T1992AGR33

IMPACT OF SKILL IN CLIMATE FORECASTING ON TACTICAL MANAGEMENT OF DRYLAND SUNFLOWER - A SIMULATION STUDY

H. Meinke and R. Stone

QDPI/CSIRO Agricultural Production Systems Research Unit, PO Box 102, Toowoomba, QLD, 4350, Australia

SUMMARY

Production likelihood of dryland sunflower in eastern Australia was quantified using the dynamic crop simulation model, QSUN, in conjunction with longterm daily climate records. When sunflower yields were simulated for a hundred year period, most of the yield variation was caused by variation in rainfall. Some antecedent knowledge of future rainfall could therefore be of value in the decision making process at planting time. The Southern Oscillation Index (SOI) can provide some degree of long-term rainfall forecasting skill and, when used as a decision aid in making tactical management decisions, average simulated sunflower yields were increased.

Rainfall in many areas of eastern Australia is influenced by the ocean/atmosphere El Niño/Southern Oscillation (ENSO) phenomenon. Significant correlations, both lag and non-lag, exist between the measure of ENSO, SOI and rainfall in eastern Australia. ENSO, which normally lasts from autumn of one year to autumn of the following year, is associated with below-average rainfall. However, the termination of an ENSO is highly correlated with above-average rain.

Using this knowledge, simulated median yields for a mid-February planting were, for instance, nearly twice as high when the SOI from August to October (i.e. during the previous spring) was consistently negative compared to periods when it was consistently positive. Choice of maturity type was related to these SOI categories. Overall, the long-term average yields at two locations in North-Eastern Australia were improved by 5.5% using this technique.

INTRODUCTION

Decisions made by farm managers are a major factor determining the overall success of dryland farming. Particularly in an environment characterised by high climatic variability, such as north eastern Australia, these decisions are largely based on previous experience of the climatic variability, particularly rainfall. However, such experience might not reflect the true rainfall variability as periods of experience of up to one lifetime duration are often insufficient to sample the climatic variability adequately (Hammer et al., 1987; Muchow et al., 1991). Much of the expansion of dryland cropping in north eastern Australia has taken place in a period of favourable rainfall, when viewed in the context of the available long-term records (Russell, 1981; Hammer et al., 1987). To provide objective assistance for the decision making process, detailed quantification of production risks is required. Dynamic crop simulation models can provide such quantification and are frequently the only possibility to assess climatic risk to production.

In dryland sunflower production, yield likelihood depends largely on the amount of soil water stored in the soil profile at planting and the timeliness of rainfall during crop growth. Meinke et al. (1992) quantified these effects on yield for two locations in north eastern Australia. They employed the dynamic sunflower simulation model, QSUN (Chapman et al. 1992), and simulated sunflower yields for a 100 year period and for a wide range of starting conditions. Rainfall received during the time of initiation of reproductive organs and during the early stages of grainfilling is more valuable to yield formation than rain received during other stages of crop development. Farmers, however, are always faced with uncertainty of future rainfall when deciding on whether to plant and which maturity type to choose. Some antecedent knowledge of future rainfall events could influence such tactical management decisions and improve the long-term performance of the whole farming system.

Recently, some advance towards improved, long-term rainfall forecasting skills have been made for eastern Australia. Stone and Auliciems (1992) demonstrated that both consistency and trend in Southern Oscillation Index (SOI, a measure of atmospheric conditions over the pacific) is related to rainfall variability and rainfall forecasting in this region. To quantify the impact of current skill of long range rainfall forecast for the region, simulated yields were categorised according to their preceding spring SOI category and yield distributions for each SOI category analysed.

Our objective was to demonstrate how a combination of crop simulation analysis and climatic research can assist farmers in making decisions. In this paper, we present a case study for sunflower simulated for two locations in north eastern Australia.

MATERIAL AND METHODS

Model description and simulations

The dynamic sunflower simulation model QSUN (Chapman et al., 1992) simulates yield as a function of total biomass and harvest index. Total above-ground biomass is calculated by accumulating daily crop growth increments. Daily growth is determined from radiation intercepted and the efficiency with which this radiation is converted into biomass or from water transpired and transpiration efficiency, depending on whether light or water is limiting crop growth. Phenology routines, including parameter values for rate of development, are identical to those described by Hammer et al. (1982) for a photoperiod sensitive cultivar. At this stage the model does not account for pest and diseases or crop nutritional effects and thus assumes that these factors are non-limiting.

Meinke et al. (1992) examined effects of planting time, soil moisture at planting and cultivar maturity type on sunflower yields, using the simulation model QSUN. They simulated sunflower yields for 2 locations (Dalby, 27°S 151°E; Emerald, 23.5°S 148°E) in north eastern Australia using 101 and 96 years of long term climate data, respectively. For each location, fortnightly plantings were simulated for three maturity types, early (E), medium (M) and late (L), differing in their time to reaching physiological maturity by four to nine days. Type M was considered a "standard" maturity type and performance of type E and L were evaluated relative to this standard. Crop development

Table 1 shows the average performance of *each maturity type in each SOI category.* Choosing to plant the maturity type with the highest average yield in each SOI category (scenario 2) improved overall performance: average yields were increased by 5.5% to 142.4 g m^{-2} (Dalby) and to 120.9 g m^{-2} *(Emerald). Scenario 2 increased yields at similar probability* levels, particularly due to effects associated with years in categories Z and CP at Dalby and categories RR, Z, and CP at Emerald (data not presented). Scenarios can be compared by calculating yearly differences between simulated yields. Fig. 2 shows that yield advantages were higher and more frequent (positive differences, ca 30% of years) than yield disadvantages (negative differences, ca 20% of years).

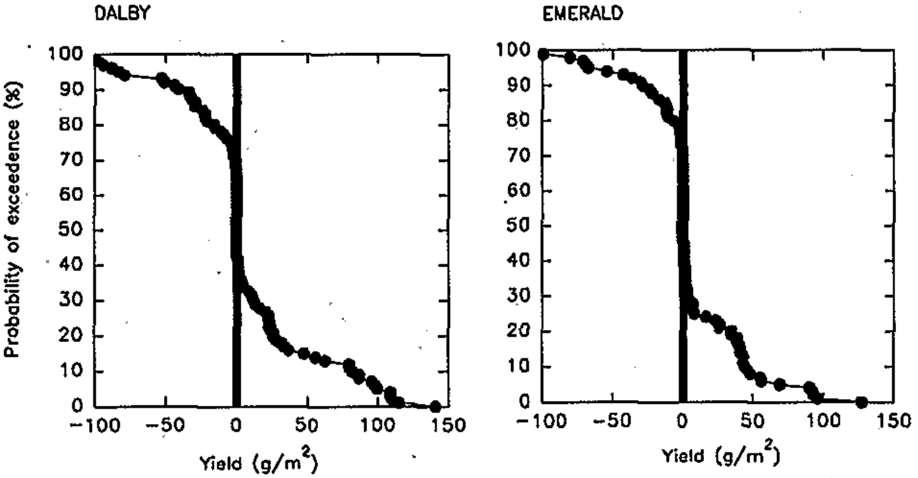

Figure 2: Cumulative distribution functions for the yearly differences of simulated yields calculated as *scenario 2 - scenario 1.* Positive differences indicate an advantage of scenario 2 and vica versa.

DISCUSSION

Yield variation in dryland sunflower production is largely due to variation in rainfall (Meinke et al. 1992). Higher yields indicate rainfall during periods when crops are most susceptible to water stress. Generally, in situations when terminal water stress occurs, earlier maturity types perform better since they convert more stored soil moisture into grain yield. Conversely, when good rainfalls prevail after anthesis and other growing conditions (such as radiation and temperature) are conducive to crop growth, later maturing types excel.

Our analysis showed how atmospheric conditions over the Pacific four to five months prior to planting can influence crop performance. The results generally conform with previous studies that suggest periods of low rainfall in eastern Australia caused by an El Niño are followed by a period of above average rainfall in the subsequent autumn, often as the El Niño terminates. Hence, it is not surprising that in our analysis periods of consistently negative SOI in the spring before planting correspond with increased yields at Dalby for a mid-February sowing date. Similarly, when periods of consistently positive SOI during the spring exist before a mid-February sowing date it is not surprising that yields are reduced. This is because many (but not all) periods of sustained positive SOI (La Niña years) are followed by a period of low SOI values (and hence low rainfall in eastern Australia) the following year as the La Niña terminates.

Regardless of maturity type and location the lowest average yields were predicted for SOI category CP (consistently positive SOI). This category is often associated with above average rainfall. However, an early maturing type yielded better at both locations during a category CP year, indicating that for the majority of years the above average rainfall period terminated at least prior to flowering, possibly even before planting. Conversely, if the SOI fell rapidly from August to October, late rainfall in autumn (i.e. after flowering) favoured later maturing types. The results demonstrate that a climatic predictor, such as the SOI, can successfully be employed as a decision aid. For cost neutral decision options (e.g. choice of maturity type) no economic analysis of benefits is required, since changes in yield are directly proportional to changes in gross margin.

At Emerald highest mean yields occurred following a spring season where the SOI fell rapidly between August and October (RF). Initial investigation of the time series of rainfall events in eastern Australia suggests a period of rapid fall in SOI the previous spring is often followed by a rapid rise in SOI and consequent higher rainfall during the following late autumn or early winter. Thus, highest mean yields at Emerald appear to follow those instances when the SOI falls during the previous spring but then rises during the following autumn or early winter.

CONCLUSION

Knowledge of atmospheric conditions in spring can be helpful in making management decisions in the following autumn. Through simulation analysis in conjunction with forecasts of long-term rainfall probabilities we were able to determine the best cultivar of three maturity types to plant in years with differeing SOI categories. By adopting the tactic of choosing maturity type based on knowledge of these categories, average simulated yields at two locations in North-Eastern Australia were improved by 5.5% when compared to planting the medium maturity type each year.

REFERENCES

Chapman, S.C., Hammer, G.L. and Meinke, H. 1992. A crop simulation model for sunflower. I. Model development. Agronomy J. (in press).

Hammer, G.L., Goyne, P.J. and Woodruff, D.R. 1982. Phenology of sunflower cultivars. III. Models for prediction in field environments. Aust. J. Agr. Res. 33:263-274.

Hammer, G.L., Woodruff, D.R. and Robinson, J.B. 1987. Effects of climatic variability and possible climatic change on reliability of wheat cropping - a modelling approach. Agricultural and Forest Meteorology 41:123-142.

Meinke, H., Hammer, G.L. and Chapman, S.C. 1992. A crop simulation model for sunflower. II. Simulation analysis of production risk in a variable sub-tropical environment. Agronomy J. (in press).

Muchow, R.C., Hammer, G.L. and Carberry P.S. 1991. Optimising crop and cultivar selection in response to climatic risk. p. 235-262. *In* R.C. Muchow and J.A. Bellamy (ed.). Climatic risk in crop production: models and management for the semiarid tropics and subtropics. C.A.B. International, Wallingford, UK.

Russell, J.S. 1981. Geographic variation in *seasonal rainfall in Australia - an analysis of the 80-year* period 1985-1974. J. Aust. Inst. Agric. Sc. 47:59-66.

Stone, R. and Auliciems, A. 1992. SOI phase relationships with rainfall in eastern Australia. Int. J. Climatology (in press).