PREDICTION OF YIELD IN IRRIGATED PEARL MILLET USING DSSAT SIMULATION MODEL

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ABSTRACT

A Decision Support System for Agro-Technology (DSSAT) model was used to simulate the grain yield of pearl millets, which was subjected to three levels of irrigation (3, 5, 7 days) during the 2006 cropping season in Minna, Nigeria. The field grain yield for Sossat and local varieties at 5 days irrigation interval with application depth 5.6 mm gave the highest value of 2.65 t/ha and 2.88 t/ha respectively, this was followed by 3 days irrigation interval (2.53 t/ha) and 7 days interval (2.25 t/ha) for Sossat variety. The simulated grain yield followed same trend (5 days>3 days>7 days) when compared with the field data. The DSSAT Model over predicted the yield values for both varieties. The Sossat variety was over predicted by 29%, 53% and 51% at irrigation frequency of 3, 5, and 7 days. Similarly, the DSSAT over-predicted local variety by 35%, 32%, and 21% at 3, 5, and 7 days irrigation intervals respectively. The economic analysis indicated that the benefit-cost ratio of the LV was higher than the SV. The LV had a benefit cost ratio of 5.2. This showed that LV has better financial returns when compared to SV.

SIGNIFICANCE: Application DSSAT model therefore has the potential for providing useful qualitative information for decision making and elimination of the repetitive trial and errors involved in pearl millet production.

KEY WORDS: DSSAT Model, Pearl Millet, Irrigation, Crop yield, B/C ratio

1. INTRODUCTION

Today more than ever, increased food productions and food security depend on judicious use of the scarce resources to produce them. In addition to issues such as climate change, climate variability, soil carbon sequestration, food security and environmental sustainability, have become important. Management factors affect the way crops respond to irrigation, fertilizer and other management practices. Determining appropriate crop management strategies under these uncertainties has major economic and environmental implications. This study has become of interest, because there is a need to match food production with the increase in population, and for the fact that sustainability and development would have no platform without enough food. Major constraints to effective millet production are poor soil fertility; drought and biotic stress such as Striga and Downy mildew (Singh and Thakare, 1986). At least 161 species of insects have been associated with millet in Nigeria (Ajayi, 1985) but few including stem borer and head miner are of economic importance. Infestation and damage are strongly influenced by date of sowing (Ajayi and Labe, 1990) and rate and time of nutrient application (Elemo and Ajayi, 1989). The problem of crop establishment resulting from dry spells early in the rainy season is also so serious that it was rated number one constraint to millet productivity in West Africa (Byth, 1993).

Computer simulation models of the soil/plant atmosphere can make a valuable contribution by both furthering our understanding of the process that determine crop responses and predicting crop performance, resource use and environmental impacts for different environment and management scenarios. User oriented simulation models greatly facilitate the task of optimizing crop growth and deriving recommendations.
concerning crop management (Boote, 2004). Models can also be used to determine the potential impact of climate change on crop production and long-term soil-carbon sequestration, carbon stock of a landscape, or provide management scenarios for adapting to climate variability. The DSSAT Computer program software was developed by a team of researchers from the Universities of Georgia, Florida, Hawaii, Iowa state University and International Centre for Soil fertility and Agriculture Development which help in crop requirements to land characteristics using crop simulation models, database and strategy evaluation programs. DSSAT provides easy access to databases and crop models so that the user may test onscreen the performance of new cultivars, sites, or management strategies on the computer screen. Sustainable agriculture requires tools that enables decision maker to explore the future. A decision support system help users to make choices today that result in desired outcomes, not only next year, but also for 10, 25, 50 or more years. Thus, the specific objectives of these investigations are: 1. To compare the yield predicted by DSSAT Model and the measured field values of two millet varieties and 2. To determine the benefit - cost ratio of the irrigated millet

2. MATERIALS AND METHOD

2.1 Description of DSSAT Model V.4

DSSAT is a microcomputer software program combining crops and weather databases programs to simulate multi-year outcomes of crop management strategies. It is a software package integrating the effects of soil, crop phenotype, weather and management strategies to predict yield. The DSSAT- model is designed to simulate plant phenological processes (nutrient and water uptake, transpiration, photosynthesis, organogenesis and biomass partitioning) and predict growth similar to the process as they are thought to occur in real plant (Japtap et al, 1992).

The working principle of crop models varies, from understanding mechanisms of plant growth process to assisting in management and decision making. Although there are considerable differences in the mathematical structures, the model was created by a team of researchers from the Universities of Georgia, Florida, Hawaii, and Iowa State University and the International Centre for Soil Fertility and Agricultural Development. DSSAT simulates crop growth, yield, water and nutrient uptake and environmental impact on agricultural production (Sharon, 2004).

DSSAT is comprised of the following components:

1. A database management system (DBMS) to enter, store and retrieve the ‘Minimum data set’ (MDS) needed to validate, list and use crop models to provide outcomes to alternative management input.

2. A set of validated crop models.

3. An application program for analyzing and displaying outcomes of long term simulated agronomic experiments.

In DSSAT, all crops share common input/output format, and are similar in level of detail. They operate on a daily time step and are based on an understanding of biophysical processes. The database Management System (DBMS) in DSSAT is used to organise and store the Minimum data set (MDS) for calibration and validation.

Specific inputs to the models are daily weather data and physical, chemical and morphological soil properties. Additional inputs such as planting date, row, planting specific amount and time of fertilizer, irrigation applications and genetic constant relating development and growth are required. DSSAT model has been used in Arkansas to help with early season Soya – bean planting dates, in Georgia for predicting agricultural water usage and in Africa to diagnose yield loss of Peanut crops from disease (Boote, 2004). DSSAT was designed primarily for user groups in agriculture, but owing to its break with traditional ways of diagnosis and prescribing solutions, other types of users have adopted it. The emergence of issues that require assessment of conditions, not in the past or present, but in the future, calls for the application of systems approach to solving encompass by DSSAT, which includes:

- Global Climate Studies.
- Use with Geographic Information Systems (GIS).
- Whole Farm Systems models.
2.2 Experimental site and location
The study location was at Chanchaga farms in Minna, Niger state, within the Southern Guinea Savanna region of Nigeria, (Latitude 09°39’N and Longitude 06°28’E and 430m above sea level). The climate is characterized by well-defined wet season that is unimodal, with a mean annual rainfall of about 1100mm, which normally begins in April/May and ends in October. The mean growing period temperature is 37°C and the mean temperature of the coolest month is 23.9°C, the average sunshine hours are 8hrs.

Soil samples were collected from different parts of experimental farm and at different soil depths using 50mm diameter sampling auger with 1.5m long extension rod, the samples were taken at 20cm intervals from 0-120cm, on each plot soil samples were collected at three points following the procedures described by Singh (1989). The soil texture in the area is sandy loam and well drained. The climatic data requirement was obtained from the weather station from Minna Airport about 4km from the research site.

2.3 Experimental layout
Irrigation water was transported manually from a flowing stream which was about 75m away. Surface irrigation was carried out at intervals of 3, 5, and 7 days. The total water applied under each irrigation interval was 600m³, 900m³, and 1500m³. Planting was done at 75 x 50cm (inter and intra row) spacing in a plot size of 27m² (6 rows x 6m), and a total number of 18 plots were used in line with the experimental design that was adopted, i.e. split plot design. Seeds were sown at 20mm deep hole and thinned to two plants per stand after emergence. Records of data began with recording of date of planting, date of emergence (>50%), date of thinning and plant population after thinning. Other records includes: date of successive leaf tip appearances and their positions, number of leaves on main stem (recorded at regular intervals until harvest). Other data include: dates of reproductive stages, grain filling, maturity and harvest. In addition, the total number of leaves on main stem and tiller at maturity, leaf senescence and tiller death as well as the 100 dry grain weight were also recorded.

Planting was carried out on the 11th of January, 2006 manually using the traditional method. Two varieties of millets were used: local variety (LV) and Sossat variety (SV). Few days after emergence, the seedlings were thinned to two plants per stand and manual weeding begun by hoeing immediately.

Compound fertilizer (NPK 15:15:15) was manually applied at a rate of 160kg/ha and was applied twice, at 10 DAP (days after planting) applications and 35 DAP. The fertilizer placement was at 5cm depth and 10cm from the base of the plant stand.

Furthermore records of data continues by counting Plant stand per plot, and it was harvested at 99-102 DAP. The weight of grain at harvest was measured at harvest. After drying, the dry weight was measured and weighed separately such as grain weight per plot at harvest, weight of 100 grain, at the different irrigation frequencies and different varieties under consideration were obtained.

The experimental design used was Split-plot design; the experiment constitutes of two factors i.e. two varieties of millets; Sossat variety (SV) and Local variety (LV) and different levels of irrigation. The two varieties were treated with three different irrigation intervals (3, 5, and 7 days).

3. RESULTS AND DISCUSSION

The result of the experiment is as presented in the figures below express perfect relation using polynomial relationship.

From figures 3 & 4 the results showed that 5 days irrigation interval had performed better than the 3 and 7 days interval on the field. By comparing the simulated values with the measured grain yield values, there is consistent over prediction of the yield by the model in both varieties.

The least grain yield occurred at 7 days irrigation interval, however, the low performance may be attributed to water stress resulting from one week interval. Thus, it’s clear that such irrigation frequency does not support irrigated millet farming in this area. The measured yield was higher in local variety (LV) than in Sossat variety.
(SV) at all irrigation intervals under consideration (Figures 3 and 4). This was not far from the fact that LV had good adaptability advantage of the environment over SV. The difference between the simulated and the field measured grain yield can be corrected using the model equation obtained in Figures 1 and 2. Therefore, based on the findings of this work, DSSAT model is recommended for use in this area of studies for predicting yield in pearl millet crop. It is also recommended that similar confirmation need to be done to validate the model for other crops such as cowpea, groundnuts, sorghum etc.

**Figure 1:** Relationship between Simulated and measured grain yield of Local variety

**Fig. 2** Relationship between Simulated and measured grain yield of Sossat variety
The relative percentage cost of production for the irrigated millet was determined and the result shows that the weeding services had the highest cost of 23.4%, and for both varieties the minimum was that transportation (less than 3%). This was followed by land clearing of 19.2% and that of irrigation 21.4% for the local variety as well as Sossat variety. The economic analysis indicated that the benefit-cost ratio of the LV was higher than the SV. The LV had a benefit cost ratio of 5.2. This showed that LV has better financial returns when compared to SV.
4. CONCLUSIONS

From the study, the following conclusions can be drawn:

i. Two varieties were used in this study (Sossat and Local). Three Irrigation levels (3, 5, and 7 days) gave yield of 2753kg/ha, 2876.3kg/ha and 2567.8kg/ha for Local variety and 2530.7kg/ha, 2654.1kg/ha, and 2246.6kg/ha for Sossat variety respectively.

ii. The simulated value over predicted the measured values by over 30%.

iii. The economic performance of the irrigated millet was determined for both varieties and the benefit-cost ratio approximates to 5.0 for both varieties as shown in the table.

iv. The model can be recommended for use on pearl millet in this area; however, 30% overprediction can be eliminated by calibration.

REFERENCES


