Adaptive significance of seed reserves in ray achenes of *Galinsoga parviflora* Cav.

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Summary. Ray achenes of *Galinsoga parviflora* Cav. are significantly heavier, higher in calorific value and contain more protein and carbohydrate than disc achenes. The ray achenes showed early and better germination from different sowing depths and the seedlings from these grew better under nutrient deficient conditions. The differential response of the 2 achenes has been attributed to differences in the seed reserves and has an adaptive significance.

Galinsoga parviflora Cav. (Asteraceae), a native of tropical America grows abundantly as a crop weed in the hill agroecosystems of Meghalaya (25°34′N lat. 91°56′E long. 500–1700 m altitude) in north-eastern India. Besides, it also occurs as a ruderal weed on disturbed wastelands and roadsides. The fruits produced by disc and ray florets of this weed are markedly different[2]. The ray achenes, which constitute 20% of total seed population, are larger, flat and devoid of pappus while the disc achenes are smaller and crowned with pappus. Seed polymorphism is common in weed species[3] and its significance in species adaptability under varied microenvironments has been emphasized by various workers[4–7]. In the present study seed germination and seedling growth of *G. parviflora* has been related to the seed reserves of the ray and disc achenes. The adaptive significance of seed reserves is also discussed.

Materials and methods. Mature seeds of *G. parviflora* were collected from a roadside population in Shillong, and the disc and ray achenes were manually separated. Viability, seed weight, protein, lipid, ash and carbohydrate content of the 2 seed populations were determined. Seed viability was tested using 0.1% triphenyl-tetrazolium chloride[8]. Seed weight was calculated by weighing 10 lots of 50 seeds of each of the 2 seed morphs and dividing the resulting average weight by 50 to determine the average weight per seed. Protein was estimated by the Folin-Lowry method[9] and lipid by the procedure outlined by Freeman et al.[10]. The ash content was determined by placing weighed seeds in a muffle furnance at 500 °C for 4 h and weighing the remains. Percentage carbohydrate content of the seeds was assayed by subtracting the sum of protein, lipid and ash contents from 100. This procedure, 'carbohydrate by subtraction' is widely used and its accuracy is discussed by Merrill and Watt[11]. Calorie values per seed were calculated by using calorie estimates of storage compounds[12].

50 ray and 50 disc achenes were separately sown in soil in pots at 4 sowing depths i.e. 0.5, 1.5, 3.0 and 5.0 cm from the surface. To prevent the downward movement of seeds during watering the seeds were underlain with coarse muslin cloth. Seedling emergence was observed on each 5th day for 1 month from the date of sowing. The seed reserve effect on seedling vigor was also studied under conditions where exogenous nutrients were deficient. Seedlings from the ray and disc achenes were raised on filter paper moistened with deionized water, and 5 seedlings raised from each of the 2 achenes were harvested 3, 6, 9, 12, 15 and 18 days after emergence for biomass estimation.

Results. The ray achenes exhibited significantly greater values for weight, calorie and protein and carbohydrate content than the disc achenes but no significant differences were observed in lipid and ash content (table). The ray achenes showed relatively earlier and better germination than the disc achenes from different sowing depths, although germination of both was substantially reduced when sown below 1.5 cm depth (fig. 1). When sown at 5 cm

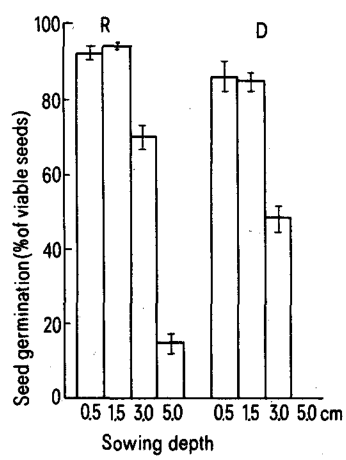

Figure 1. Cumulative germination of ray (R) and disc (D) achenes of *G. parviflora* from various sowing depths (vertical bars represent SE-values).

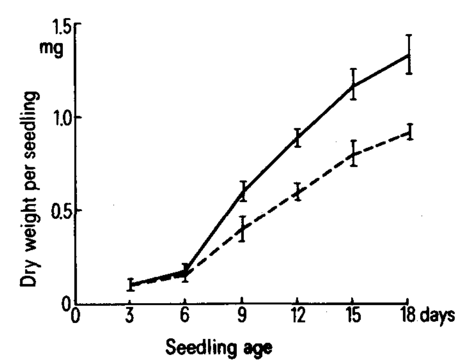

Figure 2. Dry matter yield of seedlings emerged from ray (—) and disc (---) achenes of *G. parviflora* (vertical bars represent SE-values).

Energy (calories/seed), weight (µg/seed) and storage compounds (µg/seed) of ray and disc achenes of *G. parviflora*

Achenes	Energy	Weight	Protein	Lipid	Ash	Carbohydrate
Ray	1.30	224.5	12.39	74.80	9.21	128.12
Disc	1.09	183.5	7.06	71.00	10.56	95.05
Calculated 't'-values	5.09*	4.99*	4.96*	2.02	0.88	3.42**

*Difference significant at 1% level. **Difference significant at 5% level.

depth the disc achenes failed to germinate whilst the ray achenes showed some germination (fig. 1). Initial growth of seedlings raised from the 2 achenes was similar but later on (after 9 days of emergence), the seedlings from the ray achenes produced significantly more dry matter (fig. 2).

Discussion. The relatively better germination exhibited by ray achenes, especially from a greater sowing depth, may be attributed to higher seed energy reserve which enables the seedlings to emerge out of the deeper layer of soil. The failure of emergence of seedlings from the disc achenes (which have a lower seed reserve) sown at 5 cm depth also signifies the importance of seed energy reserves in seedling emergence. The calorific difference in seeds might be due to changes in seed weight and/or proportion of storage products. Flint and Palmblad[7] have suggested that an increased proportion of protein and carbohydrate provides the readily available energy which results in quick germination. This appears to be true with the ray achenes in the present study. The effect of seed reserve is also reflected in dry matter yield of the seedlings. The better growth of seedlings from the ray achenes (fig. 2) appears to be the result of the higher protein, carbohydrate and energy content of the ray achenes. Seed fitness is frequently determined by the amount and nature of stored embryonic capital which influences the outcome of seedling competition occurring before plants become photosynthetically self-sufficient[13]. Thus, the cohort of seedling populations originating from the ray achenes may be better adapted than those from the disc achenes in competitive situations. Further, the ability of the ray achenes to germinate from the greater sowing depth has special bearing with respect to population maintenance of this weed in Meghalaya, which experiences high rainfall during the period of seed production so that the seeds are likely to be buried under eroded material (Rai and Tripathi, unpublished data).

1 Acknowledgment. The financial support from the Council of Scientific and Industrial Research, New Delhi, India is gratefully acknowledged.
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Partial migration in birds: experimental proof of polymorphism as a controlling system[1]

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Summary. When, from a partially migratory population of blackcaps, migratory-active (a) and -inactive (i) individuals were bred, the a×a pairs produced more birds of the type a than the original population and the i×i pairs, and the latter also more birds of the type i than the original population. Thus the characters 'migratory' and 'resident' in the blackcap are inherited and polymorphism is now demonstrated as a controlling system for partial migration in birds.

When hand-raised experimental groups of blackcaps *(Sylvia atricapilla)* of 4 different populations from Europe and Africa with various (exclusively and partially) migratory habits were investigated in constant experimental conditions, we found that their migratory activity was a fairly good reflection of the different migratory habits observed in the field[3]. Crossing blackcaps from an exclusively migratory European population with those from an almost nonmigratory African population, we observed in the F_1-hybrids an increase in migratory active individuals of 33% in comparison to the African parental population[4]. These findings demonstrated endogenous controlling factors for migration and supported the hypothesis first proposed by Lack[5] that partial migration in birds is based on polymorphism. According to this hypothesis, the decision as to how many and which individuals from a partially migratory population depart from or winter in the breeding area, respectively, depends on genetic factors.

To test the polymorphism (in this special case dimorphism) hypothesis, inbreeding the 2 supposed morphs 'migrant' and 'nonmigrant' appears to be the most promising method. In the case of polymorphism, the offspring of the pairing migrants×migrants should show an increase in the ratio of migrants to nonmigrants compared to the original population (prediction 1) and to the offspring of the pairing nonmigrants×nonmigrants (prediction 2). Similarly the offspring of the pairing nonmigrants×nonmigrants should show an increased amount of nonmigrants compared to the original population (prediction 3).

We started such inbreeding experiments in 1977 with blackcaps from a partially migratory population from southern France[3,6]. From 1976[3]-1980, we handraised 102

	Original partially migratory population (n = 102)	F_1-individuals from pairing nonmigratory× nonmigratory birds (n = 19)	F_1-individuals from pairing migratory× migratory birds (n = 20)
No. of migratory active individuals	79	9	17
No. of nonmigratory individuals	23	10	3
	p < 0.01	p < 0.025 (χ^2-test)	