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Rainfall trends and maize productivity in diverse agro-climatic regions of India

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Abstract

Historical data on climatic parameters as well as yield data on maize are important to look into past setbacks and achievements. In the present study, we have analysed the grain yield of the best entry, the best check and trial mean of full season maturity group grown during the monsoon (*kharif*) season in All India Coordinated Maize Improvement Project (AICMIP) trials from 1991 to 2012 in four agro-climatic zones of the country. The monthly fluctuations in rainfall during maize cropping season are high in all the zones during maize crop season and the trend was significantly increasing in the month of August in Zone V. The seasonal rainfall decreased during the month of October in all the Zones. The yield performance of best test entry was *at par* or higher than the best check with significant and strong correlation with each other and with trial mean. There was increasing trend for maize yields from 1991 to 2012 in all the zones. The new maize hybrids from AICMIP are superior even under the changing climatic conditions in different agro-climatic zones, however, there was a stabilization of the zonal yields (pooled over states within agro-climatic zones) of maize around year 2002 for 7 to 12 years in different zones of the country. In spite of high fluctuations in rainfall, there was continuous improvement in the new genotypes developed at AICMIP especially in past two decades. Thus, AICMIP had an important contribution in overall increase in zonal yields of the country even though the differential impact in different zones. The impact of new hybrids in zonal or state productivity and production took less time for Zone II and Zone III and this impact lasted for more years in Zone II than Zone III.

Key word: Advance Evaluation Trials, climate change, Mann-Kendall test, regression, trend analysis

Introduction

Maize in India is primarily grown in monsoon (*kharif*) season throughout the country. In winter (*rabi*) season, maize is sown in some part of the country, while the spring maize is also gaining importance in last few years. The maize area, production and productivity for 2011-12 were 8.782 mha, 21.759 mt and 2.478 t/h, respectively (Anonymous 2012). The full season maturity group in maize is grown in all parts of the Indian sub-continent except in Himalayan hills, where extra-early, early and medium maturity group maize are grown so as to fit in their cropping system.

Organized research on improvement of maize started in India in 1957 under the auspices of All India Coordinated Research Project (AICMIP) and was the first in a series of coordinated projects under the ICAR system. Since then, huge data on maize productivity in maize trials were generated which had much to offer. Based upon agro-climatic conditions, the maize growing area in the country is broadly classified into five zones (Table 1). The states and the names of the testing locations are given in Table 1. In Zone I, early and extra-early maturing maize crop fits better in hill cropping system than full season maize crop. All India coordinated system, is a multi-location testing system for evaluation of new entries for at least three years against known best checks. Based on the performance of these scientific planned trials committee short-list the genotype/hybrid those outclass others for specific agro-climatic regions/zones. More than 145 maize hybrids and composites are released so far by AICMIP and State Departments, suitable for different agro-climatic zones of the country. Similar system of independent assessment of new varieties are in place in UK since 1919 (Wellington and Silvey 1997), with

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Table 1. States and testing location of maize in each Zone in each agro-climatic conditions

Zone	Area covered	States	Location of testing centers
I	North-east and North-west Himalayas	Jammu and Kashmir, Uttarkhand, Himachal Pradesh, North eastern region	Srinagar, Almora, Bajaura, Barapani, Kangra and Poonch
II	North-West Indo-Gangetic plains	Punjab, Haryana, Western Uttar Pradesh	Jammu, Dhaulakuan, Ludhiana, Karnal, Delhi, Kanpur and Pantnagar
III	North-East Indo-Gangetic plains	Bihar, Jharkhand, Eastern Uttar Pradesh, West Bengal, Orissa	Jorhat, Dholi, Ranchi, Bhubaneswar, Varanasi and Bahraich
IV	Peninsular India	Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra	Arabhavi, Mandya, Karimnagar, Hyderabad, Coimbatore, Vagarai and Kolhapur
V	Central and Western India	Rajasthan, Gujrath, Madhya Pradesh, Chhattishgarh	Udaipur, Banswara, Chindwara, Ambikapur, Godhra and Jabhua

testing of varieties for multiple years for a minimum 2 years before national listing, with additional 1-3 years of testing before eligible for recommended list for the crop (Silvey 1999). Based on the past data, the genetic progress was studied at Netherlands, UK and France (Silvester-Bradley 2002; Foulkes et al. 2007; Brisson et al. 2010; Mackay et al. 2011; Rijk et al. 2013).

In last two decade, climatic parameters have seen to undergo changes, especially temperature, rainfall etc. The effect of climatic parameter is important for maize, which is ecologically and economically important crop in the country. Assessment of key climate variables such as precipitation (intensity and frequency), temperature fluctuations etc., over a period of years not less than a decade is a requisite to study impact on agriculture. INCCA (2010) validate the change in temperature and precipitation in the region. Maize and mustard are also likely to experience decrease in productivity in the entire region by 2030 (INCCA 2010). Suitable genotypes and management strategies are observed to maintain the productivity trend even under crucial climate changes as studied in past decades (Jonesa and Thornton 2003; Pandey and Beintema 2001; Manyatsi et al. 2010; White and Hoogenboom 2010). On studying the effect of climate change in rainfall in north-eastern region of India (Mahajan et al. 2012), they showed a shift in peak of rainfall, reduction in peak of total rainfall during the rainiest months and less rainfall in the initial months of the maize crop season. As per the studies on regional basis in India (Arora et al. 2005), it was observed that the stations of southern and western India show a rising trend of 1.06 and 0.36^{o}C per 100 years, respectively, while stations of the north Indian plains show a falling trend of –0.38^{o}C per 100 years. The seasonal mean temperature has increased by 0.94^{o}C per 100 years for the post-monsoon season and by 1.1^{o}C per 100 years for the winter season. It was reported that in India (Sinha and De 2003), the extreme maximum and minimum temperatures show an increasing trend in the south and a decreasing trend in the north. In another study (Sharma et al. 2000) from 1947 to 1993 in Kosi basin of the central Himalayan region showed some increasing tendency of temperature and precipitation.

Our results should help policy makers to evaluate future strategies for increasing national agricultural production and rural income. The objective of the present investigation was to understand the agro-climatic zone-wise trend of maize performance in AICMIP trials as well as zonal averages (compiled over states) *vis-a-vis* any change in one of the key parameter of climate particularly rainfall.

Material and methods

Normally, three maize hybrids are used as checks every year in Advance Evaluation Trial 2nd year (AET II) to select the superior hybrid at Zone level in All India coordinated trials. These hybrid entries in AET II had already been tested for two years i.e., Initial Evaluation Trial (IET) and Advance Evaluation trial 1st year (AET I), in multi-location testing. The data on the AET II trial mean, the best entry and the best check in the final (third) year of testing in full season maturity group for 22 years from year 1991 to 2012, of AICMIP trials was used for monsoon (*kharif*) season. Full season or late maturity maize is commonly grown in all the zones except Zone I. Due to no regular full season trials in Zone I, the data of Zone I was not considered in the present study. The best entry changes every year; however the checks continued over years till a new superior check is added (a newly released hybrid) through AICMIP. The seeds of all the entries in the trial including the best entry and the best check were obtained every year by AICMIP from the maize breeder or organization that developed it and ensure the purity of genetic material. The states and the testing location covered in each zone have been given in Table 1. The agro-metrological data from at least one centre from each zone was used to understand the trends in rainfall (mm). The centres used for the study were Delhi from Zone II, Varanasi from Zone III, Hyderabad from Zone IV and Godhra from Zone V (Table 1). The trend line was computed for each Zone for total rainfall (mm) over months in a season (July to October) for 22 years, from 1991 to 2012. Further, the trend lines for rainfall were studied zone-wise as well as month-wise over years.

The values for yield expressed as kilogram per hectare, for all the entries including the best entry and the best check from the Annual Progress Reports from 1991 to 2012 of AICMIP, were computed. The mean for each zone over states was computed and a straight line was fitted through the points using linear regression that fitted in the best curve. The variance and coefficient of determination (R^2) value were computed to understand the variations in maize productivity as well as month-wise rainfall in each zone during the crop season. Rainfall characteristics like mean, standard deviation (SD) and coefficient of variation was computed month-wise in each zone. Both parametric test (linear regression) and non-parametric Mann-Kendall method (Mann 1945; Kendall 1975) were used to detect the precipitation and yield trends in time series. Sen's slope estimation method was also performed on precipitation trends. The Pearson's correlation values were obtained between the best entry on AICMIP and the zonal yields observed after one year, after two years, after three years and so on.

Results

Climatic fluctuations

Maize crop is grown mostly under rain-fed conditions during main cropping season (*kharif*) from July to October in India. The total rainfall of the season averaged over 22 years for the maize crop season (July to October) in different zones varied, which was 511.2 mm in Zone II, 803.8 mm in Zone III, 591.9 mm in Zone IV and 760.1 mm in Zone V. The 22 years of data at various centers in different zones over years in maize crop season (July to October) indicated that numerically there was non-significant decrease in total rainfall in the maize crop season in all the zones except in Zone V where there is slight increase in rainfall (Fig. 1). The pattern of decrease in rainfall was not same in different zones and months. The increasing and decreasing trend was non-significant in all the months in all zones except for the month of August in Zone V (Table 2), where there was significant increase in the trend. The month-wise linear pattern revealed that in the month of October, numerically there was decrease in rainfall in all the zones. In the month of July, there was increase in rainfall in Zone III and IV and decrease in rainfall in Zone II and V. In the month of August, there was decrease in rainfall in Zone II and III and increase in total rainfall in Zone IV but in Zone V there was significantly increasing trend. If we look into the month of September the rainfall increased in Zone II and IV and decreased in Zones III and V. The low regression coefficient in all the months in each zones indicated that the regression lines do not fit in the data and there are wide fluctuations in precipitation in each month and zones. The highest regression coefficient was observed for the month of August in Zone V ($R^2 = 0.225$). Generally, if the dataset displays a consistently increasing or decreasing trend, S will be positive or negative, respectively with a large magnitude indicating the trend in more consistent in its direction (Patra et al. 2012). The negative magnitude for *kharif* season was highest in Zone III and lowest in Zone IV (Table 2). The positive magnitude of fluctuations was highest in the month August in Zone V and negative magnitude of fluctuations was highest again in the month of August in Zone III. The Sen's slope estimator is a non-parametric technique used to determine the magnitude of the trend line, by calculating the slope as a change in measurement per change in time. When hypothesis of no trend is rejected by Mann-Kendall test (positive value of test statistics indicates the increasing trend and negative value indicates the negative trend), the Sen's Slope is used to quantify the trend. The null hypothesis was rejected for the month of August in Zone V, with a positive trend line.

The zone-wise rainfall pattern spread over 22 years (1991 to 2012) exhibited different patterns in zones (Fig. 1). Keeping in mind the high fluctuations in total precipitation in months and zones, in general, there was a decrease in rainfall in most of the zones. The data showed that rainfall decreases in Zone II in all the months except September. In Zone III, there

Table 2. Results of the Mann-Kendall test for the month-wise precipitation data in different zones

Zones (location)	Month	Minimum value	Maximum value	Mean	Standard deviation	Mann-Kendall Tau	Test S	P	Sen's slope	Test Interpre-tation
Zone II (Delhi)	July	7.20	439.10	152.95	107.96	-0.080	-19.00	0.620	-1.850	Accept Ho
	August	66.30	425.00	217.72	98.62	-0.070	-17.00	0.660	-2.000	Accept Ho
	September	5.40	314.20	118.38	85.83	0.070	17.00	0.660	2.070	Accept Ho
	October	0.00	214.10	22.15	48.68	-0.020	-4.00	0.930	0.000	Accept Ho
	Kharif season	251.10	916.00	511.21	168.19	-0.117	-27.00	0.469	-6.030	Accept Ho
Zone III (Varanasi)	July	135.70	500.00	276.66	111.48	0.000	0.00	0.970	-0.100	Accept Ho
	August	71.20	487.10	280.64	121.47	-0.310	-64.00	0.060	-7.700	Accept Ho
	September	45.60	581.60	217.70	144.10	-0.080	-16.00	0.660	-2.720	Accept Ho
	October	0.00	142.00	28.83	37.72	-0.040	-8.00	0.830	-0.060	Accept Ho
	Kharif season	411.40	1193.00	803.85	217.28	-0.257	-54.00	0.111	-9.371	Accept Ho
Zone IV (Hyderabad)	July	32.00	308.80	164.65	83.99	-0.080	-19.00	0.620	-1.450	Accept Ho
	August	53.80	506.30	188.65	96.76	0.030	7.00	0.870	0.320	Accept Ho
	September	14.80	273.60	128.91	74.02	0.040	9.00	0.820	0.460	Accept Ho
	October	15.80	283.00	109.74	82.18	-0.140	-33.00	0.370	-1.800	Accept Ho
	Kharif season	349.40	963.10	591.94	171.85	0.022	5.00	0.912	0.607	Accept Ho
Zone V (Godhra)	July	59.60	614.50	338.79	163.17	-0.200	-47.00	0.200	-8.260	Accept Ho
	August	40.90	609.00	271.38	174.09	0.330	77.00	0.030	13.470	Reject Ho
	September	0.00	471.00	130.45	123.45	0.060	13.00	0.740	0.810	Accept Ho
	October	0.00	80.20	19.43	24.52	0.310	-63.00	0.070	-0.900	Accept Ho
	Kharif season	275.50	1301.50	760.05	289.65	0.082	19.00	0.617	4.938	Accept Ho

Note: If P value is less than the significance level $\alpha = 0.05$, Ho is rejected. Rejecting H0 indicates that there is a trend in a time series, while accepting H0 indicates no trend was detected. On rejecting the null hypothesis the result is said to be statistically significant

was decrease in rainfall in all the months except in July; while in Zone IV, there was increase in rainfall in all the months except during the month of October. In Zone V, there was decrease in rainfall in all the months except for the month of August. It was important to note that there was decrease in rainfall in all the zones especially during the month of October. Keeping aside the month of October, Zone IV alone exhibited increase in the total rainfall.

Maize performance expressed as trial mean, best entry and best check

The trends in the trial mean, best entry – a hybrid and the best check in AICMIP trials were studied. On evaluating the data for the overall trial, the best entry and the best check indicated that all the three ways of understanding the trend are similar trend as expressed by a similar regression coefficient and a very strong correlation (0.928** to 0.986**) in all zones. There was a decrease or stabilization of the yields of maize around the year 2002 in all the zones. The initial maize yields in early nineties were highest in Zone IV while the lowest maize yields were observed in Zone III in AICMIP. The yield gains as expressed through trend is maximum in Zone III (220.3 kg/ha/year) followed by Zone IV (133.1 kg/ha/year), Zone V (113.2 kg/ha/year) and Zone II (110.8 kg/ha/year). In the study, there were fluctuations for yield in different zones, which was maximum in Zone V (expressed as $R^2 = 0.217$ to 0.290). On the other hand, the fluctuation in yield was minimum in Zone III (expressed as $R^2 = 0.649$ to 0.655) (Figs. 2-5).

The best entry is always superior to the best check in each year. Whereas due to number of entries in AET trial their average yield is always low. It is important to note that the initial yield levels in 1991 were highest in Zone IV and low in Zone III (Fig. 2 to 5). Zone IV covering peninsular India exhibited highest productivity in the All India Coordinated Project (AICRP) trials and yields had been constantly increasing except for a short period from 2000 to 2004 in Zone IV (Fig. 4). Around the year 2002, there was a decrease in yields in Zone IV and constant increase in the yields in Zone V, however there was an increase in yields in Zone V.

Zonal productivity trends

The zonal productivity varied in different agro-climatic zones. Even though there was an increase in maize

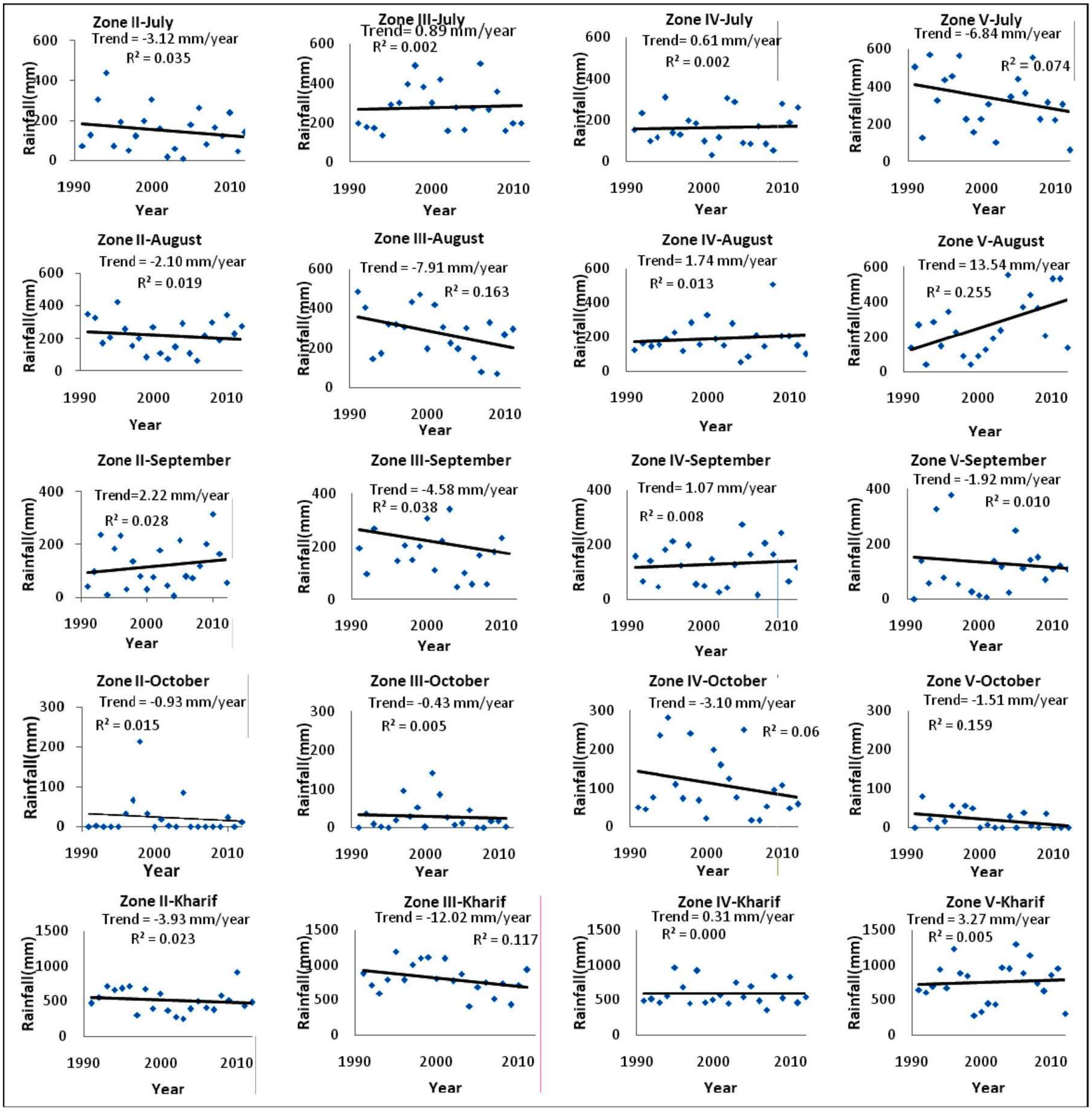

Fig. 1. Rainfall pattern in different months of *kharif* (monsoon) season and different agro-climatic zones of maize in India

yields in all the agro-climatic zones, however different agro-climatic zones behave differently over years. In 1991, nearly twenty-two years back the zonal means was lowest for Zone V and highest for Zone IV (Fig. 6). The best fitting linear/non-linear curve with highest R^2 was used for zonal means. All the zones behave differently like there was a consistent increase in productivity in Zone II during this period. Maize productivity remains constant for more time (nearly 12 years) from year 1997 to 2008 in Zone III, thereafter a slight increase was observed. In Zone V the productivity increased up to 2000 and then remains constant up to 2009 (10 years) followed by a slight increase. In case of Zone IV, maize productivity also remains stagnant from 1999 to 2005 but showed increasing trend thereafter. The correlation values

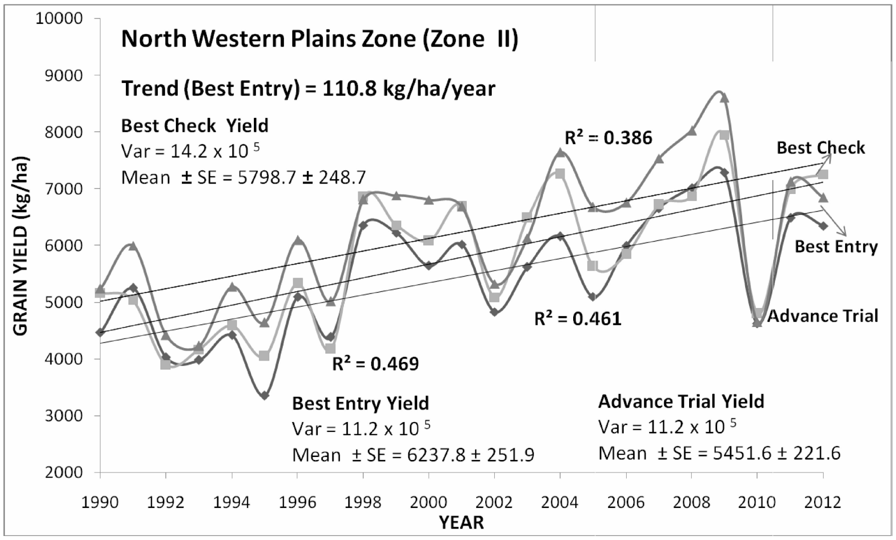

Fig. 2. Trends for trial mean, best check and best entry in North-Western Plains in last 22 years

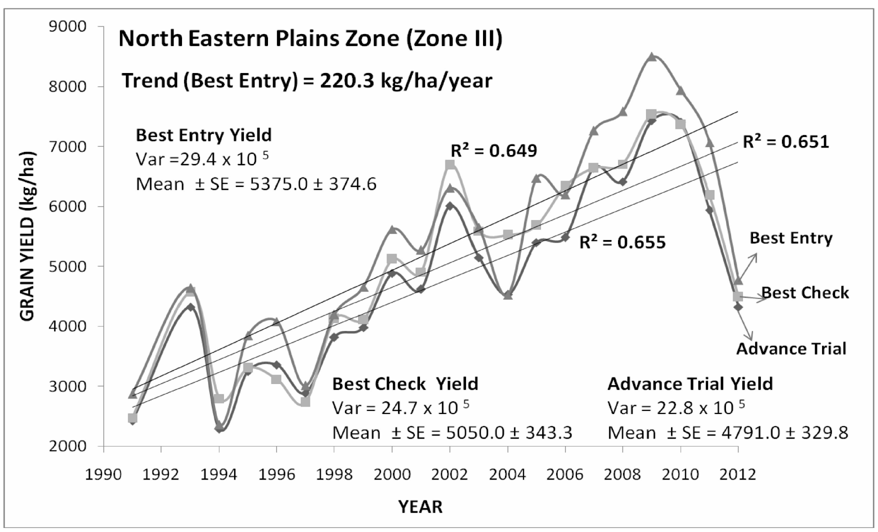

Fig. 3. Trends for trial mean, best check and best entry in North-Eastern Plains in last 22 years

studied for the best entry in AICMIP with the zonal yields (over states) was to understand the effect of newly released hybrids on AICMIP zone yield. The maize yield in Zone II, which had continuously increased since 1991 had a significant correlated up to fourth year while in case of Zone III, the correlation was significant for two years (Table 3). However, in case of Zone IV and Zone V, the correlation was not significant.

Discussion

Historical dataset have much to offer in providing strategic planning and formulating the future course of action. India is gifted with heterogeneous variety of climatic conditions with temperature varying from arctic cold to equatorial hot, and rainfall from extreme aridity with a few cms (<10 cm) to per-humid with world's maximum rainfall (1120 cm) of several hundred centimeters. The maize crop is grown mostly under rain-fed conditions during main cropping season (*kharif*) from July to October in India. There are fluctuations in precipitation and temperature over years as reported by various workers, especially during monsoon season (*kharif*). In another study on weather data it was observed that the intensity and frequency of precipitation was fluctuating for a period of 27 years (1983 to 2009) in Meghalaya (Das et al. 2009). Their climate models also predicted that in future there will be 2.0-3.5^{O}C increase in temperature. The data of past 22 years at the centers located in different zones over years in maize crop season (July to October) revealed that the pattern of decrease in rainfall was not same in different zones and months. The results indicated that there was decrease in total rainfall in the maize crop season in all the zones except in Zone V (Fig. 1). The month-wise linear pattern indicated there was decrease in rainfall in all the Zones in the month of October while in other zones there was different pattern of precipitation. In north-eastern India, there was reduction in total rainfall from 1847.6 mm in 1997-98 (mean of two years) to 1423.0 mm 2007-09 (mean of three years) (Mahajan et al. 2012). They also observed that there was delay in achieving the maximum rainfall of the season in north-eastern region.

The zone-wise rainfall pattern spread over 22 years (1991 to 2012) exhibited different patterns in zones (Fig. 1). It was important to note that among

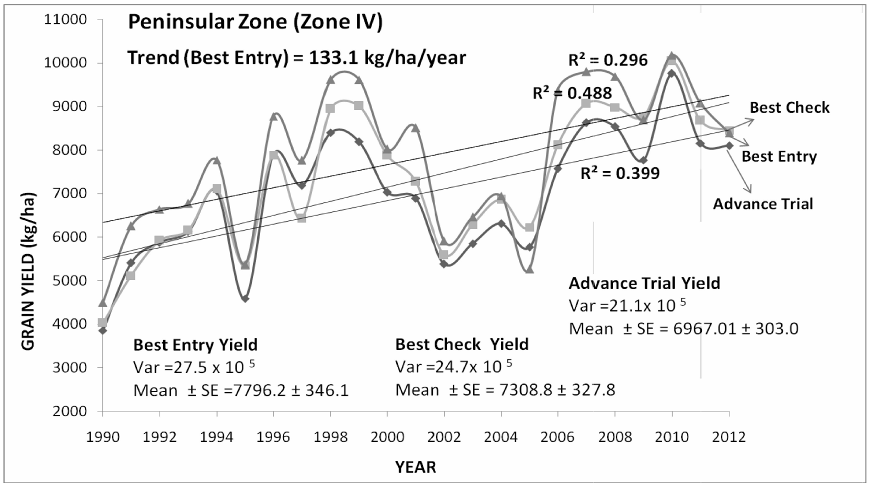

Fig. 4. Trends for trial mean, best check and best entry in Peninsular zone in last 22 years

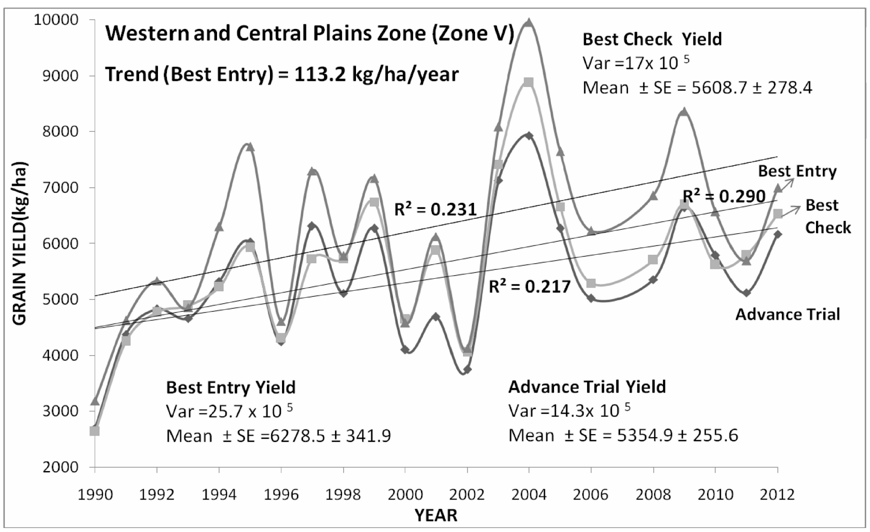

Fig. 5. Trends for trial mean, best check and best entry in Western and Central Plains in last 22 years

these zones, the highest rainfall was in Zone III and the lowest was in Zone V (dry area). Zone V was the most affected region, as monsoon not only reaches late in the season but also withdraws first during the cropping season. The changes in rainfall pattern differ in different zones and months. Numerically there was non-significant decrease in total rainfall in the maize crop season (July to October) in all the zones except in Zone V where there was slight increase in rainfall (Fig. 1). The increasing and decreasing trend was non-significant in all the months in all zones except for the month of August in Zone V (Table 2), where there was significant increase in the trend. The low regression coefficient with non-significant trend line in all the months in each zones emphasize that there were wide fluctuations in precipitation in each month and zones. The highest regression coefficient was observed for the month of August in Zone V (R^2=0.225) has comparatively low fluctuation in comparison to others. In case of consistently increasing or decreasing trend, S will be positive or negative respectively, with a large magnitude indicating the trend in more consistent in its direction (Patra et al. 2012). The positive magnitude of fluctuations was highest in the month August in Zone V (Table 2) and the Sen's Slope quantifies and exhibited a positive trend line as the null hypothesis of Mann-Kendall test of no trend was rejected. Our long term seasonal rainfall trends over 22 years are insignificant (Table 2), similar to the mean annual rainfall over Orissa (Patra et al. 2012). However, statistically significant trends may not be practically significant and *vice versa* (Daniel 1978).

Even though the trend of increase or decrease in rainfall is non-significant, but numerically, there was decrease in rainfall in all the zones except Zone IV, where the rainfall has increased except for the month of October. The rainfall had decreased in Zone II, Zone III and Zone V in all the months except September, July and August, respectively. Keeping in mind the high fluctuations in total precipitation in all months and zones, it was important to note that there was decrease in rainfall in the month of October in all the zones while for other months in the maize crop season, there was no visible pattern in different zones in other months. Keeping aside the month of October, Zone IV alone exhibited increase in the total rainfall. However, there were certain years in India which had exceptionally deficient rains. The Indian

Meteorological Department (IMD) had officially acknowledged the year 2002 as 'first-ever-all-India drought year' since 1987 (Anonymous 2002). The deficiency in rainfall amounting to 19 percent and drought conditions impacting 29 percent of its geographical area. Of this 29 percent area, 10 percent was under 'severe drought' and remaining under 'moderate drought'. The severe drought was recorded with more than 50% deficiency in rainfall, in West Rajasthan (minus 71%) and East Rajasthan (minus 60%). The moderate drought was recorded in major maize growing areas in Zone IV namely, coastal Andhra Pradesh (minus 26%), north interior Karnataka (minus 31%), south interior Karnataka (minus 44%), Coastal Karnataka (minus 30%), Tamil Nadu (minus 44%) (Anonymous 2002). During the beginning of the monsoon season i.e. July, numerically there is decrease in rainfall in northern and western part and increase in the rainfall in southern and eastern part of the country (Fig. 1). On the other hand, August witness highest rainfall during the season as the monsoon season was in its peak. In spite of that, there was decrease in rainfall in the northern and eastern part and increased rainfall southern and western part of the country. On studying the long term rainfall trends from 1871 to 2006 (Patra et al. 2012), it was also reported that during monsoon season in Orissa, the monthly rainfall in June, July and Sept decreased but increased during the month of August and analyzed trends were insignificant. With the beginning of the withdrawal of monsoon in the latter half of the month of September, rainfall decreased in the month of October in all part of the country.

The best entry, the best check and the trial mean of AICMIP trials showed same trend as expressed by a strong correlation in each zone indicating that any one of the best entry, the best check and trial mean would be equally useful in any study. In addition, the maize productivity had increased in last two decades indicating the new hybrids of maize had been more suitable even with decreasing and inconsistent rainfall pattern in different months and zones. There was a decrease or stabilization of the yields of maize around the year 2002 in all the zones. The year 2002 is known as the drought years wherein there is decrease in rainfall by 56 percent in the month of July 2002 (Bhat 2006). It is important to note that the initial yield levels in 1991 were highest in Zone IV and lowest in Zone III (Figs. 3 and 4). The yield gains per year as expressed through trend is maximum in Zone III (220.3 kg/ha/year) and minimum in Zone II (110.8 kg/ha/year). Similar study in soybean on the varieties released in 39 years (1969 to 2008) in India showed an annual genetic gain per year of 23 kg/ha and the seeds per plant increased by 1.56 percent per year (Ramteke et al. 2011). In maize, the yield gains per hectare per year were much higher than soybean in all the zones (110.8 to 220.3 kg/ha/year). Genetic progress in cereal yield was similar in Netherlands, UK and (Silvester-Bradley 2002; Foulkes et al. 2007; Brisson et al. 2010; Mackay et al. 2011; Rijk et al. 2013). Genetic progress in sugar yield since the mid-1990s in the Netherlands is 50 percent higher than in the UK (Mackay et al. 2011).

Precipitation and temperature are individually found to have opposite effects on maize yield levels and variability (Chen et al. 2007). There were fluctuations for maize productivity in different zones, which was maximum in Zone V (expressed as R^2 = 0.217 to 0.291) which experienced lowest rainfall (591.9mm) in the crop season and minimum fluctuations in productivity in Zone III (expressed as R^2 = 0.649 to 0.655) where monsoon stays for comparatively more time with highest crop season total rainfall (803.8mm) in last 22 years. The climatic factors has a cumulative effect and affect the maize yields in AICMIP trials as well as in actual farmer field conditions in different zones over states. The best entry was always superior to the best check in each year in all zones indicating that there was a constant improvement in yield performance of the new entry. Thus with the change in trend lines for the best entry over years, it was not only the climatic factors that were important over the years but also the improved genotypes were developed and evaluated by AICMIP suitable under changing climatic conditions. Hence there were constants efforts by the Indian maize scientists to provide new hybrids technology for different zones that performed better even under new changing climatic conditions.

The drought years around the year 2002 also had an impact on the performance of hybrids in AICMIP trials. The deficiencies in rainfall in various parts of the country were confirmed by various reports (Anonymous 2002; Bhat 2006). The Zone IV covering peninsular India exhibited highest productivity in the AICMIP trials and yields has been constantly increasing except for a short period from 2000 to 2004 (Fig. 4), which was around the drought year 2002. Even during this drought period the yield of best entry was either *at par* or better than the best check under

AICMIP evaluation trials. Around the drought years of 2002, there was a short decline in the yields of Zone IV and Zone V. It was important to note that in Zone IV, was mostly grown with high yielding maize hybrids from public as well as private seed sectors. On the other hand, there was an increase in yields in Zone V, which was primarily rain-fed with drought tolerant improved varieties. Keeping in mind the reducing overall rainfall during the crop season and preparedness for the drought, the use of drought tolerant germplasm shall be an important part of any breeding programmes irrespective of agro-climatic zones.

At national level, there was a constant increase in the national productivity of maize especially from early nineties (Sai Kumar et al. 2012); however the contribution of different agro-climatic zones varied. The zonal productivity was computed over the states within a zone. Even though there was an increase in maize yields in all the agro-climatic zones, but maize productivity at farmer field compiled as productivity at state level, in different agro-climatic zones show variable trend from year 1991 to 2012. The best fitting linear curve with highest R^2 was used for zonal means. The higher the value of R^2, the lower is the fluctuations observed in zonal means over years and vice versa. Nearly, twenty-two years back the zonal means was highest for Zone IV and lowest for Zone V (Fig. 6),

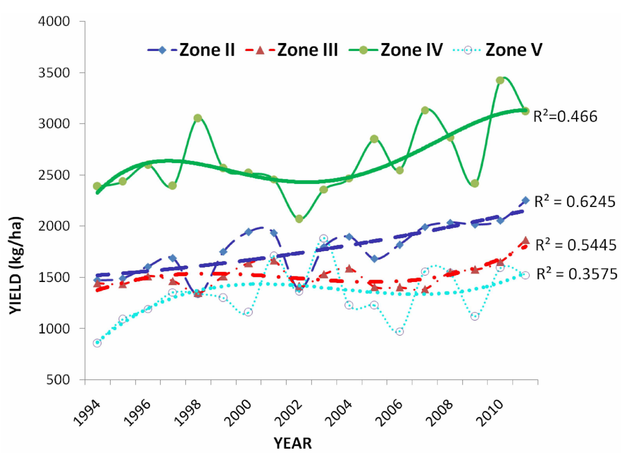

Fig. 6. Performance of maize in different zones pooled over states

which was still maintained in 2012 but the productivity has fairly increased in each zone. There was a consistent increase in productivity in Zone II. The productivity of the Zone III and Zone V remain constant for more time for twelve (1997-2008) and ten (2000-2009) years, respectively. In Zone IV, maize productivity also remains stagnant for seven years till 2005. The variation in the trend of maize productivity may be attributed to drought years around 2002 and changing rainfall pattern in zones. In spite of the regular availability of the new and improved maize hybrids for each zone, the contribution of these genotypes to state or zone level is fairly low. Farm yields for maize though continuously increasing, but could not keep in pace with the combined effect of genetic and environment suggesting a widening yield gap.

Table 3. Impact of new entry released by AICMIP on zonal productivity through correlation studies in different zones

Years after AVT II	Over best entry			
	Zone II	Zone III	Zone IV	Zone V
1 year	0.672**	0.484*	0.410	0.017
2 years	0.648**	0.502*	0.076	–0.061
3 years	0.620*	0.469	–0.030	0.073
4 years	0.649*	0.381	–0.320	–0.071
5 years	0.329	0.174	–0.390	0.174
6 years	0.360	0.014	–0.464	0.100

Note: $^*P \leq 0.05$; $^{**}P \leq 0.01$

In order to understand the impact of new hybrids evaluated in AICMIP trials, on zonal yield in different zones. The impact of technology on zonal yields was for longer duration (four years) in Zone II followed by Zone III (two years) (Table 3). No significant correlation between AICMIP and zonal maize productivity of Zone IV and Zone V exhibit more impact of other factors in addition of new maize hybrids developed. It also indicated that the impact of new hybrids quick in Zone II and Zone III and the impact lasted for comparatively more years in Zone II. However, there were number of factors that affected the actual zonal yields computed over states and new hybrid technology with more active maize improvement programme has a major impact in view of changing climatic conditions. We believe that there is lot more that need to understand in this historical dataset and its full value is yet to come.

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