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PRODUCTIVITY OF THE PLANT COMMUNITIES IN SALT AFFECTED AREAS OF THE INDO-GANGETIC PLAINS

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RESUME

Une étude systématique a été effectuée sur les parcelles à sols salés des plaines indo-gangétiques du sous-continent indien. Ces biotopes sont couverts par une végétation herbacée clairsemée, qui comprend plusieurs espèces montrant des degrés divers d'halophytisme facultatif; ces derniers résultant soit d'une plasticité écologique, soit d'une spécialisation éco-génétique, ou des deux à la fois. Les communautés établies sur sols salés montrent une productivité primaire inférieure à celle des végétations correspondant aux conditions normales des plaines indo-gangétiques. Ce fait a été attribué à des facteurs limitants tels que les faibles précipitations, l'évapotranspiration élevée et le développement de hautes pressions osmotiques dans le milieu édaphique, suite à la présence de sels solubles dans l'eau. La biomasse totale maximale s'observe en saison de moussons et coïncide avec la période d'activité végétative la plus élevée. Il existe une corrélation significative entre la variation mensuelle de la teneur en eau du sol et la biomasse de la couverture végétale.

ABSTRACT

A systematic study was conducted on the patches of salt-affected habitats in the Indo-gangetic plains of the Indian sub-continent supporting sparse grass covers, certain elements of which show facultative halophytism of varying degree either by virtue of wide ecological amplitude or through genecologic specialization or both.

A comparison of the primary productivity of the communities of these specialized habitats with that of normal grass covers of the Indo-gangetic plains indicated inferiority of the former. This has been ascribed to the limiting factors such as low rainfall, high evapotranspiration and development of high osmotic pressures in the edaphic environment due to predominance of water soluble salts. Maximum total standing crop biomass in monsoon season coincided

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with the highest vegetative activity during this part of the year. Based on regression and correlation analysis, monthly variation of moisture in the profile and the standing crops biomass of the surface feeding plants were shown to be significantly related.

INTRODUCTION

The semi-arid alluvial tract of land extending from Punjab through Haryana, Uttar Pradesh and part of Bihar in the Indian sub-continent is interspersed with patches of salt-affected areas which, because of being unproductive from an agricultural view point, constitute the 'Usar' (salt-affected) soils of India (GUPTA & REGE, 1973). The total expanse of this unproductive 'Usar' areas, according to one recent estimate, amounts to 2.5 million hectares (ABROL & BHUMBLA, 1971), which upon a successful reclamation may yield more than 10 million tonnes of food grains to feed the hungry mass of the country (MEHTA, ABROL & YADAV, 1975).

Besides having an excess of water soluble salts which results a high osmotic potential in the edaphic environment, these habitats are also characterized by high pH, poor soil structure and disturbed aeration. All these factors have an apparent adverse effect on germination, establishment, nutrition, growth and reproduction of most of the terrestrial plant species (CALDWELL, 1974; CHOUDHURI & VARSHNEY, 1975; UNGAR, 1974).

Depending upon the biologic potential of the species, plants were classified into halophytes and glycophytes as early as in 1895 (DAUBENMIRE, 1974). The halophytes have a high osmotic potential in their internal environment, which enables these plants to absorb water and nutrients from habitats under salt-stress (ASHBY & BEADLE, 1957), and such habitats are mainly found bordering either salt lakes or seas. The glycophytes normally remain confined to non-saline inland habitats. However, many of these species often reveal a successful ecesis in habitats characterized by certain degree of salt-stress either by virtue of their wide ecologic amplitude or through genecologic specialization in response to salt-stress with or without recognizable morphological differentiation (CHOUDHURI, 1968; WAISEL, 1972).

Ecology of some such glycophytes, which by virtue of their salt-adaptive potential occur as facultative halophytes in habitats suffering salt-stress, comprises the present communication. The parameter used here in the primary productivity both because it keeps up a consonance with the IBP programme as well as because the process is sensitive to water-stress (RABINOWITCH,1945). Information available so far on the aspect is extremely meagre.

SITE CHARACTERISTICS

Location

Three salt-affected habitats i.e., sites I, II and III, were selected for the present study within a hundred kilometer radius around the Banaras Hindu University campus. Site I was situated at the village Babhnoti, about 9 kilometers off Tahsil Bhadohi (25° 23' N and 82° 34' E), site II and III were at the villages Hamidpur and Patnawa, respectively, about 5 kilometers off Ramnagar (25° 16' N and 83° 2' E). The general features of these sites were reflected in the presence of extensive white or greyish-white crystallized salts on the surface during major part of the year subsequent to the monsoon. The climate of the area is tropical and the year is divisible into three main seasons viz., Winter, Summer and Rainy seasons. About 85 % of the total annual rain is received by these habitats during the monsoon season.

Edaphic environment

The soils of these areas usually remain dry for about six months or more when the moisture in the profile falls below wilting point and moist for about five or more months in a year (SHARMA, 1977). The ionic constitution of the soils of the three habitats were determined from the saturation extracts prepared from the composite soils samples (MOODIE, SMITH & HAUSENBUILLER, 1963) taken to a depth of 30 cm from the soil profile by the methods described by RICHARDS et al. (1954). Based on the ionic constitution, the sites were classified into two principal types. Site I was sulphate type where Cl^- and SO_4^{--} were the dominant anions with Na^+ representing 36 %, Ca^{++} 14 % and Mg^{++} 11 % of the total metallic cations. Sites II and III were of carbonate types. In site II, carbonate and bicarbonate ions together represented about 81 % of the total anions and the sodium above 96 % of the total metallic cations. The carbonate and bicarbonate anions together at site III amounted over 87 % of the total anions and sodium went almost to 100 % of the total metal cations (Tab. I).

pH and ionic constitution		Site I	Site II	Site III
pH		7.8	8.9	10.1
Cations	Ka^{+}	82.55	68.57	172.0
	K^{+}	0.41	0.61	2.10
	Ca^{++}	18.0	1.20	1.84
	Mg^{++}	14.6	0.76	0.64
Anions	CO_3^{--}	0.40	37.32	89.78
	HCO_3^{-}	3.00	24.80	69.50
	Cl^{-}	33.50	5.17	16.60
	SO_4^{--}	73.65	9.36	7.60

Tab. I : pH and ionic constitution (meq/l) of the saturation extracts of the soils of three salt-affected habitats.

Floristics

A record of floristic composition was maintained throughout the year. The maximum number of species was in monsoon season when the communities attained their optimum stage of development. The plant identification was based on the Flora of BOR (1941), DUTHIE (1960) and MAHESHWARI (1963). Difference in the floristic composition of three communities is discernible from a glance to Table II. Species such as *Cynodon dactylon*, *Sporobolus diander*, *Bothriochloa pertusa*, *Dichanthium annulatum*, *Convolvulus arvensis* and *Eragrostis tenella* were found to occur at all the three sites. *Dactyloctenium aegypticum* and *Euphorbia prostrata* were found only at sites I and II, while *Evolvulus alsinoides* at sites II and III. *Phyla nodiflora*, *Pluchea lanceolata*, *Eclipta alba* and *Chloris harbata* were found to occur at site I only. *Setaria glauca*, *Panicum humile*, *Bonnaya brachiata* and *Alysicarpus monilifera* were found to inhabit site II only. Even in spite of the fact that these species are all members of the flora of the Indo-Gangetic plains of this continent, their restricted occurrences among the three habitats reflect an ecologic selection which appears to be governed by the salt-stress characteristically associated with these habitats.

Species	Site I			Site II			Site III		
	R	W	S	R	W	S	R	W	S
Alysicarpus monilifer DC				+					
Bothriochloa pertusa A. Camus.	+	+		+	+	+	+		
Bonnaya brachiata Link & Otto.				+					
Chloris barbata Sw.	+								
Convolvulus arvensis Linn.	+			+			+		
Cynodon dactylon Pers.	+	+	+	+	+	+	+	+	+
Dactyloctenium aegypticum Beauv.	+			+					
Dichanthium annulatum Stapf.	+			+	+		+		
Eclipta alba Hassk.	+	+							
Eragrostis tenella Roem.	+	+		+	+		+		
Euphorbia prostrata Ait.	+			+					
Evolvulus alsinoides Linn.				+			+		
Panicum humile Nees.				+					
Phyla nodiflora Linn.	+	+	+						
Pluchea lanceolata Cl	+	+	+						
Setaria glauca Beauv.				+					
Sporobolus diander Beauv.	+	+	+	+	+	+	+	+	+
Vernonia cinerea Less.	+	+					+		
Total No. of species	13	8	4	13	5	3	8	2	2

Tab. II : Species composition of the three plant communities at three salt-affected habitats round the year (R, W and S represent Rainy, Winter and Summer seasons, respectively) + sign indicates presence of species.

METHODS

For primary productivity studies, the species were arranged under two categories on the basis of the extent of their existence in the community round the year. Species occurring throughout the year were regarded as the major species, while those which could grow only for a part of the year were considered together to represent the "other species" group (Tab. III). Net primary productivity was estimated by the short-term-harvest method (ODUM, 1960). Standing crop biomass which refers to oven dry weight of plant material from a unit area at a given time, was estimated every month. At every sampling, three monoliths at each site,

Site I	Site II	Site III
1. *Cynodon dactylon*	*Cynodon dactylon*	*Cynodon dactylon*
2. *Sporobolus diander*	*Sporobolus diander*	*Sporobolus diander*
3. *Phyla nodiflora*	*Bothriochloa pertusa*	
4. *Pluchea lanceolata*		

Tab. III : Major species of the communities of three salt-affected habitats.

were dug. Each monolith was of 25 x 25 x 30 cm dimension. The litter present on the soil surface was collected carefully prior to digging the monoliths and subsequently, the species were segregated. Aboveground and underground parts of the plants were separated carefully. Afterwards both aboveground as well as underground biomass values of individual species and of litter were determined through oven drying at 60° C for 48 hours. Values for total standing crop biomass of various species were then estimated by adding the aboveground, underground standing crop biomass plus the litter biomass values. The standing crop biomass was expressed per meter square basis.

The net primary production wes estimated by adding all monthly increments in the aboveground, underground, and total standing crop biomass for the communities. The study period was extended for thirteen months in order to have a complete estimate of the net primary productivity of these habitats for one whole year. *Pluchea lanceolata* was a deep rooted species. Net primary production of this species was determined only to a depth of 30 cm in order to maintain a consistent conformity in estimations relative to other species.

RESULTS

Monthly variation in the standing crop biomass

Aboveground standing crop biomass

The total aboveground standing crop biomass of the communities at three sites ranged between 109.73 g/m^2 (May) and 251.45 g/m^2 (Sept.) at site I; 76.16 g/m^2 (May) and 221.48 g/m^2 (Sept.) at site II, and 62.14 g/m^2 (May) and 183.19 g/m^2 (Sept.) at site III. Variance analysis indicated a significant degree of within site variation ($P < 0.05$). For all the three communities two peak values of aboveground standing crop biomass were observed. The peak values were noticed in September and in January for communities at sites I and II, and in September and in February for the community at site III. The trends in biomass fluctuations round the year were more or less similar at all three sites (Tab. IV).

Underground standing crop biomass

The total underground standing crop biomass of the community ranged between 93.73 g/m^2 (June) and 156.55 g/m^2 (Sept.) at site I; 58.88 g/m^2 (June) and 144.08 g/m^2 (Sept.) at site II, and 54.61 g/m^2 (May) and 161.11 g/m^2 (Sept.) at site III. A significant ($P < 0.05$) within site variation was observed. In this case also two peak values were recognizable, one of which coincided with the monsoon, while the other mid-winter. The underground biomass was higher for the community at site I relative to that for its counterparts at sites II and III (Tab. IV).

Total standing crop biomass

The total standing crop biomass of the community ranged between 206.60 g/m^2 (June) and 407.99 g/m^2 (Sept.); 137.11 g/m^2 (May) and 365.56 g/m^2 (Sept.) and 116.74 g/m^2 (May) and 344.27 g/m^2 (Sept.) at sites I, II and III, respectively. Of the communities studied at three sites under salt-stress, the highest total standing crop biomass was observed for site I and the lowest for site II (Tab. IV).

Cynodon dactylon and *Sporobolus diander* were the major species to contribute maximum organic matter throughout the year at site II and III. Contribution of *C. dactylon*, however, was more than that of *S. diander*. Among the four species playing a significant role in contribution to total standing crop biomass of community at site I, *Pluchea lanceolata* showed superiority year round and *C. dactylon* came next at this site. Contribution of standing crop biomass by *Phyla nodiflora* was higher relative to that of *S. diander* at this site during major part of the year. Contribution of "other species" remained confined during rainy season only. But except for site I, contributions to the total standing crop biomass by the species of this group never exceeded appreciably that due to any of the major species of the communities.

Months	% Moisture content			Aboveground Standing Crop biomass		
	Site I	Site II	Site III	Site I	Site II	Site III
June	16.56	2.76	3.83	112.876	79.792	80.991
July	18.64	20.36	20.53	168.634	144.625	137.719
August	21.49	14.84	19.18	202.966	207.406	161.536
September	16.38	19.11	17.26	251.438	221.482	183.185
October	13.21	15.21	14.31	177.685	150.195	146.623
November	9.56	8.86	12.83	183.230	102.572	113.458
December	7.65	10.34	14.62	167.551	107.102	72.555
January	11.32	8.43	9.64	182.584	133.598	86.004
February	8.46	5.82	7.60	175.305	116.560	106.537
March	4.39	4.51	5.71	142.516	90.711	81.881
April	2.18	2.26	3.24	124.353	78.214	67.563
May	1.96	1.94	2.92	109.729	76.160	62.138
June				126.491	104.075	103.635

Months	Underground Site I	Standing Site II	Crop biomass Site III	Total Site I	Standing Site II	Crop biomass Site III
June	93.725	58.876	65.729	206.601	138.668	146.720
July	115.677	94.776	111.424	284.311	239.401	249.143
August	128.742	143.687	136.455	331.708	351.093	297.991
September	156.551	114.082	161.089	407.989	365.564	344.274
October	123.139	93.639	119.835	300.824	243.834	266.458
November	134.616	79.795	86.663	317.846	182.367	200.121
December	138.172	87.003	62.698	306.023	194.105	135.253
January	151.113	94.311	32.306	333.697	227.909	168.310
February	151.186	88.446	95.979	326.491	205.006	202.516
March	127.245	72.236	74.272	269.761	162.947	156.153
April	117.410	62.527	58.738	241.763	140.741	126.301
May	101.046	60.945	54.606	210.775	137.105	116.744
June	91.857	76.645	60.495	218.348	180.720	164.130

Tab. IV : Record of monthly variation in the aboveground, underground and total standing crop biomass (g/m^2) of the plant communities and % moisture content in the soil profile upto 30 cm.

Monthly net primary production

Aboveground primary production

Increments in the aboveground standing crop biomass of the communities were observed from July through September and again in the month of June for all the sites. In winters monthly aboveground production was noticed in November and January at site I, December and January at site II, and January and February at site III. The maximum monthly aboveground production of the communities were 55.76 g/m^2/month; 64.83 g/m^2/month, and 56.73 g/m^2/month in July at sites I, II and III, respectively. The corresponding minimum values were 5.55 g/m^2/month in November, 4.53 g/m^2/month in December and 13.45 g/m^2/month in January at sites I, II and III, respectively. The annual aboveground primary productions for these communities were estimated to be 175.90 g/m^2/year; 200.63 g/m^2/year, and 177.67 g/m^2/year at sites I, II and III, respectively. Of the communities studied at three salt-affected areas, the highest annual aboveground primary production was observed for site II, while the lowest for site I. None of the communities showed increment in the aboveground standing crop biomass during summer months (Tab. V).

Underground primary production

The underground production was observed from July through September and from November through February at site I; from July through September and in the months of January, February and June at site III. The maximum and the minimum monthly underground productions were estimated to be 27.81 g/m^2/month in September and 3.86 g/m^2/month in December for site I, 48.91 g/m^2/month in August and 0.395 g/m^2/month in September for site II, and 45.695 g/m^2/month in July and 5.889 g/m^2/month in June for site III (Tab. V).

Total primary production

The positive increments in the total standing crop biomass of the communities were found to remain confined principally to rainy season i.e., June through September at all the sites. Additionally, some months of winter i.e., November and January at site I; December and January at site II, and January and February at site III, were also found effective in this respect. The maximum monthly total primary productions of the three communities were estimated to be 77.719 g/m^2/month and 102.423 g/m^2/month in July at sites I and III, respectively, and 111.692 g/m^2/

Months	Aboveground primary production Site I	Site II	Site III	Underground primary production Site I	Site II	Site III	Total primary production Site I	Site II	Site III
July	55.758	64.833	56.728	21.952	35.900	45.595	77.710	100.733	102.423
August	34.332	62.781	23.817	13.055	48.911	25.031	47.397	111.692	48.848
September	48.472	14.076	21.649	27.809	0.395	24.634	76.281	14.471	46.283
October	- 73.753	- 71.287	- 36.562	- 33.412	- 50.443	- 41.254	- 107.165	- 121.730	- 77.816
November	5.545	- 47.623	- 33.165	11.477	- 13.844	- 33.172	17.002	- 61.467	- 66.337
December	- 15.679	4.530	- 40.903	3.856	7.208	- 23.965	- 11.823	- 11.738	- 64.868
January	15.033	26.496	13.449	12.641	7.308	19.608	27.674	33.804	33.057
February	- 7.279	- 17.038	20.533	0.073	- 5.865	13.673	- 7.206	- 22.903	34.206
March	- 32.789	- 25.849	- 24.656	- 23.941	- 16.210	- 21.707	- 56.730	- 42.059	- 46.363
April	- 18.163	- 12.497	- 14.318	- 4.835	- 9.709	- 15.534	- 27.998	- 22.206	- 29.852
May	- 14.624	- 2.054	- 5.425	- 16.364	- 1.582	- 4.132	- 30.988	- 3.636	- 9.557
June	16.762	27.915	41.497	9.189	15.700	5.889	7.573	43.615	47.386
Annual production	175.902	200.631	177.673	90.873	115.522	134.530	253.637	316.653	312.203

Tab. V : Monthly and annual aboveground, underground and total primary productivities of the plant communities. Negative values stand for monthly loss in biomass, monthly production in g/m^2/month, annual production in g/m^2/year.

month in August at site II. The minimum values of monthly total production of the communities at sites I, II and III were 7.573 g/m^2/month in June, 11.738 g/m^2/month in December and 33.057 g/m^2/month in January, respectively. No monthly primary production was observed during summer months. The annual total primary production for the communities were 253.637 g/m^2/year, 316.053 g/m^2/year and 312.203 g/m^2/year for sites I, II and III respectively. The highest total annual primary production was noticed at site II, while the lowest at site I.

The consistent monthly observations on the standing crop biomass for the communities under salt-stress relative to the per cent moisture content in the profile yielded a significant positive correlation for sites II and III, where the vegetation consisted of only surface feeding species. The correlation did not appear significant for site I because the major species contributing to the standing crop biomass was *Pluchea lanceolata*, which by virtue of its deep root system is able to circumvent the stress beyond a depth of 30 cm (Fig. 1).

DISCUSSION

Although the habitats considered under present investigation represent extensions of the grasslands of the Indo-Gangetic Plains, a comparison of the primary productivity of these specialized habitats reveals their inferiority to normal habitats even being under general climatic environment (Tab. VI). The potential level of primary production is not

Habitat	Community	Annual net primary production (g/m^2)	Author
Normal	Mixed grassland	728.760 to 764.050	Singh, J.S. (1967)
Normal	Mixed grassland	1358.760	Maurya, A.N. (1970)
Normal	Mixed grassland	519.709	Tripathi, J.S. (1970)
Salt-affected			
Site I	Mixed grassland	253.637 }	Present investigation
Site II	Mixed grassland	316.053 }	
Site III	Mixed grassland	312.203 }	

Tab. VI : Primary productivity of the plant communities in salt-free and salt-affected areas in Indo-Gangetic plains.

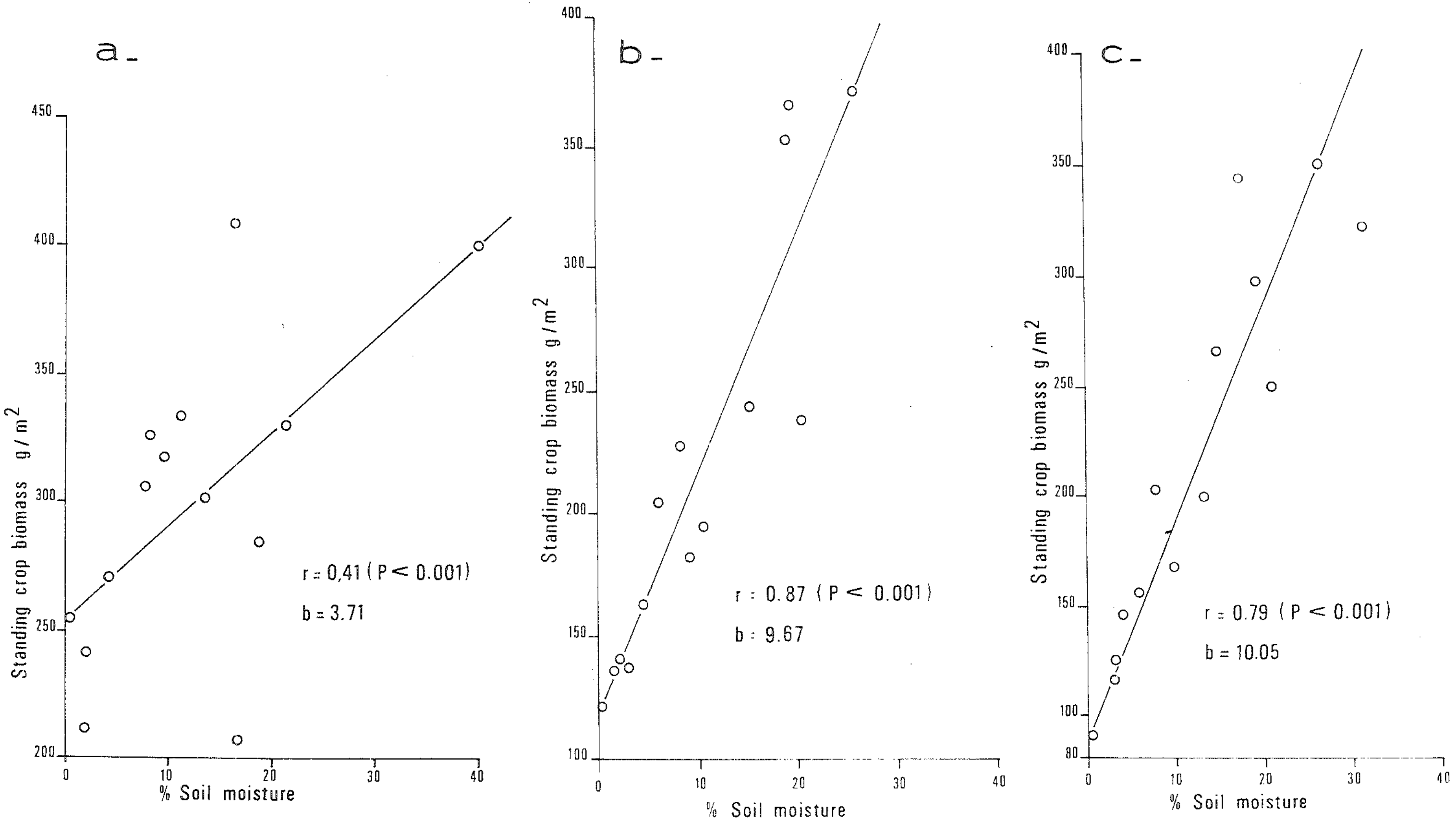

Fig. 1 : Correlations between field moisture variations and community standing crop biomass ($g.m^{-2}$) at site I (a), site II (b) and site II (c).

achieved in these habitats because of limiting factors characteristically associated with their edaphic environment. Besides the usual low rainfall coupled with a rapid evapotranspirational loss of moisture, these habitats suffer from an additional stress due to predominance of water soluble salts in the edaphic environment. All these together cause simplification of the community structure. Only a limited number of species equipped with special adaptive mechanism, which may either be due to their wide amplitude or preadaptation towards the stress, succeed in standing the stresses which gradually creep into these habitats subsequent to the rainy season. The maximum values of the total standing crop biomass for the community with the progress of monsoon reflects the extent of amelioration of the environment stresses on the process caused by the rain water. During rainy season, the salt-stress is brought to the minimum both by dilution effect as well as by downward movement of salts along with percolating rain water, and at this time, the communities attain their optimum stage of growth. Subsequently, evaporation enhances build up of salt-stress in the surface layer through capillary rise of water soluble salts together with a steady depletion of moisture in the profile. The species are thus subjected to a gradual build up of a total stress and the weaker ones failing to keep up with this, drop out. The contribution of such species to primary productivity is evidently limited just to a part of the year only.

High regression and correlation coefficients between monthly variations of soil moisture in the profile and total standing crop biomass of the communities indicated a positive and functional relationship between these parameters for sites II and III. The nonsignificant correlation between these parameters for site I might be ascribed to the deep tap root system of *Pluchea lanceolata* which by virtue of its deep feeding habit could circumvent the monthly variation in moisture in the surface layers of the profile.

With gradual increase in soil moisture-stress the primary producers are subjected to acute internal water deficit which eventually affects on physiological processes (WOODHAMS & KOZLOWSKI, 1954; KRAMER, 1963). Photosynthesis is more sensitive to dehydration than any other metabolic process (RABINOWITCH, 1945). This is reflected in the loss of biomass even by major species in the community from October onwards when the moisture content in the soil profile drops down around permanent wilting point. This is supported by the observation of ASHTON (1956), who found that in the case of sugarcane photosynthesis decreased when soil moisture attained a value between field capacity and wilting point. Further lowering of the soil moisture lowered photosynthesis rapidly approaching zero as permanent wilting point reached. The moisture stress slowed down leaf expansion before photosynthesis is affected, and roots being close to the source of limited available water were able to become a dominant sink for assimilates (BROUWER & DE WIT, 1959). Whatever biomass was synthesized during these periods appeared to be invested in the maintenance for perennation only. The increments in the standing crop biomass during mid-winter reflected the rejuvenation triggered by the winter rains, but this as such was a very transient process, as the soil moisture content still continued maintaining its depleting trend. The successful species were dormant during these months through building up of their tissue osmotic pressure in response to dehydration with a minimum shoot volume, and regained their normal productive potential in the absence of water stress in monsoon.

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