Transformation Factor from Carbon Dioxide Net Assimilation to Dry Weight in Crops

II. Peanut*

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INTRODUCTION

In a previous paper³⁾, transformation factor (t. f.) was reported on soybean plant as a representative of protein crops. T. f. was sometimes far lower than the value 0.61 often used for starch crops. It was dependent not only on plants' growth stages, but also on the distribution ratio of dry weight to seed in ripening stage.

T. f. of peanut plant was reported herein as a representative of oil crops. Peanut seed is rich in oil (oil ca. 55 percent, protein ca. 25, carbohydrate ca. 20), hence also rich in carbon. So that the t. fs. of peanut plant are naturally supposed to be lower than those of starch or protein crops in ripening stage.

MATERIALS AND METHODS

On 6th June, Azumahandachi, a variety of peanut (*Arachis hypogaea* L.) was sown in 1/2000 a Wagner pots with 40 g of compound fertilizer (N 3 percent, P₂O₅ 10, K₂O 10) and 15 g of dolomite per pot. Five plants were sampled 10 times in all once every fortnight after sowing. Sampled plants were cut into the following parts; root, stem, leaf blade, petiole, peg, seed, pod shell, cotyledon and dead part. They were dried at 80°C in a forced draft oven. Dead leaf blades and dead petioles were sampled as soon as they fell and put together with original plant at its sampling. Each dried sample was weighed and powdered. Carbon content of the sample powder was measured by wet combustion method of

Mitsui and Kurihara¹⁾. T. f. for the term t_1-t_2 was calculated by the following formula;

$$\text{t. f.} = \Delta W (\Delta C \times \text{CO}_2 / C)^{-1} \dots \dots \dots (a)$$

where ΔW and ΔC are the increases in dry weight and carbon weight per plant respectively during the term t_1-t_2 . The ratio CO_2 / C is that of molecular weight of carbon dioxide to atomic weight of carbon, that is 3.667.

RESULTS AND DISCUSSION

1. Change of carbon-percentage in organs and in a whole plant.

The carbon-percentage in organs and in a whole plant changed along with growth as shown in fig. 1. The percentage in each organ changed little except for seed. Seed was the richest in carbon by far of all the organs. Ovule was not so rich at first, but became richer as it matured as much as 61 percent (cf. soybean seed 51 percent). Pod shell was the second richest, having 46~47 percent carbon. Its carbon-percentage remained almost constant as it matured. Leaf blade had carbon-percentage of 44~45. Root, stem and peg had almost the same percentage (42~43 percent) in the latter half of growth stages. But in young seedlings, stem was richer in carbon than root, which was observed also in soybean plant³⁾. Petiole was the poorest organ (38~39 percent) as was the case with that of soybean plant. The carbon-percentage in a whole plant remained almost constant (42 percent) until the beginning of pod filling. After that it increased steadily up to 50 percent at harvesting stage.

2. T. fs. classified by sampling terms.

T. f. was dependent both on growth stage and

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Fig. 1 Time course of carbon-percentage in organs and in a whole plant. The arrow indicates beginning of flowering (11th July)

Table 1 Transformation factor classified by sampling terms

t_2		weeks after sowing								
		4	6	8	10	12	14	16	18	20
weeks after sowing	2	0.64	0.64	0.65	0.64	0.62	0.59	0.58	0.56	0.55
	4		0.64	0.65	0.64	0.62	0.59	0.58	0.56	0.54
	6			0.65	0.64	0.61	0.58	0.57	0.55	0.54
	8				0.62	0.60	0.56	0.56	0.53	0.52
	10					0.59	0.54	0.54	0.52	0.50
	12						0.46	0.51	0.48	0.46
	14							0.55	0.48	0.46
	16								0.39	0.36
	18									0.29
	20									

choice of term t_1-t_2 as shown in table 1. Until 10 weeks after sowing ($t_2=10$), that is before the start of pod filling, t.fs. were almost constant, i.e. 0.64~0.65 (cf. 0.62~0.63 for soybean plant). T.f. began to decrease from 12 weeks ($t_2=12$), when seeds began to thicken vigorously and carbon-percentage in a whole plant started increasing. T.f. became lower as t_1 and t_2 were fixed at later weeks in growth. Especially t.fs. (0.29~0.39) for shorter terms in later

stages of growth were far lower than 0.61 generally used for starch crops. They were lower also than 0.40~0.45 for soybean plant³⁾. Matured seed was the richest in carbon (61 per cent) of all the organs as mentioned before. When all the carbon atoms absorbed by current photosynthesis go into seeds, t.f. value of 0.45 is calculated by equation (a) giving, for instance, 100 g and 61 g for ΔW and ΔC respectively. In the following periods of t_1-t_2 , 16-18, 16-20 and

Fig. 2 Relationship between transformation factor and distribution ratio of dry weight to seed in ripening stage. (1) Azumahandachi, (2) Sachihomare. Empirical equations for the curves were mentioned in the text

Table 2 Weight loss due to the transformation of starch into oleic acid

	starch $3(\text{C}_6\text{H}_{10}\text{O}_5)_n$	oleic acid $(\text{C}_{18}\text{H}_{34}\text{O}_2)_n$
carbon (%)	44.4	76.5
sum of A.W. or M.W.	486	282
ratio	100	58
weight loss (%)		42

and 18–20, t.fs. were lower than 0.45, that is 0.39, 0.36 and 0.29 respectively. The possibility of getting lower values than 0.45 originates from the dry weight loss due to the transformation of carbon-poorer reserved substances into carbon-rich seed component. Starch, for instance, loses 42 percent of its weight after being transformed into oleic acid (main fatty acid of peanut oil) as explained in table 2.

3. Relationship between t.f. and distribution ratio of dry weight to seed in ripening stage.

In ripening stage, the following two factors bring about decrease in t.f. One is the increase in carbon-percentage in a whole plant due to the rapid increase of seeds rich in carbon. The other is the loss of dry weight due to the transformation of reserved substances into seed component. Hence, it is naturally supposed that the t.fs.

may be dependent on the distribution ratio of dry weight to seed.

The distribution ratio (X) corresponding to each value of t.fs. in ripening stage appeared in table 1 were plotted against t.f. values (Y), as shown in fig. 2. The relationship between the two was expressed by the following parabolic empirical equation obtained by the method of least squares.

$$Y = 0.049X^2 - 0.258X + 0.640 \quad \dots\dots\dots (1)$$

where X and Y are distribution ratio of dry weight to seed ($\Delta W_s/\Delta W$) and t.f. respectively. Just before the beginning of pod filling ($t_2=10$), t.fs. were in most cases 0.64. So that the equation was arranged so as to take the value 0.64 at $X=0$ before the calculation of the least squares. In this equation, Y value begins to increase when X exceeds 2.633. This may be incompatible with facts. So that the equation may be valid within the range of X below about 2.5. The experimental values of t.fs. deviated wider from the curve of equation (1) as the distribution ratio increased. But as a whole, the equation fitted fairly closely to the distribution of experimental values and the coefficient of multiple correlation between the experimental values of t.fs. and their corresponding Y values calculated by equation (1) was 0.991 (d.f.=33).

4. Empirical equation for the varieties whose seeds are richer in oil or in protein.

The equation (1) must be modified somewhat for the varieties whose seeds are richer in oil or in protein than the variety Azumahandachi used in this experiment. Its modification was discussed here.

Matured seeds of some leading varieties of peanut were analyzed as to carbon-percentage as shown in table 3. Oil and protein percentage were cited from some different reports, so that the values can not be strictly compared mutually. But as a whole carbon-percentage is higher, as naturally supposed, in the seeds which are richer in oil plus protein. The ten varieties can be divided into two groups. Seeds of group 1 have oil plus protein percentage above 80, and those of group 2 have the percentage below 80. Group 1 has mean carbon-percentage of 63.3 and group 2, 61.0. Matured seeds of Azumahandachi used in this experiment had carbon-percentage of 61.0, so that this variety may be regarded as a re-

presentative of group 2. While Sachihomare, whose seeds had carbon percentage of 63.3, may be chosen as a representative of group 2.

Change in carbon-percentage in seeds of Sachihomare at the last six samplings (cf. fig. 1) was estimated, in the light of the case of Azumahandachi, as follows;

$$54.7 \rightarrow 58.0 \rightarrow 60.6 \rightarrow 62.5 \rightarrow 63.3 \rightarrow 63.3\%$$

Substituting the figures from carbon analysis of seeds of Azumahandachi, with these estimated figures, t.fs. and distribution ratio of dry weight to seed for Sachihomare were calculated to find the modified empirical equation as follows;

$$Y = 0.052X^2 - 0.284X + 0.640 \dots\dots\dots (2)$$

The equation (2) may be valid within the range of X below about 2.5 as was the case with equation (1). The Y values of equation (2) at $X=1$ and $X=2$ were lower than those of equation (1) by about 0.02 and 0.04 respectively (fig. 2).

Thus, it is recommended to choose the equation (1) for the varieties whose seeds have oil plus protein percentage below 80 and the equation (2) for the varieties whose seeds have oil plus protein percentage above 80.

SUMMARY

The transformation factor from carbon dioxide net assimilation to dry weight for peanut plant (*Arachis hypogaea* L.) was examined by measuring increases per plant in each two weeks after sowing both in dry weight and in carbon weight.

1. Transformation factor was dependent both on the stage of growth and choice of sampling term t_1-t_2 . The factor was almost constant (0.64~0.65) before the start of pod filling and after that it decreased as growth stage advanced and as the sampling term t_1-t_2 was fixed shorter. In ripening stage the factors tended to be lower than those of soybean plant. The minimum value observed was 0.29.

2. Seed was the richest in carbon of all the organs. But the factor was sometimes far lower than the value calculated from the carbon content of seed.

3. In ripening stage, the factor decreased

Table 3 Carbon, protein and oil percentage in seeds of some leading varieties of peanut

percentage		carbon	protein	oil	oil + protein
variety					
group 1	Tachimasari	63.9	28.3	52.5	80.8
	Hōtakuchūryū*	63.8	37.2	53.4	90.6
	Sachihomare	63.3	28.2	54.8	83.0
	Valencia*	62.8	22.9	58.4	81.3
	Hakuyu 7-3	62.8	27.5	56.0	83.5
	mean	63.3	28.8	55.0	83.8
group 2	Benihandachi	62.2	24.1	50.2	74.3
	Chibahandachi	62.0	26.1	52.9	79.0
	Azumahandachi	61.0	—	—	—
	Tekona	60.2	23.8	52.1	75.9
	Wasedairyū	59.7	28.5	45.3	73.8
	mean	61.0	25.6	50.1	75.8

* Protein and oil percentages of these varieties were cited from Shioiri et al. (1952)²⁾. Those of the other varieties were cited from Reference data on the new varieties of peanut. Shōwa 45, 47, 49. Chiba-ken Agr. Expt. Sta.

partly due to the increase in carbon content in a whole plant owing to the rapid increase in seeds rich in carbon, and also due to the loss of dry weight after transformation of reserved substances into seed component.

4. The factor (Y) in ripening stage was dependent on the distribution ratio (X) of dry weight to seed. The factor decreased as the ratio increased. The relationship between the two was expressed by the following parabolic empirical equations within the range of X below about 2.5.

$$Y=0.049X^2-0.258X+0.640 \quad \text{.....(1)}$$

$$Y=0.052X^2-0.284X+0.640 \quad \text{.....(2)}$$

The equation (1) is for the varieties whose seeds have oil plus protein percentage below 80 and the equation (2) is for the varieties whose seeds have oil plus protein percentage above 80.

5. One can estimate transformation factor for peanut plant of one's own cultivation by choosing either of the empirical equations mentioned before and substituting the estimated distribution ratio of dry weight to seed for X .

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〔和 文 摘 要〕

作物における二酸化炭素純同化量より乾物重への換算率

第2報 落花生

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落花生アズマハンダチを供試し、播種後2週間おきの個体乾物重および個体炭素重の増加量を測った。これらの数値をもとに次式により二酸化炭素純同化量から乾物重増加量を推定するための換算率を算出した。

$$\text{換算率} = \Delta W (\Delta C \times \text{CO}_2 / C)^{-1}$$

ただし ΔW , ΔC はそれぞれ考慮の対象となる期間内の個体乾物増加量および個体炭素増加量である。

1. 換算率は個体の生育ステージおよび対象期間の長短により変化した。粒肥大初期までは 0.64~0.65 でほぼ一定であったが、それ以後は生育が進むにつれて、また対象とする期間が短いほど換算率は低下した。収穫直前の2週間における換算率は 0.29 となり著しく低かった。

2. 子実は炭素含有率の最も高い器官であったが、登熟期後半においては、子実の炭素含有率から算出される換算率 0.45 より低い値が算出される場合があった。

3. 登熟期には次の2つの原因により換算率が低下した。第1には炭素含有率の高い子実の肥大により個体の炭素含有率が高まるためであり、第2には炭素含有率の比較的低い貯蔵物質が、炭素含有率の比較的高い子実成分に変換する際に乾物重が減少するためである。

4. 登熟期には子実への乾物分配率 (X) が高まるほど換算率 (Y) が低下し、両者の関係は下記の拋物線の一部 ($0 \leq X < 2.5$) により近似された。ただし (1) 式は子実成分：油脂+蛋白が 80% 以下の品種の場合、(2) 式は 80% を超える品種の場合である。

$$Y = 0.049X^2 - 0.258X + 0.640 \dots\dots\dots (1)$$

$$Y = 0.052X^2 - 0.284X + 0.640 \dots\dots\dots (2)$$

5. 対象とする実験材料の子実成分の組成により上記の実験式を選択し、対象とする実験期間における子実への乾物分配率を推定して代入し、おおよその換算率を推定することが可能である。