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EFFECT OF FIRE ON GROWTH AND ALLOCATION STRATEGIES OF *MIKANIA MICRANTHA* UNDER EARLY SUCCESSIONAL ENVIRONMENTS

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SUMMARY

(1) The effect of fire on growth and allocation of biomass and nutrients in *Mikania micrantha*, an early successional exotic weed, was studied in seral communities developed after slash-and-burn agriculture (jhum) in north-eastern India.

(2) In successional fallows, plant vigour was stable in burnt plots, but declined with age in unburnt plots. Biomass and nutrient allocation to seeds was higher in burnt than unburnt 8-year old plots.

(3) Nutrient uptake efficiency was higher after burning and increased with age, but decreased with age in unburnt fallows, probably reflecting differences in soil nutrient availability and competition.

(4) Nutrient-use efficiency was inversely related to uptake efficiency and may be a compensatory mechanism for survival.

(5) It is concluded that *M. micrantha* is adapted to survival after fire.

INTRODUCTION

Slash-and-burn agriculture (locally called jhum) is a major land use in north-east India (Ramakrishnan 1985) and elsewhere in the humid tropics (Nye & Greenland 1960; Walters 1971; Ruthenberg 1976).

During early succession after slash-and-burn agriculture in north-east India, weed species are commonly abundant (Toky & Ramakrishnan 1983a). *Mikania micrantha* Humboldt, Bonpland & Junth (Asteraceae) is an exotic weed, with a perennating caudex and profuse vegetative and seed reproductive potentials, introduced from Latin America during the Second World War (Parker 1972). With frequent disturbances under short jhum cycles, when the length of the intervening fallow phase between two successive croppings at the same site can be only 4–5 years, weeds can predominate (Saxena & Ramakrishnan 1984) and result in an arrested succession. Such invasion by weeds, particularly exotics, is well documented for tropical Asia and Africa (Nye & Greenland 1960; Bennet & Rao 1978; Kushwaha, Ramakrishnan & Tripathi 1981; Mishra & Ramakrishnan 1981). Under longer jhum cycles, however, *M. micrantha* and other weeds are suppressed, partly by the shade created by the larger shrubs and trees and partly because of increased competition (Toky & Ramakrishnan 1983a). Since fire is a tool used in slash-and-burn agriculture, this study of *M. micrantha* was aimed at understanding its adaptive response to fire in seral environments.

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METHODS OF STUDY

Nine fallow plots with similar topographic and exposure conditions, each of 2 ha, comprising three replicates each of stands left fallow for 2, 4 and 8 years since cropping were identified at Lailad, 70 km north of Shillong, north-east India ($25^{\circ} 45' \text{ N}$, $91^{\circ} 45' \text{ E}$). The age of the fallows and the similarity in land use with a 10-year jhum cycle were based on our own observations and information from the village headman. Half of each fallow plot was slashed in February 1983 and the dried slash was burnt in March 1983 to study the effect of fire; the other half plots were maintained as undisturbed controls.

Fifty plants of uniform size were identified in the burnt and the unburnt halves of all plots in April 1983. Five replicate plants with all attached ramets were carefully harvested at monthly intervals during the growing season from May to December 1983. Soil monoliths 30 cm square by 40 cm deep were washed carefully to extract all roots. The fallen leaves and achenes were also included (Hickman 1975). The different components were dried at $80 \pm 5^{\circ} \text{ C}$ for 48 hours and weighed. Leaf area estimation, using a planimeter, and leaf dry weight per unit area were based on three replicates with fifty leaves per replicate. Total leaf area per plant was computed using leaf biomass and leaf dry weight per unit area.

Mean relative growth rate (RGR), mean net assimilation rate (NAR) and mean leaf area ratio (LAR) (Hughes & Freeman 1967; Radford 1967) were calculated as the mean of eight monthly observations of three replicates each.

The concentrations of nutrients in different plant parts were determined following Allen *et al.* (1974), nitrogen by the micro-kjeldahl method, phosphorus by the molybdenum blue method after extraction with Bray & Kurtz (1945) solution, and potassium by flame photometry after wet acid digestion.

Nutrient uptake and nutrient-use efficiencies were calculated as milligrams of nutrient absorbed per gram of root biomass and as mg dry matter produced per gram of nutrient absorbed, respectively, following Blair & Cordero (1978) and Brown (1978). Both measurements were made by making eight sequential monthly harvests.

The results were subjected to one way analysis of variance. The mean \pm S.E. in this test is a pooled estimate over the various mean monthly observations, with five replications.

RESULTS

RGR, NAR and LAR increased ($P < 0.01$) between 2- and 8-year old fallows in burnt plots (Table 1), but decreased in unburnt plots.

TABLE 1. Mean (\pm S.E.) values of RGR, NAR and LAR growth functions of *Mikania micrantha* in burnt and unburnt early successional fallows

Growth function	Fallow age (years)	Burnt	Unburnt
RGR ($\text{mg mg}^{-1} \text{ day}^{-1}$)	2	0.0235 ± 0.0005	0.0148 ± 0.0003
	4	0.0247 ± 0.0004	0.0153 ± 0.0002
	8	0.0257 ± 0.0004	0.0070 ± 0.0004
NAR ($\text{mg cm}^{-2} \text{ day}^{-1}$)	2	0.171 ± 0.003	0.154 ± 0.004
	4	0.184 ± 0.003	0.163 ± 0.003
	8	0.197 ± 0.006	0.088 ± 0.001
LAR ($\text{cm}^2 \text{ mg}^{-1}$)	2	0.195 ± 0.006	0.139 ± 0.005
	4	0.254 ± 0.008	0.214 ± 0.005
	8	0.293 ± 0.009	0.010 ± 0.005

TABLE 2. Percentage allocation of biomass in May to different components of *Mikania micrantha* in burnt and unburnt 2- and 8-year old successional fallows

	Burnt		Unburnt	
	2-years old	8-years old	2-years old	8-years old
Rosette roots	28	26	18	38
Rosette stems	36	26	18	14
Rosette leaves	13	14	6	7
Stolens	12	24	36	32
Ramet leaves	7	3	19	7
Ramet roots	4	2	3	2
Inflorescences	0	0	0	0

TABLE 3. Percentage allocation of nutrients to different components of *Mikania micrantha* (i) during peak vegetative growth (August) and (ii) reproductive growth (December) in burnt and unburnt 4-year old successional fallows

	Burnt						Unburnt					
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium	
	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)
Rosette roots	3	1	4	4	2	2	4	2	4	2	1	2
Rosette stems	4	1	2	2	2	1	4	3	2	2	2	1
Rosette leaves	0	0	0	0	0	0	0	0	0	0	0	0
Stolons	36	22	50	36	51	51	36	18	50	38	47	46
Ramet leaves	50	20	34	18	38	18	56	30	36	22	44	30
Ramet roots	8	4	10	6	7	8	2	2	8	6	6	4
Inflorescences	0	52	0	34	0	20	0	45	0	30	0	17

TABLE 4. Mean uptake efficiency of nitrogen, phosphorus and potassium (mg nutrient absorbed per g root biomass) by *Mikania micrantha* in burnt and unburnt successional fallows

Nutrient-uptake efficiency	Fallow age (years)	Burnt	Unburnt
Nitrogen	2	108	85
	4	121	98
	8	128	45
LSD at 5% level		11	7.3
Phosphorus	2	12	9.5
	4	14	9.3
	8	14	4.4
LSD at 5% level		1.3	1.2
Potassium	2	134	115
	4	155	121
	8	166	81
LSD at 5% level		15	11

*Effect of fire on Mikania micrantha*TABLE 5. Mean efficiency of use of nitrogen, phosphorus and potassium (mg dry matter produced per mg nutrient absorbed) by *Mikania micrantha* in burnt and unburnt successional fallows

Nutrient-use efficiency	Fallows age (years)	Burnt	Unburnt
Nitrogen	2	78	98
	4	76	100
	8	69	175
LSD at 5% level		7.6	7.6
Phosphorus	2	699	896
	4	672	1010
	8	583	2030
LSD at 5% level		25	157
Potassium	2	60	74
	4	56	77
	8	51	98
LSD at 5% level		6	5.2

TABLE 6. Reproductive effort (calculated as biomass or nutrient allocation to the seed as the percentage of net primary production or nutrient uptake during the growing season) of *Mikania micrantha* in burnt and unburnt successional fallows

Reproductive effort	Fallow age (years)	Burnt	Unburnt
Biomass	2	24	23
	4	25	22
	8	27	22
LSD at 5% level		5.2	6.4
Nitrogen	2	57	53
	4	60	61
	8	64	88
LSD at 5% level		8.4	9.2
Phosphorus	2	51	46
	4	53	49
	8	56	80
LSD at 5% level		7.4	7.3
Potassium	2	31	33
	4	31	39
	8	33	83
LSD at 5% level		9.2	8.4

Table 2 compares biomass allocations in May between 2- and 8-year old burnt and unburnt fallows. Rosette root biomass was higher ($P < 0.05$) in the 2-year old burnt fallow than in the unburnt, lower in burnt than unburnt plots in the 8-year old fallow, but in unburnt plots was higher ($P < 0.05$) in the 8-year old than the 2-year old fallow. Inflorescence biomass in December was higher ($P < 0.05$) in the burnt plot only in the 8-year old fallow (26% allocation compared to 12% in the unburnt plot); both burnt and unburnt plots in the 2-year old fallow had about 22% biomass allocation to inflorescences. Allocations of nitrogen, phosphorus and potassium followed a similar pattern to biomass. Table 3 gives data for the 4-year old fallow; allocations in the 2- and 8-year old

fallows were similar. Potassium in the inflorescence was lower ($P < 0.01$) than nitrogen and phosphorus but higher ($P < 0.05$) in the stolon than nitrogen. Leaf nitrogen was higher ($P < 0.05$) than phosphorus and potassium in August.

Nutrient-uptake efficiency in the burnt plots increased significantly ($P < 0.01$) with fallow age (Table 4). In the unburnt plots, however, it decreased sharply ($P < 0.01$) in an 8-year old fallow as compared to younger fallows. Nutrient-use efficiency decreased ($P < 0.01$) with fallow age in the burnt plots but increased in the unburnt plots (Table 5). Burnt plots consistently had lower use-efficiency values ($P < 0.01$) than unburnt plots for all nutrients.

There was no difference in sexual reproductive effort in terms of biomass between fallow ages or between burnt and unburnt plots (Table 6), but in terms of nutrients, cost was less in burnt 8-year old fallow ($P < 0.01$) than in unburnt plots.

DISCUSSION

The study examined the fire dependence and decline in vigour in older fallow plots of the exotic weed *Mikania micrantha*, which appears during early succession after slash-and-burn agriculture. Its fire dependence is shown by higher mean values of RGR, NAR and LAR in the burnt successional fallows of all ages than in unburnt fallows. This difference was greater in 8-year old fallow, suggesting that the species rapidly declines in vigour without disturbance. This corresponds with observations that seedlings establish only after fire (Swamy & Ramakrishnan 1987).

The ruderal nature and fire dependence of *M. micrantha* is also reflected in its allocation strategy, with it flowering better and at a lower nutrient cost in burnt than unburnt 8-year old fallow. Further, only in unburnt plots did the biomass allocation to seeds decline with fallow age. This would lead to eventual weed suppression (Toky & Ramakrishnan 1983a; Saxena & Ramakrishnan 1984). Although nutrient allocation pattern generally followed the biomass pattern, there was generally less potassium in the leaves and the seeds, a feature noted by others (Van Andel & Vera 1977; William & Bell 1981; Saxena & Ramakrishnan 1983).

Nutrient-uptake efficiency was higher in the burnt plots, perhaps because of increased availability. With a decreased nutrient pool in an unburnt 8-year old fallow, which is related to rapid transfer from the soil to the developing vegetation (Ramakrishnan & Toky 1981; Toky & Ramakrishnan 1983b), it is reasonable to expect reduced uptake efficiency. A higher use efficiency in sites of lower uptake efficiency may be considered as a compensatory mechanism for survival.

Though we know on the basis of the past land use that there was at least one 10-year crop/fallow cycle before the fallows we studied, differences between sites in soil and vegetation may to some extent confound the effect of fallow age. In spite of this, fire adaptations by *M. micrantha* and the role of fire in determining its success during early succession is obvious.

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