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Impact of climate change and IP regime on the production and availability of quality seed

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Abstract

Timely availability of high quality seeds of improved varieties, suitable to perform well in different growing environment, is a key component of agricultural production system. Hence, an effective seed production plan not only needs to take into account the overall commercial value of crop varieties, but also their potential to perform satisfactorily in respective agro-climatic regions, both under optimum and sub optimum conditions. In the present scenario of changing and fluctuating climate, this means that the seed plan should meet the demand of improved varieties having high commercial value and also be prepared to fulfil the contingent demands in fluctuating / unfavourable weather conditions. In India, drought and flood are of common occurrence in some part of the country or other. In the recent years, the rise in temperatures, particularly at flowering and grain filling stages, have also been experienced frequently. Intensive cropping schedules, growing industrialisation and poor soil management practices are affecting the soil status. Focussed and extensive crop improvement programmes, particularly in the post-New Seed Policy, 1988 period, resulted in a greater choice to the farmers with respect to new varieties and hybrids' availability. This, on one hand increased the profitability of the farmers, and on the other hand, also helped in increasing the Seed Replacement Rate (SRR), which is still much lower than the desired levels in different crops. The SRR has shown significant rise in the crops where suitable hybrids have been introduced, but in OPVs, specially in high volume, low profit crops, which are crucial for national food security, *viz.*, cereals and pulses, more is desired. The seed production programmes must, at all times, ensure availability of seeds of such varieties, which can be taken up in the event of uncertain weather / constraints. For instance, when a timely sown crop fails due to early moisture stress situation, the farmer may go for resowing with a late sown, short duration variety or if the crop fails due to unfavourable weather in one season, the farmer may go for a substitute second crop, provided seeds of suitable varieties are available and the farmers are well informed and guided. The second aspect of seed production in the changing climate concerns the yield and quality of the seed produced under unfavourable weather conditions. Of various climatic factors, it has been observed that high temperature and moisture stress to the seed crop not only reduces the seed yield, but also affects the seed quality and performance of the resultant crop. In general, delayed maturity, caused by one or more environmental factors, reduces seed quality to a significant level. However, elevated CO_2 levels do not adversely affect the seed quality or yield. Given the assumption, that in post-PPV&FR regime the focus of the private sector would be to develop hybrids / varieties for favourable growing environments, developing varieties for unfavourable / uncertain environments and making available seeds of the same, following an advanced and timely planning will be the primary objectives of the public sector research and seed production organisations. To encourage this, a policy to provide certain incentives for the latter may be considered.

Key words: Climate change, CO_2, temperature, flowering, seed set, seed yield, seed quality, PVP

Introduction

The economy of an agrarian country like India, is predominantly dependent on the weather factors. The rising population, shrinking land and water resources, greater per capita food demand (owing to socio-economic changes) lead to an ever-increasing pressure on agriculture production, leaving very little scope for compensating crop failures under drastically changing climate. The change in climate with time is a natural phenomenon, and the flora and fauna on earth undergo continuous processes of evolution to adapt to the changing environment. However, the situations have become particularly alarming, owing to the rapid climate changes being experienced world-wide, as a consequence of extreme industrialization, urbanization by reducing the green cover, depletion of natural resources due to indiscriminate use etc. All these have affected the well being of this living planet in general, and agricultural production, in particular.

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Climate change, which in simple terms refers to the rise in mean minimum and maximum temperatures, elevations in CO_2 and other green house gases, coupled with less/more or erratic rainfall patterns, is a matter of great concern for the agrarian ecologies. Climate change is predicted to bring about increased temperatures across the world in the range of 1.6^{o}C to 6^{o}C by 2050. And, although rainfall is predicted to increase globally, some areas will receive less annual rainfall, while others may record significant increase, with associated changes in the timing of rains and lengths of dry seasons. The frequency and durations of the extreme environmental pattern will also increase.

The primary objective of the crop breeders is to develop varieties suitable for different agro-ecological conditions, better adaptability, higher productivity and special consumer needs. Thus, more short duration, photo and thermo-insensitive varieties of important food crops have been bred to fit into different cropping patterns, and giving stable yields under variable conditions. A number of hybrids have been introduced since the 70s, to enhance crop productivity in some field crops, *viz*., rice, maize, bajra, sorghum, cotton, sunflower, castor etc., and several vegetables including tomato, brinjal, cucurbits, cole crops etc.

Use of quality seeds of high yielding improved crop varieties is considered one of the most effective components, which alone can increase agricultural productivity by 15-20%. In India use of poor quality, farm-saved or locally purchased low quality seeds of old crop varieties by a large section of farmers (nearly 70%), is one of the factors responsible for poor average productivity in most of the food/field crops.

In order to improve the quality and quantity of the seed produced, locations and seasons for seed production are identified and seed production technology is standardized for different crops. Flowering behaviour of varieties being very sensitive to environmental factors, such as temperature, relative humidity, rainfall and day lengths, seed production programme needs precise planning, particularly in case of hybrid seed production, requiring synchrony in the flowering of the parental lines, maximization of pollination and seed setting. The environmental factors at seed filling and maturation also influence germination, vigour, longevity and seed health of the resultant crop. Therefore, seed production strategies need to be modified and refined, keeping in view the changing climate. In general, climate change, particularly the rise in temperature and erratic rainfall, are expected to result in reduced plant growth and crop yield and greater stress imposed by pests and weeds. But for the seed crop, management of diseases and achieving an optimum seed set are more critical aspects.

India has implemented the PPV&FR Act, 2001, ensuring the protection of breeders' as well as farmers' rights in variety development. However, it is feared that as its consequence, availability of seed of improved protected varieties may not be as readily available to the farmers as it was before the enactment of this legislation. As per the provisions of this law, farmers are free to use, save, share, exchange or sell seeds of a protected variety, except as branded seed. Thus, these two factors, i.e. the climate change and implementation of the PPV&FR Act, 2001 may limit the availability of seeds of the desired varieties to the farmers in the coming years, unless addressed in time. In the present paper some of the primary impacts of climate change on different aspects of seed production will be discussed suggesting possible management practices for the same. Strategies to make available quality seeds of new improved varieties (NIV) and hybrids in view of the PPV&FR Act, 2001, will also be suggested.

Effect of climate change on pollination and seed set

Abundant and timely pollen production is a key requirement for reproductive success. Inter-annual variation in pollen production results in variable seed production in several temperate species [1-3]. Differential responses to high CO_2 and temperature on the male and female reproductive systems and their effects on pollen production, release, movement and seed set may have important implications on population dynamics. Rising CO_2 concentrations are reported to increase pollen production at an early growth stage [4, 5]. Precocious pollen production also has potential implication on the ecosystem, increasing the percentage of fertilized ovules and production of viable seeds [6, 7].

Of the two important parameters of climate change, i.e. rise in CO_2 and temperature, the later is considered more serious, in the context of seed production. A study conducted in Kansas State University, USA showed that higher mean temperatures adversely affect pollen viability, seed set and seed yield in *Sorghum bicolor* L. due to elevated tissue temperatures [8]. Temperatures of 40/30^{o}C and 44/34^{o}C inhibited panicle emergence, whereas temperatures of > 36/26^{o}C significantly decreased pollen production, pollen viability, seed set and seed yield as compared to temperatures of 32/22^oC. The effect was more deleterious at elevated CO_2 conditions, reducing seed yields by 10% at 36/26^oC, though at 32/22^oC elevated CO_2 levels showed a positive effect on seed yield.

A study based on the analysis of meteorological data of upper Kullu Valley in Hindu Kush Himalayas from 1981-2004 and the seed yields of cabbage cv. Golden Acre revealed that the mean maximum temperature in the month of May rose by 1.58^oC, whereas mean minimum temperatures in the months of April and August rose by 2.03 and 2.165^oC, respectively. IPCC has projected temperature increases of 0.15 to 0.3^oC per decade from 1990 to 2005 in different locations. The rise in Kullu Valley was found to be about 0.2^oC per decade. During this period (1981 to 2004), nearly 40% reduction in seed yield/unit area was also recorded. However, the reduction in seed yield could be a combined effect of rising temperature and delayed and /or reduced rainfall recorded during the cropping season.

The dwindling population of honey bees recorded in the valley during this period might also have contributed towards low cabbage seed production due to poor pollinators' activity. Allen *et al.* [9] reported pollination failure as one of the major factors reducing the seed yield due to temperature rise. Non-synchrony in the flowering of the parental lines and effect on anther dehiscence due to rise in the mean minimum and/or maximum temperatures are also of critical importance, particularly in hybrid seed production. A study [10] conducted at New Delhi on the effect of temperature on hybrid rice seed production revealed that a rise in the Effective Accumulated Temperature could delay the flowering of the parental lines by 2-3 days (Table 1).

Similarly, desiccation of silks and poor receptivity of stigma in maize were recorded with the rise in mean daily temperature, which also showed significant genotypic differences, particularly in spring-summer season [11].

Climate change and seed production

Seed crops comprise nearly 70% of food and feed requirements of the world. Hence, impact of the climate change has a greater consequence in terms of food grain production. An increase of 1^oC in mean temperature is estimated to reduce the annual wheat production by 4-5 Mt in the country. Over all cereal productivity is expected to decrease by 10-40% by 2100 [12]. In a study conducted at IRRI, Philippines, 1.13 and 0.35^oC increase in mean minimum and maximum temperatures were recorded during 1979-2003, consequently an yield reduction of 10% per 1^oC rise in mean minimum temperature in dry season was indicated [13]. It is, therefore, predictable that climate change, particularly the rise in temperature during seed development and maturation stages will significantly lower the seed yield. However, CO_2 enrichment shows a positive effect on seed yield [14], off-setting the negative impacts of temperature. A Regional Climate Change Model (PRECIS) for China predicts significant effect of climate change on seed yields of wheat, rice and maize, if CO_2 fertilization is not considered [14].

In soybean rise in day temperature decreased the seed yield upto 27% but high night temperatures had little impact on seed yield [15]. Egli *et al.* [16] reported that germination and vigour of soybean seed were significantly reduced with the increase in mean maximum temperature during seed filling, though the genotypic variability was noted. Higher temperature also increased seed infection with *Phomopsis longicolla* (Hobbs). Influence of high temperature was more pronounced on seed vigour than on germination of seed [16, 17]. The effect of temperature on seed could either represent the cumulative effect of stress throughout seed filling, or only at maturity [16]. As vigour contributes

Table 1. Effect of temperature on flowering time of the parental lines of rice hybrid PRH-10

Items	Site I		Site II		
	6A	PRR-78	6A	PRR-78 (R1*)	PRR-78 (R2*)
Flowering date	11 Sept.	6 Sept.	29 Sept.	30 Sept.	2 Oct.
Duration from sowing to flowering (day)	89	91	91	89	88
EAT from sowing to transplanting (T^0C)	441.8	500	442.5	392.0	339
EAT from sowing to flowering (T^0C)	1434.9	1410.2	1480.0	1463	1439

(Source : Thu *et al.*, 2008)

*:R lines sown on two different dates; EAT : Effective accumulated temperature

greatly towards determining the ultimate planting value of seed, it is desirable that all seed lots harvested from crops grown under stress/less favourable weather conditions are tested for seed vigour. If the lots show acceptable germination but poor vigour levels, these may be treated appropriately to enhance seed vigour (through priming, invigoration etc.). Also, in order to avoid major losses or production problems, two or more alternative seed production locations should be identified.

Changes in the chemical constitution of the seed due to temperature rise at maturation have also been observed, resulting in indirect effect on seed quality. In case of seed grain crops, such alterations also have impact on human/animal health [18, 19]. Such observations in many crops are common to seed growers across the region. The seed producers, therefore, select areas which have a stable and moderate weather pattern during the growing season of a seed crop to ensure good quality and economic seed yield.

In lupin, higher temperature during early seedling growth and maturation not only reduces seed yield and 100 seed weight, but the crop raised from such seeds also exhibited delayed development and flowering, which could result in variability of performance [20].

In view of the above impacts of the weather factors on flowering and seed setting, in most of the developed countries having temperate to sub-temperate climates, hybrid seed production of high value crops (mainly vegetables and flowers) is undertaken in controlled growing conditions. A favourable temperature condition, coupled with desirable levels of RH and photoperiod inside poly house/green house or shade net can be maintained to maximize hybrid seed production. Studies undertaken at IARI, New Delhi [21] showed (Table 2) that in tomato, flowering duration can be prolonged by 15 days inside a polyhouse, as compared to open fields in the winter season. The pollen viability and production was more in the male plants grown inside, resulting in higher fruit set, when the critical mean minimum temperature was below 12°C (Table 3). The hybrid seed production inside the poly house was nearly double (2.5 to 3.1 kg) than that in the open field (1.2 to 1.5 kg).

Table 2. Flowering behaviour of the parental lines of tomato hybrids (Rabi, 2004-05)

Particulars	Date of Sowing – November 15th			
	Field		Poly house	
	Male	Female	Male	Female
Date of first flower opening	17th Feb	22nd Feb	5th Feb	10th Feb
Days to first flowering (days)	62	67	45	50
Date of termination of flowering	5th Apr	10th Apr	10th Apr	15th Apr
Duration of flowering (days)	47	47	63	63

(*Source : Manjunath C., 2009)*

seed yield. The effect is seen both in winter and summer season crops, though it is more pronounced in temperate crops.

- Temperature effect at early seedling stage is carried forward till maturity both on crop duration and seed yield.

Table 3. Effect of temperature and crossing date on fruit and seed set in tomato hybrid seed production

Date of pollination	Temperature (°C)			Fruit set (%)	Seed wt per fruit (mg)
	Max	Min	Mean		
5.3.2006	30.0	11.0	20.50	70.0 (44.49)	125.0
10.3.2006	28.4	17.2	22.80	58.0 (35.48)	115.0
20.3.2006	30.0	17.0	23.50	46.0 (27.41)	100.0
28.3.2006	33.0	17.2	25.25	28.0 (16.27)	85.0
Mean				50.5	106.25 (30.91)
C.D. (p=0.05)			3.68	9.32	

(*Source : Manjunath C., 2009)*
*Figures in parenthesis are arc sine values.

Thus, with reference to the climate change and rise in mean temperatures and seed production, it may be concluded that:

- In general, rise in temperature at seed development and maturity (grain filling) reduces

- Rise in temperature at maturation of the mother crop also may influence vigour as well as onset of flowering pattern of the resultant seed crops.
- In some cases, reduction in seed yield due to temperature rise may be offset by rise in CO_2 levels, which have a positive effect.
- Days to flowering and pollination dynamics (pollen production, dehiscence, movement viability, stigma receptivity etc.) are greatly influenced by climate change. Therefore, while selecting a location for seed production, particularly of hybrids, due care needs to be taken to ensure favourable weather during flowering and maturation. This is even more critical in case of entomophilous species.
- Hybrid seed production of high value, low volume crops under artificially controlled conditions may be considered as a cost-effective alternative.

Impact of plant variety protection on seed production and availability

The seed sector in India has made considerable advancements in the post-National Policy for Seed Development, 1988 (NPSD, 1988) era. While the National Agricultural Research System (NARS) laid the foundations and still is the backbone of the agriculture development in the country, the private sector, comprising nearly 300 companies, many of which have sound research and development programmes, has also made significant advancements in developing improved plant varieties/hybrids for different conditions. The emphasis of both public research is on developing high yielding varieties resistant to biotic and abiotic stresses, whereas private sector primarily caters to that for the favourable ecosystems.

The Indian Act on plant variety protection, the Protection of Plant Varieties and Farmers Rights Act, 2001 (PPV&FRA, 2001) addresses the protection of both breeders' and farmers' rights. Farmers are the conservators, selectors and developers of many traditional varieties, landraces, farmers' varieties etc. Some of these have great potentials to be used in the breeding programme, for developing varieties in view of the climate changes. Many of the native varieties, though low yielders, are known to have resistance against biotic and abiotic stresses and wide adaptability to weather fluctuations, particularly terminal heat and moisture stress conditions most common with the present day change in global climate.

The public research institutions will have to bear greater responsibility in breeding open-pollinated varieties with desired tolerance to abiotic stresses (a direct effect of climate change) and multiple/complex biotic stresses (an indirect effect of climate change resulting in greater incidence of pests, diseases and stronger competition against weeds). Release of the Bt-cotton variety (Bt-BN-1) by the NARS is a significant step forward.

Linkages and partnerships between the public research institutions and the public and private seed sector in variety development and commercialization and inclusion of farmers' participation in quality seed production, at least of the open-pollinated varieties released by the public institutions, are some of the strategies which may be adopted as a regular practice rather than an exception. By following the principles of a dynamic cropping system [22], we can ensure (a) development of new varieties as per changing climate conditions and (b) access and availability of sufficient quantities of quality seeds of new improved varieties to the farmers at affordable prices.

Creation of Seed Banks for maintaining sufficient quantities of seeds of such varieties that can be included in case of contingent situations due to climatic vagaries, such as drought, heat waves, floods etc. could be an effective measure to meet the challenges of climate change. Varieties, which are of short duration or suitable for late (very late) or early sowing, may be recommended to compensate, to some extent, the failure of the timely sown crops.

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