5, 70.2 and 74.9% control of dicot, monocot and total weeds, respectively, over weedy check. Other weed control methods also recorded significantly lower dry matter yields of dicot, monocot and total weeds than the weedy check treatment. The dicot, monocot and total weed dry matter yields recorded under paraquat treatment were statistically at par with

that found under the manual weeding+earthing up treatment.

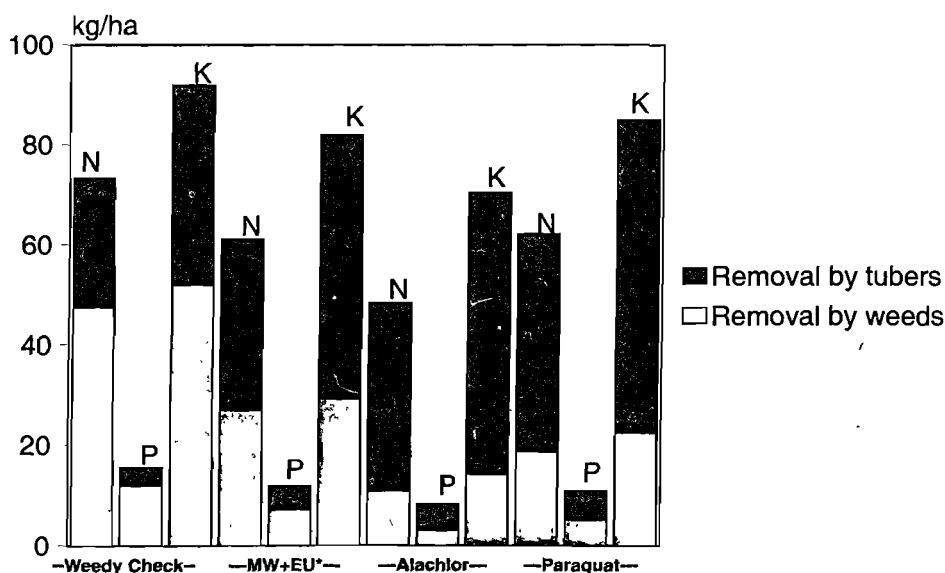
Effect on crop growth and tuber yield : The effect of different fertility levels and weed control methods as well as their interaction was not significant on number of main stems per hill. Application of nitrogen alone or in combination with other fertilisers/FYM resulted in significantly taller plants than application of FYM alone. Similarly, all the weed control methods resulted in significantly taller plants over weedy check. Effect of interaction of fertility levels and weed control methods on tuber yield was not significant. The potato yield under different fertility levels ranged from 119.8 to 129 q/ha but the effect was not significant. This might be due to high initial fertility status of the experimental plots. All weed control

methods recorded significantly higher tuber yield over weedy check. Paraquat, alachlor and manual weeding+earthing up treatments gave 61.3, 47.3 and 36.2%, respectively, higher yield over weedy check. The tuber yield obtained under paraquat treatment was statistically at par with that obtained under alachlor in spite of the fact that weed control efficiency with alachlor was higher than paraquat. This might be due to increased number of main stems per hill as well as the higher number (20.7%) and yield (19.9%) of large size tubers under paraquat treatment over alachlor.

Effect on nutrients removal : The effect of different fertility levels on N, P and K removal either by weeds or by potato tubers did not merit much attention as the differences among the fertility treatments were very narrow. The loss of nutrients caused by weeds amounted to 47.5, 11.9 and 51.9 kg of N, P and K/ha, respectively, when no weed control was done (Fig. 1). This was 65, 77 and 56% of N, P and K, respectively, of their total removal by weeds and potato tubers. The weed control methods

checked the nutrient removal by weeds and as a consequence increased uptake by potato tubers. This is in accordance with the observations of Nankar & Singh (5) who also found an inverse relationship between nutrient removal by weeds and potato crop yield. The alachlor treatment led to the minimum removal of N, P and K by weeds. Under this treatment weeds accounted for only 22.3, 36.6 and 20.0% of total N, P and K removal, respectively. The removal of N, P and K by weeds under this treatment was reduced by more than 70% whereas that of tubers was increased by more than 40% over weedy check.

From the results, it can be concluded that both the herbicides, namely alachlor and paraquat, were equally effective in increasing the potato tuber yield in the North-western hills. Alachlor and paraquat gave 74.9 and 56.9% weed control efficiency, respectively, and the respective increase in potato tuber yield was 47.3 and 61.3%. Weed control methods resulted in reduced nutrients removal by weeds and as a result increased nutrient uptake by the potato tubers.



* Manual Weeding + Earthing Up

Fig. 1. Nutrients removal by weeds and potato tubers (kg/ha)

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OPTIMUM PLANTING PERIOD OF PARENTAL LINES FOR PRODUCTION OF HYBRID TPS IN NORTHERN GUJARAT

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The availability of good quality seed is one of the constraints for potato production in non-seed producing zones (1). Resource poor farmers can not afford to buy the expensive seed imported from other states. Use of TPS, which is easier to store, transport and free of tuber borne diseases offers an alternative to costly seed tubers (2, 3). Production of large quantities of hybrid TPS at a lower price will, however, determine the economics and viability of raising crop from hybrid TPS. The present study was conducted to find out suitable period for planting TPS parental lines for hybrid TPS in Northern Gujarat.

An experiment was conducted during the *rabi* season for three years during 1996-97 to 1998-99 at Potato Research Station, Gujarat Agricultural University, Deesa. The planting material consisted of male and female parents of two recommended hybrid TPS populations, viz. V1=HPS-1/13 (MF-1xTPS-C-3) and V2=TPS-C-3 (JTH/C-107xEX/A-680-16). The experiment was conducted in split plot design with three replications. The female lines MF1 & JTH/C-107 were planted in the main plot. The six dates of planting in sub-plots were 25th October (D1), 2nd November (D2), 8th Nov. (D3), 15th Nov. (D4), 22nd Nov. (D5) and 29th Nov. (D6). Each plot of 2 x 2 m. consisted of four lines of female parents planted at 50 x 20cm spacing.

The male parents were planted in two rows on either side of female plants. To facilitate flowering both in male and female parent, the experimental field was provided 18 hours of

light by extended photoperiod with the help of sodium vapour lamp. For pollination, pollens were extracted from male flowers plucked previous day. Data was recorded on 5 randomly selected female plants on six characters, viz. i) duration of flowering was measured as the period between date from 50% to end of flowering, ii) total number of branches/plant, iii) per cent berry setting from number of flowers pollinated in a cross and the number of berries formed, iv) berry weight (kg) from the total berries harvested from a plot. v) seeds/berry from 25 randomly selected berries from each plot and vi) total TPS weight from all the berries per plot. The data gathered over the years were pooled and analyzed as per standard statistical procedures. Table 1 lists the average weather conditions that were prevailing at Deesa during the crop period, over three years of experimentation.

Potato normally flowers under cool, long days having more than 15 hour sunlight. The fifty per cent flowering in the TPS lines was observed in the 2nd week of December, when the average minimum and maximum temperatures were below 10°C and 30°C and RH was below 25% and 75%, respectively (Table 1). The duration of flowering ranged from nearly seven to ten weeks in different treatments. It was relatively more in MF-1 being the maximum in the crop planted on 25th October. The duration of flowering decreased sharply in parents planted after 15th November indicating that for optimum flowering, period

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Table 1. Average minimum & maximum temperature and relative humidity at Deesa during October to January in three years (1996-99)

Month	Standard Week	Temp.		RH	
		Min	Max	Min	Max
October	40	22.5	35.0	45.0	71.3
	41	21.4	36.5	33.7	76.3
	42	19.4	33.3	42.0	79.0
	43	19.4	32.6	38.3	75.7
November	44	17.7	33.3	34.7	75.3
	45	15.5	32.0	27.3	67.3
	46	14.0	31.0	25.9	69.6
	47	13.7	30.4	28.6	71.5
December	48	11.7	29.9	24.0	72.9
	49	11.1	28.9	27.9	70.8
	50	8.1	28.3	23.8	71.2
	51	9.5	28.5	26.3	78.7
January	52	9.4	27.6	28.4	77.8
	1	9.2	27.5	30.1	76.3
	2	9.0	26.6	29.2	74.8
	3	7.7	26.3	32.1	75.7
	4	8.7	25.5	34.6	70.0

of planting TPS parents lies between 25th October to 15th November. Similarly, a significant decrease in number of branches/plant in the crop planted beyond 15th November indicated that optimum planting of parental lines for TPS production under Deesa (Gujarat) condition also lies within the same period. Data on the six characters are presented in table 2. Except, number of branches/plant and per cent berry setting, the differences for other four characters between two female parental lines, viz. MF-1 and JTH/C-107 and among different dates of planting were significant. The interaction between the lines and dates of planting for the four characters was also significant.

A combination of prolonged flowering and total number of branches would have a direct bearing on the number of flowers available

Table 2. Performance of optimum date of planting TPS parental lines to maximize TPS production over three years (1996-97, 1997-98 and 1980-99)

Treatments	Duration of Flowering of female (No of days)	Branches /plant	% berry setting	Berry weight/plot	No. of seeds/berry	TPS Produced/plot (gm)*
V1	57.5	13.1	62.8	3.27	252.6	76.96
V2	54.5	15.4	60.9	1.96	168.7	46.44
D1	63.9	16.3	60.7	0.95	205.2	27.83
D2	64.2	16.7	60.6	1.92	206.8	53.94
D3	60.9	16.7	67.6	3.37	223.4	80.72
D4	56.0	15.2	73.9	5.00	233.4	96.17
D5	49.9	11.3	56.5	2.68	202.3	67.61
D6	41.1	9.4	51.8	1.75	193.0	43.94
V1D1	68.8	15.3	61.4	1.10	240.3	33.22
V1D2	65.1	15.1	59.9	2.07	244.3	57.22
V1D3	62.3	14.4	69.2	3.78	217.31	00.89
V1D4	57.7	13.1	76.1	6.79	271.6	117.00
V1D5	51.3	11.2	58.0	3.38	247.7	85.78
V1D6	42.7	9.1	52.1	2.48	240.4	67.67
V2D1	63.0	17.2	59.9	0.79	170.1	22.44
V2D2	63.2	18.3	61.2	1.77	167.3	50.67
V2D3	59.6	18.9	65.9	2.97	175.6	60.56
V2D4	54.2	17.2	71.8	3.22	195.0	75.33
V2D5	48.5	11.3	55.0	1.97	156.9	49.44
V2D6	38.4	9.7	51.4	1.03	145.5	20.22
Mean	56.02	14.25	61.83	2.613	210.67	61.704
CD@5%V	1.04	NS	NS	0.17	7.45	13.83
D	2.32	9.96	6.10	0.56	15.42	9.84
VD	1.53	.63	NS	0.74	12.83	4.51
CV%	2.91	10.12	6.60	14.15	6.46	7.75

V1 = HPS-1/13, V2 = TPS-C-3; D1 - D6 (six dates of planting)

over a long period for hybridization and consequently higher production of TPS. Pandey & Gupta (5) also reported a large variation in duration of flowering in 15 selected hybrids, while studying them for TPS production at Modipuram inferring that this will enable extension of hybridization period resulting in production of maximum TPS.

Per cent berry setting, weight of berries/plot, seeds/berry and total TPS production in a plot, the highest values for these four characters were obtained in the 15th November planted crop followed by 8th November. Parents planted beyond 15th November had significant reduction in the values of these characters indicated that 15th November is the optimum date for planting TPS parents for maximum production of berries and seeds. Between the two female parents, MF-1 appears to have an edge over JTH/C-107. Similar findings on dates of planting were reported by Pandey & Singh (4), where optimum flowering intensity, berry and seed set was observed to be in parents planted in the first week of October at Modipuram in North-western plains with corresponding weather conditions prevailing during the period. Planting parents beyond 15th October at Modipuram did not result in satisfactory berry setting despite repeated pollination due to environmental constraints (6).

Local production of hybrid TPS is helpful in launching a successful potato programme in any region. However, it is important to know

the flowering behavior and performance of the parents with regard to their inherent capacity for berry and seed setting in the region which ultimately determine the production of hybrid TPS. Unlike hills, the days are bright and sunny in Gujarat plains during the potato crop season (Oct-Feb), with low or infrequent incidence of late blight, hence the hybrid TPS can be produced conveniently. From the above study, it is clear that the parents of both the TPS populations (HPS-1/13 and TPS-C-3) are suitable for growing in Deesa region (Gujarat) for successful production of hybrid TPS when *planted in the first fortnight of November*.

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