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# Wheat Yield Modelling using Infocrop and DSSAT Crop Simulation Models

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## ABSTRACT

**Background:** Wheat is an important crop of India That is grown in the winter season (October to April). A field study was conducted for nine plots having a dimension of 3×2 meter and different nutrient was applied to test the biomass yield. The objectives are to describe (a): To conduct field experiments under controlled conditions and vary the dosage of fertilizers for different treatments. (b): To observe the variation in crop yield of wheat with different dosages of fertilizers. (c): To model the crop yield of different treatments using InfoCrop and DSSAT crop models.

**Methods:** An experiment was conducted for Wheat crop having a dimension of 3×2 meter at the Indian Institute of Technology, UK-India. Three plots ($C_1$, $C_2$, $C_3$) was given control fertilizer supply while plot ($F_1$, $F_2$, $F_3$) given -25%, +25%, +50% and plot ($N_1$, $N_2$, $N_3$) given -25%, +25%, +50% w.r.t to control. The simulation model Infocrop and DSSAT were simulated to check test the model.

**Result:** In this study, two crop simulation models namely Infocrop and DSSAT were used to predict the yield of wheat crops. Field experiments were carried out at a farm site at Roorkee, India and different treatments of fertilizers are applied to the field plots. In total, seven fertilizer treatments are used: C (controlled with a normal dosage of fertilizers), $F_1$, $F_2$, $F_3$ (varying amount of applied farmyard manure), $N_1$, $N_2$ and $N_3$ (varying amount of applied urea). The objective of the study was to evaluate yields of the seven treatments using Infocrop and DSSAT crop models and compare them to the observed values of yields. The grain yield of the controlled treatment ($C_1$, $C_2$, $C_3$) was predicted accurately by both models. There was a significant variation in the grain yields of the $F_1$, $F_2$, $F_3$ treatments with the application of farm yard manure (FYM). DSSAT under-predicted the grain yields for the plot $F_1$, $F_2$, $F_3$ treatments and over-predicted these for $N_1$, $N_2$, $N_3$ treatments. Overall, Infocrop, which was developed and validated for Indian conditions, simulated the grain yield more accurately as compared to the DSSAT model under varying applications of FYM and urea dosages.


**Key words:** Crop models, Crop yield, DSSAT, Infocrop, Wheat.

## INTRODUCTION

With the growing population and shrinking agricultural spaces, increased crop productivity is very much on focus (Sinha *et al.*, 1998; Aggarwal *et al.*, 2000). In this view, estimation or prediction of yield for different amounts of inputs is very important. Crop yield can be affected by nitrogen availability (Engel *et al.*, 2003; Thomsen *et al.*, 2003), water availability (Jamal *et al.*,1996, Engel *et al.*, 2003), sowing rate and sowing date (Donaldson *et al.*, 2001), fungicide treatment (Jorgensen *et al.*, 2002) as well as the type of cultivar used (Jorgensen *et al.*, 2002; Donaldson *et al.*, 2001; Engel *et al.*, 2003). In addition to this, there are a lot of variations in the above-mentioned and other cultivation practices in a vast country such as India. Crop models are often used to predict the crop yield in advance and to understand how the selection of crop and soil type will affect crop productivity. In the past few decades, various crop models have been developed. Initially developed for academic and research purposes, these models are now more trusted and being used by the farmers and concerned policy-makers (Fant *et al.,* 2012). Many crop simulation models such as APSIM, WOFOST, CERES and SUCROS have been developed in past (Aggarwal *et al.*, 2006b). These simulation models study the effect on yield and quantify the yield gap (Kropff *et al.*, 2013; Berge *et al.*,1997; Matthews *et al.*, 2002). Modeling of the crop yield for varying conditions of cultivation is important because it is not feasible to conduct the crop experiments for the assessment of every variation as the crop experiments are time-taking and cumbersome as well as expensive to set up. But, the validation of the crop models using the data from the field experiments is essential to figure out which crop model works well in which condition.

To bridge this gap, controlled field experiments were performed on the wheat crop, which is one most widely grown crops in India and globally. To observe the variation in crop yield due to varying cultivation practices related to the application of different combinations of dosages of

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inorganic and organic fertilizers; different treatments, with varying amounts and types of fertilizers applied, were used during the experiments. Two popular crop models (DSSAT and InfroCrop) are used in this study to simulate the yield of wheat crops under different applications of fertilizer amount in 'humid subtropical' climate conditions. One of these crop models, DSSAT, is widely used globally for the prediction of crop yield under different conditions while the InfoCrop model was developed in India. The specific objectives of the study are:

1. To conduct field experiments under controlled conditions and vary the dosage of fertilizers for different treatments.
2. To observe the variation in crop yield of wheat with different dosages of fertilizers.
3. To model the crop yield of different treatments using InfoCrop and DSSAT crop models.

## MATERIALS AND METHODS

### Site of field experiments

Field experiments were conducted for Rabi season in the year 2018-19 on the wheat (variety-HD2967) crop in the experimental farm of Indian Institute of Technology, Roorkee, India. Roorkee is a city located near the foothills of the Himalayas in the district of Haridwar, India. Roorkee is located at 77°53″ 52′E longitude, 29°52″ 00′N latitude and at an average elevation of 268 m above mean sea level. The climate of Roorkee is typical of north India with hot and humid summer and cold and dry winter. The average annual rainfall of Roorkee is about 1032 mm and the annual sunshine duration is 2800 h. About three-fourths of the annual rainfall occurs in the monsoon season during the months from July to September. The climate of Roorkee is classified as humid subtropical as per Koppen-Gieger climate classification (Kottek *et al.*, 2006).

### Experimental plan

The field experiments were conducted at the experimental farm of the Indian Institute of Technology, Roorkee, India. The experimental farm was a part of the agricultural fields in the city of Roorkee. Wheat was sown at 15 cm × 15 cm spacing at 5-6 cm depth on 13th December 2018 and was harvested on 22nd April 2019.

Germination of wheat was recorded as 44 plants/m$^2$ on 24th December 2018. The experiments were carried out on nine field plots of 3 m × 2 m each. Three repetitions of treatment C with a normal dosage of nitrogen fertilizer (urea) and farmyard manure (FYM), *i.e.* $C_1$, $C_2$ and $C_3$, are used. In the other three treatments ($F_1$, $F_2$ and $F_3$), a normal dosage of urea (N) is used but the dosage of FYM varied. In the remaining three treatments ($N_1$, $N_2$, $N_3$), a normal dosage of FYM is applied but the dosage of N is varied. For wheat crop, the normal dosage of FYM was taken as 1000 kg/ha and the normal dosage of urea was taken as 220 kg/ha. In F treatments ($F_1$, $F_2$ and $F_3$), urea is not applied and in N treatments ($N_1$, $N_2$ and $N_3$), FYM is not applied. The details of the seven treatments are given as follow:

- C ($C_1$, $C_2$ and $C_3$ are repetitions of C): Normal dosage of N and FYM.
- $F_1$: -25% of FYM quantity w.r.t. to the normal dosage.
- $F_2$: +25% of FYM quantity w.r.t. to the normal dosage.
- $F_3$: +50% of FYM quantity w.r.t. to the normal dosage.
- $N_1$: -25% of N, P and K quantity w.r.t. to the normal dosage.
- $N_2$: +25% of N, P and K quantity w.r.t. to the normal dosage.
- $N_3$: +50% of N, P and K quantity w.r.t. to the normal dosage.

The layout of the experimental field is shown in Fig 1. Nine plots namely, $C_1$, $C_2$, $C_3$, $N_1$, $N_2$, $N_3$, $F_1$, $F_2$ and $F_3$ were prepared with dimensions of 3 m × 2 m in the field layout of 13 m × 10 m. There was a space of 1 m between the field plots.

### InfoCrop model

InfoCrop is a generic crop model that is developed to meet various specific requirements of crops (Aggarwal *et al.*, 2006a, b). It accounts for the variation in weather, soils, agronomic management and major pests on the yield of the crops. InfoCrop burrows its general architecture from the SUCROS model (Van Laar *et al.*, 1997). In the InfoCrop model, the influence of weather on yield is considered first followed by soil factors and pests. To increase widespread applications of the model, a simple menu-driven version of InfoCrop has also been developed (Aggarwal *et al.*, 1994). Further details of the InfoCrop model can be found in Aggarwal (2006a, b).

### DSSAT model

Decision Support for Agro technology Transfer, *i.e.* DSSAT is a sophisticated model developed by International Benchmark Sites Network for Agro technology Transfer (IBSNAT, 1993). On-field, DSSAT is one the most widely used models for simulating crop growth and yield (Rivington *et al.*, 2011). DSSAT tends to focus more on nutrient processes within crops (Fant *et al.*, 2012). Further information about DSSAT can be found in Jones *et al.* (2003). Crop module CROPSIM-CERES is used for the simulation of the yield of wheat.

### Inputs to the models

Various inputs are required by used by InfoCrop and DSSAT models. The required inputs are briefed in this section.

### Meteorological data

Different agro-meteorological parameters such as rainfall, maximum-minimum temperature, relative humidity, wind velocity, *etc.* are required as inputs to InfoCrop and DSSAT models for crop simulation. Daily agro-meteorological data is obtained from a weather station located near the experimental farm at the Department of Water Resources Development and Management, Indian Institute of Technology Roorkee. The daily agro-meteorological data for the period of study is shown in Fig 2.

### Crop and soil parameters

The soil in the experiments plots was sandy-loam type as per USDA textural classification with 82.94% sand, 15.96%

silt and 1.1% clay. The bulk density of the soil at the experimental site was 1.715 kg/m$^3$. Soil parameters used in the models were taken from Carsel and Parrish (1988) which is a comprehensive database of soil parameters. Variation of LAI and plant height is measured and recorded at regular intervals. The variation of LAI for the different treatments throughout the crop season is shown in Fig 3. In addition to this, plant height and number of leaves per plant for all the treatments of wheat were also recorded. Some plant parameters of wheat required by the two models are taken from Aggarwal *et al.* (2006a).

**Irrigation and fertilization**

Irrigation and rainfall data for the crop period of wheat are shown in Fig 3. A seed rate of 120 kg/ha was applied during the sowing of wheat in all the treatments. The corresponding quantities of farmyard manure (FYM) were applied to C and F treatments before the sowing of wheat. In C and N treatments, 55% of the area (N) dosage was applied on the day before sowing while 22.5% of N dosage is applied on 16$^{th}$ January 2019 and the remaining 22.5% is applied on 15$^{th}$ February 2019.

## RESULTS AND DISCUSSION

All the field plots were harvested separately on 22$^{nd}$ April 2019 and corresponding values of grain and dry matter yields were recorded. The average of the yields of the repetitions $C_1$, $C_2$ and $C_3$ was taken as the yield of treatment C.

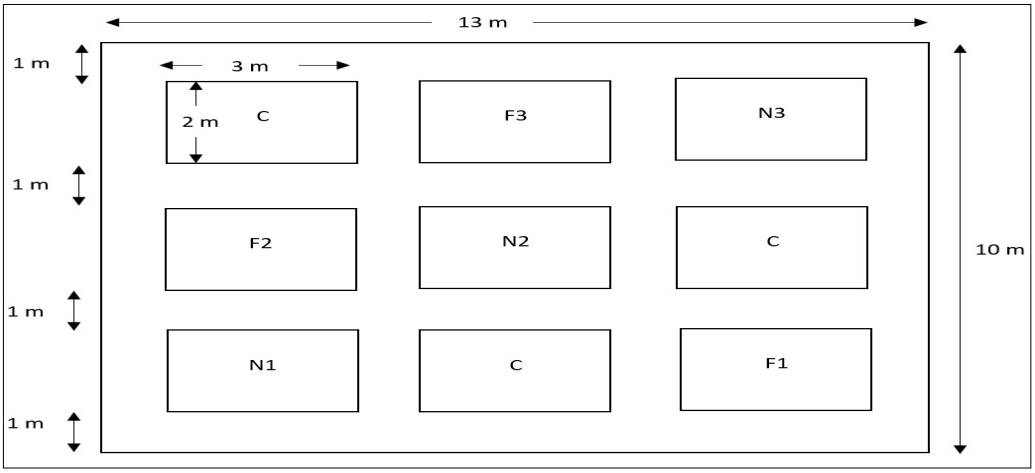


**Fig 1:** Layout of the experimental field.

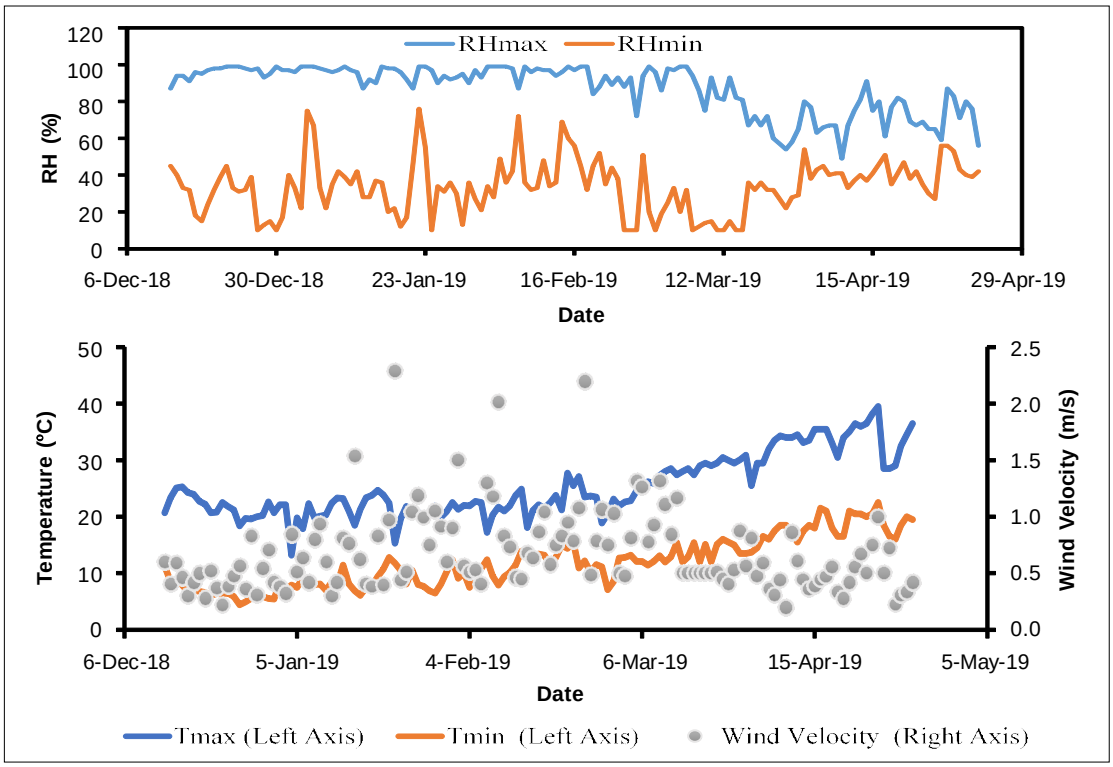


**Fig 2:** Daily meteorological data for the crop season of wheat.

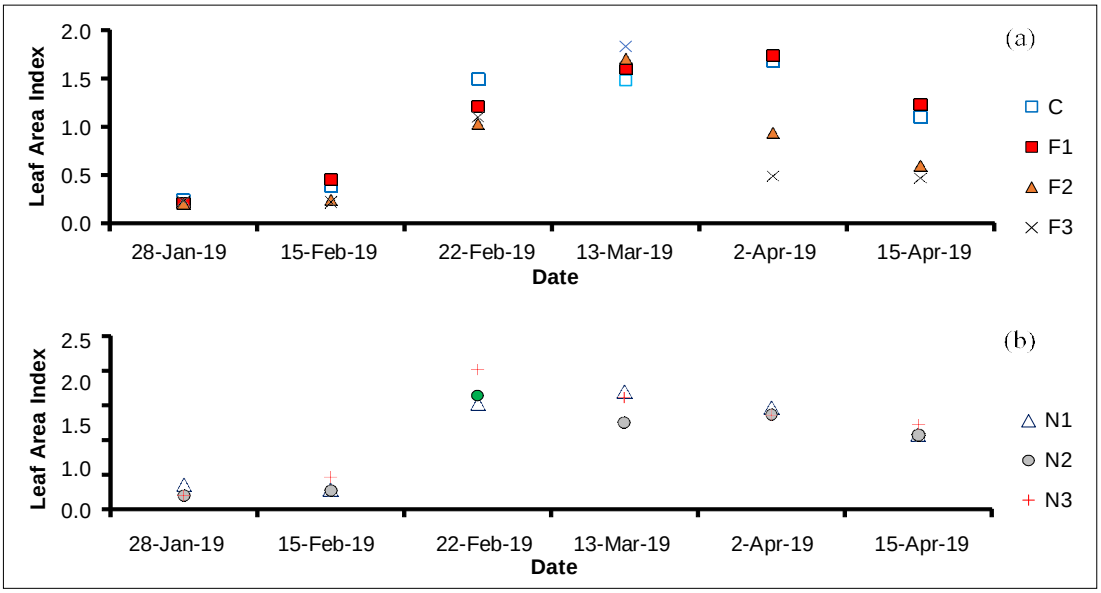


**Fig 3:** Leaf area index (LAI) variation during crop period.

### Comparison of observed yields

There were significant differences between the grain yield of F treatments. Out of the 7 treatments, the observed grain yield was maximum for treatment $F_3$ and minimum for treatment $F_1$ (Fig 5). The variation of the grain yields of different treatments concerning the controlled treatment C is shown in Table 1. The variation in the grain yields of N treatments was much less as compared to the grain yield of F treatments. The observed grain yield increased with the increase in the application of FYM (in F treatments) and urea (in N treatments) for all the treatments except $N_3$.

**Table 1:** Percentages of observed grain yields of different treatments concerning the grain yield of controlled treatment (C).

| Treatment | Percentage grain yield (%) |
|---|---|
| $F_1$ | 47.00 |
| $F_2$ | 71.95 |
| $F_3$ | 124.18 |
| $N_1$ | 95.67 |
| $N_2$ | 121.35 |
| $N_3$ | 102.19 |

### Comparison of simulated yields with the observed yields

Using the input data and the standard procedure for simulation, the yields of all the field plots are simulated by InfoCrop and DSSAT crop models. For treatment C, the average of the yields of the three repetitions ($C_1$, $C_2$ and $C_3$) was taken as the yield value. The observed grain yields along with the grain yields modelled using InfoCrop and DSSAT models are shown in Fig 5. The grain yield for controlled treatment C was simulated very accurately by both models. DSSAT under-predicted and InfoCrop over-predicted the grain yield of all the treatments in which only farmyard manure (FYM) was used *i.e.* $F_1$, $F_2$ and $F_3$. The accuracy of InfoCrop was slightly better than DSSAT in the simulation of grain yields of F treatments. The grain yields of the N treatments ($N_1$, $N_2$ and $N_3$) were better simulated by the two models when compared with that of F treatments. DSSAT over-predicted the grain yields of all the N treatments.

The comparison of the observed grain yields of all the different treatments with the simulated grain yields of InfoCrop and DSSAT models is shown in Fig 6. It can be observed that the grain yields simulate d using InfoCrop are more correlated to the observed values of grain yield when compared to DSSAT simulated grain yields. This is attributed to the large errors in the DSSAT simulation of the grain yields of F treatments. Fig 7 shows the variation of observed crop biomass of wheat for all the treatments at the time of harvest. The comparison of DSSAT simulated biomass with the observed crop biomass is also shown. Like the grain yields, the crop biomass was under-predicted for F treatments and over-predicted for N treatments by DSSAT. Unlike the grain yield of controlled treatment, DSSAT over-predicted the crop biomass.

In general, the observed grain yields of the treatments increased with the increase in the applied dosage of the organic/inorganic fertilizer. Treatment N3 (+ 50% urea treatment) was the exception to this trend and the grain yield, in this case, was comparable to the controlled treatment C. This suggests the overdose of urea will not increase the yield of wheat. However, it may lead to the degradation of the groundwater quality as the surplus fertilizer, which is not absorbed by the plants, will leach downwards out of the root zone of the soil. The observed grain yields of F treatments (in which the dosage of FYM is varied) increased with an increase in the amount of application of FYM. The grain yield of treatments $F_1$ (-25% FYM) and $F_2$ (+25% FYM) was less than that of the controlled treatment while the grain

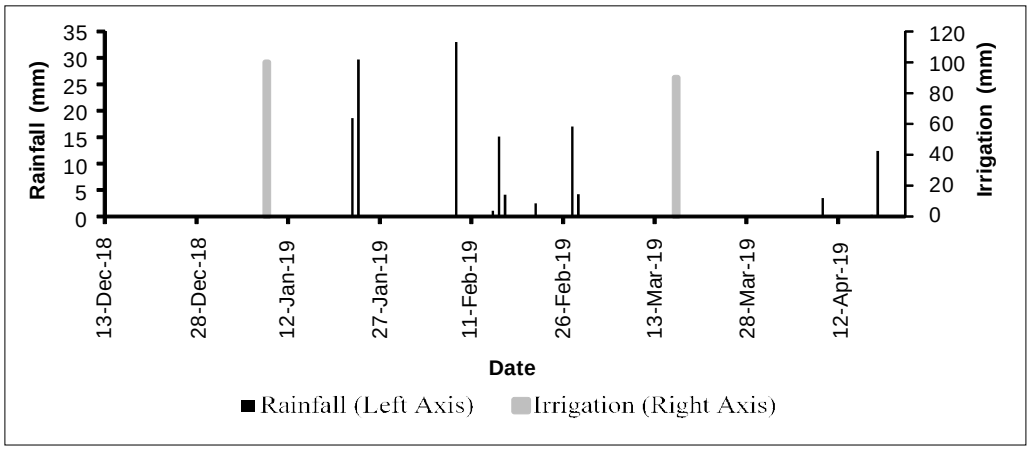


**Fig 4:** Rainfall and irrigation data for the wheat crop season.

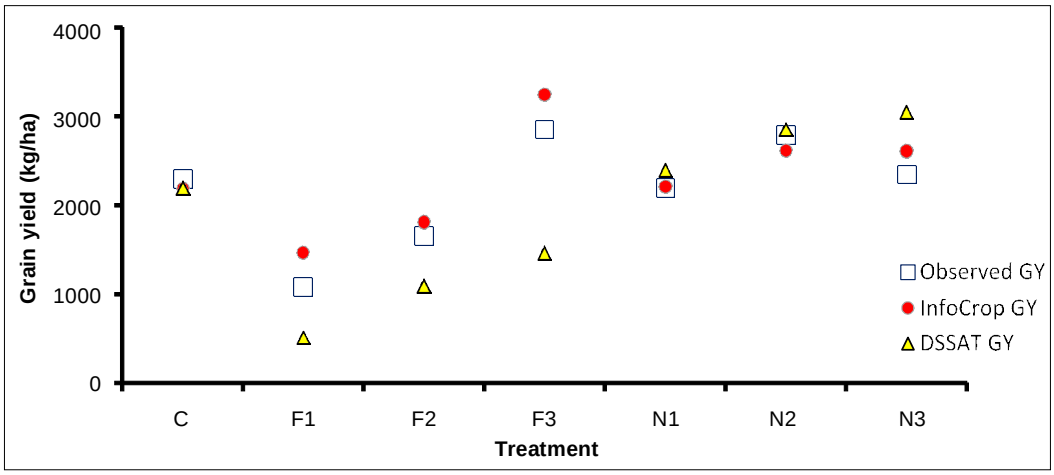


**Fig 5:** Observed and simulated grain yields for different treatments of wheat (GY in legend is grain yield).

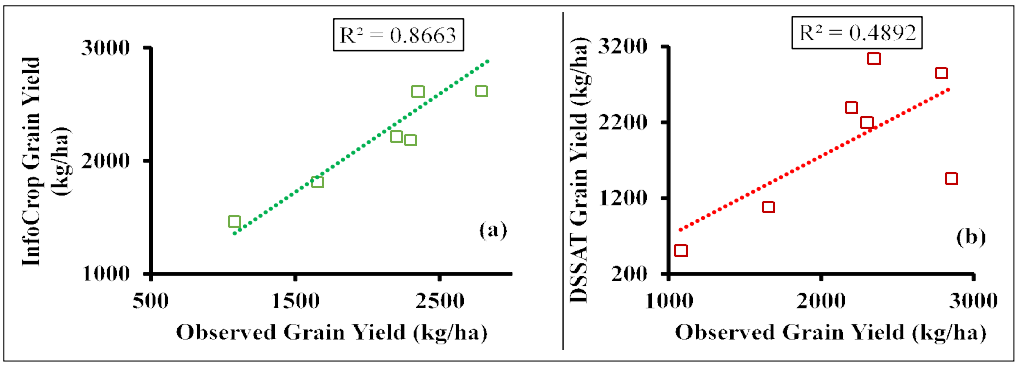


**Fig 6:** Comparison of observed grain yields for different treatments of wheat with (a) InfoCrop simulated grain yields (b) DSSAT simulated grain yields.

yield of treatment $F_3$ (+50% FYM) was considerably higher than that of the controlled treatment. This may be attributed to being the enhanced water retention in the sandy-loam soil due to the increase in organic content modelling FYM.

In modelling the grain yield, the overall performance of the InfroCrop model was better than that of the DSSAT model. InfroCrop model was developed in India and observed data for validation of the model was taken from the field experiments performed in Indian conditions (Aggarwal *et al.,* 2006a). When comparing the simulation of grain yields of C, F and N treatments, the grain yield of C treatment was predicted quite accurately using both the crop models. The error in modelled grain yield values was relatively higher for the N treatments and significantly increased for the F treatments. This points out that the simulation of grain yield for the treatments in which only organic fertilizers such as FYM are applied requires further studies and research.

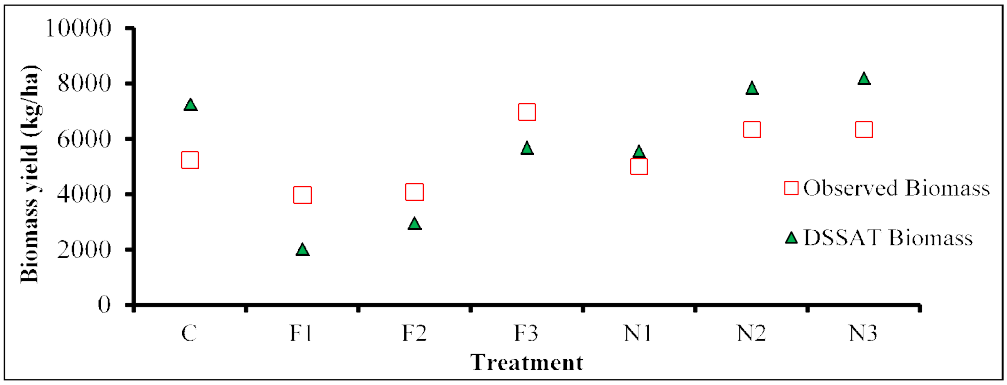


**Fig 7:** Observed and simulated biomass for different treatments of wheat.

## CONCLUSION

The application of different dosages of organic and inorganic fertilizers affected the grain yields as well as the total crop biomass significantly. The highest and lowest grain yield was observed for the treatments in which +50% and -25% of the normal dosage of farm yield manure (FYM) was applied without applying urea. There was relatively less variation in the grain yields when the application of urea is varied without applying FYM. DSSAT model under-predicted the grain yields of the treatments in which only FYM was applied and over-predicted the same for the treatments in which only urea was applied. InfoCrop model over-predicted the grain yields of treatments in which only FYM was used. The accuracy of InfoCrop was slightly better than DSSAT in the simulation of grain yields of only FYM application treatments. Overall, InfoCrop predicted grain yield values were better correlated to the observed grain yield when compared to the DSSAT predicted grain yields of wheat. Also, the yield of controlled treatment was simulated fairly accurately using both the crop models while the simulation accuracy increased for the treatments in which only urea and FYM are applied in variable quantities.

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**Conflict of interest:** None.

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