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The Effect of Nitrogen Fertilization and Emergence Cohorts on the Survival, Growth and Reproduction of *Fimbristylis miliacea* L. Vahl

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Abstract: This research was conducted in the glasshouse at Universiti Putra Malaysia to determine the influence of nitrogen fertilization and cohorts of emergence on plant survival and reproductive capacity of *Fimbristylis miliacea*. One hundred seeds were sown on the surface of the saturated soil in the buckets. The treatments were without nitrogen (N) and with 170 kg N ha^{-1}. The experimental design was CRD with eight replications. *Fimbristylis miliacea* seedling emergences was recorded weekly up to 4 weeks and were considered as 1st, 2nd, 3rd and 4th cohorts, respectively. Considering the repeated observation of emergence cohorts, statistical analysis was done as a split plot design where N treatment was considered as main plot and emergence cohorts was subplot by using the SAS statistical software and means were tested using Tukey's studentized range test at the 5% level of probability. Percentage emergence and percentage survival data were transformed into square root values and cumulative cohort data for all parameters were analyzed using unpaired t test to determine N effects. The nitrogen had no influence on *F. miliacea* emergence. Whereas, high death rates in *F. miliacea* among young seedlings indicated a Deevey Type III survivorship curve and higher number of deaths occurred in late emerging cohorts (4th cohorts) especially when nitrogen was applied. Early emerging cohorts had greater survivorship and contributed most extensively to the next generation by producing more than 90% seeds irrespective of nitrogen treatment. *Fimbristylis miliacea* plants establishing from every 100 seeds can reproduce 287,722 seeds with nitrogen treatment, which was 1.65 fold greater than without nitrogen.

Key words: Nitrogen, cohorts, life table, *Fimbristylis miliacea* L. Vahl

INTRODUCTION

Fimbristylis miliacea L. Vahl is a competitive sedge weed occurring in all type of rice culture in South Asia (Moody, 1989). Most reports agree that weeds, being more vigorous competitors, end up using a greater portion of the fertilizer applied to the rice crop (Kim and Moody, 1989). Considerable stimulation was found by Pons *et al*. (1987) that the application of fertilizers, especially nitrogen in *Marsilea crenata*, *Monochoria vaginalis*, *Fimbristylis littoralis*, *Echinochloa crus-galli*, *Ageratum conyzoides*, *Euphorbia heterophylla*, *Digitaria* sp., *Dactyloctenium aegyptium*, *Porophyllum ruderale* and *Cyperus rotundus*. Some of the more tiny species are hardly stimulated. Therefore, fertilizer

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management would strongly affect the type of weed community and their existence in the ricefields. Nitrogen fertilizer accounts for about 67% of the total amount of fertilizers applied to the rice crop in tropical areas (Cassman *et al*., 1996). As a result nitrogen responsive crop species are more competitive under high N-fertilization, but if the associated weed is also responsive to N it utilizes more of the applied N and no advantage in crop yield may be obtained. Moreover, vigorous weed has the unique ability to produce more seeds for the next generation. One *F. miliacea* plant can produce more than 42000 seeds/season (Begum *et al*., 2008); which are deposited and stored in the soil seedbank.

Weed seeds normally reach the soil in a dormant state. The dormancy frequently allows a timing of germination in a periodically fluctuating environment which makes cohorts of plants (groups of plants of the same or similar age). Once a cohort of weeds has established in a field, its success depends primarily on its survival and growth. Mortality rate usually decreases with increasing plant size or age and the smallest individuals that suffer the highest rate of mortality (Mohler and Callaway, 1992; Buhler and Owen, 1997). In the absence of post emergence weed control, survival rates for annual weeds from the cotyledon stage to maturity usually lie between 25 and 75% (Mack and Pyke, 1983). However, rates of survival to maturity sometimes exceed 90% or approach 0% (Lindquist *et al*., 1995) and fecundity of individual plants is usually a relatively constant function of size (Harper, 1977). For most weed species, rarely has sufficient research been completed to the extent that the dynamics of the entire life-cycle of a weed species are fully understood under a range of management regimes.

The proportion of young plants during the vegetative growth is an indication of the future generation, but this is dependent on the changes of the young plants surviving until production stage as adulthood. Therefore, there are three basic types of survivorship curves. Deevey Type I populations have low mortality when young. Most individuals die at maturity within a relatively narrow age span. Deevey Type II populations have constant mortality at all ages. Deevey Type III populations have high mortality when young. Those few individuals that reach adulthood have a low death risk and continue living for a long time (Barbour *et al*., 1998; Silvertown and Doust, 1993). Therefore, in intensive rice culture, particularly under high usage of nitrogen, proper understanding of a life-table especially of a dominant weed like *F. miliacea* is needed, in order prediction and accordingly to prevention of heavy infestation of the species in a ricefield. However, no published data is available on *F. miliacea* in relation to emergence, survival, mortality, growth and fecundity. Therefore, this study was undertaken to determine the influence of nitrogen fertilization and emergence cohorts on plant survival and reproductive capacity of *Fimbristylis miliacea*.

MATERIALS AND METHODS

The experiment was conducted in the glasshouse at Universiti Putra Malaysia, from October 2003 to February 2004. Seeds of *F. miliacea* were collected from a ricefield at the Malaysian Agricultural Research Development Institute (MARDI) research station, in Bertam, Pulau Pinang on August 2003. The soil collected from a ricefield was a clay soil (59.13% clay, 39.71% silt and 1.15% sand) of Bakau series (Typic Hydraquents) with pH 4.75. Six kilogram of air-dried soil was placed in 24 cm diameter plastic buckets, puddled and maintained at saturation condition. One hundred seeds were sown on the surface of the saturated soil. As a basal dose of fertilizers, 167 kg TSP and 250 kg MOP ha^{-1} were applied to the soils in all treatments. The treatments were without nitrogen and with 170 kg N ha^{-1}. Nitrogen was applied as urea in 3 splits at the rate of 0.56 g/bucket as basal and at 35 and 55 days after sowing. The experimental design was CRD with eight replications. *Fimbristylis miliacea* seedling emergences was recorded weekly up to 4 weeks and were considered as 1st, 2nd, 3rd and 4th cohorts, respectively. Emerged seedlings were marked using color-coded toothpicks to determine survivorship. A different color of toothpick was used at each weekly sampling date. *Fimbristylis miliacea* seedlings marked with the same color toothpick belonged to the same cohort. Seedling mortality counts were recorded and the toothpicks were removed for all dead seedlings at each sampling date. Emergence (%), numbers surviving, seedling mortality, number of tillers, number of inflorescence per plant, number of spikelets per inflorescence and estimation on number of seeds per inflorescence and per plant were recorded for each cohort. According to N treatments cumulative data of emergence cohorts (1st, 2nd, 3rd and 4th) were also computed for each parameter.

Seed production was quantified from 2 plants of each cohort by harvesting 10 mature inflorescences separately within each bucket as they matured. The inflorescences were dried for 1 week, threshed by hand and the seeds separated by winnowing. The seeds from 10 inflorescence were weighed and the weight of 1000 seeds were recorded. Based on the weight of 1000 seeds and the weight of seeds per 10 inflorescence, the number of seeds per inflorescence was calculated:

$$\text{No. of seeds per inflorescence} = \frac{\text{Weight of seeds from 10 inflorescence (g)}}{\text{Weight of 1000 seeds (g)} \times 10} \times 1000 \text{ seeds}$$

Total seeds per plant were estimated by multiplying the number of seeds per inflorescence by number of inflorescence per plant. Diagrammatic life-table for *F. miliacea* was derived based on the fate of individuals starting from 100 seeds in a cohort up to 4 month period to collect with the rice planting season.

Considering the repeated observation of emergence cohorts, statistical analysis was done as a split plot design where, N treatment was considered as main plot and emergence cohorts was subplot by using the SAS statistical software and means were tested using Tukey's studentized range test at the 5% level of probability. Data on percentage emergence and percentage survival were transformed into square root values. Cumulative cohort data for all parameters were analyzed using unpaired t test to determine N effects.

RESULTS

Seedling Emergence

Nitrogen treatment, different cohorts and their interaction had no significant influence on emergence percentage of *Fimbristylis miliacea*. Over the period of 4 weeks, cumulative emergence was also not significant between the two main-plot treatments (Table 1, 2).

Plant Survivorship

Significantly higher cumulative survivorship (93.26%) was found under absence of nitrogen fertilization compared to the nitrogen treatment (83.91%) (Table 3). When N-fertilizer was applied, lowest survivorship was obtained with the 4th cohort compared to without nitrogen. No significant difference was observed between nitrogen treatments in the 1st, 2nd and 3rd cohort of plants (Fig. 1). In this study no evidence of predation or pathogen induced damage on *F. miliacea* was observed. In terms of pattern of survivorship it was observed that the 4th emergent cohort plants showed the greatest variation, while the 1st, 2nd and 3rd emergent cohorts exhibited no or a low death risk from seedling to seed maturation (Fig. 2, 3). High death rates in *F. miliacea* among 3-4 weeks old 4th cohort plants is best illustrated as a Deevey Type III survivorship curve. In this case, of the 9.25 emerged seedlings in the 4th cohorts with nitrogen treatment, only 5 survive to maturity (Fig. 2). In the absence of nitrogen, total surviving seedlings in the 4th cohort was from 5.5 to 4.38 (Fig. 3). Overall mortality was higher at 7-8 weeks from the sowing date, especially for weaker members; the mortality among weaker members often coinciding with the period of maximum growth. It is the smallest individuals that die in the population of different cohorts and a greater proportion of the late emergent plants were small individuals.

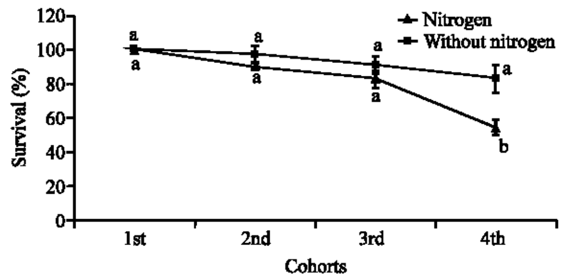

Fig. 1: Survivorship curves of *F. miliacea* (Means within cohorts with same alphabets are not significantly different at p≥ 0.05 (Tukeys Test)

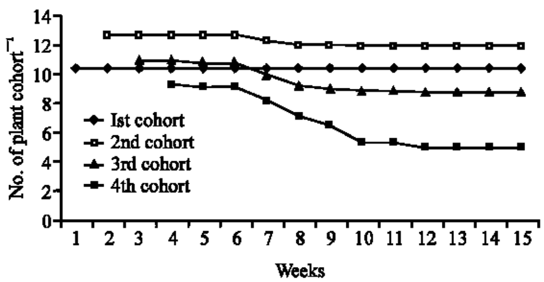

Fig. 2: Cohorts' survivorship curves of *F. miliacea* (with nitrogen application)

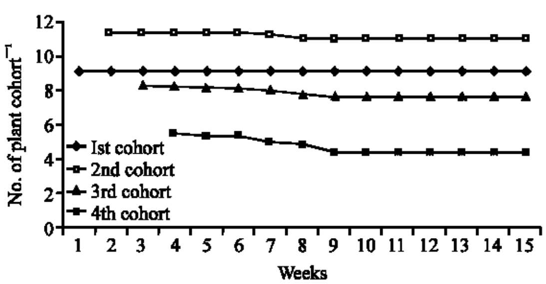

Fig. 3: Cohorts' survivorship curves of *F. miliacea* (without nitrogen application)

Reproductive Capacity

Reproduction capacity of *F. miliacea* was determined by the production of inflorescences/plant, seeds/inflorescence and seeds/plant. Maximum number of inflorescence was observed from the 1st cohort with nitrogen treatment (42/plant) compared to without nitrogen treatment (25/plant). The other three cohorts (2nd, 3rd and 4th cohorts) showed no significant differences between the nitrogen treatments (Fig. 4). All individuals of *F. miliacea* that produced inflorescence did so within a seven to eleven week period. Many individuals produced inflorescence after producing only a few leaves. These individuals were mainly from among the late emerging cohorts. In contrast, early-emerging seedlings had already formed tillers when they started to produce inflorescence. Inflorescence production and seed ripening continued uninterruptedly until the last harvest in February.

Nitrogen had no significant influence on production of seeds/inflorescence (Table 1) but higher seeds/inflorescence was observed on 1st cohorts followed by 2nd, 3rd and 4th cohorts (Table 2). The number of seeds produced per plant was invariably greatest for the cohorts that emerged immediately after sowing and decreasing exponentially in successive cohorts irrespective of nitrogen treatment

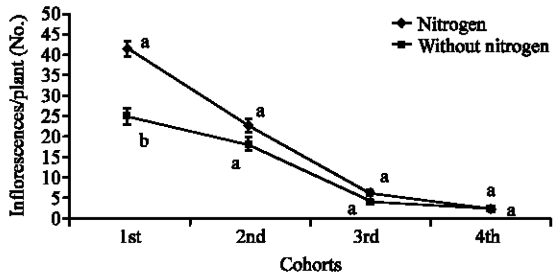

Fig. 4: Fecundity (Inflorescences/plant) of successive plants of *F. miliacea* over a four month period (Means within cohorts with same alphabets are not significantly different at $p \geq 0.05$ (Tukeys Test))

Table 1: Influence of nitrogen fertilizer on percentage emergence and seeds/inflorescence (Average value of 4 cohorts)

Nitrogen treatments	Emergence (%)	Seeds/inflorescence
Nitrogen	10.78a	272.88a
Without nitrogen	8.56a	240.28a

Means within columns with same alphabets are not significantly different at $p \geq 0.05$ (Tukeys test)

Table 2: Differences between cohorts on percentage emergence and seeds/inflorescence (Average value of 4 cohorts)

Different cohorts	Emergence (%)	Seeds/inflorescence
1st cohort	12.00a	400.94a
2nd cohort	9.75a	350.50b
3rd cohort	9.56a	172.19c
4th cohort	7.38a	102.69d

Means within columns with same alphabets are not significantly different at $p \geq 0.05$ (Tukeys test)

Table 3: Effect of nitrogen fertilizer on percentage emergence, survival percentage, total tillers/bucket, inflorescence/bucket, seeds/bucket and dry matter/bucket of *F. miliacea* (Cumulative value of 4 cohorts)

Treatments	Emergence (%)	Survival (%)	Total tillers/ bucket (No.)	Inflorescence /bucket (No.)	Seeds/bucket (No.)	Dry matter/ bucket (g)
Nitrogen	43.13a	83.91b	22.38a	749.50a	287722a	44.40a
Without nitrogen	34.25a	93.26a	14.88b	453.50b	173535b	30.58b

Means within columns with same alphabets are not significantly different at $p \geq 0.05$ (Unpaired t test)

Table 4: Fecundity (seeds/plant) of successive plants of *F. miliacea* over a four month period with or without nitrogen application

	Nitrogen application		Without Nitrogen application	
Emergence cohorts	Successive plant (%)	Seed production /plant (%)	Successive plant (%)	Seed production /plant (%)
1st Cohort	29	63	28	59
2nd Cohort	33	29	34	32
3rd Cohort	24	6	24	6
4th Cohort	14	2	14	3

(Fig. 5). Significantly higher seeds were produced from plants of the 1st cohort (16,835/plant) and 2nd cohort (7,802/plant) with nitrogen treatment compared to without nitrogen treatment of 1st cohort (10,411/plant) or 2nd cohort (5633/plant) (Fig. 5). Seeds per plant in 3rd and 4th cohorts were showed no significant differences between nitrogen treatments.

The relative contribution to seed production of the various cohorts is given in Table 4. Generally, the first cohorts established within 1 week after sowing contributed most of the total seeds produced by the population (63% with nitrogen treatment and 59% without nitrogen treatment) and hence they were the most fecund plants. Second cohorts with nitrogen and without nitrogen treatments produced 29 and 32% seeds, respectively. Later emerging plants in the 3rd and 4th cohorts with nitrogen and without nitrogen treatments contributed only 8 and 9% of the total seed production, respectively.

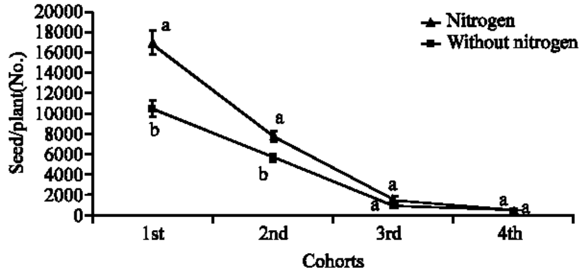

Fig. 5: Fecundity (seeds/plant) of successive plants of *F. miliacea* over a four month period (Means within cohorts with same alphabets are not significantly different at $p \geq 0.05$ (Tukeys Test))

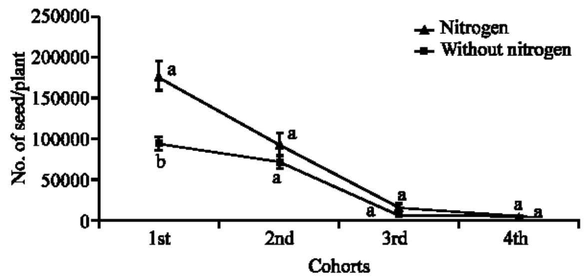

Fig. 6: Fecundity (seeds/pot) of *F. miliacea* over a four month period (Means within cohorts with same alphabets are not significantly different at $p \geq 0.05$ (Tukeys Test))

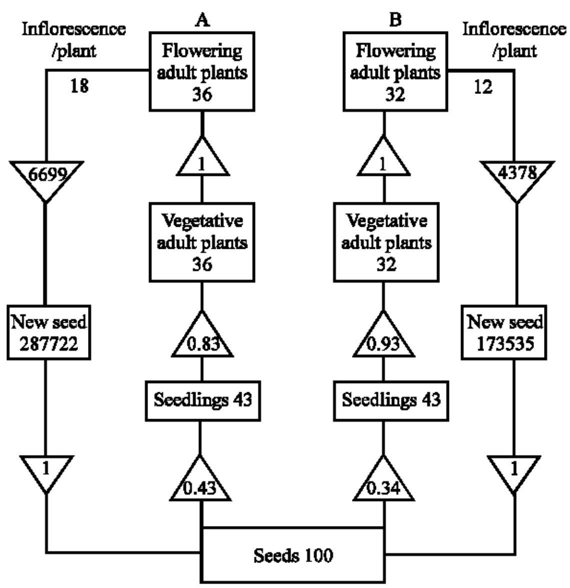

Fig. 7: The flow chart of life table of *F. miliacea* which was treated with nitrogen 100 kg ha^{-1} (A) and without nitrogen (B) (Cumulative value of 4 cohorts)

From the initial 100 seeds/pot, *F. miliacea* could produce more seeds/pot when nitrogen was applied compared to without nitrogen (Table 3). However, only the 1st cohorts produced more seeds when N was applied. All other cohorts showed no significant response to N treatment (Fig. 6).

Cumulative seed production from 100 seeds (seed rain) was 287,722 with nitrogen treatment and 173,535 without nitrogen treatment (Fig. 7).

DISCUSSION

The added N caused no increase in emergence. Other factors influencing seedling emergence, such as temperature fluctuations, moisture levels and atmosphere composition near the seed, may be more important for emergence than soil N levels. Popay and Roberts (1970) attempted to determine the cause(s) for the flushes of germination of two weed species, common groundsel (*Senecio vulgaris*) and shepherds purse (*Capsella bursa-pastoris*). They were able to characterize germination behavior in terms of seed age, light requirement, alternating temperatures, gas ratios and soil fertility. However, these factors only partially accounted for the pattern of seedling emergence observed in the field. The physiological status of the seed and environmental conditions during after ripening process are clearly important features of seed germination. Micro-environmental variability and genetic differences in seed dormancy were not measured but may contribute to the observed variation in emergence. Fawcett and Slife (1978) observed the same trend in several other weed species. They found that application of 112 to 336 kg ha^{-1} N as ammonium nitrate failed to affect population numbers of common lambsquarters (*C. album* L.), giant foxtail (*S. faberi* Herrm.), velvetleaf (*Abutilon theophrasti* Medic.), jimsonweed (*Datura stramonium* L.), or redroot pigweed (*Amaranthus retroflexus* L.). Roberts and Dawkins (1967) suggested that the rate of recruitment may be constant under a consistent cultivation regime. This suggests that emergence data from the present study can be used to estimate *F. miliacea* seedling population density based on known seedbank populations.

Lower survivorship at later emergence in N treatments is likely due to N application and an intra-and-inter cohort dominance hierarchy. According to Barbour *et al*. (1998) nitrogen fertilization as well as interspecific competition affects plant mortality. Most remarkable is the differential effect of emergence time on mortality which was relatively severe in N-fertilizer treatments compared to absence of N-fertilization. In this study, survivorship patterns may vary considerably as a function of time of emergence. Fernandez-Quintanilla *et al*. (1986) mentioned that the seedling populations of *Avena sterilis* L. and *Ludoviciana* sp. of different ages suffered at varying degrees of mortality and survivorship was highly variable for the different cohorts. Mack and Pyke (1983) observed that in *Bromus tectorum*, members of late emerging cohorts died most frequently at seedling stages. Williams (1970) also found that the density of *Danthonia caespitosa* populations decreased rapidly (a Deevey Type III curve). Cook (1980) observed that later emerging seedlings were consistently smaller than earlier emerging seedlings. Mortality was, therefore, size dependant and was concentrated among smaller individuals.

Generally, late emerging cohorts apparently suffered from competition from earlier cohorts, even when they were able to survive until harvest; their vegetative growth was minimal and were completed their life cycle with minimum seed production. Boutin and Harper (1991) observed in late emerging *Veronica* species (*V. arvensis*, *V. persica* and *V. hederifolia*) which flowered when they had developed only two true leaves, whereas the early emerging seedlings started flowering when they had already formed branches. In this study no size measurements of *F. miliacea* cohorts were made, but the early emerging seedlings developed to larger plants and set more seeds. Differential growth is the most likely explanation for the fate of individuals emerging at different time. Why the early and late emerging seedlings displayed differential growth is unclear; it could be that microsite conditions favouring early emergence are highly correlated with site conditions favoring high growth rates. However, equally likely is the possibility that early emergence leads to relatively larger size at any later point in time. Because size compounds through time in an exponentially growing system, a small difference in the time of growth due to early emergence quickly leads to large differences in size despite similar relative growth rates and seed weights. The advantage must be due, at least in part, to the capture of a disproportionate share of the environmental resources by the individuals that emerge early and a corresponding deprivation of those that emerge late (Ross and Harper, 1972).

Earliest emerging plants will have an inherent advantage over later emerging individuals and therefore will be responsible for producing greater numbers of seed (Pacala and Weiner, 1991). Greater seed production by any plant in relation to that of neighbours can be related to earlier emergence by a few weeks in *Avena fatua* (Chancellor and Peters, 1972) and by a few months in *Bromus tectorum* (Mack and Pyke, 1983). Velvetleaf seedlings emerging between 8 and 33 DAP produced greater numbers of seed than the later emerging cohorts (Lindquist *et al*., 1995). Similarly, the first four autumnal cohorts of species *V. arvensis* and *V. hederifolia* contributed most of the total seeds produced i.e., 86.7 and 70.4%, respectively (Boutin and Harper, 1991).

In this study, plants (mostly the early emerging cohorts) with nitrogen fertilizer treatment, produced significantly greater number of total tillers/pot, higher number of inflorescences/pot and higher dry matter/pot, which contributed to higher seed production than those without nitrogen treatment. The plants with nitrogen fertilization produced 1.65 fold higher inflorescence/pot and 1.66 fold higher seeds/pot than those without nitrogen fertilization. This wide range of seed production values reflects the considerable variation in seedling emergence and survivoship in different cohorts as well as the significant influence of nitrogen treatment on reproduction (Table 3). The results obtained indicate that the growth of the population during the various phases (plant emergence, growth and reproduction) was determined by moderate rates of seedling recruitment (43.14 seedlings for nitrogen treatment and 34.25 without nitrogen), high plant survivorship (83 % for nitrogen treatment and 93% without nitrogen) and high adult fecundity (6699.6 seeds for nitrogen treatment and 4377.5 without nitrogen). The resulting effect of these processes was a high potential for population growth in *Fimbristylis miliacea*. When seeds germinate and the seedlings grew to produce plants each of which in turn produced 100 seeds, then the population multiplies by one hundred fold each year.

CONCLUSION

Under intensive rice culture, farmers always apply high rates of nitrogen in order to obtain high rice yields. Perhaps, the farmers do not realize that at the same time, they are also fertilizing weeds. In this study nitrogen had no influence on *F. miliacea* emergence. However, fecundity rate of *F. miliacea* was relatively higher with nitrogen fertilization. A natural hierarchy of plant sizes occurs as a result of differences in relative emergence time, which was correlated with survival and seed production. Higher number of deaths occurred in late emerging cohorts (4th cohorts) especially when nitrogen was applied which indicated the Deevy III survivorship curve. Plants produced higher number of seeds from the 1st cohort (16835 seeds/plant) and 2nd cohort (7802 seeds/plant) with nitrogen treatment compared to treatment without nitrogen in the 1st cohort (10,411 seeds/plant) or 2nd cohort (5,633 seeds/plant). The 1st and 2nd cohorts together produced almost 92 and 93% of total seed production with and without nitrogen treatments, respectively. But, the late emerging cohorts suffered from competition with earlier emerging cohorts, resulting in poor vegetative growth and low seed production.

Nitrogen treatment stimulated the formation of tillers, increased number of inflorescences and increased dry matter production, all of which contributed to production of higher number of seeds. The results showed that with nitrogen treatment 36 seedlings which survived to adulthood originated from 100 *F. miliacea* seeds. These successful plants could produce 287,722 seeds within 4 months. This production capacity was 1.65 times greater than in plants without nitrogen. From this study, with the demographic parameters of seed production and dispersal, seed reserves in the soil, rate of seedling recruitment and expected mortality, the expected density of weed species likely to occur on a site can be predicted.

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