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Dynamics of Buried Seed Population and Seedling Cohorts of Two Dominant Weeds in a Hill Agroecosystem of the Humid Subtropics of India[1)]

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Abstract. Dynamics of the buried seeds and plant population of two dominant weeds, viz., *Emilia sonchifolia* (Linn.) DC. and *Richardsonia pilosa* HBK were studied in the crop fields of Meghalaya, north-east India during radish and maize cropping and intervening fallow periods. The total buried seed population of *R. pilosa* was always larger than that of *E. sonchifolia*, but the germinable fraction was invariably greater in the latter. A major portion (39–41%) of the viable (germinable+dormant) seed population in both weeds was confined to the surface soil layer (0–5 cm). The viable seed population of *E. sonchifolia* peaked during April, while that of *R. pilosa* showed two peaks (during August and December). The survival pattern and half-lives of seedling cohorts showed some differences in the two weed species, but both being summer annuals, their populations behaved in a similar manner by showing higher seedling recruitment (K) and survivorship (p) rates in the summer crop (maize) than in the winter crop (radish). However, the density of plants that could attain adulthood was significantly higher in *E. sonchifolia* than *R. pilosa* which might have resulted in greater seed input of the former to the soil leading to its greater abundance in the crop fields.

Key words: population dynamics, survival rate, weeds, buried seeds, seedlings.

Introduction

The population dynamics of weeds in agroecosystems are largely influenced by the growth of crop plants as well as their own growth, which in turn, are determined by the physical environment. The type of crop grown, period of cropping, time of weed seedling emergence in the crop fields as well as the seed production potential of weeds influence the buried weed seed population, weed seedling recruitment, their survivorship and future weed infestation. This calls for an *in situ* study of the population dynamics of weeds. However, this problem has not received sufficient attention, and as a result, there are only a very few studies of this nature (e.g., Fernandez-Quintanilla et al. 1987; Firbank et al. 1990; Misra et al. 1992; Sahoo et al. 1994).

The study on weed population ecology in crop fields encompasses the analysis of the dynamics of the soil seed bank and the plant populations in time and space. The former includes the study of seed rain, and spatial and temporal variation in the weed seed population in the soil while the latter involves the study of the recruitment of weed seedlings and their survival and mortality patterns during crop duration. The agroecosystems in northeast India both under traditional slash and burn agriculture (locally called 'jhum') and terrace cultivation are highly infested with a large variety of weeds due both to a lack of effective weed control measures and edapho-climatic conditions that are conducive for the luxuriant growth of weeds. *Emilia sonchifolia* (Linn.) DC (Asteraceae) and *Richardsonia pilosa* HBK (Rubiceae) are among the dominant agrestal weeds of this region. This paper analyses the population behaviour of these two weeds growing in association with two contrasting crops viz., radish and maize during the cropping and intervening fallow periods over a two year period (1988–1990).

Materials and Methods

Study sites

The study was carried out in the experimental fields of the

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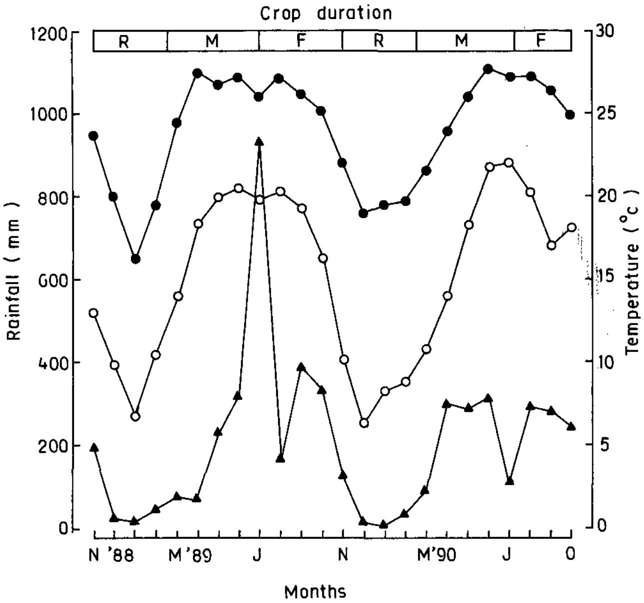

Fig. 1. Total monthly rainfall (–▲–), mean monthly maximum temperature (–●–), mean monthly minimum temperateure (–○–), and duration of radish (R) and maize (M) crops, and follow period (F) during 1988–90.

Farming Systems Research Project of the ICAR Research Complex for northeastern hill region at Barapani (alt. 952 m, lat. 25° 28' N, long. 91° 53' E), situated about 22 km north of Shillong. The soils of the crop fields are clay loam and acidic (pH 5.5). The climate of the area is monsoonic with an average annual rainfall of 2500 mm. The mean annual maximum and minimum temperatures during the study period were 24°C and 15°C, respectively. Relative humidity remains high throughout the year (mean annual 78%). The study was carried out in three replicate fields of radish (winter crop) and maize (summer crop) as well as during the fallow period between summer and ensuing winter crop seasons (Fig. 1).

Seed population in soil

Seed populations in the soil were determined by analysing twenty soil cores (diameter 5.7 cm) down to a 20 cm depth (0–5, 5–10, 10–15 and 15–20 cm), randomly collected at monthly intervals from each field of size ca. 2500 m². The soil samples corresponding to each depth were pooled and 6 replicates of 100 g each were taken for the analysis of the different fractions of buried seed populations. Three replicates were used for determining the total viable buried seed populations. Seeds were recovered from the soil samples by the floatation method (Robert and Rickets 1979) and their viability was tested through gentle pressure technique (Hayashi et al. 1978) and/or rapid germination test (Malone 1967) other three replicates were spread uniformly in plastic petri dishes (10.5 × 1.5 cm), watered and kept in seed germination at an alternating (12 h) temperature of 30°C and 7°C and 12 h photoperiod. Seedlings emerging in the petri dishes were identified and counted daily. After the seedling emergence ceased, soil was again analysed for determining the remaining viable seeds in the sample. The number of seedlings was considered equivalent to the number of seeds in the state of enforced dormancy at the time of recovery, while the non-germinated viable seeds were regarded as induced-dormant fraction. The degenerated and empty seeds were put into dead or non-viable category. The germinable fraction was estimated by subtracting the number of seeds under enforced and induced dormancy from the total viable seeds in soil.

Plant population dynamics

Seven permanent quadrates (50 × 50 cm), determined according to Misra (1968), were randomly placed in each field immediately after crop sowing. Weed seedlings, which emerged in different batches at different times were marked with waterproof paints on the top of the cotyledon as well as on the first eophyll by different colours (Yadav and Tripathi 1981). These batches of seedlings were designated as cohorts. The fate of the marked seedlings in each cohort was monitored at fortnightly interval until the crop harvest. Using time series density data, seedling recruitment, half-life (time from emergence to 50% survival) and mortality patterns were studied for each cohort of a given weed species. The total weed population flux was studied by computing seedling recruitment rate (K)—the ratio between the emerged seedlings and the number of viable seeds in soil seed bank, survivorship (p)—the probabilities of emerged seedlings surviving to set seeds, and the fecundity (F)—total seed production per m² divided by the number of mature plants per m² present at harvest. Seasonal and annual growth of seed population in the soil (λ) was determined by the following formula (Mortimer et al. 1980):

$$\lambda = \sqrt[t]{N_{t+1} \cdot N_t^{-1}},$$

where N_t is the seed population at the beginning and N_{t+1} is the seed population at the end of the period t (season/year). Seed loss (SL) from the system has been estimated as follows (Misra et al. 1992):

$$SL = (SB_t + SP_t) - (ES_t + SB_{t+1}),$$

where SB_t is the buried seed population in the soil, SP_t is the seed production, ES_t the emerged seedlings at the beginning of the season and SB_{t+1} the seed population at the end of the season. Data on seed fractions for both the species was analysed using 3-way ANOVA (fixed effects model) to test the variance among the crops, years and different seed fractions. The variation in half-lives among different seedling cohorts, crops and years was tested using the same model of ANOVA. Data on population density of viable seeds in soil and recruited seedlings, seed production, and the rates of seedling recruitment, survivorship, fecundity and increase in viable seed population in soil were analysed using 2-way ANOVA (fixed effects model) to test the variance between the crops and weed species.

Results

Buried seed population

The total weed seed population which includes both viable and non-viable fractions varied significantly among the cropping periods. The mean seed population per square metre was 13650 ± 443 and 18434 ± 1977 during cropping period of radish and maize, respectively, and 16243 ± 292 during the fallow period. Viable seeds of *E. sonchifolia* constituted 13% of the total viable seed population during radish and 17% during maize cropping, while the corresponding figures for *R. pilosa* were 16% and 15%.

The total buried seed population of *E. sonchifolia* was lower than *R. pilosa* in both the crops (Table 1). In the case of *E. sonchifolia*, it was significantly higher ($P<0.05$; ANOVA) during summer (maize crop) than winter (radish crop) and the fallow period. On the other hand, in *R. pilosa*, population density of seeds was maximum during the fallow period followed by winter and summer crops. *E. sonchifolia* had a higher percentage of germinable seeds than *R. pilosa* throughout the study period. In both the species the dormant fraction was significantly ($P<0.01$; ANOVA) higher than the germinable fraction, both during the cropping and fallow periods.

The viable seed population of the two weeds significantly ($P<0.05$) decreased with depth. The proportions of viable seeds of *E. sonchifolia* in 0–5, 5–10, 10–15 and 15–20 cm soil layers were 38, 25, 24 and 13% in the radish field, and 35, 29, 24 and 12% in the maize field. The corresponding figures for *R. pilosa* in radish and maize crops were 44, 29, 18, 9% and 42, 30, 21, 7%.

The peak viable seed population of *E. sonchifolia* in the soil seed bank was noticed during April, when the field was under maize crop (Fig. 2). *R. pilosa* showed a peak during August—September when the field was fallow. A second peak of this species was observed during winter season as well. Seedling population density in both species peaked during March-April, while the densities of their adult reproductive plants were maximal during May.

Seedling recruitment and survival

Recruitment of seedlings of *E. sonchifolia* and *R. pilosa* in the maize field was significantly greater ($P<0.01$) than in the radish field. The yearly variation in total recruitment was insignificant. The survivorship curves of the seedling cohorts were essentially similar in both weeds (Fig. 3). The first cohort in the radish and the first two cohorts in the maize field depicted Deevey's type I survivorship curve (Deevey 1947) where mortality was higher at the end of the life cycle. The second cohort in the radish field and the third cohort in the maize field showed Deevey's type II survivorship curve, which indicates that they experienced continuous mortality risk throughout the life-span. The population behaviour of *E. sonchifolia* varied with the crop field; the seedling recruitment was higher in the maize field than in the radish field and the third cohort was absent from the radish field. In *R. pilosa* too, the recruitment was greater in the maize field and only one or two

Table 1. Mean population densities of total, germinable, dormant and non-viable seeds of *E. sonchifolia* and *R. pilosa* during cropping and fallow periods.

Fraction	Radish		Maize		Fallow	
	1988–89	1989–90	1988–89	1989–90	1988–89	1989–90
E. sonchifolia						
Total seed population/m^2	945±60[a]	1049±75	1163±143	1205±83	959±66	967±60
Germinable (%)	13.8	17.1	25.5	26.8	19.7	19.6
Dormant (%)	45.6	43.0	44.6	38.7	49.1	45.8
Non-vialbe (%)	40.6	39.9	29.8	34.6	31.1	33.1
R. pilosa						
Total seed population/m^2	1358±294	1500±152	1091±258	1351±208	1663±250	1760±12
Germinable (%)	6.0	8.2	12.6	14.6	8.6	11.2
Dormant (%)	51.7	43.2	43.7	45.2	50.9	47.5
Non-vialbe (%)	42.3	48.6	43.7	40.2	40.6	41.2

[a] ±SE.

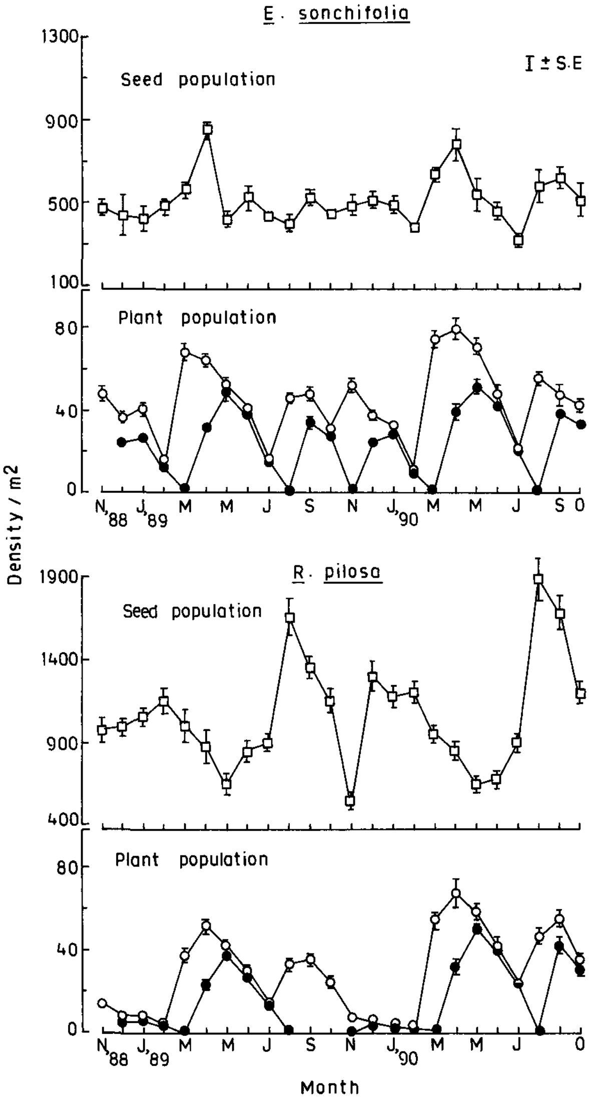

Fig. 2. Populations of viable buried seeds (-□-), total plant (-○-) and reproductive plant (-●-) of *E. sonchifolia* and *R. pilosa* during 1988–90.

cohorts were noticed in the radish field. In both species, seedling mortality in the first cohort was significantly higher ($P<0.01$; ANOVA) in the radish field than in the maize field.

In both weeds, the seedling cohorts that appeared late during the cropping period showed shorter half-lives than those appearing early, and the half-lives were generally longer in the maize than in the radish field (Table 2). In the maize field, half-lives of the first and second cohorts of *R. pilosa* were longer than the corresponding cohorts of *E. sonchifolia*. But the trend was reversed in the radish field. Difference in half-life between the cohorts was significant ($P<0.01$; ANOVA), while variation between the years was insignificant.

Population dynamics

Seed and plant population dynamics of the two weeds are summarized in Fig 4. A comparison of the two cropping seasons reveals that the population density of the viable seeds in the soil seed bank and that of the recruited seedlings of both weeds were significantly larger ($P<0.01$; ANOVA) during the summer than the winter season. The seed production in *E. sonchifolia* was significantly higher ($P<0.05$; ANOVA) that *R. pilosa* in both the crops. In both weeds, seedling recruitment rate (K) ($P<0.01$; ANOVA) and fecundity rate (F) ($P<0.01$; ANOVA) were significantly greater in the maize than the radish field. The survivorship rate (p) in the maize field was, however, significantly greater ($P<0.01$; ANOVA) than the radish field only in *R. pilosa*. Furthermore, in both fields K was higher ($P<0.01$; ANOVA) in *E. sonchifolia* than in *R. pilosa*, while in contrast F was higher ($P<0.01$; ANOVA) in the latter. The rate of increase in viable seed population in the soil (λ_1) during the winter crop was higher ($P<0.01$; ANOVA) in *E. sonchifolia* than *R. pilosa*. The trend was, however, reversed during the summer crop. The annual rate of increase (λ_2) was higher ($P<0.01$; ANOVA) in *E. sonchifolia* than in *R. pilosa*.

Discussion

Both weeds being primarily summer annuals, infested the summer crop more severely than the winter crop. This seems to be linked to seasonal variation in temperature and soil moisture condition. Relatively high temperature and frequent monsoon rains during the summer months caused greater seedling recruitment in the various cohorts of both weeds in the summer crop (maize), while the low weed seedling recruitment in the winter crop (radish) may be attributed to the lowering of temperature and soil moisture content during winter months. Inhibition of seed germination and seedling emergence due to soil moisture stress has been reported by Mack (1976), Cook (1980) and Tayalla et al.(1988) in *Bromus tectorum*, *Viola blanda* and *Ischaemum afrum*, respectively. Further, studies of Baskin and Baskin (1978, 1990), Eddleman and Romo (1988) and Egley (1990) showed that the timing of seedling emergence in the field is often related to the temperature requirement of seeds. A gradual decline in seedling recruitment in successive cohorts as well as total recruitment could also be attributed to depletion of germinable fraction in the soil seed bank (Rai and Tripathi 1984; Pandey and Dubey 1989; Misra et al. 1992) and resource competition with the already established associated vegetation (Antonovics and Levin 1980; Rai and Triphathi 1984). However, the greater population density of both weeds in the maize field where the per-

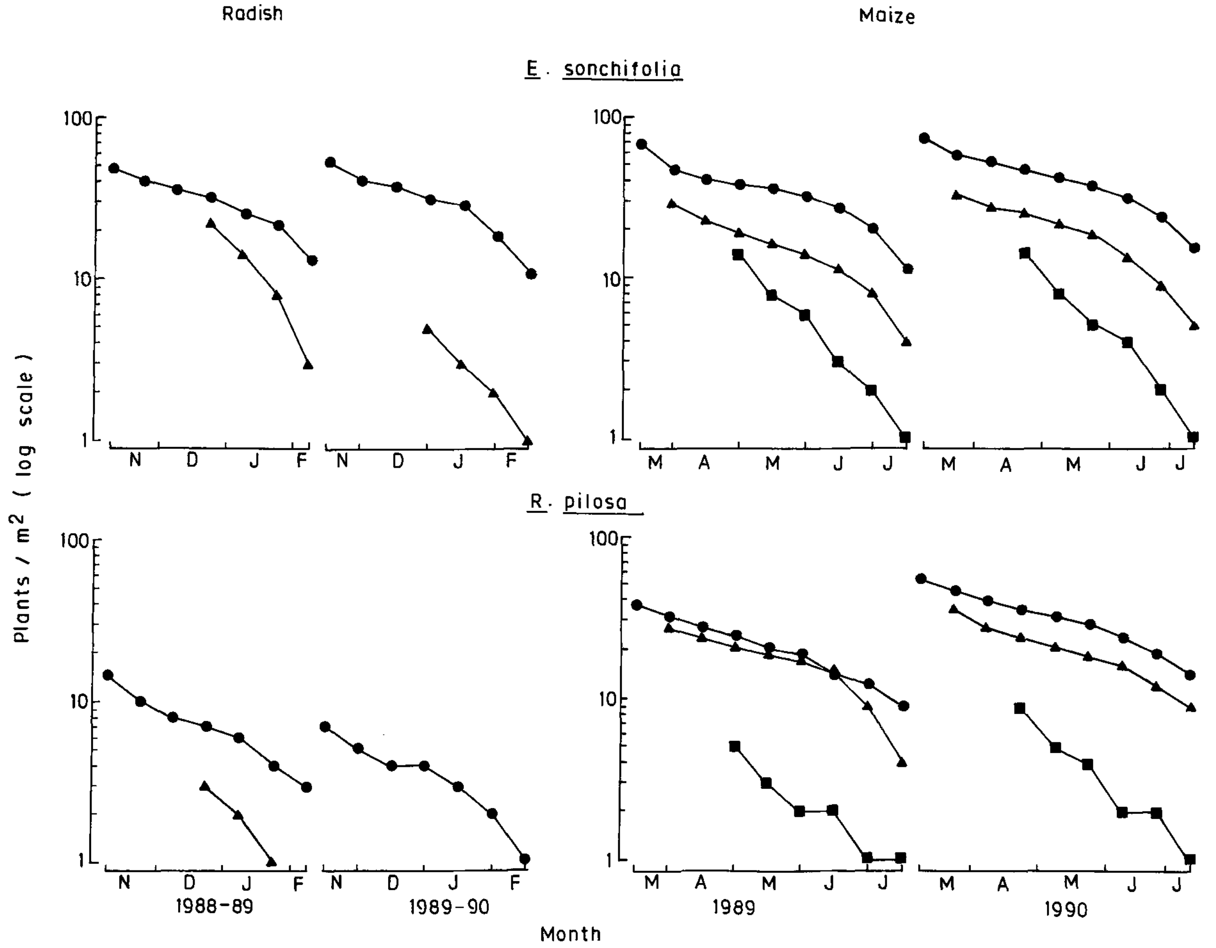

Fig. 3. Survivorship curves for seedling cohorts (cohort I, -●-; cohort II, -▲- and cohort III -■-) of *E. sonchifolia* and *R. pilosa* in radish and maize fields.

centage of germinable seeds in the soil seed bank was higher than the radish field confirm the findings of Barallis (1965) and Kropac (1966) who have reported that the weed population density during a given cropping season is generally a function of the germinable weed seeds present in soil.

The results revealed that different seedling cohorts of the same weed species exhibited two different types of survivorship curves. This is in agreement with Mack and Pyke (1983) who reported that different cohorts of the same species may show markedly different survivorship curves in different places or at different times.

The proportion of the viable seed bank in the soil, which gave rise to seedlings ranged from 13 to 19% in *E. sonchifolia* and 2 to 10% in *R. pilosa*. This range varied from 12 to 38% in *Avena fatua* (Wilson and Cussans 1975; Rauber 1978) and 31 to 46% in *A. ludoviciana* (Fernandez-Quintanilla et al. 1986). The greater recruitment rate (*K*) of *E. sonchifolia* than *R. pilosa* could be attributed to its larger germinable fraction in the soil seed bank. The proportion of the seedling population of *R. pilosa* which attained adulthood (*p*) was greater in the maize than in the radish field indicating better survival of the weed seedlings in the former field. The greater seed production by *E. sonchifolia* than *R. pilosa* in both crop fields could be attributed to higher density of its adult plants.

Table 2. Half-life (weeks) of seedling cohorts of *E. sonchifolia* and *R. pilosa* in maize and radish fields.

Crop	Cohort	*E. sonchifolia*		*R. pilosa*	
		1988–1989	1989–1990	1988–1989	1989–1990
Maize	I	9.0	10.0	12.0	11.0
	II	7.0	8.5	10.0	10.0
	III	3.0	2.5	3.0	3.0
Radish	I	9.0	8.5	6.0	7.0
	II	3.0	3.0	3.0	—

'—' indicates absence of cohort

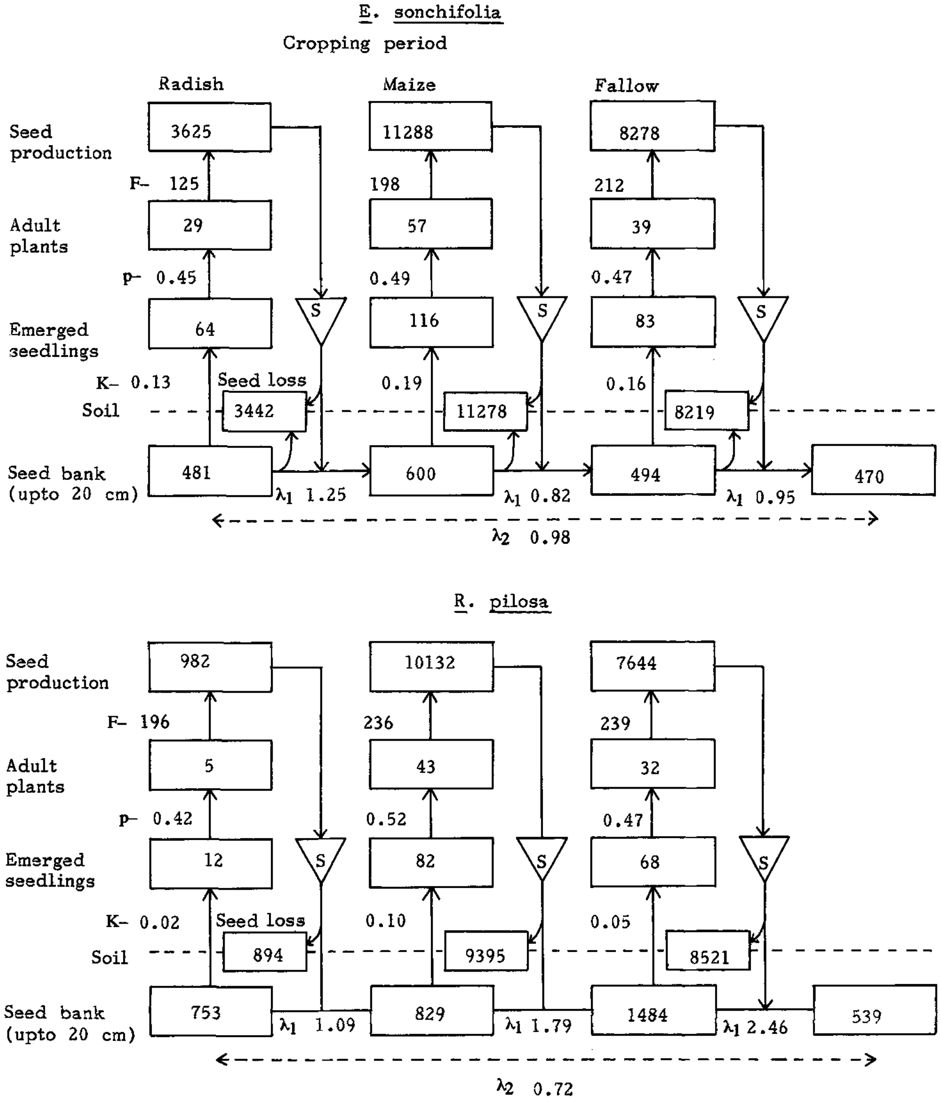

Fig. 4. Population flux (average of two years) of *E. sonchifolia* and *R. pilosa* in radish and maize fields. Figures in boxes are average numbers of viable seeds in soil and plants/m^2. Seedling recruitment (K), survivorship (p), fecundity (F) and growth rate of viable seed population (seasonal value, λ_1; annual value, λ_2) in soil are shown along the lines. 'S' indicates seed rain.

The factors known to influence weed seed input to the soil are method of cultivation, depth of ploughing, plough design and soil type (Moss 1988). All these factors are similar in maize and radish fields, and therefore the reduced input of *E. sonchifolia* seeds to the crop fields during seed rain was presumably on account of the presence of pappus which helped in the wide dispersal of seeds away from the crop field under consideration. However, in spite of this, the rate of increase in the soil seed bank was higher in the case of *E. sonchifolia* than in *R. pilosa*, which shows that the greater production of seeds in the former can more than compensate the seed loss caused by wind dispersal. This, in turn, was responsible for the greater abundance of *E. sonchifolia* in both maize and radish fields.

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