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Pre Harvest Yield Forecast in Maize-Mustard Cropping System Under Semi Arid Region Using Crop Simulation Model

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ABSTRACT: *Forecast of crop production before harvests are required for storage, pricing, marketing, import, export etc. Simulation models have been used successfully to forecast productivity of cropping systems under various weather, management and policy scenarios. The main factors affecting crop yield are weather, soil and genetic coefficient of the crop. Weather plays an important role in crop growth. Therefore crop simulation model based on weather parameters, soil parameter and crop parameters can provide reliable forecast in advance for crop yield. Experiments were conducted at research farm of IARI, New Delhi for pre harvest crop yield forecast of mustard and maize during* Rabi *(2010-11 and 2011-12) and* kharif *(2011 and 2012) seasons respectively. Weather data, crop data and soil data were collected for different seasons. Crop yield forecast were estimated twenty days before harvest using InfoCrop model. Percentage deviation was done for estimated pre harvest crop yield forecast by actual yield after harvest. The deviation of average actual yield from average pre harvest crop yield was 5.5 and 2.9 percent in maize and mustard respectively. Since the model is efficient for forecasting productivity and profitability in maize- mustard cropping systems. Therefore this model can be used for pre harvest crop yield forecast of maize and mustard for district as well as regional scale.*

Keywords*: InfoCrop model, Crop yield forecast, Maize, Mustard.*

INTRODUCTION

Maize is one of the most important cereal crops in the world agricultural economy. Maize is grown in almost all the states of India. It occupies an area of about 6 million hectares which accounts for about 23 per cent of the total area. It is next to rice, wheat and jowar with regards to area and production in India. It is grown in *kharif* season in the northern India.

Mustard is the major *Rabi* oilseed crops of India. The production of mustard in India is around 16.2 million tones which accounts for about 18 percent of the total oilseed production of the country. India is second largest producers of mustard in the world after Canada. India's contribution in the world's mustard production is the highest of any country.

Operational crop yield forecasting is mostly done with crop simulation models and empirical statistical regression equations relating yield with predictor variables, usually termed as factors. Crop forecasts are typically issued at different stages between the time of planting and the time of harvest. They use past data (data between planting or before, and the time of the forecast) and future data. Future data can be implicit or explicit. In the first case, the future is assumed to be normal whereas the second requires that numerical values be actually specified, for instance historical data or stochastic weather generator outputs.

The success of the crop yield forecasting application strongly depends on the crop simulation model's ability to quantify the influence of weather, soil and management conditions on crop yield and on the systems ability to properly integrate model simulation results over a range of spatial scales. The spatial and temporal variability of weather conditions are an important source of uncertainty when applying crop simulation models over large areas. InfoCrop has been successfully adapted, calibrated and validated for rice, (Aggarawal et al., 2006a; 2006b), potato (Singh *et al*., 2005), cotton (Hebbar *et al*., 2008) coconut (Kumar *et al*., 2008). In this paper the pre harvest crop yield forecast of maize and mustard were estimated using InfoCrop model.

MATERIALS AND METHODS

Field experiments were conducted at IARI, New Delhi research farm during *rabi* (2010-11) and *kharif* (2011)

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seasons respectively for validating InfoCrop model and during *rabi* (2011-12) and *kharif* (2012) seasons respectively for predicting pre harvest crop yield forecast (20-25 days before harvest) for maize and mustard using InfoCrop models. The climate of the station is semiarid with dry hot summers and cold winter. Two varieties of mustard viz., Pusa Gold, Pusa Jaikisan and Pusa Bold were sown on different dates during *rabi* 2010-11 and one varieties of maize HQPM-1 were sown during *kharif* 2011 under four irrigation (I0=No irrigation, I1= two irrigation, I2=three irrigation and I3=four irrigation) and four nitrogen (N0 = No nitrogen, N1 = 60kg/ha nitrogen, N2=120kg/ha nitrogen, N3 = 180kg/ha nitrogen) treatment for validating the InfoCrop model under semi arid region. During *Rabi* 2011-12 and *Kharif* 2012 two varieties of mustard and maize were sown on three different dates to generate the weather variability at different phenological stages. The crop was raised following the standard agronomic practices with three replications in a randomized block design. Number of days required to attain different phenological stages were recorded. Genetic coefficients (specific leaf area, relative growth rate of leaf area, index of greenness of leaves, root growth rate, radiation use efficiency etc.) for maize and mustard were measured for running crop simulation models for crop yield forecasting at pre-harvest stage (F3). Different parameters such as soil moisture, LAI, root growth, biomass, chlorophyll content, radiation interception were measured in different growth stages. Field measurements of LAI were carried out by Plant Canopy Analyzer (LI-COR, USA), Both incoming and outgoing Photosynthetically Active Radiation (PAR) values were measured at top of crop canopy middle of crop height and bottm of crop throughout the season using line quantum sensor (LICOR-3000). These data were further used to derive radiation use efficiency. Leaf Chlorophyll Content were measured by Dimethyl Sulfoxide (DMSO) method using Spectrophotometer Spectronic-20, Soil moisture were measured by gravimetric method. The crop yield forecasting before harvest were done using InfoCrop model for mustard during Rabi 2011-12 and Kharif 2012 one month before harvest and after harvest the percentage deviation of predicted yield were calculated by the actual yield.

InfoCrop model is used for simulation of yield of mustard and maize. The input requirement for InfoCrop models are sowing depth, seed Rate(kg/ha), sowing Date, germination date, flowering date, maturity date, harvesting date, days/interval of irrigation, amount of irrigation, days/interval and amount of fertilizer, maximum and minimum temperature, wind speed, rainfall, solar radiation, morning and evening relative humidity. Daily weather data were collected from the agromet observatory located in the research farm of IARI, New Delhi. Good quality weather data (without missing data) are needed for crop simulation models to calculate dry matter accumulation and to determine the physiological development of the crop.

The soil data required for crop models are soil texture, structure, depth, profile, level of soil nutrients, and other related variables that describe the soil-water balance and nutrient dynamics during crop growth and development. Soil physical characteristics such as hydraulic conductivity determine the movement of water in the soil. Besides, field capacity, wilting point, bulk density are also required. Soil samples were collected from experimental location of IARI, New Delhi for characterization and testing of models. The soil was sandy loam. The soil characteristics were sown in the Table 1.

Table 1
Soil characteristics of IARI, New Delhi, Research farm

	Sandy Loam		
Soil Texture	*Layer 1*	*Layer 2*	*Layer 3*
Thickness of layer (mm)	340	860	220
Sand (%)	61	54	77
Slit (%)	19	26	21
Clay (%)	20	20	2
Saturation Fraction	0.3	0.3	0.17
Field Capacity Fraction	0.15	0.15	0.1
Wilting Point Fraction	0.05	0.05	0.04
Saturated hydraulic Conductivity (mm/day)	65	40	90
Bulk density (Mg/m^3)	1.46	1.46	1.62
Organic Carbon (%)	0.4	0.17	0.05
Initial Condition at Sowing Time			
Soil moisture fraction at sowing	0.1	0.1	0.1
Initial soil ammonium	2	1	1
Initial soil nitrate	6	2.55	1

RESULTS AND DISCUSSION

Estimating maize yield by InfoCrop Model during kharif 2011

Maize crop yield was estimated by InfoCrop model during *Kharif* 2011. Maize Variety: HQPM-1 were sown on 5th July, 2011 at IARI, New Delhi research farm, There was four irrigation treatment, No irrigation, Two irrigation, Three irrigation and Four irrigation. The fertilizer treatment was four 0, 60, 120, 180 Kg/ha. The percentage deviation of actual yield by estimated pre harvest (F3) crop yield calculated by InfoCrop models are sown in the Table 2. Results showed that percentage deviation of actual yield from estimated pre harvest crop yield forecast was 0.2 to 15% for different treatments. The percentage deviation was 1.3 percentages for average value of estimated yield from the average value of actual yield.

Estimation of leaf area index and biomass by InfoCrop model for Maize during kharif 2012

Leaf area index measured for two varieties of maize sown at different dates by the leaf area meter at different intervals was compared with the leaf area index estimated by the InfoCrop models. The peak leaf area observed for varieties P3501 and P3303 was found to be 2.56 and 2.99 for first sown crop at 70 days after sowing, 2.95 and 3.38 at 60 days after sowing for second sown crop and 2.85 and 2.20 at 60 days after sowing for third sown crops. The estimated leaf area index for P3501 and P3303 was found to be 3.96 and 3.97 for first sown crop, 3.74 and 3.5 for second sown crop and 2.71and 1.86 for third sown crops. The percentage deviation of observed peak leaf area index from estimated peak leaf area index was 55 and 33 in first sown crop, 27 and 4 in second sown crop and 0.05 and 0.15 in third sown crop for P3501 and P3303 respectively (Fig 1). There was similar trend for observed and simulated value of leaf area index that is leaf area index increased reached peak value and than decrease.

The biomass was measured at different intervals. The value of biomass at 80 days after sowing was 10360 kg/ha and 10925 kg/ha for first sown crop, 12546 kg/ha and 12791 kg/ha for second sown crop and 13300 kg/ha and 14606 kg /ha for third sown crops. The estimated biomass at 80 days after sowing for P3501 and P3303 was found to be 7987 kg/ha and 8036 kg/ha for first sown crop, 10047 kg/ha and 9853 kg/ha for second sown crop and 10063 kg/ha and 8943 kg/ha for third sown crops. The percentage deviation of biomass from estimated biomass at 80 days after sowing was 22 and 26 in first sown crop, 20 and 23 in second sown crop and 32 and 38 in third sown crop for P3501 and P3303 respectively (Fig 2). There was similar trend for observed and simulated value of biomass.

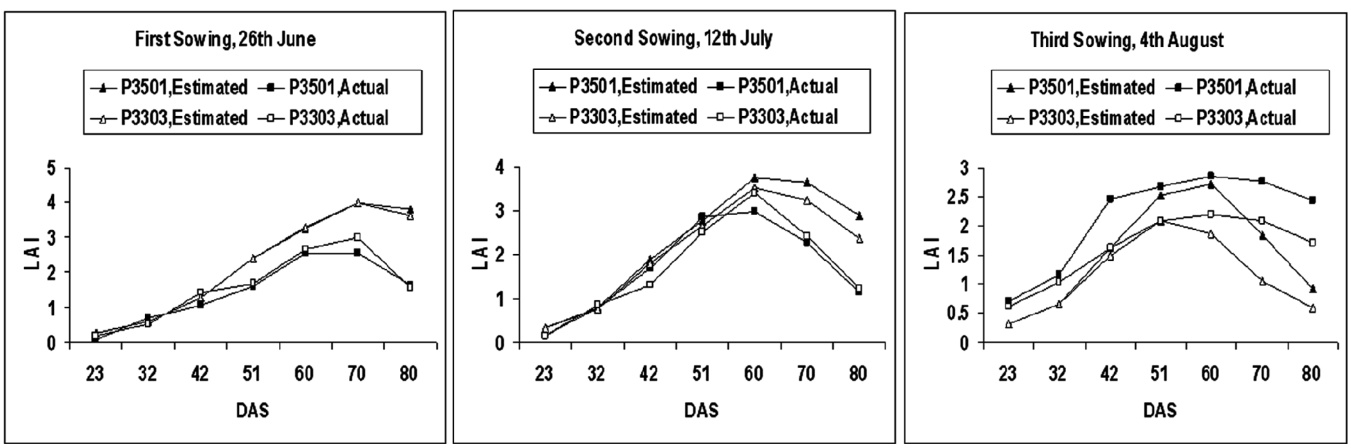

Figure 1: Estimation of leaf area index by InfoCrop model for Maize during kharif 2012

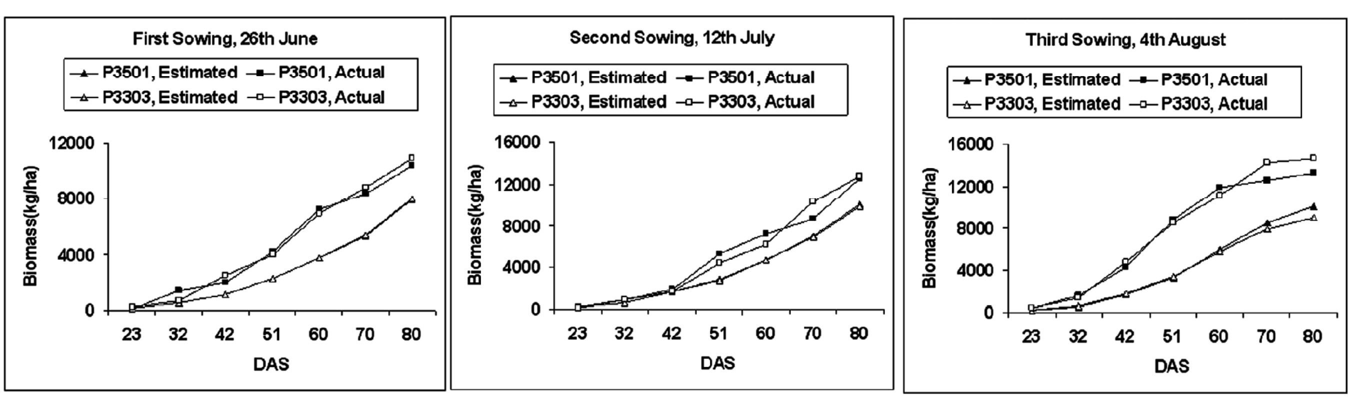

Figure 2: Estimation of Biomass by InfoCrop model for Maize during kharif 2012

Table 2
Percentage deviation of actual yield of Maize by estimated yield *Kharif* 2011

Treatment	*Actual Yield*	*Estimated Yield*	*% deviation*
I0N0	4032	4007	0.62
I0N1	6269	6597	-5.23
I0N2	6782	6761	0.31
I0N3	8047	6769	15.88
I1N0	5024	4523	9.97
I1N1	7569	6916	8.63
I1N2	8226	7385	10.22
I1N3	6985	7506	-7.46
I2N0	4343	4540	-4.54
I2N1	7369	7086	3.84
I2N2	6773	7527	-11.13
I2N3	7063	7631	-8.04
I3N0	4565	4580	-0.33
I3N1	7165	6967	2.76
I3N2	7438	7556	-1.59
I3N3	7670	7650	0.26
Average	6582	6500	1.25

I0 = No irrigation, I1 = two irrigation, I2 = three irrigation and I3 = four irrigation.
N0 = No nitrogen, N1 = 60kg/ha nitrogen, N2 = 120kg/ha nitrogen, N3 = 180kg/ha nitrogen.

Estimation of pre harvest (F3) yield for maize using InfoCrop model during kharif 2012

The pre harvest (F3) crop yield forecast was estimated by InfoCrop models for maize crop for both varieties sown at different dates. The pre harvest crop yield forecast was compared with the actual yield after harvesting. The percentage deviation was 4.89 and 0.09 in first sowing, 7.24 and 10.2 in second sowing and 11.3 and 5.31 in third sowing for P3501 and P3303 respectively. The deviation of average actual yield from average predicted yield was 5.5 percentage (Table 3). The total growing period for both the varieties was 92, 89 and 78 days in first, second and third sown crop. The total growing degree days was 1873.3, 1717.5 and 1415.1°C for both the varieties in first, second and third sown crop.

Table 3
Estimation of pre harvest (F3) yield for maize using InfoCrop model

Date of sowing	*Variety*	*Actual Yield*	*Predicted yield (F3)*	*% deviation*
First sowing (26.06.12)	P-3501	3409	3576	4.89
	P-3303	3255	3252	-0.09
Second sowing (12.07.12)	P-3501	4240	3933	-7.24
	P-3303	4868	4368	-10.2
Third sowing (04.08.12)	P-3501	3957	3508	-11.3
	P-3303	3027	2866	-5.31
Average		3793	3584	5.51

Estimating mustard yield by InfoCrop Model during Rabi 2010-11

The calibration of Infocrop model was done for mustard crop sown during 2010-11. Two varieties of mustard viz., Pusa Jaikisan and Pusa Bold were sown on two different dates 22nd October, 2010 and 30th October, 2010 at research farm of IARI, New Delhi. The percentage deviation of actual yield by estimated yield was sown in the Table 4. Results showed that percentage deviation of actual yield from estimated yield was 7 to 9 in first sowing and 3 to 10 in second sowing for Pusa Jaikisan and Pusa Bold respectively. The average deviation for average yield was 8 and 7 percentages for first and second sown crop.

Table 4
Percentage deviation of actual yield of Mustard by estimated yield *Rabi* 2010-11

	First sowing (22.10.2010)			*Second sowing (30.10.2010)*		
Varieties	*Observed*	*Simulated*	*% Deviation*	*Observed*	*Simulated*	*% Deviation*
Pusa Jaikisan	2410	2594	-7.6	1907	1708	3.9
Pusa Bold	2167	2362	-8.9	1737	1668	10.4
Average	2289	2478	-8.28	1822	1688	7.35

Estimation of pre harvest (F3) yield for mustard using InfoCrop model during Rabi 2011-12

The pre harvest yield was estimated by InfoCrop models for mustard crop for both varieties sown at different dates. The pre harvested yield was compared with the actual yield after harvesting. The percentage deviation was 4.1 and 0.5 in first sowing, 4.6 and 2.1 in second sowing and 0.4 and 5.8 in third sowing for Pusa Jaikisan and Pusa Bold. The deviation of average actual yield from average predicted yield was 2.9 percentage (Table 5). The total growing period for the crop was 165, 150 and 146 days for both the varieties in first, second and third sown crop respectively. The total growing degree days was 2038.2, 1757.1 and

Table 5
Estimation of pre harvest (F3) yield for mustard using InfoCrop model during *Rabi* 2011-12

Date of sowing		*Actual Yield*	*Predicted yield (F3)*	*% deviation*
15th October, 2011	Pusa Jaikisan	2391.7	2490.4	-4.1
	Pusa Bold	2475.0	2486.8	-0.5
31st October, 2011	Pusa Jaikisan	2375.0	2483.8	-4.6
	Pusa Bold	2537.0	2591.1	-2.12
16th November, 2011	Pusa Jaikisan	1162.0	1157.8	0.36
	Pusa Bold	1700.0	1798.0	-5.8
Average	2106.8	2168.0	-2.9	

1723.2°C for both the varieties in first, second and third sown crop respectively.

Leaf area index (LAI) and biomass measurement for mustard during Rabi 2011-12

Leaf area index is an important parameter for the crop growth studies since it is useful in interpreting the capacity of a crop for producing dry matter in terms of the intercepted utilization of radiation and amount of photosynthesis synthesized. During the crop season (*rabi* 2011-12), the maximum leaf area indices under different weather condition were found to be 4.62, 3.89 in Pusa Jaikisan and Pusa Bold respectively at 80 days after sowing for first sown crop. For second sown crop the peak value of LAI at 80 days after sowing was found 3.30 and 2.95 in Pusa Jaikisan and Pusa Bold respectively. For third sown crop the peak LAI was found to be 2.95 and 2.87 at 70 days after sowing in Pusa Jaikisan and Pusa Bold respectively.

The first sown crop has higher value of LAI as compared to second and third sown crop. The percentage reduction in peak LAI was 29 and 24 in Pusa Jaikisan and Pusa Bold respectively in second sown crop as compared to first sown crop and 36 and 26 percent in third sown crop with respect to first sow crop in Pusa Jaikisan and Pusa Bold respectively. It was further observed that the maximum LAI was at 80 days after sowing in case of early sown crops while in contrast with the early sowing, the late sown crops achieved maximum LAI at 70 days after sowing ten days earlier. It was observed that the LAI was higher in Pusa Jaikisan than Pusa bold. The peak value of LAI was 16, 10 and 3% higher in Pusa Jaikisan as compared to Pusa Bold in first sown, second sown and third sown crop (Fig. 3). Leaf area index increased and reached a maximum around pod formation stage (45% flower to 85% pod stage) irrespective of weather conditions. Later, the leaf area index declined rapidly. Senescence and abscission coincided with onset of flowering and completed well before maturity.

The maximum leaf area indices were found to be at 80 days after sowing for first sown crop, 78 days after sowing for second sown crop and at 70 days after sowing for third sown crop. Rao and Agarwal (1986) reported that, the maximum LAI was found at 90 DAS and thereafter declined towards maturity. Working on *Brassica napus* cv. B.O. 54, *B. juncea* cv. Pusa bold and *B. campestris,* Kar and Chakravarty (1999) reported that LAI was lower in a season with higher temperatures (2 to 3°C) during vegetative and grain filling stages as compared to the season with relatively lower temperatures in the same period. Working on

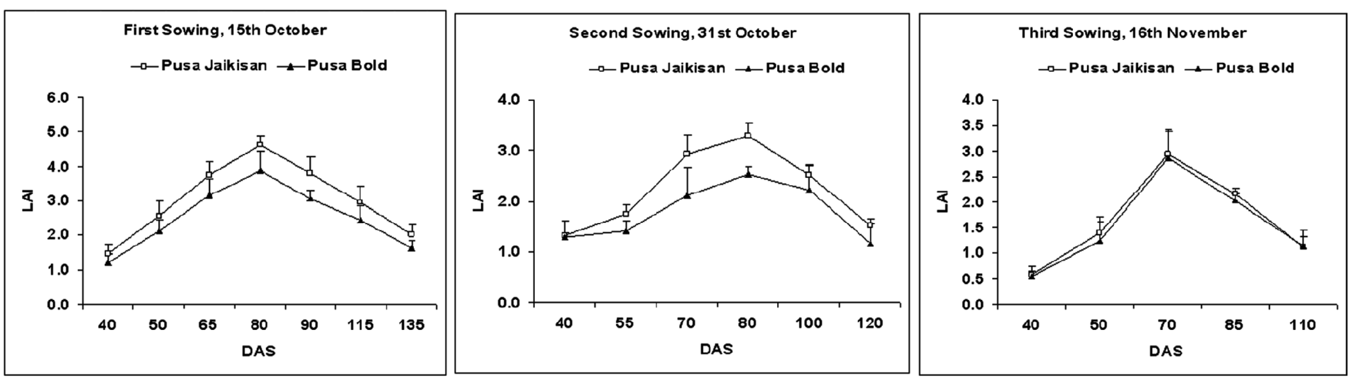

Figure 3: Leaf area index of different varieties of mustard sown under different weather conditions

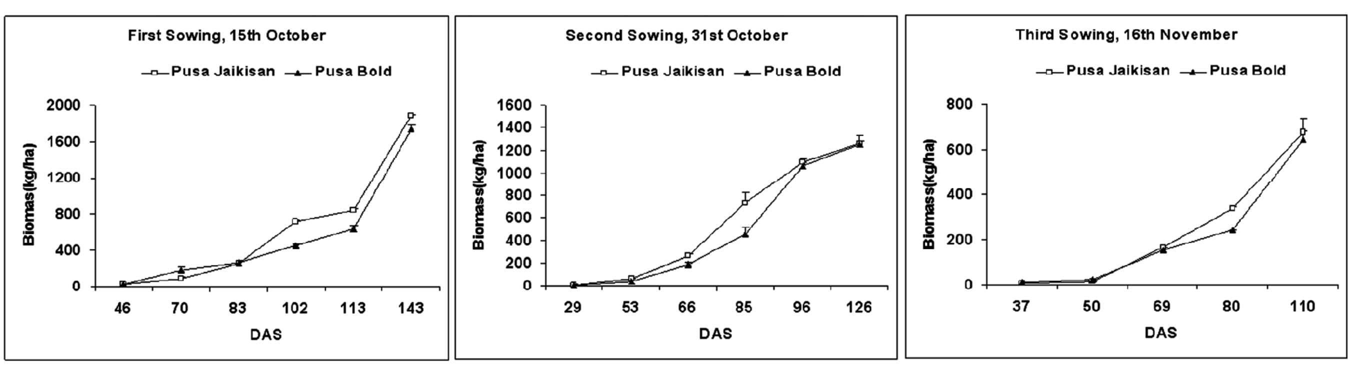

Figure 4: Biomass of different varieties of mustard sown under different weather conditions

three varieties Pusa Jaikisan, Varuna and Agrani under Delhi condition, Roy *et al*., (2005) reported that delay of a fortnight sowing from 1st October to 15th October and to 1st November reduced LAI by 8.3 and 52.8 per cent in Agrani, 12.9 and 45.4 per cent in Pusa Jaikisan and 8.8 and 45.6 per cent in Varuna varieties.

Biomass production of the plant is the process of organic substance formation of carbohydrates, the products of photosynthesis and from small quantity of inorganic substance absorbed by roots from the soil. The timely accumulation of dry matter by the crop is important as it is followed by adequate translocation of assimilates to the sink resulting in higher yield. The higher biomass in the first sowing dates may be due to favourable weather during crop growth period. The maximum above ground biomass was 1890g/m^2 and 1734 g/m^2 in first sown crop, 1260 g/m2 and 1252 g/m^2 in second sown crop, 677 g/ m^2 and 642g/ m^2 in third sown crop for Pusa Jaikisan and Pusa Bold respectively (Fig. 4). The reduction in the magnitude of maximum biomass production in second sown crop as compared to first sown crop was 33% and 28% in Pusa Jaikisan and Pusa Bold. Biomass production was further reduced in third sown crop by 64% and 63% in Pusa Jaikisan and Pusa Bold as compared to first sown crop. Thus, it may be inferred that biomass production in both varieties was higher in first sown crops as compared to late sown crops, which might be due to more favourable weather condition for first sown crop as compared to other two dates during crop growing period. Pusa Jaikisan produced higher biomass as compared to Pusa Bold irrespective of sowing dates which might be due to higher leaf area index, leaf area duration and more proliferating nature. The biomass production was higher in Pusa Jaikisan by 8%, 0.7% and 5% as compared to Pusa Bold in first, second and third sown crop. The biomass production levels obtained in the present study and the reduction of biomass production due to late sowing are in conformity with the earlier findings (Kar and Chakravarty, 1999). Leaf area index (LAI) and biomass production in *Brassica* species were reported to be positively correlated with GDD accumulation during the crop growth period (Chakravarty and Sastry, 1983 and Patel and Mehta, 1987). Reduction in seed yield of *Brassica* species under late sown conditions might be attributed to increase in temperatures at the time of pod growth and seed filling stage, which reduced the dry matter accumulation into the seed and shortened the seed filling period (Nanda , 1994).

Weather conditions during crop growth and development (Rabi, 2011-12)

The maximum temperature during different standard meteorological weeks in the *rabi* 2011-12 was observed to be lower than normal except during 45th, 49th 1st and 8th to 12th standard meteorological weeks it was found to be more than normal and in 42nd, 46th and 5th standard meteorological weeks it was equal to the normal. The maximum temperature was 0.6 to 2.6°C higher than normal and 0.2 to 2.5°C lower than normal in different standard meteorological weeks. The difference between observed and normal maximum temperature was 0.2 to 2.6 °C during different standard meteorological weeks. The minimum temperature remain lower than normal except during 49th, 1st and 12th standard meteorological weeks it was higher than normal and in 45th, 47th, 3rd and 8th standard meteorological weeks it was equal to the normal. The minimum temperature was 0.9 to 3°C higher than normal and 0.04 to 7.3°C lower than normal in different standard meteorological weeks. The difference between observed and normal maximum temperature was 0 to 7.3 °C during different standard meteorological weeks. Total rainfall of 34 mm (normal value 101.4 mm) was received during *rabi* 2011-12 on 1st (6.6 mm), 3rd (8.2 mm) and 11th (19.2 mm) standard meteorological weeks. The rainfall during the *Rabi* season was 66 percent less than the normal. However, the rainfall was received in 3 out of 23 weeks of this season. Bright sunshine hours were found to be lower than normal except during 5th and 9th standard meteorological weeks it was higher than normal and during 4th and 8th standard meteorological weeks it was equal to the normal . The bright sunshine hours was 0.7 to 1.2 hours higher than normal and 0.6 to 7.2 hours lower than normal in different standard meteorological weeks. The difference between observed and normal maximum temperature was 0 to 7.2 hours during different standard meteorological weeks. Evaporation during different weeks in the *rabi* 2010-11 was observed to be lower than normal except during 2nd, 3rd and 5th to 10th standard meteorological weeks it was more than normal and 4th and 12th standard meteorological weeks it was equal to normal. The difference between observed and normal pan evaporation was 0 to 3.2 mm/day during different standard meteorological weeks. The pan evaporation was 0.1 to 1.8 mm/day higher than normal and 0.1 to 3.2 mm/day lower than normal in different standard meteorological weeks. Wind speed was found to be lower than normal except 2nd to 4th, 6th to 10th and 12th standard meteorological weeks it was higher than normal value and in 1st standard meteorological weeks it was equal to normal value.The difference between observed and normal wind speed was 0 to 3.5 km/ hours during different standard meteorological weeks. The wind speed was 0.8 to 2.8 km/hours higher than normal and 0.4 to3.5 km/hours lower than normal in different standard meteorological weeks. Relative humidity measured at 7.21 A. M. was found to be higher than normal throughout the crop growing period except 45th, 52nd 2nd, 4th, 6th to 10th and 12th standard meteorological week it was lower than normal. The difference between observed and normal maximum relative humidity during different standard meteorological weeks was 0.1 to 13.9. The maximum relative humidity was 1.7 to 9.1 higher than normal and 0.1 to 13.9 lower than normal in different standard meteorological weeks. Relative humidity measured at 2.21 P. M. was found to be lower than normal throughout the crop growing period except 47th, 49th, 1st and 3rd standard meteorological week it was higher than normal. The difference between observed and normal minimum relative humidity during different standard meteorological weeks was 1.0 to 23.3. The minimum relative humidity was 8.3 to 23.3 higher than normal and 1.0 to 17.4 lower than normal in different standard meteorological weeks.

Weather conditions during crop growth and development (Kharif, 2012)

The maximum temperature during different standard meteorological weeks in the *kharif* 2012 was observed to be lower than normal except during 23rd, 31st and 35th standard meteorological weeks it was found to be more than normal and in 27th, 30th, 34th, 37th and 39th standard meteorological weeks it was equal to the normal. The maximum temperature was 0.5 to 2.3°C higher than normal and 0.0 to 2.6°C lower than normal in different standard meteorological weeks. The difference between observed and normal maximum temperature was 0.0 to 2.6 °C during different standard meteorological weeks. The minimum temperature remain lower than normal except during 31st and 37th standard meteorological weeks it was higher than normal and in 35th and 39th standard meteorological weeks it was equal to the normal. The minimum temperature was 0.1 to 0.7°C higher than normal and 0.0 to 1.9°C lower than normal in different standard meteorological weeks. The difference between observed and normal minimum temperature was 0 to 1.9 °C during different standard meteorological weeks. Total rainfall of 550 mm (normal value 566.9 mm) was received during *kharif* 2012 on every week except 23rd, 27th and 39th standard meteorological weeks. The rainfall during the *Kharif* season was 2.9 percent less than the normal. However, the rainfall was received in 15 out of 18 weeks of this season. Bright sunshine hours were found to be lower than normal except during 23rd standard meteorological weeks it was higher than normal and during 22nd and 39th standard meteorological weeks it was equal to the normal. The bright sunshine hours was 0.3 hours higher than normal and 0.0 to 3.7 hours lower than normal in different standard meteorological weeks. The difference between observed and normal sunshine hours was 0 to 3.7 hours during different standard meteorological weeks. Evaporation during different weeks in the *kharif* 2012 was observed to be lower than normal. The difference between observed and normal pan evaporation was 1.6 to 5.1 mm/day during different standard meteorological weeks. The pan evaporation was 1.6 to 5.1 mm/day lower than normal in different standard meteorological weeks. Wind speed was found to be lower than normal except 22nd, 24th, 38th and 39th standard meteorological weeks it was higher than normal value and in 27th standard meteorological weeks it was equal to normal value. The difference between observed and normal wind speed was 0.4 to 5.2 km/hours during different standard meteorological weeks. The wind speed was 0.4 to 3.6 km/hours higher than normal and 0.4 to5.2 km/hours lower than normal in different standard meteorological weeks. Relative humidity measured at 7.21 A. M. was found to be higher than normal throughout the crop growing period. The difference between observed and normal maximum relative humidity during different standard meteorological weeks was 2.0 to 16.9. The maximum relative humidity was 2.0 to 16.9 higher than normal in different standard meteorological weeks. Relative humidity measured at 2.21 PM was found to be higher than normal throughout the crop growing period. The difference between observed and normal minimum relative humidity during different standard meteorological weeks was 0.3 to 16. The minimum relative humidity was 0.3 to 16 higher than normal and 1.0 to 17.4 lower than normal in different standard meteorological weeks.

Radiation Use Efficiency (RUE) in different varieties of mustard crop under different weather conditions

During the crop growing period the peak value of RUE (g/MJ) was 5.73, 5.65 and 5.50, 5.33 for Pusa Jaikisan and Pusa Bold in first and second sown crop

Table 6
Radiation Use efficiency (RUE) of different varieties of mustard grown under different weather conditions.

	First Sowing			*Second sowing*			*Third sowing*		
DAS	*Pusa Gold*	*Pusa Jaikisan*	*Pusa Bold*	*Pusa Gold*	*Pusa Jaikisan*	*Pusa Bold*	*Pusa Gold*	*Pusa Jaikisan*	*Pusa Bold*
40	3.99	4.15	4.09	3.40	4.05	4.02	3.23	3.56	3.85
70	3.89	4.99	4.37	3.77	4.19	4.04	3.38	4.02	3.70
100	4.59	5.73	5.65	4.01	5.50	5.33	2.19	3.52	2.94
130	2.19	2.78	2.68	1.48	1.65	1.63	1.02	1.24	1.32

at 100 days after sowing while the peak value of RUE for third sown crop was 4.02 and 3.70 at 70 days after sowing (Table 6). The first sown crop had higher value of RUE as compared to second sown and third sown crop. The percentage reduction of peak value of radiation use efficiency was 4 and 6%, 29 and 35% for Pusa Jaikisan and Pusa Bold respectively in second and third sown crop as compared to first sown crop. Pusa Jaikisan has higher value of RUE than Pusa Bold. Pusa Jaikisan had 1, 3 and 16% higher value of RUE as compared to Pusa Bold in different weather conditions. These results are in conformity with the earlier findings of researchers (Kar and Chakravarty, 1999; Dhaliwal and Hundal, 2004) who reported RUE in the range of 1.0 to 5.0 g/MJ in different mustard varieties grown under varied thermal regimes. Gimenez *et al*., (1994) and Gardner *et al*., (1994) concluded that, for any given canopy size (LAI), canopy structure (leaf angle and orientation) determine the fraction of intercepted radiation, interception of PAR and its utilization efficiency with which, PAR drives photosynthetic gain in terms of productivity.

Early sown crop yielded higher seed yield than late sown crop in all varieties. Cold spell during initial period for third sown crop might have restricted growth. Incidentally, relatively higher temperatures at the later stage of the crop growth resulted early maturity. Also aphid infestation was found to be more in the late sown crop as compared to early sown crop.

There was reduction in seed yield due to delay of sowing (Roy *et al*., 2005). The yield attributes and yield of mustard significantly decreased in delayed sowing even under protected conditions (Patel *et al*., 2004). The results are in conformity with the earlier findings of researchers in mustard and soybean crop (Mendham *et al*., 1990; Neog *et al*., 2005; Vashisth *et al*., 2011 and 2012) who reported a reduction in seed yield due to delay of week /fortnight from the normal sowing. Aphid infestation was more in late sowing. In present study the higher yield in first sown crop might be attributed to comparatively lower aphid population during crop growth and maximum time taken by the crop for its growth and development (Verma *et al*, 1993).

CONCLUSION

The percentage deviation of the observed yield by estimated value of pre harvest yield forecast in maize crop was 4.9 and 0.1% for first sown crop, 7.2 and 10.2 % for second sown crop and 11.3 and 5.3% for third sown crop in P-3501 and P-3303 varieties respectively. In mustard the percentage deviation of the observed yield by estimated value of pre harvest yield forecast was 4.1 and 0.5% for first sown crop, 4.6 and 2.1 % for second sown crop and 0.4 and 5.8% for third sown crop in Pusa Jaikisan and Pusa bold varieties respectively. The percentage deviation of average actual yield from the average pre harvest crop yield forecast was 5.5 and 2.9 % in maize and mustard respectively. Hence InfoCrop model can be used for pre harvest crop yield forecast. Since the model is efficient for forecasting productivity and profitability in cropping systems. Therefore this model can be used for pre harvest crop yield forecast in regional as well as at national scale.

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