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EFFECT OF CLIMATE ON THE DENSITY VALUE AND PRIMARY PRODUCTIVITY OF AN INDIAN GRASSLAND COMMUNITY

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ABSTRACT

The density value, biomass and primary productivity of Indian grassland community are controlled by climatological factors. The climatic conditions *i.e.*, rain fall, atmospheric temperature, wind velocity, soil pH, organic carbon, availability of phosphorous and potassium and soil conductivity that influence the grassland community are also taken into consideration in this investigation. The study of climatic effect of density value and primary productivity of a grassland community located at Rangamatia of Mayurbhanj district, Odisha (21^0 56' N; 86^0 41' E) near the buffer zone of Similipal Biosphere Reserve. The floristic composition of the grassland community comprised of 36 species (15 were grasses and 21 were non - grasses). The density values are lowest in the month of April and highest in the month of September. The grasses showed highest density values as compared to that of the density of non grasses. The annual grass production was found to be 3289.53 g m^{-2} yr^{-1}. The non-grass production showed maximum in the month of June (868.55 g m^{-2}) and minimum in the month of September (141.11 g m^{-2}). The annual non-grass production was found to be 2246.10 g m^{-2} yr^{-1}. The changes of climatic conditions and species distributions would also be accompanied by changes in a suite of ecological processes, such as primary productivity, decomposition, nutrient cycling, soil formation and species interactions. This study helps enhancing the density value, Net primary productivity and biodiversity conservation of both natural and artificial grassland ecosystems in all over the world.

Key words : Primary productivity, Biomass, Grassland community, Biodiversity.

Introduction

Grasslands are one of Earth's major biomes and the native vegetation of up to 40 % of Earth's terrestrial surface. Grasslands occur on every continent except Antarctica, are ecologically and economically important, and provide critical ecosystem goods and services at local, regional, and global scales. Grassland ecosystems are important components of ecological communities on Earth and perform key functions in carbon (C) cycling, climate regulation, and the maintenance of biological diversity. However, since the middle of the 20^{th} century, these ecosystems have been subjected to major environmental fluctuations because of climate changes. These ongoing changes have affected grass growth and the functioning of constituent ecosystem. In this context, net primary productivity (NPP) is one key indicator that can be used to measure the ability of a grassland ecosystem to maintain a level of sustainable development, recorded via the net amount of C captured by land plants annually through photosynthesis.

The ecological study of various grassland communities in Orissa has been initiated by B. N. Misra and his scholars since two and half decades. Phytosociology as well as primary productivity of certain grassland communities of Orissa has been carried out by Misra (1978), Misra and Misra (1979, 1981 & 1982). The primary production and turnover in certain protected grasslands of Vanarasi and Delhi studied by Ambasht *et al*. (1972) and Varshney (1972). The seasonal variation and composition of plant biomass and net primary productivity of tropical grassland at Kurukshetra studied by Singh and Yadava (1974). The floristic composition and phytosociology of three grass strands in Naugarh forest of Vanarasi division studied by Singh and Ambasht (1980). The seasonal changes in the phytosociological and productive structure of two strands of *Aristida cyanantha* studied by Ambasht and Pandey (1981). The hydrology and soil fertility of some degraded grasslands at Cherapunji of Meghalaya are studied by Ram and Ramakrishnan (1988). The structure and seasonal dynamics of humid tropical grassland in India are survey by Umashankar *et al*. (1991). The rain fall and grazing effects on net primary production in a tropical savanna was analyzed by Pandey and Singh (1992).

Materials and Methods

The experimental site was selected at Rangamatia, situated at a distance of 15 kms away from North Orissa University and 11 kms from Baripada, the District headquarter of Mayurbhanj in the state of Orissa. It is located at 86^0 41' E longitudes and 21^0 56' N latitude. The altitude of the site is above 135.7m. The experimental site was protected from grazing and human interferences for a period of 1 year prior to start of the investigation. (Fig. 1).

The climate of the locality is monsoonal with three distinct seasons *viz*. rainy (July to October), winter (November to February) and summer (March to June). The total rainfall during this period was 1906.2 mm of which a maximum of 499.8 mm was recorded during July. The minimum and maximum atmospheric temperature during the study period was found to be normal. December showed the lowest temperature (9.93^0C), whereas May experienced the highest temperature (38.9^0C). The wind velocity was maximum (4.31 km h^{-1}) during April and minimum (1.99 km h^{-1}) in the month of November. The soil of the experimental site was found to be moderately acidic (pH = 5.5). The available phosphorus content was high (1.2 ppm) in lower soil and minimum (0.5 ppm) in middle soil profile. The potassium showed gradual reduction from surface (100.3 ppm) to middle (87.6 ppm) and then to lower (81.1 ppm) soil depth. The overall organic carbon (0.61%) and available potassium (59 to 140 ppm) were found medium where as the available phosphorus content was found to be very low (< 2 ppm) have been done in Table 1.

Sample collection and identification

The plant specimens preferably along with reproductive parts were collected from the experimental site and brought to the laboratory for identification (Mueller

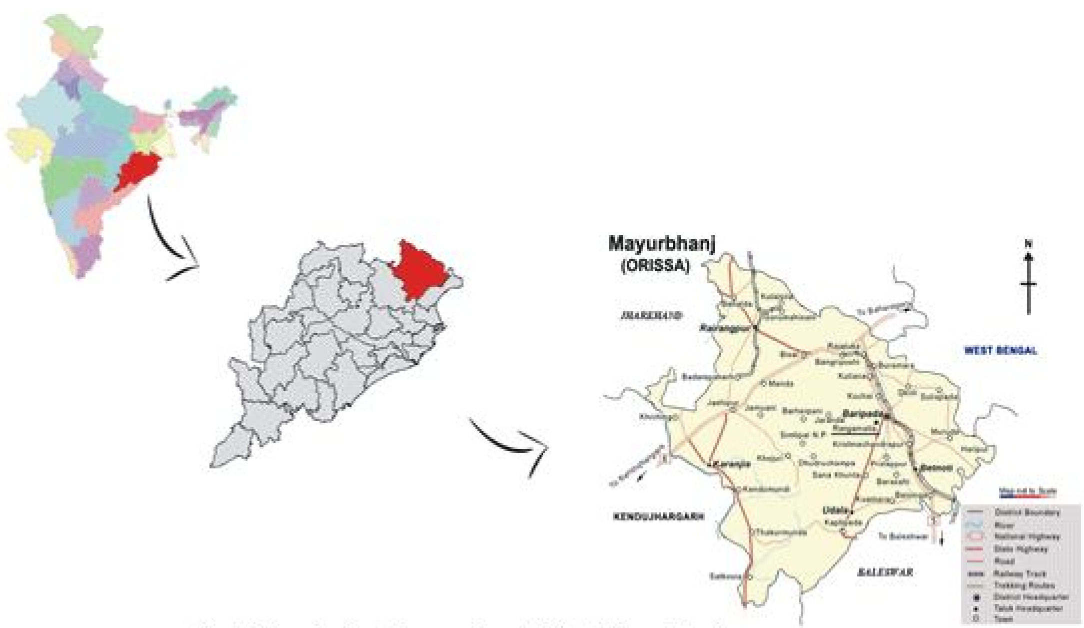

Fig. 1 : Map showing the experimental site of Mayurbhanj.

Table 1 : The pH, conductivity, organic carbon (%), available phosphorus and potassium content of the soil (values are in mean ± SD, n = 5 each).

Surface depth in cm	pH	Conductivity	Organic carbon (C) (%)	Available phosphorus (P) (ppm)	Available potassium (K) (ppm)
0 to 10	5.46 ± 0.385	0.68 ± 0.179	0.56 ± 0.057	0.66 ± 0.321	100.3 ± 28.409
10 to 20	5.38 ± 0.311	0.50 ± 0.000	0.64 ± 0.092	0.50 ± 0.467	87.6 ± 26.658
20 to 30	5.64 ± 0.358	0.50 ± 0.000	0.62 ± 0.107	1.20 ± 0.689	81.1 ± 18.716

Dombois and Ellenberg, 1974). Identification of all the species were made in consultation with various regional and national flora books *i.e.* The Botany of Bihar and Orissa (Haines, 1921-25); Supplement to the Botany of Bihar and Orissa (Mooney, 1950); Flora of Madras presidency (Gamble, 1915-36); Flora of Similipal (Saxena and Brahmam, 1989); Flora of Orissa (Saxena and Brahmam, 1994-96) and Flora of Madhya Pradesh (Verma *et al*., 1993; Mudgal *et al*., 1997 and Singh *et al*., 2001). For the analysis of soil, soil samples were collected from three different depths i.e. 0 to 10, 10 to 20 and 20 to 30cm with the help of a soil corer. Five samples were taken from each depth, labelled and were mixed thoroughly in order to make a composite soil samples. The samples were dried under open, rolled and sent to the soil testing laboratory, Department of Agriculture, Government of Orissa, District Headquarter branch, Baripada, for the determination of soil pH, conductivity, Organic carbon, available phosphorous and potash content of the experimental site. The meteorological data i.e. rainfall number of rainy days, minimum and maximum atmospheric temperature and wind velocity were collected from District Agriculture Office, Baripada, Mayurbhanj and compared to national website www.accuweather.com incorporated in this investigation.

Determination of density and primary productivity

Density describes the number of individual plants species in a given area. In situations, where identification of individuals is ambiguous, density measurements may be based on some other counting unit, such as culms or shoots for sod-forming grasses or the basal stems for shrubs.

$$\text{Density} = \frac{\text{Number of individuals of a species in all quadrats}}{\text{Total number of quadrats taken.}}$$

Primary productivity of the grassland community was determined from the biomass values following “short term harvest” method as proposed by Odum (1960). The productivity for each category of plant materials *i.e.* live green, standing dead, litter and below ground parts was calculated by summing up of the positive increments of concerned biomass during the study period and was expressed as g m^{-2} yr^{-1}. The above ground net production was calculated by summing the value of live green and standing dead. Total net production was obtained by summing the value of above ground net production and below ground production. The rate of respiration *i.e.*, respiratory loss was not measured in the present investigation and was calculated by multiplying the total net production with 0.3 factor, which is the median ratio of respiration to net production for different types of vegetation (Odum, 1960).

Results

The floristic composition of a particular community highly depends upon the climatology and soil texture of that area. The concept of life-form, “Plants related to climate” and Plants always adapt to different unfavourable conditions of the environment by which the species are in dynamic equilibrium with it (Warming, 1909). The classification of plants into different life-forms basing on the perennating buds, which is a type of adaptation having much relevance to the climatological fluctuations (Raunkiaer, 1934). According to him, “the life –form is the sum of adaptability of a plant to climate” and the phyto-climate of a locality can be found out by studying the flora of that area. He proposed a normal spectrum (Raunkiaer’s normal spectrum) of the phanerophytic flora of the world to compare the differences and similarities of various community structures. The life-form type of a locality is always identified by the dominant species of that area (Hanson and Churchill, 1961). The life-form of the species, one can indicate, how a plant passed the unfavourable season was studied (Rao, 1968). The ecology of vegetation or a locality is necessary to study the life-forms of the species of that area and the physiognomy of a plant community is determined by the life-forms of the dominant species (Kershaw, 1973). The life-forms of an association indicate the character of the habit and the nature of climate. He also revealed that, the study of floristic composition of the vegetation is a prerequisite to understand the phytosociology of a community.

In this investigation structural variable *i.e.* floristic composition, life-forms, stratification, frequency, density, abundance, basal cover, importance value index etc. of the community has been analyzed month wise. The peak density of the community *i.e.* 3439.8 Ind m^{-2} was found in the month of September. The grasses contributed 2568.2 Ind m^{-2} to the total community whereas non-grasses contributed only 871.6 Ind m^{-2}. A minimum value density (204.9 Ind m^{-2}) was observed during April whereas the grasses and non grasses exhibited 199.8 Ind m^{-2} and 5.1 Ind m^{-2}, respectively. The density value of the community showed gradual declined in trend from December (1445.3 Ind m^{-2}) to January (966.5 Ind m^{-2}), then to February (661.9 Ind m^{-2}), March (252.4 Ind m^{-2}) and lowest in the month of April (204.9 Ind m^{-2}). There after the value increased from April to May (284.2 Ind m^{-2}), June (1385.4 Ind m^{-2}), July (2527.9 Ind m^{-2}), August (3176.1 Ind m^{-2}) and then to September (3439.8 Ind m^{-2}). Again a declined trend of density value was observed

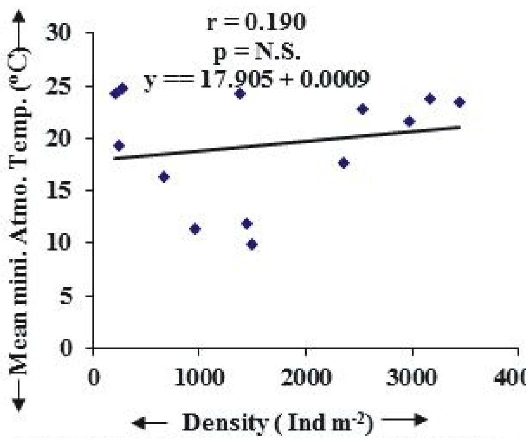

Fig. 2 : Correlation between total density and mean minimum atmospheric temperature (°C).

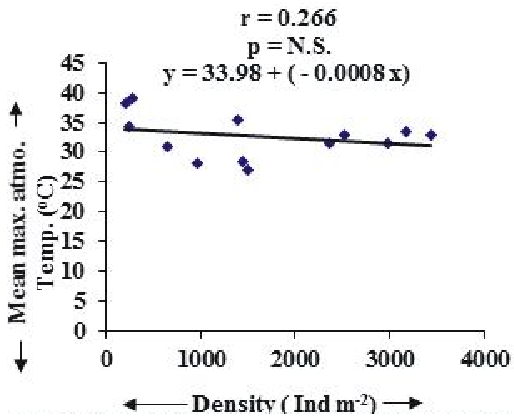

Fig. 3 : Correlation between total density and ean maximum atmospheric temperature (°C).

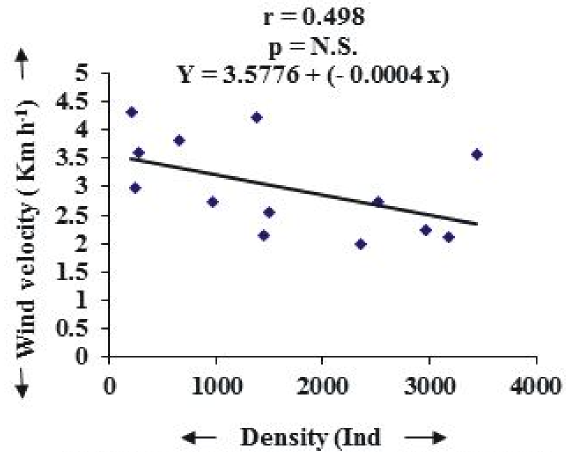

Fig. 4 : Correlation between total density and wind velocity (Km h^{-1}).

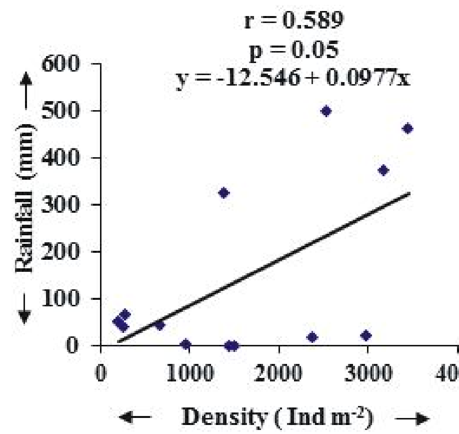

Fig. 5 : Correlation between total density and amount of rainfall (mm).

from September onwards *i.e.* from September to October (2975.1 Ind m^{-2}), November (2364.1 Ind m^{-2}) and December (1496.0 Ind m^{-2}). Among the dominated species, the grasses *i.e.* (*Cynodon dactylon*, *Digitaria abludens*, *Eleusine indic* and *Vetiveria zizanioides*) showed gradual declined in their density values from December/January to February, then to March and exhibited lower value during April/May. The values were then increased onwards and attained peak during September (except (*Vetiveria zizanioides*) which showed peak value in the month of August). There after again declined trend in density values were marked till to the end of the sampling period (*i.e.* December). Besides, among the non-grasses, the dominated species *i.e.* (*Phyllanthus fraternus* and *Sida cordifolia*) exhibited minimum density value in the month of May and March respectively and maximum in the month of September. However, the total density value of grasses and non-grasses gradually declined from the beginning i.e. from the month of December to January, February, March and April, which showed the lowest value. May onwards the value exhibited gradual increase in trend and showed a peak during September. Thereafter, the value again showed a declined trend till to the end of sampling period (*i.e.* December). The grasses showed highest density values as compared to that of the density of non-grasses in Table 2.

The primary productivity of each category of plant materials *i.e.* live green, standing dead, litter and below ground parts was calculated by summing up of the positive increments of concerned biomass during the study period. Grass production was found to be minimum during May (49.57 g m^{-2}) and maximum in the month of July (1274.09 g m^{-2}). The production of grass exhibited an increasing trend from May to June and then to July. Thereafter the value declined till September. The annual grass production was found to be 3289.53 g m^{-2} yr^{-1}. The non-grass production showed maximum in the month of June (868.55 g m^{-2}) and minimum in the month of September (141.11 g m^{-2}). The annual non-grass production was found to be 2246.10 g m^{-2} yr^{-1}.

Table 2 : Density (Ind m^{-2}) of different species during the study period.

No.	Species name	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
GRASSES														
1	*Alloteropsis cimicina*	0.80	%	%	%	%	%	7.50	12.40	13.30	12.80	12.00	3.20	1.20
2	*Cynodon dactylon*	105.00	121.00	110.80	61.20	51.10	71.90	139.90	176.00	182.10	188.60	141.30	138.20	108.70
3	*Cyperus castaneus*	58.50	3.10	%	%	%	%	31.20	116.00	114.20	104.00	86.00	79.60	56.00
4	*Digitaria abludens*	81.50	72.00	58.20	46.90	40.20	41.10	63.70	103.40	128.60	141.50	134.70	126.30	80.50
5	*Digitaria longiflora*	412.00	329.60	250.00	%	%	%	265.00	512.90	559.30	819.20	789.20	629.70	460.10
6	*Eleusine indica*	79.60	74.10	70.20	68.40	67.60	69.00	118.60	154.20	203.70	225.00	189.60	110.30	80.80
7	*Eragrostis tenella*	11.50	8.20	1.10	%	%	%	45.70	99.20	100.70	81.50	71.60	51.60	11.20
8	*Eragrostis unioloides*	41.00	31.00	21.10	10.60	3.60	%	68.70	127.50	167.60	166.40	115.50	90.80	40.60
9	*Fimbristylis dichotoma*	44.50	22.00	11.10	1.60	%	%	36.70	103.20	114.50	81.20	72.00	71.00	45.00
10	*Fimbristylis ovata*	11.50	%	%	%	%	%	76.40	191.60	198.40	156.00	107.20	42.90	11.20
11	*Lipocarpha sphacelata*	%	%	%	%	%	%	15.60	32.70	35.10	23.60	14.40	8.30	%
12	*Paspalum scrobiculatum*	31.50	2.20	%	%	%	22.80	61.10	130.70	191.50	188.50	136.00	85.50	31.20
13	*Scleria lithosperma*	63.00	45.00	2.50	%	%	%	45.00	66.10	139.40	147.60	132.70	110.80	61.60
14	*Setaria intermedia*	19.00	%	%	%	%	%	8.60	40.50	109.70	88.90	76.10	57.00	19.20
15	*Vetiveria zizanioides*	97.70	82.00	56.00	48.00	37.30	34.70	116.20	133.20	174.30	143.40	132.20	112.00	98.80
	Grasses total	1057.10	790.20	581.00	236.70	199.80	239.50	1099.90	1999.60	2432.40	2568.20	2210.50	1717.20	1106.10
NON GRASSES														
1	*Aclisia secundiflora*	1.90	%	%	%	%	%	3.40	57.50	90.10	96.10	40.10	22.60	2.40
2	*Ageratum conyzoides*	0.40	%	%	%	%	%	0.30	1.70	1.50	2.70	1.70	0.90	0.30
3	*Alysicarpus vaginalis*	9.60	6.40	2.40	%	%	%	11.90	35.40	47.30	47.40	33.50	26.80	10.30
4	*Centranthera indica*	6.80	2.80	%	%	%	%	9.40	20.00	20.80	21.50	16.10	13.60	6.20
5	*Desmodium triflorum*	34.10	20.60	8.60	%	%	11.60	37.60	54.10	64.20	51.10	51.10	47.10	32.90
6	*Elephantopus scaber*	33.80	23.30	17.30	%	%	%	29.10	23.40	39.30	51.40	53.40	54.00	33.20
7	*Emilia sonchifolia*	5.10	1.70	0.80	2.60	%	1.50	7.70	14.80	24.60	27.50	14.90	12.20	4.80
8	*Evolvulus nummularius*	29.80	21.20	10.10	%	%	18.00	56.70	65.20	60.70	65.90	78.00	50.60	31.00
9	*Hedyotis herbacea*	13.10	5.50	%	%	%	%	14.90	26.60	35.00	42.30	45.60	30.50	14.40
10	*Lindernia anagllis*	2.20	1.30	%	%	%	%	3.30	6.20	5.60	7.70	4.70	5.50	2.60
11	*Lindernia crustacea*	11.00	5.60	1.60	%	%	%	6.00	16.00	12.00	19.80	19.60	17.20	9.50
12	*Ludwigia hyssopifolia*	1.30	%	%	%	%	%	%	3.10	13.30	15.50	13.60	5.60	1.40
13	*Mecardonia procumbens*	0.20	%	%	%	%	%	0.40	1.50	1.40	2.50	2.90	1.30	0.30
14	*Melochia corchorifolia*	3.30	2.60	2.00	2.20	%	%	1.10	3.80	4.90	4.40	4.10	3.90	3.00
15	*Murdannia nudiflora*	%	%	%	%	%	%	%	2.70	12.60	15.30	10.40	8.00	%
16	*Oxalis corniculata*	8.80	6.60	3.20	%	%	%	8.40	17.80	18.90	21.60	15.70	16.10	8.10
17	*Phyllanthus fraternus*	33.90	19.00	9.50	2.70	2.80	1.30	43.10	54.80	81.60	88.60	64.90	52.70	35.10
18	*Rungia pectinata*	166.00	48.00	23.00	6.60	%	2.80	25.10	85.40	153.50	217.80	220.00	222.40	167.10
19	*Sida cordifolia*	2.00	2.40	2.40	1.60	2.30	1.10	2.70	2.50	2.20	3.60	2.90	2.50	2.00
20	*Spermacoce ramanii*	5.10	1.60	%	%	%	8.40	15.80	17.00	18.10	17.50	11.80	11.10	4.90
21	*Zornia gibbosa*	19.80	7.70	%	%	%	%	8.60	18.80	36.10	51.40	59.60	42.30	20.40
	Non- grasses total	388.20	176.30	80.90	15.70	5.10	44.70	285.50	528.30	743.70	871.60	764.60	646.90	389.90
	Total	**1445.30**	**966.50**	**661.90**	**252.40**	**204.90**	**284.20**	**1385.40**	**2527.90**	**3176.10**	**3439.80**	**2975.10**	**2364.10**	**1496.00**

Table 3 : Total annual net primary production g m^{-2} yr^{-1} of different grassland community.

Author (s)	Year	Location	Type of community (Dominance)	Annual rain fall mm	NPP (g $m^{-2}yr^{-1}$)
Ambasht *et al.*	1972	Varanasi	*Dichanthium*	725	1420
Varshney	1972	New Delhi	*Heteropogon*	800	1330
Singh and Yadava	1972	Kurukhetra	*Panicum*	770	2980
Misra	1973	Ujjain	*Dichantium*	1030	989
Billore and Mall	1977	Ratlam	Sehima	1257	846
Misra	1978	Berhampur	*Aristida*	1200	1447
Malana	1981	Berhampur	*Aristida*	1355	1180
Pradhan	1994	Bhubaneswar	*Aristida*	858	1474
Behera	1994	Phulbani	*Heteropogon*	1763	809
Barik	2006	Berhampur	*Aristida*	1341	929
Present study		Rangamatia	Mixed type	1906	6403

Total net production (6403.07 g m^{-2} yr^{-1}) was derived by adding the above ground net production (5711.69 g m^{-2} yr^{-1}) and below ground net production (691.38 g m^{-2} yr^{-1}). Gross primary production of the community was found to be 8323.99 g m^{-2} yr^{-1}. This was derived by adding respirator loss (1920.92 g m^{-2} yr^{-1}) to total net production of the community. About 89.22% of the total net production remained in the above-ground parts and about 10.78% directed towards belowground parts. From the above ground net production 0.48 g m^{-2} day^{-1} was transferred to standing dead. The transfer rate from standing dead to litter was 0.23 g m^{-2} day^{-1}. The rate of disappearance of litter and below ground was 0.03 g m^{-2} day^{-1} and 1.25 g m^{-2} day^{-1}, respectively. The total disappearance of organic matter was at the rate of 1.28 g m^{-2} day^{-1} or in other words about 7.34% of the total net production was lost annually.

Discussion

The density of all species in the community was found to high in the month of September (The grasses contributed 74.7% to the total community where as non-grasses contributed only 25.3%) and less during April (Grasses 97.5% and non-grasses 2.5%). The density value of the community showed gradual declined in trend from December to January, February, March and then to April. There after the value started increasing from April to September. Again a declined trend of density value was observed from September onwards till to the end of sampling period (December). The dominated species of grasses *i.e.* (*Cynodon dactylon*, *Digitaria abludens*, *Eleusine indica* and *Vetiveria zizanioides*) in the community showed decline in their density values from December / January to February, then to March and exhibited lower value during April / May. The values were then increased and attained peak during September expect (*Vetiveria zizanioides*), which showed peak value during August. Again a declined trend in density values was marked till to the end of the sampling period. Besides, among the non-grasses the dominated species *i.e.* (*Phyllanthus fraternus* and *Sida cordifolia*) exhibited minimum density value in the month of May and March respectively and maximum in the month of September. The total density value of grasses and non-grasses on the other hand gradually declined from the beginning *i.e.* from the month of December to January, February, March and April, which showed the lowest value. May onwards the value exhibited gradual increased in trend and attained peak during September. Then the value showed a declined trend till to the end of the sampling period.

Relationships among the density with various climatological features

The monthly density data, mean minimum atmospheric temperature, mean maximum atmospheric temperature, rainfall and wind velocity of the experimental site. When the density was correlated with mean minimum atmospheric temperature, mean maximum atmospheric temperature and wind velocity, no significant correlation were observed (Figs. 2, 3, 4 respectively). However, the density of the community with rainfall showed correlationship significant at $p = 0.05$ (Fig. 5). This indicates that the mean minimum and maximum atmospheric temperature and the velocity of wind were not dependent on the species density of the community. Besides, the value of minimum and maximum atmospheric temperature and wind velocity with respect to total density fluctuated all over the study period. The density of the community on the other hand exhibited significant correlationship ($r = 0.05$) with the amount of rainfall. It can be assumed that the rainfall and species density of the community is dependent on each other. In the present grassland community the net primary production was calculated to be 6403.07 g m^{-2} yr^{-1}, of which above ground parts contributed 5797.41 g m^{-2} yr^{-1} and the below ground parts contributed 691.38 g m^{-2} yr^{-1}.

Comparisons of net primary production

The annual, net primary production of some Indian grassland is indicates that the net production in this study was no way similar to the findings of other workers as reported earlier. It showed marked higher value compared to the findings of Ambasht *et al*. (1972), Varshney (1972), Singh and Yadava (1972), Misra (1973), Billore and Mall (1977), Misra (1978), Malana (1981), Pradhan (1994) and Barik (2006). It was observed that rain fall was not a single factor responsible for this variation showing in Table 3. There were some other factors including rain fall that influenced the net production in the community. It might be due to phenology of the species, rate of evaporation, temperature variability and fertility of soil.

Conclusion

The total density value of grasses and non grasses gradually declined from the beginning *i.e.* from the month of December to January, February, March and April which showed the lowest value. May onwards the value exhibited gradual increase in trend and showed a peak during September. Thereafter, the value again showed a declined trend till to the end of the sampling period. The grasses showed highest density values as compared to that of the density of non-grasses. The density value is peak in the September due to atmospheric temperature, rainfall and soil condition which initiate the growth and development of plant species in the community. The declined trend in density values were observed during December to April and September to December, due to the atmospheric temperature, rainfall and soil condition may not be suitable for the growth of vegetation. Compared to other grassland communities, the present grassland community showed little variation. However, the factors like soil condition, rainfall, atmospheric temperature, wind velocity and such others, regulates the density value and primary productivity of the grassland community. This study revealed that the climatic conditions are directly controlled the density value and primary productivity of Indian grassland community.

Statements and declarations

No potential conflict of interest was reported by the author.

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