USE OF THE GENERATIVE AREA AND OTHER INFLORESCENCE CHARACTERS TO PREDICT FLORET AND SEED NUMBERS IN THE SUNFLOWER

J.H. Palmer[1] and B.T. Steer[2]
1 Botany School, University of New South Wales, Sydney 2033, Australia.
2 CSIRO Centre for Irrigation Research, Griffith 2680, Australia.

SUMMARY

The number of disc florets produced by the sunflower capitulum varies with genotype and according to environmental conditions experienced in the early life of the plant. Observation showed that during the early development of the capitulum, three factors operate to control the total number of florets that can be produced; these are the initial number of floret rows appearing in floral stage 5, the extent to which row amalgamation occurs subsequently and the number of florets in each row. An empirical formula has been developed, which incorporates the initial row number and the number of florets in each row and utilises the Fibonacci series to which the row numbers conform. This formula has been used to accurately predict floret numbers for the cultivars, Hysun 21, Hysun 30 and Bianca Grande, grown under glasshouse and field conditions. Sampling established that the number of floret rows, the number of florets in each row and the extent of row amalgamation is also linked to the initial size and subsequent persistence of the generative area; the region of floret initiation at the receptacle centre. Daily integration of the surface area of the generative area in capitula of Hysun 30, grown in long or short days and also in capitula of Hysun 30, Sunfola 68-2, Sirosun 25H and its parent lines, grown in the field, established that a linear relationship exists between the daily integral and total floret number permitting the early prediction of floret number, from which seed number per plant can be estimated.

INTRODUCTION

Since seed number is a function of disc floret number and is a major component of yield in the oil-seed sunflower, it follows that yield per plant is strongly influenced by the number of disc florets initiated in the young capitulum (Steer et al 1984). Disc floret primordia first appear at the rim of the capitulum receptacle in floral stage (FS) 5 (Marc and Palmer, 1981) and their production ceases at the end of FS 8 when they have occupied all the available space on the receptacle. Over much of the receptacle surface, the disc florets are arranged into two sets of parastichies or rows, the numbers of which conform to the Fibonacci series; the most common numbers being 21, 34, 55, 89 and 144. Due to amalgamation the number of rows decreases towards the receptacle centre although the reduced numbers remain in the Fibonacci series (Ridley, 1982). At the receptacle centre, the floret primordia may be randomly arranged which is generally the case when the initial row numbers are 89 or 144.

The number of disc florets produced by a capitulum varies with genotype and is phenotypically plastic, but can range from 60 to 3,000. The influence of genotype and also photoperiod as an example of environmental control of floret number, has been investigated in relation to the growth of the receptacle from FS 5 when floret primordia first appear, to FS 8 when floret production is completed. The objective was to test the hypothesis that the generative area of the receptacle and its rate of expansion or contraction, controls the total number of florets produced and this is manifested in the number of floret rows that appears in FS 5, the degree of their subsequent amalgamation in FS 7 and 8 and the number of florets produced by each row.

MATERIALS AND METHODS

For photoperiod experiments, sunflower plants (*Heliantnus annuus* L.) cv Hysun 30, were grown in controlled environment cabinets at 28°C under an 18h irradiance of 400 $\mu E\ m^{-2}\ s^{-1}$ from fluorescent and incandescent lamps. Seven to 10 days from germination, half of the plants were transferred to a short day (SD) 10h photoperiod. The plants remaining in the 18h illumination regime constituted the long day (LD) treatment and they received 80% more irradiance than the SD plants. A field trial at Griffith, New South Wales, was sown with sunflower plants cv Hysun 30, cv Sunfola 68-2, Sirosun 89A, Sirosun 25R and Sirosun 25H. The last three are experimental lines and represent a cytoplasmic male sterile line (89A), a restorer line (25R) and the resulting hybrid (25H).

Inflorescence development was followed in each experiment by collecting samples of 5-10 terminal buds, dissecting out the receptacle and recording the floral stage using the 10-stage classification of Marc and Palmer (1981), the receptacle diameter and the diameter of the generative area, a term used to describe the central region of the receptacle where the floret primordia are formed (Fig. 1). In addition, the initial number of floret rows in each set was recorded together with the number of florets in each row. Some samples were collected at maturity in order to record seed number as a measure of seed production in each treatment.

RESULTS

A. Daylength. The combined results for two experiments are shown in Table 1. Under SD the rate of capitulum development accelerated so that floret production was completed 10 days sooner than in LD. The number of floret rows was reduced by 43% in SD and the number of florets in each short row decreased by 3. Consequently floret production was reduced to 48% of the LD total and there was a corresponding decrease in seed number. In SD the size of the generative area when it first appeared in FS 5 was less than in LD, although the initial spacing between the floret rows was the same in both SD and LD. Figure 2 shows that in LD the size of the generative area remained relatively constant for about 13 days after which it rapidly decreased as florets spread over the centre of the receptacle. In contrast, in the SD treatment the generative area was initially smaller and after 3 days it commenced to decrease in size to become zero only 15 days after its inception.

Table 1. Floret and seed production in Hysun 30 under 10h short day and 18h long day

Daylength	Seed No.	No. floret rows[1]	Initial row spacing[2] µm	No. florets per short row	Generative area Initial	Generative area Integrated
18h (LD)	1388±44	80.8	98.0±1.1	20.7±0.66	4.98±0.32	41.4
10h (SD)	673±26	45.7	100.4±3.1	17.1±0.38	1.67±0.09	16.2

[1] Initial number. Comprising means of short row numbers, of which 89 was most common in LD and 55 in SD

[2] Floral stage 5

B. Field-Grown Cultivars. The initial number of short floret rows approximated to 55 or 89 in each cultivar. Despite this similarity in row numbers there was a large variation in the mean total floret production between cultivars (Table 2), due to differences in the extent of row amalgamation and number of florets produced by each row. Examination of seed heads showed that in each cultivar each short row formed at least 15 florets before row amalgamation commenced. This indicates that row amalgamation was confined to FS 7 and 8 when more than two thirds of the receptacle area is covered by florets. Utilising this, an empirical expression was developed to permit floret number to be estimated from the number of floret rows and florets per long row, without the need for information on the extent of row amalgamation:-

$$\text{Floret number} = [a(0.67f)] + [aF.N{-}1(0.33f)]$$

where (f) is the number of florets in a long row, (a) is the initial number of long floret rows, (aF.n-1) is the next number down in the Fibonacci series. The equation was tested by counting 22 capitula of three cultivars, Hysun 21, Hysun 30 and Bianca Grande. The mean ratio of observed to estimated floret numbers was 0.98 (SE ±0.015). This method was used to estimate seed numbers in Table 2.

Table 2. Floret and seed production in field-grown cultivars and hybrids

	Seed number					Generative area		
	Actual	Estimated[1]	Potential[2]	Floret row No.	No. florets per short row	Initial row spacing µm	Initial mm²	Integrated mm²
Sirosun 25R	856	885	1013	34/55	23.7	186.4	3.02	24.8
Sunfola 68-2	1019	1076	1231	34/55	29.4	157.6	1.74	27.8
Sirosun 25H	1436	1505	1722	55/89	25.0	115.6	1.74	36.5
Hysun 30	1452	1658	1898	55/89	27.9	111.6	2.72	40.4
Sirosun 89A	1711	1856	2129	55/89	31.6	108.7	3.72	48.8

[1] Using equation presented in Results

[2] Florets per long row X No. of long rows ie 34 or 55

Figure 3 shows that in all 5 cultivars there was an initial period of 2-5 days when the generative area expanded in size, after which it gradually diminished to disappear in FS 8 as the receptacle centre was occupied by florets. Figure 3 also shows that the life of the generative area ranged from 8 days, for Sirosun 25R and 25H, to a maximum of 12 days in the case of Sirosun 89A, thus indicating the duration of floret production.

DISCUSSION

Apart from a few days in FS 5, the generative area occupies a relative small part of the receptacle surface (Figs. 2, 3), and by comparison with the rapid expansion growth of the rest of the receptacle it shows comparatively little change in size during its brief existence. Thus under SD, the generative area of Hysun 30 decreased in area by 1 mm^2 from day 25-35, while in the same period the area of the receptacle increased from 3 to 75 mm^2. For the generative area to maintain its size or even increase in area when large numbers of floret primordia are arising at its outer margin, there must be a continual replenishment of cells utilised in the

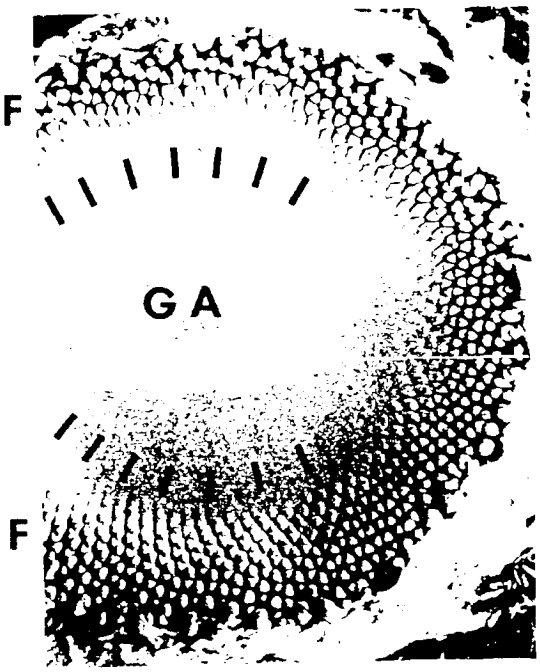

Figure 1. View of sunflower receptacle at floral stage 6, when approximately 50% of the surface area is covered by floret primordia (F). Showing left-turning long rows, right-turning short rows and the generative area (GA) with the generative zone indicated at its outer edge (IIIII).

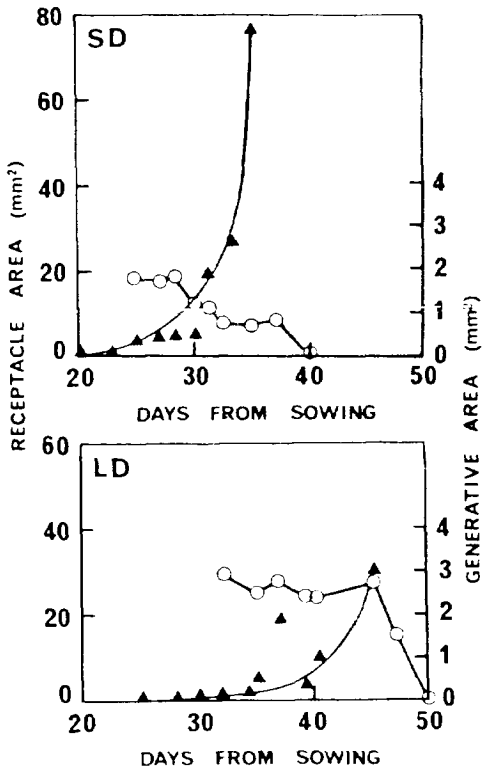

Figure 2. Change in receptacle area (▲) and generative area (○) for Hysun 30 in short (SD) and long (LD) days.

floret initiation process, suggesting that the centre of the generative area is a region of active cell division. If this is the case, then the hypothesis can be proposed that a site of floret initiation exists inside the generative area, in the form of a ring or zone, termed the generative zone (Fig.1). As newly formed cells enter this zone due to continuing division activity at the centre, they are stimulated to form either floret primordia or supporting tissue. On this hypothesis the generative zone can be regarded as a "standing wave" controlling the development of cells passing through it. Whether this standing wave, or generative zone, moves outwards expanding the generative area, remains stationary or migrates inwards, will depend on the relative balance between the production of new cells and their utilisation for floret primordia. In the field experiment the initial expansion of the generative area suggests the field environment promoted cell division activity in the generative area, while in contrast the progressive decline in the generative area in the SD environment indicates that SD favours the rate of floret production so that cells are utilised more rapidly than they can be replaced, and consequently the generative zone migrates inwards. The eventual inward migration of the generative zone in all cases may be attributed to a decline in the production of new cells in the generative area as the receptacle ages. Since the precise extent of the generative zone has not yet been determined, it cannot be used in quantitative calculations, although the results presented here suggest that the extent to which it maintains its

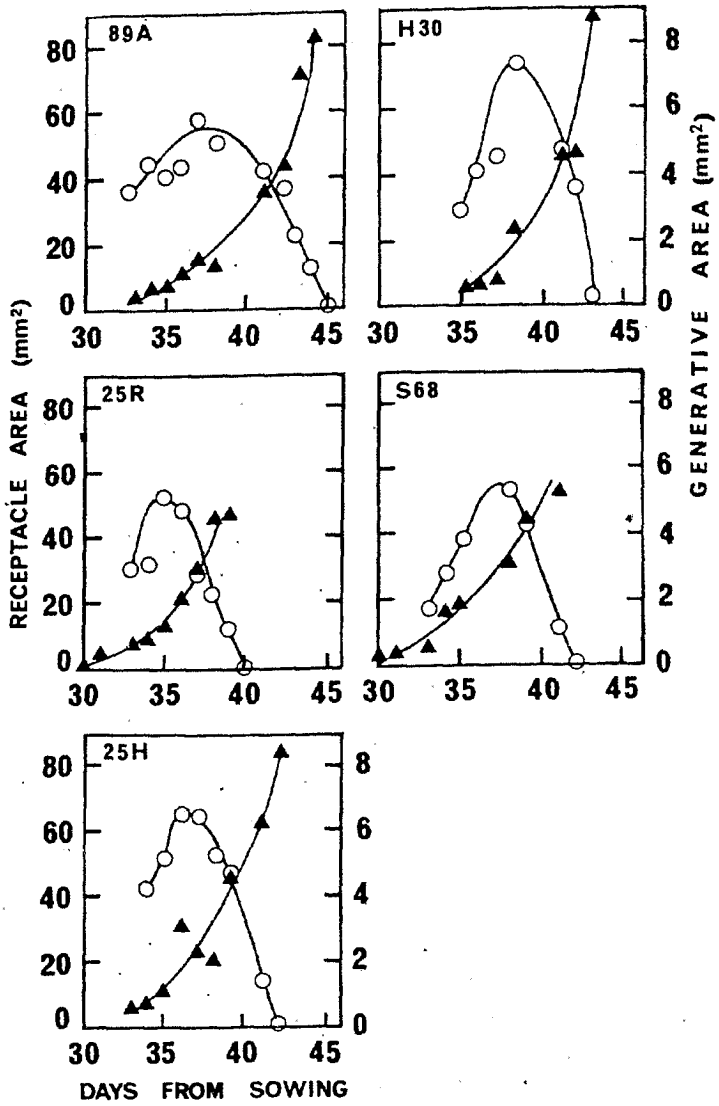

Figure 3. Change in receptacle area (▲) and generative area (○) for five field-grown cultivars and hybrids. Sirosun 89A; Sirosun 25R; Sirosun 25H; Hysun 30; Sunfola 68-2.

initial or enhanced size is an important factor promoting total floret number. However, it is clear that the generative zone occupies the periphery of the generative area, so that the generative area can be substituted for it as an indicator of generative zone activity (Fig. 1). This activity can be made quantitative by integrating the generative area on a daily basis. The integrals obtained for the SD/LD plants and the field grown plants are related to total floret number in Fig. 4 by the line of best fit determined by

$$Y = 135.55 + 31.98X \quad r^2 = 0.95$$

where (Y) is the floret number and (X) the integrated generative area. The close fit of values suggests that the equation may be valuable in predicting floret numbers and hence seed numbers, from a few early bud measurements of the diameter and duration of the generative area.

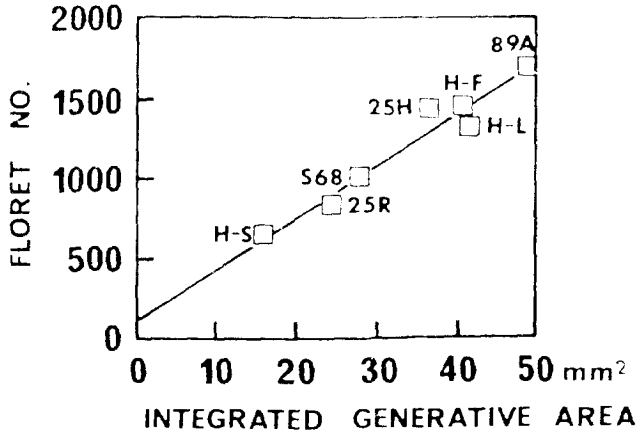

Figure 4. Relationship between floret number and integrated generative area. H-S, Hysun 30 in SD; H-L, Hysun 30 in LD; H-F, Hysun 30 in field; S-68, Sunfola 68-2; 25R, 89A, 25H, Sirosun parental lines and hybrid respectively.

ACKNOWLEDGMENTS

Part of this project was carried out with financial support to J.H. Palmer from the Australian Oilseeds Research Committee. We are indebted to Mrs J.H. Maier and Mr S. Rose for technical assistance and to Mr A. Low for the Sirosun lines.

REFERENCES

MARC, J. and PALMER, J.H. 1981. Photoperiodic sensitivity of inflorescence initiation and development in sunflower. Field Crops Research 4, 155-164.

RIDLEY, J.N. 1982. Packing efficiency in sunflower heads. Mathematical Bioscience 54, 129-139.

STEER, B.T., HOCKING, P.J., KORTT, A.A. and ROXBURGH, C.M. 1984. Nitrogen nutrition of sunflower (*Helianthus annuus* L.): yield components, the timing of their establishment and seed yield in response to nitrogen supply. Field Crops Research 9, (in press).