Geo-Eco-Trop, 1978, 2 (3) 375-389

INTRASPECIFIC COMPETITION IN GRASSLAND SPECIES II. *DESMODIUM TRIFLORUM* DESV.

K.C. MISRA & Aruna KOTHARI*

Résumé

Compétition intraspécifique dans des espèces de prairies. II. Desmodium triflorum Desv.

Les auteurs étudient l'influence de quatre niveaux de densité (17, 34, 67 et 135 plantes par mètre carré) dans une population de Desmodium triflorum sur la production de matière sèche, la teneur en azote, la surface foliaire, le volume des racines, la productivité primaire nette et le taux d'assimilation nette. Ils établissent que la production maximale de matière sèche peut être atteinte en maintenant un niveau optimal de densité, sans tenir compte de ses répercussions au niveau des individus.

Abstract

The authors follow the influence of four density levels (17, 34, 67 and 135 plants m^{-2}*) of Desmodium triflorum populations on dry matter production, nitrogen content, leaf area, root volume, net primary productivity and net assimilation rate. They establish that maximization of dry matter production can be achieved by maintaining an optimum density level, regardless of its repercussions on the individuals.*

INTRODUCTION

Legumes constitute a substantial proportion of the ground cover as well as of the primary production of the grasslands of Varanasi.

* Department of Botany, Banaras Hindu University, Varanasi 221005, India.

Of these, *Desmodium triflorum*, which forms excellent turf and adds to the quality and quantity of the forage (MOORE 1962) and to the agricultural productivity of the grasslands as a whole (SPEDDING 1971), is the most abundant and is also very much relished by cattle (DUTHIE 1960). Various ecological aspects pertaining to grazing, primary productivity and nutrient cycling of this perennial legume have been studied by NELIVIGI (1962), RAO (1970) and TRIPATHI (1970). Its population density exhibits a wide fluctuation depending upon the intensity and frequency of grazing (NELIVIGI 1962). Besides, its susceptibility to intraspecific competition may also have bearing on the structure and function of the grassland ecosystem (SINGH 1967). The findings reported in this paper are on some important ecophysiological responses of this forb to density, elucidating the effect of competition on the growth performance of the individuals as well as of the population.

MATERIAL AND METHODS

The procedures involved are essentially the same as those employed in the earlier publication (KOTHARI *et al.* 1974). Equal sized nodal cuttings of *D. triflorum* were planted on April 20, 1971 at four density levels of one, two, four, and eight nodal pieces per pot equivalent to 17, 34, 67 and 135 plants m^{-2}, respectively. Runners arising from one node have together been considered as one plant only. Leaf area was estimated with the help of the regression equation given below, derived between area and dry weight of the leaf (KOTHARI *et al.*, 1974);

$$Y = 0.26X - 0.06$$

where Y = leaf area (cm^2) and X = leaf weight (mg).

The dependent variables of plant growth investigated in the present study include moisture content in shoot on fresh weight basis, biomass, net primary productivity, nitrogen content (PAECH and TRACEY 1956) and its uptake rate, transpiration rate (CURTIS and CLARK 1950), and growth analysis parameters (RADFORD 1967, BLACKMAN 1968). Root weight ratio (RWR) was evaluated according to WELBANK (1962).

Table 1. Analysis of variance of dry weight and nitrogen content of *D. triflorum* at four levels of intraspecific competition.

Source of variation	df	Dry weight				Nitrogen content			
		Per Plant		Per m^2		Per Plant		Per m^2	
		MSS	Ratio	MSS	Ratio	MSS	Ratio	MSS	Ratio
Replicate	2	2.65	0.83^{NS}	3619.61	2.93^{NS}	1655.94	0.91^{NS}	2.24	2.94^{NS}
Density	3	12.18	3.85*	134902.43	109.42**	6391.28	3.54*	76.21	100.27**
Age	5	40.46	12.80**	89109.70	72.28**	21817.05	12.09**	47.49	62.48**
Density X Age	15	4.79	1.51^{NS}	13526.46	10.97**	2985.82	1.65^{NS}	8.25	10.85**
Error	46	3.16	-	1232.78	-	1803.65	-	0.76	-
Total	71								

* P = 0.05 ** P = 0.01 NS = Not Significant

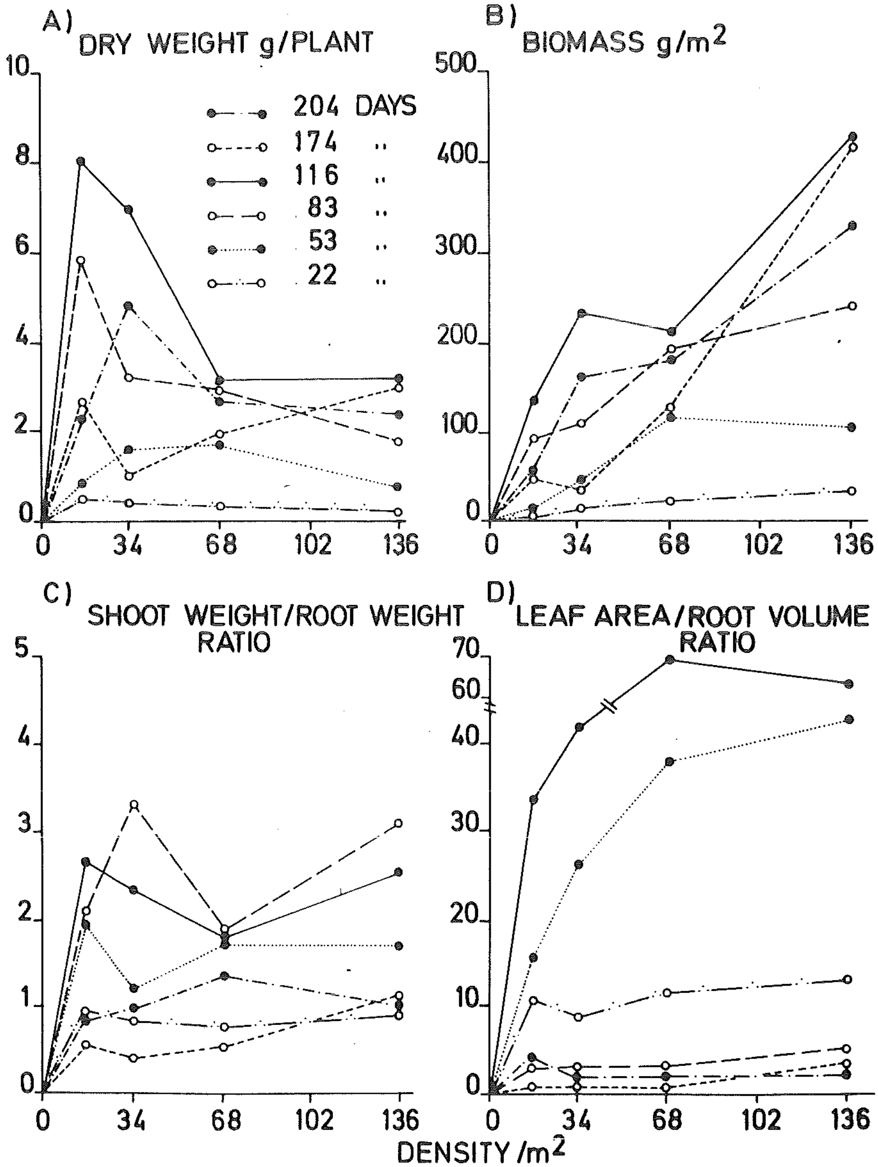

Fig. 1 : Variations in dry weight (g/plant, biomass (g/m^2), Shoot/ Root weight ratio (g/g) and Leaf area/Root volume ratio (cm^2/cc) of *D. triflorum* with density and age.

Table 2. Leaf area (cm^2) Root volume (cc) and Root weight ratio (RWR-g:g) of *D. triflorum* at four levels of intraspecific competition and six ages.

Age (days)	Parameters	Density m^{-2}			
		17	34	67	135
22	Leaf area	34.52	26.98	24.12	19.96
	Root volume	3.00	3.00	2.20	1.46
	RWR	0.50	0.53	0.56	0.53
53	Leaf area	89.90	112.22	159.84	68.06
	Root volume	5.66	4.16	4.16	1.55
	RWR	0.33	0.45	0.64	0.36
83	Leaf area	509.80	294.00	243.82	165.56
	Root volume	16.00	8.66	7.33	3.00
	RWR	0.31	0.23	0.35	0.24
116	Leaf area	662.94	468.94	259.94	250.06
	Root volume	19.66	11.16	3.75	3.87
	RWR	0.27	0.29	0.36	0.28
174	Leaf area	116.94	44.40	32.44	255.32
	Root volume	11.33	3.33	6.00	6.54
	RWR	0.61	0.70	0.64	0.46
204	Leaf area	100.30	210.54	99.00	110.46
	Root volume	2.29	11.00	5.00	4.45
	RWR	0.55	0.49	0.42	0.48

LSD at 5%. Leaf area = 66.57
Root vol. = 4.88
RWR = 0.04

Dry matter :

Dry weight of the individual plant was significantly influenced by density and age (Table 1). Increasing density reduced dry weight at almost all the ages yielding a significant negative correlation (r = - 0.87). With age, dry matter in the individuals of each density increased upto 116 days and declined subsequently (Fig. 1A).

Contrary to the individual plant, biomass of the population increased significantly in accord with density (r = 0.99). The age trend however, as similar to that of the individuals (Fig. 1B).

The shoot/root weight ratio does not show a distinct relation with density (Fig. 1C). Its peak was recorded in the 83 days old plants at all but the initial density wherein it continued to increase up to 116 days.

Leaf area and Root volume :

Leaf area and root volume were severely affected by competition stress up to 116 days (Fig. 1D). The size of both the assimilatory and absorptive organs increased with age at all densities up to 116 days (Table 2). The ratio of leaf area to root volume consequently showed a curvilinear relationship with rising density, recording its peak at 116 days.

Productivity :

Net primary productivity of the individual plant is negatively correlated with density (r = - 0.92). The trend of the curve, however, differs with age. The peak was obtained in July at 83 days after which the effect of competition became more acute (Fig. 2A). Contrary to the individual plant, productivity of the population went hand in hand with density (r = 0.94), attaining the peak at 116 days (Fig. 2B).

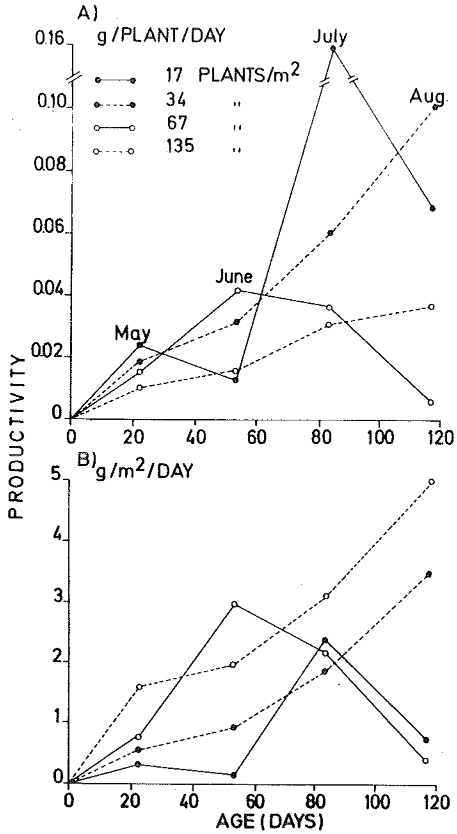

Fig. 2 : Growth analysis of *D. triflorum* at four levels of intra-specific Competition and six ages.

Nitrogen uptake and accumulation :

Although density significantly affected the nitrogen content (%), its trend is not very clear (Fig. 3A). The content increased up to 53 days and declined subsequently. Total nitrogen content in the plant as well as in the biomass was significantly affected by density and age of the plant (Table 1). Impact of age, however, is more pronounced in the case of the individual. With advancing age, nitrogen content decreased considerably and a maximum difference between the densities was observed at 116 days (Fig. 3B). Conversely, competition brought forth a considerable increase in the nitrogen content of the population as a whole (Fig. 3C). The values continued to increase up to 116 days and declined thereafter at all but the

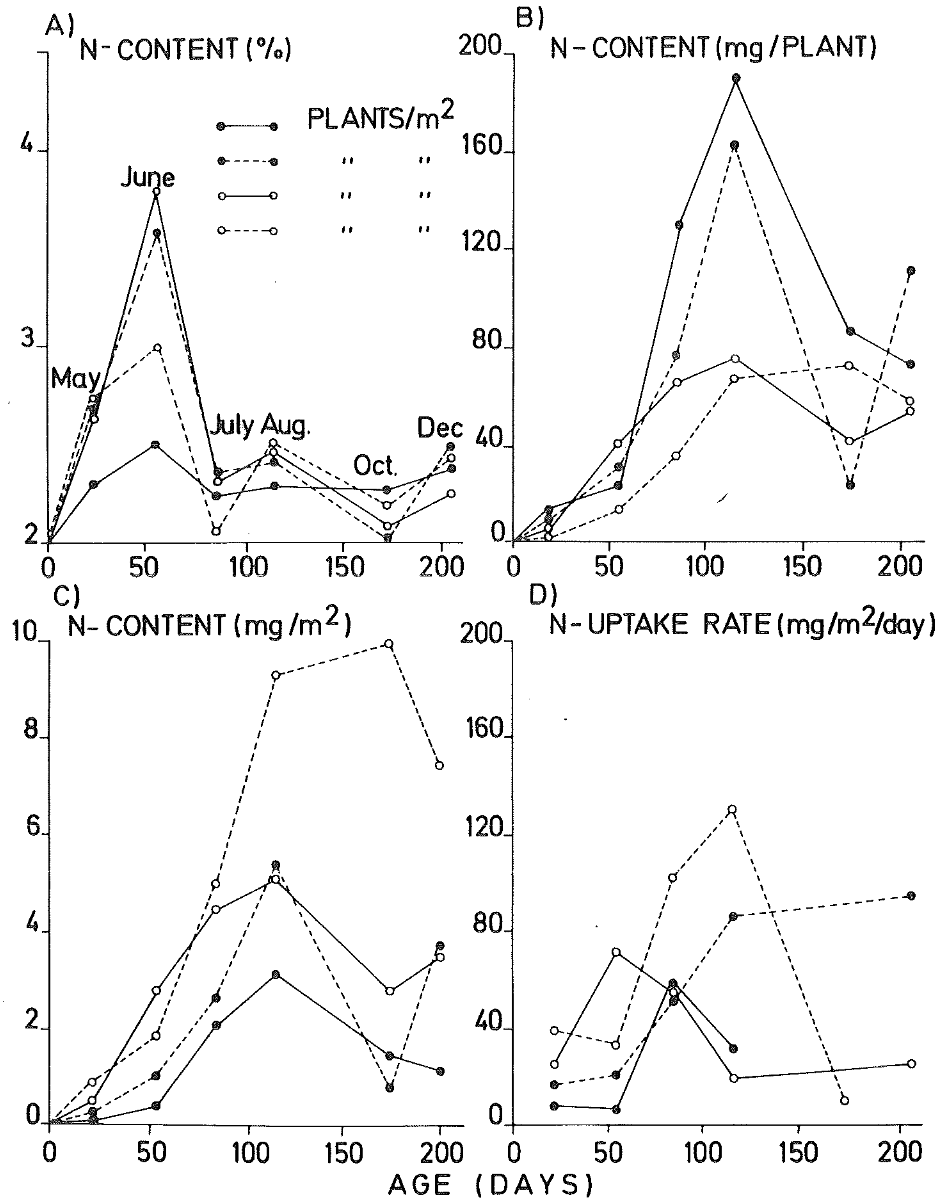

Fig. 3 : Net primary productivity (g/plant/day and $g/m^2/day$) of *D. triflorum* as affected by density and age.

highest density, where the peak was recorded at 174 days. Nitrogen uptake rate by the population as a unit body was accelerated by rising density and the peak was attained at 116 days (Fig. 3D).

Moisture content and transpiration rate :

Total amount of water transpired from the aboveground parts appears responsive to the competition intensity and age of the plants. Rate of water loss increased with age at all the densities attaining its maximum at 116 days. Moisture loss from unit weight of shoot, however, did not differ appreciably either with density or with age (Fig. 5).

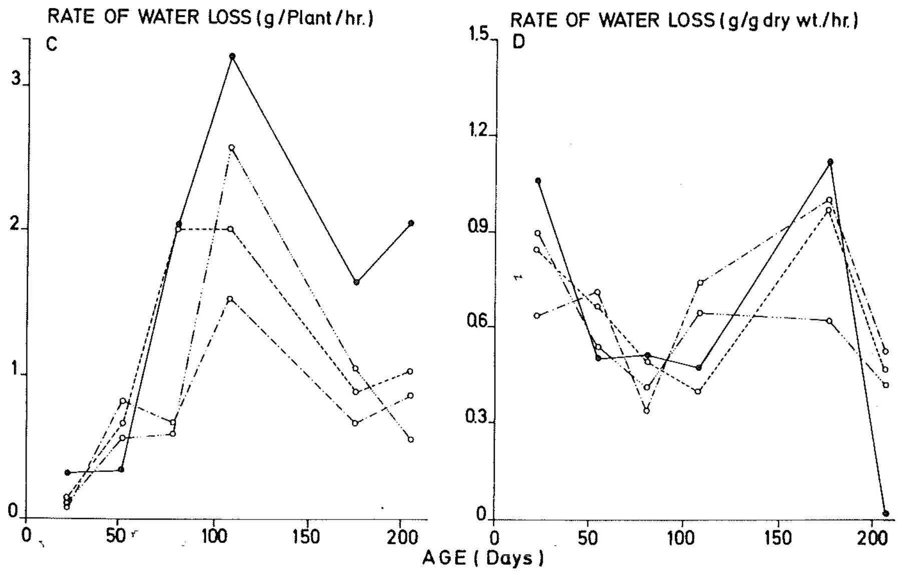

Fig. 4 : Effect of density and age on the nitrogen uptake rate and its accumulation in *D. triflorum*.

Growth analyses :

The net assimilation rate (NAR) increased at the early stages of growth (53 days) up to the second density (34 plants m^{-2}) beyond which it attained a plateau and the values ultimately declined at the highest density. At the same age, although the relative growth rate (RGR) followed a curvilinear trend, the values did not differ significantly (Fig. 2). Both NAR and RGR were adversely affected at 83 days, the

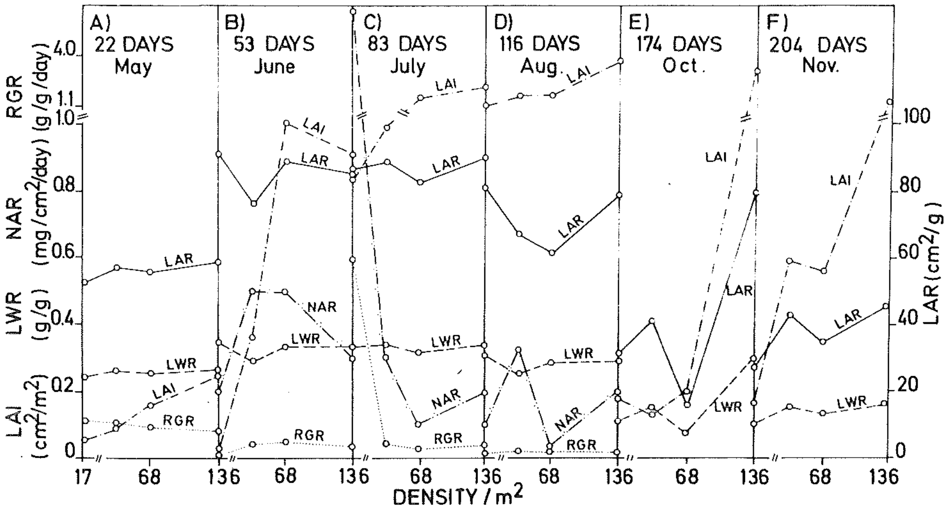

Fig. 5 : Effect of age and intraspecific competition on the rate of water loss in *D. triflorum*.

values declining sharply beyond the initial density (Fig. 5C). Leaf weight ratio (LWR) remained more or less unaffected by competition stress at almost all the ages, while density brought forth a positive change in leaf area ratio (LAR) at least at higher ages (Fig. 5E, F). Leaf area index (LAI) is positively correlated with density ($r = 0.99$). Maximum LAI was obtained at 174 days at the highest density while at the other three densities the peak was recorded earlier at 116 days. Root weight ratio increased with density up to 67 plants m^{-2} and declined thereafter. During the late ages (after 116 days), however, the ratio was suppressed by even lower densities (Table 2).

DISCUSSION

The foregoing results suggest that the functional efficiency of a population stand is not essentially a reflection of its individual's performance. Rather, the total efficiency of the individuals occupying a unit land area may increase with the density up to a certain extent, even though the resulting population stress may prove detrimental to the individuals.

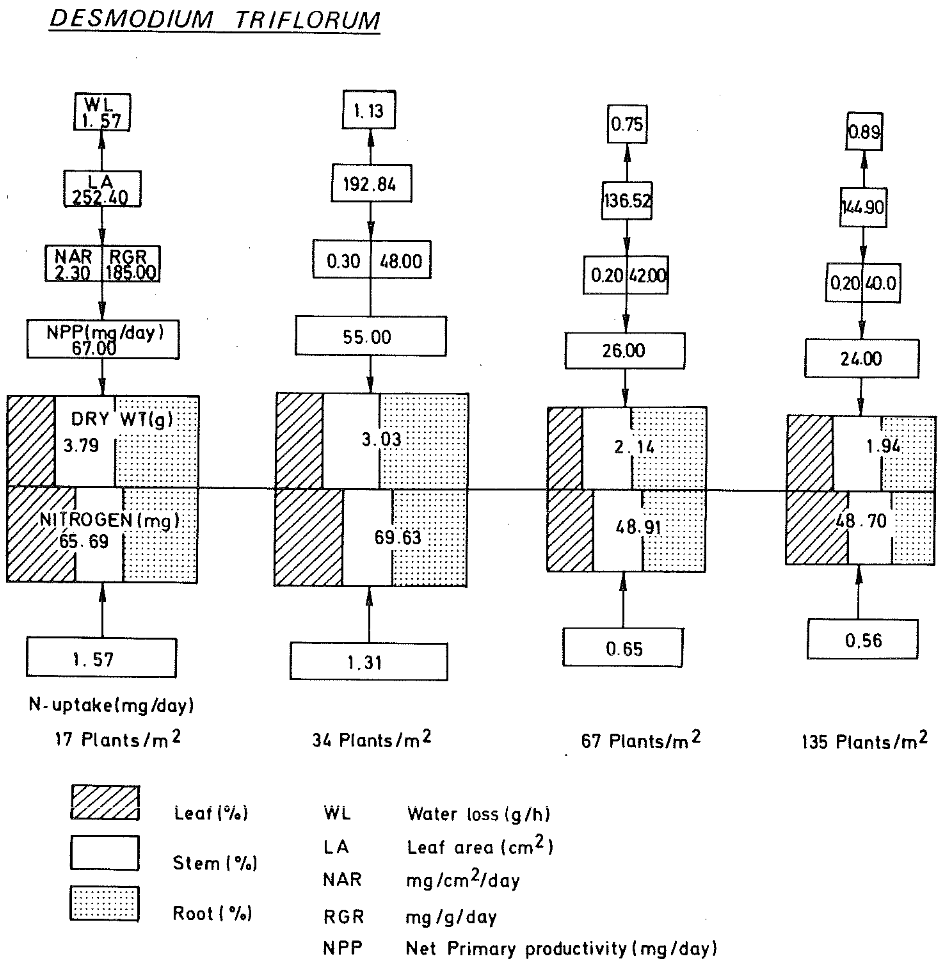

Fig. 6 : Ecophysiological responses of the individuals of *D. triflorum* to intraspecific competition.

The structural and functional responses summarised in Fig. 6 reveal that competition stress had a suppressive effect on the production process of the plant (BLEASDALE 1960). Leaf area, which is largely dependent on nitrogen and water for its expansion (WATSON 1952) is considerably reduced with increasing population stress due to reduced water absorption as apparent from the decreasing trend of transpiration rate, and declination in the nitrogen uptake rate. *D. triflorum*, being a legume, can annihilate the shortage of nitrogen by fixing it, yet declination in its nitrogen content is observed with rising density. This may possibly be due to (a) the nitrogen fixing ability of the plant is affected by competition; and (b) uptake of nitrogen is retarded due to decrease in the absorption surface area. The adverse effect of competition, although apparent on both leaf area and root volume, is more pronounced on the former causing a 57% reduction over the initial density as against 30% in the latter. The assimilatory efficiency per unit leaf area (NAR) is also impoverished by enhancing density. Thus RGR, a quantitative expression of the absorption-assimilation processes of a plant, shows detrimental effect of competition. Susceptibility of RGR to competition has also been reported by RAMKRISHNAN (1972), PANDEYA and BAGHELA (1973). The low relative growth rate is obviously responsible for low rate of dry matter production and its accumulation in the individual plant. From the root weight ratio it appears that density, exceeding 67 plants m^{-2} affects root growth more severely than the shoot. But as the resistance of the plants to stress diminishes with advancing age (DONALD 1963, RISSER 1969, KOTHARI 1972), the roots become susceptible to even lower densities. The overall physiological processes of the plant are, however, most vulnerable to competition stress during the grand period of growth (KOTHARI *et al.* 1974) at 116 days, which can be ascribed to the enhanced demand for the environmental resources.

Despite a considerable suppression of the functional efficiency and vigour of the individual plant, increase in biomass (kcal m^{-2}) and nitrogen uptake rate (g m^{-2} day^{-1}) per unit land area, as presented in Fig. 7, suggest an enhanced production efficiency of the population as a whole. It thus appears plausible that maximization of dry matter production, which is of prime concern in a grassland ecosystem can be achieved by maintaining an optimum density level, regardless of its repercussions on the individuals.

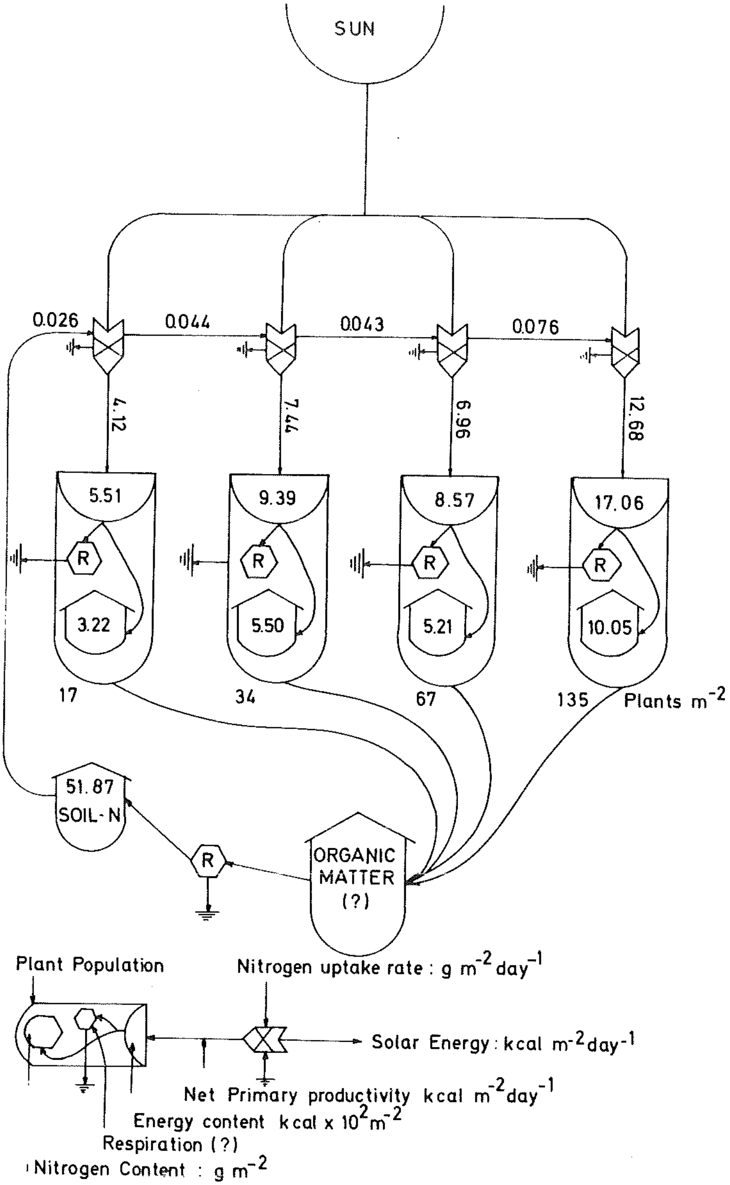

Fig. 7 : Transfer of energy (1 g dry weight = 4 K.cal), uptake of nitrogen and their accumulation in the biomass of *D. triflorum* growing at four density levels.
(For explanation of symbols, see ODUM, 1970).

ACKNOWLEDGEMENTS

We wish to thank Professor R. MISRA and Dr. M.K. SINGH for their valuable discussions. Help rendered by Dr. H.N. PANDEY is gratefully acknowledged. Thanks are also due to CSIR for awarding a Junior Research Fellowship to the junior author from 1970-73.

REFERENCES

BLACKMAN, G.E., 1968. The application of the concept of growth analysis to the assessment of productivity. In : *F.E. Eckhardt (Editor), Functioning of Terrestrial Ecosystems at The Primary Production Level,* UNESCO, Paris, pp. 243-259.

BLEASDALE, J.K.A., 1960. Studies on plant competition. In : *J.L. Harper (Ed.). The Biology of Weeds.* Blackwell, Oxford, pp. 133-142.

CURTIS, O.F. and CLARK, D.G., 1950. *Introduction to Plant Physiology.* Mc-Graw Hill, London, 188 pp.

DONALD, C.M., 1963. Competition among crop and pasture plants. *Adv. Agron.*, 15 : 1-114.

DUTHIE, J.F., 1960. *Flora of The Upper Gangetic Plain and of the Adjacent Sivalik and Sub-Himalayan Tracts. Vol. I, Botanical Survey of India,* Calcutta, 263 pp.

KOTHARI, A., 1972. *Plant Competition - An Ecophysiological Approach.* Ph. D. Thesis, Banaras Hindu University, Varanasi, mimeographed.

KOTHARI, A., PANDEYA, H.N. and MISRA, K.C., 1974. Intraspecific competition in grassland species. I. *Dichanthium annulatum* (Forsk) Stapf. *Agro-Ecosystems*, 1 : 237-247.

MOORE, A.W., 1962. The influence of a legume on soil fertility under a grazed tropical pasture. *Empire J. Expt. Agric.* 30 : 239-248.

NELIVIGI, V.G., 1962. *Ecology, Grazing Effects and Reproductive Capacity of six Forbs in The Grass Vegetation of Varanasi.* Ph. D. Thesis, Banaras Hindu Univ., mimeographed.

ODUM, H.T., 1970. The Rain Forest and Man : An Introduction. A Tropical Rain Forest. *USAEC Division of Technical Information Extension,* Oakridge, Tenn., P A-5-A-11.

PAECH, K. and TRACEY, M.V., 1956. *Modern Methods of Plant Analysis.* Springer Verlag, Berlin, pp. 479-481.

RADFORD, P.J., 1967. Growth analysis formulae- their use and abuse. *Crop Sci.,* 7 : 171-175.

RAO, A., 1970. *The Role of Desmodium triflorum on the Production and the Nitrogen Economy of Grasslands at Varanasi.* Ph.D. Thesis, Banaras Hindu Univ., mimeographed.

RISSER, P.G., 1969. Competitive relationships among herbaceous grassland plants. *Bot. Rev.,* 35 : 251-284.

SINGH, J.S., 1967. *Seasonal Variation in Composition, Plant Biomass and Net Community Production in the Grasslands at Varanasi.* Ph.D. Thesis, Banaras Hindu Univ., mimeographed.

SPEDDING, C.R.W., 1970. *Grassland Ecology.* Oxford. pp. 2-3.

TRIPATHI, J.S., 1970. *Monthly Variation in the Standing Crop, Net Production, Nutrient Content of the Species and Plant Decomposition in a Grassland at Varanasi.* Ph.D. Thesis, Banaras Hindu Univ., mimeographed.

WATSON, D.J., 1952. The physiological basis of variation in yield. *Adv. Agron.*, 4 : 101-145.

WELBANK, P.J., 1962. The effects of competition with *Agropyron repens* and of nitrogen and water-supply on the nitrogen content of *Impatiens parviflora. Ann. Bot.*, N.S., 26 : 361-373.