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Growth and yield prediction in mustard using InfoCrop simulation model

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ABSTRACT

The present study was conducted to calibrate and predict the growth and yield of *Brassica juncea* under semi-arid environment of Delhi region using InfoCrop model. Field experiments were carried out with the variety Pusa Jaikisan (most popularly grown in north western parts of India), sown on 15th and 30th October of *rabi,* 2005-06 and 2006-07 on sandy clay loam textured soils at research farm of Indian Agricultural Research Institute (IARI), New Delhi. The base temperature at different phenological stages was taken as 5^0C. The thermal time from germination to flowering was calibrated to 730^0D. Crop growth parameters like leaf area index (LAI), biomass and seed yield were simulated using InfoCrop model. The model overestimated LAI and biomass at the initial crop growth stages but underestimated at the peak/maximum level. The model overestimated the seed yield for both the sowings and the seasons. Actual seed yield was of the order of 23 to 37 q ha^{-1} while the simulated yield was of the order of 37 to 42 q ha^{-1} with a RMSE value of 3.14 indicating significant differences between observed and simulated yield. The model needs further refinement.

Key Words: *Brassica juncea*, biomass, leaf area index, seed yield, InfoCrop

In recent years considerable advances have been made in understanding the important physiological processes in plant such as photosynthesis, transpiration, growth and development. Practical attempts to integrate this knowledge has been incorporated in the form of development of dynamic simulation models of crop-weather interactions and used for simulation of growth and development of agricultural crops by computer-based techniques. Interpretation of crop growth, development and yield in terms of the prevailing weather conditions is one the objectives of these simulation models which can serve as a research tool and also at the same time they have the potential of being used in management decision making processes in our attempts to realize the potential yield. These models predict changes in crop status with time as a function of exogenous parameters (Whisler *et al.* 1986). Hellstorm and Kjellstrom (1989) made a preliminary attempt to model dry matter production of *Brassica* sp. using a temporary grassland model developed earlier by Torssell and Kornher (1983), which was based on a relative growth rate term, a development term and weather index, including soil water balance. Rao (1992) at IARI, New Delhi, developed a process-oriented dynamic simulation model *BRASSICA* retaining some features from PNUTGRO model under non-limiting moisture and nutrient conditions to predict potential yield under varying thermal and radiation regimes. Aggarwal *et al*., (1994) developed InfoCrop model to simulate growth and yield of *Brassica* spp.

A generic simulation model for annual crops in tropical environments InfoCrop was developed at IARI (New Delhi) which is a Decision Support System (DSS) that was developed to simulate the effects of weather, soils, agronomic management (including planting, nitrogen, residue and irrigation) and major pests on crop growth and yield. The crop models have been/are being validated in major crop-specific environments of India and also include databases of typical Indian soils, weather and varieties to facilitate applications. Since the information on simulation of growth and yield in mustard crop using InfoCrop model was lacking, the present study was planned for the first time to calibrate, validate and predict the growth and yield under semi-arid environment of Delhi region.

MATERIALS AND METHODS

Field experiments were carried out during *rabi* seasons of 2005-06 and 2006-07 on sandy clay loam textured soils at research farm of IARI, New Delhi representing a semi-arid environmental condition with dry hot summers and cold winters. The soil of the experimental site belongs to the major group of Indo-Gangetic alluvium. The soil texture is sandy clay loam and belongs to Holambi Series, which is a member of non-acidic mixed hyperthermic family of Typic Ustocrepts, with medium to weak angular blocky structure. The soil is non-calcareous and slightly alkaline in reaction. The variety Pusa Jaikisan (most popularly grown in north and north western parts of India) was sown on 15th and 30th October in both the seasons in a Randomized Block Design (RBD) with three replications. The crop was raised following standard recommended practices maintaining 45 cm and 15 cm spacing between rows and plants respectively. From three randomly selected plant samples, the leaf area was measured using leaf area meter (model LICOR- 3100), oven dried at 80^0C for 48

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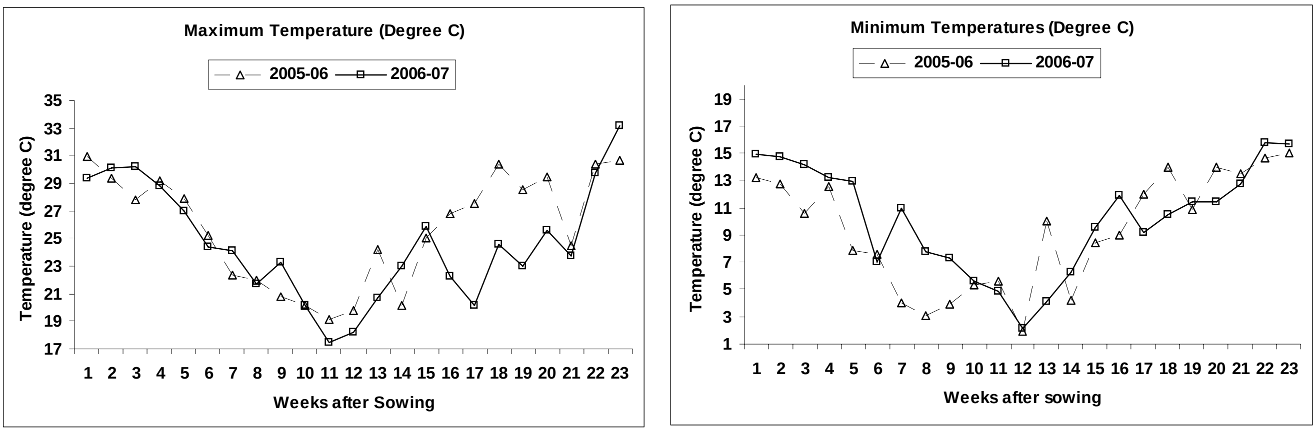

Fig. 1a: Maximum and Minimum temperatures during *rabi* 2005-06 and 2006-07

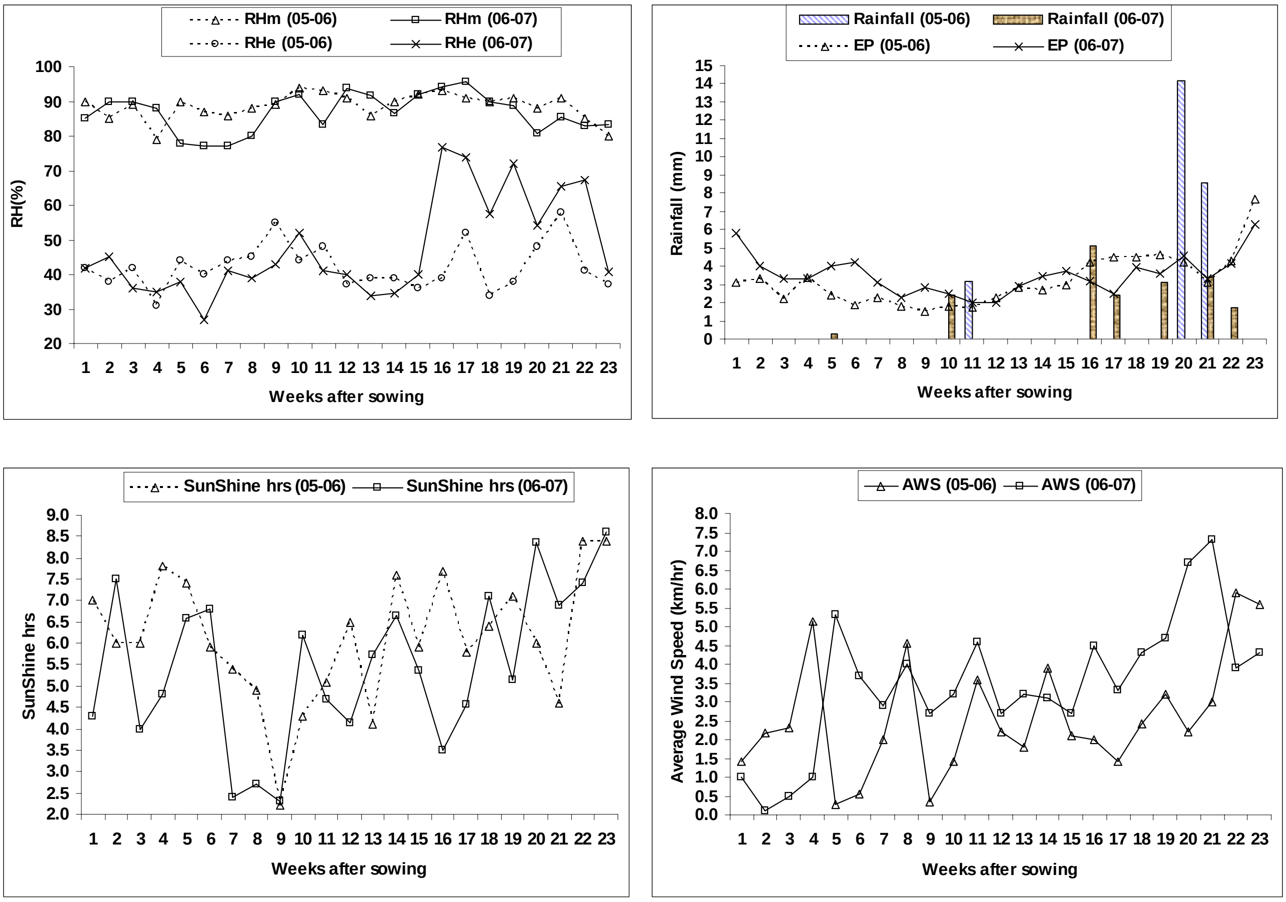

Fig.1b: Relative Humidity (%), rainfall (mm), evaporation (mm), Sunshine hours and average wind speed (kmph) during crop growth of *rabi* 2005-06 and 2006-07

hours to get constant weight for assessing biomass production. Seed yields were recorded at harvest from each plot. Weather parameters were recorded from Agrometeorological Observatory located adjacent to the experimental field. The model InfoCrop was written in Fortran Simulation Translator programming language (FST). Plant growth parameters like LAI, biomass and seed yield were simulated. The base temperature at different phenological stages was taken as 5^0C. The thermal time from germination to flowering was calibrated to 730^0D. The

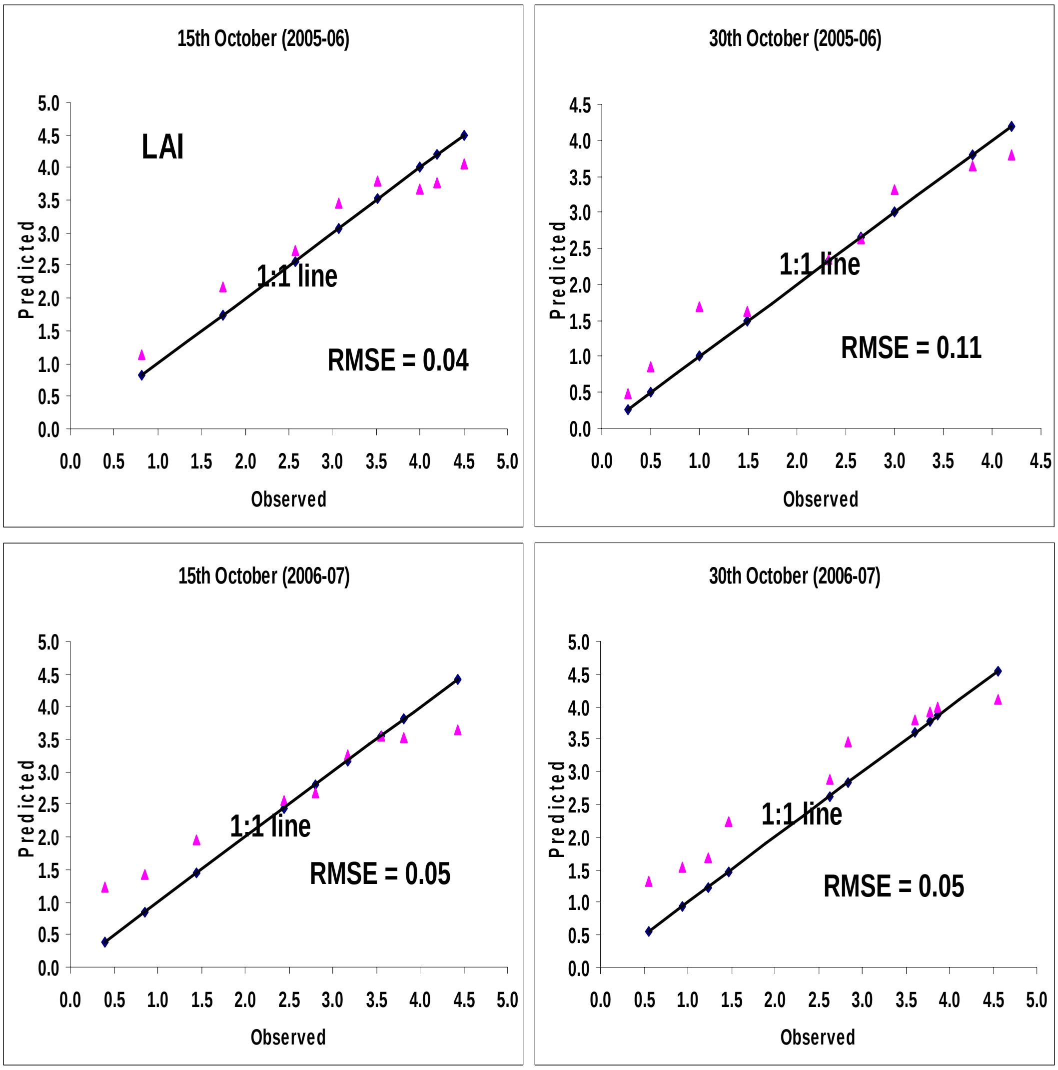

Fig. 2a: Simulated LAI in both the seasons and sowing dates

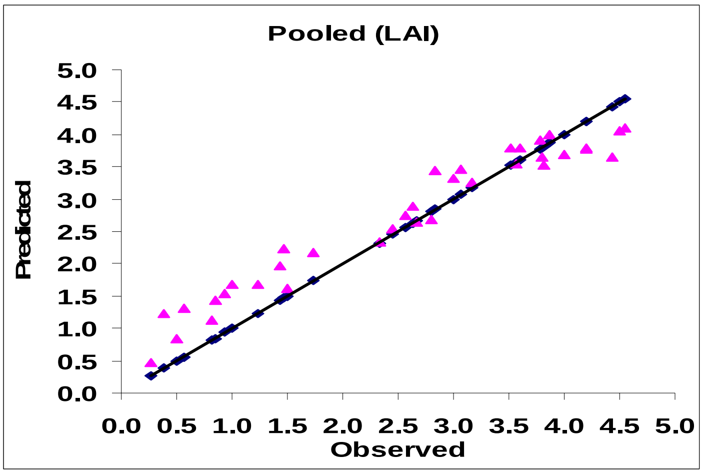

Fig. 2b: Simulated LAI (Pooled)

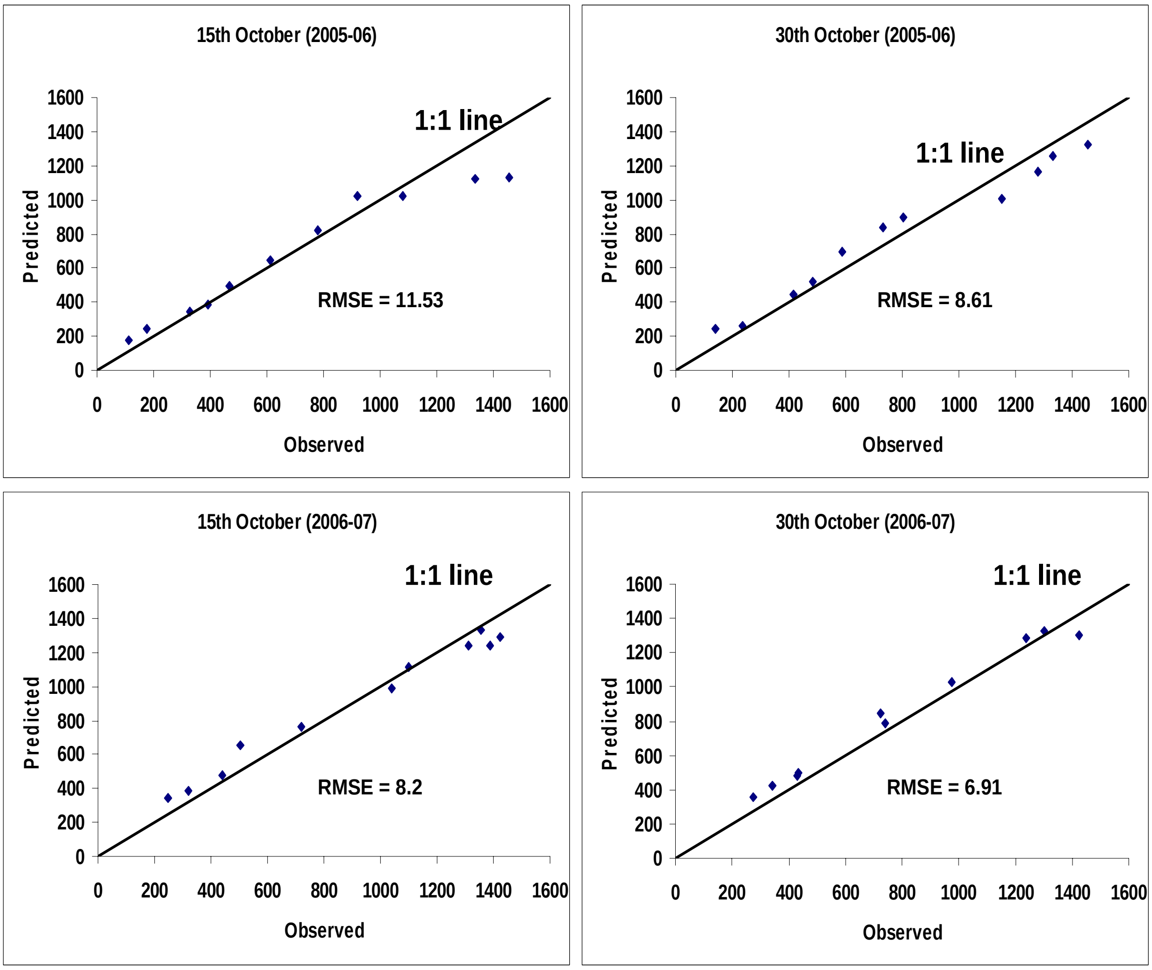

Fig. 3a: Simulated biomass in both the seasons and sowing dates

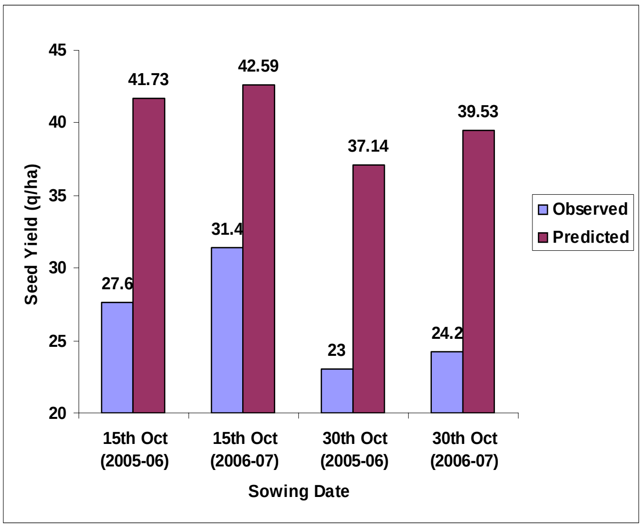

Fig. 4: Simulated seed yield in both the seasons and sowing dates

optimum temperature was taken as 24^0C. The following parameters were taken during simulation of the model. The relative growth rate of leaf area ($^0Cd^{-1}$): 0.008, Specific leaf area (m^2mg^{-1}): 0.0022 (Calibrated to 0.0033), Extinction coefficient of leaves at flowering (ha soil/ha leaf fraction): 0.6, Radiation use efficiency ($gMJ^{-1}day^{-1}$): 2.3, Root growth rate (mm day^{-1}): 35, Potential storage organ weight (mg/ grain): 8, Nitrogen content of storage organ (fraction): 0.039, Sensitivity of storage organ setting to low and high temperature: 1 (0 to 1.5). The model was calibrated using four varieties (Pusa Bold, B. O-54, Pusa Jaikisan, Varuna) grown mainly under north and north-western Indian conditions. Apart from other varieties, Pusa Jaikisan was particularly given main emphasis owing to its most popularity and wide acceptance among farmers of north and north-western states. The variety was calibrated using 4 years data of NATP project on crop-weather interaction. The crop was calibrated against wide variation in thermal regimes; sowing range of 1^{st} of week September to last week of December, representing wide differential hydro-thermal regimes. The wide sowing dates were considered keeping in view delayed harvesting of previous crop at the farmers field.

RESULTS AND DISCUSSION

Weather conditions during the crop growth

The maximum temperature although remained almost same in the early crop growth during both the seasons, it was in the optimum range (for crop growth) of 20 to 24^0C during pod filling stage in the second season. The maximum temperature was lower by 0.7 to 7.4^0C during 16^{th} to 22^{nd} week after sowing in the second season as compared to the first season. In contrast, the weekly minimum temperature in the second season was higher at the initial crop growth stages (from 1^{st} week to 12^{th} week after sowing) by about 0.3^0C to 7^0C as compared to first season facilitating rapid crop growth. During pod filling stage, minimum temperature was initially high but later on decreased (Fig. 1a). The total amount of rainfall received during first crop season was 26.0 mm (in 3 days) while 18.4 mm (in 6 days) was received in the next crop season. Although the total amount of rainfall received during the first crop season was marginally higher by 7.6 mm, the distribution was much more congenial for growth in the second season. Bright sunshine hours, wind speed and RH were more or less same in both the seasons (Fig 1b).

Simulation using InfoCrop

The model was calibrated and simulated in control plots of Pusa Jaikisan in both sowing dates and seasons. Leaf area index, biomass and seed yield were simulated. It was observed that the model overestimated the LAI at the initial crop growth stages but underestimated at the final peak/ maximum level (Fig. 2a and 2b). The root means square error (RMSE) between observed and predicted LAI values were 0.04 and 0.05 in first and second seasons respectively in 15^{th} October sowing while in case of 30^{th} October sowing the corresponding values were 0.11 and 0.05 respectively. However, the RMSE value for pooled data of LAI (both sowing dates and seasons) was 0.01. Similarly, biomass was overestimated at the beginning of crop growth stages and at later stage particularly at the final biomass, the model underestimated the biomass production (Fig.3a and 3b). The RMSE values were 11.53 and 8.2 in first and second seasons respectively in 15^{th} October sowing while in case of 30^{th} October sowing the corresponding values were 8.61 and 6.91 respectively. However, the RMSE value for pooled data of biomass (both sowing dates and seasons) was 2.31. The model overestimated the seed yield in sowings and seasons (Fig. 4). Observed seed yield was of the order of 23 to 37 qha^{-1} while the simulated yield was of the order of 37 to 42 $qha^{-1}$with RMSE value of 3.14. The simulated seed yield was higher by about 44 per cent in 15^{th} October sowing and 62 per cent in 30^{th} October sowing in both the seasons respectively. The optimum temperature for pod filling stage and partitioning of photosynthates into sink is recognized to be 24^0C. During the second season, optimum temperature of 24^0C prevailed that caused higher yield while in first season the warmer temperature (5^0C higher than 24^0C) during pod filling stage caused forced maturity and thereby reduced seed yield as observed in field data. The model also shown similar trend but the magnitude of difference in seed yield in both seasons was found to be higher than field data. Not only that, the distribution of rainfall was also congenial during second season while although the first season has received higher amount of total rainfall but its distribution is limited only to later stage of growth. These differential thermo-hydro regimes could be the possible reason for differential seed yield in two seasons.

CONCLUSIONS

Crop growth parameters like LAI, biomass and seed yield were simulated using InfoCrop model and it was found that the model overestimated LAI and biomass at the initial crop growth stages but underestimated at the final peak/ maximum level. The model overestimated the seed yield for both the sowings and the seasons. Actual seed yield was of the order of 23 to 37 q ha^{-1} while the simulated yield was of the order of 37 to 42 q ha^{-1} with a RMSE value of 3.14 indicating significant differences between observed and simulated yield. Therefore, it is inferred that the InfoCrop model needed further calibration and validation including rationalization of crop growth coefficients particularly at the later stage of crop growth. Calibration in terms of soil, weather and varietals response needs to be dealt with very carefully for accurate yield estimation.

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