Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(2): 1598-1602
Received: 01-02-2020
Accepted: 05-03-2020

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Abundance of bioagents of insect pests in rice field ecosystem under changing climatic conditions of eastern Uttar Pradesh

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DOI: https://dx.doi.org/10.22271/phyto.2020.v9.i2z.14652

Abstract
The present study was undertaken to investigate the abundance of bioagents prevalent over rice insect pests associated with rice field ecosystem under changing climatic conditions of Eastern Uttar Pradesh, India. The surveillance was conducted in 03 administrative divisions namely, Gorakhpur, Basti and Azamgarh for two consecutive years, 2014 and 2015 in rainy season (Kharif). The surveillance for abundance of major bioagent species prevalent over major insect pests of rice was conducted as per methodology of agroecosystem analysis (AESA) modified as accessibility. There were 41 bioagent species observed under 03 rice growth stages of seedling, transplanting and flowering. Among 15 major bioagent species prevalent over major insect pests of rice, there were confined 10 bioagent species as predators and 5 bioagent species as parasitoids. Of the total observed population of major bioagent groups in all growth stages of rice under temperature maximum, temperature minimum, relative humidity, and rainfall, the correlation coefficients were - 0.594, - 0.573, - 0.482, and 0.762 for spiders; - 0.463, - 0.440, - 0.341, and 0.653 for mirids; -0.481, -0.458, -0.359, and 0.668 for coccinellids; -0.524, -0.502, -0.407, and 0.705 for orthopterans; -0.475, -0.452, -0.354, and 0.663 for hymenopterans; - 0.602, - 0.581, - 0.490, and 0.768 for predators; - 0.459, - 0.436, - 0.337, and 0.649 for parasitoids; and -0.552, - 0.530, -0.436, and 0.728 for total population of most bioagent groups respectively. The abundance of major bioagent species was inference negative correlation with particular weather parameters, except rainfall was inference positive correlation. The population of major bioagent species were tended towards transplanting stage of rice. The total population of major bioagent species under major bioagent groups was highly increased in transplanting stage and abundant descendingly with transplanting, flowering, and seedling growth stages of rice with influence of weather parameters respectively.

Keywords: Abundance, bioagents, insect pests of rice, weather parameters, Eastern Uttar Pradesh, India

Introduction
Rice is the most important staple food for more than half population of the India and world. About 90% of the world's rice is produced and consumed in the Asian region and most staple food of South East Asia. The rice fragrance spreads to the entire world. More than 110 countries grow rice on one fifth of the world food grain crop area. Rice shares 27% of the world food grain production and occupies second position after wheat and 56% of the India food grain production and occupies first position. India shares 21% of the world rice production and occupies second position after China. Uttar Pradesh shares 15% of the India rice production occupies second position followed by West Bengal (17%) and first in rice production area. Despite these above proud credentials, Uttar Pradesh is not appearing leading position. The main cause of low productivity of rice is ill cultivation practices and crop losses. The crop losses share about 32.1% losses by plant ailments (pests, diseases & weeds) and among them, about 10.8% losses caused by pests globally and India have been reported about 17.5% losses caused by insect pests. Historically, insect pest outbreaks have been causing extensive losses in rice crop production ranging from 60 to 95% over world and India have been estimated rice crop losses by insect pests ranging from 21 to 51% respectively. (Pathak and Khan, 1994; Maclean *et al*., 2002; Oerke, 2006; Dhaliwal *et al*., 2015; Heinrichs and Muniappan, 2017; Sharma *et al*., 2017; DAC&FW, 2018; Pathak *et al*., 2018; FAOSTAT, 2019) [17, 12, 13, 7, 10, 22, 4, 16, 9].

Bioagents are natural enemies, which attack various life stages of insects to kill as a prey or host to complete their life cycle. They are silent suppression factors of insect pests in rice ecosystem. Predators, parasitoids and pathogens are groups of bioagents. Predators and parasitoids are major groups of arthropod bioagents against rice insect pests. Predatory insects, Spiders & predatory mites are groups of predators, whereas parasitic wasp and flies are groups of parasitoids.

Predators and parasitoids are varying in feeding and egg laying potential, which have been playing significant role in biological insect pest management. About 550 arthropod bioagent species associated with rice insect pests in India and among them, there have been 20 species of arthropod bioagents recognized as major economic significance. Environment is the key factor of insect population dynamics. The warm humid environment is congenial for rice production and conductive to the survival and proliferation of arthropods biodiversity. The population of bioagents are mostly influenced by different weather factors, *i.e.,* temperature maximum, temperature minimum, relative humidity, and rainfall. (Ooi and Shepard, 1994; Pathak and Khan, 1994; David and Ananthakrishnan, 2004; Prakash *et al*., 2014; Fahad *et al*., 2015; Heinrichs and Muniappan, 2017; Krishnaiah and Varma (2018); Rao, 2019) [14, 17, 6, 19, 8, 10, 11, 21]. Prasad *et al.* (2010) [20], studied the incidence of white backed planthopper (WBPH), and its predators during rainy season (Kharif) in different paddy ecosystems of Uttara Kannada district (Karnataka). Parasappa *et al.* (2017) [15] have also been reported that, among the predators, the spiders and mirids were the most important natural enemies. Spiders and odonates recorded as general predators of rice insect pests. The spiders, dragonfly, damselfly, and coccinellids were more during the vegetative stage of the crop, whereas mirids, staphylids, and cicindelids were more during reproductive stage of the crop.

Materials and Methods

The present study was undertaken to investigate the abundance of bioagents prevalent over rice insect pests associated with rice field ecosystem under changing climatic conditions of Eastern Uttar Pradesh, India for two consecutive years (2014 and 2015). The observation was undertaken in all 10 districts of 03 administrative divisions of Eastern Uttar Pradesh *i.e*., Gorakhpur (Gorakhpur, Deoria, Kushinagar, and Maharajganj), Basti (Basti, Santkabirnagar, and Siddharthnagar) and Azamgarh (Azamgarh, Mau, and Ballia). It lies between 27^0 40' N latitude and 80^0 00' E longitude of geographical coordinates and altitude at about 240 meters. The samples were taken randomly for concerned districts of all 03 divisions for each growth stage of rice under 03 growth stages *i.e.*, seedling, transplanting, and flowering for consecutively two years. There was each field selected at each division per growing stages for each year. The duration of rice crops started from pre week of August to mid-week of November for about 110 days. The seedling stage started when the seeds were seeded to germinate in the nursery. The transplanting stage began with the transplantation in the field to completed tillering, panicle formation and booting phase for about 50 days before flowering. The flowering stage began with the formation of flower and ended just before harvesting and lasted for about 30 days. Samples were taken 03 times at interval of 20 days after sowing (20 DAS) for seedling stage, 30 days after transplanting (30 DAT) for transplanting stage and 60 DAT for flowering stage respectively. Each plot was selected 5 spots (4 in the corner at least 60 cm inside the border and one in the centre) to collect samples at $0.25m^2$ /spot for seedling stage and at 01 hill/spot for transplanting and flowering stage to observe abundance of insect pests and their infestation. There were also at each plot, 05 net sweeps made randomly at every 05 steps to observe abundance of insect pests for all 03 growth stages of rice. The size of sweep net was 25 cm diameter and 70 cm handle and made up of nylon. The timing of sampling was 9.30 A.M. to 12.30 P.M. respectively. Each observation was recorded abundance of bioagents to calculate most bioagent groups and major bioagent species prevalent over major insect pests of rice. The observation was also calculated correlation with meteorological factors at different rice growth stages.

The meteorological recording was coordinates with Gorakhpur (India) meteorological station concerning Tutiempo (2019) [24] and Timeanddate (2019) [23] web portal regarding maximum and minimum temperature, relative humidity, and rainfall of months, *i.e.,* August, September, October, and December for years, 2014 and 2015 respectively. Surveillance was conducted as per methodology of agroecosystem analysis (AESA) (Pontius *et al*., 2002) [18] modified as accessibility. Taxonomic identification was verified with texts of reference, *i.e*., Barrion and Litsinger (1994) [1], Dale (1994) [5], Pathak and Khan (1994) [17], David and Ananthakrishnan (2004) [6]; Rice knowledge management portal (RKMP); and Subject experts respectively.

Results and Discussion

There were 41 bioagent species of rice insect pest complex belonging to 13 bioagent groups under 2 most bioagent groups, predators (spiders, coccinellids, cicindelids, carabids, odonates, orthopterans, mantids, mirids, staphylids, dermapterans, neuropterans) and parasitoids (dipterans, and hymenopterans) among 3 rice growth stages (seedling, transplanting, and flowering) observed for sum of both the years 2014 and 2015 respectively. There were 15 bioagent species confined major bioagents prevalent over major insect pests of rice for sum of both the years 2014 and 2015. They were belonged to 5 major bioagent groups under 2 most bioagent groups, as predators (spiders, mirids, coccinellids, and orthopterans); and parasitoids (hymenopterans) for all growth stages of rice. The spiders comprise 7 species- Field wolf spider (*Lycosa pseudoannulata* Boesenberg & Strand), Ground wolf spider (*Pardosa sumatrana* Thorell), Common lynx spider (*Oxyopes javanus* Thorell), Foliage jumping spider (*Phidippus indicus* Tikader), Tropical jumping spider (*Plexippus paykulli* Audouin), Field long jawed spider (*Tetragnatha maxillosa* Thorell), Brown longjawed spider (*Tetragnatha bogotensis*, Walckenaer); the mirids comprises 1 species- Common green miridbug (*Cyrtorhinus lividipennis* Reuter); the coccinellids comprises 1 species- Common ladybird beetle (*Coccinella septempunctata* Linnaeus); the orthopterans comprises 1 species- Longhorned grasshopper (*Conocephalus longipennis* de Hann); and the hymenopterans comprise 5 species-Euparasitic braconidwasp (*Cotesia flavipes* Cameron), Common rice braconidwasp (*Bracon brevicornis* Wesmael), Common rice scelionidwasp (*Telenomus rowani* Gahan), Common rice eulophidwasp (*Tetrastichus schoenobii* Ferriere), Common trichogrammidwasp (*Trichogramma japonicum* Ashmead) for major bioagent species. There were 12 insect pest species confined major insect pests of rice above 10% Infestation. The major insect pests of rice were confined, 7 insect pest species as very serious (10- 15% infestation) and 5 insect pest species as most serious (> 15% infestation). The all 12 major insect pests of rice under insect pest complex for sum of both the years 2014 and 2015 were confined namely, very serious- 1.Rice cutworm (*Spodoptera mauritia* Boisduval), 2.Common termite (*Odontotermes obesus* Rambur), 3.Rice grasshopper (*Hieroglyphus banian* Fabricius), 4.Striped stemborer (*Chilo suppressalis* Walker), 5.Plain green leafhopper (*Nephotettix virescens* Distant), 6.Spotted green leafhopper (*Nephotettix nigropictus* Stal),

7.Whitebacked planthopper (*Sogatella furcifera* Horvath); and most serious- 6.Rice hispa (*Dicladispa armigera* Oliver), 7.Rice earheadbug (*Leptocorisa acuta* Thunberg); 9.Yellow stemborer (*Scirpophaga incertulas* Walker), 11.Brown planthopper (*Nilaparvata lugens* Stal), 12.Common rice leaffolder (*Cnaphalocrocis medinalis* Guenee) respectively. The present study was revealed that, the population of major bioagent species were tended towards transplanting stage of rice. There were also observed that, the bioagent species of most of the predators prevalent over nymphs and adults of Brown planthopper (*Nilaparvata lugens* Stal) and Spotted green leafhopper (*Nephotettix nigropictus* Stal); and most of the parasitoids prevalent over eggs of Yellow stemborer (*Scirpophaga incertulus* Walker) respectively (Table-1a, 1b & 2 and Figure-1).

The population of major bioagent species under major bioagent groups prevalent over major insect pests of rice, *i.e.*, spiders, mirids, coccinellids, orthopterans, and hymenopterans were influenced by weather parameters. Of the total observed population of major bioagent groups in all growth stages of rice under temperature maximum, temperature minimum, relative humidity, and rainfall for sum of both the years 2014 and 2015 were varied each other. The correlation coefficients were - 0.594, - 0.573, - 0.482, and 0.762 for spiders; - 0.463, - 0.440, - 0.341, and 0.653 for mirids; -0.481, -0.458, -0.359, and 0.668 for coccinellids; -0.524, -0.502, -0.407, and 0.705 for orthopterans; and -0.475, -0.452, -0.354, and 0.663 for hymenopterans respectively. The correlation coefficients were inference -0.155, -0.129, -0.023, and 0.377 for total population of major bioagent groups under temperature maximum, temperature minimum, relative humidity, and rainfall, respectively. The total population of major bioagent species under major bioagent groups were inference non-significant correlation with each weather parameters in all growth stages of rice. The abundance of major bioagent species was inference negative correlation with each weather parameters, except rainfall was inference positive correlation. The influences of the weather parameters on the total population of major bioagent species under major bioagent groups were highly decreased with increasing temperature maximum, temperature minimum, and relative humidity and decreasing rainfall in seedling stage, and highly increased with moderately decreasing temperature maximum, temperature minimum, and relative humidity and increasing rainfall in transplanting stage, while moderately decreased with decreasing temperature maximum, temperature minimum, and relative humidity and increasing rainfall in flowering stage respectively. The abundance of most bioagent groups, as predators (spiders, mirids, coccinellids, and orthopterans); and parasitoids (hymenopterans) both were inferenced negative correlation with particular weather parameters, except rainfall was inferenced positive correlation. The population of major bioagent species under major bioagent groups was highly increased with influence of weather parameters under transplanting stage and abundant descendingly with transplanting, flowering, and seedling growth stages of rice, respectively. (Table-3 and Figure-2). These results are in agreement with Ooi and Shepard (1994) [14], Bhattacharyya *et al.* (2006) [2], Fahad *et al.* (2015) [8], Chakraborty *et al.* (2016) [3] Heinrichs and Muniappan, (2017) [10], and Krishnaiah and Varma (2018) [11] respectively.

Table 1a: Major Bioagents Prevalent over Major Insect Pests of Rice (Sum of 2014 & 15)

Major Bioagent Groups	Major Bioagent Species		
	Common Name	**Scientific Name**	**Order: Family**
1. Spiders	1.Field wolf spider	*Lycosa pseudoannulata*	Araneae: lycosidae
	2.Ground wolf spider	*Pardosa sumatrana*	Araneae: lycosidae
	3.Common lynx spider	*Oxyopes javanus*	Araneae: Oxyopidae
	4.Foliage jumping spider	*Phidippus indicus*	Araneae: Salticidae
	5.Tropical jumping spider	*Plexippus paykulli*	Araneae: Salticidae
	6.Field longjawed spider	*Tetragnatha maxillosa*	Araneae: Tetragnathidae
	7.Brown longjawed spider	*Tetragnatha bogotensis*	Araneae: Tetragnathidae
2. Mirids	1.Common green miridbug	*Cyrtorhinus lividipennis*	Hemiptera: Miridae
3. Coccinellids	1.Common ladybird beetle	*Coccinella septempunctata*	Coleoptera: Coccinellidae
4. Orthopterans	1.Longhorned grasshopper	*Conocephalus longipennis*	Orthoptera: Tettigoniidae
5. Hymenopterans	1.Euparasitic braconidwasp	*Cotesia flavipes*	Hymenoptera: Braconidae
	2.Common rice braconidwasp	*Bracon brevicornis*	Hymenoptera: Braconidae
	3.Common rice scelionidwasp	*Telenomus rowani*	Hymenoptera: Scelionidae
	4.Common rice eulophidwasp	*Tetrastichus schoenobii*	Hymenoptera: Eulophidae
	5.Common trichogrammidwasp	*Trichogramma japonicum*	Hymenoptera: Trichogrammatidae
Total	15		

Table 1b: Major Bioagents Prevalent over Major Insect Pests of Rice (Sum of 2014 & 15)

Most Bioagent Groups	
Predators	**Parasitoids**
1.Field wolf spider (*Lycosa pseudoannulata*)	1.Euparasitic braconidwasp (*Cotesia flavipes*)
2.Ground wolf spider (*Pardosa sumatrana*)	2.Common rice braconidwasp (*Bracon brevicornis*)
3.Common lynx spider (*Oxyopes javanus*)	3.Common rice scelionidwasp (*Telenomus rowani*)
4.Foliage jumping spider (*Phidippus indicus*)	4.Common rice eulophidwasp (*Tetrastichus schoenobii*)
5.Tropical jumping spider (*Plexippus paykulli*)	5.Common trichogrammidwasp (*Trichogramma japonicum*)
6.Field longjawed spider (*Tetragnatha maxillosa*)	—
7.Brown longjawed spider (*Tetragnatha bogotensis*)	—
8.Common green miridbug (*Cyrtorhinus lividipennis*)	—
9.Common ladybird beetle (*Coccinella septempunctata*)	—
10.Longhorned grasshopper (*Conocephalus longipennis*)	—
Total — 15	

Table 2: Bioagents Population Observed under Growth Stages of Rice (Sum of 2014 & 15)

Observation Years	Most Bioagent Groups	Growth Stages of Rice							
		Number				Percentage			
		Seedling	Transplanting	Flowering	Total	Seedling	Transplanting	Flowering	Total
2014	Predators	185	348	279	812	19.91	37.46	30.03	87.40
	Parasitoids	24	53	40	117	2.58	5.71	4.31	12.60
	Total	209	401	319	929	22.49	43.16	34.33	100
2015	Predators	195	357	323	875	19.56	35.81	32.39	87.76
	Parasitoids	26	55	41	122	2.61	5.52	4.11	12.23
	Total	221	412	364	997	22.17	41.32	36.51	100
2014 and 2015	Predators	380	705	602	1687	19.73	36.60	31.26	87.59
	Parasitoids	50	108	81	239	2.59	5.61	4.21	12.41
	Total	430	813	683	1926	22.32	42.21	35.46	100

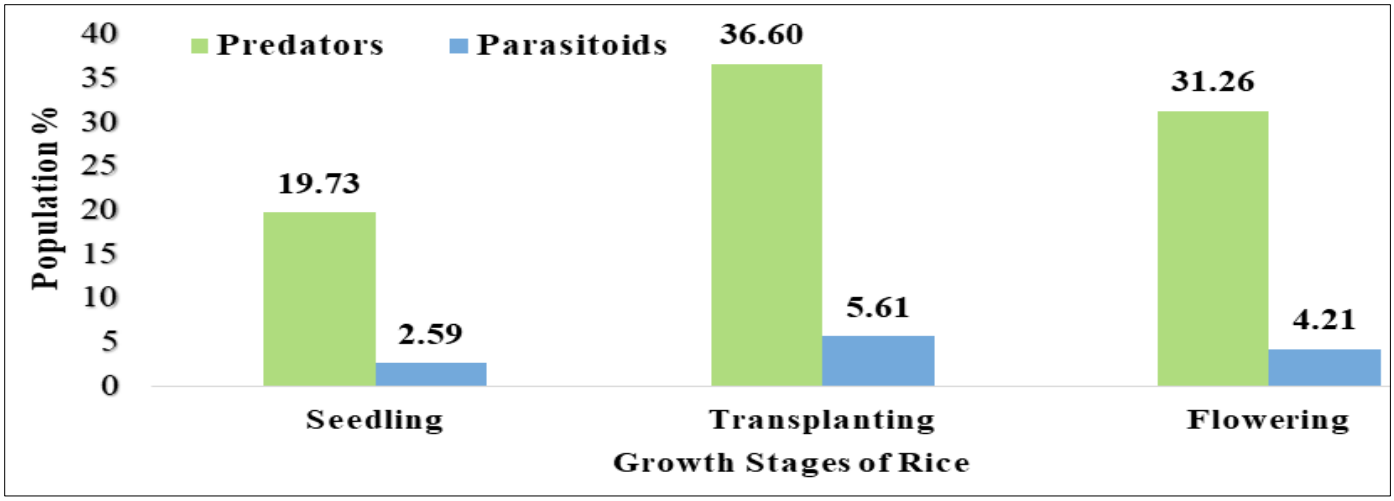

Fig 1: Bioagents Population Observed under Growth Stages of Rice (Sum of 2014 & 15)

Table 3: Population of Major Bioagents under Weather Parameters (Sum of 2014 & 15).

Influence of Major Bioagents Population under Weather Parameters								
Major Bioagent Groups	Growth Stages of Rice			Weather Parameters				
	Seedling	Transplanting	Flowering	Correlation Coefficient				
	34.10	32.40	30.10	Observations	Temperature Maximum (°C)			
	25.20	21.60	16.25			Temperature Minimum (°C)		
	78.70	75.85	69.40				Relative Humidity (%)	
	1000.60	1007.70	1011.95					Rainfall(mm)
Spiders	130	210	184	Population	-0.594	-0.573	-0.482	0.762
Mirids	20	33	27		- 0.463	- 0.440	- 0.341	0.653
Coccinellids	21	30	26		- 0.481	- 0.458	- 0.359	0.668
Orthopterans	9	19	15		- 0.524	- 0.502	- 0.407	0.705
Hymenopterans	18	38	29		- 0.475	- 0.452	- 0.354	0.663
Total	198	330	231		-0.155	-0.129	-0.023	0.377

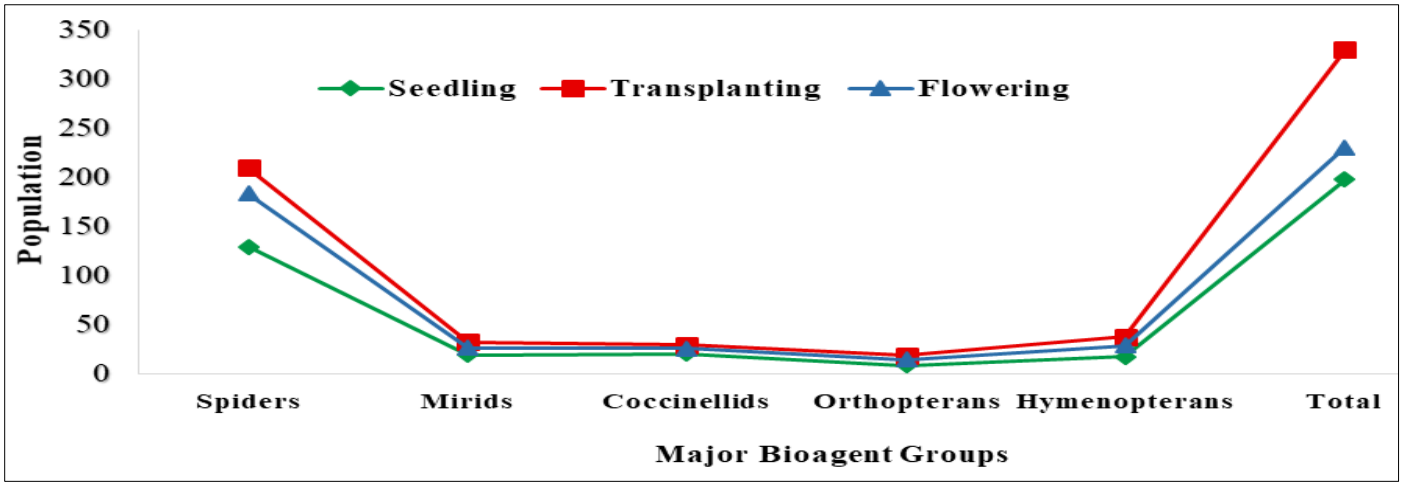

Fig 2: Population of Major Bioagents under Weather Parameters (Sum of 2014 & 15)

Conclusion

There were 41 bioagent species belonging to 13 bioagent groups under 2 most bioagent groups, predators (spiders, coccinellids, cicindelids, carabids, odonates, orthopterans, mantids, mirids, staphylids, dermapterans, neuropterans) and parasitoids (dipterans, and hymenopterans) among 3 rice growth stages (seedling, transplanting, and flowering) observed for sum of both the years 2014 and 2015. There were 15 bioagent species confined major bioagents prevalent over major insect pests of rice belonging to 5 major bioagent groups under 2 most bioagent groups, as predators (spiders, mirids, coccinellids, and orthopterans); and parasitoids (hymenopterans) for all growth stages of rice. The abundance of major bioagent species under major bioagent groups of spiders, mirids, coccinellids, orthopterans and hymenopterans were inference non-significant correlation with each weather parameters in all growth stages of rice. The abundance of major bioagent species was inference negative correlation with each weather parameters, except rainfall was inference positive correlation. The population of major bioagent species were tended towards transplanting stage of rice. The total population of major bioagent species under major bioagent groups was highly increased in transplanting stage and abundant descendingly with transplanting, flowering, and seedling growth stages of rice with influence of weather parameters, respectively.

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