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Abundance and diversity of pest's insect of rice (*Oryza sativa*) in territory of Kabare, South Kivu/ Democratic Republic of Congo

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Abstract
The study focused on the abundance and diversity of pest's insect of rice (*Oryza sativa*). Two varieties such as *Komboka* and *Nerica4* were cultivated at Kashusha's rice fields in Kabare district of south Kivu, Eastern Democratic Republic of Congo. A split plot design was used. Insects were captured using a sweep net and by hand within each elementary plot between from 6.30 am to 8.30 am at the different stages started, 15th, 66th, 91 and 121 days after transplanting. This insect collection method consisted of capturing and harvesting insects by hand from the 2 diagonals of each compartment. Four captures had taken place during its cycle and this cycle has 4 different phenological stages (Nursery or seed plot, tillering, Cob/flowering and maturity). The insect pests collections on two varieties of rice tested allowed us to assess the dynamics and abundance of pest's insect of rice. On the two varieties 3077 insects were inventoried and retorted by 2204 individuals for *Komboka* and by 873 individuals for *Nerica4*. Those species belong to 5 orders and 25 species. Insect pest dynamics were different across all rice phenological stages within Kashusha's rice area.

Keywords: Rice, phenological stages, insects, Kashusha

1. Introduction

Rice (*Oryza sativa*) is the staple food of more than half of the world's population. Global demand for rice is expected to increase from 360 million tons in 2019 to 600 million tons in 2030 tons [1]. According Mbonankira (2014) [2], cultivated rice is native to South and Southeast Asia; it belongs to the Poaceae family. There are two cultivated and 21 wild species of the genus Oryza. *Oryza sativa* is rice grown in Asia and around the world. About 85% of the total rice area is found in five Asian countries, namely China, India, Indonesia, Bangladesh and the Philippines, compared to Africa which has only 8%) [3]. Four major rice agro systems are generally recognized: Irrigated rice cultivation, flooded rice cultivation, rained rice cultivation and deep submergence rice cultivation. The rice cultivation area is distinguished according to the rice ecosystems in different regions of the world [2]. Moinina *et al.* (2020) [4] reported that in Africa, rice consumption is increasing by 1.8% per year. Current annual rice production is 560 million tons and is expected to increase to 850 million tons by 2025.Rice production is largely influenced by the yield potential of rice varieties. Therefore, improving rice yield potential is the main strategy to increase global rice production [2]. Local rice production cannot meet the growing demand for rice in many African countries. Therefore, any increase in national rice production comes from an expansion in area rather than a substantial increase in productivity [4]. Rice is the second most consumed cereal after corn in Democratic Republic of Congo (DRC). The estimated consumption of white rice varies from 7 kg to 19.5 kg/person/year [5, 6]. Rice is faced with multiple constraints, notably certain pathologies and insect pests [7]. However, damage caused by insect pests constitutes one of the major constraints to rice production in the DRC [8]. In the farmers' rice fields, a diversity of orders of insect pests is observed on rice cultivation, such as Diptera, Lepidoptera and other pests at different phenological phases [9, 10].

In Kabare territory at the South-Kivu province, few studies [8, 11, 12] were oriented on the biological diversity of insect pests of rained and irrigated rice in The Kabare rice ecosystem. The aim of this study is to assess the dynamics and abundance of pest's insect of rice.

2. Materials and Methods

Study area

This study was conducted in the Kashusha village, Kabare Territory from February 15 to July 1, 2021. The Kashusha site is located at 28°7'48" longitude and 2°55'19" latitude and at the 1535 m ASL [13]. Kashusha is limited to the North by the Bugorhe group, the South by INERA/ Mulungu, the East by the Bushumba group and the West by Combo locality. The soil of Kashusha is made up of compact clay deriving from the composition of the underlying basalts with a pH of 4.8 to 5.2; it is rich in organic matter, heavy and black in color [14]. The Kashusha site enjoys a humid tropical climate which is characterized by nine months of rain and three months of dry season. The average annual temperature is estimated between 16 and 20 °C, its rainfall is bimodal, it's growing season A begins from September to November and season B begins from March - April. The average annual precipitation recorded in Kashusha reaches 1572 mm [13].

3. Methods

The net was used to capture insects at the two diagonals of each trap not treated with insecticide following the 4 different phenological phases studied. During the study, certain insects visible to the naked eye located closer to the collar and inside the panicles were collected by hand. The dose of 5 cc per liter of Cypermethrin was used. Thus, a volume of 100cc of cypermethrin was mixed in a 20-liter backpack sprayer for an area of 50 m^2. Spraying with the insecticide was carried out between 6:30 a.m. and 8:00 a.m. The treatments were carried out following the different phenological phases of rice cultivation, at 65 days during tillering; at 90 days during cob/Flowering and 120 days (hardening of grains) following the 3 phenological phases after transplanting seedlings following the development of rice cultivation. 2 weeks of afterglow had been observed to harvest.

The insecticide treatment periods at each phenological phase are recorded in Table 1.

Table 1: Insecticide treatment periods four phenological phases

Phases	Treatments	Dates	Insecticide treatment period (days) in 2021
Nursery or seed plot	-	-	-
Tillage	First treatment with Cypermethrin	April 31	65
Cob/Flow ring	Second treatment with Cypermethrin	May 30	90
Maturity	Third treatment with Cypermethrin	June 30	120

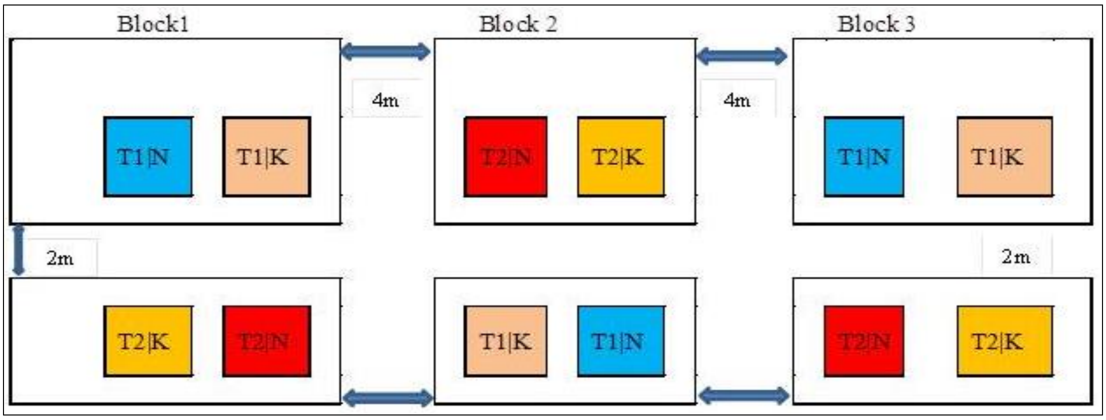
Legend without treatment

The insect capture periods are given in the following Table 2

Table 2: Insect collection period

Phases	Phases de collecte des insectes
Nursery or seed plot	February 15, 2021
Tillage	May 01, 2021
Cob/Flow ring	May 31, 2021
Maturity	July 1, 2021

The experimental design used was a split plot design; it consisted of the allocation of treatments to the experimental units by reasoned randomization. In this system, we did not take into account the heterogeneity factor. The experimental setup consisted of three (3) blocks divided into elementary plots of 10 x10 m. In each block, two types of treatments (insecticide and control) were applied to two varieties of rice (*Komboka* and *Nerica4*) with three repetitions (i.e. 4 Treatments x 3 blocks which give 12 plots). The elementary plots were separated by 2 m alleys and the blocks were separated by 4 m alleys (Figure 1).



Legend

T_1|K: Processed *komboka*, T_2|K: Untreated *Komboka*, T_1|N: Processed *Neraica4* and T_2|N: untreated Neraica 4

Fig 2: Split plot experimental design

All the control plots (untreated) of the trial were flown over with a sweep net one day after treatment (66th; 91st and 121st days). The insects observed inside the panicles were physically collected. Four captures were made one at the nursery or seed plot, three at the plots; at tillering, cob/flowering and maturity. They were carried out diagonally in both directions in the shape of an X in the plots between 6:30 and 8:30 minutes. The insect pests were captured following the phenological stages of rice cultivation (Table 3).

Table 3: Stages and phenological characteristics of insect collection periods

Phenological Stages	Phenological characteristics of rice	Insect collection period following the day of sowing (DAS)
Nursery or Seed plot	Grain germination and emergence, simultaneous exit of the coleoptile, the coleorhiza then simultaneous growth of the two elements.	15
Tillering	Successive emissions of different tillers, according to the tillering process of a grass (The definitive number of tillers is a varietal characteristic)	66
Cob/Flow ring	Emergence of the panicle, after elongation of the last internode located immediately below its insertion. Opening of the spikelets, exit of the stamens and fertilization of the ovules this very fleeting stage corresponds to anthesis and ends with the closure of the spikelets.	91
Grain Maturation	Progressive physiological changes in the fertilized ovum leading little by little to the ripe grain.	121

Legend
- DAS: Days after sowing

Two different insect identification keys were used in order to accurately confirm the types (orders) of insects found. This is the key to Burgundy and that of CPN (Nature Protection Committee) [15]. These keys made it possible to physically compare each type of insect to the different images on the identification keys showing the families, genus/species and order of insects. To classify them, the choice was based on the following number of legs, body and morphologies. Their abundance was subject to the Shannon index to confirm their extent in the Kashusha environment. The dynamics of rice pest insects was determined by counting the pest insects after their enumeration/identification on the control plots (T_2), while taking into account the varieties used (*Komboka* and *Nerica4*). Then the totals by insect pest, variety and phenological phase of rice are presented by orders/species to establish their dynamics and diversity.
The relative abundance of insects was determined by formula (1) below.

$$RA = \frac{Total\ number\ domaged\ Insects\ captured\ of\ one\ species}{Total\ captured\ captured Insects\ of\ all\ species} \quad (1)$$

The frequencies of the insects observed were found using the following formula (2).

$$Fr = \frac{Total\ number\ domaged\ Insects\ captured\ of\ one\ species}{Total\ captured\ Insects\ of\ all\ species} x\ 100 \quad (2)$$

To determine the diversity of a population in a given environment, we used the Shannon Index. The Shannon index is an index for measuring species diversity. This index gives an idea of the specific diversity of an environment, that is to say the number of species in this environment (specific richness) and the distribution of individuals within these species (specific fairness). The index is a measure of entropy. It is represented by a positive real number often between 0 and 5, but theoretically having no maximum. This number is calculated using an information function inversely proportional to the probability of occurrence of an observation. It is possible to arbitrarily choose the base of the logarithm 5 and we therefore often find in scientific literature log or log with base 2 instead of ln. This index makes it possible to quantify the heterogeneity of the biodiversity of a study environment and therefore to observe an evolution over time. This index always varies from 0 to ln S (or log S or $\log_2$ S, depending on the choice of the base of the logarithm). It is described by the following formula.

$$H' = -\sum_{i=1}^{S} p_i \log_2 p_i \quad (3)$$

Where H': Shannon biodiversity index, i: A species in the study environment, S: Specific Richness, P_1: Proportion of a species i in relation to the total number of individuals (N) in the environment of study, which is calculated as follows: $p(i) = n_i / N$ (4) Where is the number of individuals for species i and N is the total population (individuals of all species).
The data were encoded by Microsoft Excel 2010. The results were expressed as a histogram, abundance and frequency using Microsoft Excel 2010. Chi-square tests between two variables and adequacy, the multiple component analysis (MCA) and the factorial analysis of mixed data (AFDM) at the threshold of 0.05 and the bar graph were made by the R software [16]. The Shannon index by the Past software [25].

3.1 Results and Discussion
3.1.1 Results
3.1.1.1 Inventoried insect by stages
The insects found on rice in the nursery are divided into 5 orders and 25 species of insects. The most represented order is Diptera. It has 7 species such as *Culex robinotus*, *Physiphora clausa*, *Glyphodera mantis*, *Diopsis* sp, *Machimus rusticus*, *Agomysa oryzae* and *Paragus dolichorus*. The Coleoptera included 4 species such as *Lagria gesquierie*, *Cheilomenes lunata*, *Chnootriba neglecta* and *Paederus sabaeus*. The order of Hemiptera has 2 species of predators in the nursery and, finally the order of Lepidoptera. In the seed plot (Nursery), the most abundant species were *Glyphodera mantis*, *Culex robinotus*, *Physiphora clausa* F, *Machimus rusticus*, *Agomysa oryzae* which are biters, suckers or stem borers belonging to the order Diptera. During the tillering phase, the damage to the plants was only accentuated on the *Komboka* and *Nerica4* varieties despite certain spots and perforations observed on its leaves. During the tillering phase, the order Diptera was the most frequent in the nursery.The number of insects collected was higher for each variety: 269 individuals for *Komboka* and 307 individuals for *Nerica4*. The Beetles were 2 individuals for *Komboka* and 15 individuals for *Nerica4*. Three families of Lepidoptera were observed (*Danaus eresimus*, *Maliarpha separatella* and *Sesamia calamistis*) being stem borers, while only one family (*Sesamia calamistis*) had been collected at the nursery stage, all responsible for the total drop of plants. At the cob/flowering phase, on the two varieties tested, we observed the presence of insect pests and predators at this phase. The order of Diptera was the most represented with 9 individuals (*Physiphora clausa*, *Glyphodera mantis*, *Culex robinotus*,

Allongnota nasuta, *Diopsis thoraica*, *Microdon johana*, *Agomysa orizae*, *Machimus rusticus* and *Diopsis apicalis*) followed by 2 individuals (*Nephottetix nigropictus* and *Lisardo crudelis*) in each order namely Lepidoptera, Coleoptera, Orthoptera, Hemiptera. Cob/flowering are two phases in which the aroma develops in *Komboka* rice. This would explain the high number of insects collected from *Komboka* compared to the *Nerica4* variety but also in comparison with the previous phases. Indeed, the number of insects observed is 961 individuals in the Nursery, 285 individuals at tillering, 565 individuals at cob/flowering for the *Komboka* variety and 340 individuals at tillering, 312 individuals at cob/flowering in *Nerica4* variety. At the stage of maturity, 24 species of insects were inventoried and are distributed in 5 orders. The 5 Orders were observed. Only Diptera were observed in 5 families including; Culicidae, Diopsidae, Micropezidae, Otitidae, Syrphidae. The Order of Lepidoptera has two families (Pyralidae and Noctuidae). The Order of Coleoptera has been observed in two families too (Apionidae, Coccinellidae) and the order of Orthoptera has the family of Tettigoniidae. 393 insects were observed on the *Komboka* variety and 221 *Nerica4* variety. The K*omboka* variety was the most visited by insects at all phases observed. The release of a fairly high level of aroma in *Komboka* would explain the greater number of insects collected on this variety compared to *Nerica4*. Figure 2 shows the phases and insects recorded on the two varieties.

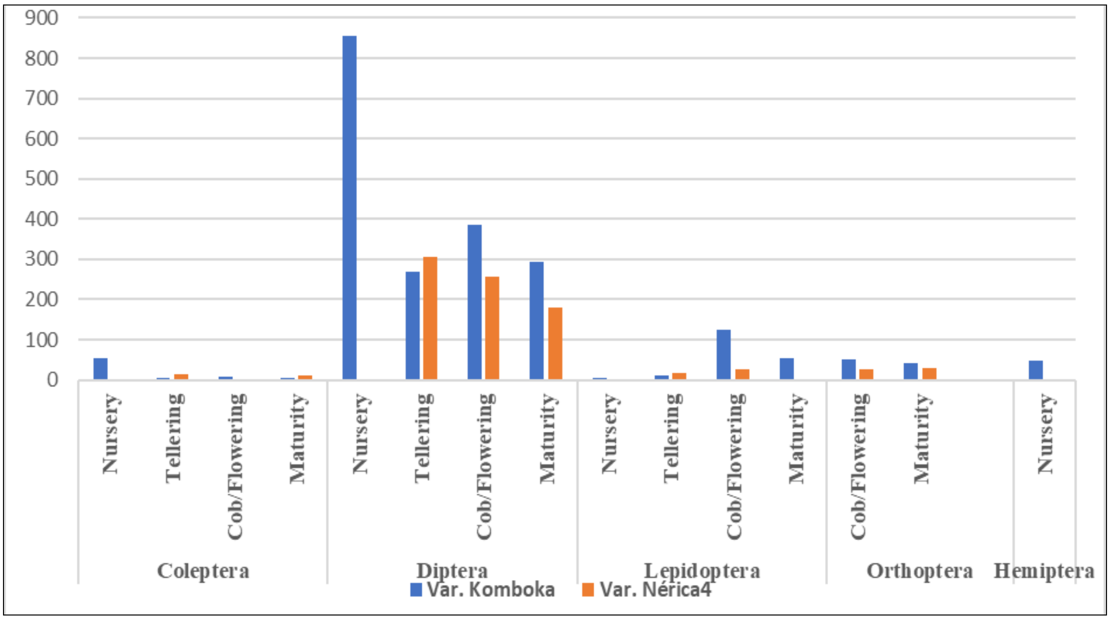


Fig 2: Inventoried insect on the two varieties of rice during the phenological phases. Relative abundance and frequency

Table 1 present the relative abundance and frequency of insects

Table 3: Relative Abundance (RA) and Frequency (Fr) of insects

Species	Effective	Abundance	Frequencies (%)
Agomysa oryzae	74	0,024049399	2,51102816
Allongnota nasuta	3	0,000974976	0,097497563
Apion africanum	4	0,001299968	0,12999675
Cheilomenes lunata	4	0,001299968	0,12999675
Chnootriba neglecta	40	0,012999675	1,299967501
Conocephalus maculatus	83	0,026974326	2,697432564
Culex robinotus	590	0,191745206	19,17452064
Cussyrtus bivittatus	2	0,000649984	0,064998375
Danaus eresimus	10	0,003249919	0,324991875
Diopsis apicalis	195	0,063373416	6,337341566
Diopsis thoracica	153	0,049723757	4,972375691
Glyphodera mantis	781	0,253818655	25,38186545
Lagria gesquierie	16	0,00519987	0,519987
Lisardo crudelis	6	0,001949951	0,194995125
Machimus rusticus	158	0,051348716	5,134871628
Maliarpha separatella	207	0,067273318	6,727331817
Mecosterthus paraplerus	62	0,020149496	2,014949626
Microdon jahanna	2	0,000649984	0,064998375
Nephottetix nigropictus	41	0,013324667	1,332466688
Paederus fuscipes	3	0,000974976	0,097497563
Paederus sabaeus	6	0,001949951	0,194995125
Physiphora clausa	590	0,191745206	19,17452064
Sesamia calamistis	23	0,007474813	0,747481313
Xanthadalia effusa	24	0,007799805	0,7799805
Total	3077	1	100

The abundance and frequency of the species are presented as follows: *Glyphodera mantis* has an abundance of 0.255 and a frequency of 25.5%, *Culex robinotus* is abundant at 0.191 and frequent at 19.1%, *Physiphora clausa* with 0.16 abundance and 16.6%, *Maliarpha separatella* with 0.07 abundance and 7.02% frequency. The species richness is presented in table below. The Shannon index is 2.205, i.e., the insect pests of rice in Kashusha are observable from different orders, hence they constitute a wide diversity of species.

Table 4: Shannon index

	Shannon
Effective	2,205

3.1.1.2. Analysis of variance between phases and orders

Insects were abundant at maturity and in the nursery on the *Komboka* variety while on the *Nerica4* variety, it was during the tillering and cob phase as well as flowering (Figure 3).

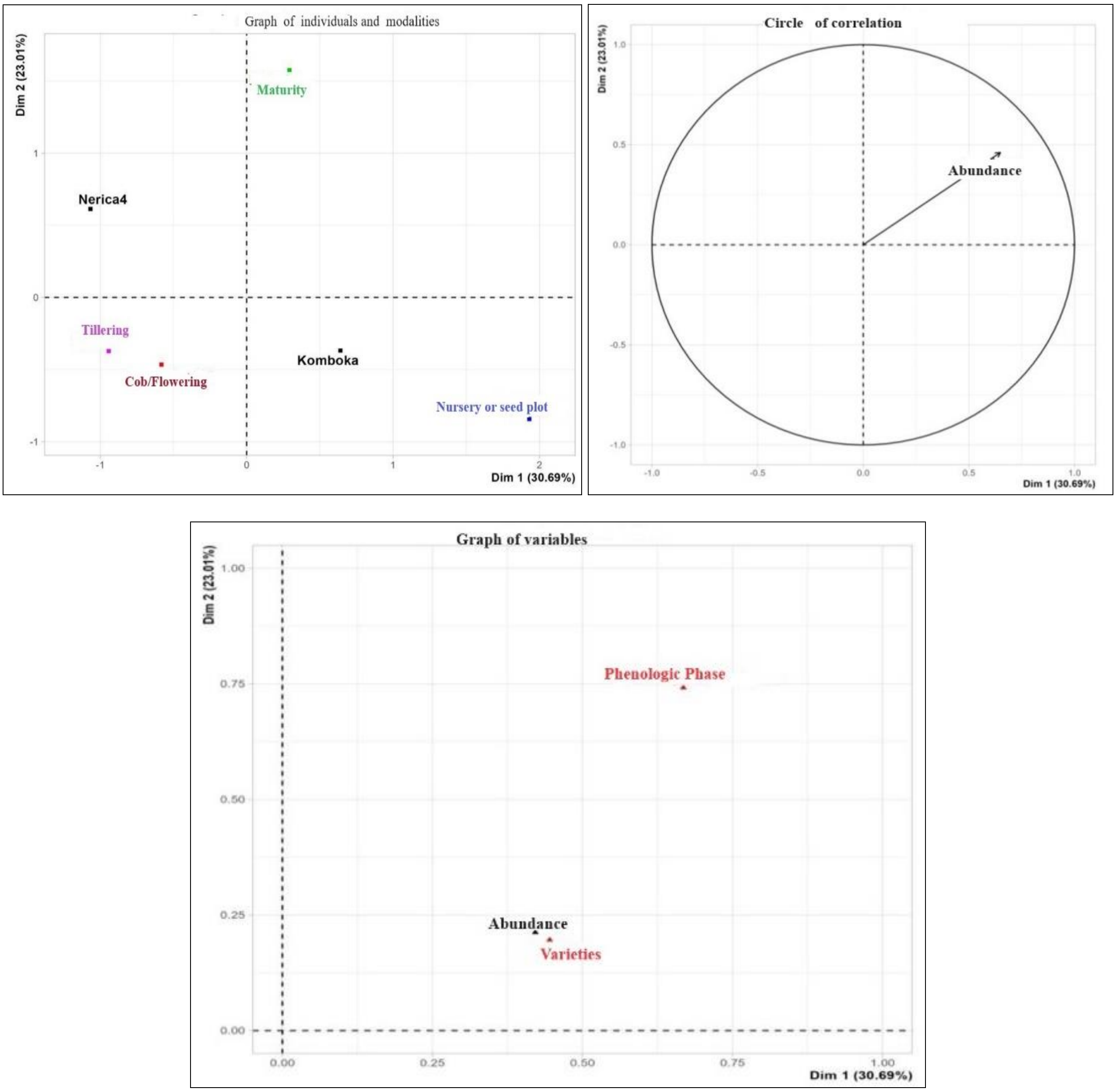


Fig 3: AFDM graph of insect abundance on phases and varieties

3.1.1.3. Observation made between phases, orders and varieties

At maturity, the *Nerica4* and *Komboka* varieties were attacked by Diptera and Coleoptera as pests and we observed an order of Hemiptera as predators of the previous orders of insects. At the nursery, Lepidoptera as pests and Hemiptera as insect predators were observed in the *Komboka* variety. The *Nerica4* variety was attacked by Lepidoptera during tillering and Orthoptera during cob and flowering (Fig 4).

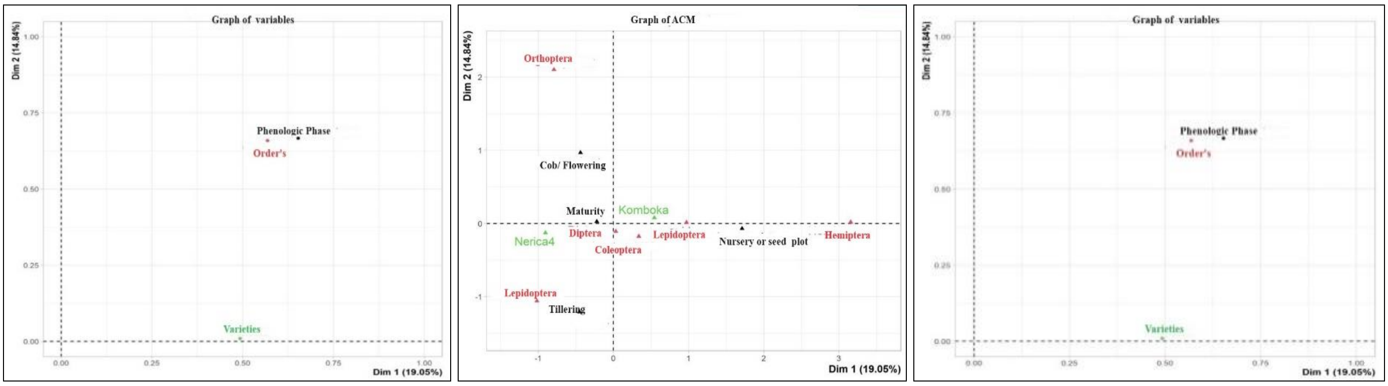
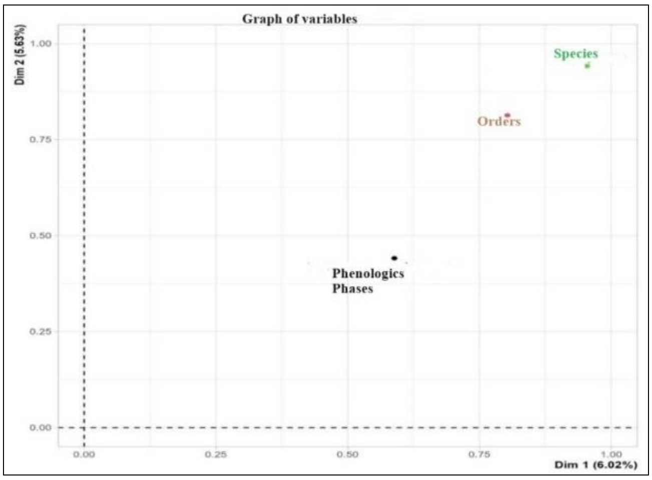


Fig 4: MCA of phases, orders and varieties

3.1.1.3 Observation made between insect phases, orders and species



Insect phases, orders and species

At Cob/flowering, the following species attacked both varieties: *Conocephalus maculatus, Mecosterthus paraplerus, Physiphora clausa, Paederus fuscipes,* and *Allongnota nasuta*. During the nursery stage, *Lagria gesquierie, Xanthadalia effusa Cheilomenes lunata, Physiphora clausa, Nephottetix nigropictus* and *Lisardo crudelis* species attacked both varieties too. The following species were present on our two varieties at tillering and maturity: *Culex robinotus, Sesamia calamisitis, Danaus eresimus, Maliarpha separatella*, and *Diopsis apicalis.*

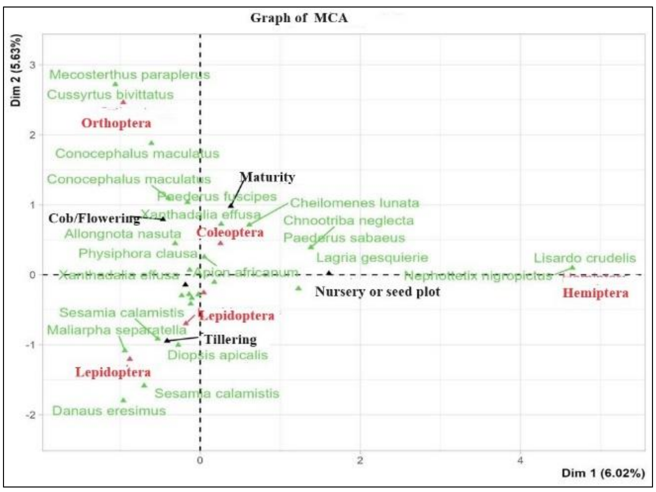


Fig 4: ACM graph of insect phases, orders and species

Phases, orders and families of insects

The Orthoptera attacked the rice during the cob and flowering period while the Lepidoptera during maturity and tillering and the beetles as well as the Hemiptera at the nursery level (Fig. 5).

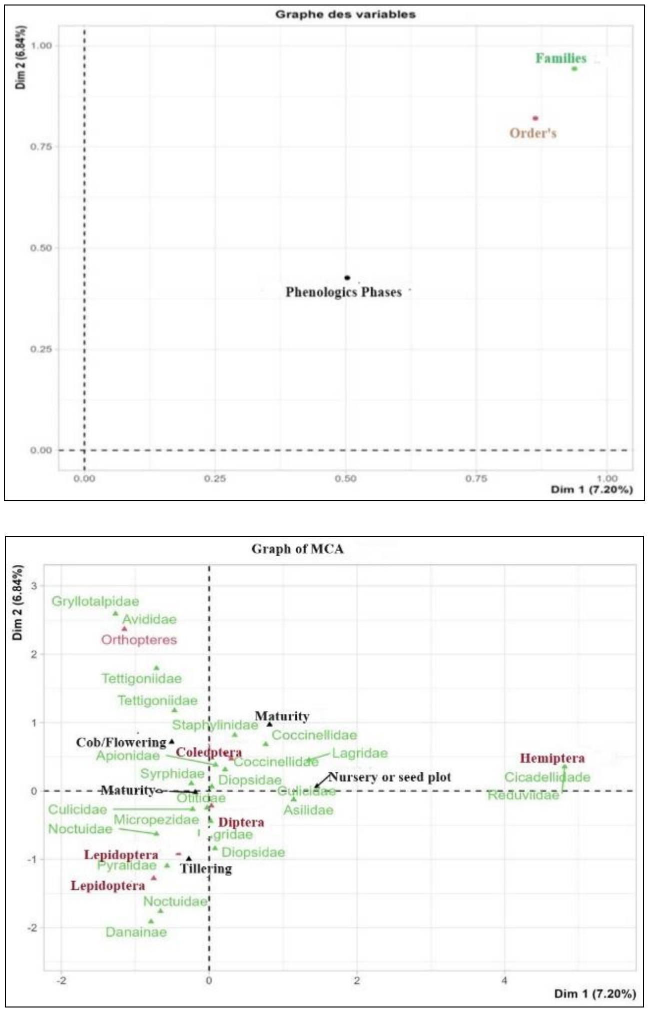


Fig 5: ACM graph of insect phases, orders and families

3.1.1.4 Observation made between orders, varieties and abundance of insects

The Komboka variety was more attacked by Diptera and less attacked by Lepidoptera, and Hemiptera were observed as predators of insects. The Nerica4 variety was attacked by Lepidoptera, Orthoptera and less attacked by Coleoptera as illustrated in the figure below.

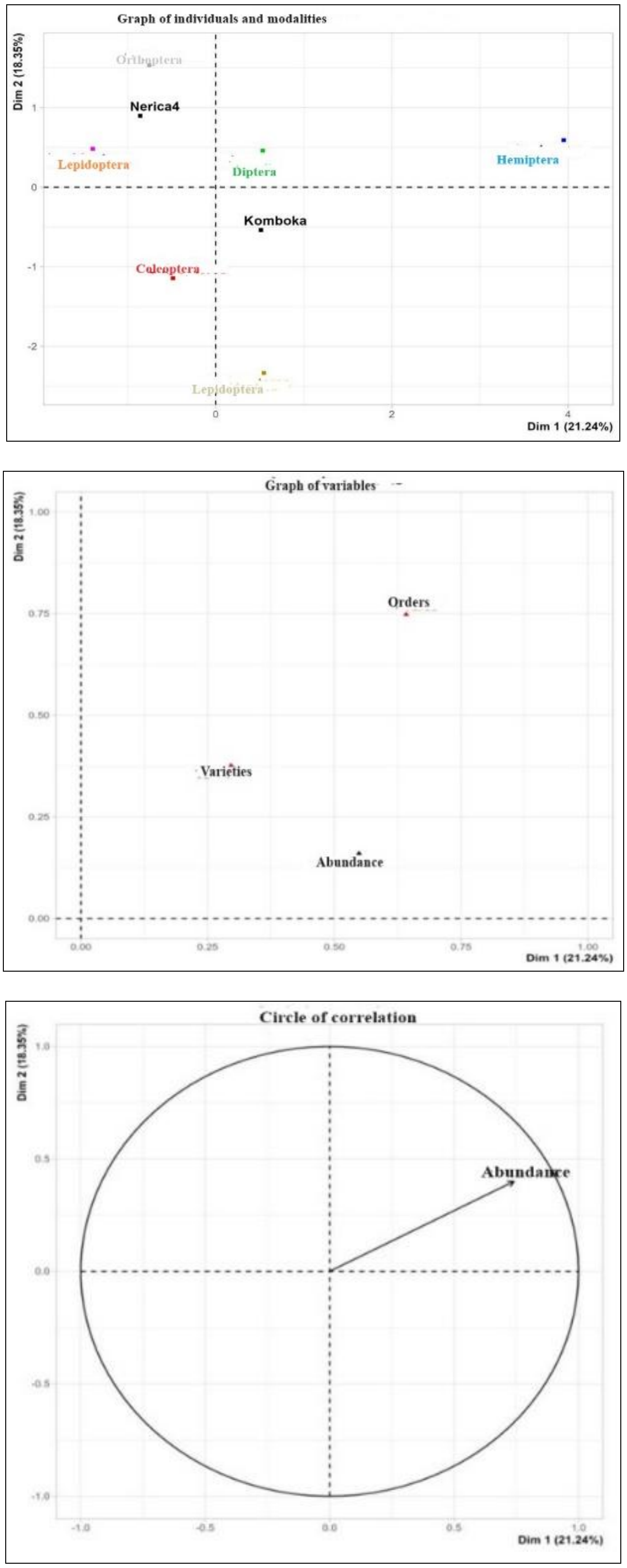


Fig 6: AFDM graph of orders, varieties and numbers of insects

3.1.1.5 Discussion

A wide diversity of insects encountered on rice in Kashusha. The Shannon index (2.205) shows this wide diversity of insect species. Our results are similar to those of Djego *et al*. (2012) [18] which determine both the abundance and regularity of species present in a given environment. That a great diversity of regular insect pests is observed in specific phases [18-20], including Lepidoptera [21], are analogous to the results of www.alpes-maritimes.gouv.fr (June 10, 2023) [22] reported two populations can present the same diversity index but different richness (species). According CIRAD (2020) [23], altitude has a positive effect on insect diversity in a given environment. It would have influenced the variability of insect diversity and their distribution in environment. Our results corroborate with it.

The orders observed had the same frequency at different phases; two populations can present the same diversity index but different richness (species). According www.alpes-maritimes.gouv.fr (June 10, 2023) [22], the higher and the regularity index is between 0 and 1, the greater the diversity between species.

Diptera and Coleoptera were frequent at all phenological phases observed. The Orthoptera and Lepidoptera were present at the tillering, the maturity and the Hemiptera (predators). This result joined the results showing that, most of these insect pests are only harmful to the rice crop during a specific stage of their development: Stem borers; Heart dead white panicles. Several species such as *Diopsis apicalis*, *Diopsis thoracica*, *Maliarpha separatella*, *Chilo zacconius*, *Scirpophaga subumbrosa* and *Sesamia calamitis* [24] are concentrated on rice cultivation [20].

Insect pests of the order of endophytic Diptera being stem borers: the African rice midge (*Orseolia oryzivora*) is observable from transplanting, tillering, fruiting and at maturity [25].

4. Conclusion

At the end of this work which focuses on the abundance and diversity of insect pests of rice (Oryza sativa) in the Kabare Territory, South Kivu/Democratic Republic of Congo, we obtained the following results: Five orders of insects including Diptera, Coleoptera, Orthoptera, Hemiptera and Lepidoptera were observed on the two varieties *Komboka* and *Nerica4*. Above all, the orders of insect pests interested us, notably Diptera, Coleoptera, Lepidoptera and Orthoptera during the phenological phases (Nursery, tillering, cob/ Flowering and maturity). Insect pests of the order Diptera and Coleoptera were present during all phases with varying frequencies and abundances. Four orders of pests (which) were observed at the heading and maturity phases. During the nursery and tillering phases, no insects of the order Orthoptera were observed compared to other orders, Diptera were more frequent up to 82% and abundant in all phenological phases compared to Coleoptera (3%) less frequent with a very low abundance, followed by Orthoptera (4%) and Lepidoptera (7%). These results confirm that the diversity of insects in irrigated rice cultivation in Kashusha. This diversity is vast. It also confirms that insect pest dynamics were different in all phrenological phases. There is dominance between different orders of insect pests. For Shannon dominance, 2 is greater than 1, confirming that high biodiversity of insects associated with rice cultivation observed between species in Kashusha.

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