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Assessment of CROPGRO-Bellpepper model under different nitrogen levels through fertigation

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■ **ABSTRACT :** Application of optimum quantity of nitrogen during the crop growing period is essential for maximizing the yield profit as well as for reducing the environmental pollution. Regional based blanket application of N should be replaced by location specific recommendations for higher productivity and increasing the nitrogen use efficiency. Keeping on this view, the present investigation has been carryout during 2014-2016 to assessment of CROPGRO-Bell pepper model under various nitrogen levels through fertigation in subtropical India at Kharagpur, India. The crop growth model was calibrated and well validated under field condition and later the performance was evaluated at increasing temperature. From the field experiments conducted in two years, it was observed the maximum growth attributes, yield and yield attributes were recorded in N100 kg ha^{-1} which is significantly higher than the remaining treatments. The sub lethal doses of N levels were at par and the control recorded the lowest values. The crop growth model showed that the effect of increasing temperature upto 1.5°C on crop yield is meagre. Crop performance under controlled condition has to be studied.

■ **KEY WORDS :** Fertigation, Nitrogen, CROPGRO-Bell pepper, Drip irrigation

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Sweet pepper [*Capsicum annuum* (L.) var. Grossum] is commonly known as capsicum or bell pepper and it belongs to Solanaceous group of vegetables. It is very rich in vitamins A and C. capsicum is one of the most important vegetable crops grown extensively throughout the world especially in the temperate countries (Manchand and Singh, 1987). The crop is very sensitive to environmental factors (Bhatt *et al.*, 1999). Owing to its sensitivity to environmental factors, its yield is affected significantly. The plant grows at soil temperatures between 18^0C and 35^0C (Anonymous, 2009). Under optimal soil temperature with effective irrigation practices like drip irrigation would play an important role for obtaining maximum yields. Drip irrigation is an irrigation method that saves water and fertlizer by allowing water to drip slowly to the root of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing and emitters. For minimizing the cost of irrigation and fertilizers, adoption of drip irrigation with fertigation is essential which maximize the nutrient uptake at minimum amount of water and fertilizer application. Proper fertigation management requires the knowledge about amount of fertilizer application and nutrient uptake by the crop to ensure maximum crop productivity. Importantly, nitrogen fertilizer (N) plays an important role in proper vegetative growth and development of the plants. Deficiencies of fertilizer (N) causes decrease in yields. Water use efficiency, fertilizer use efficiency and yield are increased by adopting drip irrigation as compared with the conventional methods (Gupta *et al.*, 2010). For improving the capsicum yield, new methods may be adopted and these methods helps for estimating the precised crop yield under different environmental and crop management strategies. Maximum crop yield is a function of the effective soil management practices and favourable climatic conditions that occur during the crop growing season. These factorial relationship with crop yield is perfectly determined by various process-based crop growth models like, CERES, CROPGRO and INFOCROP etc. The decision support system for agrotechnology transfer (DSSAT) includes a set of models of crop growth and has been widely used in recent years as a useful computational tool in the evaluation of management options associated with environmental conditions (Hoogenboom *et al.*, 2011). The modular structure of the DSSAT includes an outstanding model known as CROPGRO. Hartkamp *et al*. (2002) evaluated the performance of CROPGRO to predict phenology, growth, senescence and nitrogen accumulation in locations that represented different scenarios of environmental and agronomic management. In the present investigation we used CROPGRO model for simulating crop growth, development and yield by considering the inputs related to soil-plant-atmosphere system. Keeping in this view, the present investigation carried out to assessment of CROPGRO-Bell pepper model under various nitrogen levels through fertigation in subtropical India.

■ METHODOLOGY

Site and soil properties of experimental field plot:

The experiment conducted at the experimental farm of Agricultural and Food Engineering Department, IIT, Kharagpur, India (22°19'N, 87°19'E, 48 m) during the months of October–March for 2 years (2014–2016). The site consisted of a red lateritic soil with a sandy loam texture (18.4% clay, 22.6% silt and 59.0% sand), with a maximum water holding capacity of 14.9 per cent, bulk density 1.44 g cm^{-3} and a steady state infiltration rate of 10 mm h^{-1}.

Raising of seedlings:

The capsicum (cv. ASHA F_1 Hybrid, 140d) seeds were sown in a pro-trays made of plastic material which are placed under a low cost poly tunnel in the first week of October. In order to prevent insect and pest infestation, aldicarb was applied (12.5 g m^{-2}) to the nursery trays as well as bavistan (0.2% concentration) to prevent damping off. The seed trays were wetted with water at 3-4 days interval. After 10 days of germination blitox (3 g l^{-1}) was sprayed at 10-day interval upto the transplanting stage (6-7 leaves), which was around 25 days after sowing.

Experimental treatments and field preparation:

A field plot of size 27m×08 m was selected for experimental purpose. The 25m long strip represented a single replication which was further divided into five sub strips. Each sub strip represented as an individual treatment. There was a 30 cm buffer between each sub strip to make difference from each treatment. Laterals were laid in the centre of the strip with 4 l h^{-1} emitters. Irrigation was applied at 5-7 days interval and the experiment was laid out in a Randomized Complete Block Design (RCBD) with 5 treatments and 4 replications.

Capsicum transplanting and irrigation system installation:

Selected 24 days old seedlings were transplanted with a spacing of 50 cm×50 cm. The drip irrigation system was operated as and when required. The lateral lines were laid in between the two rows of crop and 4 l h^{-1} emitters were installed 1.0 m apart (one emitter for four plants).

Field management:

The fertilizer doses of 150 kg N, 100 kg P and 100 kg K along with 30 t of farmyard manure (FYM) per ha were applied to meet the nutritional requirements of crop. The RDF (Recommended Dose of Fertilizer) applied in the form of water soluble fertilizers (WSF)as top dressing.

Model calibration and validation:

Crop model "CROPGRO-Bellpepper" used for simulating the crop growth under various nitrogen levels at Kharagpur in subtropical India. The model calibrated with N100 treatment from the field experiment conducted during October, 2014-March, 2015 (Ist year) and model validated with remaining treatments in the first year and all treatments of the October, 2015-March, 2016 (2nd year).The crop phenological parameters such as anthesis day, first seed day, physiological maturity day, yield at maturity, unit weight of the fruit and time series tops weight were considered during the model calibration and validation. The developed genotypic co-efficient values through the model calibration, same were used for model validation. The crop variety "Asha F_1 Hybrid, 135d" was used in the present investigation and model performance evaluated using the statistical parameters such as normalized root mean squared error (RMSEn) and D-index (Willmott,1982) as common tools to test the goodness-of-fit of simulation models as given in Eqs. (1) and (2):

$$\mathrm{RMSEn} = \frac{\left\{\sum_{i=1}^{n}\frac{(S_i - O_i)^2}{n}\right\}^{0.5}}{\overline{O}_{avg}} \quad ....(1)$$

$$D-\mathrm{index} = 1 - \frac{\sum_{i=1}^{n}(S_i - O_i)^2}{\sum_{i=1}^{n}\left(\left|S_i - \overline{O}_{avg}\right| + \left|O_{bi} - \overline{O}_{avg}\right|\right)^2} \quad ....(2)$$

where, S_i and O_i are the model simulated and experimentally measured points, respectively,

$\overline{O}_{avg}$ is the average of observed values and n is the number of observations.

Simulation of crop yield :

As per the IPCC report 5 (IPCC 2014) the marginal increase in average temperature by the end of 21st century will be 2°C. We tested our genotypic co-efficient values in subtropical region by increasing the maximum and minimum temperature upto 2°C and evaluated the yield performance of the crop in the view of future climate change.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Growth attributes :

Plant growth attributes such as plant height, leaf area index (LAI), number of branches are presented in Table 1. The growth attributes were significantly influenced by various N management practices. N 100 kg ha^{-1} produced significantly higher growth attributes over remaining treatments followed by 80 kg ha^{-1}, 60 kg ha^{-1}, 40 kg ha^{-1} and 0 kg ha^{-1}. The same trend has been observed for both the years. Growth attributes were

Table 1: Effect of fertigation on capsicum growth attributes

Treatments	Plant height (cm)		Leaf area index (cm)		No. of branches at (80 days)		Individual fruit weight (g)	
	2014	2015	2014	2015	2014	2015	2014	2015
T_1	78.75	75	3.6	3.57	5.25	5.025	156.56	150.25
T_2	71.325	69.5	3.1	3.02	4	3.75	144.25	137.5
T_3	67.9	67.75	3	2.82	3.5	3	137.5	130.75
T_4	63.75	62.5	2.6	2.67	2.75	2.25	119	101.25
T_5	52.75	54.5	2.4	2.3	1.75	1.5	95	92.25
S.E. ±	2.18	1.36	0.12	0.11	0.32	0.26	3.79	3.88
C.D. (P=0.05)	6.72	4.21	0.39	0.33	1.00	0.830	11.68	11.96

Table 2: Effect of fertigation on capsicum yield parameters

Treatments	Total number of fruits at harvest		Individual fruit length (cm)		Individual fruit diameter (cm)		Yield (kg ha^{-1})	
	2014	2015	2014	2015	2014	2015	2014	2015
T_1	20.25	18.75	12.4	11.675	6.125	6.025	10659.75	10872
T_2	16.75	14.25	11.125	10	5.6625	5.525	9864.50	9958
T_3	12.5	12.25	9.975	9.5	5.2625	5.175	9143.00	9423
T_4	10.25	12	8.5	7.475	5.15	4.825	7523.00	7648
T_5	7	8.5	6.3	5.75	4.3125	3.95	6705.00	6921
S.E.±	1.11	1.44	0.29	0.46	0.13	0.15	192.95	236.59
C.D. (P=0.05)	3.43	4.44	6.37	10.18	0.41	0.49	594.55	729.00

recorded as maximum in the first year as compared to second year, but in pooled analysis the difference in between the years was insignificant. The higher rate of nitrogen showed maximum plant height and it was significantly higher than remaining treatments. Except control the remaining N application treatments were at par. Leaf area index was observed maximum at recommended dose of N and followed by 80 kg ha^{-1}, 60 kg ha^{-1}, 40 kg ha^{-1} and 0 kg ha^{-1}. This might be due to higher N application conducive for the production of maximum leaf area. Number of branches at maximum vegetative stage is one of the yield determining factor. The maximum number of branches were recorded highest in N 100 kg ha^{-1} and it was significantly higher than remaining N applications and control. The lethal dose of N application treatments were at par. Top dressing of N with optimum dose at 10 days interval positively effected the crop growth attributes. The similar resulted were observed in Khan *et al.* (2010).

Yield attributes :

Economical yield and yield attributes, *i.e.*, individual fruit weight, total no of fruits at harvest, fruit length, fruit diameter and yield of capsicum are presented in Table 2. Capsicum responded well to higher dose and rate of N application. Higher crop yield in first year was mainly attributed for higher number of fruits per unit area at harvest and higher individual fruit weight as compared to second year, but the difference was insignificant. The highest crop yield has been achieved with total N application of 100 kg N ha^{-1} and it is significantly higher than remaining N applications treatments and control. The sub lethal dose of N application produced at par yield among the treatments and it was significantly different with control treatment. Hence, the precised N application, 100 kg ha^{-1} is recommended for optimum yield and the remaining N applications resulted in marginal increase in crop yield, which is significantly different with recommended dose as well as control treatment. The remaining yield attributes followed the same trend in both the years.

Model calibration and validation :

The simulated tops weight throughout the crop growing period was within standard deviation of their observed value in both calibration and validation (Fig.1).

Table 3 (a) : Comparision of simulated and observed crop parameters of bell pepper grown under different nitrogen levels during October 2014 to March 2015 at Kharagpur, India (Calibration and Validations)

Crop parameters	Calibration		Validation							
	N100 kg ha^{-1}		N80 kg ha^{-1}		N60 kg ha^{-1}		N40 kg ha^{-1}		N0 kg ha^{-1}	
	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
Anthesis day (dap)	15	16	15	16	16	18	16	18	16	18
First seed day (dap)	31	32	30	32	32	33	32	34	33	35
Physiological maturity day (dap)	133	135	132	135	134	137	134	136	135	136
Yield at harvest maturity (kg ha^{-1})	11023	10689 (±534)	10241	9758 (±517)	9873	9372 (±631)	8137	7592 (±607)	7340	6820 (±549)
Unit wt. at maturity (g)	167	158 (±12)	159	154 (±15)	154	151 (±09)	137	131 (±09)	121	115 (±11)

Table 3 (b): Comparision of simulated and observed crop parameters of bell pepper grown under different nitrogen levels during October 2015 to March 2016 at Kharagpur, India (Validations)

Crop parameters	Validation									
	N100 kg ha^{-1}		N80 kg ha^{-1}		N60 kg ha^{-1}		N40 kg ha^{-1}		N0 kg ha^{-1}	
	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
Anthesis day (dap)	16	17	16	18	16	17	16	18	16	18
First seed day (dap)	32	33	32	34	32	33	32	34	32	33
Physiological maturity day (dap)	134	135	134	135	134	136	134	136	134	136
Yield at harvest maturity (kg ha^{-1})	11291	10872 (±513)	10340	9958 (±503)	9931	9423 (±631)	8162	7648 (±592)	7287	6921 (±549)
Unit wt. at maturity (g)	169	161 (±13)	164	155 (±11)	159	153 (±12)	142	134 (±09)	129	116 (±10)

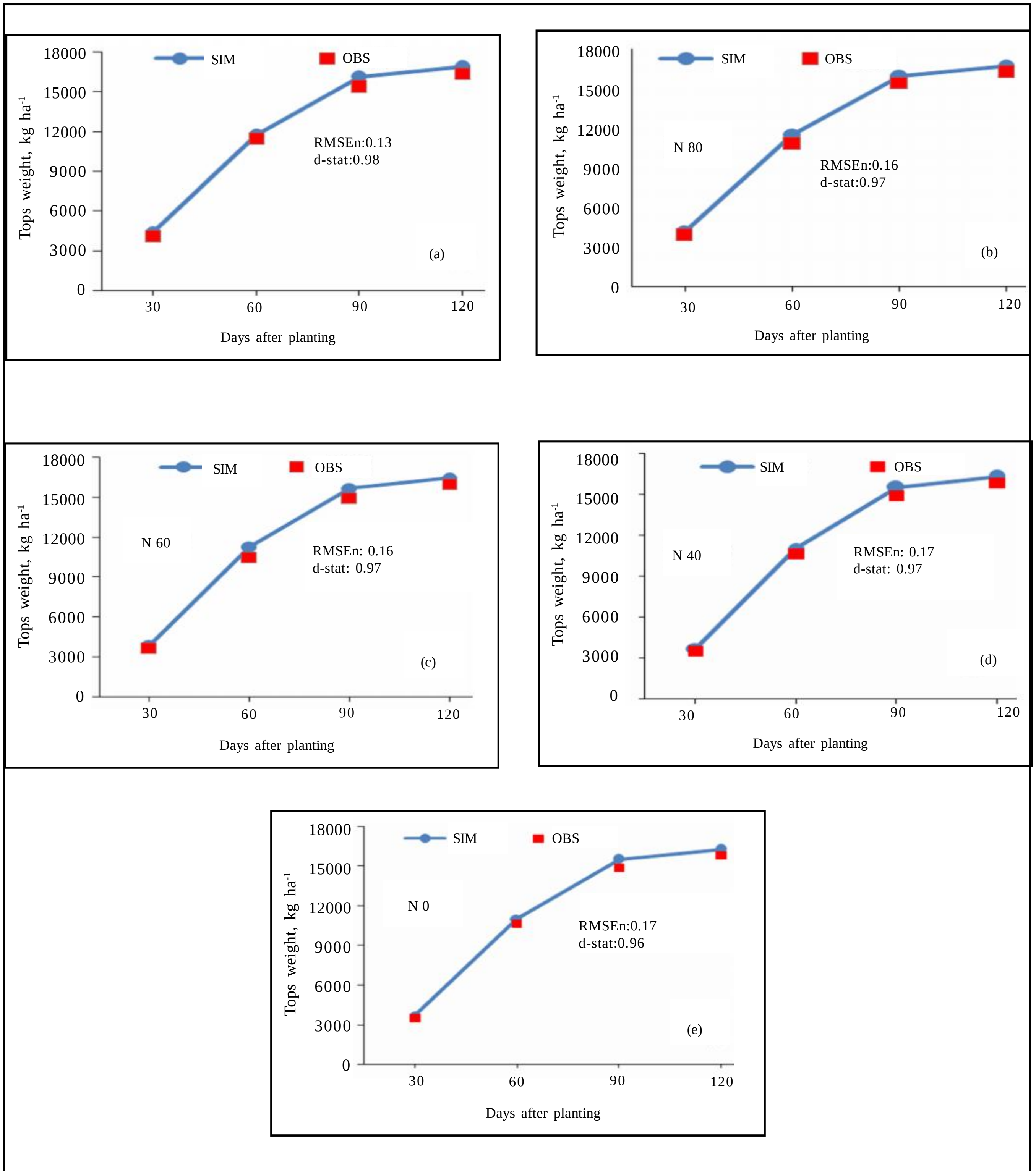

Fig. 1 : **Simulated (SIM) and observed (OBS) time series tops weight in days after planting of bell pepper grown under different nitrogen levels, 100(a) kg ha^{-1} (Calibration), 80 (b), 60 (c), 40 (d) and 0 (e) kg ha^{-1} (Validations) during October 2014 to March 2015 at Kharagpur, India**

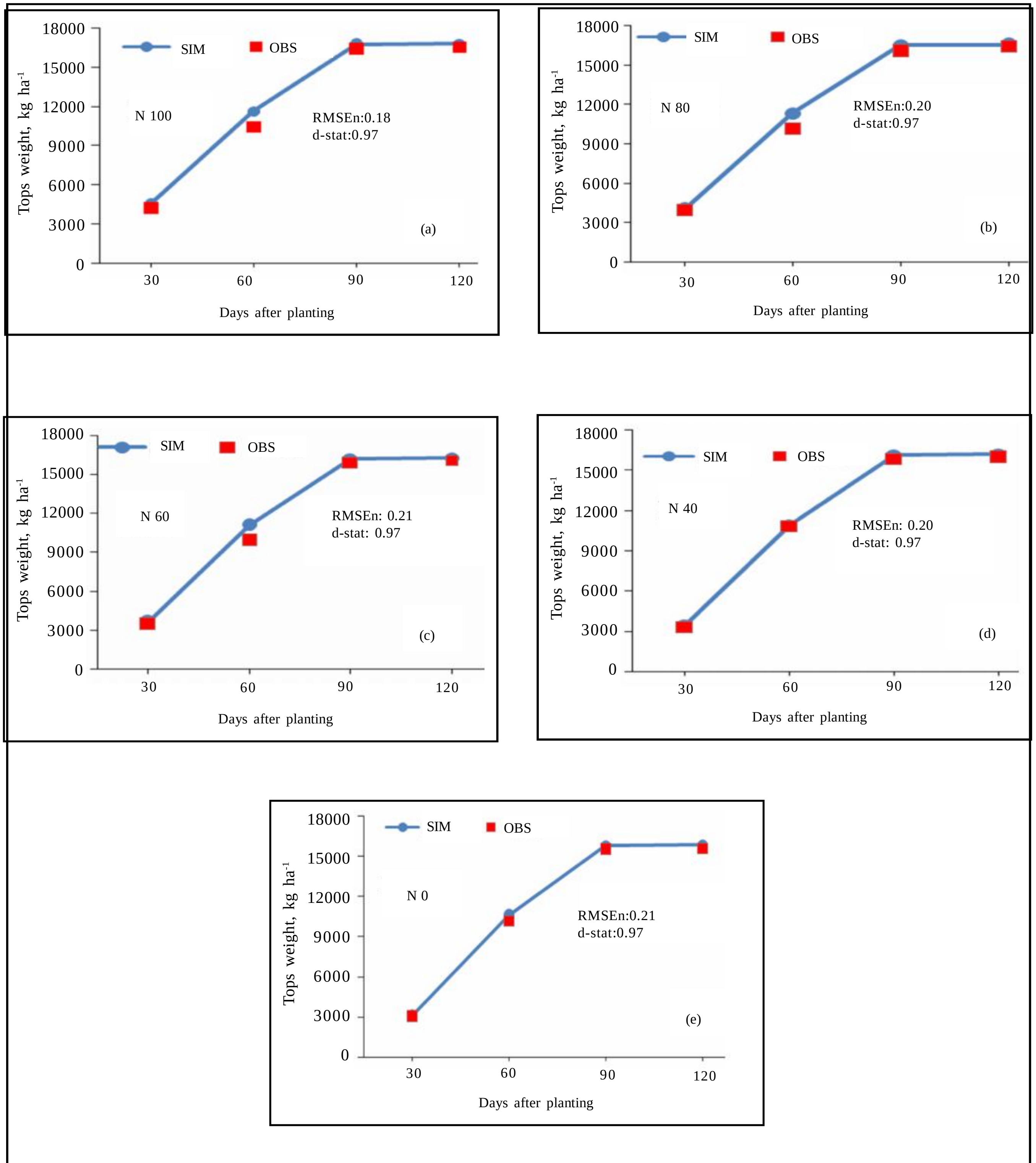

Fig. 2 : Simulated (SIM) and Observed (OBS) time series tops weight in days after planting of bell pepper grown under different nitrogen levels 100(a), 80 (b), 60 (c), 40 (d) and 0 (e) kg ha^{-1} during October 2015 to March 2016 at Kharagpur, India (Validations)

Between the simulated and observed time series tops weight, RMSEn is 0.13; d-stat value is 0.98 for calibration and the same 0.16 to 0.21 and 0.96-0.98 for validation, respectively (Fig.2). The observed anthesis day is one day higher than simulated anthesis day in calibration (Table 3a) and it has the difference in 1-2 days higher for validations (Table 3b) in all treatments. The observed first seed day is 1 day higher than simulated first seed day in calibration and the difference is 1-2 days in validation. The observed physiological maturity day is 2 days higher than simulated physiological maturity day in calibration and the difference is 1-3 days higher in case of validation. The simulated fruit yield and individual fruit weight at maturity were with in standard deviation of their observed values in both calibration and validation. The developed genotypic co-efficient values through model calibration were same used for model validation.

Evaluation of model performance under various temperature:

Evaluation of model performance has been done for simulating the crop yield under various maximum and minimum temperature combinations in subtropical India. The increasing average temperature upto 1.5°C does not decreased crop yield significantly. In another controlled experiment, black sheet covered shade house condition the bell pepper crop showed 25-30 per cent higher in yield.

Conclusion :

We studied the effect of various N levels through fertigation on crop growth, development and yield at Kharagpur, India. The maximum growth attributes, yield and yield attributes were recorded in N100 kg ha^{-1} which was significantly higher than the remaining treatments. The sub lethal doses of N levels were at par and the control recorded the lowest values. The crop growth model (CROPGRO-Bellpepper) showed that the effect of increasing temperature upto 1.5°C on crop yield is meagre. Crop performance under controlled condition has to be studied.

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