



**Decree of the Rector n. 1332 of 15/12/2023**  
Competition for awarding 1 research grant at the University of Udine

**DISCLAIMER:**

The official and legally binding call for applications is in Italian only. This document cannot be used for legal purposes and is only meant to provide information in English on the call for applications (Decree of the Rector n. 1332 of 15/12/2023). Please refer to the official call published on: <https://www.uniud.it/it/albo-ufficiale>

Any change and integration will be made available on the above mentioned web page. Therefore, no personal written communication regarding the examination date and/or competition results shall be provided to applicants.

**Annex 1**

**Competition announcement for the assignment of 1 research grant at the University of Udine, entitled "Potential use of hydroxyapatite from organic residues as a nanofertilizer" SSD: AGR/02 (principal investigator, Luca Marchiol)**

**Research grant funded by the resources of the project PRIN 2022 - Prot. n. 2022AAATEA**

**Art. 1**

A selection procedure is hereby launched for the award of 1 research grant at the University of Udine, as identified in Attachment A which constitutes an integral part of the present announcement.

The research grant is linked to the research project and is subject and conditioned upon the relative funding.

The fellowship may be renewed, in compliance with Art. 22, Law No. 240 of 30 December 2010 (as in the text in force before the implementation of the Conversion Law of the D.L. 36/2022, L. 79/2022), Law No. 11 of 27 February 2015, and the current regulations of the University of Udine for awarding research grants, issued with the Rector's Decree No. 182 of 31 March 2021. The renewal is subject to the scientific coordinator's positive assessment of the researcher's activities, an adequate scientific rationale, and a corresponding financial covering.

The research fellowship does not give rise to any right with regards to accessing University posts.

Any personal communication to candidates related to this selection will be sent exclusively to the email address indicated when registering for the selection, as mentioned in Art. 5.

**Art. 2**

The research grant described in this competition announcement and the required qualifications to apply for the position are identified in Attachment A. The lack of the admission requirements leads to the automatic exclusion from the competition procedure.

Possession of a PhD or equivalent degree obtained abroad or, only for the interested areas, of a medical specialization accompanied by an adequate scientific production, constitutes a preferential qualification for awarding the research fellowship of this selection, if it has not been provided as a mandatory requirement.



For the only purpose of the admission to the competition, the Examining Board (Art. 7) shall assess the equivalence of the qualification obtained abroad, except for the evaluation of the medical specialization qualification to which Article 38 of the Legislative Decree 165/2001 and subsequent modifications and additions, and EU regulations on the matter, shall be applied.

The Examining Board will proceed to the evaluation of the qualification obtained abroad according to the documentation attached to the application form. The Examining Board may exclude the candidate if the submitted documentation does not provide sufficient information for the assessment.

Therefore, applicants must enclose all the documentation in their possession relating to their qualification in order to provide the Examining Board with sufficient information for assessment.

Candidates holding a qualification issued by a **European Research Area country**, if successful, must submit, if not already attached to the application form one of the following options:

- Supplement Diploma in English issued by the competent University.
- CIMEA Certificate of comparability of the foreign qualification, issued by CIMEA (Information Centre on Academic Mobility and Equivalence) via the "diplome" service at <https://cimea.diplo-me.eu/udine/#/auth/login>

Candidates holding a qualification issued by a **non-European Research Area country**, if successful, must submit, if not already attached to the application form one of the following options:

- Declaration of the on-site value of the qualification and the certificate relating to the degree with examinations and grades. A certificate in a language other than Italian or English must be accompanied by an official translation into one of these languages (certified by the competent diplomatic-consular authority or certified by a court in Italy).
- CIMEA Certificate of comparability of the foreign qualification, issued by CIMEA (Information Centre on Academic Mobility and Equivalence) via the "diplome" service at <https://cimea.diplo-me.eu/udine/#/auth/login>

If the Supplement Diploma or the statement/attestation of comparability are not available when signing the contract, the applicant must demonstrate that he/she has requested the documentation and submit it as soon as possible.

Any exclusion from the selection procedure due to lack of eligibility requirements, absence of required documents, failure to sign the selection application or submission of the selection application in a manner different from what is provided for in this call for applications will be communicated to applicants exclusively at the email address indicated in the application form.

### Art. 3

#### **The research grant referred to in this call for applications cannot be awarded:**

- a. to employees of Universities and the entities referred to in Article 22, section 1, of Italian Law no. 240 of 30 December 2010 (in the text prior to the reform introduced by Law no. 79 of 29 June 2022);
- b. to those who have already been awarded research grants pursuant to Italian Law no. 240 of 30 December 2010 (prior to the reform introduced by Law no. 79 of 29 June 2022) for the maximum period provided by law, even if not continuously, excluding the period in which the grant was used in conjunction with the doctorate, up to the legal term of the relative course;
- c. to those who have already benefited from research grants and fixed-term researcher contracts provided for, respectively, in Articles 22 and 24 of Italian Law no. 240 of 30 December 2010 (in the



text prior to the reform introduced by Law no. 79 of 29 June 2022), for a total of 12 years, even if not consecutive;

- d. to anyone who has a degree of kinship or affinity, up to and including the fourth degree, with:
- the Rector, the Director General or a member of the Board of Directors of the University of Udine;
  - the scientific supervisor or a professor/researcher belonging to the department or organisation hosting the research grant in question.

The research grant provided for in this call for applications cannot be combined:

- a) with scholarships of any kind, except for those granted by Italian or foreign institutions to supplement, by means of stays abroad, the fellow's training or research activities;
- b) with other research grants;
- c) with an employment relationship, even if part-time, without prejudice to the relevant provisions for employees of public administrations.

The grant awarded under this call for applications is also incompatible with simultaneous attendance at university degree courses, either Bachelor's degree or Master's degree courses, research Doctorates with scholarships and medical specializations, in Italy or abroad.

#### **Art. 4**

Applicants must enclose with their application, under penalty of exclusion, the following documents:

- a) their professional scientific CV, highlighting the candidate's aptitude for carrying out and implementing the research project (Attachment A);
- b) their identity card, their passport or any other identification document<sup>1</sup>;
- c) (for candidates with a foreign qualification only) certification or self-certification of both the academic qualification required for the admission to the selection, and of the exams (with evaluation) took during the period of study abroad, and of any other document that can be useful to the evaluation of the degree by the Examining Board.

Applicants can attach to the application, publications and any other certification considered useful to demonstrate the qualification based on the research program (Attachment A) and to certify any research activity accomplished at public or private institutes (indicating the starting and ending date and the duration).

The documents and qualifications mentioned above must be submitted in Italian or English. Those that are not as requested will not be evaluated. Documents originally written in a language other than Italian or English must come with a translation in Italian or English, that the candidate will do on its own responsibility. The translation can be an abstract concerning the thesis.

Italian and Community candidates wishing to submit qualifications referring to conditions and facts attested by Public Administrations must proceed exclusively with self-certification.

Non-EU citizens legally residing in Italy may self-certify only data that can be verified or certified by Italian public bodies. They may also use declarations in lieu when provided for by an international convention between Italy and the declarant's country of origin.

Non-EU citizens not residing in Italy cannot self-certify.

Only the qualifications possessed by the candidate on the date the application form is submitted and submitted in accordance with the procedures set out in Article 5 will be assessed.

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<sup>1</sup> Please be aware that the residence permit is not an identification document.



Failure to submit mandatory documents provided for in this article will constitute grounds for exclusion from the selection.

#### **Art. 5**

The submission of the applications for the present call starts on January 12, 2024 at 2:00 pm (Italian time) and ends on April 19, 2024 at 2:00 pm (Italian time).

The application to take part in the selection must be completed, under penalty of exclusion, using the appropriate online procedure, available at the link <https://pica.cineca.it/>. The procedure involves an applicant registration step, for those who do not already have an account, and then an application completion step.

Once completed, the online application must be signed in the manner described in the online procedure (manual signature with attached identity document or digital signature), under penalty of exclusion from selection. The application does not have to be signed if you access the above-mentioned online procedure using your SPID ID.

The qualifications referred to in Article 4 must be attached to the application in .pdf format. Individual .pdf files may not exceed 30MB.

The application for participation in the selection is automatically sent to the University of Udine with the definitive closing of the online procedure.

The University Administration:

- is not responsible if it is impossible to read the submitted documentation in electronic format due to damaged files;
- shall not accept or take into consideration qualifications or documents received in paper form or by any means other than what is specified in this article.

Reference to documents or publications already submitted in connection with other competitions is not allowed.

The Administration is not responsible for any missing document or communication because of inaccurate indication of residence and/or address submitted by the candidate during the application. Also, the Administration is not responsible if the candidate has not communicated changes in this information, or has communicated them too late. The Administration is also not responsible for any postal or telegraphic problems not attributable to the Administration itself.

Applicants are advised not to wait until the last few days before the closing date to submit their application. The University accepts no responsibility for any malfunctions due to technical problems and/or overloading of the communication line and/or application systems.

#### **Art. 6**

The selection procedure is held in accordance with the modality indicated in Attachment A.

The test will aim to assess the general preparation, experience and aptitude for research of the candidate. It will consist in the evaluation of the professional scientific curriculum, of the publications and qualifications presented, and of the interview, where foreseen.



### **Art. 7**

The Examining board for the competition is identified in Attachment A of the present competition announcement, of which it is an integral part.

At its first meeting, the Examining board shall appoint its President and Secretary, and establish the criteria and methods for evaluating the qualifications and the interview, where foreseen.

The results of the qualifications assessment must be disclosed to applicants during the interview, where foreseen.

The Examining board can award a maximum of 100 points (one hundred out of one hundred) to the selection.

At the end of the evaluation procedure, the Examining board shall formulate the general merit list based on the overall score of each candidate, and draw up the minutes of the whole competition procedure.

Based on the ranking list, the assignment is awarded to candidates who have obtained a minimum overall score of 70/100 (seventy out of one hundred).

The Examining board's judgement is final.

The ranking list will be made public exclusively through publication on the University's official website.

Applicants will not be notified of the outcome of the evaluation.

Those who do not declare their acceptance of the research grant and do not present themselves at the research centre within the deadline communicated by the latter, even if not formally, shall lose the right to receive it. Exceptions to this term will only be granted in cases of documented force majeure.

### **Art. 8**

The research activity cannot be started before signing the contract defining the terms and conditions of the collaboration.

The activity covered by the research grant must have the following characteristics:

- a) it must be carried out as part of the research programme covered by the grant and not be a merely technical support to it;
- b) it must have a close connection with the realization of the research program for which the winner of the grant has been awarded the contract;
- c) it must be continuous and, in any case, temporally defined, not merely occasional, and in coordination with the overall activity of the University;
- d) it must be carried out autonomously, solely within the limits of the programme prepared by the programme supervisor, without predetermined working hours.

The researcher is required to submit a detailed written report on the work carried out and the results achieved, accompanied by the opinion of the scientific supervisor, to the reference organisation at the intervals set out in the contract. The researcher must also submit interim reports and timesheets, if requested by the reference organisation.



Either the fellow or the reference organisation may withdraw from the contract.  
The reference organisation may terminate the contract not only in the cases referred to in Article 9, sections 2 and 3, of the "Internal rules for awarding research grants pursuant to law 240 of 30 December 2010" of the University of Udine, but also in the event the research project and therefore the financial coverage on which the research grant is based cease to exist.

#### **Art. 9**

The following legal dispositions shall apply to the grant referred to in this call for applications:

- for tax matters, the provisions of Article 4 of Italian Law no. 476 of 13 August 1984, as subsequently amended and supplemented;
- for social security matters, the provisions of Article 2(26) *et seq.* of Italian Law no. 335 of 8 August 1995, as subsequently amended and supplemented;
- for mandatory maternity leave, the provisions of the Italian Ministerial Decree of 12 July 2007;
- with regard to sick leave, the provisions of Article 1(788) of Italian Law no. 296 of 27 December 2006 and subsequent amendments.

During the period of mandatory maternity leave, the allowance paid by INPS according to Art. 5 of the Italian Ministerial Decree of 12 July 2007 is supplemented by the University up to the full amount of the research grant.

The grant will be paid in monthly instalments.

#### **Art. 10**

The data collected as part of the procedure referred to in Art. 5 are necessary to properly manage the selection procedure, for any subsequent management of the research grant and for purposes related to managing services provided by the University. The University of Udine is the Data Controller. At any time, the data subject may request access, rectification and, depending on the University's institutional purposes, cancellation and restriction of processing or oppose the processing of their data. The data subject can always lodge a complaint with the Italian Data Protection Authority. The complete disclosure is available on the University of Udine website in the "Privacy" section, accessible from the home page [www.uniud.it](http://www.uniud.it) Direct Link: <https://www.uniud.it/it/it/pagine-speciali/guida/privacy>

#### **Art. 11**

For all matters not expressly mentioned in this call for applications, refer to the regulations in force on the subject cited in the introduction and to the "Internal rules for awarding research grants pursuant to Italian Law no. 240 of 30 December 2010" of the University of Udine, issued by Rector's Decree no. 182 of 31 March 2021.

#### **Art. 12**

The procedure supervisor is Dr Sandra Salvador, Head of the Research Services Area of the University of Udine.

The Responsible office at the University of Udine is "Area Servizi per la Ricerca - Ufficio Formazione per la Ricerca", via Mantica n. 31 - 33100 Udine, Italia.

To request information about the call for applications, please complete the following form available on the University of Udine website:

[https://helpdesk.uniud.it/SubmitSR.jsp?type=req&accountId=universityofudine&populateSR\\_id=42105](https://helpdesk.uniud.it/SubmitSR.jsp?type=req&accountId=universityofudine&populateSR_id=42105)



## Attachment A

### Responsabile scientifico della ricerca / Principal investigator:

Nome e cognome / Name and surname: Luca Marchiol  
Qualifica / Position: Professore Associato / Associate Professor  
Dipartimento / Department: Scienze agroalimentari, ambientali e animali / Agricultural, Food, Environmental and Animal Sciences  
Area MUR / Research field: 07 – Scienze agrarie e veterinarie  
Settore concorsuale e Settore scientifico disciplinare / Scientific sector: 07/B1; AGR/02 – Agronomia e coltivazioni erbacee

### Titolo dell'assegno di ricerca / Topic of the research fellowship "assegno di ricerca":

*I bandi sono consultabili dal sito dell'Ateneo, del MUR e di Euraxess / The calls are available on the University, MUR and Euraxess websites*

#### Testo in italiano:

Potenzialità di impiego di idrossiapatite da residui organici come nanofertilizzante.

#### Text in English:

Potential use of hydroxyapatite from organic residues as a nanofertilizer.

### Obiettivi previsti e risultati attesi del programma di ricerca in cui si colloca l'attività dell'assegnista di ricerca / Foreseen objectives and results of the research programme performed by the research fellow "assegnista di ricerca":

*I bandi sono consultabili dal sito dell'Ateneo, del MUR e di Euraxess / The calls are available on the University, MUR and Euraxess websites*

#### Testo in italiano:

La crisi ambientale e la sicurezza alimentare sono questioni globali che necessitano di interventi scientifici e politici immediati <sup>[1]</sup>. Le pratiche agricole convenzionali, l'uso eccessivo di acqua e i combustibili fossili hanno reso l'agricoltura insostenibile <sup>[2]</sup>. Inoltre, il settore alimentare rappresenta il 7-15% delle emissioni globali di metano e protossido di azoto <sup>[3]</sup>. Ciò accadrà mentre, entro il 2050, gli agricoltori dovranno produrre cibo per una popolazione mondiale di circa 9,6 miliardi di persone <sup>[4]</sup>.

Nello specifico, in condizioni di campo, le pratiche di fertilizzazione convenzionali sono scarsamente efficienti. In media, l'efficienza nell'uso dei nutrienti (NUE) dei fertilizzanti N e P è rispettivamente del 30-55% e del 18-20%, il che significa che solo una piccola frazione di nutrienti entra nelle piante <sup>[5]</sup>. Il resto dell'azoto viene perso, causando impatti negativi sulla qualità delle acque dolci e sotterranee, rischi per la salute umana e cambiamenti climatici <sup>[6]</sup>. Ciò si verifica anche nel caso di P ma con implicazioni globali diverse. Mentre il processo Haber-Bosch garantisce la fornitura di N all'industria dei fertilizzanti, la produzione di fertilizzanti P dipende dalla disponibilità di rocce fosfatice estratte da depositi geologici di P non rinnovabili, una risorsa sempre più limitata <sup>[7]</sup>. Il recupero del P dalle ossa animali trattate termicamente è stato recentemente suggerito come una delle soluzioni economicamente valide e sostenibili per superare la crisi del P <sup>[8]</sup>.

Nutrire in modo sostenibile la popolazione mondiale richiederà cambiamenti fondamentali nel sistema alimentare globale. La nanotecnologia ha acceso l'interesse della ricerca verso l'agricoltura nano-abilitata <sup>[9]</sup>. Sono attualmente in corso studi sul potenziale delle nanostrutture intelligenti per il rilascio e la distribuzione mirati di nutrienti, prodotti agrochimici e biomolecole. In termini di nutrizione delle



piante, si prevede che i nanomateriali controllino in modo intelligente il periodo di tempo in cui i nutrienti vengono rilasciati in base alle fasi di sviluppo della pianta <sup>[10]</sup>.

L'idrossiapatite (HAP), con la formula  $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH}_2)$  e un rapporto molare Ca/P = 1,67, può essere estratta da fonti e rifiuti biologici, come ossa bovine e equine, lische di pesce e scaglie <sup>[11]</sup>. Rispetto alla struttura sintetica quella biologica contiene altri ioni come  $\text{Na}^+$ ,  $\text{Zn}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ,  $\text{Si}^{2+}$ ,  $\text{Na}^+$  e  $\text{CO}_3^{2-}$  <sup>[12]</sup>. Applicazioni promettenti in agricoltura derivano dalle proprietà dell'HAP acquisite su scala nanometrica (nano-idrossiapatite, nHAP), come l'uso di nHAP come fonte di P per le colture o come vettore di altri elementi (N e micronutrienti) o molecole per la protezione delle piante <sup>[13]</sup>.

Una recente indagine bibliografica ha verificato i progressi della ricerca scientifica riguardo all'utilizzo di nHAP cristallino come fertilizzante per le colture. In particolare, gli studi hanno esplorato il potenziale di nHAP nelle seguenti direzioni: (i) fertilizzante P a lento rilascio, (ii) uso di batteri solubilizzanti i fosfati (PSB) per stimolare il rilascio di P, (iii) trasportatore N, (iv) micronutrienti vettore. Nel complesso i risultati indicano il potenziale promettente di nHAP – da solo o combinato con altre molecole – come alternativa più efficiente ai fertilizzanti convenzionali a base di azoto e fosforo <sup>[14]</sup>.

Il potenziale di nHAP è dovuto alla maggiore solubilità rispetto all'HAP sfuso e la chimica della superficie può essere personalizzata per massimizzare l'efficienza della distribuzione del P nel suolo e dell'assorbimento da parte delle piante. Inoltre, il rilascio di P da nHAP potrebbe essere migliorato a causa dell'attività del PSB o dei funghi micorrizici arbuscolari. I primi risultati promettenti hanno dimostrato che i batteri che solubilizzano il P dalla massa  $\text{Ca}^3(\text{PO}_4)^2$  e dai fosfati naturali erano efficaci anche con nHAP come nuovo fertilizzante alternativo <sup>[15]</sup>. Tali prove dimostrano che l'agricoltura basata sui nanometri ha un potenziale considerevole ma ancora inesplorato e che è possibile sviluppare strategie innovative nella fertilizzazione con P delle colture in pieno campo. Alla mesoscala, la funzionalizzazione di nHAP con urea ha rallentato il rilascio di N e migliorato la resa del raccolto utilizzando il 50% in meno di urea. Tuttavia, la maggior parte degli studi ha analizzato solo le proprietà dei fertilizzanti nanotecnologici e la risposta delle piante senza alcuna valutazione aggiuntiva del NUE <sup>[16]</sup>, un aspetto fondamentale della fertilizzazione delle colture.

Al di là del potenziale intrinseco di nHAP, la ricerca si sta concentrando su: (i) la progettazione di fertilizzanti nHAP per sfruttare appieno il loro potenziale di rilascio modulabile di nutrienti, (ii) l'uso di nHAP funzionalizzato nei piani di fertilizzazione delle colture e (iii) lo sviluppo di nHAP nuove strategie di fertilizzazione basate sull'uso combinato di nanoibridi e microrganismi, per migliorare ulteriormente l'efficacia dei nanofertilizzanti.

Il progetto PRIN 2022 CLEOPATRA si propone di studiare sistematicamente il potenziale della nano-idrossiapatite (nHAP) derivata dai rifiuti organici e dai nanoibridi risultanti, con l'obiettivo di produrre nanofertilizzanti efficaci e rispettosi dell'ambiente. CLEOPATRA mira a sviluppare nuove conoscenze all'avanguardia sull'agricoltura nano-abilitata, in particolare sulla nano-fertilizzazione (ovvero, nHAP da rifiuti organici drogati con urea con e senza la co-applicazione di microrganismi solubilizzanti P) e il miglioramento del NUE attraverso l'applicazione di nanofertilizzanti nei sistemi agricoli. Esistono progressi concreti riguardo allo stato dell'arte in materia poiché gli studi hanno preso in considerazione l'apatite sintetica.

Il progetto comprende attività a diversi livelli di scala, ovvero la preparazione di nHAP da rifiuti organici, la sua funzionalizzazione con urea, la solubilizzazione del P fornita da batteri solubilizzanti fosfati (PSB), l'applicazione di nanoibridi ad una coltura modello (*Zea mays*) in condizioni sia controllate che condizioni di campo, per valutare, da un lato, la fisiologia della nutrizione e, dall'altro, i parametri quanti-qualitativi della resa colturale.

Come risultato generale atteso, CLEOPATRA porterà a una conoscenza completa dell'uso del nHAP naturale come nanofertilizzante, come fonte di P e/o vettore di N. In questo senso risultati più specifici sono attesi nelle seguenti aree:

- Progettazione e sintesi di nanofertilizzanti HAP efficienti a base naturale.





- Contributo microbico del suolo alla solubilizzazione del P da nHAP.
- Valutazione delle dinamiche di rilascio di P e N da nanofertilizzanti.
- Risposta della coltura modello ai nanofertilizzanti.
- Parametri di resa delle colture e caratteristiche di qualità del grano in piante trattate con nanofertilizzanti.
- Valutazione della NUE dei nanofertilizzanti.

#### Referenze:

- [1] Behl et al. 2022. Chemosphere 288, 132533.
- [2] Springmann et al. 2018. Nature 562, 519-525.
- [3] Lynch et al. 2021 Front. Sustain. Food Syst., 4, 518039.
- [4] OECD/FAO. 2020. doi:10.1787/1112c23b-en.
- [5] Smith et al., 2018. ACS Sustain. Chem. Eng. 6, 11, 13599-13610.
- [6] Kanter et al. 2019. Nat. Food. 1, 27-32.
- [7] Alewell et al. 2020. Nat. Commun. 11, 4546.
- [8] Ahmed et al. 2021. Soil Sci. Plant Nutr. 67, 4, 4471-481.
- [9] Pulizzi 2019. Nat. Nanotechnol. 14, 507.
- [10] Ur Rahim et al., 2021. Nanomaterials, 11, 8, 206.
- [11] Maschmeyer et al., 2020. Chem. Soc. Rev. 49, 4527.
- [12] Mohd Pu'ad et al. 2019. Heliyon 5, e01588.
- [13] Ramírez-Rodríguez et al. 2020. Nanomaterials 10, 1043.
- [14] Fellet et al. 2021. Agronomy, 11, 1239.
- [15] Monroy Miguel et al. 2020. Antonie Leeuwenhoek 113, 1033-1047.
- [16] Xiong et al. 2018. Geoderma 323, 113-125.

#### Text in English:

Environmental crisis and food security are global issues that need immediate scientific and policy interventions <sup>[1]</sup>. Conventional farming practices, excessive water use, and fossil fuels have made agriculture unsustainable <sup>[2]</sup>. Moreover, the food sector accounts for 7-15% of global methane and nitrous oxide emissions <sup>[3]</sup>. That happens while, by 2050, farmers will need to produce food for a worldwide population of approximately 9.6 billion people <sup>[4]</sup>.

Specifically, in field conditions, conventional fertilization practices are poorly efficient. On average, the nutrient use efficiency (NUE) of N and P-fertilizers is 30-55% and 18-20%, respectively, meaning that only a tiny fraction of nutrients enters plants <sup>[5]</sup>. The rest of N is lost, causing negative impacts on freshwater and groundwater quality, human health risks, and climate change <sup>[6]</sup>. That also occurs in the case of P but with different global implications. While the Haber-Bosch process ensures the N supply to the fertilizer industry, P fertilizer production depends on the availability of phosphate rocks extracted from non-renewable geological P deposits, an increasingly limited resource <sup>[7]</sup>. The recovery of P from thermally treated animal bones has been suggested recently as one of the economically viable and sustainable solutions to overcome the P-crisis <sup>[8]</sup>.

Sustainably feeding the world population will require fundamental changes in the global food system. Nanotechnology kindled the research interest in nano-enabled agriculture <sup>[9]</sup>. Studies on the potential of smart nanostructures for targeted release and distribution of nutrients, agrochemicals, and biomolecules are currently underway. In terms of plant nutrition, nanomaterials are expected to intelligently control the length of time nutrients are released according to the plant's developmental stages <sup>[10]</sup>.

Hydroxyapatite (HAP), with the formula  $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$  and a Ca/P molar ratio =1.67, can be extracted from biological sources and wastes, such as bovine and horse bones, fish bones, and scales <sup>[11]</sup>. Compared to stoichiometric synthetic HAP, biological HAP contains other ions such as  $\text{Na}^+$ ,  $\text{Zn}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ,  $\text{Si}^{2+}$ ,  $\text{Na}^+$ , and  $\text{CO}_3^{2-}$  <sup>[12]</sup>. Promising applications in agriculture arise from the HAP's properties



acquired at the nanoscale (nano-hydroxyapatite, nHAP), such as the use of nHAP as a source of P for crops or as a carrier of other elements (N and micronutrients) or molecules for plant protection <sup>[13]</sup>.

A recent literature survey was carried out to verify the progress of scientific research regarding using crystalline nHAP as crop fertilizer. The studies explored the potential of nHAP in the following directions: (i) slow-release P fertilizer, (ii) use of phosphate solubilizing bacteria (PSB) to stimulate release of P, (iii) N-carrier, (iv) micronutrient-carrier. Altogether the findings indicate the promising potential of nHAP – alone or combined with other molecules – as a more efficient alternative to conventional N and P fertilizers <sup>[14]</sup>.

The potential of nHAP is due to increased solubility compared to bulk HAP, and surface chemistry can be tailored to maximize the efficiency of soil P distribution and plant uptake. In addition, P release from nHAP could be enhanced due to the activity of PSB or arbuscular mycorrhizal fungi. Promising early results demonstrated that bacteria that solubilize P from bulk  $\text{Ca}_3(\text{PO}_4)_2$  and rock phosphates were also effective with nHAP as an alternative novel fertilizer <sup>[15]</sup>. That evidence demonstrates that nano-enabled agriculture has considerable but still unexplored potential and that innovative strategies can be developed in the P fertilization of field crops.

At a greenhouse scale, the functionalization of nHAP with urea slowed down N release and improved crop yield using 50% less urea. However, most studies only analyzed the properties of the nano-enabled fertilizers and plant response without any additional assessment of NUE <sup>[16]</sup> - a fundamental aspect of crop fertilization.

Beyond the intrinsic potential of nHAP, research must focus on (i) the design of nHAP fertilizers to fully exploit their potential for tuneable release of nutrients, (ii) the use of functionalized nHAP in crop fertilization plans, and (iii) the development of new fertilization strategies based on the combined use of nanohybrids and microorganisms, to improve the effectiveness of nanofertilizers further.

The PRIN 2022 CLEOPATRA project has set out to systematically investigate the potential of nano-hydroxyapatite (nHAP) derived from biowastes and its resulting nanohybrids, with the aim of producing effective and environmentally friendly nanofertilizers. CLEOPATRA aims to develop new cutting-edge knowledge on nano-enabled agriculture, particularly nano-fertilization (i.e., nHAP from biowastes doped with urea with and without the co-application of P solubilizing microorganisms) and the enhancement of NUE throughout the application of nanofertilizers in agricultural systems. There is concrete progress concerning the state of the art on this subject since the studies have considered synthetic apatite.

The project includes activities at different scale levels, i.e., the preparation of nHAP from biowastes, its functionalization with urea, P-solubilization provided by phosphate solubilizing bacteria (PSB), application of nanohybrid to a crop model (*Zea mays*) in both controlled and field conditions, to evaluate, on the one hand, the nutrition physiology and, on the other hand, the quantitative-qualitative crop yield parameters.

As a general expected result, CLEOPATRA will lead to a comprehensive knowledge of using natural nHAP as a nanofertilizer, both as a P source and/or as an N carrier. Along this line, more focused results are the following:

- Design and synthesis of efficient natural-based HAP nanofertilizers.
- Soil microbial contribution to P solubilization from nHAP.
- Evaluation of P and N release dynamics from nanofertilizers.
- Assessment of the model crop (*Zea mays*) to nanofertilizers.
- Crop yield parameters and grain quality traits in plants treated with nanofertilizers.
- Evaluation of NUE of nanofertilizers.



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**Struttura dell'Università di Udine presso la quale verrà sviluppata l'attività di ricerca / Department or other structure of the University of Udine where research activities will be carried out:**

Dipartimento di Scienze Agroalimentari, Ambientali e Animali (DI4A) e Azienda Agraria Universitaria A. Servadei (AZIA UNIUD) / Department of Agricultural, Food, Environmental and Animal Sciences and A. Servadei University Agricultural Company (AZIA UNIUD)

**Importo dell'assegno di ricerca (al lordo oneri carico assegnista) / Total grant gross for the research fellowship:**

€ 20.000,00

**Durata dell'assegno di ricerca / Duration of the research fellowship "assegno di ricerca":**

12 mesi / months

**Finanziamento / Financed by:**

La copertura finanziaria graverà sul progetto PRIN 2022 – "Circular economy and sustainable agriculture: hydroxyapatite from biowastes as smart nanofertilizer - CLEOPATRA"; Prot. n. 2022AAATEA. Decreto di finanziamento n. 1048 del 14/07/2023 - Settore LS9. Codice CUP G53D23003950006. Ministero dell'Università e della Ricerca (Finanziato dall'Unione Europea, NextGenerationEU).

**Requisiti di ammissione / Minimum qualifications necessary:**

- Possesso di un diploma di laurea vecchio ordinamento (ante decreto 3 novembre 1999 n. 509) o di laurea specialistica/magistrale (ex decreto 3 novembre 1999 n. 509 e decreto 22 ottobre 2004 n. 270) o titolo equivalente conseguito all'estero;
- possesso di un curriculum scientifico professionale idoneo allo svolgimento dell'attività di ricerca contemplata.



- University degree obtained before Decree n. 509 of 3 November 1999 or specialistic/Master's degree (post decree n. 509 of 3 November 1999 and decree n. 270 of 22 October 2004) or equivalent degree obtained abroad;
- professional scientific curriculum suitable for the research activity above mentioned.

**Procedura selettiva / Competition procedure:**

Valutazione per titoli e colloquio / Evaluation of titles and oral exam

I risultati della valutazione dei titoli saranno resi noti agli interessati nel corso del colloquio / The evaluation of the qualifications will be disclosed to candidates during the interview

|   |                     |  |
|---|---------------------|--|
| Calendario del colloquio /<br>Calendar of the oral exam | Modalità / Modality | In presenza / On site  |
|   | Data / Date         | 10 giugno / June 2024  |
|   | Ora / Time          | 10:00 / 10:00 am (Italian time)  |
|   | Luogo / Place       | Sala dei Cereali del Dipartimento di scienze agroalimentari, ambientali e animali (DI4A) - Sede dei Rizzi – via delle Scienze 206, Udine |

Per sostenere il colloquio i candidati devono esibire un valido documento di riconoscimento. / Candidates must come to the interview with a valid identity document.

Eventuali variazioni saranno rese note esclusivamente mediante pubblicazione all'albo ufficiale on line dell'Ateneo / Any change will be made public solely through publication on the University web site [http://web.uniud.it/ateneo/normativa/albo\\_ufficiale](http://web.uniud.it/ateneo/normativa/albo_ufficiale)

I candidati impossibilitati a partecipare alla prova orale presso la sede possono chiedere alla Commissione giudicatrice di svolgere il colloquio in videoconferenza, allegando alla domanda di partecipazione alla selezione istanza motivata. / Candidates unable to attend the interview at the University of Udine, may request to the Examining board to take the interview by video conference, attaching the request to the online application.

**Commissione giudicatrice / Examining Board:**

| Nome e Cognome                              | Qualifica | SSD    | Università                      |
|---|-----------|--------|---------------------------------|
| <b>Membri Effettivi / Permanent members</b> |           |        |                                 |
| Luca Marchiol                               | PA        | AGR/02 | Università degli Studi di Udine |
| Guido Fellet                                | PA        | AGR/02 | Università degli Studi di Udine |
| Marco Contin                                | PA        | AGR/13 | Università degli Studi di Udine |
| <b>Membri Supplenti / Temporary members</b> |           |        |                                 |



| Nome e Cognome  | Qualifica | SSD    | Università                      |
|-----------------|-----------|--------|---------------------------------|
| Guido Incerti   | PA        | BIO/07 | Università degli Studi di Udine |
| Maurizia Sigura | PA        | AGR/10 | Università degli Studi di Udine |