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# A model based case study on impact of weather on different cultivars of Bt-Cotton and sowing dates

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## A B S T R A C T

One has to understand all the intricacies of its biotic and abiotic stress to pave the a way for the Silver Fibre Revolution. This is also, to imply the best management practices necessary, well derived through experiments or modeling. Since the introduction of Bt-Cotton there occurred a revolution in the production of cotton crop in India. The study includes three Bt-Cotton varieties at three different sowing days to assess the suitable variety at suitable planting date. This is due to the going on debate, i.e. which variety and sowing date would give a better output. And, as many studies suggest that earlier sowing date could give a better yield. This has been done through modeling through DSSAT upon field experiment data. As per model output we observe that the Pancham-541 variety shows the best average yield over the years with the sowing date 10th May over years. Also the values of SD and CV suggest that the yield of this variety has been impacted with the changing years as compared to the other varieties and other sowing dates. Least production can be seen in the variety SP-7007 as compared to other varieties. Also in SP-7007 with increasing sowing date the production has been decreasing, in contrary to the variety Pancham-541 which has shown increasing trend with increasing dates, as suggested by the model studies. Sowing date of 21st May has shown least variability in all three varieties over years. Where least CV of the variety SP- 7007 in all sowing dates as compare to other variety as per model output suggest least impact of changing weather conditions over year on this variety. Maximum average yield is seen in Panchan-541 as compared to other varieties.

***Keywords:*** *Bt-cotton, sowing date, modeling.*

## 1. Introduction

Cotton belongs to the Gossypium genus comprising various species of family Malvaceae. It is one of the most important fibre crops of global significance. It is also termed as "White Gold of India". It is an important commodity crop globally and provides us with fibre, oil and protein as food supplement, and potentially a fuel for diverse industries. It is one of the most important cash crops and material for textile industry. The economy of an agro based country like India is predominantly based upon the Agriculture Sector. This includes the production of edible crops for food security and cash crops as well for economic empowerment. Due to its economic relevance it is our

priority to provide it with best management practices to increase its production.

With the changing world, climatic trends, monsoon unpredictability and erracticism linked with rising global warming in the Indian Subcontinent there is now a dire need for the study of impact of weather on crops as well. Despite the milestone achievement of highest production, the productivity has still not been enhanced. This basically signifies that the country is not being able to achieve its potential productivity. Also the recent incidence of pests affecting the crop has prime concern which puts mark of interrogation on the effectiveness of Bt-cotton. The Bt-cotton, a genetically modified form of cotton crop introduced in 2002 in India has brought to control the incidence of pest without the use of pesticide [1, 2].

Cotton is a tropical and subtropical type of crop. It requires mean annual temperature of 16°C and an annual rainfall of 50 cm distributed evenly throughout the season. Cotton requires a minimum temperature of 15°C during germination. Since, germination is severely affected when the temperature fall below 14°C. Chilling injury is the damage brought about by near freezing low temperatures in cotton plants at various growth stages. Chilling causes a disruption of metabolic activity leading to death of the plants. The stage of germination had been known to be important in determining the extent of injury (e.g., chilling of pre-emergence seedlings can cause delay in maturity). An optimum range of air temperatures for the process of photosynthesis is 25°C to 45°C; this process may drop to zero at 55°C. The day degrees summations for the completion of development of the cotton plant to be 3000-4000 m above a base temperature of 10°C. The branching habit of cotton crop is also influenced both by temperature and photoperiod.

Certain stress factors including precipitation and/or irrigation, humid weather, if prevalent during later stages i.e., once the balls begin to open, may lead to complications pertaining to defoliation, reduction in the yield, quality and the crop's ginning properties. Also, Boyd in 2004 studied that humidity is a major contributor to pest and insect attacks, for e.g. ball rot after ball opening. Hence, one can reason that the most suitable conditions for maximizing the yield include warm, dry weather conditions, abundant sunlight and availability of soil moisture since the period when the balls start opening through harvest. Parameters such as cultivar characteristics, maximum and minimum temperature, solar radiation and crop management's factors are considered for crop growth models [1].The suite of crop simulation models encompassing the Decision Support System for Agro technology Transfer (DSSAT) includes the Cropping System Model (CSM)-CROPGRO-Cotton model [1]. CROPGRO-Cotton is a recently developed crop model and consists of several parameters [2]. A study states that the model simulates growth, development and yield of cotton in correspondence to various factors like weather and soil conditions as well as management practices. In terms of modification of weather simulation generators/or introduction of a package with the aim of evaluating model performance with respect to changing climate, CROPGRO (DSSAT) is one of the first such package.

Various studies are being conducted upon the plant responses to multiple environmental factors. To maintain optimum growth plants require a balance of all resources. It includes water, energy, and mineral nutrients [3]. However, this may differ in orders of magnitude in their availability. Different species respond differently as per their genetic make-up. The nutritional hypothesis in combination with hormonal influences play a key role in relation to changes in growth patterns during the cotton ontogeny, with a negative correlation between vegetative and reproductive growth [4]. Vegetative and reproductive growth could continue indefinitely under favourable conditions. However, due to demand on the resource supply by the reproductive organs the vegetative growth ceases at the time which is called 'cut-out' as described [5].

Effect of different sowing dates on the yield of seed cotton in Sargodha and Faisalabad district was studied and reported that cotton sown during the period from 15$^{th}$ to 30$^{th}$ April provided the highest per acre yield in comparison to that from late sowing. It was observed

that seasonal variation is an important factor influencing the yield of different varieties of cotton. They concluded the second fortnight of May as the best planting period under the prevalent conditions [6]. Early sowing of cotton in the month of May produced taller plants than the late sowing in June. Increase in plant height in early sowing may be due to longer duration of crop. Also, the number of yield per hectare, balls per plant and seed cotton yield per plant were significantly higher for early sown crop in comparison to that of late sown crop. Higher yield was due to better growth and more number of balls produced per plant. Cotton crops in Sakrand, Pakistan as sown in the period from 5th to 20th May provided highest yield rather than any early or late sown crops [6, 7]. Under Bahawalnagar, Punjab conditions, sowing on 16th May gave the highest yield per hectare [8]. Yield and its attributes in cotton plants were significantly higher in early sown crop than in late sown conditions [9]. Based on mean of two years early sowing of cotton on 15th May has produced higher yield over other two dates 30th May and 15th June of sowing in Rajasthan [10]. Ball weight, the number of balls per plant and the plant height were increased on early sowing. There is also a gradual reduction in the observations with delayed sowing. The study aims at comprehending the productivity pattern of Bt-cotton varieties at different planting dates in response to rainfall variability during the period 2002 to 2014 in Hisar region.

## 2. Materials and Methods

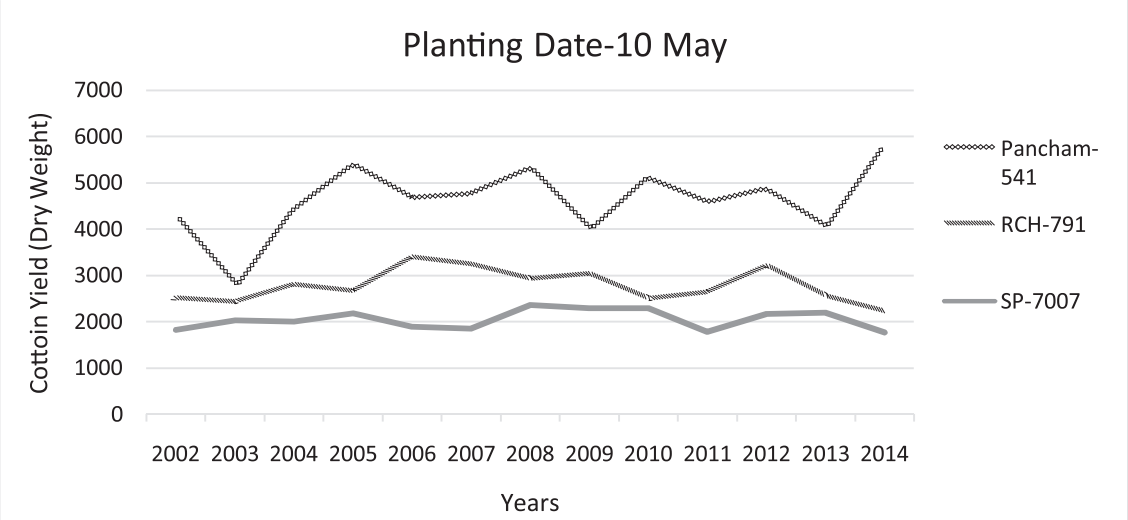
Cotton is a Kharif crop grown mostly between May/June to September/October. Here the crop is well grown in irrigated conditions. In such environments, the productivity of cropping systems is primarily determined by both the amount and distribution of rainfall as well as irrigation quantity and scheduling. This work attempts to study the kharif season cotton plant growth at different phenological stages in Hisar region of Haryana under irrigated condition. Study Area is Hisar which is the western district of Haryana, situated between 74°24' to76°18'E longitude and 28°54' to 29°59'N latitude at an elevation of 215.2 m. The total area of the Hisar district is 3,983 sq km.

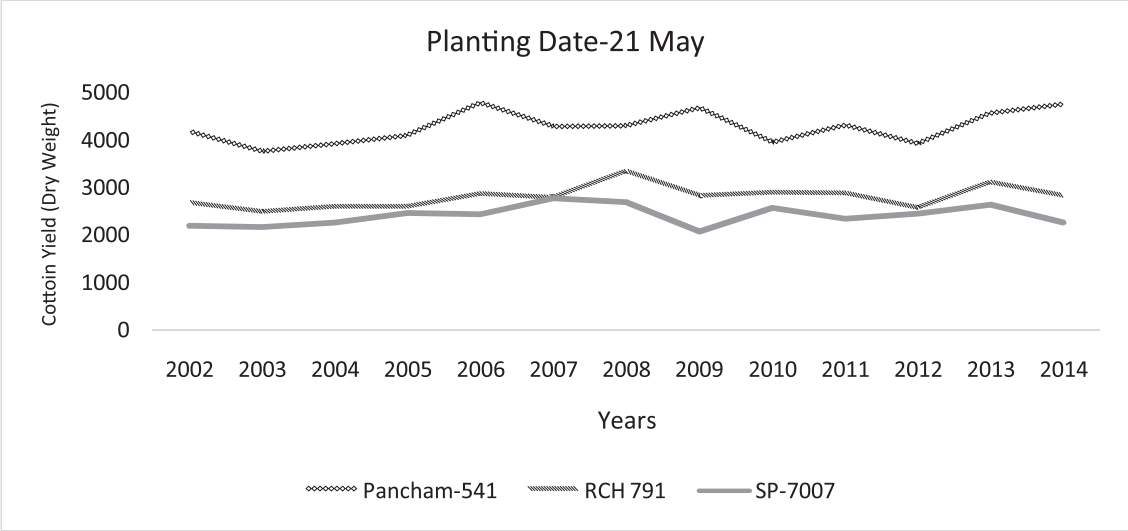
For the model simulation, daily weather station data of Hisar during the period from 2002-2014 was provided by IMD. The crop simulation model tool DSSAT-CROPGRO was used. The CROPGRO model of DSSAT assesses various parameters of the crop and provides output based upon the following phenological stages. The genetic coefficient for this variety has been already developed and reported earlier [11, 12]. For simulation of model three Bt-cotton crop varieties Pancham-541, RCH-791, SP-7007 have been selected as it is cultivated generally in Hisar region of Haryana during the Kharif season. These cultivars were sown on 10th May, 21st May, and 06th June. To achieve this general objective, field experiment is conducted during Kharif season at CCS University, Hisar under the FASAL project of IMD. The soil is shallow and its texture class is sandy loam. In all 200 kg/ha of urea (NH2–CO–NH2) was applied in two equal doses (basal and vegetative growth stage). Daily weather data for the parameters viz. maximum temperature, minimum temperature, hours of bright sunshine and rainfall collected at Hisar during the experiment period were used. Crop management treatment is given as per regular package practices prescribed for the area and carried out during the experiment.

Model is simulated for the period 2002-2014, as Bt-cotton was introduced in the field since 2002. It has been analysed for three cultivars Pancham-541, RCH-91, SP-7007 for three different sowing dates in Table 1. Further simulated deviation % of Dry Yield for given varieties Pancham-541, RCH-91, SP-7007 has been considered on the sowing date 10th May during the years 2002 to 2014 is shown in Table 2 and Fig. 3. Also the values of SD (Standard Deviation, measure to quantify the amount of variation or dispersion in the set of data values) and CV (Coefficient of Variation) is a measure of spread that describes the unitless amount of variability relative to the mean. They are studied to determine the impact of changing environment and sowing dates on the cultivars.

**Table 1. Simulated Cotton crop yield (Dry Weight) using DSSAT-CROPGRO for during different varieties Pancham-541, RCH-91, SP-7007 at three sowing dates 10th May 21nd May and 6th June during 2002 to 2014**

| SOWING DATE | 10th May | | | 21st May | | | 06th Jun | | |
|---|---|---|---|---|---|---|---|---|---|
| VARIETY | Pancham - 541 | RCH-791 | SP-7007 | Pancham -541 | RCH -791 | SP-7007 | Pancham -541 | RCH-791 | SP-7007 |
| YEAR | Cotton Yield (Dry Weight) (kg/ha) | | | Cotton Yield (Dry Weight) (kg/ha) | | | Cotton Yield (Dry Weight) (kg/ha) | | |
| 2002 | 4225 | 2461 | 1815 | 4127 | 2636 | 2202 | 3894 | 2606 | 2402 |
| 2003 | 2763 | 2377 | 2029 | 3701 | 2443 | 2176 | 1485 | 591 | 2434 |
| 2004 | 4354 | 2756 | 1995 | 3859 | 2557 | 2268 | 3703 | 2752 | 2354 |
| 2005 | 5339 | 2612 | 2185 | 4044 | 2548 | 2464 | 4986 | 2313 | 2085 |
| 2006 | 4621 | 3346 | 1884 | 4731 | 2821 | 2437 | 4464 | 3828 | 2724 |
| 2007 | 4705 | 3195 | 1846 | 4230 | 2745 | 2773 | 4375 | 2709 | 2858 |
| 2008 | 5256 | 2882 | 2359 | 4247 | 3295 | 2688 | 3764 | 3027 | 2592 |
| 2009 | 3960 | 2990 | 2283 | 4618 | 2784 | 2083 | 3857 | 3688 | 2622 |
| 2010 | 5053 | 2454 | 2292 | 3888 | 2850 | 2573 | 3485 | 2371 | 2673 |
| 2011 | 4517 | 2591 | 1771 | 4251 | 2832 | 2351 | 4894 | 2937 | 2548 |
| 2012 | 4815 | 3158 | 2163 | 3859 | 2524 | 2452 | 4561 | 3136 | 2432 |
| 2013 | 4012 | 2509 | 2191 | 4514 | 3070 | 2635 | 3812 | 2690 | 3007 |
| 2014 | 5719 | 2174 | 1764 | 4699 | 2785 | 2275 | 3224 | 2350 | 2812 |
| **Mean** | **4565** | **2731** | **2044** | **4213** | **2761** | **2414** | **3885** | **2692** | **2580** |
| **SD** | **753** | **358** | **213** | **344** | **234** | **212** | **898** | **787** | **244** |
| **CV** | **17** | **13** | **10** | **8** | **8** | **9** | **23** | **29** | **9** |



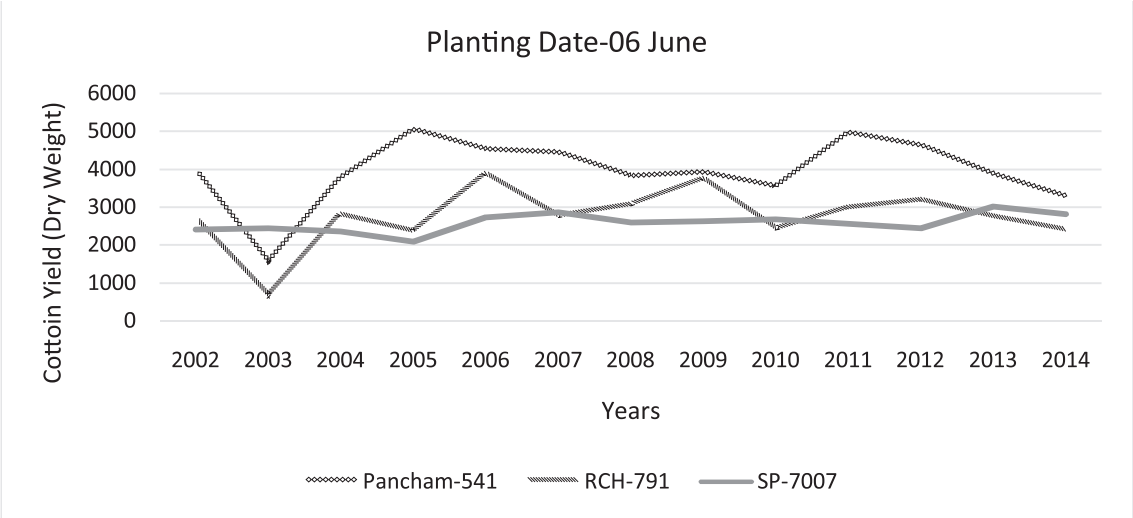




**Fig. 1. Simulated Cotton crop yield (Dry Weight) using DSSAT-CROPGRO for during different varieties Pancham-541, RCH-91, SP-7007 at three sowing dates (a) 10th May (b) 21nd May and (c) 6th June during years 2002 to 2014**

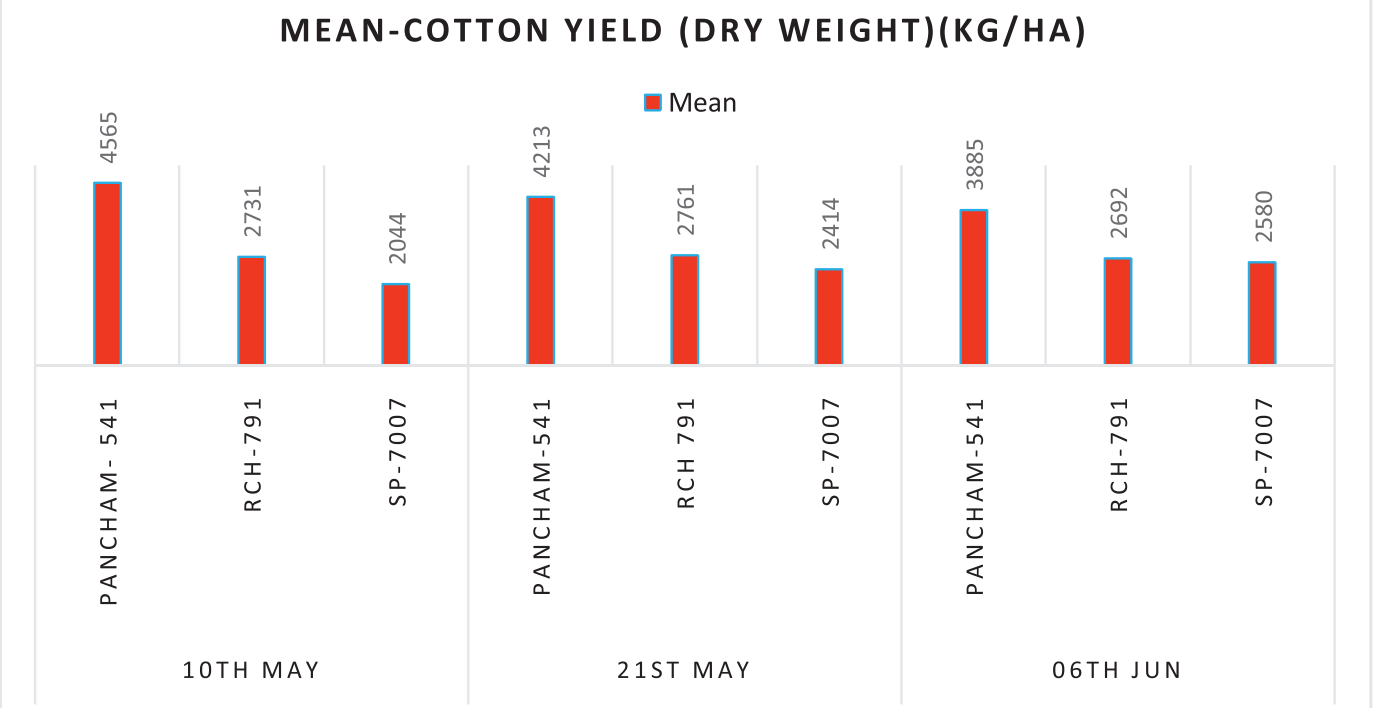



**Fig. 2. Simulated mean of Cotton crop yield (Dry Weight) in kg/ha using DSSAT-CROPGRO for during different varieties Pancham-541, RCH-91, SP-7007 at three sowing dates 10th May 21nd May and 06th June during years 2002 to 2014.**

## 3. Results and discussion

This study includes three Bt-cotton varieties at three different sowing days to assess the suitable variety at suitable planting date. Many researchers suggest that earlier sowing date could give a better yield. But in the recent years yield losses are caused at regional level due to abiotic and biotic stresses. Mostly it has been found due to the pest attack. It is also under question whether it has to do something with the weather conditions arising out of changes in the climatic extremes. Although the model is not successful in analyzing the impact of pest on the crop, but it shows good analogy with effect of weather on the crop.

As per model output in Table 1 and Figure 1, one could conclude that the Pancham-541 variety shows the best average yield over the years with the sowing date 10th May over years. Also the values of SD and CV suggest that the yield of this variety has been impacted with the changing years compared to the other variety and other sowing dates. Least production can be seen in the variety SP-7007 compared to other varieties. As per the model output, it is observed for the cultivar SP-7007 with increasing sowing date, the productivity has been increasing, in contrary to the observations for the cultivar Pancham-541 which has decreasing trend in yield with increasing sowing dates. Sowing date of 21st May has shown least variability in all three cultivars over the years. As per simulated model output the least CV is for the cultivar SP- 7007 in all sowing dates as compared to other cultivars. This could be primarily due to least impact of changing weather conditions over years on this variety. Maximum average yield is seen in Panchan-541 as compared to other varieties. With Figure 3 which contains the mean of the cotton crop yield (Dry Weight) from 2002 to 2014 one can perceive that early sowing gives the best yield value for all the three cultivars. With increasing the sowing dates i.e. later sowing the production values are also falling which is in accordance with the earlier researches.

Further analysis is done taking the sowing date as 10th May on different cultivars of cotton. The simulated deviation % of dry yield is derived for different years

during 2002-2014. In Table 2 and Figure 3 it is clearly indicated for the yield of all three varieties that, deviation are on the positive and negative sides in different years. Deviations are more pronounced on variety Pancham-541 followed by RCH-791 and SP-7007. This could be due to various biotic and abiotic factors as discussed earlier. Maximum range of deviation can be seen in the variety Pancham-541 from -39 in 2003 to 25 in 2014. Earlier, one have seen the maximum mean of yield for these years in the same variety.

**Table 2. Simulated deviation % of Dry Yield using DSSAT-CROPGRO model for the three different varieties Pancham-541, RCH-91, SP-7007 on the sowing date 10th May during 2002 to 2014**

| Year / Variety | Pancham - 541 | RCH-791 | SP-7007 |
|---|---|---|---|
| 2002 | -7 | -10 | -11 |
| 2003 | -39 | -13 | -1 |
| 2004 | -5 | 1 | -2 |
| 2005 | 17 | -4 | 7 |
| 2006 | 1 | 23 | -8 |
| 2007 | 3 | 17 | -10 |
| 2008 | 15 | 6 | 15 |
| 2009 | -13 | 9 | 12 |
| 2010 | 11 | -10 | 12 |
| 2011 | -1 | -5 | -13 |
| 2012 | 5 | 16 | 6 |
| 2013 | -12 | -8 | 7 |
| 2014 | 25 | -20 | -14 |

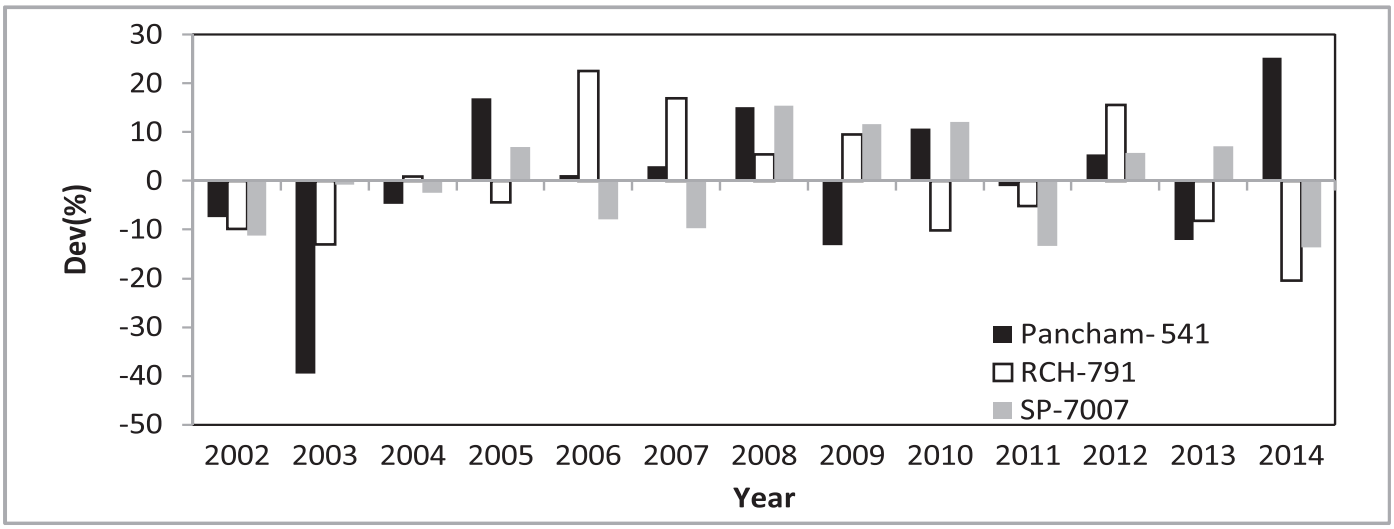



**Fig. 3. Simulated deviation % of Dry Yield for different varieties Pancham-541, RCH-91, SP-7007 on the sowing date 10th May during 2002 to 2014**

## 4. Summary and conclusion

Cotton crop is unique and has its own innate growth pattern, which makes it challenging to understand and demarcate the physiological stages. However, there is somewhat predictable pattern of its physiological stages with complexities and overlap of stages. Broadly the growth has two phases, first the vegetative phase then the reproductive phase. In vegetative phase vegetative structures are developed which further support the future reproductive growth. So, we can say that they are somewhat dependent i.e. if the vegetative growth is compromised due to unfavourable climatic conditions, subsequent reproductive growth will also suffer. Unlike many other crops cotton plant continues with its vegetative growth even after flowering has begun. But, the development of fruiting structures ultimately reduces the vegetative growth. And during the peak flowering period, the vegetative growth is almost negligible. This may continue after flowering has occurred. The environment also regulates the developmental process of the plant both for its vegetative and reproductive phases. Adverse environmental conditions could result into various abiotic and biotic stresses.

Bt-cotton since its introduction in 2002 has been under dispute for sustainability, environment affliction etc., but is widely cultivated since it provides substantial production. Dry yield is considered for the studies and for comparative analysis as simulated output. This is because it is the best indicator of the crop productivity and its economic relevance. Pancham-541 variety shows the best average yield over the years with the sowing date 10$^{th}$ May. Least production can be seen in the variety SP-7007 as compared to other varieties. Also in SP-7007 with increasing sowing date the production has been decreasing, in contrary to the variety Pancham-541 which has shown increasing trend with increasing dates, as suggested by the model studies. Sowing date of 21$^{st}$ May has shown least variability in all the three varieties over years. The simulated yield for variety RCH-791 has closer values to the actual yield. The maximum simulated yield can be observed for the sowing date 10th May. Cotton grown in May has higher yield than June. Earlier research also revealed that the early sowing of cotton in Kharif season, in the month of May produced taller plants than the late sowing in June. Increase in plant height in early sowing may be due to longer duration of crop. Number of balls per plant, yield per hectare and seed cotton yield per plant were significantly higher for early sown crop as compared to late sown crop. Higher yield was due to better growth and more number of balls produced per plant. Yield attributes were significantly higher in early sown crop when compared with late sown conditions of cotton plants [9].

## 5. Future Scope

Since the production cost has increased the price of the commodity is increasing day by day, cotton producers have to critically evaluate every input and management strategies to gain profit at the end. Thus understanding the development of crop environment and requirement of resource input at different stages of the cotton plant is crucial. It is for further implication of making better management decisions and affirming profitable production. This could be further complimented with the better pest management which is again one prime concern in recent years to achieve the milestone production.

Cotton is a crop with an uncertain or ambiguous growth habit and has a very dynamic growth response towards the environment and management practices. Site-specific management strategies considering the soil, weather etc. need to be taken into consideration to optimize yields. Further, management strategies should be flexible enough to allow for changing environmental conditions. With the modeling studies, precise and clearly communicated guidance to farmers can be given for the optimal crop selection and sowing time, irrigation, and fertilization etc.

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