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# Crop yield in India in relation to El-Nino

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**सार** — इस अध्ययन में प्रशांत महासागर में एल नीनो की परिघटनाओं और भारत में फसल उपज के बीच संबंध का परीक्षण किया गया है। इस अध्ययन हेतु पांच जिलों — चुरू, ग्वालियर, रीवा, पलामाऊ और बंकुरा का चयन किया गया। ये जिले सामान्य मानसून द्रोणी क्षेत्र में स्थित है और इनमें सर्वथा भिन्न प्रकार की, मुख्यत: वर्षा पर निर्भर, फसलों की खेती होती है। इस विश्लेषण में 1951-88 के फसल एवं मौसमी वर्षा के आँकड़ों का उपयोग किया गया है।

प्रस्तुत अध्ययन के परिणामों से पता चलता है कि भारत में खरीफ फसलों पर एल नीनो परिघटना का विशेष प्रभाव नहीं पड़ता।

**ABSTRACT.** Association between the *El-Nino* events in the Pacific Ocean and the crop yields in India has been examined. Five districts, *viz.*, Churu, Gwalior, Rewa, Palamau and Bankura located on the normal monsoon trough zone and cultivating altogether different, mostly rainfed crops, were selected for the study. Crop and seasonal rainfall data from 1951-88 were utilised in the analysis.

The results indicate that the *El-Nino* phenomenon does not exert much influence on the kharif crops in India.

**Key words** — El-Nino, Annawari system, Yield, Variability, Surges, Sea surface temperature (SST), La-Nina, Trend.

## 1. Introduction

Variable climatic condition is well recognised to exert dramatic impact on the food production. No doubt, recent agro-technological innovations, such as, appropriate choice of crop strain, intensive irrigation, judicious water management, pest and disease control, large scale application of fertiliser etc. strongly influence crop yield and often ameliorate the consequence of short term climatic variability. However, as shown by Mc Quigg *et al.* (1973), the variations in crop yield are functions of weather variability.

Largest climatic fluctuations observed in recent years are, perhaps, the ocean's near sea-surface temperature (SST) field which occur over equatorial Pacific Ocean. These interannual variations are often referred to as *El-Nino* and were recognised decades ago. Occurrence of *El-Nino* events is acknowledged as associated with major changes in ocean-atmosphere system across many parts of the globe.

Quinn *et al.* (1978) have shown that droughts in Indonesia coincide with *El-Nino* episodes. Droughts in Australia have been observed in association with these warm temperature events (Angell 1981). Bhalme (1984), Sarker (1987), Chowdhury and Mhasawade (1991) etc., investigated association between *El-Nino* and rainfall and droughts in India. However, studies linking the warm sea surface episodes of the Pacific with agricultural production in particular, have, unfortunately, not attracted the attention of scientists in India.

In this paper, possible association between crop yield in selected locations and *El-Nino* have been explored to find out if the crop data could act as proxy for the monsoon climate.

## 2. Data

Reliable crop data are available in India only after 1950. Prior to that, crop estimation was done by what is known as "annawari" system, which was highly subjective. We have, as such, used data from 1951 to 1988. Five districts located on the normal position of monsoon trough zone, *viz.*, Churu, Gwalior, Rewa, Palamau and Bankura were selected in the study. These districts have traditionally rainfed agriculture with bajra, jowar and paddy as the major crops. The yield data have been collected from Agricultural Situations in India published by Ministry of Food and Agriculture, New Delhi.

Quinn *et al.* (1978) have categorised years with warm episodes. A comparison of the same with that given by Rasmusson and Carpenter (1983) revealed that many of the cases do not agree. We have used



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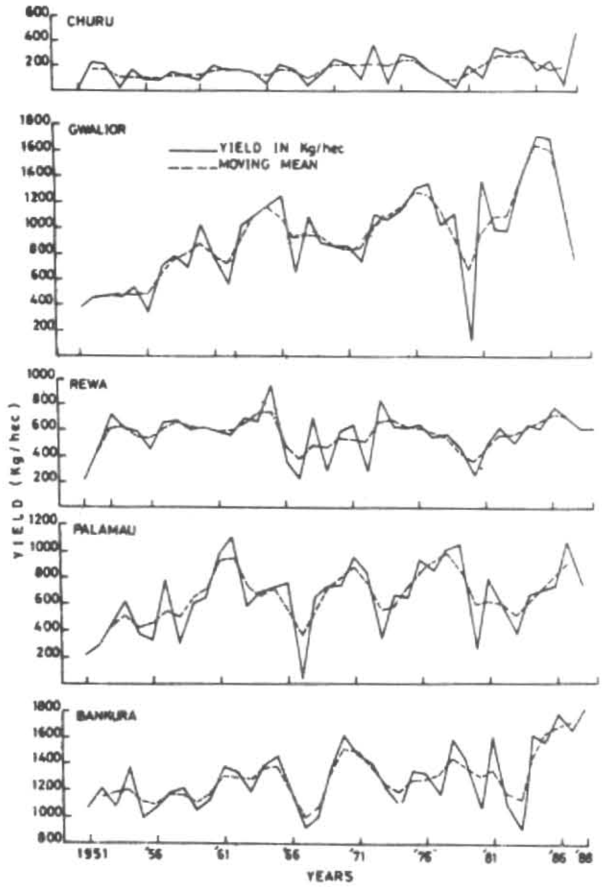


Fig. 1. Yearly variation in yield and trend (1951-88)

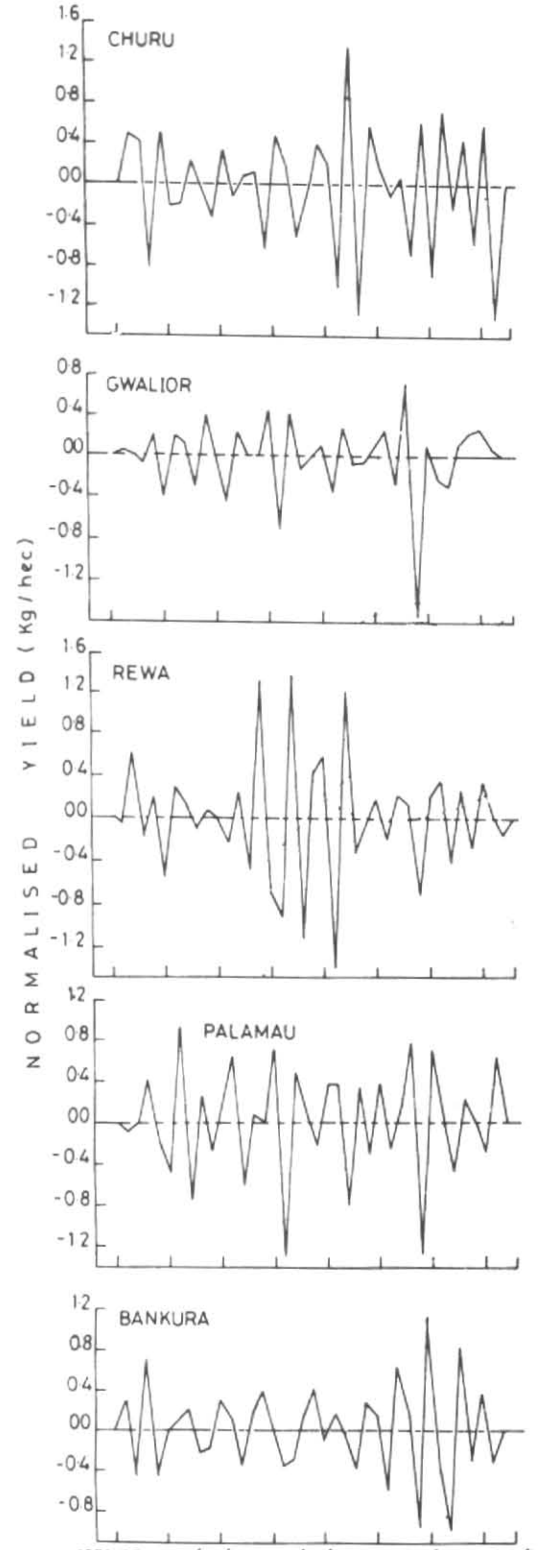


Fig. 2. Time series of normalised yield

Rasmusson and Carpenter's data which was supplemented by the SST data given in Diagnostic Climate Bulletin publised by NOAA.

### 3. Results and discussion

The actual yield for all the five locations is depicted in Fig. 1. The arid Churu district recorded the lowest yield of about 170 kg/ha (ranging from 60 to 480 kg). Instability in crop production is evident from the coefficient of variation which is as high as 62%. Gwalior, in semi-arid tract has the predominant crop as jowar. The yield variability here is about 39% with a mean of 930 kg/ha. The yield of jowar, which is also a major crop in Rewa, has a coefficient of variation (CV) as 28% and mean yield as 570 kg/ha. In the eastern sub-humid region, where paddy is extensively grown, the yields are 650 and 1280 kg at Palamau and Bankura respectively, the corresponding CV being 40 and 19%. It is evident that large oscillations in crop yield are inherent in all climatic types within the monsoon trough zone.

The year-to-year fluctuations in the yield were smoothened by subjecting the data to 3-year moving average with 1, 2 and 1 weights. The moving average values represent the trend in the data series. The yield residuals were then computed as $(Y_i - \hat{Y}_i)$

TABLE 1

**Large scale yield variations**

| S. No. | Station | Years $> 0.8\ \sigma$ | Years $< -0.8\ \sigma$ |
|---|---|---|---|
| 1. | Churu | 1970, 1975, 1976*<br>1982*, 1983, 1984<br>1988 | 1951* 1954, 1956<br>1957* 1972*, 1973<br>1974, 1979, 1987*<br>1965*, 1968 |
| 2. | Gwalior | 1965*, 1975, 1976*<br>1980, 1983, 1984<br>1985, 1986* | 1950, 1951*, 1952<br>1953*, 1954, 1955<br>1961, 1979 |
| 3. | Rewa | 1952, 1964, 1967<br>1972* | 1950, 1951*, 1965*<br>1966, 1968, 1971<br>1979 |
| 4. | Palamau | 1960, 1961, 1970<br>1975, 1977, 1978<br>1986* | 1950, 1951*, 1954<br>1955,1957*, 1966<br>1972*, 1979, 1982* |
| 5. | Bankura | 1969*, 1977, 1980<br>1983, 1984, 1985<br>1986*, 1987* | 1950, 1952, 1954,<br>1955, 1958, 1966<br>1967,1973, 1979<br>1981, 1982* |

* Years of *El-Nino* : 1951, 1953, 1957, 1965, 1969, 1972, 1976, 1982, 1986, 1987

where, $Y_i$ is the actual yield in $i$th year and $\hat{Y}_i$ is the corresponding moving average value. The residuals were normalised by dividing it with standard deviation ($\sigma$) of the yield series.

Normalised yield series for the 5 stations is shown in Fig. 2.

The diagrams exhibit a high degree of variability typical of the yields in India. The variability is, it is surmised, due to weather since affects due to the technological factors associated with long term trend, have already been removed. Incidently during the period under study, several episodes of *El-Nino* as well as *La-Nina* were available. It may be seen that there are as many departures (both positive and negative), in *El-Nino* events as in *La-Nina* cases.

Table 1 gives years of large deviation between trend and actual yields. Only those cases, where the deviations exceed $\pm$ 0.8 $\sigma$, have been included. Years of *El-Nino* have also been suitably indicated.

It is significant to note that in none of the cases large negative departures were associated with *El-Nino* years.

Depending upon the standard deviation $\sigma$ and the deviation $d$ from the trend line, yields were categorised into following classes :

| | |
|---|---|
| $d < -\sigma/4$ | below trend |
| $-\sigma/4 \leqslant d \leqslant \sigma/4$ | at trend |
| $d \geqslant \sigma/4$ | above trend |

The data for the districts are presented in $3 \times 2$ contingency table alongwith their $\chi^2$ values in Table 2. The $\chi^2$ values were not found significant in any of the districts. In other words, this implies that there was no statistical difference between the observed and estimated values. The ratio of below trend years to above trend years were 3 : 2 at Churu, 2 : 1 at Gwalior, 1 : 1 at Rewa, 3 : 4 at Palamau and 1 : 2 at Bankura districts for *El-Nino* years. For the *La-Nina* years these ratios were respectively 9 : 8, 5 : 7, 1 : 1, 10 : 7 and 2 : 3. When *El-Nino* and *La-Nina* cases are taken together, there are nearly equal number of cases belonging to above trend and below trend except at Bankura where above trend values seem to be significantly larger than below trend values.

The analysis, thus, does not support the hypothesis that warm SST anomalies in the equatorial Pacific Ocean occur concurrently with

TABLE 2

**Deviation of crop yields in El-Nino and La-Nina years**

| Yield | *El-Nino* | *La-Nina* | Total | $\chi^2$ |
|---|---|---|---|---|
| | | **Palamau** | | |
| Below trend | 1 | 9 | 10 | 2.048 |
| At trend | 5 | 9 | 14 | |
| Above trend | 4 | 10 | 14 | |
| | | **Bankura** | | |
| Below trend | 3 | 9 | 12 | 0.42 |
| At trend | 5 | 11 | 16 | |
| Above trend | 2 | 8 | 10 | |
| | | **Rewa** | | |
| Below trend | 2 | 8 | 10 | 2.10 |
| At trend | 3 | 15 | 18 | |
| Above trend | 5 | 5 | 10 | |
| | | **Churu** | | |
| Below trend | 3 | 7 | 10 | 0.14 |
| At trend | 3 | 11 | 15 | |
| Above trend | 4 | 10 | 13 | |
| | | **Gwalior** | | |
| Below trend | 2 | 7 | 9 | 1.93 |
| At trend | 7 | 13 | 20 | |
| Above trend | 1 | 8 | 9 | |

lower crop yield in the monsoon trough zone. Bhalme (1984) also concluded that the years of *El-Nino* episodes, are not always associated with deficient monsoon rainfall over India. The link between the crop yields in India and equatorial Pacific Ocean temperature appears much weaker. Apart from rainfall, it is possible that other meteorological variables, such as, sub-soil moisture, which is the integrated measure of climate, are more closely related to the growth of crops in India (WMO 1977, Stapper and Arkin 1980). Harnack (1979), Barnett (1980) and Angell (1981) also did not find any significant association between monthly temperature and precipitation for U.S. summers and equatorial Pacific Ocean.

The results may be construed to show absence of an association between SST anomalies in Pacific and monsoon rainfall variations in India for which crop yield acts as proxy. From the analysis it is clear that not all the five districts had significantly below normal yields in the same year during *El-Nino*. Only in 1965, Churu and Rewa had below normal yield and warm temperature anomalies in the Pacific simultaneously. In this year, rainfall during June, the month when normal planting takes place, was 100% below normal. This caused delay in the planting and perhaps, the crop could not reach its full potential. In this warm SST year of below normal rainfall, the yield was, thus, very much below the trend, at these two districts.

## 4. Upward and downward surges

The pattern of variability in yield in *El-Nino* years for the 5 districts is shown in Fig. 3 (a). The

| YEAR | CHURU | GWALIOR | REWA | PALAMAU | BANKURA |
|---|---|---|---|---|---|
| | | (a) EL - NINO | | | |
| 1951 | ↓ | ↑ | ↑ | ↑ | ↑ |
| 1953 | → | → | ↓ | ↑ | ↑ |
| 1957 | ↓ | ↑ | → | ↓ | → |
| 1965 | ↓ | ↑ | ↓ | → | ↓ |
| 1969 | ↑ | → | ↑ | → | ↑ |
| 1972 | ↓ | ↑ | ↓ | ↓ | ↓ |
| 1976 | → | → | ↓ | ↓ | ↓ |
| 1982 | ↑ | → | ↓ | ↓ | ↓ |
| 1986 | ↑ | ↓ | ↓ | ↑ | ↓ |
| 1987 | ↑ | ↓ | ↓ | ↓ | ↑ |
| | | (b) LA - NINA | | | |
| 1960 | ↓ | ↓ | → | ↑ | ↑ |
| 1961 | ↑ | ↓ | → | ↑ | → |
| 1962 | ↓ | ↑ | ↑ | ↓ | ↓ |
| 1963 | → | ↑ | → | ↑ | ↑ |
| 1979 | ↓ | ↓ | ↓ | ↓ | ↓ |
| 1980 | ↑ | ↑ | ↑ | ↑ | ↑ |

↑ > 5 % INCREASE ↓ SIMILAR DECREASE → CHANGES WITHIN ±5 %

Figs. 3(a & b). Relative yearly trend in yields during (a) El-Nino and (b) La-Nina years

upward arrow (↑) shows more than 5% increase in yield in *El-Nino* year compared to previous year, while the downward arrow (↓) represents a similar decrease. Horizontal arrow (→) represents changes within ± 5% in *El-Nino* year with respect to preceding year and virtually can be taken as an insignificant change. The jowar yield in Gwalior clearly shows a tendency towards increased crop yields from the previous year. In contrast, bajra yield in Churu, jowar in Rewa and rice in Palamau and Bankura districts show a distinct tendency towards decreased yield. Though rice yields show a prominent decline, jowar yield, in comparison, does not show sympathetic fall. This may be due to jowar areas being more diverse in western India, west of 82° E, whereas rice is concentrated in the more moist eastern India east of 82° meridian.

1972 and 1982 are supposed to be the two severest warm sea temperature episodes in recent years. A comparison has been made to find out the yield variability in these two years. Crop yield dropped to their lowest values in last two decades in 1982. The number of yield reductions in 1972 was marginally more than in 1982. The remaining *El-Nino* cases were, however, rather evenly divided. A marked reversal in yield trend could be noticed in *El-Nino* events after 1972 with larger number of cases registering decreased yields. A sharp recovery was generally observed in yields in 1983 but this pattern was somehow lacking in 1973.

Yield variations in the *La-Nina* years have been depicted in Fig. 3 (b). In preparing the figures, the years before and after the *El-Nino* year were excluded. The sample available for analysis was, thus, smaller compared to the *El-Nino* years. With a possible exception for bajra yield at Churu, by and large, crop yields registered a rising trend in the *La-Nina* years.

## 5. Conclusion

The results did not bring out any clear association between presence of warm sea surface temperature in Pacific and crop yields in monsoon trough zone. Crop yields in India do not appear to bear any statistically significant relationship with the *El-Nino* phenomenon. Perhaps plant is sensitive to other facets of Indian monsoon not captured by mean summer monsoon rainfall.

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