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Studies on the Nitrogen Economy and Primary Production of a *Helianthus annuus* Population

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해바라기 群落의 一次生産과 窒素經濟

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ABSTRACT

The nitrogen economy and primary production of a *Helianthus annuus* "Manchurian" population were studied with special reference to the pattern of seasonal changes of vertical distributions of dry matter and nitrogen quantities, and its quantitative significance was discussed in relation to the pattern of the plant poulation growth, distribution ratios among organs, and turnover rates of dry matter and nitrogen.

The population was established in plant density of 11.1 plant/m^2 at the experimdntal field of Kyungpook National University, Daegu. During the period of population development (April-September, 1973), the annual inflow rates and outflow rates of dry matter and nitrogen were 5560 gDM/m^2/year and 89 gN/m^2/year, respectively. The distribution ratios of dry matter and nitrogen to leaves were 28% and 45%, to stems 48% and 18%, to roots 13% and 5%, and to flowers and seeds 11% and 32%, respectively. The maximum turnover rates of inflow of dry matter and nitrogen were attained in May-June, and were 216%/month and 210%/month, respectively. The amount of nitrogen demand was 52gN/m^2/year (58%) for the foliage growth, 13 gN/m^2/year(15%)for the stem growth, 20 gN/m^2/year(23%) for the reproductive organs, and 4 gN/m^2/year(4%) for the growth of the underground parts. The amount of nitrogen supply by the nitrogen withdrawn from senescing leaves and stems was 25 gN/m^2/year(28%) and the amount of nitrogen absorption by the root from the environmental soil was 64 gN/m^2/year(72%). The ratio of the a mount of produced dry matter to that of assimilated nitrogen during a year was calculated for this annual plant population as 60, which can be used as the nitrogen utility index.

INTRODUCTION

Recently, many field experiments have brought about good examples of the fact that dry matter production is a material basis of the plant life, and is materialized through photosynthesis — the key function of the plant. In the research concerning the primary production of plant population, i.e. dry matter production, successful methods were developed, e.g. by Boysen Jensen(1932), Monsi and

Saeki(1953), Midorikawa(1959), and Kira and Umesao(1961) (cf. also Milner and Hughes, 1968; Newbould, 1967) To understand the actual status of matter economy, it may be required to larger extent to construct the integrated figure of the plant community, since dry-matter production and mineral uptake or other functional aspects are intimately connected with each other by forming a particular structure of each plant population.

Nitrogen does not take part directly in the energy metabolism, is a more structural component of organisms than the other bioelement. The nitrogen assimilation by a plant population in relation to dry-matter production is regarded as a major limiting factor for the growth of organsims and the most important bioelement among essential elements in a quantitative sense. With special reference to nitrogen metabolism, an attempt was made to specify the pattern of seasonal changes of dry-matter and nitrogen assimilation of a perennial herb community in a stable state and made clear the relation of the nitrogen economy to the dry-matter growth, taking into consideration the nitrogen movement in the plant body and nitrogen budget of the population(Hirose *et al.*, 1970; Hirose, 1971; Song and Monsi, 1974). The method is considered to be very useful in the analysis of dry-matter production and nitrogen budget of the population dynamics.

The present study deals with the nitrogen economy and primary production of *Helianthus annuus* "Manchurian" population grown from seeds to a mature stage. The primary productivity of this annual population had been intensively studied from the view point of comparison of the maximum production rates between seven localities in Korea (Kim *et al.*, 1974)(cf. also Hogetsu *et al.*, 1960; Hiroi and Monsi, 1966).

MATERIAL AND METHODS

Helianthus annuus "Manchurian" was used as material in the present experiments. The carefully selected seeds(excluding seed coat, 0.45g in an air dry weight) were sown on a field of 5 are of the experimental nursery of Kyungpook National University at Daegu, on April 17, 1973. The soil mainly consisted of sandy loam, containing 0.16% of nitrogen and pH6.5 of acidity, and was sufficiently fertilized with chemical fertilizer(N, 2.5 kg/a;P, 1.0kg/a; K,1.5kg/a) and compost(20kg/a) prior to the sowing. The planting density, 11.1 plant/m^2, was employed in square disposition with spacing of 30cm. During the experimental period no unusual climatic conditions were observed in the field and the population developed normally (Kim *et al.*, 1974).

Experimental measurements were carried out two weeks after sowing at intervals of a week until the seed maturing period. On every sampling occasion we chose 10 or 15 plants of average diameters without edge effects from the randomized block design. The aerial parts of the sample plants were clipped in every 20cm depth from top to base. Then the plant parts were separated into two systems, photosynthetic and non-photosynthetic. Underground part of the population was carefully dug out and washed thoroughly to remove soil particles. After being measured in fresh weight, all of these samples were oven-dried at 80°C to obtain their dry weight and to be prepared for determination of the total nitrogen content by microkjeldahl method. Before drying, subsamples of leaves were copied directly onto the sheet of photographic paper to determine the leaf area with a planimeter.

RESULTS AND DISCUSSIONS

1. Seasonal changes of dry-matter standing crop

Seasonal changes of dry-matter accumulation in each organ of the *H. annuus* population are shown in Fig. 1. The population attained to the maximum standing crop of 3180g dw/m^2 in September, to the maximum leaf area index(LAI) of 10.2 in July, and to the maximum height of 325cm in August. The flowering in the middle of July brought about the seed production of 550g dw/m^2 through September.

The ratios of top to root(T/R) and non-photosynthetic system to photosynthetic one(C/F) at the maximum LAI period were 6.14 and 4.40,

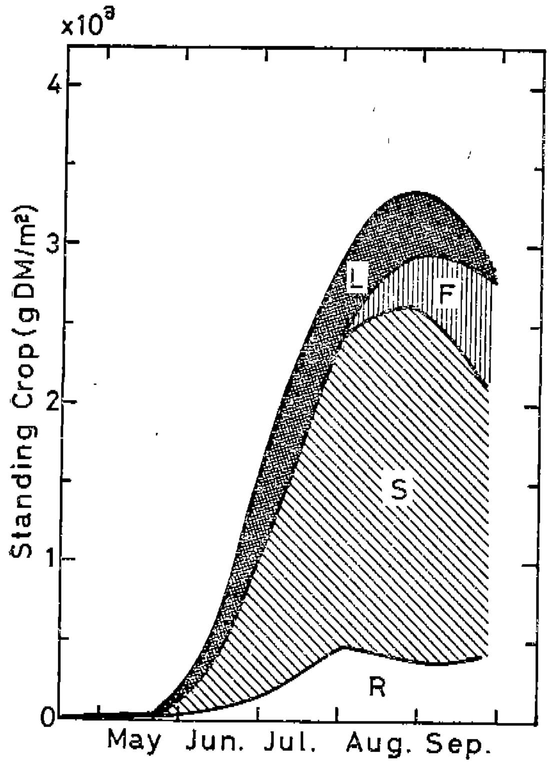

Fig. 1. Standing crops of dry matter of the *Helianthus annuus* "Manchurian" population from April to September. L, foliage; S, stems; F, flowers and fruits; R, roots.

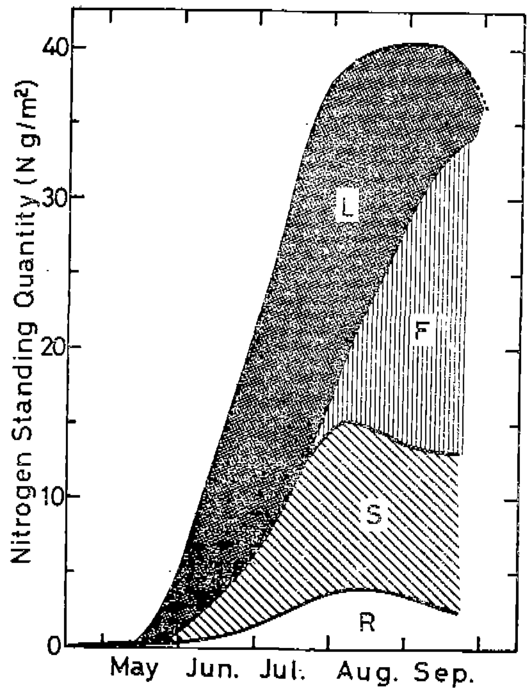

Fig. 2. Seasonal changes of nitrogen standing quantity of the *H. annuus* population. L,foliage; S, stem; F. flowers and fruits; R. roots.

respectively. The maximum values of relative growth rate(RGR), net assimilation rate(NAR), leaf area ratio(LAR), and crop growth rate(CGR), were 1.48g dw/g/week(in May), 125.6g dw/m² leaf area/week(in May), 147.8cm²/g(in May) and 438.2g dw/m²/week(in June), respectively. The efficiency of solar energy utilized by this population was 2.36% on an average during the growth period.

2. Seasonal changes of nitrogen standing quantity

Seasonal changes of the total nitrogen quantity of the population are summarized in Fig. 2. The nitrogen quantity of each organ could be estimated by multiplying the nitrogen percentage of each stratum and organ from the productive structure by the corresponding biomass as described in the later(see Fig. 3b). The growth pattern in terms of total nitrogen was similar to that in terms of dry matter, though the properties of distribution among organs were different between nitrogen and dry matter.

The maximum quantity of total nitrogen in the population was 41gN/m² in August, and the amount of nitrogen for seed production was 20gN/m² in September. The T/R and C/F ratios in terms of nitrogen quantity at the maximum LAI period were 38.5 and 0.59, respectively.

3. Vertical distribution of dry matter and nitrogen

The population structure in terms of vertical distribution of dry matter in individual organs and its development from May to September are depicted in Fig. 3a. They were constructed by applying the stratified clip technique (Monsi and Saeki, 1953). The underground part was also in-

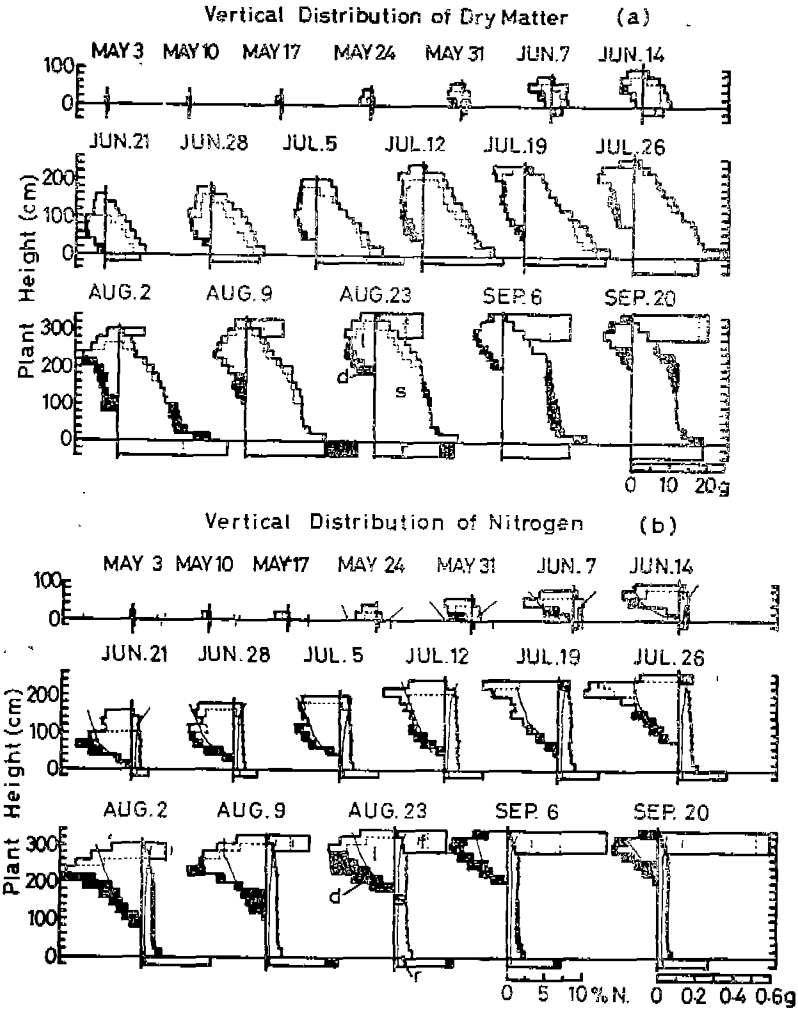

Fig. 3. Vertical distributions of dry matter (a) and nitrogen (b) in the *H. annuus* population. l, s, f, and r stand for leaves, stems, fruits and roots. Black parts show the loss by death or shedding. Nitrogen contents(%) are given in thin lines(or segments) in b at corresponding quadrant and stratum.

cluded in the fourth quadrant of the diagram.

The nitrogen content changed by the strata of each organ in a close connection with the growth pattern(see Fig. 3b, thin lines or segments). The diagrams which signify the vertical distribution of the standing quantity of nitrogen were constructed by multiplying the nitrogen percentage on a dry weight basis by the dry-matter profiles of the corresponding strata and organs(Fig. 3b).

These diagrams depicted the seasonal changes in the patterns of spatial accumulation of dry matter and nitrogen in the population. Dry matter was distributed more in the non-photosynthetic system(stems) than in the photosynthetic system (foliage), while nitrogen was accumulated in the photosynthetic system. Nitrogen quantity in the stems was not changed greatly along with the height as stated in other species(Iwaki and Kuroiwa, 1965; Hirose, 1971; Song and Monsi, 1974). The amount of nitrogen in the foliage showed great seasonal changes as a result of the development of production system.

To determine the newly ɛdded biomass by the net production(including translocation from other parts) and the old lost biomass by shedding(including translocation to other parts), the growth of respective organs in the plant population was analysed by comparisons of the two successive profile diagrams in Fig. 3; the area enclosed by thick lines, excluding the area of dotted lines, represents the new added biomass, and the area enclosed by dotted lines, excluding the area of thick lines, represents the old lost biomass(black parts in the diagrams).

4. *Net production*

The successive applications of stratified clip technique to respective organs gave the real feature of the growth of plant population, for the changes

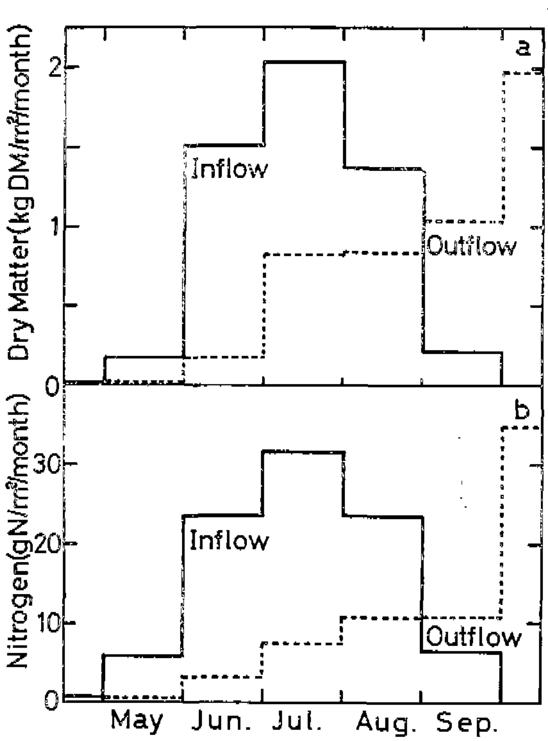

Fig. 4. Seasonal trends of the monthly net production of dry matter (a) and of the monthly net nitrogen assimilation (b) of the *H. annuus* population.

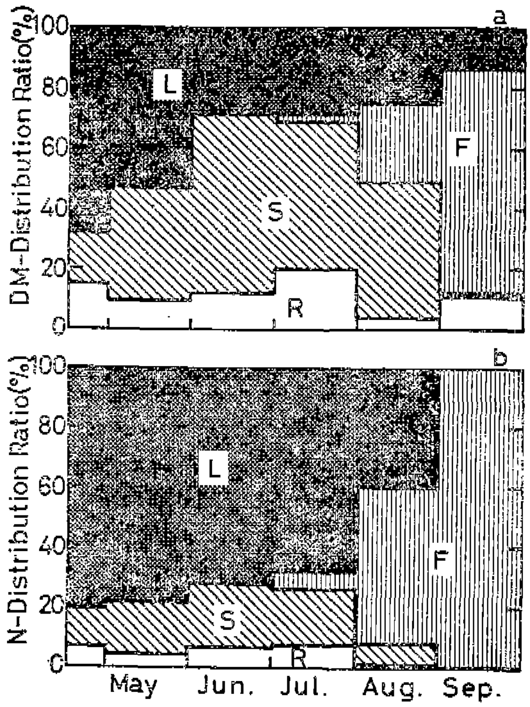

Fig. 5. Monthly distribution ratios of net production of dry matter (a) and of not nitrogen assimilation (b) to leaf(L), stem(S), fruit(F) and root(R) in the *H. annuus* population.

of biomass or of standing quantity resulted in gain. The rate of withdrawn of dry matter aed nitrogen from the senescing leaves was assumed to be 10 and 50 percent, respectively(Iwaki *et al.*, 1969; Oland, 1963). The monthly changes of annual net production were estimated as shown in Fig. 4. The annual inflow rates(Rin) and outflow rates (Rout) of dry matter and nitrogen were 5560 g DM/m²/year and 89 gN/m²/year, respectively. The total annual Rin is equal to the total annual Rout. Fig. 4a represents the seasonal changes of monthly Rin(net production) and Rout(litter production) of this *H. annuus* population. The seasonal trends of Fin shows a bell-shaped pattern with a peak of 2(30 gDM/m²/month in June-July.

The distribution ratios of the total dry matter to each organ in month are illustrated in Fig. 5a. The annual distribution ratio to the leaves was 28%, to the stems 48%, to the roots 13%, and to the flowers and seeds 11%. The differences in the allotment and distribution ratios are considered to bring about large difference not only in total dry weight of the plants but also in their constitution, i.e. in the structure of the plant as productive systems (Monsi, 1960; Kuroiwa, 1960).

The monthly net nitrogen assimilation of the *H. annuus* population is presented in Fig. 4b. The peak appeared during June-July, and was 24 gN/m²/month. The monthly distribution ratios of net nitrogen assimilation to each organ are shown in Fig. 5b. The largest was to the leaves; it was 45% of the annual net nitrogen assimilation of the population. To the stems it was distributed 18%, to the roots 5%, and to the flowers and seeds 32% of the annual net nitrogen assimilation.

5. Turnover rate

Seasonal trends of monthly turnover rates of inflow and outfow of dry matter and nitrogen in the population are presented in Fig. 6. The term "turnover rate" was calculated as the rate of inflow or outflow of matter to the mean standing crop at a month interval during the population growth period(Odum, 1960; Reiner, 1953). The inflow of dry matter and nitrogen attained to the maximum turnover rates in May-June, and were 216%/month and 210%/month, respectively. Seasonal changes of turnover rates of inflow and outflow of dry matter were similar to those of nitrogen from May to September, though the latter was somewhat lower.

6. The demand and supply of nitrogen

It is assumed that nitrogen assimilation is dependent on photosynthetic processes, and dry-matter production is dependent on nitrogen assimilation (Joy, 1967). The ratio of the amount of dry matter produced to that of assimilated nitrogen during a year (annual Rin of dry matter/ annual Rin of nitrogen), i.e. the nitrogen utility index (NUI) was 60 in this popolation, which was implied as an important indicator of the population function of the annual herb plant in relation to the ecosystem metabolism. The reciprocal of NUI is 1.6, meaning the average nitrogen content(%) of the newly produced matter(cf. Ovington, 1959; Midorikawa *et al.*, 1963; Rodin and Bazilevitch,

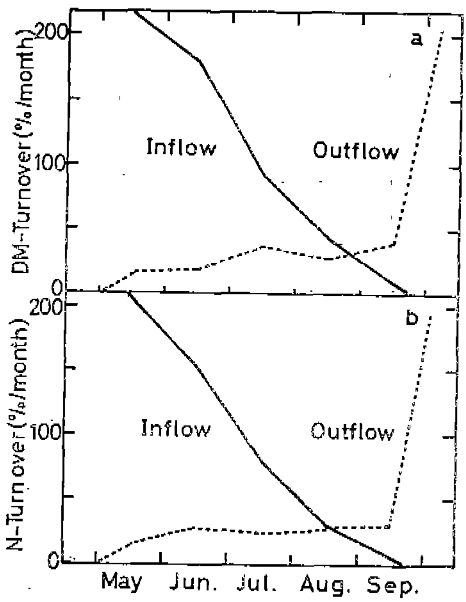

Fig. 6. Seasonal trends of monthly turnover rates of inflow (solid line) and outflow (dotted line) in dry matter (a) and nitrogen (b) in the *H. annuus* population.

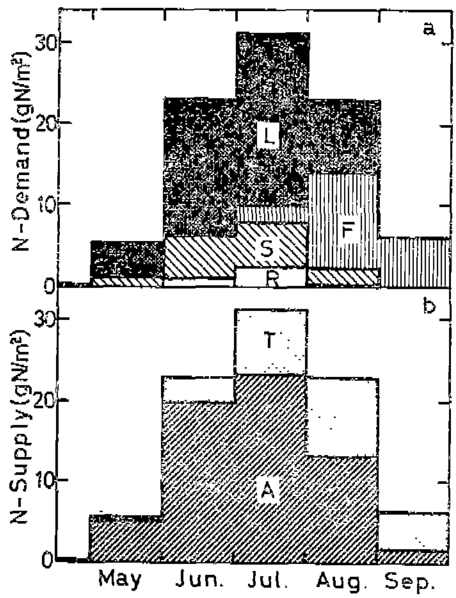

Fig. 7. Changes of monthly nitrogen demand and supply of the *H. annuus* population.
Demand (a): L, foliage; S, stems; F, fruits; R, roots. Supply (b): A, the nitrogen absorption; T, the nitrogen translocated from leaves and stems.

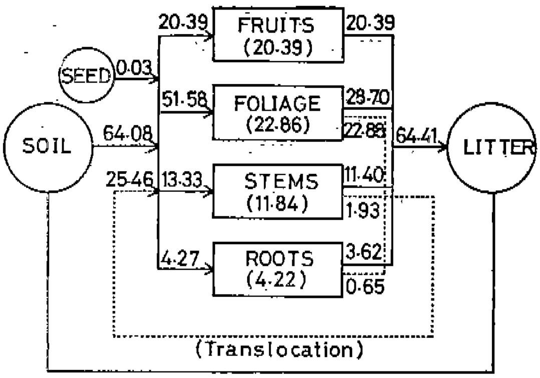

Fig. 8. Annual nitrogen budget in the *H. annuus* population.

Numbers on arrow indicate the flux rates in $gN/m^2/year$, and those in parentheses, the maximum standing quantity in gN/m^2.

1967).

Seasonal trends in the nitrogen requirements for the growh of organs and their supplies of the *H. annuus* population is illustrated by Fig. 7a and b. As mentioned in the net production above a large demand of nitrogen($89gN/m^2$) was observed from May to September for the population development, especially of the foliage, which coresponded to the rapid dry-matter growth. Of the total nitrogen demand, 52 $gN/m^2/year$ (58%) were allotted to the foliage growth, $13gN/m^2/year$(15%) to the stem growth, 20 $gN/m^2/year$(23%) to the reproductive organs, and 4 $gN/m^2/year$(4%) to the growth of underground parts.

These demands were partly supplied by the nitrogen withdrawn from senescing leaves and stems, i.e. 25 $gN/m^2/year$(28%). The supply by nitrogen absorption from soil, which is primarily important, was 64 $gN/m^2/year$(72%) of the total nitrogen demand.

In this annual herb plant population, the nitrogen quantity of the seed harvest is equivalent to one forth of the total demand or one third of the nitrogen absorption from soil. A relatively large amount of nitrogen due to the litter decomposition must be fertilized to the environmental soil.

Fig. 8 summarized the annual nitrogen budget of this developing *H. annuus* population from April of the sowing to September of the harvest.

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