Photosynthesis and Yield of Rapeseed

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According to Allen et al.[1], it is likely that in rapeseed the pods themselves rather than the leaves produce the assimilates necessary for their own increase in size and weight during the pod development.

However, Freyman et al.[2], Krogman and Hobbs[7] and Mager[8] indicated that the leaves made an important contribution to the yield of rapeseed.

The experiments reported here were designed to obtain evidences on the relative importance of the leaves and the pods in determing the yield of pods in rapeseeds (*Brassica napus* L.), cultivar Norin No. 16 grown in the field under standard cultural conditions.

Canopy photosynthesis and respiration

The carbon dioxide exchange of rapeseed plants was measured in an assimilation chamber under field conditions at two-week intervals during the period from an early stage of growth to full maturity of the pods. After the later stage of flowering when the routine measurements using the intact plants were over, all the leaves of intact plants in an assimilation chamber were removed and carbon dioxide exchange of the defoliated plants which consisted of only pods and stems was measured. This experiments[4] was designed to estimate the contribution of pods and stems to photosynthesis and respiration of the canopy during the pod development.

Change with time in gross photosynthesis, i.e., apparent photosynthesis plus dark respiration, of the intact plants and of the defoliated plants, both at about 0.6 ly min^{-1}, are shown in Fig. 1. The gross photosynthetic rate of intact plants increased, gradually during the rosette stage, and rapidly after the

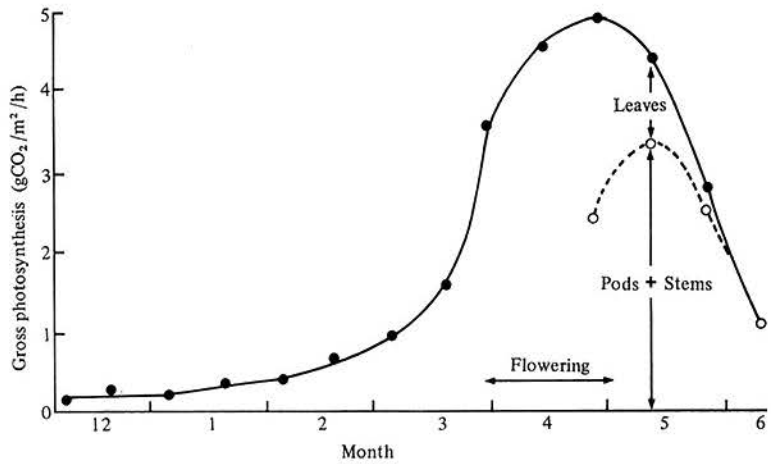

Fig. 1. Changes with time in gross photosynthesis of the intact plants (●) and of the defoliated plants (○) in rapeseed.

beginning of bolting (the end of February), remaining at a high level from the later stage of flowering to the early stage of pod development. On the other hand, the gross photosynthetic rate of the defoliated plants remained at a high level after the later stage of flowering. The proportion of gross photosynthesis of the defoliated plants to that of the intact plants was 49% at the later stage of flowering, 75% at the early stage of pod development, 90% at the middle stage of pod development and 100% at full maturity of the pod, the last measurement. The dark respiration rate of the intact plants followed a time course quite similar to the rate of gross photosynthesis. The high respiration rate continued from the later stage of flowering to the early stage of pod development. The dark respiration rate of the defoliated plants increased gradually from 62% to 71%, 77% and 100% of that in the intact plants at the stage of pod development.

Fig. 2 shows that the pods possess extensive surface area occupying the upper levels of canopy where there is plenty of sunlight at

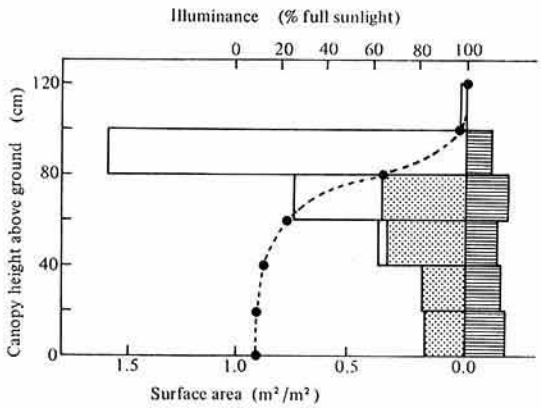

Fig. 2. Distribution profile of surface area of each organ and light intensity in the canopy of rapeseed at the middle stage of pod development: ● illuminance, ▒ stems, ⁞ leaves, □ pods

Table 1. Surface area, gross photosynthesis and dark respiration in each organ of the shoot of rapeseed

	Organ	At the beginning of flowering	At the middle stage of pod development
A. Surface area (cm^2/shoot)	Stem	2,533 (27)	2,485 (35)
	Leaf	6,918 (73)	—
	Pod	—	4,560 (65)
	Shoot	9,451 (100)	7,045 (100)
B. Rate of photosynthesis ($mgCO_2/dm^2$ surface area/hr)	Stem	13.0	8.5
	Leaf	12.2	—
	Pod	—	12.0
C. Rate of respiration ($mgCO_2/dm^2$ surface area/hr)	Stem	6.4	0.9
	Leaf	1.7	—
	Pod	—	2.5
A×B. Total gross photosynthesis ($mgCO_2$/shoot/hr)	Stem	329.3 (28)	211.2 (28)
	Leaf	844.0 (78)	—
	Pod	—	547.2 (72)
	Shoot	1,173.3 (100)	758.4 (100)
A×C. Total dark respiration ($mgCO_2$/shoot/hr)	Stem	162.1 (58)	22.4 (16)
	Leaf	117.6 (42)	—
	Pod	—	114.0 (84)
	Shoot	279.7 (100)	136.4 (100)

Photosynthesis: light intensity, 40 klux, air temperature, 15°C.
Respiration: dark, air temperature; 15°C.

the middle stage of pod development[4].

The rate of gross photosynthesis and of dark respiration in each organ of the shoot at both the beginning of flowering and the middle stage of pod development are shown in Table 1. The rapeseed plants used in this experiment[5] were soil-cultured singly in 1/2000a pots under field conditions. At both stages, the carbon dioxide exchange of each detached organ was measured in an assimilation chamber kept at 15°C and 40 Klux in light intensity. The surface area of each organ was also measured.

At the beginning of flowering, the shoot consisted of stems, leaves and flowers. The proportion in the surface area (A) of stems and of leaves to that of the shoot except for flowers were 27% and 73%, respectively. The rate of gross photosynthesis (B) was 13.0 for the stem and 12.2 for the leaf, expressed in $mgCO_2/dm^2$ surface area/hr. The proportion in the total gross photosynthesis (A×B) of stems and of leaves to that of the shoot were 28% and 72%, respectively. The rate of dark respiration (C) was 6.4 for the stems and 1.7 for the leaf, expressed in $mgCO_2/dm^2$ surface area/hr. The proportion in the total dark respiration (A×C) of the stem and of the leaves to that of the shoot were 58% and 42%, respectively.

At the middle stage of pod development, the shoot consisted of stems and pods. All the leaves had already fallen from the shoot by the early stage of pod development. The proportion in the surface area of the stems and the pods to that of the shoot were 35% and 65%, respectively. The rate of gross photosynthesis was 8.5 for the stem and 12.0 for the pod, expressed in $mgCO_2/dm^2$ surface area/hr. The pod showed a photosynthetic rate as high as the leaf. Hozyo et al.[3] reported similar results. The proportion in the total gross photosynthesis of stems and of pods to that of the shoot were 28% and 72%, respectively. The rate of dark respiration was 0.9 for the stem and 2.5 for the pod, expressed in $mgCO_2/dm^2$ surface area/hr. The proportion in the total dark respiration of stems and of pods to that of the shoot were 16% and 84%, respectively.

The results presented above indicate that the pods themselves contributed considerably to the canopy in both photosynthesis and respiration during their development.

Photosynthesis, respiration and carbon balance sheet of the pod

The carbon dioxide exchange of the detached pod was measured in an assimiration chamber under controlled environment once in 12 days throughout the period of pod development. Surface area, dry weight and carbon content of the pod were also measured. Details of this experiment were described elsewhere[6].

Changes with time in surface area and dry weight of the pod are shown in Fig. 3. Surface area of the pod approached to the maximum values 24 days after flowering, keeping the value thereafter. Dry weight of the pod

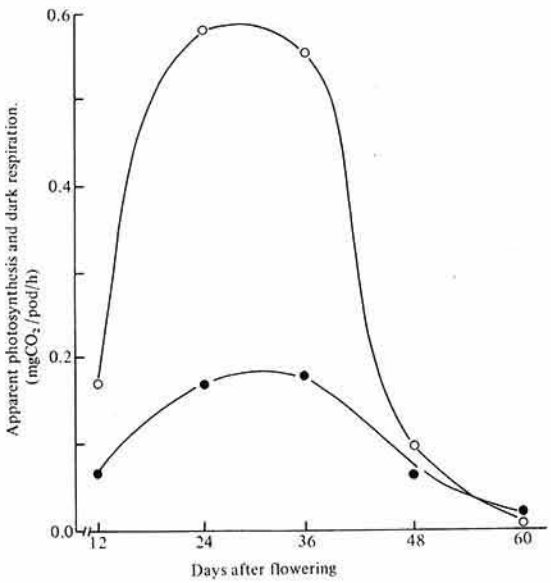

Fig. 3. Changes with time in apparent photosynthesis and dark respiration by the pod of rapeseed: ○ apparent photosynthesis, ● dark respiration.
Photosynthesis: light intensity (PAR), 0.26 cal/cm²/min; air temperature, 20°C.
Respiration: dark, air temperature, 20°C.

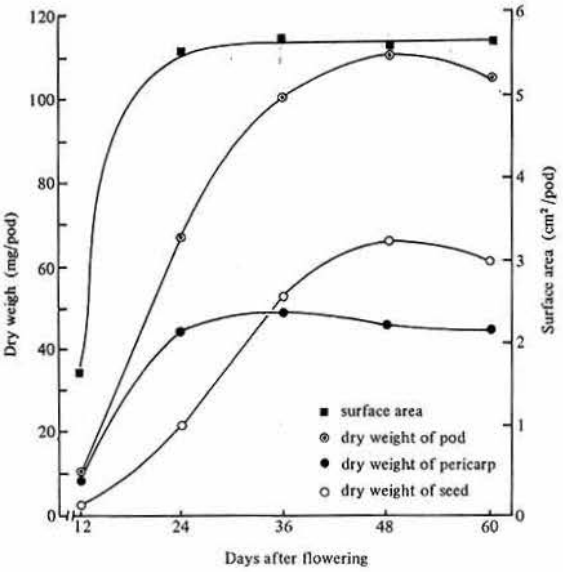

Fig. 4. Changes with time in surface area and dry weight of the pod of rapeseed

increased gradually during its development. The maximum value was found 48 days after flowering.

Changes with time in photosynthesis and respiration of the pod are shown in Fig. 4. Apparent photosynthesis of the pod reached the maximum value 24 days after flowering, maintained a similar value until 36 days after flowering, and then declined rapidly as the pod matured. Dark respiration of the pod reached the maximum value during the period from 24 to 36 days after flowering, and declined thereafter.

On the other hand, the relationships of light intensity and air temperature with photosynthetic and respiratory rates of the pod were also determined by laboratory experiments[6], not described here.

From the results on the time course in the change of surface area and dry weight of the pod mentioned before, actual climatic data and above-mentioned relationships, the contribution to the total requirements for the growth of pod was sought in relation to pod photosynthesis and translocation from other organs. The relative contributions of different organs can be estimated by the following equation:

$$W = Pg - R + T$$

where W, Pg, R and T stand for the pod growth, gross photosynthesis of the pod, respiration of the pod and translocation from other organs, respectively. The value of each component and the contribution of Pg or T to the total pod requirements (W+R) are shown in Table 2. The value of each component, average for the whole period of pod growth, was as follows: W, 48.5; R, 30.7; Pg, 55.6 and T(W+R−Pg), 23.6, expressed in mgC/pod. The contribution of Pg and T to W+R were 0.70 and 0.30, respectively. This means that pod photosynthesis contributed 70% to the total pod requirements during its development. In a young stage of pod development (12-23 days after flowering), T contributed more heavily to W+R than Pg. On the other hand, Pg contributed more heavily to W+R than T in the later stage of pod development. From these and the pod

Table 2. Balance sheets in the contributions of pod photosynthesis and of translocation from other organs to the total requirements for the pod growth at all the stages of pod development in rapeseed

	Days after flowering	W	R	W+R	Pg	T	$\frac{Pg}{W+R}$	$\frac{T}{W+R}$	$\frac{W}{W+R}$	$\frac{R}{W+R}$
I	12-23	26.4	7.9	34.3	14.9	19.4	0.43	0.57	0.77	0.23
II	24-35	22.2	10.8	33.0	21.1	11.9	0.64	0.36	0.67	0.33
III	36-47	3.7	8.5	12.2	15.7	−3.5	1.29	—	0.30	0.70
IV	48-59	−3.8	3.5	−0.3	3.9	−4.2	—	—	—	—
	12-59	48.5	30.7	79.2	55.6	23.6	0.70	0.30	0.61	0.39

Note: W, pod growth; R, respiration of the pod; Pg, gross photosynthesis; T, translocation from other organs; all expressed in mg C/pod.

growth pattern (Fig. 3), it is likely that translocation from other organs contributed mainly to the pericarp growth, and pod photosynthesis contributed mainly to the seed growth.

From all the results of this study, it is concluded that in rapeseed the leaves are main photosynthetic organs until flowering, but after flowering the pods themselves do play an important role in contributing to the production of dry matter in pods, including seeds.

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