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Ecology of jungle rice (*Echinochloa colonum*), a weed of the rice agroecosystem: a case study in Bilaspur (Chhattishgarh)

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Chhattisgarh in India is a rice-growing state, with about 80% of its population living in villages that directly or indirectly depend on rice cultivation. The types of rice culture used are direct seeding and transplanting (dry seeded rainfed or wet seeded lowland and/or upland). Bilaspur in Chhattishgarh has a very high temperature, thus assuming an ecological importance with respect to vegetation of cultivated crops, especially rice. There is a great need for research that will prevent losses caused by weeds and will enable management of weeds in direct seeded rice using the most economical and feasible method.

These objectives can be achieved through a better understanding of the ecology of different weeds infesting direct-seeded rice.

The present study aimed to study some ecological aspects of jungle rice (*Echinochloa colonum* Link), the most common and obnoxious weed of direct-seeded rice. The investigation included a general survey of the weed flora, phytosociology and phenology of the weeds, and autecological observation of *E. colonum*. Knowing the peculiarities in the life history of the plant and its epharmony with its environment may provide a tool to alter that epharmony to man's advantage in terms of better rice yield. The study observed the morphology of the seed, seed germination, and growth performance.

Phytosociology is the study of detailed structure and description of different plant species or a set of individual plant species grouping together and having mutual relationships among themselves and to their environment. It is through a series of complicated interactions and reactions that the phytosociological interrelationship of any plant community is established. Various climatic, edaphic, and biotic factors combine to determine the floristic composition of a particular plant community. In case of cultivated rice, the natural floristic composition is very much disturbed when we continually manipulate vegetation by cultural means such as tillage or hoeing or by use of herbicides or fire. Weeds appear to be those plants that occupy the earliest stages of secondary succession. Quantitative phytosociological characters such as percentage frequency, density, and abundance were studied following the methodology described by Ashby (1948) and Misra (1968). The plant species were identified preserved in herbarium sheets.

Seasonal ecological phenomena are described by superimposing the phenological calendar over the civic calendar. Observations of the different phases of a life cycle such as seed germination, vegetative growth, flowering, fruiting, and seed maturation in their temporal occurrence are used to prepare a phenological calendar. Such phonological observations recorded in the field can provide good information about the ecological behavior of an organism. The phenology of weeds was studied through several visits to the rice fields at regular intervals during the growth period and observations were recorded in the form of a phenogram. (Fig. 1).

Jungle rice (*E. colonum*), popularly known as 'sawan,' is a troublesome weed. It was the dominant weed species, showing monthly variation in quantitative phytosociological characteristics. *E.colonum* exhibited 68% and 86% frequency in September and October, which was maximum among all weeds. Its density increases as rice matures, thus making competition severe. *E. colonum* was found to be the most common and uniformly distributed throughout the rice fields in all study sites having direct-seeded rice culture. The increasing peaks of frequency, density, and abundance revealed that September and October are critical periods for competition with rice. Not only was there more severe competition; quantity

Table 1. Percentage frequency (F), density (D), and abundance (A) of weed species in rice fields.[a]

Name	July			August			September			October			November		
	%F	D	A	%F	D	A	%F	D	A	%F	D	A	%F	D	A
Oryza sativa	100	10.72	100	10. 72	12.0	12. 0	100	12.5	12. 5	100	13.0	13. 0	100	13.0	13.0
Paspalum scrobiculatum	40	1.36	3.4	48	1.4	2.91	52	1.44	2.76	56	1.44	2.57	44	1.74	3.95
Echinochloa colonum	42	1.06	2.52	60	1.03	2.20	68	1.72	2.52	86	1.84	2.13	64	1.30	2.03
Cyanotis axillaris	18	2.8	1.55	24	0.50	2.08	14	0.16	1.14	22	0.6	2.72	12	0.26	2.16
Crotalaria albida	24	0.70	2.91	26	0.48	1.84	20	0.38	1.9	12	0.14	1.16	28	0.62	2.1
Cieome cheledonii	4	0.06	1.50	10	0.12	1.20	22	0.32	1.45	24	0.3	1.24	16	0.30	1.87
Cassia tora	– – –	– – – – –	– – – –	4	0.04	1.0	4	0.04	1.00	10	0.14	1.40	– – – –	– – –	– – – – –
Cyperus rotundus	22	0.54	4.72	12	0.24	2.0	24	0.38	1.58	32	1.16	3.62	16	0.4	2.5
Cyperus iria	18	0.84	4.66	24	0.5	2.08	30	0.42	1.40	42	0.12	1.0	16	0.36	2.25
Cyperus flavidus	20	0.54	2.70	18	0.40	2.22	16	0.30	1.87	– – –	– – – –	– – – –	26	0.6	2.30
Cyperus haspens	8	0.12	1.50	12	0.2	1.66	22	0.50	2.27	– – – –	– – – –	– – – – –	8	0.1	1.25
Fimbristylis ferruginea	30	1.00	3.33	50	0.6	1.20	36	0.58	1.61	46	0.78	1.69	14	0.2	1.42
Aeschynomene aspara	10	0.20	2.00	36		0.82	20	0.26	1.30	36	0.4	1.11	12	0.24	2.00
Kyllinga triceps	12	0.24	2.0	1.86			26	0.38	1.46	42	0.58	1.38	8	0.1	1.25
Scirpus gressus	– – –	– – – –	– – – –	18		0.28	22	0.42	1.90	– – – –	– – – –	– – – –	28	1.00	3.57
Eriocolon quinquangulare	16	0.32	2.00	1.55			24	0.5	2.08	28	0.34	1.21	20	0.2	2.5
Euphorbia hirta	16	0.42	2.62	14		0.22	8	0.14	1.16	12	0.2	1.66	26	0.5	1.92
Eclypta alba	16	0.44	2.75	1.57			12	0.24	2.00	18	0.2	1.11	– – –	– – –	– – –
Aneilema nudiflorum	10	0.1	1.0	22		0.52	6	0.06	1.0	24	0.62	1.40	4	0.04	1.0
Ischemum rugosum	12	0.4	3.33	2.36			10	0.1	1.0	26	0.4	1.53	22	0.22	1.57
Sida acuta	– – –	– – –	– – –	8		0.14	– – –	– – –	– – –	22	0.36	1.63	22	0.22	1.57
Sida veronaecifolia	38	1.72	4.52	1.16			26	1.30	5.00	32	2.96	2.00	16	1.78	2.51
Sida rhombifolia	6	0.06	1.00	– – – – –	– – – – –	– –	6	0.08	1.33	8	0.14	1.75	18	0.32	1.77
Abutilon indicum	6	0.06	1.00	– –			– – – –	– – –	– – – – –	20	0.24	1.20	– – –	– – –	– – –
Aegeratum conizoides	14	0.28	2.0	26		0.4	8	0.12	1.50	14	0.24	1.71	14	0.18	1.28
Striga euphrasiodes	14	0.32	2.28	1.53			– – – – –	– – – –	– – – –	16	0.16	1.00	12	0.24	2.0
Phyllanthus madraspatensis	14	0.26	1.85	– – – – –	– – – –	– – – –	22	0.36	1.63	20	0.32	1.60	18	0.3	1.66
Alternanthera sessilis	– – –	– – –	– – – –	– – – – –	– – – – –	– – – –	12	0.2	1.66				6	0.06	1.0
Echinochloa crus-galli	– – –	– – – –	– – – –	40		2.54	12	0.12	1.0	8	0.08	1.00	– – – –	– – – –	– – – –
Commelina benghalensis	– – – –	– – –	– –	6.35			– – –	– – –	– – –	14	0.12	1.03	– – – –	– – –	– – – –
Aerua lanata	14	0.4	2.85	10	0.22	2.2	10	0.14	1.4	– – – –	– – – –	– – – –	6	0.08	1.33
Centella asiatica	10	0.12	1.2	– – – – –	– – – –	– – –	14	0.20	1.42	12	0.16	1.33	8	0.88	1.00
Euphobia microphylla	14	0.4	2.85	–			– – –	– – –	– – –	– – –	– – –	– – –	6	0.1	1.66
Amaranthus spinosus	– – – –	– – –	– – –	– – – – –	– – – –	– – – –	6	0.08	1.33	12	0.16	1.33	– – –	– – –	– – –
Achyranthus aspara	– – – – –	– – –	– – –	22	0.36	1.63	22	0.32	1.45	6	0.06	1.00	– – – –	– – –	– – –
Corchorus aestuans	– – –	– – – –	– – – –	– – – – –	– – – – –	– – –	16	0.32	2.00	6	6.06	1.00	– – –	– – –	– – –
Partheniun hysterophorus	12	0.26	2.16	– – – – –	– – – – –	– – – –	8	0.12	1.5	16	0.08	0.50	8	0.14	1.75
Xanthium strumarium	18	0.32	1.77	– – – – –	– – – –	– – –	10	0.12	1.2	– – –	– – –	– – – –	14	0.42	3.0
Indigoferra linifolia	4	0.06	1.00	–			12	0.24	2.00	10	0.1	1.0	– – –	– – –	– – – –
Coldenia procumbens	– – –	– – – –	– – – –	4	0.04	1.0	– – –	– – –	– – – –	10	0.12	1.20	– – –	– – –	– – – –
Desmodium triflorum	4	0.04	1.00	– – – –	– – – –	– – – –	6	0.12	2.00	4	0.04	1.00	– – – –	– – –	– – – –

Table 1 continued...

Croton bonplendianum	---	---	---	10		0.12	----	---	---	---	---	6	0.08	1.33
Ammania baceifera	36	0.74	2.05	1.20			36	0.78	6.5	---	---	32	0.62	1.93
Oxalis corniculata	---	----	----	8		0.16	10	0.6	6.00	----	---	---	---	---
Heliotropium subinum	---	----	---	2.00			24	0.4	1.66	---	----	4	0.12	1.00
Rungia spp.	---	----	---	----	----	---	---	---	---	10	0.6	2	0.04	2.00
Chrozophora indica	---	---	---	---	-		6	0.12	2.00	12	0.24	4.00	32	0.32	2.00
Spheranthus indicus	4	0.04	2.00	----	----	---	12	0.20	1.66	10	0.16	1.60	22	0.32	1.45
Celosia argentea	----	---	----	-			10	0.24	2.40	14	0.48	3.42	6	0.20	4.00
Pistia strateiodes	2	0.2	1.00	---	---	---	8	0.20	2.50	2	0.02	1.00	---	----	---
Cynodon dactylon	20	0.20	1.00	-			24	0.24	2.24	18	0.22	2.00	12	0.12	1.88
Ludwigia parviflora	---	---	---	----	----	---	12	0.24	2.00	---	---	---	----	---	---
Marsilea quadrifolia	16	0.40	2.5	-			18	0.44	2.44	6	0.20	3.33	---	---	---
Oryza sativa (red rice)	8	0.24	3.0	16	0.3	1.87	24	0.60	2.50	18	0.70	3.88	6	0.16	2.66
Polygonum glabrum	12	0.28	2.33	------	----	---	14	0.42	3.00	---	---	---	---	---	---
Dactyloctenium aegypticum	10	0.24	2.00	------	---	------	28	0.60	2.14	14	0.40	2.85	---	---	---
Echinochloa glabrescens	8	0.16	2.00	4	0.04	1.00	32	0.80	2.50	22	0.40	1.8	6	0.06	2.00
Cyperus difformis	---	---	---	12	0.16	1.33	34	1.12	3.29	32	1.00	3.12	64	0.64	3.55

[a]Results are expressed as av of samples from 10 localities.

and quality of grain was likewise reduced.

E. colonum germinates and emerges in July with rice after the rains. Flowering starts in the first week of September and the seed matures from September to October, simultaneously with rice. This is the reason jungle rice seeds are often harvested with the crop and the weed inoculum is retained for the next crop.

Autecological investigations reveal that jungle rice is an emergent aquatic annual grass, appearing as a self-sown plant in rice field with water. Its very small size and rotundate-elliptic shape help in seed dispersal. This explains its widespread distribution throughout the rice fields. These seeds get easily mixed with the crop seeds, thus retaining the weed inoculum. Seed production per plant was very high, varying greatly with different environmental conditions (Table 2). A large seed output and reproductive capacity indicate its success in the ecosystem. Longevity and the prolonged viability suggest that, once an area of land is infested by it, the potential exists for continued reoccupation over time. Freshly collected seeds exhibit a period of innate dormancy, which seems to be adjusted to the environmental conditions to which the seeds are exposed. Potassium nitrate treatment proved successful in breaking dormancy. The plant could not tolerate waterlogged conditions. Hence, jungle rice is characterized by high plasticity in its vegetative growth, rapid early growth phases,

and a prolonged vegetative phase before and during reproduction. This allocates a large proportion of resources to seed production. Thus *E. colonum* seems fit in the category of a "competitive ruderal," according to Grime's concept of plant strategies and resource allocation.

Some of the traits that correlate *E. colonum* with 'r' selection are

- Variable and unpredictable climate
- High seed output (8,000–43,000 seeds plant^{-1})
- Density-dependent mortality
- Mortality at the early stage (otherwise it survives)
- Population size variable with respect to time and not in equilibrium; can recolonize each year
- Interspecific and in traspecific competition
- Short life span (usually <1 yr)
- Selection favors rapid development, early reproduction, small body size, and single reproductive period in a life span
- Results in overall productivity

Thus *E.colonum* is a "competitive ruderal" showing optimum resource capture and seed production. This enables it to survive in the agroecosystem of Bilaspur.

Table 2. Vegetative and reproductive characteristics of *Echinochloa colonum*.[a]

Maturity (d)	Height (cm)	Seeds plant^{-1} (no.)	Seed weight (mg)	Reproductive capacity
90-105	47–70	9,000–42,327	2.26–2.30	1055–1489

[a]Results expressed as av of five populations from 10 localities.

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p. 49, first sentence, last paragraph: "5-d-old seedlings should be 35-d-old seedlings."

p. 50, Table 3, some entries are incorrect. The table should look like this. Corrected values are in boldface.

Table 3. Physicochemical properties of surface soil (0–15) after 8 y of experimentation, Karnal, India, 1994-2001.

Treatment		pH	Organic C (%)	Available nutrients (kg ha^{-1})			DTPA extractable Zn (mg kg^{-1})	**SAR**
				N	P	K		
Rice	Wheat							
T^1 (control)	Control	8.50	0.26	90	11.0	220	0.64	18.7
T_2 (N_{120})	N_{120}	8.53	0.27	146	**8.5**	**250**	**0.65**	**13.5**
T_3 ($N_{120}P_{26}$)	$N_{120}P_{26}$	8.48	0.27	146	18.5	240	0.65	13.5
T_4 ($N_{120}P_{26}K_{42}$)	$N_{120}P_{26}K_{42}$	8.52	0.26	146	22.2	282	0.66	14.2
T_4 ($N_{120}P_{26}K_{42}Zn_{4.5}$)	$N_{120}P_{26}K_{42}$	8.50	0.26	144	20.5	279	1.12	14.1
T_6 (T_4 + FYM 10 t ha^{-1})	$N_{120}P_{26}K_{42}$	8.40	0.41	158	22.0	296	1.03	12.1
T_7 (T_4 +gypsum 5 t ha^{-1})	$N_{120}P_{26}K_{42}$	8.20	0.37	148	18.9	291	0.69	11.7
T_8 (T_4 FYM 10 t ha^{-1} + gypsum 5 t ha^{-1})	$N_{120}P_{26}K_{42}$	8.30	0.40	159	23.3	297	1.11	10.3
T_9 (T_4 + pressmud 10 t ha^{-1})	$N_{120}P_{26}K_{42}$	8.30	0.41	155	23.8	295	0.96	11.5
T_{10} (T_4 + pressmud 10 t ha^{-1} + gypsum 5 t ha^{-1})	$N_{120}P_{26}K_{42}$	8.30	0.40	157	23.2	292	0.95	10.1
CD (P=0.05)		0.09	0.05	8	3.1	22	0.14	0.8