Compte-rendu de la réunion du Conseil d'unité du 20/05/2019

Présents : Alain Gojon, Christophe Maurel, Anne-Alienor Very, Fanchon Divol, Ester Izquierdo, Stéphane Mari, Perrine Rudinger, Cécile Abauzit, Sandrine Chay, Jeremy Villette, Cécile Fizames, Valentin Chaput, Jossia boucherez, Henrique Afonso, Antoine Martin, Isabelle Gaillard

Excusés : Philippe Nacry, Sandrine Ruffel, Pierre Berthomieu, Martin Boeglin, Laurence Marquès

Comte-rendu rédigé par Fanchon Divol et Esther Izquierdo

Ordre du jour :

- **Discussion sur la partie générale (concernant l'ensemble du labo) du rapport d'activité HCERES**
- **Présentation des grandes lignes du projet scientifique de l'unité pour le contrat 2021-2025**
- **Projets d'équipements moyen et lourd de l'unité**

1- Discussion sur la partie générale (concernant l'ensemble du labo) du rapport d'activité HCERES (voir texte en annexe).

Le rapport doit être fini pour le 7 juin, avec un pré-dépôt à l'Université le 15 juin, et un dépôt effectif le 7 septembre. La visite du comité HCERES aura lieu les 23 et 24 janvier 2020.

Deux remarques sont remontées :

1- La partie interaction avec le monde socio-culturel pourrait être détaillée davantage. Il est proposé d'ajouter un paragraphe pour mentionner les efforts faits par l'unité pour la vulgarisation : participation à la journée « fascination of plants », participation récurrente à la fête de la science. Il est également demandé de mentionner que le nombre de contrats avec le secteur privé a été multiplié par trois.

2- Il n'y a pas de paragraphe dédié aux collaborations internationales : c'était une volonté car ça relève des équipes, donc c'est chaque équipe qui détaille dans sa partie ce sujet-là. Le détail est dans les annexes (annexe 4). Néanmoins, il est proposé d'ajouter un paragraphe pour détailler les zones géographiques des collaborateurs et faire apparaître le pourcentage des projets de recherche financés qui ont un caractère international (PRCI notamment).

La direction valide ces demandes et s'engage à modifier le texte en conséquence. Par ailleurs, elle précise qu'un paragraphe de description des moyens de culture (serre, chambres de culture, etc…) va être ajouté dans l'annexe 3.

Avec ces modifications, le conseil d'unité valide le document proposé.

2- Présentation du projet d'unité 2021-2025 (voir texte en annexe).

Il s'agit d'un document de 6 pages destiné aux évaluateurs et aux tutelles, dans lequel beaucoup d'aspects du fonctionnement interne de l'unité ne sont pas traités. Ce document a été rédigé suite à la retraite de BPMP et à une série de réunions avec les chefs d'équipes de la période 2021-2025.

Christophe présente les grandes lignes du projet de l'unité et propose de faire une réunion d'échange avec les ITA en Septembre-Octobre (le document ne sera traduit en français qu'en septembre). Les représentants des ITA (techniciens) confirment l'intérêt de cette traduction et de la réunion d'échange, même si elle aura lieu après le dépôt du rapport. L'objectif est que chacun dans l'unité ait pris connaissance des domaines de recherche développés à BPMP, à savoir : la nutrition hydrominérale des plantes et les réponses aux contraintes environnementales.

Les thèmes prioritaires de l'unité sont : l'étude des racines, la signalisation des stress environnementaux, la reprogrammation de l'expression des génomes et la réponse intégrée à des stress complexes.

Une attention particulière va être apportée à la visibilité de BPMP au niveau local avec son intégration dans le Labex, la mutualisation des plateformes et le maintien d'un lien fort avec l'université. Au niveau national, la co-gestion par l'INRA et le CNRS est fructueuse et devrait continuer de bien se passer. Au niveau international, le fort impact de l'école thématique Mistral sera à maintenir. Un point à améliorer reste l'interaction de BPMP avec des partenaires privés. S'il était accepté par l'ANR, le Labcom porté par Guilhem Desbrosses devrait favoriser ce dernier point.

Pour ce qui est du fonctionnement interne, une attention particulière sera portée au bon fonctionnement des différents comités ainsi qu'une vigilance sur le maintien financier des équipes. Le défi de l'économie d'énergie sera poursuivi. Le développement des équipes émergentes sera également accompagné.

Le conseil d'unité valide le texte proposé.

3- Projets d'équipements moyen et lourd de l'unité

D'habitude, les demandes sont faites à l'automne, mais cette année les procédures ont dû être lancées dès maintenant pour des raisons diverses exposées ci-dessous.

Demande de financement d'équipement lourd (> 80 000 euros) :

Le Pôle Protéomique de Montpellier (PPM) soutient chaque année, à tour de rôle, les différentes plateformes qui le constituent, en faisant remonter à l'appel d'offres IBiSA (Infrastructures en Biologie Santé et Agronomie) une demande d'équipement lourd pour une de ses plateformes. Cette année, c'est le tour de la MSPP de BPMP. Du point de vue du PPM, une telle demande est nécessaire pour qu'il puisse garder sa labellisation IBiSA. Pour ce qui est de la MSSP, un soutien de 200 k€ est demandé pour l'achat d'un Spectromètre de Masse pour un coût total de 350 k€. Alain a donné le feu vert pour cette demande de financement. Nous saurons avant septembre si les 200 k€ sont accordés par IBiSA. Même si ce financement est obtenu, il ne nous engage en rien et au final nous pouvons le refuser. Alternativement, nous avons jusqu'à 2021 pour utiliser le financement s'il est accordé. La demande INRA/ CNRS pour le complément sera à faire début septembre. Actuellement nous sommes en attente de la réponse de IBiSA.

Des membres du conseil attirent l'attention sur la liberté de l'unité, par la suite, de compléter ou non le coût de cette acquisition. Mais pour le moment aucune autre demande d'équipement lourd (>80k€) n'a été remontée par les équipes.

Demande équipement moyen (>25 000 euros) :

L'INRA a mis en place l'année dernière une procédure de labélisation ISC (Infrastructures Scientifiques Collectives), au cours de laquelle ni PHIV ni MSPP n'ont été labélisées. Cette année l'INRA lance un nouvel appel d'offres par la CNOC (Commission Nationale des Outils Collectifs) spécifiquement destiné aux plateformes dans le périmètre ISC (toutes celles qui ont candidaté, dont PHIV, sont éligibles) avec une date limite pour déposer une demande d'équipement moyen début mai. PHIV a fait remonter une demande d'aide de 40 k€, pour l'achat d'un macroscope d'un coût total de 77 k€. Si le financement est accepté l'unité devra compléter à hauteur de 37 k€.

Nous avons 50k€ à dépenser en 2019 sur notre réserve stratégique car aucune aide particulière aux équipes n'a été nécessaire cette année. Les finances de l'unité sont actuellement bonnes.

Département d'évaluation
de la recherche

Research Unit
Self-assessment document

EVALUATION CAMPAIGN 2019-2020
GROUP A

The self-assessment file contains, the present document (including Annexes on page 5) as well as two Excel files "Current contract data" and "Next contract data". All documents are downloadable on the Hcéres website.

NB: If needed, you can refer to « Guide for the writing of a self-assessment document » to help you fill in your self-assessment document.

GENERAL INFORMATION

Name of the unit concerned by the current contract: Biochimie et Physiologie Moléculaire des Plantes
Name of the unit concerned by the next contract (if different):
Acronym of the current contract: **BPMP**
Acronym of the next contract (if different):
Scientific field (name two fields if interdisciplinary evaluation): **SVE**
Scientific sub-domains (in Hcéres' nomenclature) in descending order of importance: **SVE1, SVE2**

Director for the current contract: **Alain GOJON**
Director (or project leader) for the next contract: **Christophe MAUREL**

Type of application:

Identical renewal ☒ Fusion, scission, restructuring ☐ *Ex nihilo* creation[1] ☐

[1] Units created *ex nihilo* will be evaluated based on a project.

Academic institutions and affiliated organisms:

List of Institutions and Organisms supervising the Research Unit **for the current and next contract**:

Current contract:	Next contract:
- CNRS	- CNRS
- INRA…	- INRA
- Univ Montpellier…	- Univ Montpellier
- Montpellier SupAgro…	- Montpellier SupAgro

Choice of the research unit's interdisciplinary evaluation (or of one or more in-house teams):

Yes ☐ No ☒

Clinical research activities:

Yes ☐ No ☒

RESULTS

1- Presentation of the unit

Introduction

History, localisation of the unit
Structure of the unit (teams or themes)

The UMR "Biochimie et Physiologie Moléculaire des Plantes" (BPMP, *https://www1.montpellier.inra.fr/wp-inra/bpmp/*) is located on the INRA/Montpellier SupAgro Campus ("La Gaillarde") and gathers from 110 to 150 people (127 on 01/06/2019), including permanent staff from four institutions (CNRS, INRA, Montpellier SupAgro and University Montpellier), and students, post-Docs and non-permanent technical assistants from various origins (14 different nationalities on 01/06/2019).

BPMP directly originates from the "Laboratoire de Biochimie et Physiologie Végétales" (BPV), founded in 1971 by Prof. Louis Salsac on the Campus La Gaillarde, with the physiological and biophysical aspects of mineral nutrition in higher plants as its main scientific focus. In the following years, BPV was associated with the four institutions to which BPMP belongs, and from 1981 was directed by Prof. Claude Grignon. The current UMR BPMP was created in 1999. This was simply a modification of the name of the unit, without any change in staff or in scientific activities. BPMP was successively directed by Prof. Claude Grignon (until 2006), Dr. Jean-François Briat (2006-2012) and Dr. Alain Gojon (2012-).

BPMP is constituted of 11 research teams created between 1999 and 2019 (https://www1.montpellier.inra.fr/wp-inra/bpmp/en/research/the-teams/), one administrative team, one logistics team, and several technological platforms or common facilities (see the organization chart below). All teams, platforms and facilities are located in a single building (named "Institut de Biologie Intégrative des Plantes"), shared since 2005 with the UMR LEPSE ("Laboratoire d'Etude des Plantes sous Stress Environnementaux") with which BPMP has long standing collaborations. BPMP has another minor location in the Faculté des Sciences (Campus Triolet, University of Montpellier), which corresponds to the rooms used by the University staff of BPMP in connection with their teaching activities.

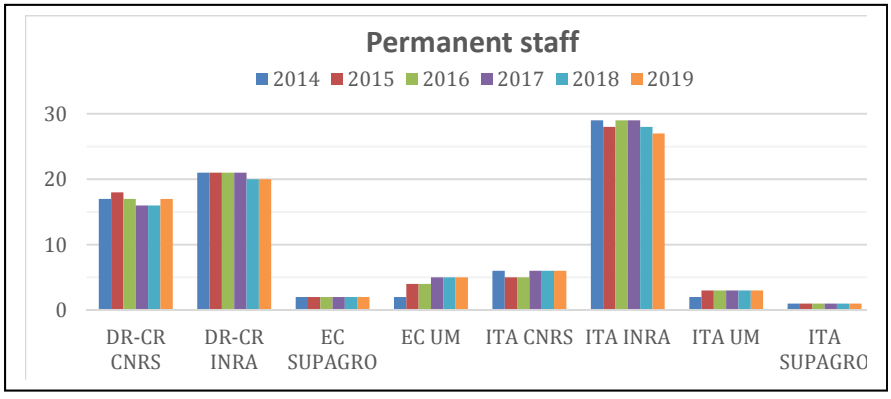
A key characteristic of BPMP is that it has kept over nearly 50 years a strong common focus on the mechanisms involved in the water and mineral nutrition of plants, and in the response of the plants to abiotic factors.

Unit's workforce and means

Unit's Workforce

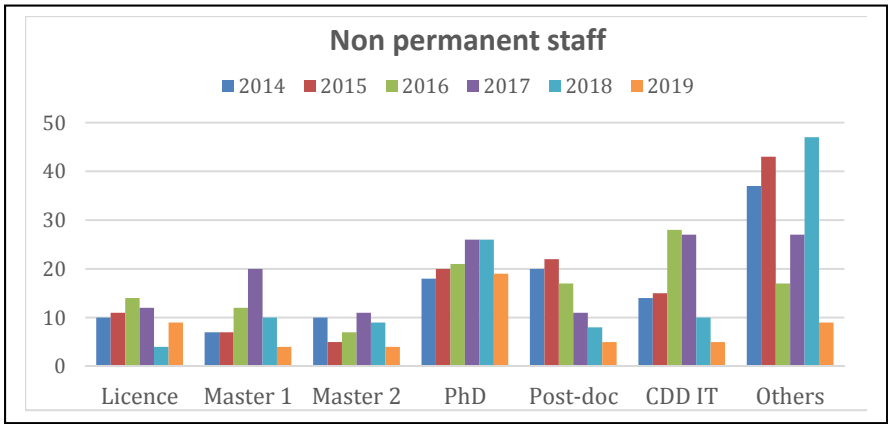
Permanent and non-permanent staff

Between 2014 and 2019, BPMP's workforce relied on around 80 permanent staff (50% scientists, 50% technical and administrative assistants), and a variable number of non-permanent staff (between 30 and 70 are present at any time, depending on the period of the year). The total number of permanent staff remained stable during the 2014-2019 period (see graph below), with the exception of the University staff, which increased from 4 to 8, as a consequence of our marked efforts to strengthen our links with the University (see section below).



In more details, 13 permanent staff left the unit during the current contract (6 retirements and 7 outgoing mobility), and these departures were more than fully compensated by the arrival of 15 newcomers (4 recruitments and 11 incoming mobility).

More pronounced changes occurred among the non-permanent staff. In particular, the number of post-Docs and technical assistants has markedly decreased since 2015 or 2016, due to the decrease of ANR projects funded in the unit. The number of graduate students increased, whereas no real significant trend was noticed for the other categories. **During 2014-2019, BPMP hosted 446 non-permanent staff in total**, among which 67 visiting scientists and students, 37 post-Docs, 46 graduate students, 46 non-permanent technical assistants, and 250 undergraduate students. All these numbers are higher than during the previous 2008-2013 reporting period. This is especially true for Master students (96 in 2014-2019, as compared to 53 in 2008-2013).



General organization

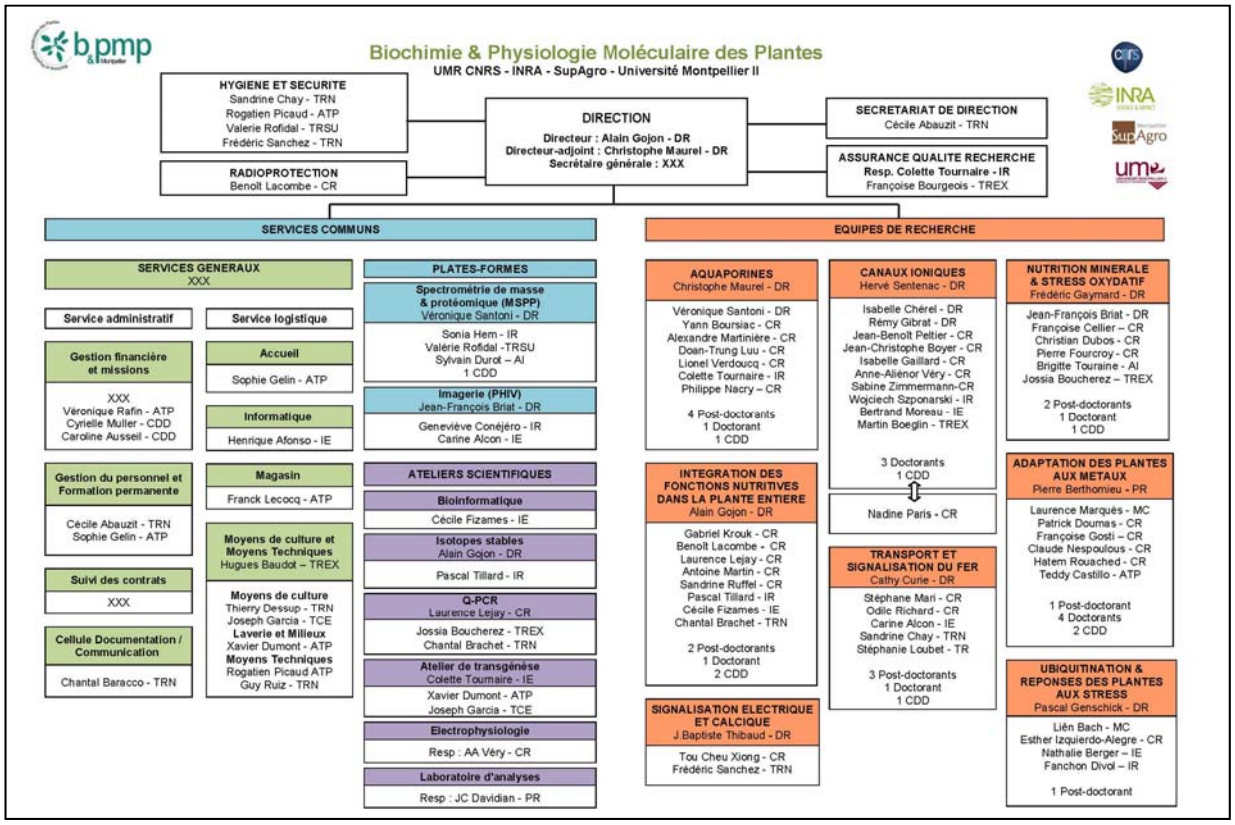
Whereas BPMP shows a well-identified and focused research topic, its scientific organization relies on individualized research groups having both a significant size and strong scientific and financial autonomy. In our view, this organization provides the best compromise between the needs for a collective efficiency and international visibility, and a recognized creativity and autonomy of scientists. On the one hand, the significant size of the groups improves their credibility, allows ambitious strategies, and partly solves transient funding problems for individual researchers. On the other hand, the autonomy of the groups permits the development of original and innovative projects. One consequence of this organization is that BPMP has no formal transversal scientific structure. Common themes or joint projects are encouraged between teams, but are not mandatory, as they may limit the freedom of these teams.

Another key characteristic of the scientific organization of BPMP is that it is not determined by the institutional affiliation of the staff (CNRS, INRA, SupAgro, University). All groups mix people from several of these institutions, making BPMP a true "Unité Mixte de Recherche" (Joint Research Unit) where the scientific objectives of each group are examined and validated by all institutions.

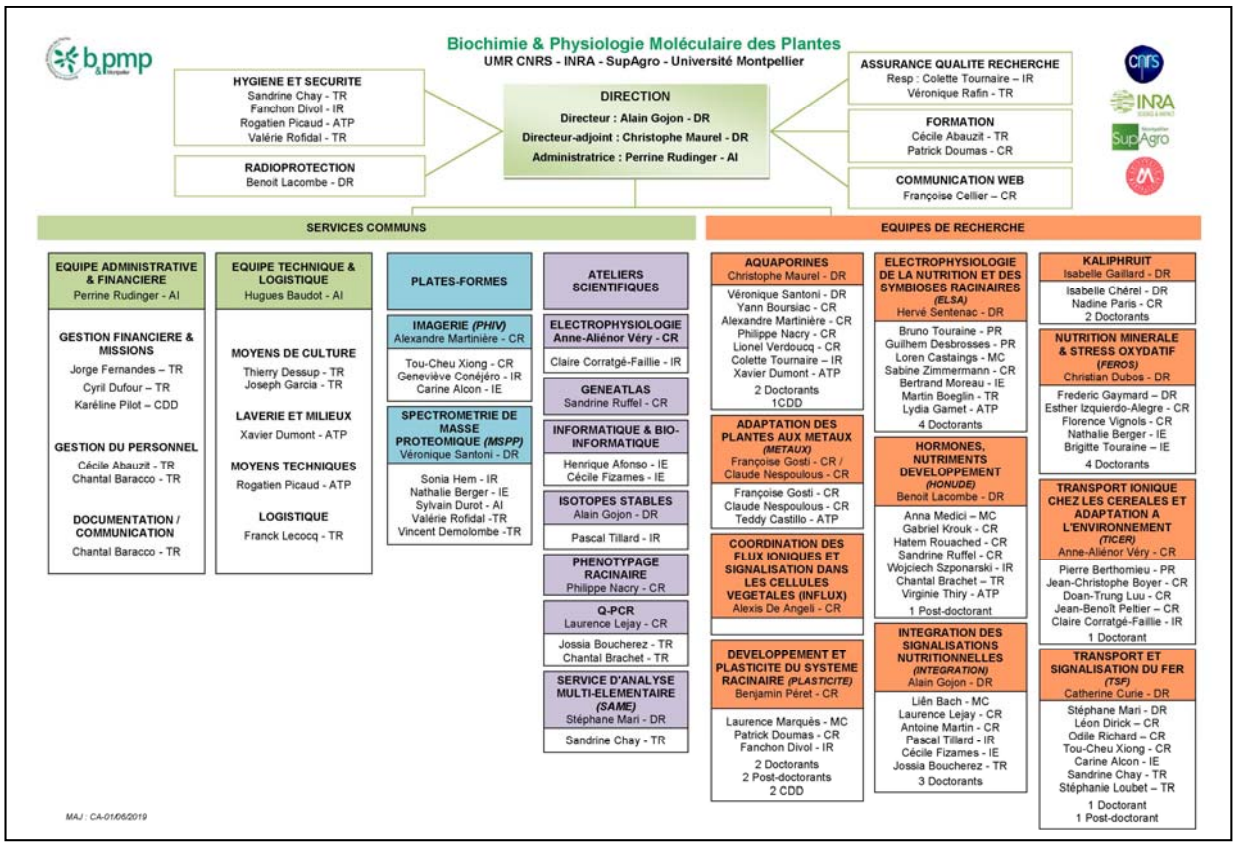
Although the principle of research team autonomy was preserved during the whole 2014-2019 period, a genuine general strategy was implemented at the whole unit level. In particular, the structuration and organization of the unit was significantly changed during the current contract period. The changes mostly resulted from events that occurred immediately before this period (2012-2013), from the recommendations made by the AERES Committee which performed the previous evaluation (in 2014), and from our own dynamics to conduct the project proposed during this evaluation.

This evolution is visualized by the comparison between the BPMP organization charts of 2014 and 2019 (see below).

2014 Organization chart



2019 Organization chart



The most significant changes and associated actions are listed below.

At the strategic and scientific levels:

- *The creation of 5 new research teams in 2015* (ELSA, HoNuDe, Integration, KaliPHruit and TICER), resulting from the split of two previous larger teams (Ion Channels and Integration). The objective was to strengthen the scientific dynamics of BPMP through the emergence of new independent projects and to ensure a significant renewal of research team leaders. Both aims were clear recommendations of the AERES Committee in 2014. This also allowed to favor projects centered on crops as the KaliPHruit and TICER teams focus their studies on grapevine and cereals, respectively.

- *The integration of 2 new research teams* (Plasticity and Influx, in 2015 and 2019, respectively) created *de novo* by young scientists who joined BPMP with grants dedicated to the emergence of junior research teams: ERC Starting grant for B. Péret (Plasticity), and ATIP-Avenir for A. de Angeli (Influx).

- *The closure of the "Ubiquitination and responses of plants to stresses" team* (UbiStress) in 2016, due to the mobility of the head of this team (P. Genschik) to the IBMP Institute in Strasbourg. The other permanent staff of this team joined other teams of BPMP.

- *A strategy to increase the staff from Montpellier University*. This was a recommendation of the AERES committee of 2014 and also a strong priority we put forward in our 2014 project. Between 2014 and 2017, we doubled the number of permanent University staff working at BPMP (from 4 to 8), due to the move of 3 colleagues (including 2 full professors) from another unit in 2015, and the recruitment of an assistant professor in 2017.

At the organizational level:

- *A sustained policy to support and develop common technological facilities in BPMP (see Annex 3)*. This had several aspects at both human resources and financial means levels: (i) an strong financial effort for the acquisition of scientific equipment (approximately 1.7 million €) including 3 major investments ("heavy equipment") for a confocal microscope, a proteomic mass spectrometer and a stable isotopes mass spectrometer, (ii) the integration of our proteomics and imaging platforms (MSPP and PHIV, respectively) into dedicated institutional mutualized organizations of the Montpellier area ("Pôle Protéomique Montpelliérain" and "Montpellier Ressources Imagerie", respectively, see Annex 3), (iii) the total renewal of the scientific and technological staff of the Electrophysiology platform (EHEV), a unique facility in the French plant science community, and (iv) the *de novo* creation of three new common facilities for transcriptomics (GeneAtlas), elemental analysis (SAME platform) and high-throughput root phenotyping (HIRROS) (see the organization chart above).

- *An in-depth reorganization in 2015 of the "General services" team*. This was one of the recommendations of the AERES committee of 2014 as this team had faced various difficulties during the previous contract period. The team was split in two distinct teams (Administrative and Logistics, respectively), with new leaders at their head. In addition, and thanks to a major support from both CNRS and INRA, the staff of the Administrative team was significantly renewed in 2014-2015 (3 new permanent positions). We now consider this problem as solved since both teams largely demonstrated their ability to conduct their tasks satisfactorily.

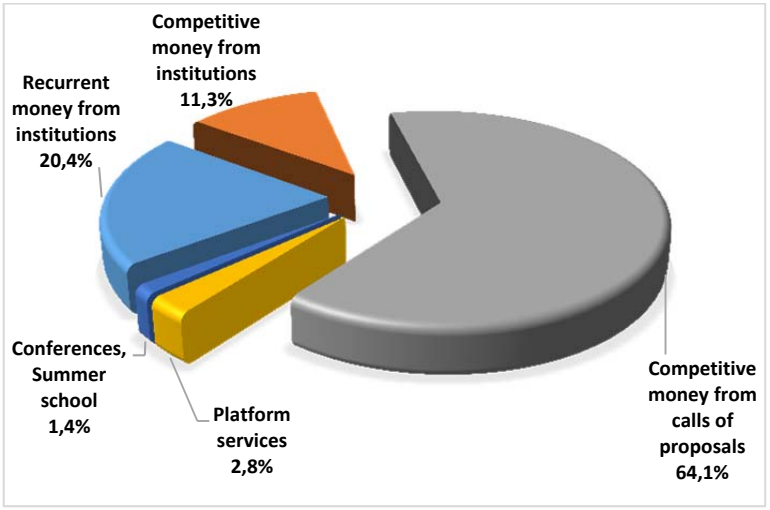
At the human resources level:

- *A significant turn-over of the permanent staff.* This was due to the arrival of 30 new permanent staff between 2012 and 2015 from various origins (external recruitments, people coming from other units, integration of the INRA MSPP proteomic platform previously located in another unit of the campus), but also to the departure of 14 permanent staff over the same period (for various individual reasons). This obviously had strong consequences during the current reporting period. The successful integration of the new colleagues and the functional replacement of those who left our unit constituted a challenge.

- *The human resources action plan* elaborated for reinforcing the 7 new research teams and the MSPP proteomic platform (to fulfil our principle of significant size of the teams). In addition to the people initially involved in these creations, our plan led to the integration of 12 new permanent staff in these teams between 2016 and 2018 (mostly by internal move within BPMP, but also from external recruitments). To date, this action plan is nearly completed, with the exception of two requests for new permanent positions (to CNRS and INRA) for the KaliPHruit and Influx teams.

Financial means

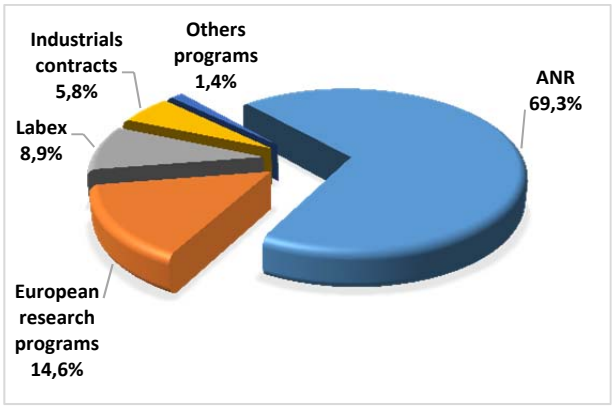
Concerning the financial means of BPMP, the 2014-2018 period was globally highly favorable but with a markedly decreasing trend. The Excel file "Current contract" displays the total funds spent by the unit between 2014 and 2018. Note that these data somewhat underestimate the actual operational budget of BPMP: they do not take into account several grants obtained by BPMP and for which the funds were handled by other institutions (AgreenSkills grants, PHC grants, SATT contracts, etc…). Altogether, the actual operational budget amounted to 11.25 million € for the whole 2014-2018 period (1.99 million € expected in 2019). It gathered the recurrent support from the four institutions to which BPMP belongs (20.4% of the total, see Figure below), the competitive grants from these institutions (11.3%, mostly for investment in scientific equipment), the competitive money from local, national or international calls of proposals (64.1%, mostly for research projects), the income resulting from services of our platforms (2.8%), and the resources we obtained for organizing conferences and summer schools (1.4%). This budget does not include most PhD grants (because the money was directly provided to the students).



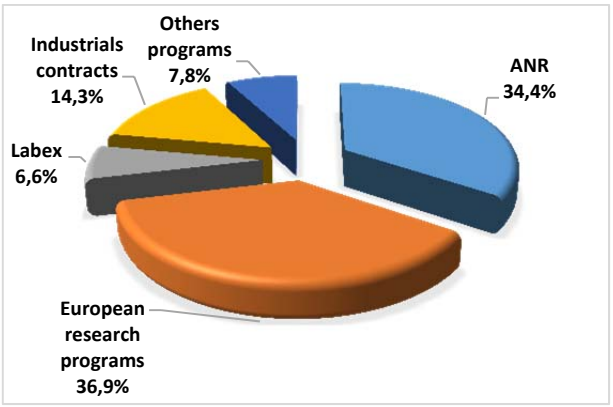
This mean annual budget of around 2.2 million € for the current reporting period represented a nearly 50% increase as compared to the previous period (2008-2013). Because the recurrent support from the institutions only increased from roughly 400 to 450 k€/year between the two periods, this shows that BPMP has been quite efficient in its quest for competitive grants. **However, the origin of the competitive money markedly evolved between the two periods (see Figures below). In 2011-2012, the main provider of competitive grants was by far the ANR (70% of the total), whereas it only represented 34% of the 2014-2018 budget.**

Origin of the competitive money from calls of proposals

2011-2012



2014-2018



This evolution was due to a very significant and constant decrease during the current period in our success rate to the ANR calls for proposals. This decrease also affected a large majority of research units focused on fundamental plant biology. In more details, we had 6 ANR projects accepted in 2014-2016 (out of 54 proposed), whereas only 2 were accepted in 2017-2018 (out of 49 proposed). The contribution of the Labex AGRO (created in 2011) also decreased during the current period as compared to the previous one. This reflected an increasing priority of the Labex for scientific and technological actions promoting the agronomical development of Southern countries. These actions are clearly outside the scope of BPMP. These abrupt changes in funding created a challenging situation for the teams of BPMP. However, they collectively reacted and were able to increase their funding from the European Union, from private partners and from other various sources. In particular, BPMP was awarded 3 ERC grants since 2014 (1 starting grant to B. Péret, and 2 advanced grants to P. Genschik and Christophe Maurel), which correspond to a total budget of 4.4 million € (the grant of P. Genschik was only partly carried out in BPMP, from 2014 to 2016). Also noticeable is our success to the 2018 call for proposals of the Montpellier iSITE (MUSE, created in 2017), with a federative pluridisciplinary project (eCO_2THREATS, 360 k€). These successes did not compensate, however, the general decrease in funding from the ANR and the Labex. Thus, the yearly amount of competitive money available from research projects decreased from 1.64 million € in 2014 to 0.91 million € in 2018 (see current contract Excel file).

The use of the operational budget is defined by the following rules:

- Each group has an independent budget, which is fueled by the competitive money (non-permanent staff salaries, small equipment and consumables) that it receives from funded projects. Collectively, the individual budgets of the research teams correspond to 70-75% of the total operational budget of the UMR. A “tax” amounting to 15% of the money dedicated to consumables is levied by the unit on all contracts, except (until 2018) those specifically devoted to young researchers (e.g., ANR JCJC, ERC Starting). Each group uses its budget according to its own priorities.

- The general common budget (not distributed to the groups) is constituted of the recurrent allocations from the Institutions, plus the 15% tax taken from the projects. This budget usually represents about 25-30% of the total operational budget, and is used to pay all infrastructure expenses, maintenance costs of all significant equipment and common facilities, expenses related to hygiene and safety, quality assurance, training, communication, scientific animation, and student (Masters) gratifications. As a consequence, almost all common facilities are free of cost for all the research teams (at the exception of proteomics, imaging, elemental analysis and stable isotopes platforms). Furthermore, the money left overs are used at the end of the year for common equipment, following a collective discussion.

- Rules for financial solidarity have been defined in 2012, in order to provide minimal funding to the groups that would transiently lack their own competitive funds. These rules were discussed in the various lab committees (see below) and were formally approved by the Unit Council.

Scientific policy

BPMP can be defined as an Integrative Biology research unit. **Our general objective is to understand how plants ensure their hydro-mineral nutrition, and respond to environmental factors (mostly abiotic) that may impair their nutrition and growth. The activity profile of the unit is predominantly directed towards basic research, with a significant involvement in higher education**. We predominantly aim at identifying fundamental molecular and cellular mechanisms, using the most relevant models and approaches for reaching a high quality scientific standard and maintaining our visibility at the international level.

All research teams investigate various functional and/or developmental processes determining the hydro-mineral status of the plants. **Many of these groups have a strong focus on membrane transport processes involved in the acquisition of water and mineral nutrients by roots, and their distribution between various organs.** As a consequence, the study of membrane transporters and channels, of their integration into the whole plant and of their regulation in response to environmental factors, has been the first pivotal axis of BPMP’s research projects. In addition to water, most main macro- and micronutrients are investigated (potassium, nitrogen, phosphorus, iron, zinc, manganese, etc…).

The second main scientific axis of BPMP is to elucidate the signaling mechanisms that allow plants to perceive abiotic constraints, and to develop relevant adaptive responses. This encompasses a wide palette of responses, from genome-wide transcription reprogramming or large-scale proteome modifications to

adaptive changes in growth and development. This second topic is not disconnected from the first one (transport), because it also involves the determination of how the transport machinery is modulated to maintain an optimized nutrition under environmental fluctuations. However, a significant evolution during 2014-2019 was to strongly focus on signaling mechanisms triggering root developmental responses. As a consequence, the root system has become a privileged model for most projects of BPMP. The abiotic factors under study are mostly the external availability of water and mineral nutrients or metals, light, CO_2 and temperature. As a general rule, the levels of biological organization addressed by the research projects go from the molecules to the whole individual plant, which is the most integrated level investigated in BPMP (populations are outside of our scope).

The basic research made at BPMP clearly addresses major socio-economic challenges. In the context of sustainable agriculture and global climate change, we believe that the questions related to nutrient and water use efficiency by plants will be of increasing strategic importance. Furthermore, the abiotic factors investigated correspond to major environmental stresses that already strongly hamper crop production world-wide, such as drought, flooding, saline stress, and nutrient starvation or metal toxicity. During the recent period, we also had an increasing interest in investigating the responses of the plants to the main abiotic factors of climate change (high temperature and elevated CO_2), as well as in studying beneficial biotic interactions (PGPR bacteria and symbioses) that may be relevant for ecological intensification of agriculture.

Finally, training is also a major objective for BPMP, in direct connection with its basic research activity. We contribute to the general formation in Plant Sciences at both Montpellier University and Montpellier SupAgro. Staff from these two institutions is present in the laboratory, and researchers from both CNRS and INRA significantly participate in training. Furthermore, our unit has a long-standing experience in supervising French and foreign Master and PhD students, as well as post-Doc researchers or temporary technical assistants. Fifty to 100 of these non-permanent people are joining BPMP each year.

Following the previous evaluation by the AERES committee (in 2014), several weaknesses were identified and BPMP received recommendations dealing with both its scientific strategy and organization. As detailed below, most have been taken into account since then:

- *The committee recommended that BPMP should develop more ambitious actions to better exploit its scientific leadership*. We took this remark as an important issue, which was somewhat successfully addressed along two key aspects. The international visibility of BPMP was enhanced by organizing three major international congresses, and its attractivity and ability to develop more ambitious projects were validated by hosting three ERC projects conducted by BPMP group leaders.

- *The committee pointed out that several leaders of the former research teams will retire or will be close to retirement before the end of the current 2014-2019 period, and that a strategy to favor the emergence of new research groups should be developed.* This has been a key priority as soon as 2014 and resulted as stated above in the creation of 7 new research teams since 2015. Overall, this period has seen a major renewal of the research team leaders (6 new leaders out of 11).

- *We were strongly encouraged to get more involved in the training at Montpellier University, and to attract more staff from the University.* This goal was reached with success as the University staff doubled during the period (from 4 to 8), and because the number of Master students from the University hosted at BPMP was significantly increased as compared to the previous period (93 as compared to 53).

- *We were encouraged to better communicate on the scientific strategy of the unit towards technical and administrative staff*. To address this point, various aspects of BPMP's strategy were discussed during an increasing number of meetings of the Unit Council (see the "Organization and life of the unit section"). In addition, all creations of new research teams by incoming team leaders were preceded by an internal seminar to inform all BPMP staff of the corresponding project. Finally, the scientific project of each new team was discussed during Unit Council meetings.

- *The committee recommended that BPMP should be more active in widening its collaborations with private partners and other local research Units focusing on ecophysiology and soil science.* Several significant actions were conducted to sustain valorization (research contracts with Syngenta, Solvay, Imperial Tobacco and the local SATT). These efforts proved successful as the total funding from private partners increased from 384 k€ during the 2008-2013 period to 1,030 k€ during the 2014-2018 period. However, partnership with private companies remains an aspect where BPMP has still decisive progresses to make. Efforts to involve BPMP into more integrated projects with ecophysiologists and soil scientists were also successful, in particular through a main collaborative project with soil scientists

coordinated by BPMP and funded by the iSITE MUSE ("eCO$_2$THREATS" project), and our partnership with ecophysiologists within the ERA-CAPS "Root Barriers" project.

2- Presentation of the unit's research ecosystem

Despite the institutional context of BPMP has remained stable concerning the four organizations to which the unit belongs (CNRS, INRA, Montpellier University, Montpellier SupAgro), the local context was significantly modified at several levels, which had consequences for BPMP.

The Labex AGRO to which BPMP belongs was created in 2011 to replace the previous RTRA (Réseau Thématique de Recherche Avancée). The Labex AGRO had most of its funding and structuring actions during the 2014-2019 period, which were predominantly focused on scientific questions related to the agricultural development in Southern countries. Therefore, it has been, and still is, a challenge for BPMP to appear as a key player in the Labex. Most of our project proposals were rejected, because of their supposedly lack of impact, and the overall funding from the Labex significantly dropped when compared to the previous RTRA period. BPMP obtained only ca~2% of the total funding provided by the Labex between 2011 and 2018. When normalized to the number of scientists working in different units belonging to the Labex, BPMP funding was up to 8-times lower than in similar plant biology UMRs, but working on tropical plants. Nonetheless, support from the Labex was significant for the two international congresses organized by BPMP in Montpellier, and for our collaboration with Solvay. Noticeably, together with the support from the CNRS, our continuous exchanges with the Direction of the Labex finally allowed to set up a Federative project on "Fundamental Plant Biology" (2019-2022) funded by the Labex (600 k€) that BPMP will lead together with the LGDP Unit (CNRS/University of Perpignan) (see project).

University of Montpellier (UM) was created in 2016 from the merge of the previous Montpellier 1 and 2 universities. The UM has been significantly supporting BPMP through a new assistant Professor position in 2017 (in addition to the 3 other University staff who joined BPMP in 2015) and the funding of several projects for scientific equipment (120 k€ in total). Conversely, and in connection with our general strategy to strengthen the links with the University, BPMP has been a main contributor of the building and functioning of the Scientific Department "Biology-Agrosciences" of the new Montpellier University. Indeed, the Director of this Department (Prof. B. Touraine) is a member of BPMP, and the Director of BPMP (A. Gojon) is a member of the Council of this department.

The Montpellier iSITE project MUSE (Montpellier University of Excellence) to which BPMP contributes was launched in 2017. Its main objective is to structure the Life Sciences community of Montpellier. MUSE gathers 120 research units and focusses on scientific questions related to three main research communities that are strongly represented in the Montpellier area: (i) Animal and Medical sciences, (ii) Ecology and Environment, and (iii) Plant Sciences and Agronomy. Despite its recent creation (2017), MUSE already funded around 70 competitive research projects, among which 10 major ones in 2018. One of the major projects (360 k€) is coordinated by BPMP, highlighting our visibility in the iSITE.

The former Region "Languedoc-Roussillon" merged with its neighbour ("Midi-Pyrénées") to give birth to the new "Occitanie" Region. As compared to the former one, the new "Occitanie" region has a significantly different strategy for funding research, notably concerning PhD grants that are now easier to obtain as soon as the PhD project is relevant for the Regional economy. This in particular provides an important opportunity for our projects on grapevine, which already benefited from two half-PhD grants since 2016.

Finally, two additional important players in BPMP's local ecosystem are the Biocampus unit, and the GAIA Doctoral School. Biocampus is a technological structure (UMS CNRS/INSERM/UM) gathering a large number of mutualized platforms for medical and biological research in Montpellier. BPMP is both a contributor and a beneficiary of Biocampus because our imaging (PHIV) and proteomic (MSPP) platforms are integrated into the large imaging (MRI) and proteomic (PPM) platforms of Biocampus, respectively (see details in Annex 3). Concerning GAIA, BPMP is contributing to its functioning (A. Gojon is a member of the GAIA Council, B. Lacombe is a member of the evaluating committee for PhD grant allocation), and has also been very successful in obtaining PhD grants from this Doctoral School (11 over the period, taking into account that 57 research units are associated to GAIA, which delivered only around 120 PhD grants since 2014).

3- Research products and activities for the unit

Scientific track record

Scientific production

The total number of publications during the Jan 2014-June 2019 period (5.5 years) is 239 articles (excluding BioXriv), among which 217 appeared in journals having an impact factor (see Table below and Annex 4).

Name of the journal	Number of articles	Impact factor 2017		Name of the journal	Number of articles	Impact factor 2017
Science	2	41,058		Aquat. Toxicol.	1	3,884
Cell	1	31,398		Mol. Microbiol.	1	3,816
Nat. Genet.	1	27,125		Plant Sci.	2	3,712
Physiol Rev.	1	24,014		Int. J. Mol. Sci.	4	3,687
Nat. Protoc.	1	12,423		BBA - Gen. Subjects	1	3,679
Nat. Commun.	3	12,353		Front. Plant Sci.	17	3,677
Trends Plant Sci.	8	12,149		Environ. Exp. Bot.	3	3,666
Nucleic Acids Res.	1	11,561		Ann. Bot.-London	1	3,646
Nat. Plant.	4	11,471		Mol. Plant-Microbe Interact.	1	3,588
Proc. Natl. Acad. Sci. USA	6	9,504		Plant Mol.Biol.	1	3,543
Mol. Plant	7	9,326		Proteomics	1	3,532
Curr. Biol.	1	9,251		Planta	1	3,249
Plant Cell	7	8,228		J. Integr. Plant Biol.	1	3,129
eLife	3	7,616		Molecules	1	3,098
New Phytol.	8	7,433		Rice	2	3,039
Curr. Opin. Plant Biol.	4	7,349		Febs Lett.	1	2,999
Compr. Rev. Food Sci. F	1	7,028		Biochem.	1	2,997
Sci. Signal.	2	6,378		J. Biol. Inorg. Chem.	1	2,952
Plant Biotechnol. J.	1	6,305		Reg. Envir. Chang.	1	2,872
Plant Physiol.	18	5,949		J. Plant Physiol.	4	2,833
Plant J.	8	5,775		Environ. Sci. Pollut, Res.	1	2,800
PLoS Genet.	2	5,540		Mycorrhiza	1	2,778
Plant Cell Environ.	4	5,415		PLoS one	4	2,766
Development	2	5,413		Plant Physiol. Biochem.	2	2,718
J. Exp. Bot.	19	5,354		MicrobiologyOpen	1	2,682
Crit. Rev. Biotechnol.	1	5,239		BioMed Res. Int.	2	2,583
Mol. Cell. Proteomics	1	5,236		Physiol. Plantarum	1	2,580
Environ. Microbiol	1	4,974		J. Cereal. Sci.	1	2,302
Plant Methods	1	4,269		Transgenic research	1	2,197
Mol. Plant Pathol.	1	4,188		Curr. Genomics	1	2,172
Sci. Rep. - UK	9	4,122		Trees-Struct. Funct.	2	1,782
Metallomics	1	4,069		Biol. Platarum	1	1,424
Plant Cell Physiol.	4	4,059		Adv. Bot. Res.	6	1,388
Plant Cell Physiol.	4	4,059		Arid Land Res. Manag.	1	0,970
J. Biol. Chem.	2	4,040		J.Agric.Sci.Technol.	1	0,890
Front. Microbiol.	1	4,019		Int. J. Agric. Biol.	1	0,869
BMC Plant Biol.	2	3,930		Chil. J. Agric. Res.	1	0,775

These 217 articles correspond to a weighted mean journal impact factor of 6.12, with 117 (54% of the total) of these articles published in journals with an impact factor higher than 5. **Furthermore, 43 articles (20% of the total) were published in top ranking journals** (*Science*, *Cell*, *Nature Genetics*, *Physiological Reviews*, *Nature Protocols*, *Nature Communications*, *Trends in Plant Sciences*, *Nucleic Acids Research*, *Nature Plants*, *PNAS*, *Molecular Plant*, *Current Biology*, *Plant Cell*).

Compared to the previous reporting period (see table below), **our current data illustrate a significant quantitative improvement (25% increase in publication rate per full-time permanent scientist) without loss in quality**: BPMP's production between Jan 2008 and Jun 2013 (5.5 years) was 169 articles in journals with a mean impact factor of 6.15 (IF 2011). Furthermore, this increase in scientific production is in continuation of a long term trend recorded since 2004 (see table below). It should be highlighted that this occurred despite the fact that about half of the current research teams were created only in July 2015, and that several of them did not have time yet to fully publish the results of their new research project.

Long-term evolution of the scientific production of BPMP in journals with impact factor

Period	Total number of articles	Mean number/year/Full-time permanent scientist	Mean impact factor
2004-2008 (4.5 years)	120	0.81	5.40
2008-2013 (5.5 years)	169	0.82	6.15
2014-2019 (5.5 years)	217	1.02	6.12

Noteworthy, the vast majority (>95%) of the 239 articles published over 2014-2019 is directly connected with the scientific topic of BPMP. The remaining articles mostly result from the open activity of our technological platforms, which provided a methodological support to scientific projects from other research units (see Annex 3).

Considering the 217 articles published in journals with an impact factor, 36% include a PhD student of BPMP as an author, and 62% are with a member of BPMP as first and/or corresponding author. In addition, 40%, 25% and 43% of these articles are in co-authorship with French, European and foreign (other than European) collaborators, respectively.

Finally, 2 patents, 20 books or book chapters, 6 softwares, 25 defended theses and 82 invited talks in national or international conferences have also been recorded during the 2014-2019 period. With the exception of the patents and defended theses, these numbers also show a marked increase as compared with the previous period (3 patents, 9 book chapters, 0 software, 25 defended theses and 65 invited talks between 2008 and 2013).

Main scientific outcomes at the whole unit level

For the last evaluation in 2014, we proposed several priorities for the current contract of BPMP (see our AERES report of 2013). These priorities are listed below:

- *Strengthen our studies on plant water transport and responses to water stress.*
- *Develop more integrated projects connecting root development and function.*
- *Expand our Systems Biology approaches.*
- *Generalize the study of post-translational regulatory mechanisms.*
- *Initiate more prospective genetic approaches.*

Most of these priorities actually translated in strengthened research projects and led to significant advances, illustrated by original publications in high-ranking journals.

The topic where this was particularly obvious is the one on studies on water transport and responses to water stresses. Indeed, several projects, mostly led by the Aquaporin team, have shed new light onto the regulation of water transport in the shoots and roots of *Arabidopsis*. While the role of aquaporins in stomatal movements had remained elusive, the team elucidated a dual hydraulic and signaling function of aquaporins in guard cells (Grondin et al., 2015; Rodrigues et al., 2017). In particular, tight connection between stomatal closure, hydrogen peroxide-mediated ABA signaling, and aquaporin functions and regulations were established. Another major breakthrough was brought by quantitative genetics analyses of water transport in Arabidopsis roots (Shahzad et al., 2016; Tang et al., 2018). Based on its unique capacity to phenotype root hydraulics at high throughput, the group was able to isolate several genes involved in water transport regulation. In

particular, a new signaling pathway that mediates root responses to hypoxia, in relation with K^+ availability was uncovered.

Work on the responses of root development to abiotic signals was strongly reinforced since 2014. A first set of studies addressed the sensing/signaling mechanisms of nitrate and their impact on integrated functional and developmental properties of roots. In particular, studies on the NRT1.1/NPF6.3 transceptor and its connections with auxin signaling were pursued and amplified (HoNuDe and Integration teams). These projects reached their full maturity in terms of scientific production, and unraveled novel connections with phosphate, ABA and cytokinin signaling (Mounier et al. 2014, Bouguyon et al. 2015, Léran et al. 2015, Medici et al. 2015, Bouguyon et al. 2016, Ristova et al. 2016, Poitout et al. 2018, Medici et al. 2019). Second, investigations on the developmental plasticity of the root system were initiated in several other groups (Aquaporins, ELSA, FeROS, Metal toxicity), leading to new information on root responses to other nutrients (e.g., iron and zinc) or to rhizospheric bacteria (Reyt et al. 2015, Poitout et al. 2017, Bouain et al. 2018). Third, BPMP was able to strengthen its positioning in the field of the environmental control of root development by assisting the creation in 2015 of the "Development and Plasticiy of the Root System" team (B. Péret, see above). In addition to its work on Arabidopsis, this group has introduced lupin cluster roots as an additional model (Gallardo et al. 2019). Fourth, another important milestone was the development of an automated robot for root architecture phenotyping (HIRROS). Even before 2014, our capacity to conduct refined analyses of root system architecture at sufficient speed had been identified as a crucial bottleneck. Our high-throughput phenotyping device is currently fitted for fast acquisition of root system pictures on plants grown *in vitro*. The prototype was fully developed in house, and will soon be fully operational as a platform for BPMP teams and external users, thanks to the planned recruitment of a technical assistant in 2019.

Systems biology approaches expanded into two directions. First, frontline developments were carried out on algorithms used to handle large-scale genomic data (HoNuDe), in collaboration with applied mathematicians (Krouk et al. 2015, Carré et al. 2017, Val et al. 2017, Carré et al. 2018). This effort was associated with software developments (See annex 4) that may now have an innovation potential (project funded by SATT). Second, systems biology tools were progressively integrated into more classical biological approaches to infer gene regulatory networks and identify new regulators of plant mineral nutrition (Integration, HoNuDe, KaliPHruit, Metal toxicity), often within the frame of collaborations with other teams in the USA and Chile (Alvarez et al. 2014, Ristova et al. 2016, Pal et al. 2017, Varala et al. 2018, Brooks et al. 2019). In a broader sense, mathematical modelling approaches have been initiated by several other groups, but with different aims. For instance, the Aquaporin group has been integrating elementary water flows into whole root systems to model the root hydraulic architecture of different *Arabidopsis* genotypes.

Posttranslational regulatory mechanisms are now routinely investigated in almost all teams of BPMP. Not surprisingly, this led to the identification of protein phosphorylation and protein-protein interactions as key mechanisms for modulating water or ion transport, and nutrient signal transduction (Ronzier et al. 2014, Bouguyon et al. 2015, Grondin et al. 2015, Léran et al. 2015, Bellati et al. 2016, Lefoulon et al. 2016, Shahzad et al. 2016, Corratgé-Faillie et al. 2017, Prado et al. 2019). Our strategy on this topic also included a strong support for both personnel reinforcement and technological upgrade of our proteomic platform (MSPP, see Annex 3).

Quantitative genetics has recently emerged as a highly successful approach in BPMP (Aquaporins, Metal toxicity), allowing several breakthroughs in our understanding of complex mechanisms associated with responses of plants to abiotic constraints (Shahzad et al. 2016, Bouain et al. 2018, Kisko et al. 2018, Tang et al; 2018). One consequence is that GWAS can now appear as a major approach in the recent proposals concerning federative projects coordinated by BPMP (eCO_2THREATS and Flagship project CalClim).

Beyond the above priorities identified in our 2014 project, several other important developments occurred during the last years. These developments will undoubtedly structure the scientific strategy of BPMP in the coming years:

- A renewed interest on transcriptional reprogramming in response to abiotic signals. Several projects focusing on signaling mechanisms and gene regulatory networks triggering responses to nutrients identified a handful of transcription and chromatin factors as key players in these responses (Alvarez et al. 2014, Khan et al. 2014, Medici et al. 2015, Pal et al. 2017, Bellegarde et al. 2018, Bellegarde et al. 2019, Medici et al. 2019, Tissot et al. 2019). Therefore, the mechanisms of transcriptional regulation, now including chromatin dynamics, have been increasingly investigated by several teams (HoNuDe, Integration, FeROS).

- Convergent data from several teams highlight the general importance of ROS signaling and redox processes in governing water and nutrient (N, Fe) homeostasis. Although this was generally not the

objective, the pivotal role of these processes emerged from several independent projects (Reyt et al. 2015, Wudick et al. 2015, Rodrigues et al. 2017, Bellegarde et al. 2019, Martinière et al. 2019).

- Significant efforts were devoted to interactions between nutrient signaling pathways, in the context of combinations of abiotic constraints (N and P, N and C, N and water, P and zinc, etc…). These studies resulted in many original discoveries, showing that multi-stress situations often unravel emerging properties: plant responses to combined stresses rely on specific mechanisms that are not the simple addition of the responses to each individual stress (Khan et al. 2014, Medici et al. 2015, Li et al. 2016, Shahzad et al. 2016, Kisko et al. 2018, Medici et al. 2019).

- Several groups (Aquaporins, Influx, KaliPHruit, TSF) expressed an increasing common interest in technological developments concerning cutting-edge imaging techniques and the use of biosensors (pH, iron, ROS, hormones, calcium, nitrate, …) adapted to *in vivo* studies (Xiong et al. 2014, Hosy et al. 2015, Martinière et al. 2018). As a consequence, dedicated projects were developed by our imaging platform (PHIV) that are expected to provide many novel tools for both transport and signaling studies.

Finally, the investigation of membrane transports, the historically strong topic of BPMP, has remained very active in several teams. As in the past, some studies aimed at the functional characterization of *Arabidopsis* transporters for major mineral nutrients (Nieves-Cordones et al. 2014, Léran et al. 2015, Taochy et al. 2015, Castaings et al. 2016, Alejandro et al. 2017). However, a significant number of new projects has been addressing more original questions, such as the transport of organic solutes associated with iron nutrition (Fourcroy et al. 2014, Grillet et al. 2014, Fourcroy et al. 2016), Na^+/K^+ transporters involved in saline stress tolerance in cereals (Ben Amar et al. 2014, Tounsi et al. 2016, Nguyen et al. 2017), K^+ channels and transporters determining grape berry acidity (Nieves-Cordones et al. 2019), or transport systems ensuring nutrient transfer or electrical signaling in root symbioses (Garcia et al. 2014, Charpentier et al. 2016, Guerrero-Galan et al. 2018, Wang et al. 2019).

Key events

Beyond a simple list, it is important to detail the significance of these key events with regard to the scientific strategy of BPMP. Therefore, these events were grouped to relate them, when relevant, to the scientific priorities put forward by BPMP in 2013, or to the recommendations of the AERES Committee in 2014. Also, we only refer to scientific key events here, as those associated with the organizational changes of the unit were previously detailed in the “Unit’s workforce and means” section above.

National and International visibility and attractivity of BPMP

- *The organization of three major international conferences*: (i) Nitrogen2016: the 3rd International Symposium on the Nitrogen Nutrition of Plants (EMBO conference also supported by the NSF), (ii) IPMB2018: the 12th Congress of International Plant Molecular Biology, and (iii) IPSB2018: the 1st International Plant System Biology Meeting. These three conferences provide an unprecedented demonstration of BPMP’s renown in international scientific communities at the heart of our research field.

- *The creation of a LIA* (Laboratoire International Associé) between BPMP and the Center for Genomics and System Biology of New York University (USA). Based on a long standing collaboration, this LIA played a strong structuring role in the development of our systems biology approaches.

- *The creation of two new teams led by young scientists moving from other research units.* BPMP succeeded in attracting two promising colleagues, Benjamin Péret (CR CNRS) and Alexis de Angeli (CR CNRS) who selected our unit to run their projects supported by an ERC starting grant and an ATIP-Avenir grant, respectively. These achievements assess our strategy to provide an attractive scientific and material environment to external team leaders.

Water transport and response to water stress

Recent work of BPMP on root water transport represents a major breakthrough with respect to previous studies in the field of plant water relations. The work relied on an innovative quantitative genetics approach that was

centered on root hydraulic conductivity, a key trait that had not been explored before. This work has had several impacts:

- It led to two high-rank publications (Shahzad et al., Cell, 2016; Tang et al., 2018, Nature Commun.) and a third publication to come (Shahzad et al., Plant Cell, in revision).
- In recognition of this outstanding *work,* the Aquaporin team was awarded two prizes from the French Academy of Sciences (Major French Advances in Biology 2017 to Dr Z. Shahzad; Georges Morel Prize to C. Maurel in 2018).
- The results provided a robust ground for the ERC Advanced grant obtained by C. Maurel in 2017. This grant will allow the Aquaporin team to explore the many facets of root hydraulic architecture of maize plants under water stress.
- Finally, the press release related to the work by Shahzad et al. (Cell, 2016) led to several interviews in public broadcasts (France, Switzerland) and the national press.

Integration of functional and developmental responses of the root system

Convergent studies made by HoNuDe and Integration teams (both arising from the split of the former Integration team) provided major insights into nitrate signaling pathways, and in particular the pathway triggered by the NRT1.1/NPF6.3 nitrate transceptor (transporter-receptor). In a series of publications (Mounier et al. 2014 *PCE*, Bouguyon et al. 2015 *Nature Plants*, Léran et al. 2015 *Sci Signal*, Medici et al. 2015 *Nature Commun*, Bouguyon et al. 2016 *Plant Physiol*, Medici et al. 2019 *Plant Cell*), these teams unraveled the far reaching functions of NRT1.1/NPF6.3 in governing a large palette of physiological and developmental responses of the plant to nitrate, and demonstrated that NRT1.1/NPF6.3 also participates in a signaling cascade integrating nitrate and phosphate signals to modulate both N or P transport and root growth. Altogether, these publications constitute a unique comprehensive study of nutrient sensing mechanisms, which in turn coordinate functional and developmental responses of the root system.

See press releases: Les stratégies des plantes pour optimiser l'utilisation des nitrates, and Détection des ions minéraux par les plantes : du nouveau pour le nitrate et le phosphate.

See also the 2015 INRA report on key scientific events at the national level (pp 19-20): http://institut.inra.fr/Reperes/Documents/Rapports-d-activite/Rapport-d-activite-2015

Other scientific key events

- 3 ERC grants have been hosted in BPMP.

- The *de novo* sequencing of the white lupin genome was completed in 2018. This large scale project was headed by the Plasticity team and involved a large consortium of a dozen of research teams from various institutes.

Interaction with social, economic and cultural environment

The 2014-2018 period has seen a marked improvement of our interactions with private companies, through 3 major projects corresponding to an unprecedented level of private funding for the BPMP teams (Syngenta: 600 k€, Solvay: 300 k€, and Imperial Tobacco: XXX k€).

Training

A key aspect is the long-standing continuation of the MISTRAL international summer school (Montpellier international school on ion and water transport in plants), which is fully managed by BPMP. Created in 2012, MISTRAL aims at providing a high-level research training on both theoretical and practical aspects of ion and water transport in plants. MISTRAL supports our strategy to position BPMP as a internationally leading Institute in the field of water and mineral nutrition. Each session of this bi-annual summer school is limited to around 15 PhD students, post-docs or senior researchers with an already significant background on the topic. The summer school runs over two full weeks, with both lectures (one week) and practical training on the various technological platforms of BPMP (one week). During the evaluation period, the 3 sessions, run in 2014, 2016 and 2018, gathered 43 attendees in total (68% from abroad), from 13 different countries.

4- Organisation and life of the unit

Steering, life, organisation in the unit

In complement to the autonomous scientific functioning of the research teams, the organization and life of BPMP rely on three main pillars:

- *The «Internal Regulations Statement» («Règlement Intérieur»)* of BPMP. This document, establishes all formal rules related to main aspects of our individual and collective functioning, such as «Hygiene and Safety», «Informatic chart», «Working hours and organization of work during nights or week-ends».... Any newcomer at BPMP receives this document and attests its reading by a signed statement.
- *The functioning of various executive or non-executive management committees (detailed below).*
- *Several supporting teams and groups with administrative and logistical tasks (detailed below).*

Management committees

BPMP is currently managed by a direction team including Alain Gojon as a Director, Christophe Maurel as a Deputy-Director, and Perrine Rudinger as an Administrative Manager.

The Unit Council, where the various worker categories are represented according to the legislation which applies to our laboratory size, is the only official and obligatory council. It meets on average 4 times a year and can give advice on all issues related to the laboratory life, with emphasis on those concerning the general strategy of the unit, hygiene and safety, financial resources, human resources and management of common services. Since 2013, the role of the Unit Council was reinforced regarding major scientific orientations. This resulted from a recommendation of the AERES committee that suggested that new communication means on these issues should be set up between the direction and the technical staff. In practice, two main procedures were developed. First, the rules and criteria for validating the creation of a new research team (or promoting someone as a team leader) were detailed in a written chart, which was discussed and validated by the Council. Second, each creation of a new research team was discussed in the Council, which in most instances expressed its opinion by a formal vote.

The Team Leaders Committee meets once a month and helps the Direction to take decisions related to the scientific policy and human resources management, such as defining the scientific priorities, creating or closing teams, elaborating the resource requests to our four Institutions, and making investments for scientific equipment. This committee is composed of the research team leaders, but also of the administrative and logistics team leaders, and of the scientific leader of the proteomic platform. All these people (14 in total) exert a direct hierarchical responsibility on permanent staff downstream of the Director.

In addition, two other collective structures participate in the organization and life of the unit:

The Laboratory Technical Committee is composed of one member per team and of the Direction. It is in charge of elaborating solutions to any technical or practical problem that arises in the unit (with the exception of plant cultures, see below). It also makes recommendations for ameliorating «BPMP's life» on a day to day basis. It meets once a month and has its own budget (10 k€) to be distributed collectively.

The Plant Growth Facilities Committee is also composed of one member per research team, and of the technical assistants involved in managing the plant growth facilities (greenhouse, grown chambers, growth cabinets). This committee has a crucial role in ensuring a smooth and efficient collective use of plant growth facilities, by setting rules for attributing growth space to the research teams and by defining protocols for plant growth (management of various species, environmental conditions, pest management, etc...). This is particularly important because most plants grown in the unit are GMOs. In addition, the increasing number of plant species investigated in BPMP results in an increasing difficulty to satisfy all needs of the various teams. This requires a strict organization for the use of our facilities.

Finally, *the General Assembly* of all the people working at BPMP takes place once a year, generally in January. This meeting gives a good opportunity for the Director to detail the main aspects of the unit's life during the previous year, and the prospects for the incoming year. In addition, specific meetings between the Direction and each college of staff (permanent scientists, permanent technical and administrative assistants, and non-permanent staff) are organized each year.

Supporting services

In addition to well-structured technological platforms and common facilities (see Annex 3), BPMP research activities are supported by several teams and groups with both administrative and logistical tasks (see organization chart above).

The Administrative and Financial team () is headed by the administrative manager (P. Rudinger). It is in charge of the reception of visitors and human resources management, the accounting follow-up, the organization of the business travels, and the communication media (at the exception of the Website). Concerning financial aspects, the team (two full-time administrative assistants) establishes a forecast budget and an analytical budget management, integrating all the funding resources of BPMP. This difficult task is achieved by means of the Geslab CNRS software using a specific procedure developed by the team. This enables the Direction of BPMP and all the research groups to follow on line their purchases and invoices and to be informed almost in real time of the status of their financial resources. Concerning the human resource management, BPMP hosts each year between 50 to 100 non-permanent people (undergraduate and graduate students, post-doc, visiting scientists …) from France or abroad, for periods from few months to three years. We have therefore established a "welcome procedure" for these new-comers, which facilitates their arrival and integration. A full-time administrative assistant (with the help of another part-time administrative assistant) is in charge of human resources and professional training for the whole BPMP staff. Finally, a part-time administrative assistant is in charge of the communication and of the scientific and technic information.

The Technical and Logistics team (6 full-time technical assistants) is headed by the technical manager. It maintains our highly developed setup of plant growing facilities (https://www1.montpellier.inra.fr/wp-inra/bpmp/en/platform/plant-culture/), runs the plant cultures in the green house, and ensures a strict regulatory monitoring of the GMO plants produced in the Unit. This team also performs building maintenance, and inventories the equipment (including scientific apparatus), while monitoring its removal when out of order. Finally, the team takes care of the dishwashing and the preparation of media. It receives all deliveries by external suppliers, and runs the internal store where all teams can pick up most consumables needed (more than 600 different items in stock).

In addition to these two fully-dedicated teams, several groups take care of the Health and Safety (see specific section below), of the Research Quality Assurance (see specific section below), of the in house training of BPMP staff, and of the Website monitoring. These groups are predominantly constituted by volunteers who perform the related tasks in addition to their main activity in a research or support team.

Main actions concerning the organization and life of the unit

As stated in the "Unit's workforce" section above, these teams and groups have been significantly reorganized during the current period, with the exception of the Hygiene and Safety group (compare 2014 and 2019 organization charts above). This allowed the development of several important actions, mostly led by our new administrative and technical managers, and improving the general organization and life of BPMP. These actions are listed below.

On the technical aspects:

- *Changes in space allocation within the building*. As a consequence of major structural changes in many research teams and the two support teams, and in connection with the integration of the proteomic platform in 2013, a general reallocation and layout of nearly half of the building space was decided in 2015. This involved the move of almost all staff. Our aim was that, when possible, each team present in the building (currently, 14 including the proteomic platform, as compared to 9 in 2014) can be located within a unique and dedicated area. This plan also required specific funding to modify the building infrastructure for hosting the proteomic platform that moved from another building (84 k€).

- *Upgrade of the plant growth facilities and energy saving plan*. Due to the needs of the LupinRoots ERC project on the one hand, and on the recommendation of both the Unit Council and the Team Leaders Committee on the other hand, an ambitious upgrade of our growth chamber facilities was carried out by the technical manager. This work required the building of three brand-new growth chambers, the installation of three high-tech phytotrons for refined environmentally-controlled experiments, the replacement of the regulatory systems of three older growth rooms, and the doubling of air conditioning systems for all growth rooms (to prevent any of these to be out of function for more than one day). Altogether, this ambitious upgrade required a 572 k€ budget. In addition, we

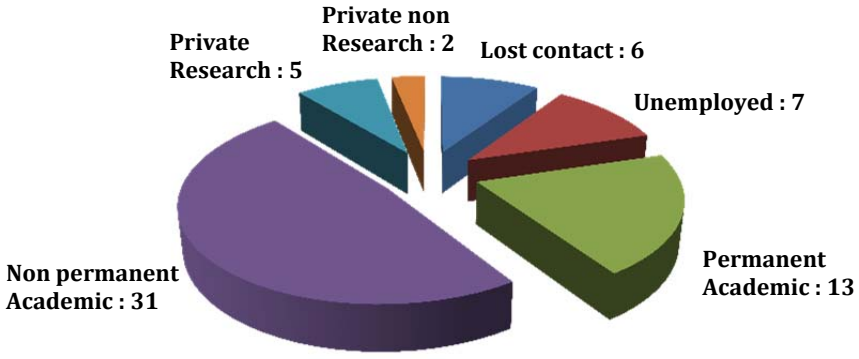
decided to replace all former lighting devices by new LED systems for energy saving purpose (still ongoing)

On the human resources aspects:

- *Help in the career evolution of administrative and technical staff*. Upon her arrival in 2015, our administrative manager proposed to set up a procedure for supporting the non-scientific staff of BPMP in its career evolution. The writing of annual activity reports is supported, and trainings for oral examination during professional selections and contests are proposed. This initiative fills a gap in the strategy of the Unit on these aspects. The general record of promotions of BPMP permanent staff (including scientists) is provided in the table below.

Type of promotion	Number of people promoted	Type of promotion	Number of people promoted
ATP2 >ATP1	1	IE>IR	1
ATP1>TCN	2	IR1>IRHC	1
TCN>TCS	3	CR2>CR1	5
TCS>TCX	1	CRCN>CRHC	4
TC>AI	1	CR>DR2	3
AI>IE	1	DR2>DR1	1
IECN>IEHC	2	MDC>PU	1

- *Mentoring of the non-permanent staff and its fate*. Another clear lack that was identified in BPMP was the absence of formal assisting procedures for the large number of students and non-permanent staff. Many actions that cannot be presented in detail here were undertaken to correct this problem. In brief, we focused our efforts on improving the communication towards this category of staff by organizing mandatory information meetings for all newcomers and dedicated collective meetings with the Direction team. We also initiated a systematic monitoring of the fate of the PhD students, the post-Docs, and the long-term (> 1 year stays) non-permanent technical or administrative assistants. We considered crucial to understand how their work at BPMP helped them to find a job thereafter. The graph below summarizes the current outcome of this monitoring, considering the 64 people who left BPMP between 2014 and 2019. It shows that among the 58 colleagues we have kept contact with, 49 (85%) have presently a job related to research or training in plant sciences (either in public academic institutions such as research organizations or universities, or in private companies). Among the 13 people having a permanent academic position, 2 were recruited at BPMP. Finally, only 7 people are presently unemployed and 2 have a job unrelated to plant sciences.

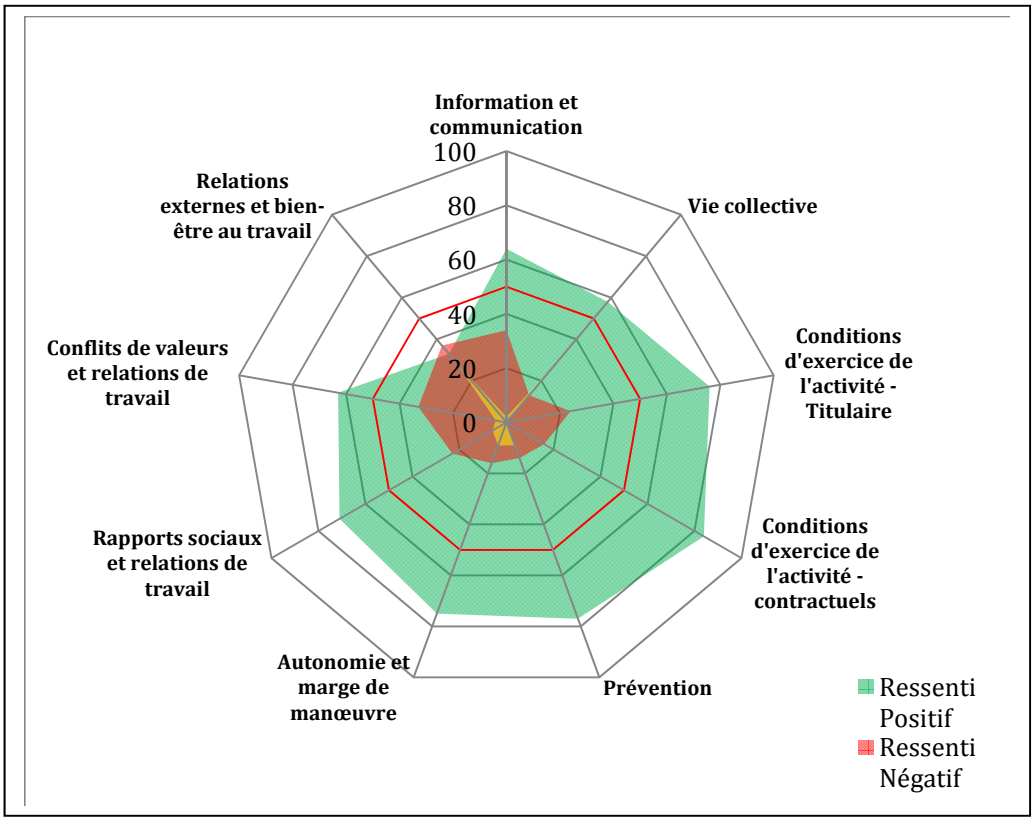


- *Communication strategy*. Another area where significant actions were pursued is the internal and external communication of BPMP. On this aspect, the main event of the period was the total renewal of our Website by a group headed by the Administrative manager, with both extranet (https://www1.montpellier.inra.fr/wp-inra/bpmp/) and intranet pages. We defined a procedure and installed a dedicated team for ensuring a continuous update of the website. We included in the intranet numerous resources, services and applications (agenda, scientific protocols, administrative guidelines, safety information, reports of Councils meetings, room and equipment booking, etc.) that are crucial for running all common facilities and optimizing the work of all staff. In addition, we carried on publishing a weekly electronic information letter, which sorts all the scientific, technological,

administrative and organizational information useful to the whole unit. All the letters (since 2006) are stored on the intranet and can be browsed for a specific topic.

Most importantly, BPMP had a unique opportunity in 2018 to evaluate all aspects of its organization and life. This resulted from the national initiative of INRA to monitor the psychosocial risks and the quality of life in its research units. Since 2016, the various research units of the Montpellier INRA centre are subjected to this action (3-4 units/year). Therefore, all BPMP staff (regardless of his/her employer) was proposed to answer in January 2018 an anonymous survey consisting of more than 100 questions dealing with quality of life and management in the unit. A large majority of BPMP staff (78%) answered the survey, allowing a good feedback evaluation of the Unit.

The graph below shows the synthetic outcome of the survey on the major items investigated. A majority of BPMP staff (between 60 and 80% depending on the items) has a positive judgement (green area) on all items, with the exception of the one dealing with "External" means outside BPMP, mainly at the local administration and employer levels. The latter item somehow reflects that conditions for career evolution are judged unsatisfactory. Concerning information, communication, and collective life, the outcome is also generally positive (around 60% of satisfaction). However, a more refined analysis of the various criteria included in this item (not shown here) indicates that most people in the unit (75%) point out a clear lack of communication and interaction between research teams. This is certainly a consequence of the large scientific independence and functional autonomy of these teams. Of particular interest, the working conditions are judged very good or excellent by all people, especially the non-permanent ones (>80% of satisfaction). This is a strong reward to all BPMP staff that has been involved in supervising the general organization of BPMP, and in particular all people involved in the actions listed above that aimed at improving these working conditions.



The 2018 survey discussed above also led to initiatives for improving social interaction between BPMP teams. Therefore, a "conviviality meeting" open to all is organized every month, following one of our scientific seminars by an external invited scientist. This is an opportunity to further discuss with this scientist, and also to have informal interaction between all BPMP staff. In addition, the 2018 scientific retreat (see below) was an opportunity to propose a more ambitious social program than in previous events. To this end, the Administrative manager applied to the 2018 "Psychosocial risks and quality of life" call for proposals of CNRS,

and obtained specific funding for ensuring what happened to be a unique and unprecedented friendly event (games, cocktail, dinner and party).

Scientific animation

The general scientific animation of BPMP first relies on many exchanges during meetings of the various unit committees or in weekly lab meetings of the teams. It is also promoted by a series of specifically dedicated actions, as listed below.

- *Scientific seminars*. All over the year, scientists are invited to give seminars (in general on Thursdays afternoon). Since 2014, 138 seminars were given (https://www1.montpellier.inra.fr/wp-inra/bpmp/actualites/), mostly from scientists outside BPMP, with a high proportion of them coming from abroad (58%). The vast majority of these seminars are open to the whole Montpellier scientific community. A specific group of people in BPMP (the Seminar Committee) has been handling very efficiently these aspects for more than 10 years (collecting the proposals from the research teams, taking care of the trips and housing of the invited scientists, booking of seminar rooms, advertising the seminars). A special budget is allocated to this Committee (about 10 k€/year on average). Each year, all incoming PhD students are also invited to give in house seminars to present their research project to all BPMP staff.

- *Thematic full-day seminars*. To focus more precisely on specific topics that appear important for the scientific strategy of BPMP, 3 full-day seminars have been organized since 2014. Each of these events included a couple of seminars given by invited external specialists of the chosen topic, several seminars by BPMP scientists, and a round-table for exchange and conclusion. The selected topics were: Cell signaling, Quantitative genetics, and Biotic interactions.

- *Scientific retreats*. These events were held twice during the current contract period (2015 and early 2019). The retreats took place outside of Montpellier and gathered for a couple of days all BPMP staff (BPMP building is closed at this occasion to make sure that everyone will attend the retreat). The main aim is to perform an in-depth exchange on the scientific strategy of the unit. Each event included specific seminars by all teams, and thematic round-tables. The 2015 retreat was designed to allow the new research teams created at that date to present their new projects and have them discussed with all BPMP staff. The 2019 retreat was more specifically devoted to the preparation of the unit's project for 2021-2025.

Parity; scientific integrity; health and safety; sustainable development and environmental impacts; intellectual property and business intelligence.

Parity

With 39 women for 42 men, the parity is almost complete within the permanent staff of BPMP. At the management level, a significant evolution occurred in 2015 following the creation of new research teams. Overall, more women have become team leaders. As a consequence, the current team leaders Committee comprises 6 women (43%) as compared to 3 (30%) in 2014. Finally, recruitments or arrivals of permanent staff since 2014 are almost equilibrated, with 9 men and 8 women.

Scientific integrity

These questions are addressed at two different levels. At the unit level, precise guidelines are given to all new comers concerning handling of lab books, storage and saving of raw data, traceability of all biological materials, etc…This is done by the mean of a "welcome book", and by a mandatory information meeting. At an upper level, all PhD students are requested to follow a specific training on this topic, organized by the Doctoral school.

Health and Safety

The health and safety care is a crucial activity in BPMP. Therefore, it has been decided since 2012 that this should be taken in charge by a strong team of volunteer staff. This team currently comprises 5 people (including radioprotection, see organization chart), who have official letters of assignment validated by the

Director and the four Institutions to which BPMP belongs. As a consequence, the amount of work performed by this team is important, and most aspects of health and safety care are performed at the BPMP level, most often without the support of corresponding services of the Institutions.

The work of this team is guided by precise procedures. First, health and safety rules have been explicitly defined in an annex of our Internal Regulations Statement. Second, we use the INRA system, and in particular the corresponding computer application OPPI (Outil Principal de Pilotage de Prévention de l'INRA), which provides rigorous and comprehensive methods to deal with these problems. The OPPI also generates all relevant warnings when the needed actions are not performed in due time. Third, we have set up our own procedures, which involve: regular meetings between the Safety team and the director (at least 4/year), the elaboration of an annual report and an annual action plan, a dedicated meeting of the Unit Council for discussing this report and action plan, mandatory health and safety information meetings for all incoming staff and student (in French and in English), a mandatory re-education training for all permanent staff (every 4 years), specific documents and clearance procedure for allowing the work out of regular working hours and during week-ends. We also have identified all required financial investments (the overall annual budget is around 10 €/year), and interact with the research campus direction for ensuring safety within the building or relevant medical monitoring of the staff.

Collectively, these team, actions and procedures have proven their efficiency. Fortunately, no serious safety incident has been recorded over 2014-2019, and most importantly, among the main items considered for the psychosocial risks and quality of life survey, health and safety displays the second highest satisfaction score (close to 80%, see figure above). This clearly demonstrates the efficiency of our health and safety team.

Sustainable development

Two main actions towards reducing wastage have been developed since 2014. First, an ambitious energy saving plan has been implemented to replace by LED systems all the lighting devices of our growth chambers (nearly 80 k€ budget). Second, the Technical team has defined very efficient methods for eliminating, through appropriate means, all out of order equipment and of all plastic waste.

Intellectual property and Economic Intelligence

One of the team leaders (C. Curie) is specifically in charge of following BPMP projects with private partners or organizations aiming at supporting innovation (SATT, Pôle de compétitivité). Nevertheless, most of our activity on these topics relies on the support provided by the corresponding services of the institutions to which BPMP belongs (CNRS, INRA, SupAgro, University). In particular, our main focus on basic research does not require that we develop on our own an ambitious and specific Intellectual Property strategy. Also, the rationale governing our partnerships with private companies predominantly relies on their scientific relevance, and not on their potential for generating financial resources. Thus, we did not feel the need for a specific plan for Economic Intelligence. However, our increasing interest in crops as plant models may change these views in the future.

Research Quality Assurance

Significant efforts were devoted to improve our procedures for Research Quality Assurance. Besides actions targeting the research teams (reliability and traceability of genetic resources, seed storage, correct handling of lab books), the dedicated committee conducted an ambitious update on the inventory and monitoring of all technical and scientific equipment (more than 700 items). Furthermore, work on Research Quality Assurance was markedly increased in our platforms and common technological facilities (ISO9001 certifications for MSPP and PHIV, and award of the "Fiabilité des mesures" certification to the stable isotopes analysis facility, see Annex 3). The importance associated with Research Quality Assurance is further illustrated by the recent (2019) reinforcement of the dedicated committee with a full-time administrative assistant (see organization chart above).

1- SWOT analysis

Strengths ✓ A broad expertise in transport and stress physiology and biophysics ✓ A renewed set of research teams ✓ A diversified and upgraded set of equipments and platforms ✓ A good national attractivity and international visibility	***Needs for improvements*** ✓ Integration of biotic and other soil components in plant nutrition ✓ Links with private partners
Opportunities ✓ Diversification of plant models and technological developments for crop studies ✓ Structuration of the Montpellier site (I-*SITE*) ✓ Pressing needs for solutions to climate change	***Threats*** ✓ Uncertainties of fundamental research funding results in large resource variations and heterogeneities between teams ✓ Local policy favoring studies on tropical crops

2- Structure, workforce and scientific orientations

1) WORKFORCE AND COLLECTIVE ORGANIZATION

1) Elaborating the project:

The main lines of the present project were elaborated through several rounds of concertation run over the last 12 months. A first step was, from spring 2018 on, the identification of the future director and management team, based on an intention letter and prospective discussions during a general assembly. A scientific retreat gathering all BPMP staff over 2 days in January 2019 provided a unique opportunity for exchange and strategic reflection. This event included oral presentations of individual team projects, round-tables on six prospective topics, each being prepared and animated by a pair of BPMP scientists, and a plenary discussion of BPMP organization and scientific perspectives. Prior to these discussions, BPMP platforms had presented their activities and perspectives in the frame of weekly seminars. Later on, a series of 5 thematic meetings between group leaders allowed finalizing the strategic orientations described below. The main lines of this project were also presented to the laboratory council in May 2019.

2) Strengths and overall organization

The present project reflects the marked scientific reorganization of BPMP over the last few years. Our laboratory was able to attract external teams (Plasticity, Influx), and let emerge a new generation of internal teams and leaders (HoNuDe, TICeR, KaliPHruit, FeROS). Also, it was agreed that, because of a lack of leader, two former teams (ELSA, Metal Toxicity) would stop their activity, their members being redeployed in other teams. Thus, the BPMP project will be structured around nine scientific teams, the technical organization remaining essentially unchanged (see last paragraph). While the great scientific and budget autonomy of teams ensure their creativity, we will mobilize collective strength on transversal and institutional challenges that go beyond single team objectives.

2) SCIENTIFIC STRATEGY

Plant biology has experienced a continuing revolution over the last decades. Molecular and cellular mechanisms at work throughout plant life can now be described with a great accuracy, mostly in model plant species, and BPMP has contributed to this effort. Also, ever more powerful genomics methods such as deep genomic sequencing, GWAS, and genome editing are now generalized to numerous plant species including major crops. Thus, there is virtually no limitation for developing fundamental mechanistic studies in these species, and explore their biological originality or relevance to applied objectives.

While BPMP was founded nearly 50 years ago, its chance and major challenge have been that its historical research field, the mineral and water nutrition of plants under abiotic constraints, has constantly remained a highly disputed scientific topic. From the beginning, the long-term societal demand directed to research institutes such as ours has been to improve crop yield with a minimal and sustainable use of inputs.

On top of this challenge, climate change has recently been raising increasing emotion and political concerns in our societies. From a biological perspective, climate change exacerbates the

environmental constraints experienced by plants through a primary increase in atmospheric CO_2 and temperature, which in turn induce more extreme climatic events. More unexpectedly, elevated atmospheric CO_2 (eCO_2) and high temperatures alter the plant nutritional status through as yet unknown mechanisms. Thus, in conjunction with a steady rise in human population, climate change puts agriculture and food security under strong pressure.

In view of these pressing challenges, BPMP wants to mobilize its efforts on exploring and proposing solutions to many facets of climate change:
- To secure plant productivity under environmental constraints and degraded environments
- To preserve the nutritional value of plants, and therefore food quality
- To work on solutions for carbon storage in the soil.

For this, our strategy will be to strengthen the exploratory potential of BPMP in fundamental plant biology. Through this, we aim at developing high standard studies in plant biology, using the Arabidopsis thaliana model when it is the most relevant, but with a stronger emphasis on model crops than in the past. Although it is a narrow way, we believe that it is the best strategy to operate a relevant transfer of knowledge from the study of biological mechanisms (our primary mission) to applied objectives (our ultimate contribution).

3) MAIN SCIENTIFIC OBJECTIVES

BPMP has prioritized four major fields of investigation in which significant scientific contributions can be brought during the next years. Note that the long-standing interest and expertise of BPMP teams in membrane transport will underlie and consolidate most of this research.

1) Root functions

Studies on root functions have been and will remain central at BPMP. This research addresses a wide range of topics, mostly investigated through the lens of plant nutrition. These include the mechanisms of water and nutrient uptake and their coordination with adaptive responses of root growth and development to environmental signals (Aqua, HoNuDe, Integration, KaliPHruit, Plasticity). Also, studies on interaction of roots with beneficial (myccorhizae, diazotrophic bacteria) or pathogenic microorganisms will be further developed (TICeR, FeROS). Root growth is also an important target for improving carbon storage in the soil (Integration).

With respect to our previous activities, a specific attention will be brought to specialized root structures and types such as root hairs, cluster roots (lupin), and nodal roots (cereals). On a longer perspective, root functions will have to be considered in relation to the soil. Specific programs on root adaptation to calcareous soils, on the mode of action of bio-fertilizers or on root exudation may be adequate to address these difficult issues.

2) Environmental stress signaling

The mechanisms of environmental signaling will be investigated, both at the cell level and over long-distances, mostly using roots as a model of choice.

First, these studies will address how cells are able to perceive multiple stress-related signals (nutrient or water availability, plant hormones), with complex roles of receptors, membrane transporters or transceptors. These signals (*e.g.* NO_3^-) and the downstream role of various second messengers (H^+, Ca^{2+}, ROS) will be addressed using specific biosensors (Aqua, HoNuDe, Influx, Integration, KaliPHruit, TSF). Understanding how signals are transduced through membrane dynamics with protein complexes being mobilized in nanodomains or endocytic vesicles will also be a key aspect (Aqua, TICER). Signal transduction also involves master protein kinases/phosphatases that are extensively studied by several teams (Aqua, HoNuDe, KaliPHruit, TSF). Our aim will be to understand how these molecular actors serve in the regulation of specific targets such as transcription factors or membrane transport proteins.

Second, long-distance signaling related to water or N availability will be investigated using original split root systems (Aqua, HoNuDe). Multiple types of signals (miRNAs, peptides, major phytohormones, ROS) are potentially involved. Their identification will rely on a fine combination of physiological, transcriptional and genetic analyses.

We note that many of our studies point to a major signaling role of ROS. Because of the generalized involvement of these molecular species in stress responses and nutrient homeostasis, characterization of their function and more generally of the plant redox status will represent a major transverse axis of BPMP research.

3) Genome expression reprogramming

Our aim is to analyze how environmental stimuli induce profound plant transcriptional reprogramming by acting on gene regulatory networks. More than one half of the research teams (Integration,

HoNuDe, FeROS, Plasticity, KaliPHruit, Aqua) develop projects with such questioning, thereby using a set of complementary approaches.

Systems biology, which offers a robust theoretical frame to address these issues, is now more widely used at BPMP. This approach will be further developed by implementing epigenetic and chromatin accessibility data (FeROS, Integration), in addition to more classical gene expression or protein interaction data. Frontline studies on cell-type specific epigenetics and inter-individual expression variability will also be strengthened in the Integration team.

Besides, BPMP will further enhance its capacity to study the function of transcription factors per se. In complement to chromatin interaction studies, specific protein regulation mechanisms that involve post-translational mechanisms (see MSPP platform) or interaction with protein partners with multiple functions (e.g. chromatin remodelers) will be investigated (FeROS, Integration, TSF). These mechanisms can play a key role in linking environmental perception and signaling to the function of master transcriptional regulators.

4) Integrated responses of plants to complex environmental stresses

BPMP teams want to move their focus from plant responses to punctual stresses in simplified experimental systems to a comprehensive analysis of plant stress responses under more realistic contexts.

One first aim of these studies will be to understand how plants can perceive and respond to combined stresses. GWAS and systems biology have proved to be highly efficient for revealing emerging signaling mechanisms and response networks that had been missed in earlier studies and may be of major agronomical importance. A typical context is nutrient stress interaction (Zn vs. P vs. N) which provokes unanticipated responses in Durum wheat and Arabidopsis (HoNuDe). In relation with climate change, BPMP teams will also investigate how high temperature interferes with plant nutrition in calcareous soils (TSF and others).

A second aim will be to analyze integrated responses of plants to complex stresses. One example is how environmental stresses like drought, salinity or high CO_2 alter directly or indirectly the functioning of osmocontractile cells such as stomatal guard cells (Influx TICeR)) or cells determining leaf rolling in cereals (TICeR)). Beyond plant growth, BPMP teams will also investigate the plant nutrient status as it ultimately determines food product quality. Several BPMP teams address the mechanisms that underlie the negative effects of eCO_2 and high temperature on plant nutrient assimilation or grape K^+/pH homeostasis, respectively (Integration, FeROS, KaliPHruit, TSF).

4) SCIENTIFIC AND TECHNICAL APPROACHES

To reach its scientific objectives, BPMP will engage strong efforts in the following approaches.

1) Articulated work on model and cultivated plant species.

In recent years, BPMP has moved from exclusive studies on Arabidopsis to projects on an expanding set of plant species with two main objectives: (1) to explore novel biological systems with questions that cannot be addressed in Arabidopsis, (2) to open new routes to translational biology. Time has come to a more rational and focused planning of such developments with several complementary goals.

(i) The impacts of climate change on plant nutrition as a key target of translational biology approaches. BPMP wants to cover main issues related to drought (Aqua, Plasticity), eCO2 (FeROS, Integration, TSF), and high temperatures (KaliPHruit, TSF). Our aim is to explore solutions to the impacts of these threats on water and nutrient uptake, and their allocation to the edible parts of the plants, using relevant crops (maize, rice, grapevine, tomato), or by parallel studies on model and cultivated plant species (*e.g.* Arabidopsis *vs.* Durum wheat).

(ii) Fundamental and long-term studies in crops potentially leading to new openings in translational biology. Efforts of BPMP in this direction will mostly rely on cereals. The teams will address some specific classes of transporters (HKT; TICeR), their highly differentiated root systems (Aqua), or their pronounced response to composite stresses (HoNuDe).

(iii) Arabidopsis as an intermediate step in translational biology approaches. This approach represents a strength and originality of the BPMP teams. For instance, the Plasticity team would like to introduce cluster roots in new plant species, based on its fundamental work in lupin. Here, Arabidopsis may be used as a model to explore issues related to species barriers. While work by KaliPHruit aims at improving grape quality, this teams routinely establishes the functionality of grapevine K^+ transport systems using Arabidopsis expression.

Because of the important issues and difficulties of these approaches, we have been keen on securing them in large scale projects (ERC HyArchi) or in collective projects ensuring a robust partnership (Flagship Programs CalClim and eCO2THREATS; LabCom SOLSTIS). Overall, sharing efforts and

experience on crops will represent a major axis for future cooperation between teams. After an initial phase of exploration and diversification, our aim would be to constrict the number of crop species investigated at BPMP. Nevertheless, a challenge for the plant growth facility team will be to secure the simultaneous production of plant materials from these species.

2) Interdisciplinary research and method developments

In support of its historical expertise in membrane transport and stress physiology, BPMP will further develop interdisciplinary approaches as a key component of its integrative projects.

(i) Mathematical modelling of solute and water flows, from cellular to organismal levels will represent one first direction. These so-called Functional-structural plant models aim at integrating water flows in root system architecture (Aqua), ion transport between guard cell subcellular compartment (Influx), auxin transport in lateral root primordia (Plasticity, ion loading from phloem to mesocarp or cell wall plasticity, both in grape berry (KaliPHruit).

(ii) Imaging techniques will be used to monitor the water and ionic status of complex organs. For instance, elemental imaging allows to access tissue profiles of iron concentration and speciation (TSF). Several teams will use MRI to monitor the water status of plant tissues in relation to their hydraulic properties (Aqua), local pH (KaliPHruit, Influx) or intracellular NO_3^- and Cl^- (Influx.

(iii) Systems biology will be further developed at BPMP. The discovery power of this approach will be enhanced along two complementary directions (i) improved mathematical analysis based on newly developed machine learning algorithms (HoNuDe) (ii) optimized plant phenotyping to test candidate master-regulators with a high throughput. We believe that BPMP has strong potentialities on the latter point, which will also be instrumental in GWAS. Along these lines, BPMP teams will pursue their efforts in developing new instruments for microfluidics (Integration), pressure chamber techniques (Aqua) or novel microscopic setups (PHIV platform).

Several institutional contexts have been identified for developing these programs: the University of Montpellier and its departments of physics and mathematics and associated LabEx (Numev) offer a privileged environment. Also, INRA has launched a Métaprogramme in Predictive Biology, to which BPMP wishes to contribute. For this, BPMP will have to reinforce its internal strength and organization. This will require the continuing involvement of BPMP researchers in specific interdisciplinary areas together with reinforced partnerships with specialized chemists, physicists and mathematicians. Relevant international collaborations (Chile; CNRS LIA with University of New York) will also be promoted. Finally, we believe that the recruitment of an engineer in computer coding (profile is under discussion) may provide a higher autonomy to the laboratory, and smoother development of projects requiring specific programming.

3) Scientific platforms

These equipments provide a unique competitiveness to BPMP in several main scientific lines of our project.

(i) Root phenotyping. Due to our major focus on roots, we will pursue the development of tools for automated phenotyping, and thereby implement the current HIRROS platform. This will include new device for 2D phenotyping of larger root systems grown on filter paper (PhenoROOT). Image analysis remains a central challenge for tracing the dynamics of root system architecture and monitoring root growth rates. Novel approaches involving machine learning will have to be used. Another challenge for BPMP will be to improve our capacity in root tissular and cellular phenotyping, to track root hairs or lateral or cluster roots under development, for instance. While new imaging equipments may be required, these efforts will open new perspective in functional analysis and genetic screening. The efforts will be developed within a well-identified frame of collaborators specialized in root phenotyping (4PMI, AgroEcology, INRA, Dijon) and we will seek additional support through interdisciplinary CNRS or MUSE programs.

(ii) Imaging. Important challenges in imaging (super-resolution microscopy, biosensor technologies) will require specific efforts. In the latter case, BPMP wants to develop biosensors for ROS and ions (potassium, phosphate, ammonium, nitrate, iron, manganese,...), mostly by expressing in plants sensors, such as ClopH, that have been developed in animals or microorganisms (Influx, KaliPHruit, TSF). Due to the generalization of this approach, it might also be relevant to enhance our local set of instruments for imaging these sensors. Accordingly, a CNRS technician position was requested, to reinforce the PHIV platform and allow its current engineer to spend more time in method developments.

(iii) Mass Spectrometry Proteomic Platform (MSPP): With respect to proteomics, quantitative analyses of protein modifications (phosphorylation, ubiquitination) will remain a major focus. While the potential demand of BPMP teams in proteomics is important, the synergy between these teams and MSPP can still

be improved. Another challenge will be to secure the competiveness of MSPP by renewing its major mass spectrometry instrument in the next two years. A good local positioning within the Montpellier Proteomic Pole (BioCampus)(IBISA calls), but also a support from our national institutions will be crucial.

(iv) Electrophysiology. Based on its robust experience, BPMP aims at further developing in planta measurements, on stomata in particular (Influx, TICeR). A second objective will be to couple electrophysiological and imaging approaches (Influx, TICeR).

(v) Ion and stable isotope analysis. BPMP possesses several key equipment and platforms in this area. For optimization and better visibility at local and national levels, it might be judicious to merge these activities within a common structure. In these respects, and because of an anticipated retirement, the stable isotope analysis activity will need support through a new recruitment. An assistant engineer position has been requested from INRA.

(vi) Bioinformatics. We all face an increasing demand in bioinformatics for analyzing proteomic, chip hybridization, RNAseq or New Generation Sequencing (NGS) data. GWAS also requires specific statistical analysis in relation to complex genotypic data. Due to this increasing and diversified demand, BPMP feels a strong need for better structuring its activities in this field. While some data treatments can be externalized, we will also have to reinforce and continuously adapt our capacity for in house analyses. First, the individual needs of each team and the competencies present in the teams or technical platforms will have to be confronted. Following this step, the training of dedicated staff, and possibly the identification of a new technical recruitment profile and of a dedicated platform can be anticipated.

4) Quality and traceability

A better implementation of these approaches throughout our various activities is important but collectively demanding. First, efforts to better organize our common biological resources and accredit methodological facilities will be pursued. Second, a pragmatic approach will be undertaken using emblematic actions to demonstrate the overall benefits of rational planning and organization of large scale projects (e.g. ERC projects).

5) BPMP IN ITS ENVIRONMENT

Taking into account guidelines of its four institutions, BPMP will articulate its research and teaching activity at various levels

1) To assert the scientific positioning of BPMP within the Montpellier site.

Because of its local policy, our site undoubtedly provides a key level for exploring solutions to climate change from a plant biology perspective. Thus, we will play an active role in scientific animation of local structures such as LabEx Agro, Scientific Department of the University, and the future "Agriculture and Environment" pole of the MUSE I-SITE. Beyond individual team projects, Flagship or collective programs led by BPMP (eCO2THREATS, CalClim) and addressing impacts of climate change on plant production are typical examples of actions to be pursued at this level.

Complementary to this, we will be keen on defending the relevance of our positioning in fundamental plant biology, in both model plants and crops. As in the past, scientific interactions with neighboring laboratories will be instrumental for enlarging the scope of our studies (*e.g.* mathematical modelling, food quality, plant-soil interactions). In particular, the emergence of an Institute of Plant Health in Montpellier may open new cooperation opportunities, within the frame of the LabEx Agro, to develop projects on plant-biotic interactions

Our imaging and proteomic platforms are well-integrated within a multi-institutional technical service consortium (UMS BioCampus), mostly linked to the Medical Biology pole. Yet, the Montpellier site needs a better integration of equipments and platforms that are specific to the Plant Biology and Agronomy community. BPMP is willing to contribute to this evolution by bringing in its centralized and highly visible capacities in root phenotyping, electrophysiology, and ion analyses.

Last but not least, BPMP will pursue its efforts in teaching, at both University of Montpellier and Montpellier SupAgro. Beyond lectures, that are mostly delivered by colleagues from these institutions, all teams can provide a significant offer in research training (Undergraduate and Graduate students). This may be a typical means for reinforcing our links with SupAgro. For now, the positioning of BPMP within the Biology-Agrosciences department is excellent but may be weakened in a few years, due to anticipated retirement of its director (B. Touraine).

2) To contribute to national scientific challenges

At the national level, BPMP will defend its rank in fundamental plant biology and contribute to major challenges carried by the INRA Plant Biology and Breeding section and the CNRS Biological Science

Institute. For instance, BPMP will work at finding an original positioning within the promising area of predictive biology, through a dedicated INRA Metaprogramme for instance. Studies on root functions (phenotyping) and plant responses to multiple stresses also fall with the scientific priorities of INRA. In line with the 4 per 1000 initiative, BPMP is also willing to bring original insights into the links between carbon metabolism and root growth. Finally, several BPMP projects clearly fit with the interdisciplinary research agenda promoted by the CNRS.

3) To defend BPMP international visibility.

As in the past, BPMP wants to bring its research activity at the highest international level. Beyond well-established collaborations in Western countries (Europe, USA), the teams now explore with a special emphasis links with Asia (China, Japan). Beyond research collaborations, student training using dedicated instruments (*e.g.* CSC fellowships) or through our bi-annual summer school MISTRAL will be crucial. Our relations to the South will specifically target Maghreb and Vietnam, and a support from the Labex Agro is anticipated for all these international actions.

4) To enlarge BPMP industrial partnership

BPMP has substantially improved its industrial partnership over the last few years, mostly through bilateral projects (Solvay, Syngenta, SATT AxLR). Yet, its activity in this field needs to be consolidated. One direction is to establish a close partnership between BPMP and a private company using a specific ANR call (LabCom). Contacts have been established with Frayssinet, a company selling organic fertilizers. We are discussing the opportunity of establishing a joint public-private research structure, hosted in our institute, to investigate the mechanisms of biostimulation and the role of soil micro-organisms. Beyond its partnership dimension, this project would fill an obvious scientific gap in our activities and strengthen studies on plant soil-interactions. On a longer term, we anticipate that our reinforced efforts on crops will open new partnership opportunities with private companies.

6) HUMAN RESOURCES AND INTERNAL ORGANIZATION

While scientific programming and local positioning represent major challenges for BPMP future, several internal organization items will also require a specific attention,

1) To consolidate the collective functioning of the unit.

Over the last period, BPMP has developed a robust collective organization. The research teams receive efficient support from two well-organized and autonomous common service teams and from a wide spectrum of technical platforms and facilities. Our economic model, which has been challenged by but resisted to a recent drop in research funding, provides a fine balance between individual team initiatives and collective solidarity. Yet, daily life and harmony between all staff categories require a continuous attention. Special care will be put into the animation of our multiple management committees which address key pillars of our collective activity, such as common equipment and plant health and production. In addition, a strong collective mobilization will be required to pursue our energy saving plan.

2) To handle a steady flow of retirements

Due to inevitable ageing of our staff, we anticipate the retirement of about two scientists and one technical assistant per year over the next five years. Thanks to the scientific dynamics of BPMP, and to its attractivity, this should not impede our scientific dynamics. However, a particular attention should be paid on personals of common facilities (plant growth, laundry) and platforms (stable isotopes). Corresponding positions have already been requested at INRA and CNRS. Our future representation at University of Montpellier and Montpellier SupAgro is also one of our weak points. BPMP will have to be a source of proposals when several professor positions have to be renewed in next years.

3) To secure small team development

Our scientific organization and management have been deeply renewed in recent years but are not fixed. Some teams have pointed to the potential emergence of novel group leaders (A. Martin, H. Rouached). The human strength of these teams and other small size teams (Influx, KaliPHruit) will have to be reinforced by targeted recruitments. We note that the arrival of a young CNRS Research associate (S. Cortijo) in the Integration team already contributes to this dynamics.

Finally, we are aware that soil micro-organisms play a key role in plant nutrition and that BPMP activity in this field requires additional strength. Hosting news colleagues or even a new team on this topic will be a strategic priority.