INDIVIDUAL BEHAVIOUR OF SOME LEGUMES IN MONOCULTURES RELATED TO GROWTH RATE

By P. S. Ramakrishnan

(*Department of Botany, Panjab University, Chandigarh* 160014, *India.*)

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Abstract

The three leguminous species under consideration here, whilst having a number of common behavioural features in monocultures also show differences with regard to mortality, plasticity and productivity which could be related to the growth rate of the species concerned. Thus it is seen that the density-induced mortality is much higher in fast growing species as compared to the one with slower growth rate with the result that in the former species there was an ultimate reduction in population size at very high densities. Not only was the dry weight yield different at low and high nutrient levels in the soil for all the species, but in the case of the fast growing species like *Cassia* the dry weight yield/m^2 declined significantly at very high densities whereas in the case of the slow-growing one it tended to level off. The seed output/m^2 tended to decline at very high density in all the species but this decline was most pronounced in the case of the fast-growing species. The significance of these results are discussed.

Introduction

Interference between individuals of closely similar competitive ability as within pure stands of a species has received much attention as an agronomic problem influencing crop yield. One of the earliest attempts to study self-regulation of numbers in natural populations was made by Sukatchev (1928) who showed in the case of *Matricaria inodora* that increased soil fertility and high density resulted in a small number of survivors at maturity. Such a study was extended by Yoda *et al.* (1963) who concluded that : (i) the chance of a seed producing a mature plant declined with increasing density, (ii) whatever the density of the seeds sown, a maximum population size is attained and densities beyond which cannot be realized, (iii) in the case of overcrowded populations densities converge with the passage of time

and the converging densities are lower on the more fertile soil than in a less fertile one, and (iv) the converging density is closely related to the plant size regardless of the differences in stand age, inital density and fertilizer level. The results obtained by other workers confirm that the pure stands behave essentially in the same way as suggested by Yoda *et al.* (Black, 1960; Harper and McNaughton, 1962 ; Ramakrishnan and Kumar, 1971 *a*, *b* ; Ramakrishnan and Jeet, 1972).

Preliminary observations made earlier suggested that the behaviour of pure populations under varied density stress may be related to an important ecological characteristic of the species, namely, growth rate (Ramakrishnan, 1972; Ramakrishnan and Kumar, 1971 *a*, *b*). Hence the present studies aim at an extension and confirmation of this observation and an assessment of its significance in pure cultures of three leguminous weeds of varied growth rates.

Methods

Individuals of *Crotalaria medicaginea*, *Cassia occidentalis* and *C. tora* were raised from seeds. The seeds were sown in excess and after emergence the seedlings were thinned down to the desired density ranging from 25 to 2,500 individuals/m^2.

The experiments were performed in culture pots of 22·5 cm diameter and the plants were allowed 2 months growth during August-September 1972. Two nutrient levels were maintained, either by keepnig the soil, unaltered (low nutrient level) or by altering with mixtures of salts (high-nutrient level) at the following rates : K_2SO_4, 25·06 g/m^2 ; $NaNO_3$, 45·38 g/m^2 ; NaH_2PO_4, 7 g/m^2. Mixtures of salts were mixed thoroughly into the top layer of the soil followed by watering. Fertilizer application was done twice during the course of the experiment, once in the beginning and another after one month. The pots were watered heavily following fertilizer application. All treatments were replicated four times.

Results

Growth Rate

The average dry matter production of shoot/plant in competition-free cultures was low in the case of *Crotalaria medicaginea* whereas it was markedly high in the case of *Cassia* species. Another simple estimate of growth rate was provided by expressing dry weight yield of plant as a multiple of original

seed weight, a higher multiple indicating a high average relative growth rate though it offered no indication of the shape of the growth curve during this period (Rorison, 1967). Accordingly, *Crotalaria medicaginea* was found to have slower relative growth but with higher values for *Cassia tora* and *C. occidentalis* (Table I).

TABLE I

Dry weight yield of the three species after 2 months

Species	Dry weight yield (g)	Dry weight as a multiple of seed weight
Crotalaria medicaginea ..	0·612	158
Cassia occidentalis ..	10·602	482
C. tora ..	18·862	857

Mortality

All the three species responded to increase in density by mortality and plastic reduction. At lower densities, mortality was negligible and set in very late whilst at higher densities mortality was higher and set in right from the very beginning and was a continuing risk throughout. In all the three species, mortality tended to be higher in the high nutrient soil than in the low nutrient one resulting in a smaller population size in the former soil. This tendency was more marked in the case of *Cassia* species. Further, this difference in mortality due to nutrient status of the soil was more obvious at very high densities only (Figs. 1 and 2).

In the case of *Crotalaria medicaginea* the population size increased with increase in density but tended to level off at very high density. In the case of *Cassia* species, the population size increased initially with increase in density but it decreased at very high densities and this decrease was more pronounced in the high nutrient soil (Fig. 2).

Dry Weight Yield of Shoot

Individual plant weight declined significantly with increasing density in the case of all the species. In general, the dry weight yield was higher at high nutrient soil than at low nutrient soil (Table II).

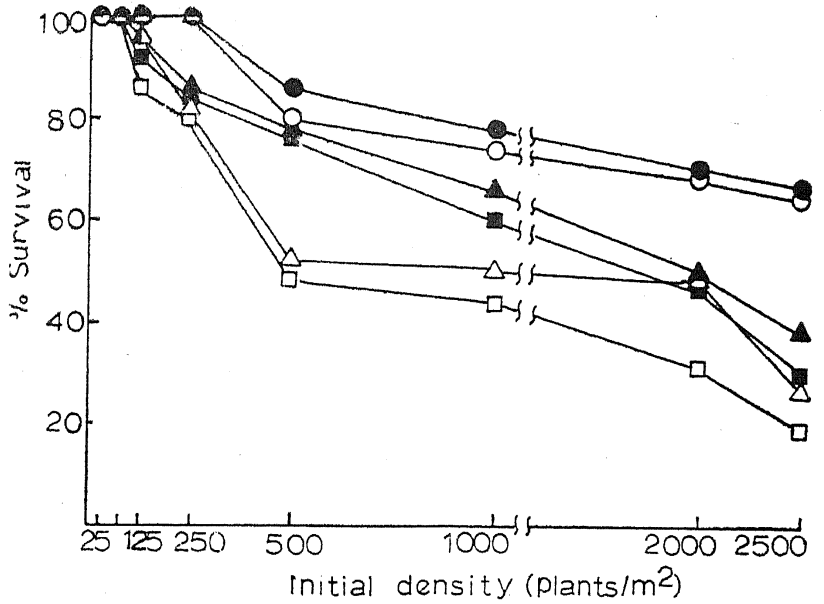

FIG. 1. Effect of density on the percentage survival of the three species. ● ○, *Crotalaria medicaginea*; ▲ △, *Cassia occidentalis*; ■ □, *Cassia tora*. Closed symbols, low nutrient soil; open symbols, high nutrient soil.

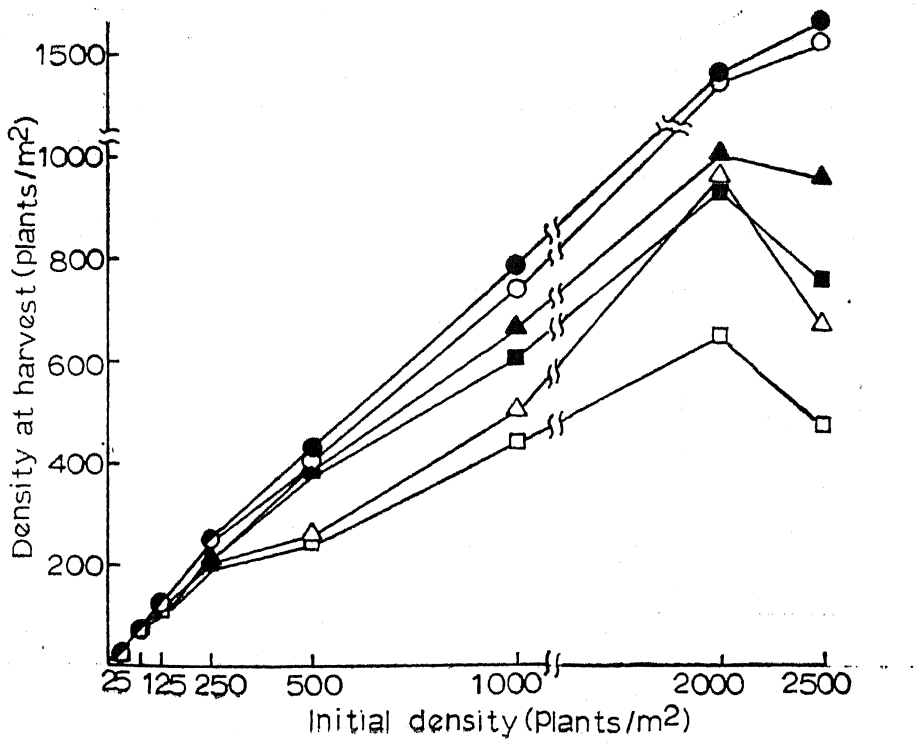

FIG. 2. Relationship between the number of seeds sown and the number at the time of harvest. ● ○, *Crotalaria medicaginea*; ▲ △, *Cassia occidentalis*; ■ □, *Cassia tora*. Closed symbols, low nutrient soil; open symbols, high nurtrient soil.

Dry weight yield/m^2 initially increased with increase in density in the case of all the three species. In the case of *Crotalaria medicaginea* the yield/m^2 levelled off at very high densities whereas in the case of *Cassia* species the yield/m^2 declined markedly at higher densities. This decline was more pronounced in the nutrient rich soil in the case of both the species. Further, this density dependent decline in dry weight yield/m^2 was more marked in the case of *Cassia tora* compared to *C. occidentalis* irrespective of the nutrient status of the soil. In the case of *Crotalaria medicaginea*, the yield/m^2 was consistently higher in the high nutrient soil compared to the low nutrient one. In the case of *Cassia* species, however, the yield/m^2 was higher in the high nutrient soil only at lower densities whereas at higher densities of these two species the reverse was the case.

TABLE II

Effect of density on dry weight yield of shoot/plant (g) of the three species in low (L) and high (H) nutrient soil

Density	*Crotalaria medicaginea*		*Cassia occidentalis*		*Cassia tora*	
	L	H	L	H	L	H
25	0·612	1·100	10·602	12·688	18·862	21·208
75	0·532	1·002	7·111	9·902	9·002	13·727
125	0·404	0·810	6·182	7·999	7·224	9·889
250	0·302	0·612	5·002	6·222	6·542	7·677
500	0·200	0·584	3·814	4·800	3·021	5·202
1000	0·161	0·363	3·615	3·711	1·800	2·723
2000	0·101	0·190	2·161	2·008	0·887	1·362
2500	0·086	0·162	1·100	1·220	0·722	1·100
L.S.D. (P=0·05)	0·078		1·008		0·979	

Seed Output

Seed output/plant of all the species decreased with increase in density. All the three species showed higher seed output/plant in the nutrient rich soil compared to the other, at all density levels (Table III).

TABLE III

Effect of density on seed output/plant of the three species in low (L) *and high* (H) *nutrient soil*

Density	*Crotalaria medicaginea*		*Cassia occidentalis*		*Cassia tora*	
	L	H	L	H	L	H
25	39	188	322	487	492	502
75	30	89	287	379	372	448
125	27	67	202	274	304	397
250	15	47	181	228	249	375
500	19	38	172	207	202	262
1000	16	38	101	128	143	161
2000	10	21	56	62	74	91
2500	8	18	48	50	60	77
L.S.D. (P=0·05)	4·4		35·2		48·5	

In the case of *Crotalaria medicaginea* seed output/m^2 increased with increase in density and either levelled off at higher densities in the low nutrient soil or declined slightly in the high nutrient soil. In the case of *Cassia* species the seed output though increased initially with increase in density, at higher densities it declined markedly and this decline was more pronounced in the high nutrient soil. At a given density, seed output/m^2 was consistently higher in the nutrient rich soil compared to the low nutrient

soil, in the case of *Crotalaria medicaginea*. In the case of *Cassia* species, however, only at lower densities was the seed output/m^2 higher in the high nutrient soil, the reverse being the case at higher densities.

DISCUSSION

The three species under consideration are of markedly different relative growth rate, and these species whilst having a number of common behavioural features, show also between themselves varied responses in pure cultures with regard to mortality, plasticity and productivity.

Density regulated establishment confers self-regulating properties on pure populations of species (Harper and McNaughton, 1962; Yoda *et al.*, 1963). Thus the present studies indicate that more the seeds sown, the greater the chance that a seed failed to produce a mature plant, as was also shown by earlier workers.

However, there was a clear-cut tendency for the density-induced mortality to be related to the growth rate of the species. Generally speaking, faster the growth rate lower is the survival of the individuals in the population. Such a relationship between mortality response and growth rate has been discussed by Ramakrishnan (1972) and Ramakrishnan and Kumar (1971 *a*, *b*). Besides, mortality at a given density tended to be higher in a more fertile soil, an observation similar to Yoda *et al.* (1963).

It has been shown that there is a maximum population size for any given species, a size beyond which cannot be attained whatever may be the number of seeds sown (Yoda *et al.*, 1963). Thus increase in density resulted in a levelling off of the size of the population within the range of densities tested in the case of *Crotalaria medicaginea* which has a comparatively slow growth rate. However, in the case of species like *Cassia* which have a faster growth rate, the ultimate population size decreased significantly at very high density levels and this decline was more pronounced in a nutrient rich soil compared to that at a nutrient poor soil. The results obtained earlier on maize (Ramakrishnan, 1971 ; Ramakrishnan and Kumar, 1971 *b*), a species of comparatively faster growth rate, also indicate that the ultimate population size declined tremendously at higher densities due to very severe mortality. It appears, therefore, that whether the population size attains a plateau level or it declines at high density stress is a function of the growth rate characteristic of the species.

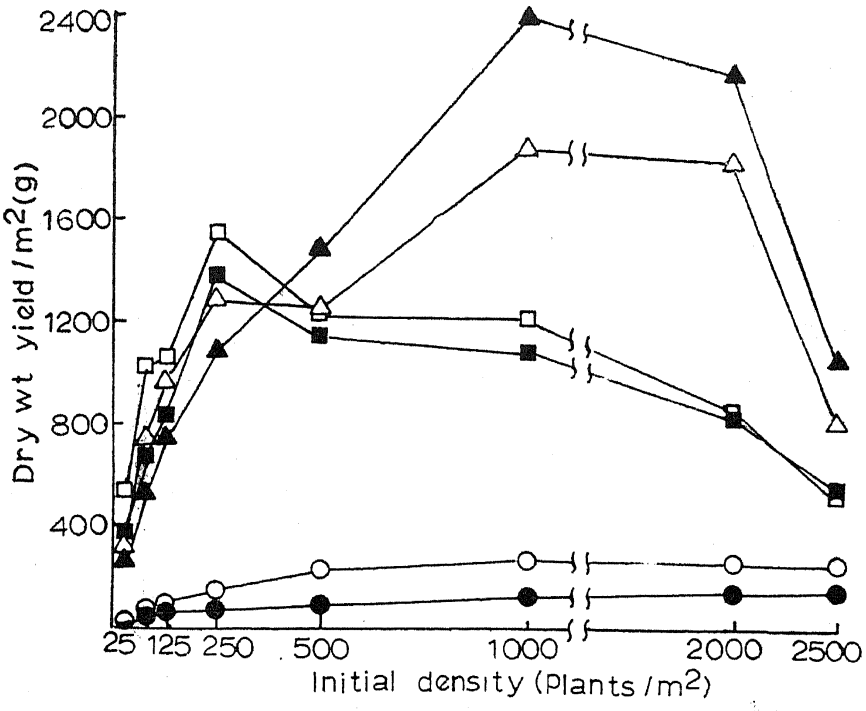

FIG. 3. Effect of density on the dry weight yield/m² (g) of the three species. ● ○, *Crotalaria medicaginea*; ▲ △, *Cassia occidentalis*; ■ □, *Cassia tora*. Closed symbols, low nutrient soil ; open symbols, high nutrient soil.

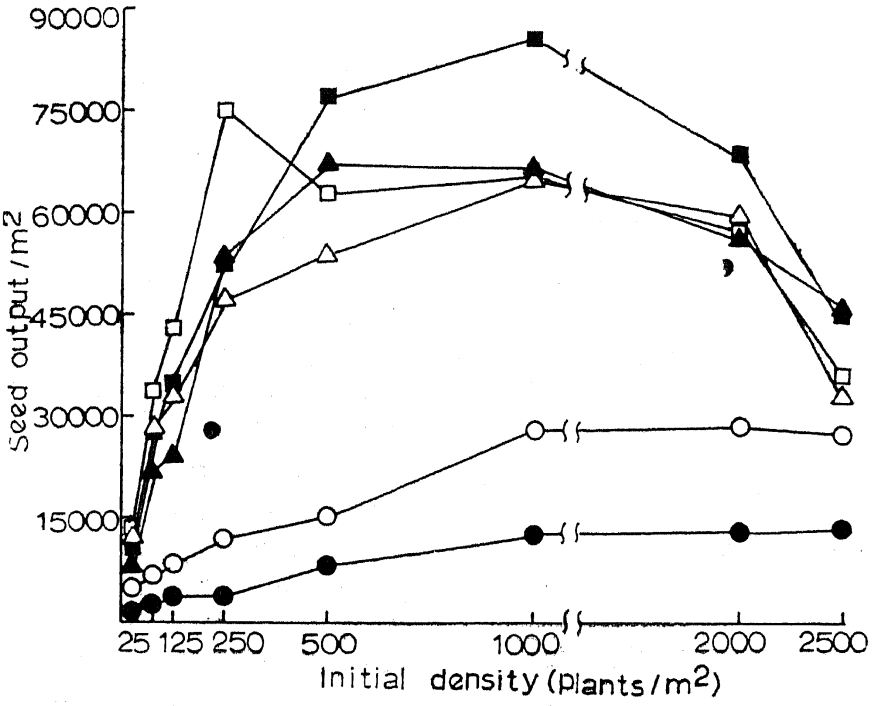

FIG. 4. Effect of density on the seed output/m² of the three species. ○ ●, *Crotalaria medicaginea*; ▲ △, *Cassia occidentalis*; ■ □, *Cassia tora*. Closed symbols, low nutrient soil; open symbols high nutrient soil.

Whilst the dry matter production tended to level off at higher densities in the case of *Crotalaria medicaginea*, in the case of faster-growing species like *Cassia* there was significant decline in yield/m^2 at very high densities which could be related to the ultimate decline in population size due to severe mortality discussed above. The seed yield/m^2 also showed a similar tendency as dry matter production.

The results discussed here thus indicate a close correlation between density-induced mortality and growth rate, mortality in turn affecting other parameters like dry weight yield and seed output. This is in agreement with earlier observations (Ramakrishnan, 1972). Though growth rate is an important feature determining the behaviour of populations in response to density stress, the intrinsic efficiency of the individuals to utilize the available resources of the medium (Ramakrishnan, and Gupta, 1972) is equally important in inter and intraspecific struggle.

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REFERENCES

Black, J. N. .. "An assessment of the role of planting density on competition between red clover (*Trifolium pratense* L.) in the early stages," *Oikos*, 1960, **11**, 26–42.

Harper, J. L. and McNaughton, I. M. "The comparative biology of closely related species living in the same area. VII. Interference between individuals in pure and mixed populations of *Papaver* species," *New Phytol.*, 1962, **67**, 175–88.

Ramakrishnan, P. S. .. "A comparative study in monocultures of species of varied ecological characteristics," In *Tropical Ecology with an Emphasis on Organic Production*, Ed. F. M. Golley and P. M. Golley, Athens, Georgia, 1972, pp. 121–35.

——— and Kumar, S. "Productivity and plasticity of wheat and *Cynodon dactylon* (L). Pers. in pure and mixed stands," *J. appl. Ecol.*, 1971*a*, **8**, 85–98.

——————— .. "Mortality, plasticity and productivity of interfering mode populations of maize and *Cynodon dactylon* (L.) Pers.," *J. Indian bot. Soc.*, 1971 *b*, **50**, 321–31.

Ramakrishnan, P. S. and Jeet, N. "Competitive relationships existing between two closely related species of *Argemone* living in the same area," *Oecologia*, 1972, **9**, 279–88.

Ramakrishnan, P. S. and Gupta, U. "Ecotypic differences in *Cynodon dactylon* (L.) Pers. reated tol weed–crop interference," *J. appl. Ecol.*, 1972, 9, 333–39.

Rorison, I. .. "A seedling bioassay of some soils in the Sheffield area," *J. Ecol.* 1967, **55**, 725–41.

Sukatschev, V. N. .. *Plant Communities* (in Russian), Moscow, 1928.

Yoda, K., Kira, T., Ogawa, H., and Hozumi, K. "Self–thinning in over crowded pure stands under cultivated and natural conditions," *J. Biol. Osaka*, Cy. Univ., 1963, **14**, 107–29.