INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

WORLD METEOROLOGICAL ORGANIZATION

PRELIMINARY REPORT OF THE ICRISAT/WMO SYMPOSIUM/PLANNING MEETING ON THE AGROMETEOROLOGY OF SORGHUM AND MILLET IN THE SEMI-ARID TROPICS

15-19 November 1982

Co-sponsored by

FAO FIAT PANIS

INTSORMIL

International Crops Research Institute for the Semi-Arid Tropics
ICRISAT Patancheru P.O.
Andhra Pradesh 502 324, India

Preliminary report of the preparatory planning meeting and the ICRISAT/WMO Symposium on the Agrometeorology of Sorghum and Millet in the Semi-Arid Tropics at ICRISAT 15 thru 19 November 1982. The full proceedings will be published in late 1983.

C O N T E N T S

JOINT ICRISAT/WMO SYMPOSIUM/PLANNING MEETING ON THE AGRO-METEOROLOGY OF SORGHUM AND MILLET IN THE SEMI-ARID TROPICS

SUMMARY

Agriculturists and climatologists from 18 countries joined ICRISAT scientists for wide-ranging discussions the past two weeks on how agro-climatology can be put to better use in improving the production of sorghum and millet.

The planning meetings and international symposium on "The Agro-meteorology of Sorghum and Millet in the Semi-Arid Tropics" were sponsored by ICRISAT and the World Meteorological Organization (WMO), an agency of the United Nations. Co-sponsors were the Food and Agricultural Organization of the UN (FAO), INTSORMIL, a program of international research on sorghum and millet sponsored by the U.S. Government, and Texas A&M University, USA.

A total of 112 scientists participated in the sessions that began with a series of planning meetings 8 November and ended with a 5-day symposium 15-19 November. The meetings were held at ICRISAT Center, the headquarters and main research farm of the International Crops Research Institute for the Semi-Arid Tropics at Patancheru, near Hyderabad.

Participants reviewed the present state of knowledge regarding the agroclimatological factors that primarily influence the growth and development of sorghum and millet and identified the gaps, current needs, and future perspectives in research on how weather affects these crops.

They recommended among other things:

- Establishment of an interagency data bank on agroclimatological information and a global system for disseminating knowledge on agroclimatology in relation to agricultural and other research areas.

- Increased emphasis on training in the collection and use of agroclimatological data in the semi-arid tropics.

- Research in laboratory and field to assess the thresholds of damaging temperatures for sorghum and millet. This concerns high temperatures in relation to plant emergence and crop establishment as well as low temperatures with regard to possibly extending the crop in high altitude regions.

- Increased attention to root penetration characteristics in evaluating germplasm and selecting crops that will be more resistant to drought.

- Improvement and continued use of crop-weather models in making agroclimatic assessments for particular regions. Such models as already developed should be critically examined and validated in the region of application for which they are intended.

ICRISAT's Director of Research, R.W. Gibbons, noted in opening the final session that yields of sorghum and millet have remained low and unstable in the semi-arid tropics mainly because of the undependable rainfall and harsh environments in which these crops are grown. The recommendations of the symposium, he said, will undoubtedly be of great significance in identifying priority items of research in agroclimatology as it relates to sorghum and millet.

S.M. Virmani, principal agroclimatologist and leader of the ICRISAT Farming Systems Research Program, was Coordinator of the symposium/planning meetings.

JOINT ICRISAT/WMO SYMPOSIUM/PLANNING MEETING ON THE AGRO-METEOROLOGY OF SORGHUM AND MILLET IN THE SEMI-ARID TROPICS

The planning meetings and international symposium on "The Agrometeorology of Sorghum and Millet in the Semi-Arid Tropics" were sponsored by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the World Meteorological Organization (WMO), and co-sponsored by the Food & Agricultural Organization of the United Nations, INTSORMIL--a program of International Research on Sorghum and Millet sponsored by the US Government, and Texas A&M University, USA. The symposium was hosted by ICRISAT at its headquarters, Andhra Pradesh, India.

The sessions began with a series of preparatory planning meetings 8 November and ended with a 5-day symposium 15-19 November 1982.

Objective

The meeting's objective was to promote the use of climatic data information and knowledge to increase the production of sorghum and millet crops and to reduce their vulnerability to climatic hazards. The objectives included: (a) reviewing the state of agroclimatological knowledge that primarily influences the growth and development of sorghum and millet and identify gaps, current needs, and research needed; (b) reviewing, evaluating, and promulgating techniques and methods to describe and better understand the extent and intensity of climatic or weather risks, particularly drought to sorghum and millet, and to quantify the response of those crops to their growing environments; (c) formulating a plan to identify priority items of research in various areas with emphasis on interdisciplinary approaches for arriving at answers quickly; collecting evidence from the field to improve and apply knowledge on crop/climate relationships; increasing climatic awareness among meteorologists; (d) involving national and international operational and research institutions in exchanging ideas, collaborative work, and disseminating existing techniques and methods and research results at all levels, including farmers.

I. Preparatory Meeting 8-14 November

Participants at the Preparatory Planning Meeting were individual experts engaged in applied research and in operational work, convened by ICRISAT who had prepared papers for the Planning Meeting using different analysis techniques of climatic data from their countries. Their techniques were tested and made operational on ICRISAT's computers. The experts highlighted research needs and potentials

from applying research results in their areas. Detailed report of the pre-planning meeting is given on pages 17-21 (Annexure I).

II. Symposium/Planning Meeting 15-19 November

Participants reviewed the state of knowledge regarding agroclimatological factors that primarily influence the growth and development of sorghum and millet and identified the gaps, current needs, and future perspectives in research on how weather effects sorghum and millet.

In the planning meeting three main groups (Asia and Australia, Africa, and Americas) discussed the framework of future data needs, experiments needed to acquire basic crop and environmental data, applying climate/crop results, and disseminating information to the users.

Organization and attendance

The symposium/planning meetings were coordinated by Dr. S.M. Virmani, principal agroclimatologist and leader of the ICRISAT Farming Systems Research Program. The three types of participants were:

a. Individually invited lecturers engaged in research in academic institutions with knowledge about the response of sorghum/millet crops to their climatic environment.

b. Individually invited participants involved in applying climatic knowledge to increase production in the sorghum/millet based cropping systems in the SAT areas of the developing world.

c. Nonlecturing participants designated by states, engaged or likely to be engaged in projects involving extensive use of climatic data/information/knowledge, in planning agricultural research or development projects in sorghum- and millet-growing areas.

The preparatory planning/symposia/planning meetings involved 82 scientists from throughout the world. Additionally about 30 ICRISAT staff from administration, farming systems, economics, crop physiology, computer services, and information services participated.

Opening Ceremony

Dr. A. Bozzini, chief, crops and grassland production service, FAO, in welcoming remarks, said that sorghum and millets as cereals are very important for mankind in arid and semi-arid tropics and subtropics where most of the developing countries are located. We must increasingly use our knowledge of climatic influences on sorghum and millets to increase agricultural production in tropics, which are

inhabitated by millions of people. He said that getting two groups, agronomists and climatologists, together with a definite purpose is a special happening; we must put the results to maximum use to increase food production. Meteorologists, agronomists, and plant breeders, he said, have distinct but complementary, synergistic, and interdependent functions, so any modification or action proposed by any of them must be discussed from different angles to see possible outcomes or results. The exercise needs to be continuous, interdisciplinary, and dynamic to increase food production.

Dr. L.D. Swindale, director-general of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), also welcomed the participants to the symposium, and explained ICRISAT's mandate and its responsibility for agricultural development in the semi-arid tropics. He said that as ICRISAT is an international institute, the principles of everything we do, including management and data collection, are very important for extending the benefits of research to all SAT areas.

Because we need to understand more about climate and its effects, he said, the conference is very appropriate. And it is necessary for us to try to improve forecasting of climate and weather.

Increased food production, he said, is more important than merely gathering and analysing data. The data must be synthesized and applied to food production. Because sorghum and millet are crops of small farmers in the semi-arid tropics (the food crops of the developing world) what you do is important because it helps the large number of people who need the benefits of science and technology. He asked the participants to come up with valuable and practical recommendations.

Mr. H.M. Choudhury, additional director general of meteorology, meteorological office, Pune, India, welcomed the participants on behalf of India. He reminded them that production of sorghum and millets is attended with severe natural constraints, and he reviewed the history of dryland agriculture in India and efforts of the Indian Council of Agricultural Research (ICAR) in promoting research in dry farming. He discussed recent progress by the India Meteorological Department (IMD) in weather forecasting and farm advisory work.

Dr. V. Krishnamurthy from the World Climate Program Office of the World Meteorological Organization (WMO) welcomed the participants on behalf of the Secretary-General of WMO. He outlined WMO activities in agrometeorology and in co-sponsoring the symposium. He said that WMO has been involved with UNESCO in agrometeorological surveys of various regions and these activities have been intensified to understand the effect of weather or climate on food production.

Dr. S.M. Virmani, principal agroclimatologist and leader of the Farming Systems Research Program at ICRISAT, discussed the need, relevance, and objectives of the symposium. He said that our task is to review and discuss the technological advances made in environmental studies, particularly climate applications that help increase and stabilize agricultural production in the semi-arid tropics (SAT). He said SAT is a large ecological zone where famine and drought have recurred in cycles. The widening gap between production and demand, he said, stems partly from lack of suitable technologies. The purpose of this meeting is to review the status of agricultural research on sorghum and millets with particular reference to research planning and development in the next decade. It is to promote the use of climatic data information, and knowledge to increased production of sorghum and millets and to reduce their vulnerability to natural calamities.

Dr. N.J. Rosenberg, director, Center for Agricultural Meteorology and Climatology, University of Nebraska, USA, in his keynote address, discussed the role of meteorologist and climatologist in improving food production capabilities of the semi-arid tropics. He speculated the future of the arid and semi-arid regions in meeting the future world food needs. He repeated that water is the key to increased food production and emphasized the importance of increasing water use efficiency and described a few ways to manipulate the environment to use water efficiently and increase crop production. Crop modeling, he said, is a good exercise that should not be overdone.

SYMPOSIA SESSIONS

Session I

Session I was chaired by Dr. A. Bozzini, chief, Crops and Grassland Production Service, Food and Agricultural Organization (FAO). The first session was devoted to global production of sorghum and millets. Physical environment and ecological zoning of sorghum and millets in the world were discussed. Physical environment of millet and sorghum growing areas in south Asia, West Africa, and Americas were discussed separately. Predictions were also made on the future global production and demand for sorghum and millets.

Session II

Dr. V. Krishnamurthy, World Climate Program Office, World Meteorological Organization (WMO), chaired the second session, which was devoted to the climatic requirements of sorghum and millet crops. Responses of millet and sorghum to light, temperature, and drought stress were highlighted. Water requirement and water-use efficiencies of sorghum and millet also were discussed.

Session III

The third session was chaired by Dr. H.M. Choudhury, additional director general of meteorology, India Meteorological Department (IMD). Its four presentations were devoted to agroclimatological studies in sorghum- and millet-growing regions. Speakers presented several agroclimatic models and analyses of climatic data, which they have either used or suggest as being suited to delineating potential sorghum- and millet-production regions. In general the models required minimal information for execution, attributes which lend themselves to their intended application, and which make them worth considering.

Session IV

This session was chaired by Dr. J.L. Monteith, Department of Physiology and Environmental Studies, University of Nottingham, UK, and was devoted to modeling climatic responses. Minimum data set for modeling sorghum growth and development were discussed. Examples of using models to forecast crop production and to assess drought were cited. The framework of a millet model was presented and model problems were recognized. The role of agroclimatic studies in increasing and stabilizing production of sorghum- and millet-based farming systems in SAT was discussed.

Planning Meeting

The planning session with five speakers was chaired by Dr. R.L. Vanderlip, agronomist, Kansas State University, USA. Need, relevance, and objectives of the pre-planning meeting were discussed and overall achievements highlighted. Participants in the pre-planning said the pre-planning meeting was useful in that it exposed them to methodologies available at ICRISAT and other institutes of the SAT for data analysis and interpretation in agricultural planning. The participants divided into three working groups--Asia and Australia, Africa, and Americas—to discuss data needs, disseminating research information, and future training.

Plenary Session

Mr. R.W. Gibbons, director of research, ICRISAT, who chaired this session said in opening remarks that yields of sorghum and millet have remained low and unstable in the semi-arid tropics because of harsh environments and undependable rainfall. Recommendations of the symposium, he said, undoubtedly will have great significance in identifying priority items of research in agroclimatology as it relates to sorghum and millet. Then the chairmen of various sessions presented their reports followed by the report of the pre-planning meeting.

Dr. S.M. Virmani thanked all the participants for their active participation in making the symposium a success.

SUMMARY AND RECOMMENDATIONS OF THE SYMPOSIUM

Session I--Summary

The five papers presented can be subdivided into two groups. The first two provided general information on the "ecological zones of sorghum and millet production in the world" (M. Frere) and on "global production and demand for sorghum and millet to the year 2000" (J.G. Ryan and M. von Oppen). Mr. Frere, using FAO data, compared production and productivity of sorghum and millet with maize, the other important coarse-grain cereal. The three cereals' respective areas were analyzed in relation to agroecological and climatological factors. Possible trends in expanding or contracting each cereal's area and production were discussed with special reference to competition between maize and sorghum and between sorghum and millet. The second paper analyzed more specifically the seven semi-arid tropical regions of the world and the function of sorghum and millet in the nutrition of millions of people in developing countries.

Future trends were projected, based on recent past, and taking into account the possible role of recently established national and international research and development efforts. Global and regional production and demand also were projected as a function of growing respective populations. Special emphasis was given to the Indian subcontinent and Africa south of Sahara, with projections on sorghum and millet production, consumption, and prices toward 2000 A.D. Possible factors modifying the projected trends also were discussed, with particular reference to food habits and preferences, socio-political influence, basic food availability connected mainly with climatic conditions in critical areas.

The next three lectures gave more detailed information on sorghum and millet production with emphasis on the agroclimatological environments in south Asia, West Africa, and the Americas. Each paper proposed methodologies for improving or assessing sorghum and millet production. Dr. M.V.K. Sivakumar (physical environment of sorghum and millet growing areas in south Asia), in particular, considered the function of soil fertility, water retention, temperature, and precipitation extremes and variations in relation to production. He emphasized assessing the possibility of increasing production stability by breeding short-season of growing period. He used the results of three years data from a multilocation sorghum-modeling experiment to illustrate how to collect appropriate data for use in designing crop-development models.

Mr. M. Konate reported on the mechanisms of weather behaviour in West Africa related to winter (dry) and summer (wet) conditions. In the western part of the continent where rainfall is from 250 to 500 mm, millet is found; where rainfall is from 500 to 1000 mm, both millet and sorghum.

Maize generally is grown in areas where rainfall exceeds 1000 mm. Photoperiodic response affects several land races that are specifically selected and adapted to narrow ecological conditions.

Mr. R.E. Neild underlined the dramatic increases in areas where sorghum is produced in USA, Mexico, and Argentina, using hybrid vigor and genetic dwarfing that permits mechanical harvest with the same harvester used for wheat. To contribute to the improvement of lesser developed areas interested in the sorghum and millet cultivation, Mr. Neild proposed a model that considers climatic data and the crop's physiology and phenology and their interrelations to determine for each area the best planting time considering duration of the growing season and evaluations of different varieties or even different species (like maize) in monocropping or multiple-cropping sequences.

2. Discussion

All papers were followed by lively discussions. Important items questioned were:

a. The criterion for classification and the extent of areas that could be considered belonging to the SAT.

b. The importance of the stability of yield in SAT areas and how agrometeorology can contribute to stability.

c. The value of simulation models, their limitations and advantages to provide information for agronomists, plant breeders, and even farmers to improve production levels and stability.

d. The advantages and need of interdisciplinary research to achieve the basic goals mentioned in b and c.

e. The need of more information on the basic value and the possibility of improving simulation models considering other important factors including variability among locations, varieties, and management systems.

3. Recommendations

Recommendations from Session 1 can be summarized as follows:

1. Set up an interagency data bank on agroclimatological information.
2. Assure that data relevant to agroeconomic conditions are being properly collected.

3. Make data available for application in various fields such as forecasting, planning, and monitoring. Models that simulate water balance, phenology, crop production, and other plant characteristics will be required to understand the complexity of the relationships measured and to help identify gaps in existing knowledge.

4. Establish a system to disseminate knowledge on agroclimatology in relation to agricultural and other research areas. In the interest of general agricultural development, do not restrict it to only sorghum and millet or the SAT but for global use on all crops.

5. Establish training of persons to collect and use agroclimatological data.

Session II--Summary

The first paper, "response of pearl millet to light and temperatures" by C.K. Ong and J.L. Monteith was presented by Ong, who stressed the importance of temperature on the rate pearl millet develops and grows. He suggested further work on response of plants to damaging temperatures. His presentation gave information useful for modeling temperature and light effects on pearl millet. However, all their work has been carried out in growth chambers and/or green houses, so their results need to be verified in field experiments.

Dr. J.M. Peacock and Dr. G.M. Heinrich's paper on "light and temperature responses in sorghum" demonstrated that some germplasm sources can withstand extremely high temperatures, a germplasm characteristic that should permit better establishment and development of sorghum and stabilized yields.

They suggested that agrometeorologists, among others, develop a clearer picture of temperature conditions, particularly the timing and range of extremes throughout the sorghum-growing areas.

The third paper by N. Seetharama et al. on "response of sorghum and millet crops to drought stress in semi-arid India" concluded that breeding and management strategies to obtain consistently high yields should take into account the rapid establishment of the crop canopy to maximize transpirational water use (during rainy season) and ability to withstand sporadic droughts. They also stressed conservation of water during vegetative growth in the postrainy season and considering both transpiration during grain filling and sorghum's ability to use soil moisture from deeper soil layers. In discussing "water use and water-use efficiency of pearl millet" by Dr. E.T. Kanemasu et al., Dr. Kanemasu stressed the importance of water use and water-use efficiency of the millet crop in managing production strategies. His fundamental work gave useful information for modeling this important crop.

The last paper on the influence of rainfall patterns on fluctuations in sorghum yields by Mr. F. Forest, IRAT, was given by Mr. Franquin of ORSTOM, who presented a water balance model and demonstrated that yield fluctuations can be explained by patterns of moisture supplied to the crop during its life cycle. The work is an interesting approach to characterize the growing season in terms of crop responses based on water availability.

Recommendations

1. A multidisciplinary team should assess in laboratories and fields the thresholds of damaging temperatures for sorghum and millet. This concerns high temperatures combined with soil moisture in relation to crop emergence and establishment as well as low temperatures and possibilities for extending these crops into high-altitude regions.

2. First experiences in crop physiology have demonstrated germplasm sources with high-temperature resistance--a systematic screening of sorghum germplasm for evidence and appropriate use of the characteristic is essential to increase and stabilize crop yields. ICRISAT, cooperating with other interested organizations, should initiate such a study.

3. The adequate use of soil water has demonstrated critical factors in the drought resistances of millet and sorghum crops. Root penetration, if facilitated by adequate cultural practices, is a germplasm characteristic that should receive increased attention in germplasm evaluations and crop-selection work.

4. Adaptation of crop-life cycles to available length of growing seasons remains a key to improving the agriculture of the semi-arid tropics. Evaluation of these characteristics through sound methods based on energy and water balances must be systematically done by all research institutes and development projects. WMO and FAO should provide the leadership.

5. The presentations concerning assessing the climatic requirements of sorghum and millet crops have demonstrated many interactions among climatic elements, soil characteristics, and cultivars. The symposium recommends a multidisciplinary approach to this problems be continued by groups of agrometeorologists, agronomists, crop physiologists, soil scientists, genetic resources specialists, and other interested specialists.

6. The results of past crop experiments should be reassessed with a critical agrometeorological viewpoint for evidence of crop reactions to their environment. Complementarily,

future experimentation on millet and sorghum crops should be carefully monitored regarding soil and atmospheric environments to allow precise evaluations of the contribution of climatic factors. A series of multi-local experiments could be launched similar to those being undertaken for rice by the International Rice Research Institute in cooperation with WMO. WMO, in cooperation with ICRISAT, should initiate such action.

Session III--Summary

Dr. P. Franquin, reporting on results of his studies in Africa, spoke of the problem of establishing probability characteristics on the duration and time of the vegetation growth period. The simplest, immediate procedure is to analyze reinfall, at suitably spaced intervals, but it is more useful he said, to draw up a water balance as the results can be used in evaluating and statistically analyzing the AET/PET ratio as an index of dry matter production. That index has been used for constructing the probability model of the growth period called the vegetation-frequency period.

Dr. R.P. Sarker presented an analysis of rainfall and calculation of assured rainfall in different periods of the sorghum crop's life in India. Evapotranspiration (ET) data from three stations were examined in relation to the march of rainfall, evaporation power of air, and crop growth. The weekly distribution of the ratio of ET to evaporation indicates the critical period (peak consumption of water) by sorghum. Shifting sowing to an early period appears worth considering. He also suggested harvesting the dryland crop on the basis of physiological maturity to conserve root-zone moisture.

Dr. R.P.P. Robles showed present practices in sorghum and millet cultivation in Mexico with a set of pictures. He mentioned the different regions, different altitudes, and variations in temperature where sorghum is cultivated, emphasizing environmental effects in pest and disease incidence.

Hargreaves's paper touched several basic issues, stressing improved management for increased production, and wider application of basic relationships among climate, management, and crop yields. He identified energy, water, and fertility as three cardinal factors largely governing yields of sorghum and maize. He presented procedures for estimating the dependability of rainfall amounts and suggested developing an economical model relating yield to applied nitrogen. He also stressed that more trained professionals and technicians are needed in this field.

Recommendations

1. Proper analyses of available meteorological information, suitable for use by farming communities are a prime necessity. Such analyses either of basic or derived data need to be encouraged.
2. Close interaction of meteorologists and agriculture scientists is necessary and should be further encouraged.
3. Studies of general atmospheric conditions, which could be associated with agricultural drought conditions particularly on a medium to long-term basis, should be undertaken.
4. Models (crop-weather) are useful for making agroclimatic assessments. Models that have been developed need to be critically examined and validated for application, keeping in mind the specific uses for which the models were intended.

Session IV—Summary

In Session IV a set of papers by Arkin, Lopes, Huda, Vanderlip, et al. described various aspects of a computer simulation for sorghum (SORGF) developed in USA; and the possibility of extending the model to millet. The paper by Frere and Popov observed a mechanistic model for relating crop growth and water supply. Virmani showed how a prototype tank and watershed developed at ICRISAT was tested at other sites with various degrees of success.

Discussion of sorghum and millet models can be divided into three categories: requests for information about details; comments on deficiencies and limitations; and skepticism about the future values of modeling. Some of the skepticism was based on imperfect understanding of what modelers are trying to do. The authors spiritedly defined their work and convinced most of the audience of its current and potential value. They made no attempt to disguise weaknesses of their models.

Questions needing to be clarified concern the procedure for estimating soil evaporation and foliar transpiration, the choice of plant population, generation of variances associated with different types of management, applicability to many cultivars, and extrapolation to nearby areas. Deficiencies identified in the current model include the lack of a subroutine for tillering, inability to deal with soil nutrient status or with extremes of temperature and photoperiod, the empirical and unrealistic treatment of water stress (especially in relation to leaf expansion and root elongation), the arbitrary assumption of a constant plant population because losses during germination and establishment cannot yet be modeled, and doubt about the

appropriateness of base temperatures derived by extrapolation. Still the sorghum model probably has been tested as thoroughly as other models of crop growth, most of which share similar defects.

It appears that SORGF can be adopted for millet with little structural change but much less information is available about millet's physiological responses to weather. But some such information has appeared in the proceedings of this meeting and the rest will be sought in field and growth-chamber experiments. Questions about millet concerned tillering, leaf area in relation to temperature, partitioning dry matter, and modeling losses from pests.

Discussing his paper, Mr. M. Frere said his model could be used to forecast crop yields quantitatively and that it took account of drainage but not runoff.

The discussion of Dr. Virmani's paper returned to defining the distribution of the semi-arid tropics. He confirmed that ICRISAT has adopted Troll's method—also that the Farming Systems Program at ICRISAT has made substantial research contributions on intercropping. An IARI participant referred to improving sorghum yields by retaining ideotypes with shorter stems and larger harvest indices. And Dr. Virmani agreed with another IARI participant that the technology developed by government and international institutes could not be applied directly to SAT farms until relevant environmental factors have been defined and measured.

In a more general discussion, another participant suggested that soil fertility and socioeconomic factors should be considered for defining the SAT. Because farmers in the SAT generally owned little land (72% own less than 2 ha in India), technology, as summarized by models, should be specific to individual farmers as well as to sites. The problem of predicting yield from plant size at the time of spikelet initiation was dealt with briefly.

While some participants were unduly pessimistic about the utility of models, others were realistically expecting models to link together more than two levels of organization—the plant and the crop. No model can be expected to encompass behaviours of the individual plants, of crop stands, and of farming systems.

It was perhaps unfortunate that some of the time spent on a computer simulation of crop growth was not used on such relevant topics as the models used by microclimatologists and measurements they are trained to use. Their models provide subroutines for larger models of crops where information is extremely scanty in some areas. For example, we do not yet estimate well soil and meristem temperatures from screen temperatures.

The session ended with a general feeling that modeling is to be encouraged, providing the modeling components are based on repeatable observations. It is likely that model building in the sense of computer simulation will remain the prerogative of relatively few specific groups, and it would be dangerous to distribute such models indiscriminately to potential users who do not understand how they work. Less complex mechanistic models like the Penman formula (which would have been called a model had it been developed recently) are more appropriate for general use.

Finally, building a model that works can bring great satisfaction to the builders, but such activity should not be indulged into excess, as Norman Rosenberg reminded us in the opening session.

Planning Meeting--Summary and Recommendations

Three working groups--Asia and Australia, Africa, Americas--convened and discussed the needs for data, disseminating research information, and training. Reports from the three areas were similar with needs summarized as follows:

Environmental definition

1. Definition of the SAT.
2. Collection of a minimum macroclimatological data set using methods and instruments recommended by WMO.
3. Computerize data where feasible and insure ready availability of data in a usable form.
4. Description of special data needs, e.g., soil moisture, rainfall intensity, wind speed.
5. Develop a standard microclimatic and crop-data set for all research needs.

Research needs

1. Increased synthesis of research results.
2. Increased farm-level research.
3. Increased basic and applied research, particularly on pearl millet because as it has received much less attention than sorghum.
4. Among the wide range of research topics than discussed, no single one appeared to have priority.

Information and Training

1. Another conference on the Agroclimatology of Sorghum and Millet should be held within three years.
2. The next conference should be supplemented by regional and national conferences.
3. There should be wider circulation of data and results through printed and other media--both technical and popular information and involving the national extension services.
4. A list of resource persons knowledgeable in sorghum and millet agroclimatology should be drawn up for each country in the SAT.
5. More workshops in which the participants can work with their own data, learn measurement techniques, etc. should be held.
6. A training manual should be developed to cover meteorology and crop phenology with how to take data and what measurement units to use.

Annexure I

REPORT OF THE PRE-PLANNING MEETING OF THE JOINT ICRISAT/WMO SYMPOSIUM/ PLANNING MEETING ON SORGHUM AND MILLET IN THE SEMI-ARID TROPICS

Opening of the Pre-Planning Meeting

Dr. B.C.G. Gunasekara, acting director, International Cooperation, ICRISAT, opened the preparatory planning meeting at 10.00 8 November 1982. Dr. S.M. Virmani, on behalf of ICRISAT, welcomed the participants. He said that ICRISAT valued highly the cooperation of WMO in organizing this symposium/planning meeting. He was particularly grateful to WMO for having a representative (Dr. Krishnamurthy) here from the start of the session. He welcomed Dr. Krishnamurthy and the permanent representatives of some WMO member countries, who were present as participants. He wished the participants a fruitful meeting and a pleasant stay. The list of the participants is appended.

Dr. D.L. Oswalt presented a 15-minute video program on ICRISAT and its main functions, which followed by a presentation of slides. Participants were provided a program for the five days (appended).

Participants then were taken on a field tour where Dr. S.M. Virmani stressed the important role that agrometeorology can play in assessing the agricultural potential of a region. His presentation included the following:

I. Farming systems

ICRISAT, using agroclimatological data has convinced farmers to raise two crops during the year instead of using the traditional one-crop system.

II. Intercropping

ICRISAT has demonstrated that taking into account crop maturity period, two crops could be raised at the same time.

III. Farming operations

Agroclimatic data have helped bring about efficient use of machinery for preparing fields well before sowing time.

IV. Evapotranspiration

Hydraulic lysimeters are more useful than gravimetric ones.

V. Wind

Wind-energy equipment should be recommended only after careful scrutiny of wind data, particularly of maximum speed in gusts over 24-hour periods.

VI. Soil moisture

Neutron probe to determine soil moisture is not particularly useful in clay soils when they are cracking from moisture deficiency.

After the tour, Dr. Virmani explained the purpose of the meeting and asked Dr. Krishnamurthy to explain the WMO training program. Dr. Krishnamurthy said the WMO Commission for Agricultural Meteorology has been actively involved in organizing symposia of single crops and that symposia on wheat, maize, and rice have been held. During the symposium on rice, a planning meeting was organized to review the requirements for further research needed to understand the agroclimatology of the rice crop. As a result of the planning meeting, he said the international rice-weather experiments are being carried out in many countries with UNDP funds.

The WMO/ICRISAT organizational meeting not only agreed to planning a similar meeting but decided also to convene a pre-planning or preparatory meeting, with the main purpose of training experts working on the sorghum and millet crops in the use of operational models and methodologies developed by ICRISAT. Participants could use their countries' data on the ICRISAT computers, and use ICRISAT models for which ready programs were available. They were, however, free to use models and methodologies of their own choice in analyzing their data. He concluded by saying that the pre-planning meeting fits the objectives of the World Climate Program very well because transfer of technology is a priority of all major WMO programs.

Brief introductions to ICRISAT computers were then given by Mr. J.W. Estes and Mr. J.G. Sekaran. Programs available to participants included:

I.	CONDRP	Conditional probabilities week-wise according to Markov chain model.
II.	GAMMA	Proportional probabilities using gamma distribution.
III.	MONTHSTD	Monthly statistics of rainfall.

IV. WATBAL Soil water balance "Keig and McAlpine".

V. LAYER Modified Ritchie's soil moisture model.

VI. BAIER Baier's soil moisture model.

Dr. S.M. Virmani lectured on "climatological features of the semi-arid tropics of agronomic relevance." His lecture was followed by a workshop on probability analysis of rainfall using Markov Chain Model.

A practical exercise on rainfall probability analysis was given.

Three locations 'Hyderabad,' 'Dharwar,' and 'Gulbarga,' all having about the same annual rainfall and lying almost on the same latitudes were chosen. From the rainfall probability estimates (Research Bulletin No. 1 of ICRISAT) the trainees were asked to locate the best station for raising a dryland crop (choosing 70% probability of rainfall as adequate for growth).

A lecture and an exercise on incomplete gamma analysis of rainfall data was presented. Several participants contributed to the discussion that followed. Several other analyses for a better understanding of the problem were proposed from the floor. It was made clear to participants that the preparatory planning meeting was attempting to inform trainees about available models in operation at ICRISAT; to introduce data analysis; and to let participants work on ICRISAT computer using any model of their own available.

Dr. Piara Singh, aided by slides, gave a detailed account of water-balance studies carried out in ICRISAT. He said that water-balance models were developed mainly to estimate soil moisture for use in crop-yield models.

Dr. M.V.K. Sivakumar lectured on the water-balance models operational at ICRISAT computers. He said that for dryland crops Ritchie's water balance model, as modified in ICRISAT, gives highly comparable results. The general consensus among participants was that Baier and Robertson's varasatile soil-moisture model, because of its simplicity and applicability, is more adoptable to all conditions.

Participants then briefly presented models used in their countries and expressed thair interests in adopting one model or another to help serve the agricultural sectors of their countries. The participants and experts concluded that models should be simple and application oriented, and that more dialogue between meteorologists and agriculturists is needed in this field.

Dr. N.V. Joshi, Indian Institute of Science, Bangalore gave simulating lecture on methodology and application of cluster analysis. He gave practical examples of agroclimatic classifications of India using cluster analysis. It was concluded that cluster analysis could be used to locate new stations (meteorological) and to transfer agrotechnology from a region to a location to be determined.

Dr. J.I. Stewart gave some practical applications (from his work in California and Kenya) of climatic data for operational management. He stimulated an interesting discussion on further applications of climatic data for management practices.

Friday 12 November 1982 participants joined the meeting on Multilocation Sorghum Modeling Research Program (appended).

The purpose of the preparatory planning meeting seemed to be fully met as participants were satisfied with the training and practical exercises given on modeling techniques, their applications and usefulness. Many expressed a keen desire to use models in their respective countries with modifications if needed.

The pre-planning meeting: a participant's viewpoint

Mama Konate

It was quite judicious on the part of the organizers to hold a pre-planning meeting before the symposium. It enabled the participants to get to know certain methodologies used at ICRISAT and other institutes of the semi-arid tropics for data analysis and interpretation and their use in agricultural planning. Besides, it also provided for fruitful exchanges of experience during plenary sessions as well as in personal discussions. Certain data-analysis and data-processing techniques already used at ICRISAT seemed very interesting because of their relevance to some of our problems (rainfall data analysis by the Markov Chain method and incomplete Gamma distribution, cluster analysis, etc.). I would like to mention here that ICRISAT is collaborating with Mali to bring out an agroclimatology report on Mali. Other Sahelian countries may follow this example. Moreover, I have learned recently of ICRISAT's contribution to improving farming techniques and the rigor with which basic data are collected.

Sahelian farmers have yet to adapt to the complete disruption of the cropping schedule by the changing rainfall pattern in this region over the last 10 years. It is the responsibility of agrometeorologists and agronomists working in multidisciplinary teams, to help them adopt a cropping calendar that allows for weather and climatic fluctuations. In Mali, we are currently involved in a pilot project whose objective is to develop a set of methodologies to enable more rational decisions on cropping operations. In this, the pre-planning meeting and the symposium were of great help to my work.

I would like to thank the organizers for the excellent arrangements and facilities provided to us. Thank you.

Annexure II

PROGRAM FOR THE PRE-PLANNING MEETING

08-13 November 1982

Monday 08 November

0830	Participants assemble/Registration	S.M. Virmani/M.V.K. Sivakumar/ S. Krishnan
0840	Welcome	
0900	Video show on ICRISAT Slide presentation	D.L. Oswalt/B. Diwakar S.K. Das Gupta/A. Laxminarayana
1030	Field tour	S.M. Virmani
1400	Purpose of the meeting and discussion on program format	S.M. Virmani/V. Krishnamurthy
1530	Familiarization with ICRISAT Computer and working on terminals	J.W. Estes/D.L. Oswalt/ J.G. Sekaran
1700	Adjournment	

Tuesday 09 November

0830	Climatological features of the semi-arid tropics of agronomic relevance	S.M. Virmani
1030	Probability analysis of rainfall: Markov Chain Model	M.V.K. Sivakumar
1400	Entry of data sets and their verification	J.G. Sekaran
1700	Adjournment	

Wednesday 10 November

0830	Incomplete Gamma analysis, results and discussion	S.M. Virmani/J.G. Sekaran
1030	Water balance studies and interpretation of water balance results	Piara Singh
1400	Computer water balance models operational at ICRISAT Center	M.V.K. Sivakumar

1600	Discussion on the relevance of water balance data for crop planning	M.V.K. Sivakumar/Piara Singh/S.M. Virmani
1700	Adjournment	

Thursday 11 November

0830	Pattern analysis: theory and practice	N.V. Joshi/J.G. Sekaran
1030	Discussion of results of pattern analysis program	
1130	Sorghum modeling	A.K.S. Huda
1330	Use of climatic data for operational management	J. Ian Stewart
1530	Discussion	
1700	Adjournment	

Friday 12 November

a.m.	Participants join sorghum modeling meeting.	
p.m.	Writing of reports	V. Krishnamurthy

Saturday 13 November

	Finalization of reports	V. Krishnamurthy

###

PROGRAM OF THE COOPERATORS' MEETING ON MULTILOCATION SORGHUM MODELING RESEARCH, 12-13 NOVEMBER 1982

Friday 12 November

Session I : Overall validation of SORGF model
Chairman : R.W. Gibbons
Rapporteur : M.V.K. Sivakumar

0830 Welcome address: R.W. Gibbons

0840 Need and relevance of crop modeling research in the context of farming systems research - S.M. Virmani

0900 Presentation of the report on collaborative multilocation sorghum modeling experiment - validation of the SORGF model in the SAT - A.K.S. Huda

1030 Discussion

Session II : Discussion on specific SORGF subroutines
Chairman : G.F. Arkin
Rapporteur : N. Seetharama

1100 Evaluation of subroutines on light interception, dry matter accumulation and soil water - M.V.K. Sivakumar

1145 Discussion

1400 Effects of moisture stress on phenology, leaf area, dry matter accumulation and partitioning - A.K.S. Huda

1430 Discussion

Session III : Improvements in SORGF - Review by cooperators, demonstration on the use of SORGF on ICRISAT computers
Chairman : S.M. Virmani
Rapporteur : Sardar Singh/J.G. Sekaran

1500 The participating cooperating scientists from Temple, Coimbatore, Delhi, Hissar, Kenya (KARI), Khon Kaen, Ludhiana, Parbhani, Patancheru (ICRISAT), Pune, Rahuri and Sholapur present the progress made in sorghum modeling research.

1700 Adjournment

Saturday 13 November

0830 Session III continued

Session IV : Planning future strategies
Chairman : J.M. Peacock
Rapporteur : G. Alagarswamy

0930 Environmental and genotypic effects on sorghum yield components - N. Seetharama

1000 Discussion

1045 Discussion on proposal of pearl millet modeling research - A.K.S. Huda

1145 Identifying gaps in knowledge and planning for future research - S.M. Virmani/M.V.K. Sivakumar

1245 Vote of thanks - A.K.S. Huda

###

PROGRAM OF THE ICRISAT-WMO SYMPOSIUM/PLANNING MEETING ON THE AGROMETEOROLOGY OF SORGHUM AND MILLET IN THE SEMI-ARID TROPICS

15-19 November 1982

Sunday 14 November 1982

1800 Registration

Monday 15 November 1982

0800 Registration continues

OPENING SESSION

0900 M.Bozzini, FAO - Opening remarks/welcome

Welcome address

0915 L.D. Swindale, ICRISAT
0925 H.M. Choudhury, IMD
0935 V. Krishnamurthy, WMO

0945 S.M. Virmani, ICRISAT - Need, relevance and objectives of the symposium

1000 N.J. Rosenberg, George Holmes, University of Nebraska - Key-note address: Role of the Meteorologist and Climatologist in improving food production capabilities in the semi-arid regions.

SESSION I - Global Sorghum and Millet Production

Chairman : A.Bozzini, FAO
Co-Chairman : M. von Oppen, ICRISAT
Rapporteur : A.K.S. Huda, ICRISAT

1100 Chairman's opening remarks

1100 M. Frere, FAO - Ecological Zones of Sorghum and Millet Production in the World.

1140 J.G. Ryan and M. von Oppen, ICRISAT - Global Production and Demand for Sorghum and Millet to the year 2000.

1210 M.V.K. Sivakumar, A.K.S. Huda, and S.M. Virmani, ICRISAT - Physical Environment of Sorghum and Millet Growing Areas in South Asia.

1240 Discussion

1430 M. Konate, Division Agrometeorologie, Meteorologie Nationale du Mali - Study of the Environment with Particular Reference to Climate, of the Sorghum and Millet Cultivation Areas in Semi-Arid Tropical Regions of West Africa.

1500 R.E. Neild, University of Nebraska - Agroclimatology of Sorghum - The Americas

1600 Summation

1645 Adjournment

Tuesday 16 November 1982

SESSION II - Climatic Requirements of Sorghum and Millet Crops

Chairman : V. Krishnamurthy, WMO
Co-Chairman : M. Frere, FAO
Rapporteur : Piara Singh, ICRISAT

0830 Chairman's opening remarks

0840 C.K. Ong and J.L. Monteith, University of Nottingham - Response of Pearl Millet to Light and Temperature.

0910 J.M. Peacock and G.M. Heinrich, ICRISAT - Light and Temperature Responses in Sorghum.

0940 N. Seetharama, V. Mahalakshmi, F.R. Bidinger, and Sardar Singh, ICRISAT - Response of Sorghum and Millet Crops to Drought Stress in Semi-Arid India

1010 Discussion

1100 E.T. Kanemasu, Kansas State University, Piara Singh, ICRISAT; and U.N. Chaudhuri, Kansas State University - Water Use and Water Use Efficiency of Pearl Millet (*Pennisetum Americanum (L.)* and Sorghum (*Sorghum bicolor (L.) Moench*).

1130 F. Forest, IRAT - Influence of the Rainfall Pattern on Fluctuations in an Intensified Sorghum Crop Yield (paper presented by P. Franquin).

1200 Summation

SESSION III - Agroclimatological Studies in Sorghum and Millet Growing Areas

Chairman : H.M. Choudhury, IMD
Co-Chairman : G.F. Arkin, Texas A&M University
Rapporteur : N. Seetharama

1400 Chairman's opening remarks

1410 P. Franquin, ORSTOM - Agroclimatological Studies in Sorghum and Millet Growing Regions in Africa - Climatic Hazards

1440 R.P. Sarker, IMD - Some Agroclimatological Aspects of Sorghum Crop in India

1510 Discussion

1600 R.P. Peregrina Robles, Instituto Nacional de Investigaciones Agricolas - Agroclimatic Research to Delimit Optimal Areas for Sorghum and Millet Cultivated for Grain

1630 G.H. Hargreaves, Utah State University - Developing Practical Agroclimatic Models for Sorghum and Millet

1700 Summation

1730 Adjournment

Wednesday 17 November 1982

SESSION IV - Modeling of Climatic Response

Chairman : J.L. Monteith, University of Nottingham, UK
Co-Chairman : P. Franquin, ORSTOM
Rapporteur : G. Alagarswamy, ICRISAT

0830 Chairman's opening remarks

0840 A.K.S. Huda, M.V.K. Sivakumar, S.M. Virmani, N. Seetharama, Sardar Singh, and J.G. Sekaran, ICRISAT - Environmental Factors and Modeling Sorghum Growth and Development

0910 G.F. Arkin and W.A. Dugas, Texas A&M University - Evaluating Grain Sorghum Production Strategies Using a Crop Model

0940 W.A. Dugas, G.F. Arkin, and Fred Ainsworth, Texas A&M University - Making Agricultural Drought Assessments with Crop Models

1010 Discussion

1100 A.K.S. Huda, M.V.K. Sivakumar, G. Alagarswamy, S.M. Virmani, ICRISAT and R.L. Vanderlip, Kansas State University - Problems and Prospects in Modeling Pearl Millet Growth and Development: A Suggested Framework for Millet Model.

1130 G.F. Popov, FAO - Crop Monitoring and Forecasting

1210 S.M. Virmani, ICRISAT - Increased and Stabilized Production of Sorghum/Millet-based Farming Systems in the Semi-Arid Tropics: Role of Agroclimatic Studies

1240 Summation

1300 Adjournment

1400 Field Tour

1600 Poster Session

Thursday 18 November 1982

PLANNING MEETING

Chairman : R.L. Vanderlip, INTSORMIL
Co-Chairman : H.E. Dandaula, Meteorological Department, Malawi
Rapporteur : V. Mahalakshmi

0830 Chairman's Opening Remarks

0840 S.M. Virmani, ICRISAT - Need, Relevance and Objectives of the Pre-Planning Meeting

0900 M. Konate, Division Agrometeorologie, Meteorologie Nationale du Mali - Pre-Planning Meeting: A Participant's View Point

0910 V. Krishnamurthy, WMO - Overall Achievements of the Pre-Planning Meeting

0925 J. Ian Stewart, USAID, Kenya - Integrating Available Information for Strategic Planning

0955 M.V.K. Sivakumar, ICRISAT - Bibliography of Agrometeorology - Initial Synthesis and Gaps in Knowledge

1010 Chairman's Remarks

1100 PLANNING MEETING SESSIONS

I)	Asia ..	Discussion Leaders	: J.M. Peacock, ICRISAT R.P. Singh, AICRPDA
II)	Africa ..	Discussion Leaders	: J. Ian Stewart, USAID, Kenya M. Konate, Division Agrometeorologie, Meteorologie Nationale du Mali.
III)	Americas ..	Discussion Leaders	: G.H. Hargreaves, Utah State University Everaldo Rocha Porto, EMBRAPA

1600 Reports of Discussion Leaders

Asia - J.M. Peacock, ICRISAT

1615 Africa - J. Ian Stewart, USAID, Kenya

1630 Americas - G.H. Hargreaves, Utah State University

1645 Summation

1700 Adjournment

Friday 19 November 1982

PLENARY SESSION

Chairman : R.W. Gibbons, ICRISAT
Co-Chairman : V. Krishnamurthy, WMO
Rapporteur : M.V.K. Sivakumar, ICRISAT

0830 Chairman's Opening Remarks

0840 Reports of Symposium Sessions

Session I - A. Bozzini, FAO
Session II - V. Krishnamurthy, WMO
Session III - H.M. Choudhury, IMD
Session IV - J.L. Monteith, University of Nottingham

1000 Discussion

1100 Report of Planning Meeting - R.L. Vanderlip, INTSORMIL

1120 Discussion

1200 Concluding remarks by the Chairman

1220 Vote of Thanks - S.M. Virmani

p.m. Visit to Hyderabad City

###

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