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Ecological interactions in paddy fields: Population dynamics of natural enemies rove beetle in relation to weather parameters

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Abstract

The present study investigates the population dynamics of rove beetle (*Paederus fuscipes*) in paddy fields across different locations during the *Kharif* seasons of 2022 and 2023. The study was conducted in Palpur, SHUATS, and Korsand to analyze the seasonal abundance of rove beetles and their correlation with weather parameters. Observations revealed that the rove beetle population first appeared in the 37th Standard Meteorological Week (SMW) and persisted until the 44th SMW. The beetle population, recorded in terms of beetles per hill and percentage beetle population, varied across locations and years. In Palpur, the population ranged from 0.56 (0.14%) to 0.97 (0.24%) in 2023 and from 0.60 (0.15%) to 1.07 (0.27%) in 2022, peaking in the 42nd SMW. Similar trends were recorded in SHUATS and Korsand, where the beetle population peaked during the third week of October before declining in early November. Weather parameters such as temperature, relative humidity, rainfall, wind velocity, and sunshine hours were analyzed for their influence on beetle populations. The pooled data from 2022 and 2023 indicated that the population increased with rising temperatures and sunshine hours while showing a decline with increasing rainfall and wind velocity. Correlation analysis revealed that rove beetle populations were positively correlated with evening relative humidity ($r=0.515$) and mean relative humidity ($r=0.438$), while negative correlations were observed with maximum temperature, mean temperature, rainfall, and wind velocity. The findings suggest that weather conditions play a crucial role in determining the population dynamics of rove beetles, influencing their role as natural enemies in rice ecosystems. Understanding these ecological interactions can contribute to the development of sustainable pest management strategies by enhancing the effectiveness of natural predators like rove beetles in controlling paddy insect pests.

Keywords: Correlation, Influencing, Investigates, *Kharif*, Sustainable, Temperature etc.

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple food crops, supporting the livelihood and food security of millions of people worldwide, particularly in Asia, where approximately 90% of global rice is grown and consumed (Pathak *et al.*, 2002) ^[10]. The productivity of rice is significantly affected by various biotic and abiotic factors, with insect pests posing a major challenge. Over 1400 insect species have been reported to attack rice at different growth stages (Grist and Lever, 1969) ^[15], and their management is crucial for sustainable rice production. Climate change, along with agronomic interventions such as crop diversity, irrigation, fertilization, and pesticide application, has significantly influenced the intensity and severity of pest infestations and their natural enemies in rice ecosystems (Way and Heong, 1994; Ooi and Shephard, 1994) ^[15, 9]. Conventional pest management strategies rely heavily on chemical insecticides, leading to environmental concerns, pest resistance, and adverse effects on non-target beneficial organisms, necessitating the adoption of ecologically sustainable alternatives (Gurr *et al.*, 2016) ^[6].

Natural enemies, including predatory beetles and spiders, play a critical role in regulating pest populations in rice fields. Among these, rove beetles (*Paederus fuscipes*) and various spider species have gained attention for their potential as biological control agents (Meena *et al.*, 2019) ^[8]. Their population dynamics are largely influenced by abiotic factors such as temperature, humidity, and rainfall (Dhurva and Soni, 2020) ^[4]. However, despite their significance in integrated pest management (IPM), there is a lack of comprehensive studies

documenting the seasonal incidence and environmental factors affecting these beneficial arthropods. Previous research has primarily focused on pest attraction to light traps, with limited data available on the light trap collection of natural enemies such as predatory beetles and spiders (Atwal *et al.*, 1969; De Bach, 1974; Sharma *et al.*, 2010)^[1, 3, 13]. Given their importance in sustainable agriculture, understanding the population trends of these predators and their correlation with weather parameters is crucial for improving biological pest control measures. Light traps have long been used as an indigenous and eco-friendly pest monitoring tool in rice ecosystems, capturing a diverse range of phototactic insects, including pest species and their natural enemies (Hufnagel *et al.*, 2008)^[7]. The efficiency of light traps in assessing insect biodiversity has been demonstrated in various studies, though their role in monitoring the population dynamics of predatory arthropods remains underexplored. Limited research has examined the diversity and seasonal abundance of natural enemies in rice fields, particularly in high-altitude rainfed ecosystems, where insect populations are influenced by unique climatic conditions (Bhattacharyya *et al.*, 2006; Pathak *et al.*, 2014)^[11]. Therefore, there is a pressing need to document the diversity and seasonal trends of insect natural enemies to enhance conservation efforts and optimize their use in pest management strategies.

The present study aims to analyze the population dynamics of natural enemies, particularly rove beetles and spiders, in rice agroecosystems and assess their relationship with key abiotic factors such as temperature, humidity, rainfall, and sunshine hours. By utilizing light traps and field surveys, this research seeks to provide a comprehensive understanding of the seasonal incidence of these beneficial predators and their potential in sustainable rice pest management. The findings will contribute to biodiversity conservation and integrated pest management efforts, ensuring a balanced approach to pest control while minimizing environmental risks.

Materials and Methods

This study aimed to assess the population dynamics of major insect pests, with a focus on rove beetles and spiders, in relation to climatic factors affecting rice ecosystems. The research was conducted during the *Kharif* seasons of 2022 and 2023 at three locations: Palpur, SHUATS, Central Research Farm, and Korsand. At each location, a bulk plot of 100 m² of paddy was established to monitor the seasonal build-up of insect pest populations. To assess pest populations, experimented on randomly selected ten hills from adjacent paddy plots surrounding the main trial field each week. They counted the insect pests on these hills and calculated the average population per ten hills to determine seasonal incidence. Rove beetles and other insect pests were regularly monitored to understand their population dynamics and biological control potential. In addition to pest population assessment, observation recorded insect pest damage to the rice crop weekly. They correlated this data with meteorological parameters, including maximum and minimum temperatures, mean temperature, relative humidity, sunshine hours, wind speed, and rainfall. Meteorological data were collected from the Department of Meteorology's observatory at SHUATS, Prayagraj. The correlation between weather parameters and the occurrence, population dynamics, and damage caused by both pest

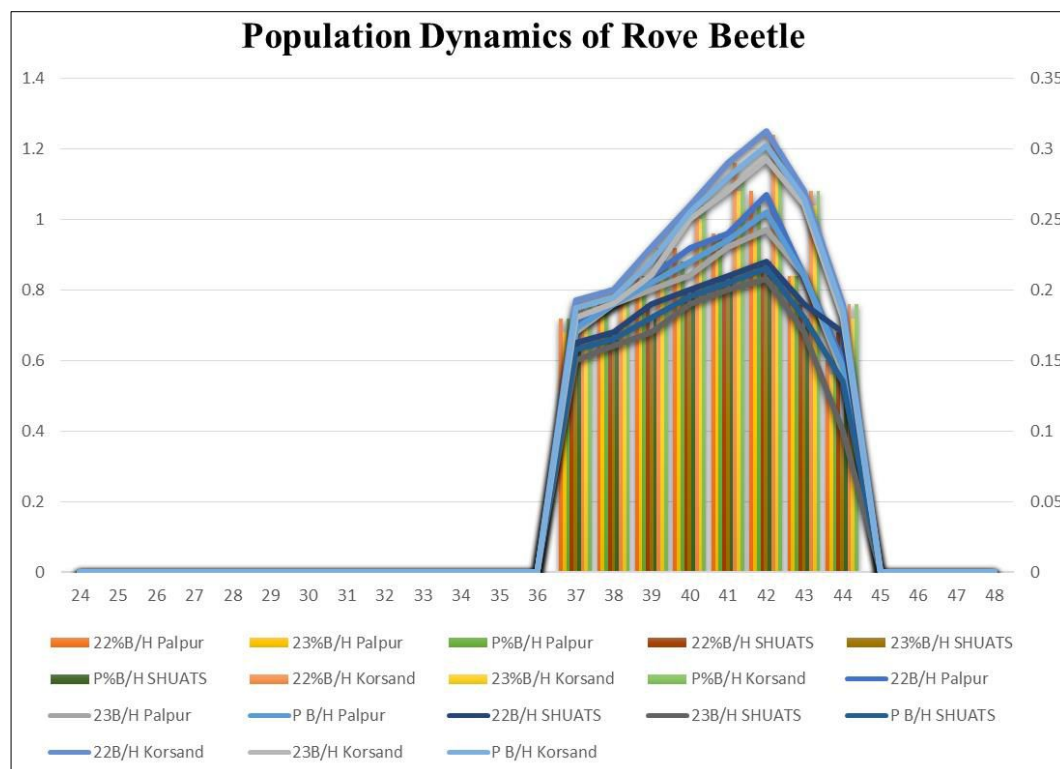
species and beneficial insects, such as rove beetles, was analyzed to determine the impact of climatic factors on pest management in rice.

Results and Discussion

Population Dynamics of Rove Beetle (*Paederus fuscipes*) in *Kharif* Season

Palpur, Tehsil: Karchhana (*Kharif* 2022 & 2023)

The rove beetle population first appeared in the 37th (SMW) and persisted until the 44th SMW in both years. During *Kharif* 2023, beetle density ranged from 0.56 (0.14%) to 0.97 (0.24%), peaking in the third week of October (42nd SMW) before declining in early November (44th SMW). Weather parameters during this period varied: temperature (25.89°C to 35.46°C), relative humidity (54.29% to 85.14%), rainfall (1.57 mm/day), wind velocity (1.25 km/hr), and sunshine hours (7.34 hr/day). In *Kharif* 2022, beetle density varied between 0.60 (0.15%) and 1.07 (0.27%), also peaking in the third week of October. The weather ranged as follows: temperature (21.20°C to 32.09°C), relative humidity (58.00% to 92.43%), rainfall (0.00 mm/day), wind velocity (1.03 km/hr), and sunshine hours (7.49 hr/day). Correlation analysis revealed a positive association with evening relative humidity ($H_{\min}$ = 0.621) and mean relative humidity (H_{mean} = 0.558) in 2022, while in 2023, positive correlations were observed with temperature and sunshine hours but negative with relative humidity, rainfall, and wind velocity. Pooled data analysis confirmed similar trends (Table 1). SHUATS, Naini, Tehsil: Salempur (*Kharif* 2022 & 2023). In 2023, the rove beetle population ranged from 0.40 (0.10%) to 0.83 (0.21%), peaking during the 42nd SMW, with a decline from the 44th SMW. Weather conditions included temperatures between 25.89°C and 35.46°C, relative humidity from 54.29% to 85.14%, rainfall at 1.57 mm/day, wind velocity of 1.25 km/hr, and 7.34 sunshine hours per day. For *Kharif* 2022, population density ranged from 0.65 (0.16%) to 0.88 (0.22%), peaking in mid-October. Weather parameters were: temperature (21.20°C to 32.09°C), relative humidity (58.00% to 92.43%), rainfall (0.00 mm/day), wind velocity (1.03 km/hr), and sunshine hours (7.49 hr/day). Correlation analysis for 2022 indicated a strong positive relationship with relative humidity and sunshine hours, while in 2023, temperature showed a stronger positive correlation. Pooled data reaffirmed the significant influence of evening relative humidity ($H_{\min}$ = 0.522) and sunshine hours on beetle population (Table 2). Korsand, Tehsil: Soraon (*Kharif* 2022 & 2023). In 2023, the beetle population varied from 0.72 (0.18%) to 1.17 (0.29%), reaching its peak in the 42nd SMW. Weather conditions during this period included temperatures of 25.89°C to 35.46°C, relative humidity of 54.29% to 85.14%, rainfall of 1.57 mm/day, wind velocity of 1.25 km/hr, and sunshine hours of 7.34 hr/day. During *Kharif* 2022, the population ranged from 0.76 (0.19%) to 1.25 (0.31%), peaking in mid-October. The weather conditions recorded were temperature (21.20°C to 32.09°C), relative humidity (58.00% to 92.43%), no recorded rainfall, wind velocity of 1.03 km/hr, and 7.49 sunshine hours per day. Correlation analysis highlighted a strong positive correlation with relative humidity in 2022, whereas in 2023, temperature and sunshine hours showed stronger associations. The pooled data validated these findings, with evening relative humidity ($H_{\min}$ = 0.495) and sunshine hours significantly influencing the population dynamics (Table 3).



*B/H- Beetles Per Hill, SHUATS- Sam Higginbottom University of Agriculture Technology and Sciences.

Fig 1: Seasonal Population Trends of Rove Beetle During *Kharif* 2022 and 2023 with Combined Data Analysis

Table 1: Pearson's Correlation Matrix of Rove Beetle Population Dynamics with Abiotic Factors at Palpur

2022								
Parameter	B. /Hill	Mean	Std. D	Std. Error	% P	Mean	Std. D	Std. Error
Bugs/Hill	1.00	0.27	0.41	0.79	1.00	0.07	0.10	0.39
T Max	-0.369 ^{NS}	34.30	3.55	0.61	-0.369 ^{NS}	34.30	3.55	0.61
T Min	-0.028 ^{NS}	23.39	4.88	1.01	-0.027 ^{NS}	23.39	4.88	1.01
T Mean	-0.179 ^{NS}	28.84	4.03	0.75	-0.179 ^{NS}	28.84	4.03	0.75
% H Morning	0.392 ^{NS}	87.90	6.84	0.73	0.392 ^{NS}	87.90	6.84	0.73
% H Evening	0.621 ^{**}	53.42	10.32	1.41	0.620 ^{**}	53.42	10.32	1.41
H Mean	0.558 ^{**}	70.66	8.15	0.97	0.557 ^{**}	70.66	8.15	0.97
Rainfall	0.124 ^{NS}	3.75	6.45	3.33	0.123 ^{NS}	3.75	6.45	3.33
Wind V.	-0.238 ^{NS}	1.23	0.30	0.27	-0.237 ^{NS}	1.23	0.30	0.27
Sunshine	0.245 ^{NS}	5.78	1.70	0.71	0.244 ^{NS}	5.78	1.70	0.71
2023								
Bugs/Hill	1.00	0.26	0.39	0.76	1.00	0.06	0.10	0.38
T Max	0.111 ^{NS}	34.02	2.62	0.45	0.111 ^{NS}	34.02	2.62	0.45
T Min	0.181 ^{NS}	24.11	4.54	0.92	0.181 ^{NS}	24.11	4.54	0.92
T Mean	0.160 ^{NS}	29.07	3.49	0.65	0.159 ^{NS}	29.07	3.49	0.65
% H Morning	-0.179 ^{NS}	88.26	3.19	0.34	-0.179 ^{NS}	88.26	3.19	0.34
% H Evening	-0.026 ^{NS}	57.42	5.20	0.69	-0.025 ^{NS}	57.42	5.20	0.69
H Mean	-0.094 ^{NS}	72.84	3.76	0.44	-0.093 ^{NS}	72.84	3.76	0.44
Rainfall	-0.164 ^{NS}	7.50	8.39	3.06	-0.163 ^{NS}	7.50	8.39	3.06
Wind V.	-0.173 ^{NS}	1.32	0.29	0.26	-0.173 ^{NS}	1.32	0.29	0.26
Sunshine	0.173 ^{NS}	6.89	1.98	0.76	0.173 ^{NS}	6.89	1.98	0.76
Pooled data 2022 and 2023								
Bugs/Hill	1.00	0.26	0.40	0.78	1.00	0.07	0.10	0.39
T Max	-0.183 ^{NS}	34.16	2.79	0.48	-0.184 ^{NS}	34.16	2.79	0.48
T Min	0.074 ^{NS}	23.75	4.60	0.95	0.074 ^{NS}	23.75	4.60	0.95
T Mean	-0.023 ^{NS}	28.96	3.61	0.67	-0.023 ^{NS}	28.96	3.61	0.67
% H Morning	0.260 ^{NS}	88.08	4.05	0.43	0.260 ^{NS}	88.08	4.05	0.43
% H Evening	0.515 ^{**}	55.42	6.10	0.82	0.516 ^{**}	55.42	6.10	0.82
H Mean	0.438 [*]	71.75	4.79	0.57	0.439 [*]	71.75	4.79	0.57
Rainfall	-0.050 ^{NS}	5.63	5.76	2.43	-0.048 ^{NS}	5.63	5.76	2.43
Wind V.	-0.216 ^{NS}	1.28	0.28	0.25	-0.216 ^{NS}	1.28	0.28	0.25
Sunshine	0.238 ^{NS}	6.34	1.59	0.63	0.239 ^{NS}	6.34	1.59	0.63

Table 2: Pearson's Correlation Matrix of Rove Beetle Population Dynamics with Abiotic Factors at Shuats

2022								
Parameter	B. /Hill	Mean	Std. D	Std. Error	% P	Mean	Std. D	Std. Error
Bugs/Hill	1.00	0.24	0.36	0.74	1.00	0.06	0.09	0.37
T Max	-0.377 ^{NS}	34.30	3.55	0.61	-0.377 ^{NS}	34.30	3.55	0.61
T Min	-0.043 ^{NS}	23.39	4.88	1.01	-0.044 ^{NS}	23.39	4.88	1.01
T Mean	-0.192 ^{NS}	28.84	4.03	0.75	-0.193 ^{NS}	28.84	4.03	0.75
% H Morning	0.401*	87.90	6.84	0.73	0.401*	87.90	6.84	0.73
% H Evening	0.621**	53.42	10.32	1.41	0.621**	53.42	10.32	1.41
H Mean	0.561**	70.66	8.15	0.97	0.561**	70.66	8.15	0.97
Rainfall	0.119 ^{NS}	3.75	6.45	3.33	0.119 ^{NS}	3.75	6.45	3.33
Wind V.	-0.228 ^{NS}	1.23	0.30	0.27	-0.229 ^{NS}	1.23	0.30	0.27
Sunshine	0.252 ^{NS}	5.78	1.70	0.71	0.252 ^{NS}	5.78	1.70	0.71
2023								
Bugs/Hill	1.00	0.22	0.33	0.71	1.00	0.05	0.08	0.36
T Max	0.117 ^{NS}	34.02	2.62	0.45	0.117 ^{NS}	34.02	2.62	0.45
T Min	0.190 ^{NS}	24.11	4.54	0.92	0.190 ^{NS}	24.11	4.54	0.92
T Mean	0.167 ^{NS}	29.07	3.49	0.65	0.168 ^{NS}	29.07	3.49	0.65
% H Morning	-0.191 ^{NS}	88.26	3.19	0.34	-0.192 ^{NS}	88.26	3.19	0.34
% H Evening	-0.020 ^{NS}	57.42	5.20	0.69	-0.020 ^{NS}	57.42	5.20	0.69
H Mean	-0.095 ^{NS}	72.84	3.76	0.44	-0.096 ^{NS}	72.84	3.76	0.44
Rainfall	-0.154 ^{NS}	7.50	8.39	3.06	-0.154 ^{NS}	7.50	8.39	3.06
Wind V.	-0.170 ^{NS}	1.32	0.29	0.26	-0.170 ^{NS}	1.32	0.29	0.26
Sunshine	0.161 ^{NS}	6.89	1.98	0.76	0.161 ^{NS}	6.89	1.98	0.76
Pooled data 2022 and 2023								
Bugs/Hill	1.00	0.23	0.35	0.72	1.00	0.06	0.09	0.36
T Max	-0.187 ^{NS}	34.16	2.79	0.48	-0.188 ^{NS}	34.16	2.79	0.48
T Min	0.073 ^{NS}	23.75	4.60	0.95	0.073 ^{NS}	23.75	4.60	0.95
T Mean	-0.025 ^{NS}	28.96	3.61	0.67	-0.026 ^{NS}	28.96	3.61	0.67
% H Morning	0.263 ^{NS}	88.08	4.05	0.43	0.264 ^{NS}	88.08	4.05	0.43
% H Evening	0.522**	55.42	6.10	0.82	0.523**	55.42	6.10	0.82
H Mean	0.444*	71.75	4.79	0.57	0.445*	71.75	4.79	0.57
Rainfall	-0.046 ^{NS}	5.63	5.76	2.43	-0.046 ^{NS}	5.63	5.76	2.43
Wind V.	-0.216 ^{NS}	1.28	0.28	0.25	-0.215 ^{NS}	1.28	0.28	0.25
Sunshine	0.239 ^{NS}	6.34	1.59	0.63	0.238 ^{NS}	6.34	1.59	0.63

Table 3: Pearson's Correlation Matrix of Rove Beetle Population Dynamics with Abiotic Factors at Korsand

2022								
Parameter	B. /Hill	Mean	Std. D	Std. Error	% P	Mean	Std. D	Std. Error
Bugs/Hill	1.00	0.31	0.47	0.85	1.00	0.08	0.12	0.42
T Max	-0.372 ^{NS}	34.30	3.55	0.61	-0.372 ^{NS}	34.30	3.55	0.61
T Min	-0.050 ^{NS}	23.39	4.88	1.01	-0.050 ^{NS}	23.39	4.88	1.01
T Mean	-0.194 ^{NS}	28.84	4.03	0.75	-0.194 ^{NS}	28.84	4.03	0.75
% H Morning	0.399*	87.90	6.84	0.73	0.400*	87.90	6.84	0.73
% H Evening	0.609**	53.42	10.32	1.41	0.609**	53.42	10.32	1.41
H Mean	0.553**	70.66	8.15	0.97	0.553**	70.66	8.15	0.97
Rainfall	0.098 ^{NS}	3.75	6.45	3.33	0.099 ^{NS}	3.75	6.45	3.33
Wind V.	-0.248 ^{NS}	1.23	0.30	0.27	-0.248 ^{NS}	1.23	0.30	0.27
Sunshine	0.256 ^{NS}	5.78	1.70	0.71	0.256 ^{NS}	5.78	1.70	0.71
2023								
Bugs/Hill	1.00	0.29	0.45	0.83	1.00	0.07	0.11	0.41
T Max	0.113 ^{NS}	34.02	2.62	0.45	0.113 ^{NS}	34.02	2.62	0.45
T Min	0.173 ^{NS}	24.11	4.54	0.92	0.173 ^{NS}	24.11	4.54	0.92
T Mean	0.155 ^{NS}	29.07	3.49	0.65	0.155 ^{NS}	29.07	3.49	0.65
% H Morning	-0.193 ^{NS}	88.26	3.19	0.34	-0.193 ^{NS}	88.26	3.19	0.34
% H Evening	-0.047 ^{NS}	57.42	5.20	0.69	-0.046 ^{NS}	57.42	5.20	0.69
H Mean	-0.114 ^{NS}	72.84	3.76	0.44	-0.114 ^{NS}	72.84	3.76	0.44
Rainfall	-0.198 ^{NS}	7.50	8.39	3.06	-0.198 ^{NS}	7.50	8.39	3.06
Wind V.	-0.174 ^{NS}	1.32	0.29	0.26	-0.174 ^{NS}	1.32	0.29	0.26
Sunshine	0.195 ^{NS}	6.89	1.98	0.76	0.195 ^{NS}	6.89	1.98	0.76
Pooled data 2022 and 2023								
Bugs/Hill	1.00	0.30	0.46	0.84	1.00	0.08	0.12	0.42
T Max	-0.183 ^{NS}	34.16	2.79	0.48	-0.185 ^{NS}	34.16	2.79	0.48
T Min	0.058 ^{NS}	23.75	4.60	0.95	0.057 ^{NS}	23.75	4.60	0.95
T Mean	-0.033 ^{NS}	28.96	3.61	0.67	-0.035 ^{NS}	28.96	3.61	0.67
% H Morning	0.261 ^{NS}	88.08	4.05	0.43	0.263 ^{NS}	88.08	4.05	0.43

% H Evening	0.495*	55.42	6.10	0.82	0.497*	55.42	6.10	0.82
H Mean	0.426*	71.75	4.79	0.57	0.428*	71.75	4.79	0.57
Rainfall	-0.087 ^{NS}	5.63	5.76	2.43	-0.086 ^{NS}	5.63	5.76	2.43
Wind V.	-0.223 ^{NS}	1.28	0.28	0.25	-0.223 ^{NS}	1.28	0.28	0.25
Sunshine	0.259 ^{NS}	6.34	1.59	0.63	0.259 ^{NS}	6.34	1.59	0.63

Conclusion

The study revealed that the population dynamics of rove beetles (*Paederus fuscipes*) were significantly influenced by environmental factors such as temperature, relative humidity, rainfall, wind velocity, and sunshine hours. Peak population activity was observed in the third week of October, followed by a decline in early November. The findings underscore the importance of rove beetles as effective natural enemies in integrated pest management (IPM) strategies, particularly in rice ecosystems. The significant correlations observed between beetle populations and key weather parameters further highlight their role in regulating pest populations. Encouraging the conservation of these natural enemies through habitat management and reduced pesticide usage can enhance sustainable pest control, reducing reliance on chemical interventions and promoting ecological balance.

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