TECHNICAL SPECIFICATIONS

Article 1 – AUTOMATED CONTROLLED-CONDITION PLANT PHENOTYPING SYSTEM	
General technical description - scope of use	
AUTOMATED CONTROLLED-CONDITION PHENOTYPING SYSTEM for measuring the architecture, biomass, leaf damage, growth rate of the epigeal part and, preferably, photosynthetic efficiency in both the presence and absence of controlled light, humidity and temperature stress conditions for plants with different architectures and heights of between 0 and 130 cm. The system must be fitted with at least two supplementary measurement modules for subsequent functional extension (fluorometers for kinetic chlorophyll fluorescence and hyperspectral measurements).	
System composition and minimum technical characteristics required:	
1) GROWTH CHAMBER	The growth chamber must allow a high-throughput and be fully integrated with the phenotyping system it houses for the growth of at least 45 plants with maximum dimensions of 130 cm (height) x 50 cm (canopy diameter) with accurate and homogeneous light, temperature and relative humidity control. The lighting required must be within the 400-700 nm spectral range provided by LEDs with at least 3 wavelengths (blue, red, far-red), whose relative and absolute intensities must guarantee the optimum growth of a number of plant species. The minimum guaranteed lighting intensity must be 250 micromoles m^{-2} s^{-1} of photons with a maximum variation of +/-10% in relation to effective direct light (excluding reflection) at the maximum distance between work bench and lighting source. The maximum variation between the set lighting values and those measured in a number of points that are representative of the growth area must be specified by the bidder together with the experimental protocol used for the measurements. The growth chamber must guarantee, at full capacity with plants 130 cm tall, the constant maintenance of relative humidity (RH) values set by the user within a minimum range of 50% - 70%, with a maximum tolerated variation of +/- 5% from the set value. Relative humidity (RH) control ranges that are greater (but include the minimum range) and that meet the above specifications will be rated more favourably. The maximum variation between the set RH values and those measured in a number of points that are representative of the growth area must be specified by the bidder together with the experimental protocol used for the measurements. The growth chamber must guarantee, at full capacity with plants 130 cm tall, the constant maintenance of temperature values set by the user within a minimum range of 18°C - 30°C, with a maximum tolerated variation of +/- 5% from the set value. Temperature control ranges that are greater (but include the minimum range) and that meet the above specifications will be rated more favourably. The maximum variation between the set temperature values and those measured in a number of points that are representative of the

	growth area must be specified by the bidder together with the experimental protocol used for the measurements. It must be possible to house the growth chamber in a room measuring 6.5 m x 7.25 m with a height of 3 m, with the possibility of housing certain parts in an adjacent room measuring 4.7 m x 2.27 m with a height of 3 m. It must be possible to interface the growth chamber with the ethylene glycol cooling system present at the installation site.
2) AUTOMATED PLANT TRANSPORTATION SYSTEM	The automated plant transportation system must be housed inside the growth chamber and will be used to transport the plants from the growth area to the measurement area. The automated plant transportation system must be compatible with different pot types suited to holding plants with heights of between 0 cm (rosette plants in the vegetative phase, e.g. *Arabidopsis thaliana*) and 130 cm (including arboreal plants with canopy diameters of up to 50 cm, e.g. vines, apple trees or beech trees). The system must be able to manage and allow the randomisation of at least 45 individual pots of sizes suited to plants with a height of 130 cm or at least 450 pots (including in trays) for smaller plants. The automated plant transportation system must be provided with a built-in reader for the automatic randomised design recognition of pots/trays that is connected to the irrigation, weighing and physiological measurement systems. Bidders must specify the maximum number of individual pots, trays and pots/tray, indicating the system's maximum capacity for each type.
3) AUTOMATED IRRIGATION AND WEIGHING SYSTEM	The automated irrigation and weighing system must be connected to the plant transportation system. It must be able to dispense variable controlled and exact volumes of water and/or other aqueous solutions (e.g. fertiliser, saline or osmolite solutions, etc.). The system must be provided with a reservoir connected by a tap to a running water supply in order to guarantee the possibility of automatic filling or manual filling with aqueous solutions other than water. The system must be flexible enough to permit the automatic irrigation of plants with heights of between 0 cm (rosette plants in the vegetative phase, e.g. *Arabidopsis thaliana*) and 130 cm (arboreal plants with foliage diameters of up to 50 cm, e.g. vines, apple trees or beech trees). The system must be able to manage at least 45 individual pots of sizes suited to plants with a height of up to 130 cm or 450 pots for smaller plants. The irrigation system must be connected with a weighing system able to monitor the irrigation process for gravimetric analyses that allow the application of controlled water stress. The weighing system(s) must be able to perform weighing in the 10g +/-1% to 10000g +/-1% range, in order to be suitable for use with all the plant and pot types indicated above.

4) **VISIBLE LIGHT (RGB) MEASUREMENT MODULE**	The visible light imaging measurement module must be suitable for automatic data acquisition from plants with a height of between 0 cm (rosette plants in the vegetative phase, e.g. *Arabidopsis thaliana*) and 130 cm (including arboreal plants with a foliage diameter of up to 50 cm, e.g. vines, apple trees or beech trees). The system must be able to perform 3D reconstructions of the architecture of the aerial part of the plants (both model plants, such as *Arabidopsis*, and non-model plants, such as vines, apples trees, woodland species). For this purpose, the system must be provided with three digital cameras (in order to acquire images on three planes: from above, from the front and from the side) or, preferably, with at least two digital cameras (image acquisition from above and from the side) connected to a continuous plant rotation system. Each of the digital cameras must have a definition of at least 5 megapixels and a suitable lens and focusing system. It must be possible for the user to programme the time of image acquisition, so that it can be adjusted to suit the species being analysed (in order to avoid acquisition from taking place when parts of the plant are still moving after they enter the measurement module). The system must guarantee the possibility of independent use of the images acquired, and be able to combine the data of multiple images. The measurement module must be provided with a lighting system for the acquisition of RGB images of a quality that is consistent with the processing of the data indicated above and in point (8).
5) **FUNCTION EXTENDIBILITY (KINETIC CHLOROPHYLL FLUORESCENCE IMAGING, HYPERSPECTRAL IMAGING)**	Two modules with no fluorometers must make it possible to extend the functions of the phenotyping system with the addition of i) a PAM system for measuring the kinetics of chlorophyll fluorescence fitted with a pre-adaptation tunnel and ii) a hyperspectral imaging system. The modules must be suitable for automatic data acquisition from plants with a height of between 0 cm (rosette plants in the vegetative phase, e.g. *Arabidopsis thaliana*) and 130 cm (including arboreal plants with a foliage diameter of up to 50 cm, e.g. vines, apple trees or beech trees). The modules must be provided with actinic light with an adjustable intensity of between 0 and at least 1000 micromoles m^{-2} s^{-1} of photons. The modules must be arranged for connection with PAM and hyperspectral fluorometers.
6) **DATA ACQUISITION AND STORAGE SYSTEM**	The data acquisition and storage system must be integrated with all the modules (environmental control, transportation, irrigation and weighing and image acquisition) listed in this phenotyper configuration and any future extension resulting from the addition of further fluorometers (more specifically, PAM and hyperspectral fluorometers). The system must allow graphically, simply and efficiently, the remote management of system settings, alert and malfunction messages by text messages and e-mail and data-logging of the growth chamber, fluorometers, phenotyping, irrigation, weighing and transportation systems, etc. It must also allow, by means of a user-specific authentication and access system, (1) experiment planning, consultation and management;

	(2) the definition of experimental protocols; (3) access to raw data and data at various stages of processing and their complete exportation (database dumping) in open-source formats, as well as any proprietary formats whose specifications shall be provided by the bidder. The data acquisition and storage system must be able to collect and integrate with the measurements of all the other modules and data regarding the experimental design (1) the environmental data (T, RH, lighting and be arranged for any environmental fluorometers that may be added in the future, for example, for CO_2 concentration, etc.); (2) the irrigation and weighing data (and be arranged for any other parts that may be added in the future, such as control of the mixing and dispensing of irrigation solutions, additional scales, etc.); and (3) the RGB imaging data. The data acquisition and storage system must guarantee the storage of both raw data and data at varying stages of processing, in a dedicated database with public or open-source format specifications that make it possible to organise and export in open-source format and any proprietary formats (the specifications of which must be provided by the bidder) all the data relating to each individual plant for each experiment and from different experiments. The system must be fitted with systems that guarantee data storage and integrity, even in the case of malfunctions, such as blackouts, hardware failures, sudden software closure, absence of network connection, etc. The data must be accessible from remote locations using secure protocols that permit simultaneous access to multiple users without multiuser license costs.
7) **DATA ANALYSIS SOFTWARE**	Phenotyping data analysis software must allow the graphic, simple and efficient processing and exportation of the data obtained from each experiment and contained in the database indicated in the previous point. The software must make it possible to consult the acquired images and to automate series of basic image processing operations such as pre-processing, segmentation, extraction and feature classification with state-of-the-art methods. For each analysis/ operation performed, it will be possible to export the intermediate data into individual csv, tsv or similar non-proprietary format files. The software must be able to perform RGB image analysis by calculating/ estimating, for each plant, parameters such as leaf surface area, perimeter, sequential leaf growth rate (including comparative data), greening index, biomass, architecture, growth and foliage development. The software must also be arranged for the measurement of fluorescence parameters (F_v/F_m, $F_v´/F_m´$, Φ_{PSII}, NPQ, q_n, q_p, R_{fd}, ETR) and reflectance parameters (NDVI, PRI, OSAVI, MCARI1 indices), and automatic RGB/fluorescence data integration (in 2D: top view). The software must allow unlimited multiuser access, including from remote locations using secure protocols that permit the simultaneous access of multiple users without multiuser license costs, according to user-specific access permits using an authentication system.

8) **SAFETY SYSTEM**	The phenotyper must be fitted with safety systems that meet CE standards. A remote monitoring and alarm system (text messages, e-mail) and malfunction system for all system software and hardware components (growth chamber, transportation, irrigation, weighing and imaging systems, hardware and software associated with raw and processed data acquisition, storage and back-up, etc.) must guarantee full control of all situations that are potentially hazardous for the system and/or users. In the event of a risk of damage to data, experiments, hardware components or system users, the system must have an immediate and automatic shut-down and cut-off feature. The system must also allow immediate user shut-down/cut-off in the event of necessity and/or a hazard, for example by means of an immediate shut-down sensor or button in the event that a user is confined to an area with moving parts.
9) **BEFORE- AND AFTER-SALES ASSISTANCE**	The successful bidder must guarantee an efficient and all-inclusive before- and after-sales service for the phenotyping system. Once the contract has been concluded, the successful bidder must perform a preliminary inspection of the site where the phenotyper is to be installed, following the designing of the system by the company's experts in order to verify with the FEM engineering department the space, water, electrical and cooling systems, internet connection, etc. The pre-assembly and commissioning of the phenotyper can be performed by the vendor before delivery. The installation and commissioning on FEM premises must be performed by the successful bidder's technicians with documented experience in the sector. The company must indicate the project manager with whom the FEM may liaise when necessary and must provide a plan of the various stages of the project and corresponding time-line, indicating the deadlines for each phase. It also undertakes to provide a progress report for the various stages of the project at regular (monthly) intervals. The full warranty for the whole phenotyping system (hardware and software components) must have a duration of at least 24 months, during which the company must provide remote advice at no extra cost for issues regarding phenotyping activities within 1 working day from the time the user sends a query/assistance request. The company must specify and justify the maximum intervention time following an after-sales assistance request that cannot be managed remotely, having agreed with the client on the trouble-shooting procedure and any related costs. With the exception of cases of *force majeur*, the problem must be resolved within 10 days of the definition with the customer of the trouble-shooting procedure and any related costs. The deadline for complete system delivery and installation and commissioning with a positive outcome on FEM premises must take place within 5 months of the conclusion of the contract. The bidder must guarantee the free and indefinite (unlimited over time) upgrading/ replacement of all system management and data analysis software and the correction of any software bugs. It must also provide a detailed plan (with clear and accurate service explications and characteristic specifications) of: (1) warranty extension; (2) routine maintenance not covered by warranty

	(maintenance of moving and/or airtight parts, calibration of fluorometers, scales, etc.); and (3) extraordinary maintenance not covered by guarantee. Conditions and will constitute an essential part of the bid assessment process.[A1] Please do not specify any type of costs.
10) TRAINING	The bidder must provide flexible on-site basic training courses for users/supervisors in the post-installation phase (for 4-10 participants). It will also repeat the post-installation basic training course for users/ supervisors (timing to be established according to user requirements; for 4 - 10 participants). For both types of training, the company will provide a detailed plan (with clear and exhaustive service explications and characteristic specifications[A2]). The bidder shall guarantee the client will be provided with all the information material available regarding the phenotyping system and all its hardware and software components and will issue and regularly update an advanced user, maintenance, troubleshooting, etc. manual at no additional charge.

DOCUMENT DEVELOPMENT			
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