

A PRELIMINARY MODEL TO PREDICT GROWTH AND OIL YIELD OF SUNFLOWER CV. HYSUN 30

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Abstract

We describe growth of sunflower cv. Hysun 30 as affected by radiation, temperature, applied nitrogen fertilizer and population under irrigation. The description is based on unpublished field experiments at Camden, Australia (Lat. 34°S) and on published data. It allows prediction of crop dry weight at the end of floret initiation and at maturity. Dry weight at these two times is a good predictor of oil yield (Steer and Hocking, 1984). Floret initiation was completed at a heat sum of 900 day degrees (above a base of 0°C) and physiological maturity at 2200 day degrees. Crop growth was predicted from intercepted radiation. Leaf area was given by the product of plant population, rate of leaf production, the duration and rate of expansion of individual leaves, and leaf senescence. Rate of leaf production did not vary with leaf position, plant population or nitrogen; it increased linearly with temperature. Duration of individual leaf expansion was quadratically related to leaf position, in contrast to one other study which found the duration did not change with leaf position. Duration was not affected by nitrogen fertilizer or plant population and it decreased with increasing temperature. Rate of leaf expansion was described by a set of straight lines constrained through 18 cm² per day and declined with increasing leaf number; the rate of decline with leaf number being related to N fertilization. The rate of leaf expansion decreased with increasing plant population.

Introduction

The oil yield of sunflowers (Helianthus annuus L.) is given by the number of seeds per ha and the oil content of each seed. The number of seeds per ha is determined at about floral initiation; in the hybrid Hysun 30, number of seeds is related linearly to shoot dry weight at this time by $S = 50.82 + 57.53 W$ where S is seed number and W is top dry weight at floral initiation: Steer and Hocking 1984). The oil content of each seed is related positively to shoot growth after anthesis and negatively to the number of seeds present (e.g. Steer and Hocking 1984). Thus, a simple model of growth of this sunflower hybrid will predict oil yield if it accurately predicts shoot dry weight at floral initiation and the increase in shoot weight between floral initiation and maturity.

The purpose of this paper is to synthesize published data and unpublished data collected over two seasons at Camden, Australia to describe the growth of sunflower cv. Hysun 30. The model attempts to describe the dependence of growth on radiation, nitrogen and temperature.

Materials and Methods

Hysun 30 was grown under irrigation in two seasons, 1981-2 and 1982-3, at Camden, Australia. In 1981-2 the design was a complete factorial with three

populations (50, 100 and 150 thousand plants ha⁻¹) each at three rates of nitrogen fertilizer (0, 100 and 300 kg N ha⁻¹). In 1982-3 the experiment was an incomplete factorial with two populations (50 and 150 thousand ha⁻¹) and rates of nitrogen of 0, 100, 300 and 500 kg N ha⁻¹. Harvests for dry weight, leaf area and tissue nitrogen concentrations were made throughout the growing seasons. Areas of individual leaves were used to analyse leaf growth as a function of mean rate of expansion and the duration of leaf expansion, following Rawson and Hindmarsh (1982). Agronomic aspects of these results will be reported elsewhere. Here we report data from these experiments and other published data on cv. Hysun 30, in the context of a preliminary model of growth and yield of this hybrid.

Results and Discussion

Our model considers two processes: development, the progression of the crop through various events; and growth, the accumulation of dry weight and ultimately, oil.

Timing of development

The time of various developmental events up until anthesis may be predicted simply from heat sums for sunflowers which are not greatly sensitive to day-length (Table 1; see also Goynes et al. 1977).

Table 1. Cumulative day-degrees to various developmental events

		Emergence to bud emergence	Bud emergence to anthesis	Anthesis to physiological maturity	Source
Hysun 30 at:					
Camden	1981-2	964	554	792	unpublished
	1982-3	900	510	713	unpublished
Griffith	1981-2	899	556	1085	unpublished
	1982-3	903	550	1017	unpublished
Peredovick		831	535	672	Anderson <u>et al.</u> 1978
Peredovick		852	520	-	Doyle 1975

At Camden, developmental events in Hysun 30 were not affected by more than 2 days by nitrogen or plant population. It thus appears that linear temperature functions can be used for Hysun 30 and other cultivars at least when they are sown at times when changes in daylength do not markedly affect development. For other cultivars a non-linear function may be more appropriate (Hammer et al. 1982) whereas in some cultivars at widely spaced times of sowing, photo-period also has to be considered as a variable during development (A.J. Hall, University of Buenos Aires, pers. comm. 1984).

Growth rate

Warren-Wilson (1971) proposed, and Monteith (1981) and Charles-Edwards (1982) have used:

$$C = \epsilon I (1 - e^{-KL}) \quad \dots 1$$

where C is crop growth rate, ϵ is the efficiency of conversion of radiation into dry matter, I is incident radiation and $1 - e^{-KL}$ the proportion of that radiation which is intercepted by the crop canopy. For sunflower $\epsilon = 2.6 \text{ g MJ}^{-1}$ (Warren-Wilson 1971) although this efficiency will vary with temperature. This variation can be described by a dimensionless scalar based on data collected by Warren-Wilson (1971):

$$\epsilon = 2.6 (1 - 0.956^T) \quad \dots 2$$

where T is ($^{\circ}\text{C}$). Likewise there appears to be no significant variation in canopy extinction coefficient: K may be set at 0.8 at solar angles above 30° (Lemeur 1973). Thus the dependence of growth of sunflower on temperature and nitrogen depend primarily on a description of how these variables affect leaf area L.

Canopy leaf area is described by the identity

$$L = p * n * \sum_{I=1}^n (D(I) * E(I)) \quad \dots 3$$

where p is plant population, n number of leaves per plant, D duration of expansion of each leaf and E the average rate of expansion during time D.

The number of leaves per plant is given by the rate of leaf production (R, leaves per d) (Rawson and Hindmarsh 1982):

$$R = 0.129 + 0.022 T \quad \dots 4$$

Our experiments in the field at Camden and in glasshouse at Griffith (Steer and Hocking 1983) indicate that R does not vary with leaf position or plant population.

The duration of expansion of each individual leaf (D, days) is variable: it was relatively constant in Rawson and Hindmarsh (1983) but it increased with height of insertion at low leaf positions in our field experiment in 1982-3. (Fig. 1).

The duration of expansion decreases with increasing temperature (Rawson and Hindmarsh 1982) but it was not affected by nitrogen fertilization or plant population in the Camden experiments. Thus a useful description is

$$D = 1 - 1.05 T \quad \dots 5$$

where T is $^{\circ}\text{C}$, the regression coefficient is fitted from Rawson and Hindmarsh's (1982) data and the intercept probably varies with genotype and location. The intercept is about 38 for Hysun: it was 37 in the Camden experiments where the mean air temperature was 20.7°C and 39 in Rawson and Hindmarsh's (1983) field experiment with Hysun 31 at Canberra where the mean air temperature was 19.1°C .

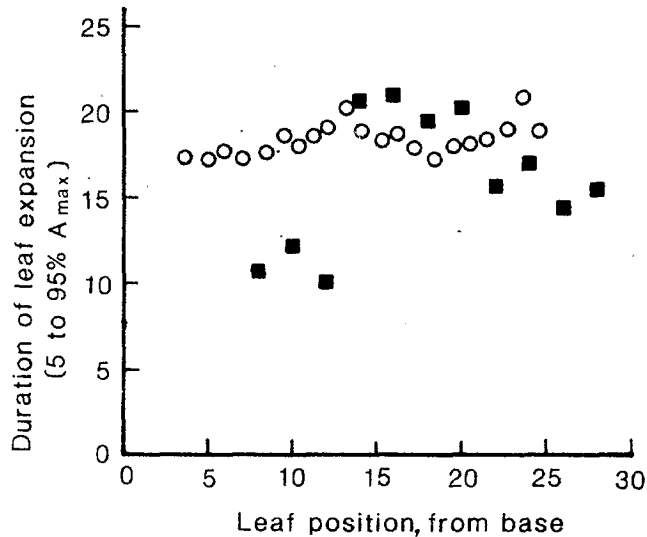


Figure 1: Duration of leaf expansion as a function of leaf position: ■ mean of N and density treatments, Camden, ○ Rawson and Hindmarsh 1983

The rate of individual leaf expansion (E , cm^2 per d) varies systematically with leaf number (position of insertion of the leaf on the mainstem), nitrogen and plant population. Rawson and Hindmarsh (1982) found that E increased with leaf position:

$$E = 1.03 + 1.93 \log N \quad \dots 6$$

whereas Rawson and Hindmarsh (1983) found that in the field E increased to leaf number 15 and then declined. In the Camden experiment, E was highest at leaf 10. There appeared to be a non-linear positive relationship between E and nitrogen supply or some plant parameter e.g. petiole nitrogen, which reflects nitrogen status. The rate of leaf expansion decreased with increasing plant population at Camden; the decrease was progressively greater at higher leaf numbers so that the extension rates were virtually zero for uppermost leaves (leaf numbers 22 to 26, depending on treatment) at 150,000 plants per ha. E at 150,000 plants per ha expressed as a fraction of E at 50,000 plants per ha was given by:

$$E_{150}/E_{50} = 0.89 - 0.035 N \quad \dots 7$$

where N is leaf number from the base of the stem.

Thus agronomy (nitrogen and plant population) affects canopy structure and total leaf area of Hysun 30 through effects on the rate of individual leaf expansion. Other variables e.g. water would also be expected to effect D and E . By describing these effects we predict leaf area (equation 3) and hence light interception growth rate and crop dry weight. Crop dry weight at floral initiation is correlated with, and hence can be used to estimate, the number of seeds (Steer and Hocking 1984).

The model described in this paper will predict dry weight of Hysun 30 at floret initiation and anthesis. Predicted crop growth rates conform reasonably well with those measured at populations of 50 and 150,000 plants ha^{-1} at Camden (Table 2) although predicted leaf areas are inexplicably low at the

lower population. After anthesis our preliminary model requires further refinement to incorporate leaf senescence. There are virtually no data available for senescence of leaf area after anthesis (our crops at Camden retained their leaf area because they were irrigated in a humid climate). Collection of data on senescence will allow the present model to predict oil yield of Hysun 30 in a range of environments.

Table 2. Measured and predicted LAI and crop growth rate from sowing to anthesis. Ranges of observed values are extremes from various nitrogen treatments

Day	LAI		Crop growth rate $\text{kg ha}^{-1} \text{d}^{-1}$	
	measured ^a	predicted	measured	predicted
<i>50,000 plants ha⁻¹</i>				
37	0.36 - 0.46	0.28	51 - 62 ^b	61
51	1.1 - 1.5	0.53	101 - 116 ^c	107
69	1.6 - 2.7	0.85	93 - 194	152
<i>150,000 plants ha⁻¹</i>				
37	0.60 - 0.63	0.83	120 - 136 ^b	149
51	1.5 - 1.7	1.64	130 - 200 ^c	225
69	2.3 - 2.4	2.54	130 - 275	268

(a) From length x breadth estimates

(b) Between harvests at 30 & 40 days and (c) 40 and 49 days

References

- ANDERSON, W.K., SMITH, R.C.G. and MCWILLIAMS, J.R. (1978). A systems approach to the adaptation of sunflower to new environments. 1. Phenology and development. *Field Crops Research* 1, 141-52.
- CHARLES-EDWARDS, D.A. (1982). "Physiological Determinants of Crop Growth". Academic Press. Sydney.
- DOYLE, A.D. (1975). Influence of temperature and daylength of phenology in sunflower in the field. *Australian Journal of Experimental Agriculture and Animal Husbandry* 15, 88-92.
- GOYNE, P.J., WOODRUFF, D.R. and CHURCHETT, J.D. (1977). Prediction of flowering in sunflowers. *Australian Journal of Experimental Agriculture and Animal Husbandry* 17, 475-81.
- HAMMER, G.L., GOYNE, P.J. and WOODRUFF, D.R. (1982). Phenology of sunflower cultivars. III. Models for prediction in field environments. *Australian Journal of Agricultural Research* 33, 263-74.

- LEMEUR, R. (1973). A method for simulating the direct solar radiation regime in sunflower, Jerusalem artichoke, corn and soybean canopies using actual stand structure data. *Agricultural Meteorology* 12, 229-47.
- MONTEITH, J.L. (1981). Does light limit crop production? In: Johnson, C.B. (Ed.). "Physiological Processes Limiting Plant Productivity", Butterworths, London pp. 23-38.
- RAWSON, H.M. and HINDMARSH, J.H. (1982). Effects of temperature on leaf expansion in sunflower. *Australian Journal of Plant Physiology* 9, 209-19.
- RAWSON, H.M. and HINDMARSH, J.H. (1983). Light, leaf expansion and seed yield in sunflower. *Australian Journal of Plant Physiology* 10, 25-30.
- STEER, B.T. and HOCKING, P.J. (1983). Leaf and floret production in sunflower (Helianthus annuus L.) as affected by nitrogen supply. *Annals of Botany* 52, 267-77.
- STEER, B.T. and HOCKING, P.J. (1984). Nitrogen nutrition of sunflower (Helianthus annuus L.): acquisition and partitioning of dry matter and nitrogen by vegetative organs and their relationship to seed yield. *Field Crops Research* 9, in press.
- WARREN-WILSON, J. (1971). Maximum yield potential. In: Transition from Extensive to Intensive Agriculture with Fertilizers. Proceedings of 7th Colloquium of International Potash Institute. International Potash Institute, Berne pp. 34-56.