

# GROWTH OF POTATO PRODUCTION IN INDIA: A NON-PARAMETRIC ANALYSIS OF TIME SERIES DATA

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**ABSTRACT:** Growth rates of area, production and yield of potato in India including its major producing states were estimated. *Kernel Weighted Local Linear Regression Smoother*, a non-parametric regression technique was used for this purpose. The temporal and spatial structural changes of cost of cultivation and remunerativeness of potato cultivation were also analysed. During the last 58 years, overall potato yield grew @ 1.5% at national level. After achieving spectacular growth during the seventies, the yield growth started to decline and in the recent past it became negative. Production also behaved similarly and reached a plateau. Cost of cultivation increased over the years. Farm harvest prices fluctuated greatly over the years leading to uncertainty of return from potato cultivation. During the last decade, share of seed in total cost of cultivation decreased in UP and Bihar and that of manure-fertilizers and machinery increased in all the states. Though the Himachal farmers received consistent good return over the years but West Bengal, UP and Bihar farmers incurred losses in many years when all the costs were considered. There is an immediate need to arrest the declining trend of yield. Concerted efforts to develop high yielding varieties with multiple disease-pest resistance, better post-harvest management technologies like latest innovative tools of biotechnology, agri-business, etc should be adopted to make potato cultivation a profitable enterprise.

## INTRODUCTION

Potato, a major vegetable crop in India, is being grown on a wide range of climatic conditions. During 2006-07 the country produced 22.09 million tonnes of potato from 1.48 million ha of land with the yield level increasing to 14.90 t/ha from a meager 6.58 t/ha during 1949-50. Presently, India is the third largest potato producer in the world (9). Moreover, India has one of the most organized potato seed production programme in the world.

Growth rates of crops are of utmost importance to the planners and policy makers. These show the past behavior of the variables and enable us to forecast the near future trend. Hence, to study the growth behavior in area, production and yield a sound technique is required. Many of the studies (1, 2, 13) estimated growth rates from simple trend estimation assuming linear and/or other functional relationship

between the time and response variable, *viz.*, area, production and yield. In this study the non-parametric regression analysis (5) were used. The parametric methods presume the distributional requirements of the underlying variables which, however, are often not fully met. Therefore, non-parametric regression was followed for modeling the potato area, production and productivity and computation of growth rate where no assumptions on functional form are made. In addition to this, an attempt has also been made to analyse the temporal and spatial changes in cost of cultivation and trend of remunerativeness of potato cultivation.

## METHODOLOGY

Kernel Weighted Local Linear Regression Smoother (4) is a nonparametric method and was used in the present study. This technique is independent of any assumptions on functional relationships. Further, the growth

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rate at each point of time can also be obtained. Secondary data for area, production and yield for the period 1949-50 to 2006-07 and cost of cultivation data for 1996-97 to 2005-06 were taken from Pandey *et al.* (9) and DES (3). Growth rate of area, production and yield was analysed for major potato producing states, *viz.*, UP (Uttar Pradesh), WB (West Bengal), Punjab, Bihar and Assam along with all India figure. Analysis of cost of cultivation was carried out only for Bihar, UP, WB and HP (Himachal Pradesh) due to non-availability of the data for other states. The actual model considered was:

$$y_i = m(t_i) + \varepsilon, t_i = i/n, i = 1, \dots, n$$

Where,  $y$  is observation of  $i^{\text{th}}$  year,  $m(\cdot)$  is trend function which is assumed to be smooth and  $\varepsilon$  is random error with zero mean and finite variance,  $m(\cdot)$  is estimated as the value of  $\alpha_0$  where  $\alpha_0$  and  $\alpha_1$  are chosen to minimize local least square function:

$$\sum_{i=1}^n [y_i - \alpha_0 - \alpha_1(t_i - t)]^2 K[(t - t_i)/h]$$

Here  $K$  is a bounded symmetric kernel density function and  $h$  is bandwidth,  $\hat{\alpha}_0$  and  $\hat{\alpha}_1$  are the estimates of the equation (2), the estimator of trend function is given by:

$$\hat{m}(t) = \hat{\alpha}_0 = \frac{\sum_{j=1}^n W_{t_j} y_j}{\sum_{j=1}^n W_{t_j}} \text{ where,}$$

$$W_{t_j} = K[(t - t_j)/h] \sum_{i=1}^n K[(t - t_i)/h] (t - t_i)^2 - (t - t_j) \sum_{i=1}^n K[(t - t_i)/h] (t - t_i)$$

Choice of bandwidth ( $h$ ) is of great importance in nonparametric regression estimation. To estimate optimum bandwidth, cross validation or leave out procedure is commonly used (6). The slope  $m'(t)$  of  $m(t)$  at time  $t$ , which is a simple growth rate can be estimated as:

$$\hat{m}'(t) = \hat{\alpha}_1 = \frac{\sum_{j=1}^n W'_{t_j} y_j}{\sum_{j=1}^n W'_{t_j}} \text{ where,}$$

$$W'_{t_j} = K[(t - t_j)/h] \sum_{i=1}^n K[(t - t_i)/h] (t - t_i)^2 - (t - t_j) \sum_{i=1}^n K[(t - t_i)/h] (t - t_i)$$

Under some regulatory conditions on bandwidth, consistency and asymptotic normality of above estimator, *viz.*  $m'(t)$ , is established. From  $m'(t)$  the relative growth rate is computed as per capita growth rate.

Different cost concepts have been used as per DES (3). DES calculated the  $C_3$  on revised  $C_2$ , here it is calculated on  $C_2$ . The other details are given below:

Cost  $A_1$ : Hired human labour+ bullock labour + machinery labour + seed + plant protection chemicals +manure and fertilizer +depreciation+ irrigation+ land revenue, cesses and other taxes +interest on working capital +Miscellaneous.

Cost  $A_2$  : Cost  $A_1$ + rent paid for leased-in land.

Cost  $B_1$  : Cost  $A_1$ + interest on owned fixed capital (excl. land).

Cost  $B_2$  : Cost  $B_1$  + rental value on owned land (net of land revenue) + leased-in land.

Cost  $C_1$  :  $B_1$ + imputed value of family labour.

Cost  $C_2$  :  $B_2$ + imputed value of family labour.

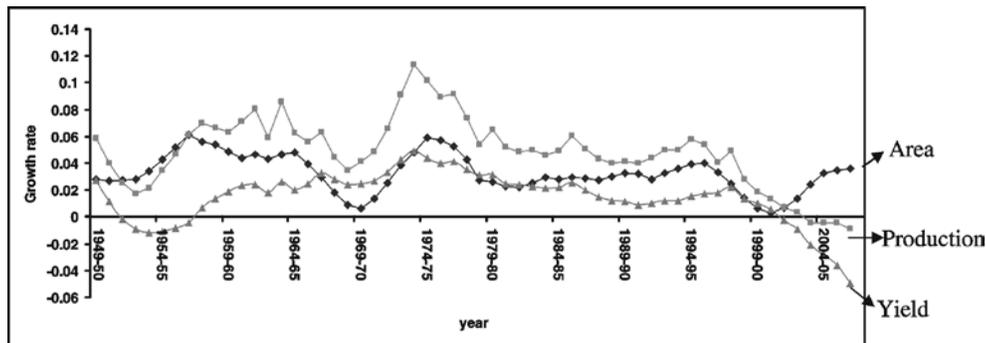
Cost  $C_3$  : Cost  $C_2$  + 10% of Cost  $C_2$  to account for managerial input of the farmer.

All the costs and market prices have been converted into constant prices by using the consumer price indices of agricultural labourers (food). Co-efficient of variability (CV) % was calculated to show the variability in cost of cultivation and farmers' price.

## RESULTS AND DISCUSSION

**Fig. 1** depicts the estimated nonparametric growth rates of area, production and yield of potato for India. All the  $R^2$  of the models fitted were having value more than 0.70. A close examination of the figure shows that growth rate of production was highest during mid-seventies due to the positive growth rates of area as well as yield.

1.77 for production and yield, respectively. West Bengal also managed a reasonably good growth rate in production (5.31%). The performance of Assam and Bihar were not satisfactory, particularly in yield. The growth rates in area in Punjab and West Bengal were more than that of overall Indian figure. Similarly in production also Punjab and West Bengal achieved better growth rates than all



*Fig. 1. Trend of growth rates of area, production and yield of potato at all India level.*

However, after that a continuous declining trend is observed in the growth rates of both production and yield. A negative growth trend in yield was observed during early fifties but very soon it recovered. The growth rate of production had always been positive, only recently it became negative. A matter of concern is the negative growth of yield since 2001-02 and of production since 2003-04 although the growth of area continued to be positive.

### State-wise comparisons

Average growth rates of area, production and yield of potato in UP, WB, Punjab, Bihar, Assam along with national scenario are presented in the **table 1**. During the past 58 years, potato yield in India grew at moderate growth rate of 1.47% at national level. UP and Punjab achieved better growth rates in production and yield, being 5.31, 7.28 and 1.89,

**Table 1. Average growth rates (%) of potato.**

State	Area	Production	Yield
India	3.27	4.85	1.47
UP	3.22	5.31	1.89
WB	4.21	5.20	0.91
Bihar	2.27	3.62	0.85
Assam	1.95	2.20	0.20
Punjab	5.01	7.28	1.77

India level. Because of good yield growth, UP also managed to surpass the average Indian growth of production.

An attempt was made to analyse the decade-wise growth rates and the same was presented in **table 2**. It shows that during seventies, the yield growth rates were highest in UP (5.36) and WB (5.38), the two largest potato growing states of India.

As a result India also achieved a very decent yield growth rate of 3.69% during

**Table 2. Decadal growth rates in India and its major potato growing states (%).**

India/ State	Growth Rate in	1949-50 to 1958-59	1959-60 to 1968-69	1969-70 to 1978-79	1979-80 to 1988-89	1989-90 to 1998-99	1999-00 to 2006-07
India	Area	4.10	3.74	3.71	2.69	3.14	1.97
	Prod	4.42	6.20	7.71	5.06	4.55	0.25
	Yield	0.14	2.42	3.69	2.19	1.41	-1.63
UP	Area	3.53	3.85	4.29	3.31	2.33	1.73
	Prod	2.11	7.12	10.32	5.53	4.15	1.94
	Yield	-1.21	2.68	5.36	2.19	1.72	0.29
WB	Area	3.23	3.42	5.69	4.41	4.69	3.70
	Prod	3.88	3.97	10.35	7.92	5.47	-1.77
	Yield	1.29	0.39	5.38	3.08	0.59	-6.84
Bihar	Area	5.69	3.66	3.16	1.01	1.14	-1.84
	Prod	10.13	8.82	2.50	2.34	0.69	-4.35
	Yield	2.23	4.28	-0.52	1.28	-0.36	-2.50
Assam	Area	2.33	0.79	0.75	4.95	2.95	-0.57
	Prod	0.19	2.51	1.66	6.70	5.55	-4.81
	Yield	-2.13	1.34	1.06	1.72	2.53	-4.19
Punjab	Area	7.64	2.23	11.37	-2.82	9.11	1.88
	Prod	18.74	1.11	15.51	-2.85	10.18	-0.58
	Yield	9.07	-1.16	3.64	0.04	0.52	-2.30

this decade. Punjab and Bihar achieved their highest growth in yield during fifties and sixties, respectively. Yield growth rate in Assam was very low, achieved its peak during nineties and then recently became negative to the tune of -4.19%. In majority of the cases after seventies, the growth rate of yield started diminishing and became negative at present in all the states except UP which also showed a meagre growth rate of 0.29%. Keeping in view the burgeoning population trend and increasing demand of the processing sectors this negative growth in yield is a matter of grave concern and need immediate attention of planners, policy makers and researchers.

### **Spatial and temporal changes in cost of cultivation**

Share of different components in total cost and thereby relative importance of them could be ascertained from the structural composition of cost of cultivation. It also indicates the technological advancements over the years. An attempt was made to analyse the temporal

changes in cost of cultivation and the same is presented in **table 3**.

The table 3 shows that the cost of cultivation (Cost  $C_2$ ) was increased by 13% in West Bengal and 46% in Bihar during 2005-06 over 1996-97 and by 22% in Uttar Pradesh and 13% in HP during 2005-06 over 1998-99 at constant prices. The market price increase ranged from 23% in Bihar to 86% in West Bengal. Even the changes were negative for Himachal Pradesh. A linear trend model was fitted to see the pattern of trend in market price and cost of cultivation. The dependent variable was market price/cost of cultivation and independent variable was time. The results of the fitted model were used only for comparison purposes since the estimates of trend coefficient were not significant in all the cases. The second last row of the table 3 shows that though the Himachal farmers enjoyed relatively better market prices but the market price had negative trend. Similarly in Bihar also the market price showed negative

**Table 3. Comparison of cost of cultivation and market price (all are at constant 1996-97 price).**

Year	Market price (Rs./Q)				Cultivation cost (C <sub>2</sub> , Rs./ha)			
	Bihar	UP	WB	HP	Bihar	UP	WB	HP
1996-97	199	-	165	-	20330	-	48179	-
1997-98	375	-	215	-	23207	-	44711	-
1998-99	280	199	170	631	24391	32139	48667	27379
1999-2000	211	138	149	462	25153	26250	40933	26762
2000-01	283	229	195	647	26093	26993	41622	31474
2001-02	320	291	240	715	28908	35834	48597	32222
2002-03	283	168	137	608	31274	33875	42268	36578
2003-04	241	188	246	421	30088	29432	47865	34698
2004-05	264	242	240	419	25757	34813	44781	31468
2005-06	244	324	307	524	29707	39196	54334	30964
Trend coeff.	-1.9	13.68	11.16	-20.82	920	1162	381	746
p value	0.76	0.17	0.04	0.26	0.00	0.92	0.43	0.15

trend. However, trend coefficients of cost of cultivation for all the states were positive and ranging from 381 in WB to 1162 in UP. We attempted to analyse the variability in potato yield and production, market price and cost of cultivation and the same was presented in **table 4**.

The market prices were highly variable (ranging from 18.59 to 28.00) over the years (**Table 4**). Among the different states, UP has got maximum variability followed by WB, HP and Bihar. Bihar has got maximum variability in yield, whereas in production and cost of cultivation HP and UP, respectively have got maximum variability. Table 4 also shows that among the three parameters, market price was most variable. Only Bihar showed the acute variability in yield as it experienced significant changes in yield over their respective previous years, *viz.*, during 1998-99 (+23%), 2001-02 (-12%), 2002-03 (+16%), 2003-04 (+26%) and

2005-06 (+21%), and hence, the variability became high. Nevertheless, in Bihar also market price was highly fluctuating (CV being 19%). Among other things, variability in production contributes to variability in prices. But the variability of prices was much more than the variability in production, indicating the interplay of certain other factors which call for the attention of researchers. Cost of cultivation was moderately variable. Seed price, seed rate and labour wages might be the major source of variability in cost of cultivation. The variability in market price was a major concern for the farmers (10). There was no clear trend in market prices which often leaves the farmers in great distress. Farmers do not have any idea about the behaviour of the market prices in the post-harvest period. In many years, the prices ruled so low that he even might not get back the operational cost, leave alone the fixed and imputed costs.

**Table 4. Variability (CV%) in yield, production, market price and cost of cultivation.**

Particular	Bihar	UP	WB	HP
Yield	22.63	10.25	7.40	9.51
Production	14.58	5.78	9.41	15.6
Market price	18.59	28.00	25.60	20.36
Cost of cultivation	12.73	13.93	8.93	10.49

### Structural changes in cost of cultivation

The component-wise analysis of cost of cultivation is presented in the Fig. 2. It shows that the share of seed has drastically come down from above 40% to a little above 30% in Bihar and UP. In WB and HP, the share of seed was almost constant, being about 20 and 33%, respectively. The machine labour is becoming more important, being evident from the fact that its share has increased in all the states. No machine labour was employed during 1998-99 in HP due to unsuitability of contemporary machineries in the planes owing to difficult hilly terrain. Small agricultural implements suitable for hill region are gradually coming up. As a result, human labour has given way to machine labour and its share became about 1% in 2005-06. Other three states also follow the same trend, increasing its share marginally.

Except HP, the share of fixed costs has increased in the other three states. This indicates that farmers made some long term investment by purchasing fixed assets. West Bengal farmers were more resourceful since the share of fixed cost was highest (30.97%) during recent year, whereas in Bihar it is lowest (24.10%). Now a days farmers put more emphasis on fertilizer and manure as the share in all the states has increased.

### Trend of remunerativeness of potato cultivation

Benefit cost-ratio was calculated over different levels of cost of cultivation to show the trend of remunerativeness. It is evident from the Fig. 3 that the potato farmers of HP enjoyed consistent good return over the years. Though the yield was low as compared to other states, the market prices were good,

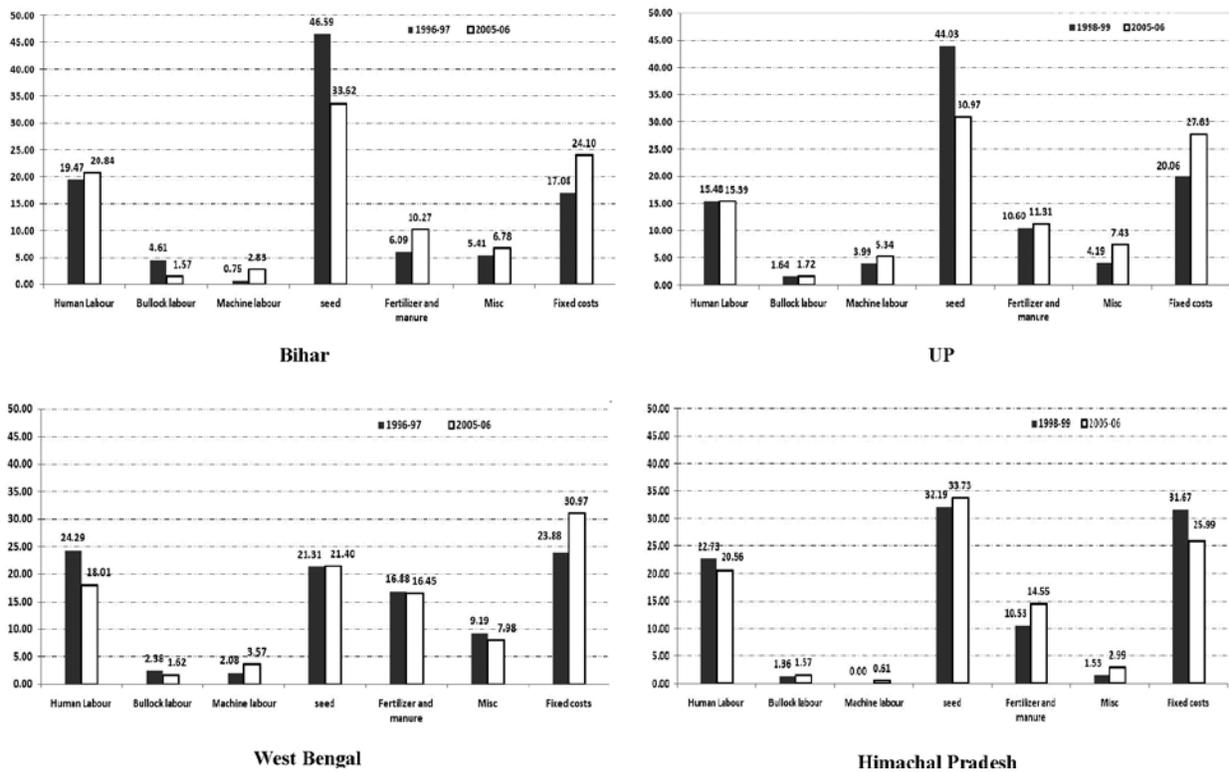


Fig. 2. Percentage share of different components in total cost of cultivation (C<sub>2</sub>).

hence B:C became more than 1 in almost all the years. The average price of the last 8 years in HP was Rs. 664/q, whereas in Bihar, UP and WB it was Rs.314, Rs. 270, Rs. 237, respectively. Potato from HP fetches premium prices due to their availability in the off-season and suitability for seed and processing purposes.

Potato cultivation turned out to be remunerative in all the states when one considers only cost  $A_1$ , i.e. when farmers don't include the imputed costs, like rent for owned land, interest on owned fixed capital and family labour. Upto the cost  $B_1$  (includes with  $A_1$ , the interest on owned fixed capital) benefit exceeds the cost in all the states. However,

beyond cost  $B_1$  farmers starts loosing. As for example, in UP, out of 8 years only 5 times the farmers were able to get their money back over cost  $C_2$ . Even at cost  $B_2$  (excluding family labour) in one year they incurred losses.

In WB the scenario is worst. The return on cost  $C_2$  was negative in 7 out of 10 years. Bihar situation was a bit better. Farmers incurred losses in two years over Cost  $C_2$ . If analysis also includes the farmers' management cost ( $C_3=C_2+10\%$  of  $C_2$ ) the marginal benefit years were converted into loss years. Even Himachal farmers also operated at no-profit no-loss basis during 2002-03 and 2003-04 and got only a slight benefit during 2004-05. In

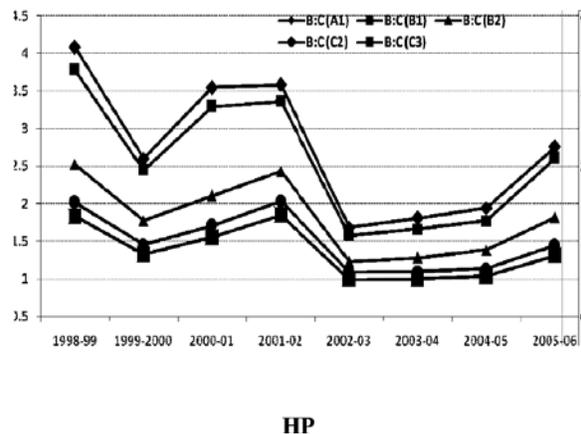
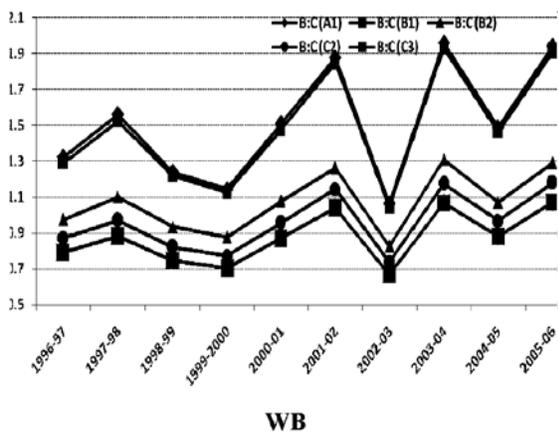
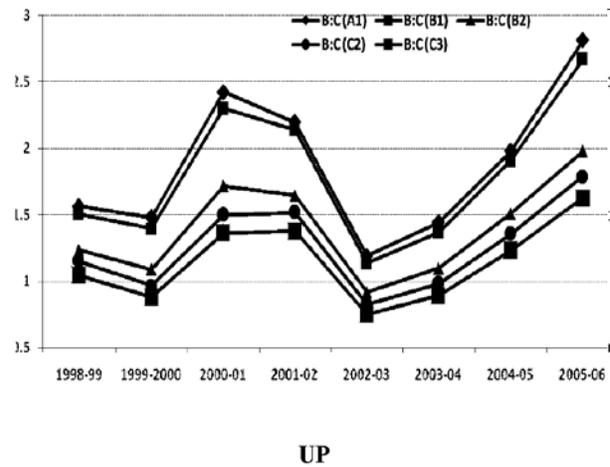
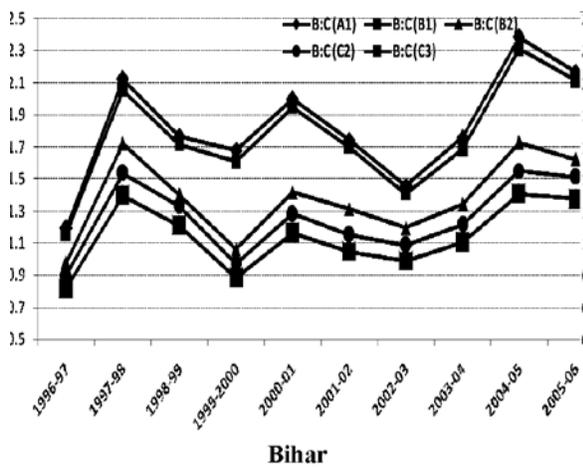


Fig. 3. Trend of benefit-cost ratio over cost  $A_1$ ,  $B_1$ ,  $B_2$ ,  $C_2$  and  $C_3$ .

case of manufactured goods, the entrepreneur includes all the costs (even managerial, advertisement *etc.*) and adds some margin while fixing the MRP. Whereas, potato farmers don't have any say over the price of his own produce. Same is the case with other crops. Therefore, it is not a surprise that NSSO found that given alternate opportunity 40% of the farmers will quit farming. Hence, the study strongly recommends the establishment of price stabilization fund, compensating farmers in loss years from the fund originating from the cess of profit years. Alternately, government can also fix the MSP like other crops.

## CONCLUSIONS AND SUGGESTIONS

Growth rates of potato area, production and yield in major potato producing states along with the trend of structural changes of cost of cultivation and trend of remunerativeness of potato cultivation were analysed in the present study. Non-parametric analysis of growth showed that overall, at national level, India achieved 3.3, 4.9 and 1.5% growth rates in area, production and yield, respectively during the year 1949-50 to 2006-07. The growth rate of production was highest during mid-seventies. However, after that a continuous declining trend was observed in the growth rates of both production and yield and since 2001-02 growth of yield became negative. Cost of cultivation has got increasing trend and its variability was less than that of market price. Some structural changes took place in cost of cultivation. Share of seed decreased in UP and Bihar and that of manure and fertilizers and machinery has increased in all the states. HP potato farmers received consistent good return over the years. If the imputed costs, like rent for owned land, family labour were not included then potato cultivation was remunerative. But if all the costs are included in the analysis then farmers, particularly of West Bengal, suffered losses in a number of years.

Farmers need to adopt better post-harvest management practices as the post-harvest losses in potato are too high (8). A large chunk of technologies developed did not reach to the farmers. A policy thrust regarding revamping the extension machinery is the need of the hour. Still non-institutional sources play a major role in agricultural credit delivery systems (11). To purchase better inputs, low cost institutional credits should be made available to the farmers. Further, it is also suggested to establish price stabilization fund which can compensate farmers in loss years from the proceeds of cess in profit years. There is immediate need to reverse the declining trend of the yield. Development of high yielding varieties with multiple disease pest resistance by taking the inputs of biotechnology are need of the hour. Rural agribusiness and contract farming have the potential to increase the farmers' net return (12). Government should also encourage establishing more processing firms, can rationalize the price of inputs, specially of seed, regular exports of potato and its products so that farmer can get better price.

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