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Effect of Nitrogen Applications on the Growth and Primary Production of Soybean Population

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窒素勾配에 따른 大豆個體群의 生長 및 一次生產性

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ABSTRACT

Growth analytical and primary productivity experiments of soybean populations were conducted with special references to the development of productive structures and environmental conditions of nitrogen levels (N_1, control; N_2, 6.67gN/m^2; N_3,13.34gN/m^2). The maximum amounts in LAI for N_1, N_2 and N_3 stand were 17.3, 19.0 and 18.5; in total standing grops, 1570, 1785 and 1704gDM/m^2; in total net productions, 543, 648 and 636gDM/m^2, respectively. The maximum CGR attanined were 208, 237 and 272 gDM/m^2/week, while the mean EU was 2.55, 2.92 and 2.84% for N_1, N_2 and N_3, respectively. The total nitrogen standing quantity attained 53.4, 71.8 and 59.8 gN/m^2 at the maximum standing crop period. The net nitrogen absorption rates showed highly significant differences among nitrogen treatments, i.e., 1.34, 10.77 and 13.22 mg/g/day for N_1, N_2 and N_3 stand, respectively.

Introduction

There have been considerable recent investigations on the assessments and utilizations of primary productivities and on the production processes of ecosystem by ecologists and agriculturists from the recognition of the world wide problems of population increment, food shortage, energy and resource deficiencies[3,6,7,8]. As useful methods a series of growth analytical and matter dynamic experiments were conducted with some important crops of various environmental gradients and a good number of results have been accumulated[1,2,5,8,10]. In this study we attempted to clarify the effects of environmental nitrogen levels on the growth analytical characteristics and production processes of the soybean population throngh its productive structural development.

Materials and Methods

Material used in this experiment is a high yield variety of soybean, *Glycine max* Merr, cv. Kwanggyo population grown at the Experimental Field of Suengju middle school, covering an area of about 60m^2. Soil consists of sandy loam and was controlled to pH 7.0 by applying CaO. Three gradient treatments of nitrogen were made as N_1 (control), N_2 (6.67 gN/m^2) and N_3 (13.34gN/m^2) in addition of P_2O_5(6.67gP/m^2) and K_2O (6.67 gK/m^2). Seeds of uniform size were selected by weight (0.25g) and sown at a regular distance of 20cm from each other in line pattern. On every 2 weeks after sowing samplings were made for 20plants by randomized block design. Subsamples were clipped in 20cm stratum, separated and measured the fresh and dry weight of each organ. Leaf area was determined by punch method. As comparisons among nitrogen treatments seasonal trends of biomass were analyzed by the growth charateristics and matter dynamics through productive structural development[1,4,5]. Nitrogen amount was determined by micro-Kjeldahl method[6,9]. All the meteorological data were obtained from Suengju branch station and observed as normal during the period (Fig. 1).

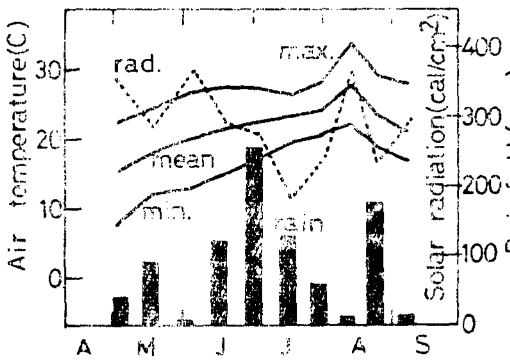

Fig. 1. Changes of average meteorological data observed in the experimental area during the growing season

Results and Discussion

1. Growth analysis

The population attained to the maximum plant height of 130~132cm in early August. The maximum leaf area indices (LAI) attained in N_1 stand was 17.3 in early August, but those in N_2 and N_3 stands were 19.0 and 18.5 appearing two weeks earlier (Fig. 2). The maximum specific leaf area (SLA) for N_2 and N_3 stands appeared to be 496 and 486cm^2/g in early July, but that of N_1 appeared to decline by 478cm^2/g on two weeks later.

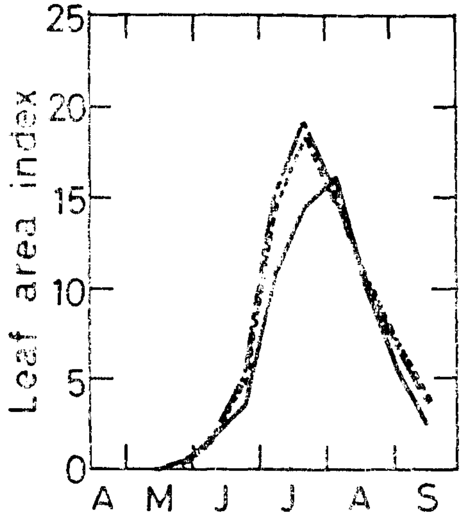

Fig. 2. Changes of leaf area indices of soybean populations: N_1,——; N_2,-—-; N_3,……

As shown in Fig. 3 the maximum standing crops for N_1, N_2 and N_3 stands attained 1570, 1785 and 1704 gdw/m^2 respectively in the middle of September. Seed productions showed also the highest in N_2 stand (648gdw/m^2) in comparing with N_1 (543gdw/m^2) and N_3 (636gdw/m^2) stands. On the contrary, the seasonal changes of nodules formation during the population development were affected significantly by nitrogen treatment gradients, the maximum amount appearing 38, 15 and 10gdw/m^2 for N_1, N_2 and N_3 stand, respectively on early August.

The seasonal changes of F/C ratios showed the maximum of 1.33~1.35 during the earlier stage then gradually decreased in each stand

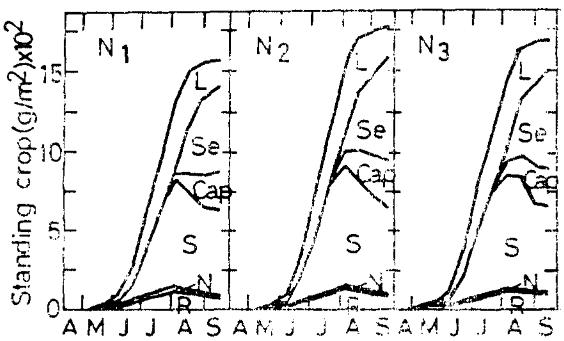

Fig. 3. Changes of standing crops of soybean populations: L, leaves; S, stems: N, nodules; Se, seeds; Cap, capsules.

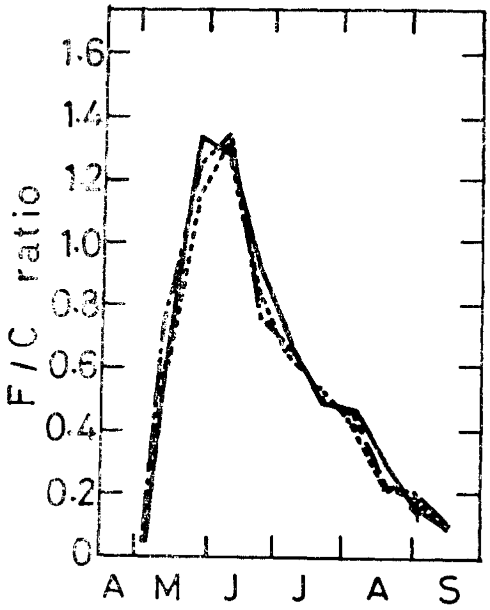

Fig. 4. Changes of F/C ratios of soybean populations: N_1,——; N_2,—·—; N_3,·······.

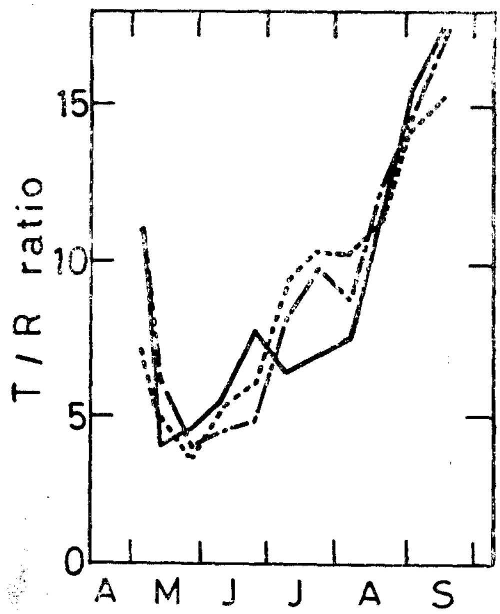

Fig. 5. Changes of T/R ratios of soybean populations: N_1,——; N_2,—·—; N_3,·······.

(Fig. 4). The seasonal changes of T/R ratios showed the minimum of 3.8~4.2 in the earlier stage and the maximum 17.5~15.1 in the later stage for each stand (Fig. 5). The seasonal changes of relative growth rate (RGR, $1/W \cdot dw/dt = (\ln W_2 - \ln W_1)/(t_2 - t_1)$), showed the max-

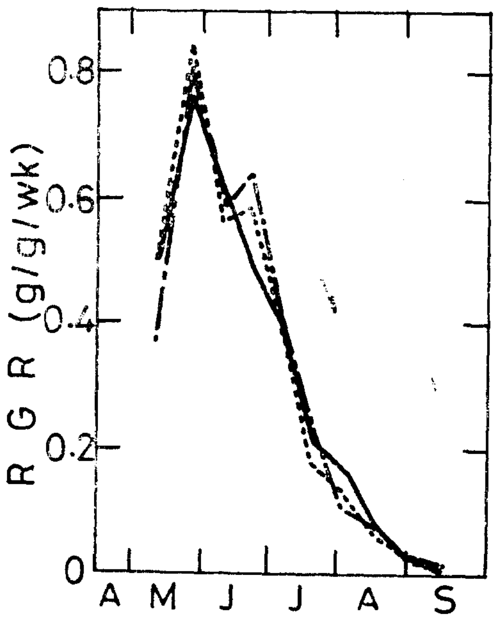

Fig. 6. Changes of RGR of soybean populations: N_1,——; N_2,—·—; N_3,·······.

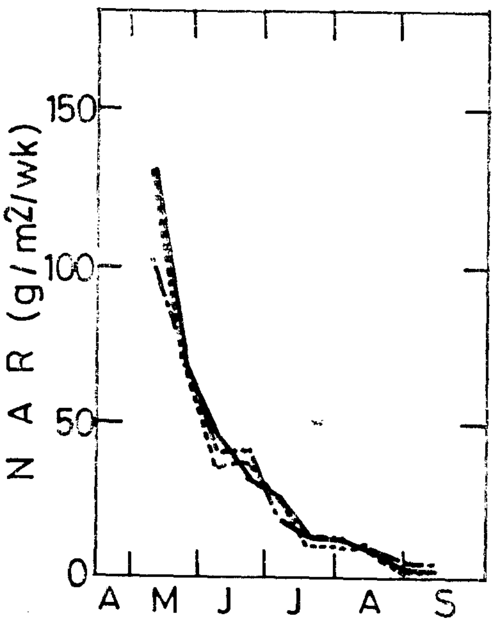

Fig. 7. Changes of NAR of soybean populations: N_1,——; N_2,—·—; N_3,·······.

imum of 0.768–0.840g/g/week in the early stage, then gradually decreased to the minimum values for all the stands (Fig. 6). The relationships between RGR and mean temperature showed negative correlations ($r=-0.75$). But there were no significant relationships between RGR and radiation($r=0.45$). The seasonal changes of net assimilation rate (NAR, $1/L \cdot dW/dt = (lnL_2-lnL_1)(W_2-W_1)/(L_2-L_1)\ (t_2-t_1)$), showed the maximum of 100~130 gdw/m²/week in early period and no significant differences among nitrogen treatments (Fig. 7).

The relationship between NAR and mean temperature shewed a negative correlations ($r=-0.85$), but the NAR like RGR had no significant relationship with radiation ($r=0.56$). The seasonal trends of crop growth rate (CGR,$dy/dt = (lnL_2-lnL_1)\ (W_2-W_1)/(t_2-t_1)\ (L_2-L_1)\times(L_2-L_1)/$

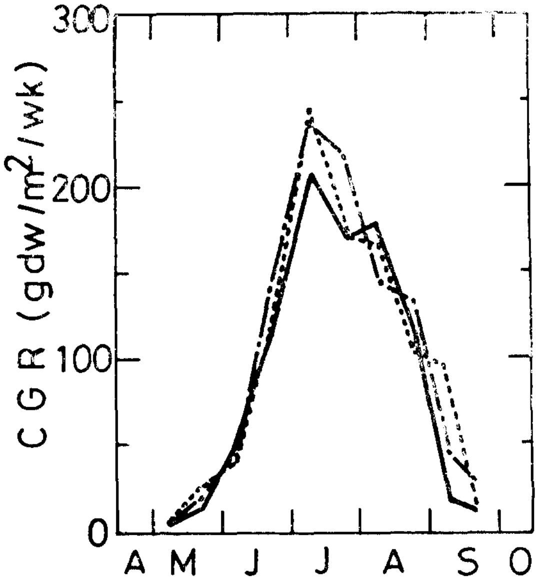

Fig. 8. Changes of CGR of soybean populations: N_1,; N_2,; N_3,.

Table 1. Net productions and their distributions for each organ in the soybean populations (gDM/m²)

N_1	Date					Total
	5.5~5.27	5.28~6.22	6.23~7.20	7.21~8.18	8.18~9.14	
leaves	20.8	112	333	145	—	610
stems	8.0	8.5	423	165	—	677
fruits	—	—	4.0	418	356	778
roots	5.8	37.8	48.5	20.0	—	112
nodules	0.3	9.8	14.5	15.5	—	40.1
Total	34.9	241	822	764	356	2,218
N_2						
leaves	20.3	140	360	188	2.5	710
stems	7.5	130	500	148	—	785
fruits	—	—	3.5	547	389	939
roots	6.3	43.5	47.5	35.0	—	132
nodules	0.8	7.8	4.0	2.5	—	15.1
Total	34.9	321	915	919	391	2,581
N_3						
leaves	21.5	185	408	82.5	25.0	685
stems	9.8	126	494	145	10.3	785
fruits	—	—	1.8	500	393	894
roots	7.5	38.0	47.5	20.0	—	113
nodules	1.5	4.8	1.8	4.0	2.5	14.6
Total	40.3	318	952	752	430	2,492

Table 2. Efficiencies of solar energy utilization of soybean populations (%)

Treatment	Date					Total Mean
	5.5~5.27	5.28~6.22	6.23~7.20	7.21~8.17	8.18~9.14	
N_1	0.25	1.72	6.11	4.38	1.31	2.55
N_2	0.25	2.48	6.74	5.88	2.40	2.92
N_3	0.29	2.43	6.59	4.42	1.84	2.84

(lnL_2-lnL_1)), showed the maximum values of 208, 237 and 272 gdw/m²/week for N_1, N_2 and N_3 stands, respectively in the exponential growth period from the end of June to early July (Fig. 8).

2. Dry matter production and distribution pattern

The seasonal pattern of vertical distribution of the population standing crop so called productive structure showed no significant variation among nitrogen treatments[4]. The net production estimated by adding of all net gain from each period is summarized in Table 1.

The annual net production attained to 2581g/m² for N_2, 2492g/m² for N_2 and 2217 g/m² for N_1 stand. The distributional ratios to each organ showed 27.5~27.6, 30.4~31.5, 4.5~5.1, 0.6~1.8 and 35.0~36.4% for leaves, stems, roots, nodules and seeds, respectively. Leaf and root growth occupied 53.6~59.5% and 16.7~18.8% of the total net production in the early period and seed growth occupied the main part of the population in the later period.

The efficiencies of solar energy utilization (EU) showed seasonal changes as presented in Table 2. The maximum and minimum EU values were 6.11 and 2.55% for N_1, 6.74 and 2.92% for N_2, 6.59 and 2.84% for N_3 stand, respectively.

3. Nitrogen assimilation

Nitrogen contents of leaves, stems, roots and nodules were very high in the early period as 8.99~9.68, 8.23~8.59 and 5.63~6.22%, then decreased rapidly in the end of the population growth as 3.00~3.29, 0.80~1.20, 1.01~1.30 and 5.00~5.99%, respectively. Seed parts reserved

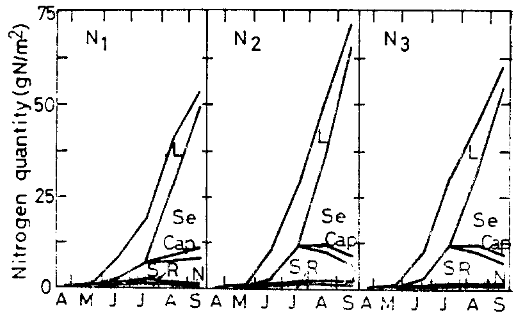

Fig. 9. Changes of nitrogen quantities of soybean populations: L, leaves; S, stems; R, roots; N, nodules; Se, seeds; Cap, capsules.

6.94~8.70% of nitrogen content. The total nitrogen standing quantity of the soybean population increased by moderate nitrogen fertilizer, i.e., 53.4, 71.8 and 59.8gN/m² for N_1,N_2 and N_3 stand, respectively at the maximum standing crop period (Fig. 9). While the average soil nitrogen contents at 0~30cm depth were 0.08~0.12, 0.12~0.17 and 0.13~0.16% for N_1, N_2 and N_3 stand, respectively. The annual distribution ratios of total nitrogen assimilation were 67.0~70.0% to leaves, 13.6~21.3% to stems, 6.7~9.4% to roots and 3.9~10.0% to nodules. At the end of the population development the largest share was 37.9~66.3 gN/m² in fruits, i.e., 71.0~78.0% of the total nitrogen quantity, twice higher than the distribution of dry matter production (34.6~37.1%).

4. Nitrogen absorption rate

The total nitrogen assimilations during the growing period were calculated as 73.5, 101.2 and 87.7gN/m² for N_1, N_2 and N_3 stand, respectively. The attributions by nirogen withdrawn from senescing ogans and nitrogen fixation by root nodules were estimated 60 and 9.3gN/m^2 for N_1 48 and 14.7gN/m^2 for N_2, 32 and 13.9g N/m^2 for N_3 stand, respectively. Therefore the nitrogen absorption from soil were 4.2, 38.5 and 41.7gN/m^2 for N_1, N_2 and N_3 stand, respectively. The average total nitrogen increment rates ($1/N \cdot dN/dt = (lnN_2 - lnN_1)/(t_2 - t_1)$) were 3.15, 3.38 and 3.26%/day for N_1,N_2 and N_3, respectively. While the average nitrogen absorption rates from soil were 1.09, 2.77 and 2.83%/day for N_1, N_2 and N_3 stand, respectively. The nitrogen net absorption rates by root system, so called specific absorption rate ($1/R \cdot dN/dt = (lnR_2 - lnR_1)(N_2 - N_1)/(R_2 - R_1)(t_2 - t_1)$), showed highly significant differences among nitrogen treatments, i.e., 1.34, 10.77 and 13.22mg/g/day for N_1, N_2 and N_3 stand, respectively.

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摘　　要

無施肥區, 窒素施肥區(6.67gN/m²) 및 過窒素施肥區(13.34gN/m²)의 窒素勾配處理에 따른 大豆個體群의 生育過程別 諸 生長解析的特徵 및 一次生産性을 比較檢討하였다. 窒素施肥區 및 過窒素施肥區에서는 對照區에 比해 8~10倍의 純窒素吸收率과 比較的 높은 生産性 및 最大 LAI의 到達이 2週程度 빨리 나타났고 SLA의 增加를 보였으나, 根粒의 形成은 $\frac{1}{3} \sim \frac{1}{4}$의 減少를 보였다. 그러나, H, F/C, T/R, RGR, NAR, 및 CGR 등 生長解析的特徵에는 큰 有意差가 없었다.

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