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Evaluation of N Submodel of CERES-Maize under Egyptian Desert Soil Conditions of North Sinai

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MAIZE (*Zea mays* L.) is one of the most important cereal crop cultivated in Egypt. A new research techniques and technology transfer are needed to provide with more efficient use of resources and alternative systems for increasing productivity and prediction of yield. The Decision Support System for Agro technology transfer (DSSAT V 4.5) that includes N sub model of CERES-Maize was evaluated under Egyptian desert condition of North Sinai. The study area located at El Maghara Research Station of Desert Research Center at North Sinai – Egypt (30 34 N', 33 19 E'). Maize (*Zea mays*) was sown in summer growing season of year 2001. The experimental treatments were eight levels of N (0, 60, 100, 140, 175, 215, 250, 290 kg N ha^{-1}) as nitric acid (15.6% N) applied through drip irrigation system. The input data to the model included daily weather data, site information, soil characteristics for each layer, soil initial conditions and fertilizer management, crop and irrigation management. The evaluation of the N sub model was conducted on maize grains and straw yield as a validation parameter. The results of the study indicated that the regression coefficient (R^2) for grains and straw are between field and predicted results 0.61 and 0.77, respectively. The average of the simulated maize grains yield for all treatments was 117% of the measured yield. The average of the simulated corn straw yield for all treatments was 89.1% of the measured yield. The N sub model of CERES-Maize provided acceptable rage of prediction for grains and straw yield of maize under different rates of N application. The predicted results of the treatments followed the same trend as the observed ones. The model can be used to predict grains and straw yield of maize after calibration and evaluation of the experimental data for the field tested. Further research is needed to evaluate the ability of the N model to predict maize grain and straw yield under different conditions of soils, cultivar and weather. The decision support tool can be used for evaluation of predicted maize yield based on local weather and soil conditions and management practices. The proposed decision support tool will provide decision makers with an additional option to integrate local weather and soil conditions in their management decision making which will be transferred and delivered to farmers. This weather, soil and crops-based decision support system should lead to an enhanced production of maize and provide information for future agricultural planning that will lead to an improvement of the food security in Egypt.

Keywords: N sub model of CERES- Maize, Desert conditions, North Sinai.

Maize (*Zea mays* L.) is one of the most important cereal crops cultivated in Egypt after wheat and rice. It is a major source of carbohydrate for human consumption and animal feed. The response of maize to different crop management studies in Egypt, specially, fertilization had been documented (El Kadi *et al.,* 1990, Hatem *et al.,* 1991, Hatem, 1993, Hasanein, 1999 and Hasanein, 2001).

The maize production in Egypt is not sufficient to meet the increasing demand and consumption, which is covered by following the importing policy. Recently, some of the exported countries for grain crops have introduced difficult new economic strategy such as using maize for fuel production. It means that in near future importing policy for gains from other countries will not be guaranteed. So, it is a vital to increase the productivity of crop nationally to meet the requirements of growing population. A new research technique and technology transfer is needed to provide with more efficient use of resources and alternative systems for increasing productivity and prediction of yield.

Decision support systems and crop simulation models are considered as new techniques for technology transfer usage. It can predict yield of crops and nutrients uptake in response to local weather conditions, which is considered as a useful tool for economical and environmental evaluation of cropping systems (Bowen *et al.,* 1993 and Asadi *et al.,* 2001).

The CSM -CERES-Maize model (the cropping system model -the crop-environment resource synthesis) *i.e.,* Maize model is considered as a part of the Decision Support System for Agro technology Transfer (DSSAT v4.5) (Jones *et al.,* 2003 and Hoogenboom *et al.,* 2008). The model has been tested and used under different circumstances. The model can simulate quantitatively the growth and yield of maize for a wide range of weather conditions, different type of soils and crops varieties to predict information for future agricultural planning and to evaluate a different alternative options for crop management practices (Hodges, *et al.,* 1987, Carberry *et al.,* 1989, Jones & Ritchie, 1990, Singh, *et al.,* 1993, Thornton *et al.,* 1995 and Hoogenboom, 2000).

The N CERES-Maize sub model can describe the processes of N transformation and transport and soil water movement following fertilizer N addition incorporation of plant residue, N losses by leaching and dentrification and N uptake by maize on a daily basis from sowing to maturity considering the physiological processes which is determining by response of crop soil and weather condition. The sub model can simulate the processes of nitrification, denitrification, hydrolysis of urea, ammonia volatilization for a wide source of N (chemical fertilizers, green manure) and organic matter turnover including the mineralization and immobilization of N, in addition to N uptake in crop tissue, where crop yield, N uptake, N leaching can be evaluated as affected by different irrigation and management conditions (Jones and Kriniry, 1986, Hoogenboom *et al.,* 1999, Godwin and Jones, 1991 and Asadia & Clemente, 2001).

The objective of this study was to use N sub model of CERES-Maize to evaluate its performance in simulating yield of maize in response to different N fertilizer treatments. Soil, climate and crop data collected from field experiment conducted under Egyptian desert condition of North Sinai were used.

Material and Methods

The study area and field experiments

The study area was located at El Maghara Research Station of Desert Research Center at North Sinai , Egypt (30 34 N$^{\circ}$, 33 19 E$^{\circ}$). The field data were collected from a previous study which had been explained by Hasanein (2001). Mazie (*Zea mays*) was sown in summer growing season of year 2001 under drip irrigation system. The experimental treatments were eight levels of N (0, 60, 100, 140, 175, 215, 250 and 290 kg N ha^{-1}) as nitric acid (15.6% N). Phosphoric acid as 75 kg P_2O_5 ha^{-1} and potassium solution are 125 kg K_2O ha^{-1} were applied with water through drip irrigation system. All treatments were applied each two weeks with a total of six times. The treatments were replicated three times in a randomized block design. At harvest time, grains and straw yield were recorded.

Model description and input data

The Decision Support System for Agro technology transfer (DSSAT V 4.5) that includes N sub model of CERES-Maize was used for input data (Hoogenboom *et al.,* 2008). The input data to the model covered daily weather data such as minimum and maximum air temperature, solar radiation and rainfall. Also, data included site information, soil characteristics for each layer (chemical–physical–morphological), soil initial conditions and fertilizer management (amount of treatments, times and methods of application, type of fertilizer and method of addition). A crop management (plant cultivar, plant population, date of planting, seeding depth and raw spacing) and irrigation management (schedule, times, amounts of water, method of application) were included (Jones and Kriniry, 1986, Ritchie and Alagarswamy, 2003 and Soler *et al.,* 2007).

Genetic coefficient calibration

The experimental data were used to calibrate and evaluate the model. The N sub model of CERES-Maize was used for calibration. It gives the simulated quantitative determination of maize growth, development and yield from sowing to maturity on a daily basis. It does simulate N in soil and plant as recently introduced in the model (DSSAT v4.5).

The process of calibration starting sequentially with phonological parameters (maturity and flowering dates), then, the parameters of crop growth (kernels number per plant and kernel filling rate).

As soon as soil, weather and management files were input to the model, the calibration of genetic coefficients can be started. The set of five genetic parameters (P_1, P_2 and P_5 for phonology and G_2 and G_5 for grains yield) were estimated. First, P_1 (the growing degree days from emergence to the end of juvenile stage) was calibrated , then P_2 (the photoperiod sensitivity parameter). P_5 (the growing degree days from slinking to physiological maturity was also, calibrated. G_2 (the potential number of kernels per plant) and G_3 (the potential kernel growth rate in mg kernel^{-1} day^{-1}) were determined. An iterative procedure was used to select the most appropriate values for the parameters, where values were adjusted until the model estimates were very close to observed values (Hunt *et al.*, 1993, Hunt and Boot, 1998, Ritchie *et al.*, 1998, Ritchie and Alagarswamy, 2003 and Hoogenboom *et al.*, 2008).

The growing degree days (P_1) was calibrated to 245.0 and the photoperiod sensitivity coefficient (P_2) was set to 0.750. The accumulated thermal time from slinking to physiological maturity (P_5) was calibrated to 930.0. The value of G_2 (maximum kernel number per plant when plant grown without stress) was set to 990.0 kernel plant^{-1} and G_3 (the potential kernel growth rate) was set to 8.00 mg kernel^{-1} day^{-1}.

These values of the parameters produced a simulated yield equal to the maximum measured yield when N, P and water were not limiting factors. The predictions of model were compared with measured data of the treatments. Simulated data were regressed against observed data for grains and straw yield.

Results and Discussion

Predicted and observed grains yield

The predicted and observed values of maize grains yield for eight application rates of N (control, 60, 100, 140, 175, 215, 250 and 290 kg N ha^{-1}) are shown in Fig. 1. The slope of regression line was 0.8419 and R^2 was 0.61 for maize grains yield. The predicted control treatment was slightly overestimated by 103.5% of the observed one.

The predicted grain yield was overestimated at 60, 100, 140, 175, 215, 250 and 290 kg N ha^{-1} treatments by 130.3%, 126.1%, 123.9%, 122%, 115.5% and 124.4% of the observed N treatments. The rate of 250 kg ha^{-1} was slightly underestimated, where the predicted treatment was 90.5% of the observed one. The average of the simulated maize grains yield for all treatments was 117% of the measured yield. The observed nitric acid application significantly increased yield of grains compared to control treatment. Where application of 250 kg N/ha produced the highest vegetative growth and grains yield (Hasanein, 2001). The predicted results of the treatments were in consistency with the predicted treatments. By contrast, under prediction treatment of 250 kg N ha^{-1} might signal that there is a problem with the model because field conditions always worse than the ideal pest and disease free conditions under which simulation runs are carried out on the computer. The lower mazie grains yield was observed even at high rates of N application. This may be due to deficiencies of nutrients other than N or over dosage of the treatment added. In general, by using CERES-

Maize simulation model, similar studies have shown good prediction of grains yield with all N treatments (Asadi and Clemente, 2001). The overestimated and underestimated grains yield could be justified by uncontrolled factors in the experimental field where the model is not sensitive to these factors or undetectable (Kowacs *et al.,* 1995 and Thornton *et al.,* 1995). Generally, the model predicted the grains yield in acceptable manner for all N treatments including control treatments.

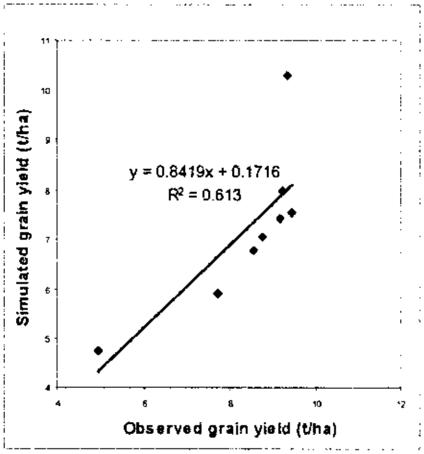

Fig. 1 a. Observed vs. simulated maize grain yield.

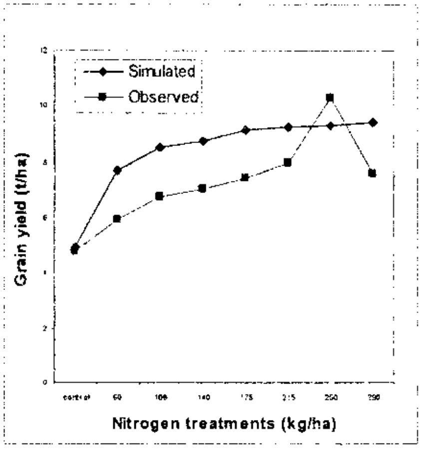

Fig.1 b. Observed and simulated grain yield as affected by N treat.

Predicted and observed straw yield

The predicted and observed values of maize straw yield for eight application rates of N (control, 60, 100, 140, 175, 215, 250 and 290 kg N ha^{-1}) are shown in Fig. 2 a and b. The slope of regression line was 1.5467 and R^2 was 0.77 for maize straw yield. The predicted control treatment was slightly underestimated by 90.6% of the observed one.

The simulated straw yields were underestimated at 60, 100, 140, 175, 215, 250 and 290 kg N ha^{-1} treatments by 94.7%, 96.4%, 92.5%, 92.7%, 83.5%, 70.8 and 91.7% of the observed N treatments. The average of the simulated maize straw yields for all treatments was 89.1% of the measured yield. The observed nitric acid application significantly increased yield of straw compared to control treatment, where the highest vegetative growth and straw yields application were 250 kg N / ha (Hasanein, 2001). The predicted results of the treatments followed the same trend as the observed ones. The under-prediction treatments might signal that there is a problem with the model because field conditions will always be somewhat worse than the ideal pest and disease free conditions under which simulation runs are carried out on the computer. The lower maize straw yields were observed even at high rates of N application. This may be due to deficiencies of nutrients other than N or higher dosage of the treatment. In general, by using CERES-Maize simulation model, this study has shown good prediction of straw yield with all N treatments. The under-estimated straw yield could be justified by uncontrolled factors in the experimental field where the model is not sensitive to these factors or undetectable (Kowacs *et al.*, 1995 and Thornton *et al.*, 1995). Generally, the model predicted the straw yield is in acceptable manner for all the studied N treatments.

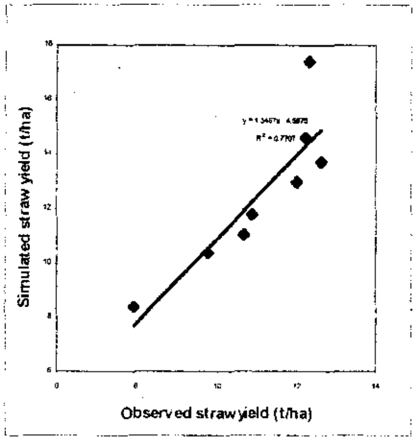

Fig.2 a. Observed vs. simulated maize straw yield.

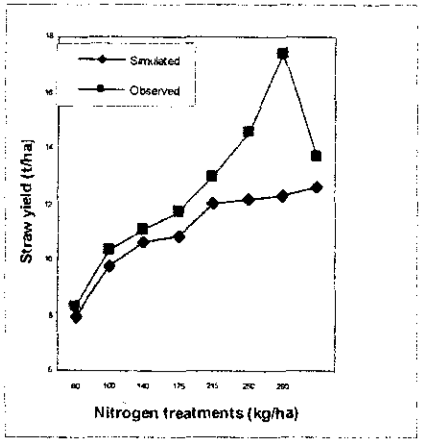

Fig. 2 b. Observed and simulated straw yield of maize as affected by N treat.

Conclusions

The average of the simulated maize grains yield for all treatments was 117% of the measured yield. The slop of regression line was 0.8419 and R^2 was 0.61 for maize grains yield. The average of the simulated maize straw yield for all treatments was 89.1% of the measured yield. The slop of regression line was 1.5467 and R^2 was 0.77 for maize straw yield. The predicted results of the treatments followed the same trend as the observed ones. The N sub model of CERES-Maize provided acceptable rage of prediction for grains and straw yield of maize under different rates of N application where the model performed adequately for the studied location. The overestimated and underestimated grain yield could be justified by uncontrolled factors in the experimental field where the model is not sensitive to these factors or undetectable. The model can be used to predict grains and straw yield of maize after calibration and evaluation of the experimental data for the field tested. Further researches are needed to evaluate the ability of the N model to predict maize grains and straw yield under different conditions of soils, cultivar and weather. Also, new research and innovative technology transfer are needed to provide farmers with alternative options for crop management practices that use resources more efficiently and increase crop productivity.

Decision support systems and crop simulation models are considered as new information tools for technology transfer as well as for research. The models can be used as a tool to provide a quantitative prediction of growth and yield of crops for a wide range of weather conditions, different types of soil, crops varieties, and management practices. They can also be used to provide information for future agricultural planning in Egypt.

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تقييم برنامج محاكاه لانتاجيه محصول الذره تحت ظروف الاراضى الصحراويه المصرية - شمال سيناء

بدران مرسى حسنين ، فتحى عبد الفتاح العزيزى و حسين هاشم حاتم
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يعتبر محصول الذره احد اهم محاصيل الحبوب المنزرعه فى مصر ونظرا للزياده السكانيه المضطرده فهناك حاجه ماسه لزيادة الانتاجيه باستخدام امثل للموارد المتاحه و ايجاد بدائل للانظمه الزراعيه التقليديه. ان برنامج دعم اتخاذ القرار لنقل التكنولوجيا الزراعيه (موديل النيتروجين للحبوب) قد تم استخدامه لتقييم انتاجيه حبوب وقش الذره ومحاكاتها بالقياسات الحقليه تحت ظروف الاراضى الصحراويه فى شمال سيناء. حيث تم استخدام بيانات تجربه بحثيه لمحصول الذره فى محطه بحوث المغاره التابعه لمركز بحوث الصحراء باستخدام سماد النيتروجين فى صوره حمض نيتريك خلال نظام الرى بالتنقيط بمعاملات صفر ، ٦٠ ، ١٠٠ ، ١٤٠ ، ١٧٥ ، ٢١٥ ، ٢٥٠ ، ٢٩٠ كجم/هكتار.

وتشمل مدخلات الموديل بيانات الارصاد الجويه وموقع الدراسه وخواص التربه الطبيعيه والكميائيه والمعاملات السماديه والرى. وتشير النتائج الى ان معامل الانحدار للحبوب ٦١,٠ ،ولقش الذرة ٧٧,٠ بين المعاملات الحقليه والمحاكاه . كذلك متوسط انتاجيه الحبوب المتنبىء به ١١٧ ٪ ، ٨٩,١ ٪ للقش من القيم الحقليه .ان هذا الموديل قد اعطى مدى مقبول للتنبوء بانتاجيه الحبوب والقش تحت معاملات النيتروجين المختلفه، كما ان نتائج المعاملات المضافه تتبع نفس اتجاه النتائج الحقلية . ولهذا يمكن القول بأن البرنامج يمكن استخدامه للتنبوء بانتاجيه محصول الذره وذلك بعد عمليه المعايره والتقييم لبيانات التجربه والتى تجرى من خلال تطبيق الموديل فى الحقل تحت الدراسه. ويقترح اجراء مزيد من البحوث والدراسات لتقيم هذا الموديل لمحاكاه انتاجيه محصول الذره تحت ظروف مختلفه من الاراضى والارصاد الجويه. هذا القرار يمكن ان يمد صانعى القرار ببدائل اضافيه تؤدى الى تعظيم الانتاجيه والامداد بمعلومات من شانها ان تساعد فى التخطيط الزراعى المستقبلى الذى يؤدى بدوره الي تحسين الامن الغذائى فى مصر.