Response of maize genotypes to changing climatic conditions in Himalayan region

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Abstract

Maize is a major cereal grown in upland regions of Himalayas especially, Himachal Pradesh, Sikkim, Nagaland and Meghalaya. These states are part of Zone 1 region of All India Co-ordinated Research Project of maize varietal testing of the country. This study aims to assess the change in trend of key traits *viz.*, days to anthesis, days to silk and yield in checks which are used for at least eight years in a row in All India Co-ordinated Research Project of maize in northern hills region. On studying the effect of climate change in rainfall, a shift in peak of rainfall, reduction in peak of total rainfall during the rainiest months and low rainfall in the initial months of the maize crop season was observed. In maize hybrid 'Seed Tech 2324', days to anthesis and silk have decreased by 0.31 and 0.11 days per year, respectively, while in 'Bio 9681' days to anthesis and silk decreased by 0.27 and 0.07 days per year, respectively. Concomitently, there is an increase in yield by 0.29 per cent and 0.10 per cent per year. Over the years, the check genotypes showed change in days to anthesis, days to silk and yield suggesting the importance of crop genetic background in adaption. 'Seed Tech 2324' and 'Bio 9681' are more fit to climate change as compared to 'HIM 129' and 'Surya'. Suitable genotypes like 'Seed Tech 2324' and 'Bio 9681' showed increase in yield in changing favourable conditions in Himalayan region.

Key words: Crop adaption, climate change, days to anthesis, days to silk, maize, hybrid

Introduction

Maize (*Zea mays* L.) is one of the most versatile emerging crops with wider adaptability under varied agro-climatic conditions. Globally, maize is known as 'Queen of Cereals' because of its highest genetic yield potential among cereals. In India, maize is the third most important food crops after rice and wheat. Since 1950-51, the area, production and productivity of maize have increased by several folds. The current level of area, production and productivity is 8.17mha, 19.33mt and 2414kgha^{-1}, respectively, *vis-a-vis* increase in maize demand for diversified uses. The North-Eastern region accounts for the production of 250.9 thousand tonnes out of 177.6 thousand hectare with an average productivity of 1500 kg/hectare [1]. Maize is an important cereal crop in Sikkim, Nagaland and Meghalaya [2]. Maize in Himalayas especially Sikkim, is grown in lower hills (tropical 300-500m above mean sea level - a.m.s.l.); (sub-tropical 500-1500m a.m.s.l.), mid hills (temperate: 1500-2000m, a.m.s.l.) and high hills (temperate 2000-2700m, a.m.s.l.) [3].

Organized research on improvement of maize started in India in 1957 under the auspices of 'All India Coordinated Research Project' (AICRP) and was the first in a series of coordinated projects under the ICAR system. It broadly divides India into five major agro-climatic zones among which Zone 1 (Jammu and Kashmir, Himachal Pradesh, Uttrakhand and North Eastern states) is our area of study. More than fifteen maize hybrids and composites are so far released for Himalayan region of the country. North-Eastern region comprising states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura is eco-sensitive and unique, where the impact of climate on agriculture is ecologically and economically important for the hill farmers. Over a period of twenty years, climatic parameters have seen to undergo changes. Assessment of key climate variables such as temperature fluctuations, precipitation (intensity and frequency), humidity and soil erosion over a period of years not less than a decade is a requisite to study impact on agriculture. Several reports [4-6] validate the change in temperature and precipitation in the north-eastern region. Maize and mustard are also likely to experience decrease in productivity in the entire region

by 2030 [5]. Suitable genotypes and management strategies are observed to maintain the productivity trend even under crucial climate changes as studied in past decades [7-11]. In the present study, we assess the changes in genotypes (hybrids/composites) used as checks over a period of twenty years in maize AICRP with respect to three key traits *viz*., days to anthesis, silk and yield considering the change of climatic variables like rainfall.

Materials and methods

The first stage of Co-ordinated varietal trials is the Initial Evaluation Trial (IET). Trials on two different maturity groups of maize *i.e.* 'full season' and 'extra early' were considered for the study. Out of several checks grown in northern Himalayan region (Zone 1) over a period of years (1990 and 2010) those checks which were tested for at least eight years were used for the study in a row in these twenty years [12]. Among them, two checks *viz*., 'Surya' and 'HIM 129' were chosen in extra-early group and two hybrids *viz*., 'Seed Tech 2324' and 'Bio 9681' were chosen from the full season group. The seeds of the hybrids and composites were obtained from the same source every year for testing under co-ordinated evaluation. This will eliminate the possibility of any change in gene frequency or genetic composition especially in composite Surya. Detailed features of the checks are given in Table 1. Himalayan region is characterized by low temperature and high rainfall especially in north-eastern states. The maize entries and checks are evaluated in this zone at four active stations *viz*., Almora, Bajaura, Kangra and Barapani representing the mid-altitude conditions. The mean monthly rainfall of Jorhat station of Assam surrounded by north-eastern hills states in AICRP reports of last fifteen years was computed to plot the variation in these variables. The north-eastern region is known for its high

rainfall especially during monsoon season [4]. The traits studied were days to 50% anthesis, days to 50% silk and grain yield (kg/ha) of the checks.

Simple linear regression of the values obtained for the IET of each check on years was computed to observe change in traits in twenty years. A straight line was fitted through the points using linear regression. The variance and coefficient of determination (R^2) value were computed to understand the changes in the traits under study [13]. The variance was calculated to assess the extent of response of genotypes over years. The lower the value of R^2, the lower is the fluctuations observed over years and *vice versa*.

Results and discussion

In order to understand the change in the climatic variables, monthly rainfall was used for the Jorhat center which is surrounded by north-eastern states. Even though the year effects are associated with variables like temperature, precipitation, biotic and abiotic stresses etc., the parameter rainfall/precipitation was used to understand any fluctuation in the rainfall and its pattern to represent any change in the climate. The rainfall during crop season (April to September) was high in this region for years 1997-1998, 2002-2003, 2007-2009, was 1847.6 mm, 1431.8 mm, 1423.0 mm, respectively, [12] indicating that there is reduction in total precipitation in total rainfall during crop season. Similar trend was observed in the total average rainfall over years at Jorhat, Assam.

The monthly rainfall in these three discrete block years (1997-1998, 2002-2003, 2007-2009) of Jorhat region of Assam (Fig. 1) indicated a change in the climatic conditions. It was observed that in last 15 years, there is shift in peak of rainfall from July to August, the total rainfall during the peak month has reduced and

Table 1. A list of the genotypes (checks) and their pedigree used for study

| Variety	Year of release	Pedigree	Features	Period of testing
'Surya' (Composite)	1988	(Gulat x Ant. GR.II) XD743, (DIXJ603)XD743, (J603 x J602) x D743 D765 (D745 x D743, D743	Early, tolerance to stalk rot, Nitrogen responsive, average yield 30 q/ha	1997-2008
'HIM 129' (Three way cross)	1997	(CM128 x CM129) x CM 502	Early, tolerance to MLB, TLB, ESR, average yield 40-42 q/ha	1998-2008
'Seed Tech 2324' (Three way cross)	2001	Private sector release	Full season, Average yield 65-70q/ha	2004-2011
'Bio 9681' (Single cross hybrid)	1997	Private sector release	Full season, Average yield 85-90q/ha	2004-2011
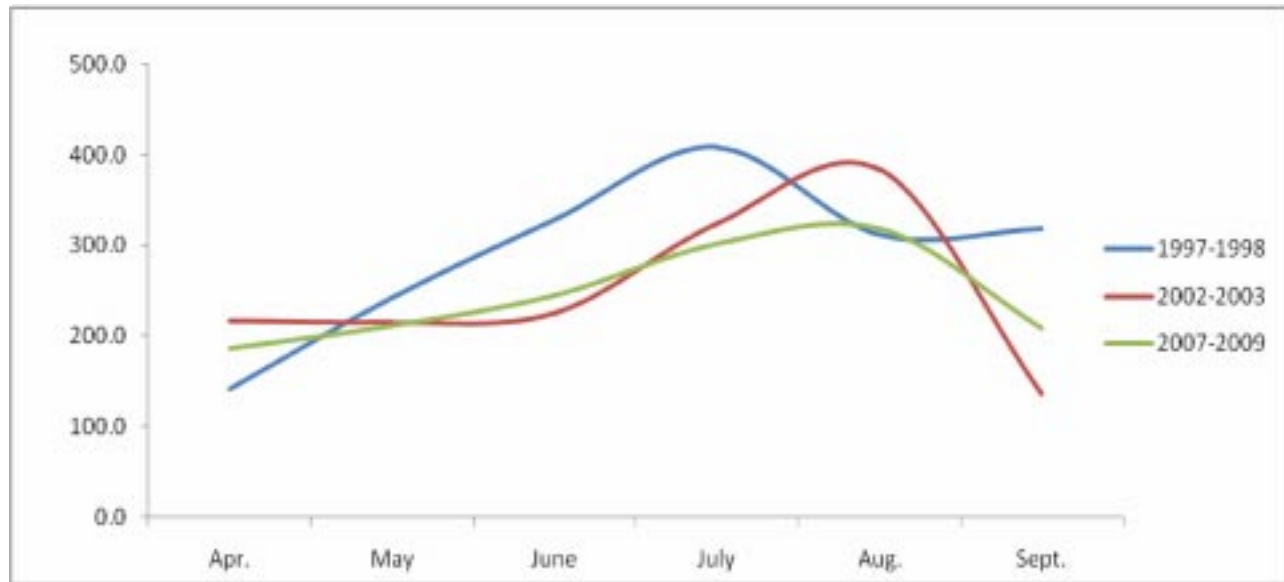
Fig. 1. Trend of monthly rainfall distribution (mm) in three block years of Jorhat region of Assam

the rainfall in the initial months (April, May and June) of the crop season *i.e.* during the vegetative growth of the maize crop has been reduced. The choice of two or three block years is so as to highlight the discrete change in shift and spread of the rainfall. Purposeful choice of block years avoids merging the effects of rainfall because the change in rainfall is continuous year after year and it is not possible to observe visible change just in one year. Similarly, analysis of weather data [4] shows that rainfall was normal for a period of 27 years (1983 to 2009) in Meghalaya. They also observed that the intensity and frequency of precipitation was fluctuating and misleading the crop planning in rainfed areas. Their climate models predict that in future there will be 2.0-3.5^{o}C increase in temperature and 250-500mm increase in precipitation in the north-eastern region. Another study [14], predicts that by 2030 AD, there will be increase in temperature from 1.7 to 2.0^{o}C and rainfall may increase of 940±149mm to 1330±174.5mm in north-eastern region. Both the studies predicted an increase in rainfall which is contrary to our observation of last 15 years at Jorhat. The optimum temperature of maize is 25°C to 33°C during day time and 17°C to 23°C during night time [15] and rainfall ranges from 500-1200mm in a well drained soil [16] for proper growth and development. The climatic conditions in northern hills characterize with low temperature and high rainfall and with the changing climatic conditions like reduction in total and monthly rainfall (Fig. 1), the climate for the cultivation of maize becomes more favourable.

After being convinced on the change in climatic conditions, the linear regression curves of checks namely 'Surya', 'HIM 129', 'Seed Tech 2324' and 'Bio 9681', for three traits (days to anthesis, days to silk and yield) shown in Figure 2 was studied. Days to anthesis and days to silk were reduced in full season hybrid checks where as increased in extra-early checks (Fig. 2a,b,c&d) indicating a shift in these traits. Figure 2e and 2f represent trend of yield in checks. The data revealed that days to anthesis and silk were increased in 'Surya' with an average of 0.44 and 0.05 days per year, respectively. In 'Surya' yield reduction is at the rate of 92kg/ha per year while in HIM 129 decrease in yield is at the rate of 293 kg/ha per year. The same trend was observed in 'HIM 129' with increase in days to anthesis and days to silk at the rate of 0.65 and 0.35 days per year, respectively. The observed data explains that days to anthesis and silk were reduced in 'Seed Tech 2324' at an average of 0.31 and 0.11 days per year, respectively. The reduction in days to anthesis and silk in 'Bio 9681' was 0.27 and 0.07 days per year, respectively. Yield is a complex trait, increased by 3034 kg/ha in 'Seed Tech 2324' and 907 kg/ha in 'Bio 9681'from 2004 to 2011. Increase in temperature and reduction in rainfall become more favourable for the cultivation of maize in northern Himalayas. The increasing trend in maize yield in hybrids like 'Seed Tech 2324' and 'Bio 9681' may be attributed to maximization of their yield potential under changing favourable conditions in Himalayan region.

The non-significant R^2 value exhibited lower

Extra-early checks   **Full season checks**
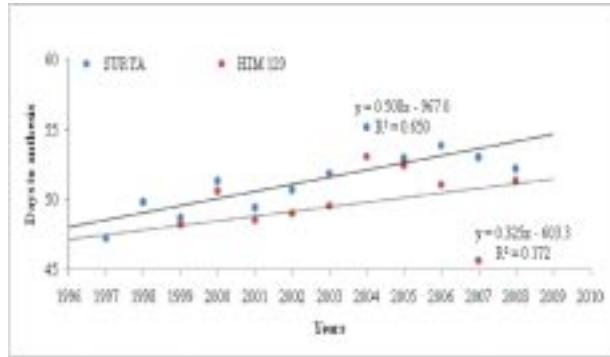
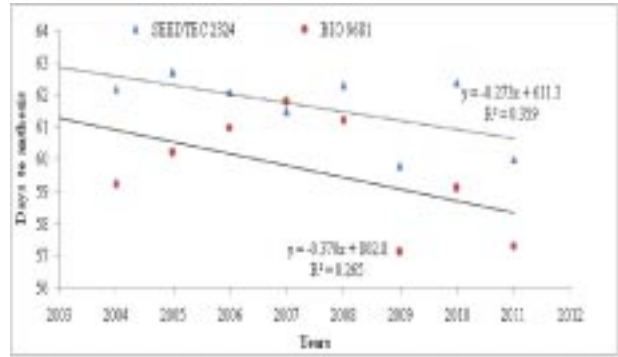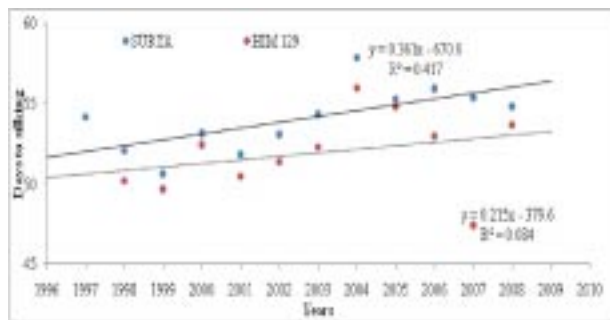(a)   (b)

(c)   (d)
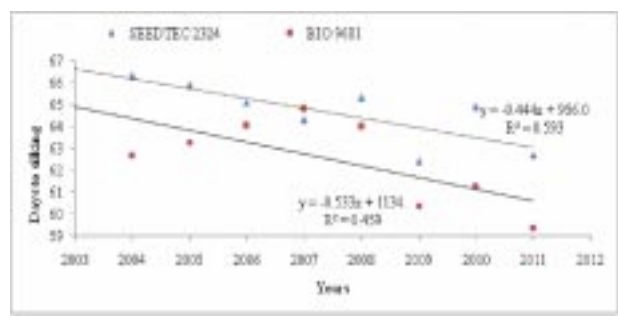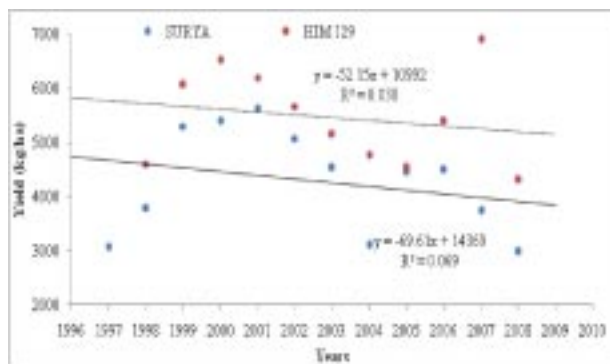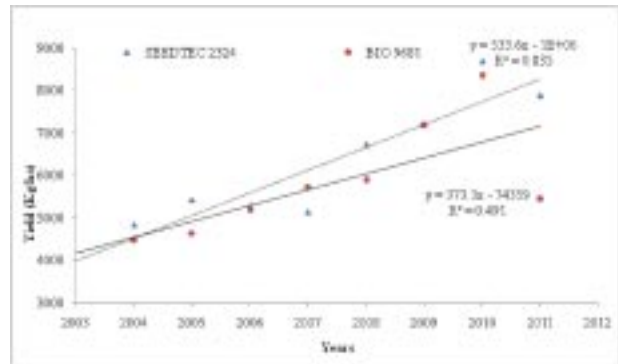

(e)   (f)

Fig. 2. Performance of extra-early and full season maturity checks for days to anthesis, days to silk and yield in their respective years of testing

variation and *vice-versa*, over years for the trait under study. In case of days to anthesis and days to silk, the variance was high in 'Surya' and 'HIM 129' and lower for 'Bio 9681' and 'Seed Tech 2324'. In addition, the R^2 was significant for days to silk in 'Bio 9681' and yield in 'Bio 9681' and 'Seed Tech 2324'. The lower R^2 values in case of extra-early check 'HIM 129' indicate less variation explained by these traits over years. Significant R^2 values of late season checks explain higher variance

to these traits over years (Table 2).

'Seed Tech 2324' showed non-significant R^2 values for days to anthesis and silk exhibited better adaptability to the changing climatic conditions over years, while the yield showed steep increase coupled with significant R^2 and high variance. 'Seed Tech 2324' also showed similar steep rise in yield zone IV [17] as compared to other zones of the country keeping in mind the same seed source. The hybrid 'Bio 9681' showed

Table 2.   Trend of change, variance and coefficient of determination among the genotypes

Checks	Days to anthesis			Days to silk			Yield (Kg/ha)		
	Change	$\sigma^2 \pm SE$ days/year	R^2	Change	$\sigma^2 \pm SE$ days/year	R^2	Change	$\sigma^2 \pm SE$ days/year	R^2
Surya	0.44(+)	5.16±0.65	0.65*	0.05(+)	4.07±0.58	0.42*	92(-)	906±0.3	0.03
Him 129	0.65(+)	6.78±0.78	0.17	0.35(+)	6.07±0.14	0.08	293(-)	772±0.3	0.06
Seed Tech 2324	0.31(-)	1.25±0.39	0.36	0.11(-)	1.99±0.47	0.59	3034(+)	2045±0.5	0.83*
Bio 9681	0.27(-)	3.09±0.62	0.27	0.07(-)	3.76±0.54	0.46*	970(+)	1701±0.5	0.49*

(+) – Increasing trend; (-) – Decreasing trend; * $\leq$ P 0.05

high variation and significant R^2 for days to silk and yield with increase in yield. High variance and significant R^2 in composite 'Surya' for days to anthesis and silk; and non-significant R^2 and low variation for yield, exhibited the effect of changing climate on parameters like days to anthesis and silk but had a reduction in yield though non-significant. Such genotypes are more vulnerable to changing climatic conditions. Similarly, 'HIM 129' showed low variation, non-significant R^2 and reducing yield. Keeping in mind, that increasing temperature in hills [4, 14] and reducing rainfall in high rainfall north-eastern region has become more suitable for maize cultivation, the 'Seed Tech 2324' and 'Bio 9681' is more fit to climate change as compared to 'HIM 129' and 'Surya'.

The better performance of hybrids ('Seed Tech 2324' and 'Bio 9681') lies in the ability of its genotypic background to adjust its genes to the environment over 'Surya' (composite) and 'HIM 129' (three-way cross). Hence, irrespective of the method of breeding used it is the elite genotypic background of any genetic material that makes it primarily high performing.

Extra-early checks Full season checks

Himalayan zone is well known for its genetic variability and vast genetic resource. Several workers have emphasised the utility of genetic resources and diversity which are abundant in hills to cope up the effect of projected climate changes [18, 19 and 20]. Breeding efforts in mission mode approach is needed to develop superior genotypes tolerating drought like situation arising due to fluctuating rainfall, water-logging in foot-hills and threat of new pest and diseases [20]. Traits of interest in maize would be for earliness, drought (fluctuating intensity and frequency of rainfall), photosynthetic efficiency in low-light intensity, harvest index (physiological expression of yield), root traits, osmotic adjustment, primary and secondary defensive metabolites, stay greenness, water use pattern (litres

plant^{-1}week^{-1}), genotypic response in stress at flowering, grain-filling period and anaerobic germination created by flooding in foothills and diseases like Banded Leaf Sheath Blight and Turcicum Leaf Blight prevalent in north-eastern hills. We would suggest early genotypes that would mature before September end when sown in May month viewing the shift in rainfall pattern as shown in Figure 1. Development of base population and introgressing it with new genetic material is suitable for changing climatic conditions. From the improved base population elite inbreds can be derived and used in new superior combinations. Prospecting new genotypes for novel direct and indirect tolerance traits and utilizing them in cross-combinations can enhance climate readiness of maize. Scientists are making concerted efforts in identifying genotypes with higher yield coupled with relatively better abiotic tolerance [21-24]. In years to come, the change in climate is indispensible and the aberration in climatic factors like rainfall with a crop season has increased. There is a shift in peak of rainfall from July to August, the total rainfall during the peak month has reduced and the rainfall in the initial months (April, May and June) of the crop season has been reduced. This study lays emphasis on the inherent ability of genotypes to show positive response and adaptation under changing climate. The genotypic background of inbred can be improved through the development of base population in this region and deriving good inbreds. The results indicated that 'Seed Tech 2324' and 'Bio 9681' is more fit to climate change as compared to 'HIM 129' and 'Surya'. Area-specific crop improvement and management strategies are required taking into account change in climatic variables in north east. Conventional breeding aided by modern tools and techniques can bring in high yield cultivars integrated with climate ready traits. Genotyping is more informative, faster and reliable due to the recent biotechnological tools available. With sustainable resource management coupled with excellent and affordable hybrids, climate readiness of maize can be improved further.

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