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Valorisation of a water hyacinth in vermicomposting using an epigeic earthworm *Perionyx excavatus* in Central Vietnam

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The feasibility of vermicomposting water hyacinth (WH) [*Eichhornia crassipes* (Mart.) Solms] mixed with pig manure (PM) in different proportions was tested using tropical composting earthworm *Perionyx excavatus*. Earthworms grew and reproduced normally until the incorporation of 50% WH in initial substrate. Higher water hyacinth proportions induced earthworms' mortality and significantly affected the numbers of hatchlings and cocoons produced during vermicomposting period. The influence of the application of compost/vermicompost obtained from water hyacinth mixed with pig manure was also studied on seeds germination. Only water hyacinth substrate with 25% WH + 75% PM enhanced seeds germination for *Oryza* sp. and *Nasturtium officinale*. At the end of experiments, a significant decrease was observed in organic carbon content for each tested substrates (S1 to S8), in total nitrogen (N) for substrates containing 70% to 100% of water hyacinth (S5 to S3) and compost substrates (S1 and S2). An important decrease was also noted in total potassium for all vermicompost substrates (S3 to S8), in total magnesium for composted substrates (S1 and S2), and in C/N ratio for substrates containing 0% to 50% of water hyacinth (S8 to S6). Whereas total N in vermicompost containing 0% to 50% of water hyacinth (S8 to S6), total phosphorus, total potassium in composted substrates (S1 and S2), total magnesium in vermicompost substrates (S3 to S8) and C:N ratio in substrates containing 70% to 100% of water hyacinth (S5 to S3) expressed a significant increase after eight weeks. The result suggested that water hyacinth could be potentially useful as raw material in vermicomposting and biofertilizing if mixed with 75% of pig manure.
Keywords. Water hyacinth, *Eichhornia crassipes*, pig manure, vermicomposting, seed germination, *Perionyx excavatus*.

Valorisation de la jacinthe d'eau dans le lombricompostage par le ver de terre épigé *Perionyx excavatus* dans le Centre du Vietnam. Le lombricompostage de la jacinthe d'eau (WH) [*Eichhornia crassipes* (Mart.) Solms] en mélange avec différentes quantités de fumier de porc (PM) est réalisé avec le ver du compost tropical *Perionyx excavatus*. Les vers de terre grandissent et se reproduisent normalement jusqu'à incorporation de 50 % de WH dans le substrat initial. De plus grandes quantités de jacinthe d'eau induisent la mortalité des vers de terre et affectent significativement le nombre de juvéniles et de cocons produits durant la période de lombricompostage. L'influence de l'application de compost/lombricompost obtenu à partir de la jacinthe d'eau en mélange avec du fumier de porc a également été étudiée sur la germination de graines. Uniquement le substrat avec 25 % WH et 75 % PM améliore la germination des graines pour *Oryza* sp. et *Nasturtium officinale*. À la fin des expérimentations, une diminution significative est observée pour la teneur en carbone organique dans chaque substrat testé (S1 à S8), en azote total (N) pour les substrats avec une teneur en jacinthe d'eau de 70 % à 100 % (S5 à S3) et pour les composts (S1 et S2). Une importante diminution en potassium est également notée pour tous les lombricomposts (S3 à S8), en magnésium pour les composts (S1 et S2) et pour le rapport C/N pour les substrats contenant de 0 % à 50 % de jacinthe d'eau (S8 à S6). Alors que l'azote total dans le lombricompost contenant de 0 % à 50 % de jacinthe d'eau (S8 à S6), le phosphore total, le potassium total dans les composts (S1 et S2), le magnésium total dans les lombricomposts (S3 à S8) et le rapport C/N des substrats contenant de 70 % à 100 % de jacinthe d'eau (S5 à S3) présentent une augmentation significative après huit semaines.

Les résultats suggèrent que la jacinthe d'eau pourrait être utilisée comme matière première dans le lombricompostage et comme bio-fertilisant si elle est mélangée à 75 % de fumier de porc.
Mots-clés. Jacinthe d'eau, *Eichhornia crassipes,* fumier de porc, lombricompostage, germination de graines, *Perionyx excavatus*.

1. INTRODUCTION

Water hyacinth [*Eichhornia crassipes* (Mart.) Solms] is one of the most troublesome weed in aquatic systems in the world (Abbasi, 1998; Tchobanoglous et al., 1999). This invasive weed has successfully resisted to chemical, physical, biological or hybrid means used to eliminate it (Abbasi et al., 2001). Different strategies were developed in Central Vietnam to use water hyacinth in agricultural activities: litter for animal, food for pig, poultry, or cow, and fertilizing residues. However quantities of water hyacinth used in these activities were relatively weak. Some studies try to find another viable means of utilizing water hyacinth in order to encourage farmers to harvest the tropical invasive species. These attempts include use of water hyacinth in treating the biodegradable wastewater (Tchobanoglous et al., 1999), extraction of volatile fatty acid from water hyacinth to supplement cow dung as feed in biogas digesters (Ganesh et al., 2005), and solid-feed digesters to generate fuel as methane (Ramasamy, 1997; Abbasi et al., 1999). Even if these solutions are gainful, the problem of water hyacinth still remains.

Therefore a new technology respecting ecological and economical aspects was studied by authors using vermicomposting of water hyacinth (Gajalakshmi et al., 2001a; 2001b; 2002a; 2002b; Gupta et al., 2007). These studies used *Eudrilus eugeniae* Kinderg and *Eisenia fetida* Savigny as earthworms' species.

Only some earthworms' species are used on a widespread scale in vermicomposting: *Eisenia fetida*, *Eisenia andrei*, *Eudrilus eugeniae*, *Lumbricus rubellus*, *Dendrobaena veneta*, *Perionyx excavatus* and *Perionyx hawayana* (Edwards et al., 2004). *P. excavatus* is a tropical, very common in Asia, species of earthworm. Its time to sexual maturity, from cocoons to hatch and time egg to maturity are average shorter than other vermicomposting earthworms' species (Edwards et al., 2004). Moreover, this species was found as the second earthworm adapted to water hyacinth decomposition after *E. eugenius* (Gajalakshmi et al., 2001b).

In this study, we present the *Perionyx excavatus* capacity to degrade different proportion of water hyacinth with pig manure to achieve the aim of obtaining a value-added biofertilizer with maximum of available nutrients. We have estimated the quality of obtained vermicompost in seeds germination assays.

2. MATERIALS AND METHODS

2.1. Water hyacinth (WH), pig manure (PM) and *Perionyx excavatus*

Fresh water hyacinth plants were collected from two natural wetlands, one in Quang Thai township (North of Hue, UTM data: X = 759299.6; Y = 1839705.9) and one in Vinh Hung township (South of Hue, UTM data: X = 801838.1, Y = 1816010.5). The soil residues adhered with plants were eliminated. The main physico-chemical characteristics of fresh WH are presented in **table 1**. In order to facilitate earthworms' decomposition the plants were cut in 1-2 cm pieces and partially air dried up to half its fresh weight (**Figure 1a**) before being used in vermicomposting assays.

Fresh pig manure came from two farms in Thua Thien Hue region, Vietnam. The main physico-chemical characteristics of fresh PM are presented in **table 1**. The pig manure was grind with a sieve to 2 cm and air dried (**Figure 1b**) before being used in vermicomposting assays in order to be degraded more easily and rapidly.

Earthworms, *Perionyx excavatus*, used in this study came from the experimental farm of the Agronomic and Forestry University of Hue, Vietnam.

Table 1. Nutrients content of water hyacinth and pig manure — *Teneur en éléments nutritifs de la jacinthe d'eau et du fumier de cochon.*

	Dry matter (%)	**TOC** (%)	**TKN** (%)	**TP** (%)	**TK** (%)	**TCa** (%)	**TMg** (%)
Water hyacinth	6.45	47.78	1.57	0.51	1.43	0.51	0.44
Pig manure	22.91	36.70	1.72	0.93	0.48	2.08	0.32

TOC: Total organic carbon — *carbone organique total*; TKN: Total Kjeldhal nitrogen — *azote Kjeldhal total*; TP: Total phosphorus — *phosphore total*; TK: Total potassium — *potassium total*; TCa: Total calcium — *calcium total*; TMg: Total magnesium — *magnesium total*.

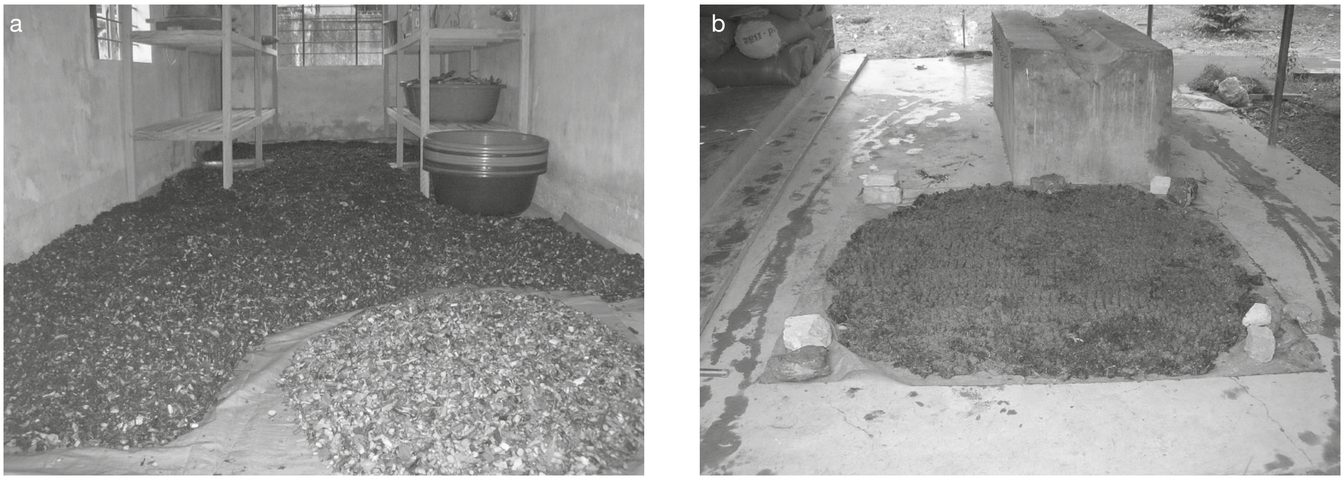

Figure 1. Air dried of water hyacinth (a) and pig manure (b) — *Séchage à l'air de la jacinthe d'eau (a) et du fumier de cochon (b).*

2.2. Assays of vermicomposting

In eight PVC circular vermireactors (0.045 m^3) closed with a circular top (**Figure 2**), WH and PM were mixed in different ratios (0%, 25%, 50%, 70%, 85% and 100% of water hyacinth). One kg of substrate (on dry weight basis) was placed in each plastic vermireactor. All substrates (WH and PM) were used on dry weight basis. For this, known quantities of feed mixture were dried at 105°C in hot air oven in order to obtain a constant mass. The vermireactors were shared out into two categories: composting and vermicomposting with precomposting. The composition of substrates in reactors is presented in **table 2**. The experiments were replicated twice for each feed mixture. The mixtures with precomposting were turned once a day during 15 days with a rake before earthworms' release.

The moisture content was controlled two times per week and distilled water was added if necessary to maintain humidity content between 70 and 80% (an approximately 25 g sample of substrates was dried at 105°C for 48 h to determine the moisture content). All reactors were kept in the dark, at the temperature of 32 ± 3°C and with a relative humidity around 70%. After eight weeks, the number of earthworms, hatchlings and cocoons was recorded in each reactor by hand sorting. Hatchlings and cocoons were counted in five samples of 100 g from each reactor. Numbers of adult earthworms were determined from entire reactor substrate.

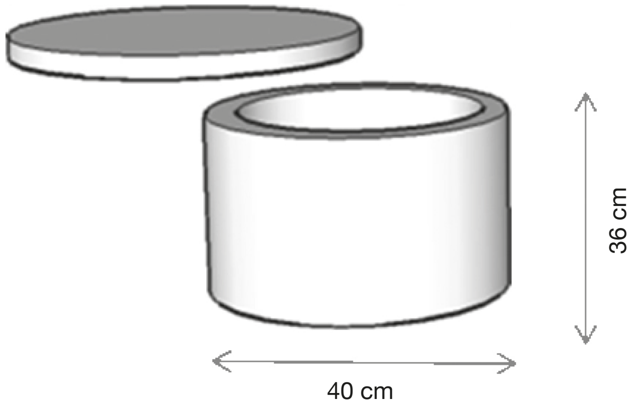

Figure 2. Vermireactor set-up — *Dispositif de lombricompostage.*

Table 2. Substrates composition — *Composition des substrats.*

Substrate	Water hyacinth (kg)	Pig manure (kg)	Earthworms
S1	1	0	0
S2	0.85	0.15	0
S3	1	0	100
S4	0.85	0.15	100
S5	0.70	0.30	100
S6	0.50	0.50	100
S7	0.25	0.75	100
S8	0	1	100

2.3. Quality of compost and vermicompost

In order to evaluate the quality of compost and vermicompost a germination test was realized with

Oryza sp. and *Nasturtium officinale*. Two 200 g samples of each feed mixture were extracted from each vermireactor substrate. Twenty four seeds by sample were sown and the number of germinated seeds was then recorded every 12 h during 6 days. This experiment was replicated two times.

2.4. Chemical analysis

The samples were used on dry weight basis for chemical analysis that was obtained by oven drying the known quantities of material at 105°C. Chemical analyses were realized on 500 g of each eight feed mixtures before starting experiments (so before earthworms' incubation for vermicomposting assays) and at the end of them. Total organic carbon (TOC) was determined according to the Walkley and Black method as described in reference laboratory manuals (Page et al., 1996; Van Ranst et al., 1999); the oxidized C, as measured at room temperature, was multiplied by 1.3 to estimate total organic C. Total Kjeldhal nitrogen (TKN) was determined by following Bremner et al. (1982). Available phosphorus (TP) was extracted by the method of Bray II and P was quantified by a spectrophotometer. Exchangeable bases (TCa, TMg and TK) were extracted by acetate ammonium 1M at pH 7 and TCa and TMg were measured out by EDTA titration and TK was determined by flame spectrophotometer.

2.5. Statistical analysis

Data were analyzed statistically by balanced ANOVA and one-way ANOVA using Minitab 15. For each determined parameter, like the number of earthworms, the number of germinated seeds, etc., the means were separated statistically using Gupta test. The probability levels used for statistical significance were $p < 0.05$ for the tests.

3. RESULTS AND DISCUSSION

3.1. Growth and reproduction of *P. excavatus* in different reactors

Table 3 shows the number of earthworms, hatchlings and cocoons observed in 6 different WH substrates.

WH proportion has a significant impact on growth and reproduction of *P. excavatus* (**Table 3**). The number of earthworms, hatchlings and cocoons was linear decrease with increasing percentage of water hyacinth in the precomposted treatment. Three Gupta tests were realized to determine which WH ratio is favorable to vermicomposting process. These result analyses determine that S6, S7 and S8 substrates are marginally better wastes for mature and hatchling earthworms development. Number of cocoons was not significantly different from S5 to S8. According with these results, it was concluded that substrate with 50% of water hyacinth and 50% of pig manure could be a suitable waste for vermicomposting with *P. excavatus*. Higher percentage of WH in the feed mixture has significantly reduced the number of earthworms, hatchlings and cocoons and caused adult earthworms mortality. Earthworm mortality during water hyacinth vermicomposting is observed for the first time (Gajalakshmi et al., 2001b; 2002b; Gupta et al., 2007). Different hypotheses could explain this earthworms' mortality. Some observations show that substrates with a high quantity of water hyacinth are compact. This high density could cause anaerobic conditions. Limited oxygen diffusion could inhibit earthworms' growth and reproduction. Satchell (1967)

Table 3. Total number of mature earthworms, hatchlings, and cocoons produced at the end of vermicomposting for each precomposted treatment — *Nombre total de vers de terre adultes, de juvéniles et de cocons produits à la fin du lombricompostage pour chaque traitement précomposté*.

Substrate	**Water hyacinth** (%)	**Pig manure** (%)	**Mature earthworms** (n = 2)	**Hatchlings** (n = 10)	**Cocoons** (n = 10)
S3	100	0	76.0 ± 6.0^a	8.8 ± 2.5^a	0.5 ± 0.2^a
S4	85	15	88.5 ± 6.5^a	9.6 ± 1.8^a	0.7 ± 0.3^a
S5	70	30	98.5 ± 6.5^a	10.3 ± 2.1^a	1.1 ± 0.3^b
S6	50	50	118.5 ± 6.5^b	21.2 ± 5.2^b	1.3 ± 0.4^b
S7	25	75	133.5 ± 6.5^b	24.5 ± 5.0^b	1.7 ± 0.5^b
S8	0	100	142.5 ± 4.5^b	32.8 ± 6.6^b	2.0 ± 0.5^b

Mean ± standard deviation — *Moyenne ± écart-type*; The alphabetical order of the letters is classifying the means by increasing order, a same letter indicating that means are not significantly different ($p = 0.05$) — *L'ordre alphabétique des lettres fournit le classement des moyennes par ordre croissant, une même lettre indiquant que les moyennes ne sont pas significativement différentes au seuil retenu* (p = *0,05*).

has postulated that the distribution of two earthworm species (*B. eiseni* and *D. octaedra*) are limited in some sites by minimum oxygen tension occurring. Anaerobic conditions could also be responsible of substrates fermentation which induces emission of methane and carbon dioxide. Presence of an undesirable gas like methane or carbon dioxide would especially be repellent to earthworms and they did not survive a long time in substrates that emit this kind of gas during composting (Majumdar et al., 2006). In anaerobic conditions, ammonium could be produced from amino acids (Voet et al., 2008). Earthworms are very sensitive to ammonium and cannot survive in organic wastes containing high level of this cation (Dominguez, 2004). The production of ammonium could also affect pH of substrate. An increase of pH was associated with a decrease in numbers of earthworms in Egyptian soils, demonstrating that substrates can also be too alkaline to favor earthworms (El-Duweini et al., 1965; Edwards et al., 1996). Some futures analyses of pH for each substrate could help to answer to this hypothesis.

In the experimental conditions of this study, some phytotoxic compounds could be produced by water hyacinth and cause earthworms' mortality. Some extracts of *Eichhornia crassipes* (Mart.) Solms have already reported to be phytotoxic compounds (Ahmed et al., 1982). More experiments on anaerobic conditions and toxic compounds could help to explain why earthworms' mortality is observed with high quantity of water hyacinth.

Therefore, *P. excavatus* was effective to vermicompost substrate with 50% of water hyacinth and 50% of pig manure whereas *E. fetida* was efficiency to feed a mixture composed of 25% of water hyacinth and 75% of cow dung (Gupta et al., 2007). Feed mixture with higher quantity of WH could not contain enough easily metabolizable organic matter and it is well-known that the kind and amount of food available influence the rate of growth and fecundity of earthworms (Edwards et al., 1996).

3.2. Germination tests

The impact of different WH ratios was tested on germinated seeds of rice and cardamine in order to determine quality of compost and vermicompost with water hyacinth (**Figures 3** and **4**). Composting treatments (S1 and S2) were included in these tests but no seeds were germinated during the experimentation. So these treatments were not considered in followed analyses. These results show clearly that vermicompost could be used beneficially to increase seeds germination.

The number of rice and cardamine germinated seeds was also compared according to WH proportions in vermicomposting wastes. Like for growth and reproduction of *P. excavatus*, the rate of seeds germination varies significantly with WH proportion (**Figures 3** and **4**). Gupta tests show that S7 and S8 wastes were significantly better for seeds germination. Water hyacinth vermicompost offers great potential as component of germination media. It could be used beneficially to enhance the seeds germination of rice and cardamine with 25% of water hyacinth and 75% of pig manure. Gajalakshmi et al. (2002c) have reported that water hyacinth vermicompost improved significantly the growth and flowering of crossandra plants even in kitchen gardens owned by farmers. Standard commercial greenhouse container medium substituted with 20% of vermicompost pig manure maximized the production of greenhouse tomatoes (Atiyed et al., 2000). In future studies, mix between S7 and commercial medium could be investigated to determine the better proportion to rice and cardamine production.

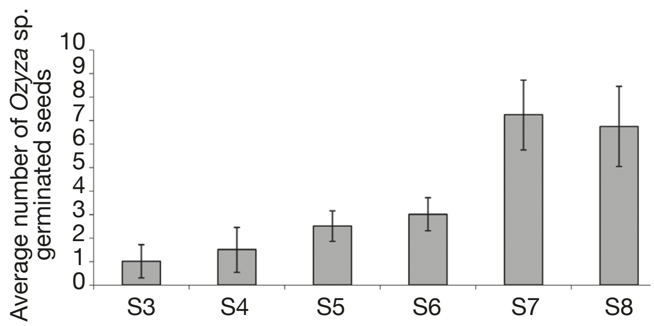

Figure 3. *Oryza* sp. seeds germination after six days in relation with water hyacinth proportion in vermicompost — *Germination des graines d'*Oryza *sp. après six jours au contact de lombricompost comprenant différentes proportions de jacinthe d'eau.*

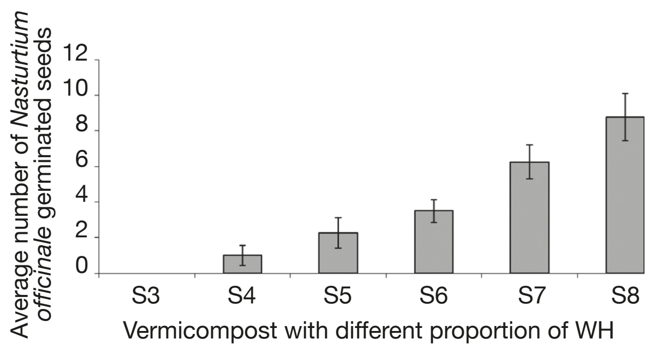

Figure 4. *Nasturtium officinale* seeds germination after six days in relation with water hyacinth proportion in vermicompost —*Germination des graines de* Nasturtium officinale *après six jours au contact de lombricompost comprenant différentes proportions de jacinthe d'eau.*

The poor rate of seeds germination with high density of water hyacinth could be explained by production of concentrated phytotoxic compounds emitted by water hyacinth. Ahmed et al. (1982) show that *Eichhornia crassipes* extracts of water from leafs and rhizomes are phytotoxic and inhibit seeds germination of radish.

3.3. Chemical changes in different vermireactors

Carbon and nitrogen are essential for the survival and the growth of all animals and for earthworms. Absolute deficiency of one or both elements limits earthworms' populations but more commonly it is the C/N ratio that limits populations. *P. excavatus* can degrade substrates with initial C/N ratio comprised between 28 and 45 (Suthar, 2007).

The TOC (total organic carbon) for each substrate significantly ($p < 0.05$) decreases by the end of composting and vermicomposting period (**Table 4**). The decrease in TOC was ranged from 5% to 22.8%. This reduction is partially due to microbial degradation of organic carbon in CO_2 by biooxydation (Mustin, 1987). The great transformation of TOC in CO_2 is observed in compost with only water hyacinth (22.8%). Comparison between different proportions of water hyacinth in vermicompost shows that TOC reduction in substrate P85 was significantly ($p < 0.05$) higher than other vermicomposts. Gupta et al. (2007) found that TOC reduction was inversely related to the water hyacinth content. But this study shows that the lower reduction is associated with 100% pig manure substrate. This difference is probably due to the higher TOC content in WH than in PM whereas organic carbon content is lower in WH than in cow dung in Gupta's study. TOC reduction in vermicompost was supported by other workers (Kaushik et al., 2003; Kaviraj et al., 2003; Gupta et al., 2008).

A significant ($p < 0.05$) decrease in the TKN (total Kjeldhal nitrogen) content occurred during vermicomposting process except for S6 (vermicompost with 50% of water hyacinth), S7 (vermicompost with 25% of water hyacinth) and S8 (vermicompost only with pig manure) (**Table 4**). A diminution of nitrogen content during vermicomposting was a surprising

Table 4. Nutrient content (%, n = 3) in the initial substrate and the final mixture after vermicomposting and composting period for different substrates and water hyacinth proportions — *Teneur en éléments nutritifs (%, n = 3) dans le substrat de départ et le mélange final après la période de lombricompostage et de compostage pour différentes proportions de substrats et de jacinthe d'eau.*

Substrates	**TOC** (%)	**TKN** (%)	**C/N**	**TP** (%)	**TK** (%)	**TCa** (%)	**TMg** (%)
Initial substrate							
S1	47.8	1.57	30.4	0.51	1.43	0.51	0.44
S2	43.8	2.02	21.7	0.64	1.83	0.63	0.46
S3	38.9	1.81	21.5	0.41	1.97	0.50	0.26
S4	36.8	2.14	17.2	0.52	1.63	0.66	0.28
S5	37.7	1.86	20.3	0.55	2.07	0.60	0.22
S6	37.9	1.26	30.1	0.65	1.83	0.53	0.27
S7	36.8	1.26	29.2	0.56	1.80	0.71	0.27
S8	35.8	1.61	22.2	0.71	1.93	0.83	0.21
Final mixture							
S1	36.9	1.41	26.2	0.60	2.17	0.77	0.33
S2	36.4	1.56	23.3	0.56	1.87	0.60	0.31
S3	33.8	1.54	21.9	0.65	1.77	0.76	0.28
S4	30.3	1.18	25.7	0.62	1.60	0.67	0.34
S5	32.7	1.30	25.2	0.61	1.47	0.57	0.32
S6	32.4	1.29	25.1	0.66	1.57	0.61	0.48
S7	31.5	2.25	13.9	0.62	1.43	0.63	0.35
S8	34.0	1.75	19.4	0.51	1.50	0.55	0.43

TOC: Total organic carbon — *carbone organique total*; TKN: Total Kjeldhal nitrogen — *azote Kjeldhal total*; C/N = carbon/nitrogen — *carbone/azote*; TP: Total phosphorus — *phosphore total*; TK: Total potassium — *potassium total*; TCa: Total calcium — *calcium total*; TMg: Total magnesium — *magnesium total*.

result. Indeed, an increase of TKN is generally obtained during feed mixture degradation by earthworms like for S6 to S8 (Kaushik et al., 2003; Garg et al., 2006; Suthar, 2007; Gupta et al., 2008; Tajbakhsh et al., 2008). However Parvaresh et al. (2004) observe at the end of vermicomposting period a great variation in nitrogen concentration and no significant differences in TKN were found by Mitchell (1997) and Ndegwa et al. (2000) in feed mixture before and after earthworms' degradation. This decreasing in nitrogen content for substrates with a high density of water hyacinth could be explained by the evaporation of ammonium in anaerobic conditions (Myrold, 2007; Voet et al., 2008).

The C/N ratio is used as an index for maturity of organic matter. Due to our particular results for nitrogen content, an increase of C/N ratio is observed instead of a reduction except for S6, S7 and S8 (because in these cases TKN increases) and for S1 (**Table 4**). Indeed, composting of farmyard manure shows a reduction C/N ratio after three months of storage (Levi-Minzi et al., 1986) but normally earthworm activities accelerate this diminution (Atiyed et al., 2000; Gupta et al., 2008). Initial C/N ratios (from 17.18 to 30.43) are adequate to *P. excavatus* (Suthar, 2007) but *P. excavatus* was most abundant in soils with low C/N ratios. Increasing C/N ratios are not favorable to earthworms' development and could explain weak growth and reproduction in substrates with high quantity of water hyacinth. Moreover an increase in C/N ratio could reflect an anaerobic decomposition of water jacinth (Gopal, 1978).This finding suggests that anaerobic conditions are a likely hypothesis to explain earthworms' mortality and diminution of nitrogen content.

The chemical nutrient contents of vermicompost in comparison with commercial plant growth medium usually contain most of the necessary mineral elements for plants (Edwards et al., 2004). Content of phosphorus, potassium, calcium and magnesium is evaluated in each vermicompost and compost with water hyacinth.

The amount of phosphorus content (TP) increased during composting and vermicomposting period except for compost with 75% of WH and 15% of pig manure (S2) and 100% pig manure vermicompost (S8) (**Table 4**). TP is between 1% and 37% more important at the end of vermicomposting comparing to initial substrates whereas the decreases for S2 and S8 were respectively 12.2% and 28.1%. Gupta et al. (2007) reported an increase in TP after ingestion of water hyacinth feed mixture by *E. fetida*.

TK (total potassium) content significantly increases for compost substrates from 2% to 35% and decreases during vermicomposting from 2% to 29% (**Table 4**). Degradation of water hyacinth by *E. fetida* induces a higher TK content at the end of vermicomposting (Gupta et al., 2007).

A great variation of total calcium (TCa) is observed in different feed mixture (**Table 4**). TCa increases between 1.5% and 34.2% for S1 (compost with only water hyacinth), S3 (vermicompost with only water hyacinth), S4 (vermicompost with 15% of water hyacinth and 75% of pig manure) and S6 (vermicompost with 50% of water hyacinth) and decreases between 5% and 33.7% for other substrates. The vermicomposting of sludge from distillery industry shows that calcium content increases after *P. excavatus* decomposition (Suthar, 2008; Tajbakhsh et al., 2008).

By the end of vermicomposting period total magnesium (TMg) significantly ($p < 0.05$) increased from 7 to 50% (**Table 4**). These results are similar to the finding of Gratelly et al. (1996), Tajbakhsh et al. (2008) and Suthar (2008). Therefore, a decrease of magnesium content was observed for compost.

An important feature of vermicompost is that, during the processing of the various organic wastes by earthworms, many nutrients that they contain are changed to forms that are more rapidly taken up by plants, such as nitrate or ammonium nitrogen, exchangeable phosphorus, and soluble potassium, calcium and magnesium (Lee, 1985; Edwards et al., 2004; Garg et al., 2006). Analyses of results show that for all end products a lack of potassium is present. Moreover, vermicomposts and composts with high quantity of water hyacinth have less nitrogen than initial substrates and vermicompost with 70% of water hyacinth is poorer in Ca at the end of the process. This lack in Ca after vermicomposting is also observed to S7 (25% of water hyacinth, 75% of pig manure) and S8 (only pig manure). According to these findings, S6 presents the best chemical nutrient content except its lack in potassium.

4. CONCLUSION

The information presented here confirm the utilization of water hyacinth in vermicomposting using the earthworm *Perionyx excavatus*. The results indicate that 25% and 50% of water hyacinth (dry weight) mixed with pig manure do not affect vermicompost quality. For S6, S7 and S8 the final product was more stabilized as shows the significant decrease in C/N ratio. Pots containing vermicompost with maximum 25% of water hyacinth with 75% of pig manure (dry weight) have achieved the germination rate of rice and cardamine. No seed was germinated in compost product. The experimental conditions induce poorer potassium content in vermicompost than in initial raw material, poorer nitrogen content to end product with more than 50% of water hyacinth and in some cases, poorer calcium content is recorded but substrate with

50% of water hyacinth contains the better chemical nutrient content followed by S7 which is poorer in calcium content.

According to earthworms' mortality, germination and chemical results, substrate with 25% of water hyacinth and 75% of pig dung presents the best proportion to vermicompost water hyacinth with *P. excavatus* and to obtain a good amendment with calcium addition.

The use of water hyacinth as raw material can help to convert the weed into a value-added fertilizer for farmers in Central Vietnam. Nevertheless, more information on earthworms' mortality and on surprising variation in chemical nutrients content must be studied before applying this vermicomposting process.

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