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FORECASTING OF SUNFLOWER YIELDS - DERIVATION AND APPLICATION

By

Hammer, G.L.,[1]
Woodruff, D.R.,[2]
Goyne, P.J.[3]

Abstract

The majority of sunflowers grown in Queensland are grown under a contract system. Forward estimates of yield are required to make best use of market opportunities. A simple model of sunflower phenology and yield has been developed. It is currently under test as a tool in aiding yield forecasting via continued updating and hence narrowing of yield probability distributions throughout the growing season.

Introduction

In Queensland the majority of sunflower seed produced is grown under area contracts with a marketing organization. The earlier in the growing season that regional yields can be estimated accurately then the better is the bargaining situation of the marketing body for arranging sales contracts. In turn, this should provide for enhanced returns to the grower.

A simple model of sunflower phenology and yield has been developed. The model uses basic daily meteorological information to drive crop growth and development. This paper briefly describes the model and discusses how it could be applied to meet the yield forecasting needs of marketing bodies.

The Model

The model is based on the conceptual model of Woodruff (1973). It uses a daily time step and consists of three major interacting components viz. crop development, soil moisture budget and crop yield. At present the model relates to the cultivar Sunfola 68-2 (an open-pollinated selection from Peredovik) but the general structure is suitable for other cultivars. The model has been developed on soil moisture and crop data collected from time of planting trials on deep alluvial cracking clay soils at Biloela, Qld. (Goyne, et al, 1977). All model functions have been adjusted to achieve empirical fit to these data.

[1]G.L. Hammer, Agronomist, Queensland Department of Primary Industries, Brisbane.

[2]D. R. Woodruff, Senior Plant Physiologist, Queensland Department of Primary Industries, Qld. Wheat Research Institute, Toowoomba.

[3]P. J. Goyne, Senior Agronomist, Queensland Department of Primary Industries, Toowoomba.

In the crop development component planting date is input and the time between successive stages is predicted via the following relationships:

(i) Number of days from planting to emergence

$$= 26.08 - 1.394MAT + 0.0218MAT^2 \qquad R^2 = 0.995$$

where MAT = mean daily air temperature $(\frac{max+min}{2})$ (^oC) between planting and emergence.

Time from emergence to first anther:

(ii) GDD (emergence to anthesis) = 1351.7 $\pm$ 51.8 (Goyne, et al, 1977) where GDD is the heatsum computed by accumulating the mean daily temperature minus the base temperature (base = -1.3^oC).

Time from anthesis to physiological maturity is similarly given by:

(iii) GDD (anthesis to physiological maturity) = 800 (Goyne, et al, in press).

The crop yield component consists of a set of regression equations for the prediction of yield (kg/ha), oil percentage and linoleic acid percentage, viz.

(iv) Seed yield (kg/ha) = 2229 - 380.9ln (SI) - 49.9RI R^2 = 87.7 (Goyne, et al, 1978).

where SI = mean daily moisture stress index in the 30 day period from 15 days before to 15 days after anthesis. Daily stress is defined as 100 (1 - Ea/Et).

Ea and Et are the actual and potential daily evapotranspiration amounts respectively.

RI = rust index (from one to ten based on infestation on the top 50% of green foliage at last anthers).

(v) Oil % = 72.77 - 1.26T r = -0.69 (Goyne, et al, in press).

where T = mean daily temperature (^oC) in the period from emergence to physiological maturity.

(vi) Linoleic acid % = 63.41 + 2.46T1 - 0.10 $(t1)^2$ R^2 = 79.4 (Goyne, et al, in press).

where T1 = mean daily temperature in the period from 300 GDD after first anthesis to physiological maturity.

The influence of rust is not considered in the model. The yield prediction function is truncated at a maximum of 2000 kg/ha as at higher yield levels the logarithmic relationship is too sensitive and factors other than moisture stress would dominate yield. The prediction of oil percentage remains uncertain and must be regarded with caution at this stage.

The soil moisture budget component incorporates three soil layers. Infiltration rate is obtained from a function on the proportion of available soil moisture adapted from data presented by Shaw and Yule (in press). If rainfall exceeds the infiltration rate then the excess is lost as surface runoff. Potential evapotranspiration (Et) is derived from the daily pan evaporation (Eo) and an empirical function of the ratio Et/Ea against stage of crop development (represented by GDD).

Actual evapotranspiration (Ea) is the minimum of Et and potential uptake. The latter is determined via a function on the square of the proportion of available soil moisture proposed originally by Linacre (1973) and found by Johns and Smith (1975) to be among the most accurate of a range of relationships for the influence of soil water availability on actual water use. Partitioning of Ea and Et among soil layers is achieved by a set of empirical rules which attempt to account for root growth and function.

The ratio of Ea/Et, which has been favorably evaluated as an index to characterise the crop water environment by Nix and Fitzpatrick (1969), can thus be calculated and used in the determination of the stress index necessary for yield prediction. This stress index is also used to derive a weighting factor which, when applied to the rate of increase of the Et/Eo ratio, attempts to simulate the decline in the rate of leaf expansion and subsequent loss of transpiring surface as the crop encounters moisture stress.

Hence, given inputs of planting date, initial soil moisture status, and other relevant soil characteristics, daily maximum and minimum temperature, rainfall and pan evaporation the model predicts dates of emergence, anthesis and physiological maturity, seed yield, oil % and linoleic acid % as well as providing detail of soil moisture and crop water usage patterns. The model makes no allowance for disease, insect pests, waterlogging, frost or pollination problems, all of which may have significant effects on the crop. Hence, predictions relate to yield potential in the absence of these factors.

The gathering of independent data for validation is being undertaken at present. Difficulties have been encountered in attempts to use data from other trial sites, particularly with respect to the accurate specification of necessary soil information and detail of rust infestation. Although good qualitative agreement of predicted and actual yields has been found more rigorous validation employing accurately known inputs is necessary.

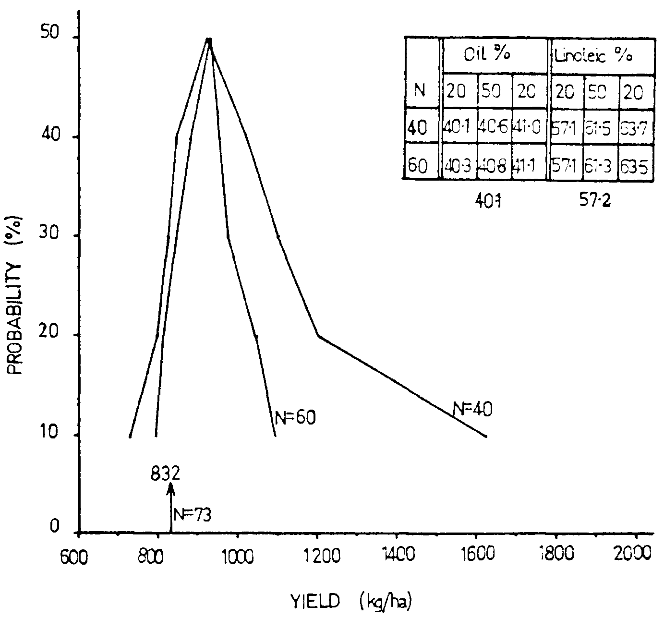
Application to Yield Forecasting

The rationale for employing the model for yield forecasting is that given time of planting, necessary input information and the weather experienced up to any stage of crop development, the use of stochastically generated daily weather or long term records for the remainder of the crop growing season enables the generation of yield probability distributions. As the season progresses and a longer period of weather actually experienced is incorporated, narrowing of the probability distributions is expected.

The yield estimates of the model relate to experimental plot yields and it will thus be necessary to derive a relationship between these yields and farm yields to produce realistic predictions. Furthermore, to predict yields over a region a number of sites throughout the region must be employed to make allowance for local spatial climatic variability.

Long term daily meteorological records extracted for Biloela, Qld. have been used to demonstrate the procedure. Figures 1 and 2 show the yield probability distributions generated from N days into the growing season for early December and early February times of planting respectively. The arrow on the yield axis indicates the yield outcome predicted at 15 days after anthesis. No variation of yield expectation is predicted after this date. The corresponding table of probability points for oil % and linoleic acid % is included in each figure. The percentages at the base of the table are the final predictions which are realized at the time of physiological maturity.

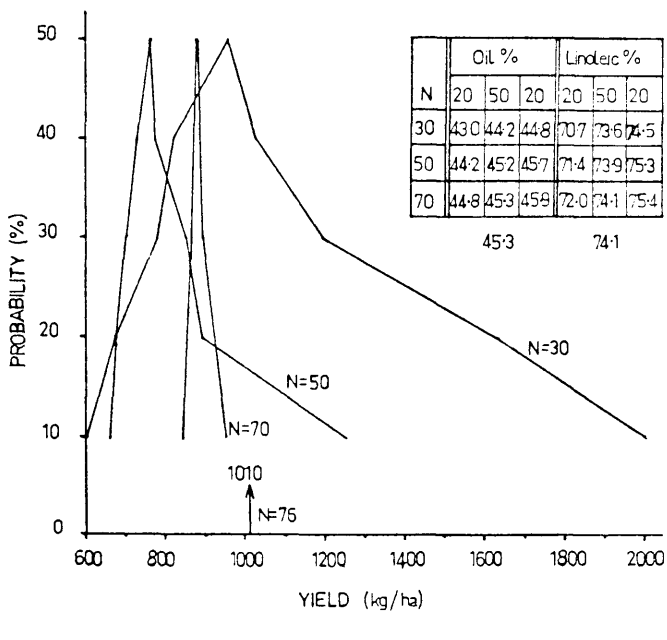
Figure 1



N	Oil %			Linoleic %		
	20	50	20	20	50	20
40	40·1	40·6	41·0	57·1	61·5	63·7
60	40·3	40·8	41·1	57·1	61·3	63·5

40·1   57·2

Figure 2



N	Oil %			Linoleic %		
	20	50	20	20	50	20
30	43·0	44·2	44·8	70·7	73·6	74·5
50	44·2	45·2	45·7	71·4	73·9	75·3
70	44·8	45·3	45·9	72·0	74·1	75·4

45·3   74·1

Both figures 1 and 2 demonstrate the narrowing of yield probability distribution as N increases. However it is only in Figure 1 that the distributions converge about the final estimate and in this case significant narrowing is not realized until about the time of anthesis. In Figure 2 the distributions shift significantly, first towards lower yields and then back towards higher yields. This results from a harsh moisture regime experienced between days 30 and 50, followed by relief late in the season. Hence, although the final yield prediction at N = 76 suggests an average result (approximates the median at N = 30) the unusual climatic pattern throughout the growing season has lead to the situation where even at N = 70 the final yield prediction is in the outer 10% of the predicted yield distribution.

In both figures 1 and 2 the predictions of oil characteristics, being derived from mean temperatures, show far less variation thanthe yield predictions. Hence, the latter is the dominating consideration for the purposes of this application.

Discussion

The variability of the moisture environment is such that although the yield probability distributions represent the best available forecasting information, it is not until late in the growing season that significant narrowing of these distributions and reasonable accuracy are obtained. The utility of this information to a marketing body is dependent upon the time at which accurate forecasts are required. At 15 days after anthesis, which varies from 10 to 20 days before physiological maturity and thus is still about 20 to 35 days before harvest, the final yield prediction is available.

If this is sufficiently far in advance to enable best use of marketing opportunities to be made then the detail of yield probability distributions at an earlier stage is an unnecessary sophistication. However, if forecasts at an earlier stage are required then the results described above depict the information that would be available to the marketing body. The yield distributions for any time prior to anthesis will be of limited value as they will give only general trends. If forecasts are required before anthesis then it appears that there would be better return in pursuing short term (i.e., about 30 days) weather prediction than relying on stochastically-generated weather or long term records.

Attempts to use past records to evaluate the approach to yield forecasting described have encountered problems with respect to reliability of crop area figures and the relation of deliveries to depots with region of origin. It is possible that the dramatic visual changes observed with the onset of flowering in sunflowers would enable ease of identification of the crop on satellite imagery and hence accurate estimates of flowering time and crop area. Thus, use of the model in combination with satellite imagery appears to offer prospects for yield forecasting in the future. In the meantime more reliable ground data is required to examine and test the procedure outlined so that it can be evaluated and compared with existing techniques of yield forecasting.

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Legends for Figures

FIGURE 1 Yield probability distributions for early December planting. N = number of days since planting. Anthesis is at N = 58. Physiological maturity is at N = 86.

FIGURE 2 Yield probability distributions for early February planting. N = number of days since planting. Anthesis is at N = 61. Physiological maturity is at N = 99.