chemistry proceedings

Proceeding Paper

Use of Radioisotopes to Produce High Yielding Crops in Order to Increase Agricultural Production †

Ayaz Latif Siyal [1,*], Akbar Hossain [2], Fozia Khan Siyal [1], Tahira Jatt [1] and Sadia Iram [3]

1 Department of Botany, Faculty of Natural Sciences, Shah Abdul Latif University, Khaipur 66020, Pakistan; f.asad.siyal@salu.edu.pk (F.K.S.); tahirajatt@gmail.com (T.J.)
2 Department of Agronomy, Bangladesh Wheat and Maize Research Institute, Dinajpur 5200, Bangladesh; akbarhossainwrc@gmail.com
3 School of Natural Sciences, National University of Sciences and Technology, Islamabad 44000, Pakistan; sadia.iram@sns.nust.edu.pk
* Correspondence: latifayazsiyal@gmail.com
† Presented at the 1st International Online Conference on Agriculture—Advances in Agricultural Science and Technology (IOCAG2022), 10–25 February 2022; Available online: https://iocag2022.sciforum.net/.

Abstract: Nuclear technology can play an important role in innovating weapons capabilities and energy. With the use of the influence of radioisotopes, the agricultural sector has made tremendous progress. Fertilizers are used in agriculture to increase soil fertility, thereby increasing crop yields. Radio-isotopes are used to produce high-yield crop seeds to increase agricultural production globally. The use of chemical fertilizers is very expensive; improper use will lead to a waste of money and resources and may cause damage to the environment. Radioisotopes can be applied in a variety of ways to resolve many problems in agricultural production and improve industry efficiency. These applications are particularly important for resource-poor developing countries or regions where water is scarce as a result of drought, and for protecting natural resources while addressing food security challenges. This article will explore how to use radiation to improve plant nutrition in fertilizers and produce seed variants, both of which have created higher efficiency in seed production.

Keywords: radioisotopes; soil fertility; crop productivity; drought-resistant; disease-resistant

Citation: Siyal, A.L.; Hossain, A.; Siyal, F.K.; Jatt, T.; Iram, S. Use of Radioisotopes to Produce High Yielding Crops in Order to Increase Agricultural Production. *Chem. Proc.* **2022**, *10*, 86. https://doi.org/10.3390/IOCAG2022-12267

Academic Editor: Bin Gao

Published: 14 February 2022

1. Introduction

Radioisotopes are isotopes of chemical elements. The production of radioisotopes in the reactor is based on the capture of neutrons in the target material, which is generated by the fission of the target material through activation or thermal neutron bombardment. Radioisotopes are used as research tools to develop new agricultural strains [1]. Drought-resistant, disease-resistant, high-quality, short-growing crops produce higher yields. Radioactive elements emit all kinds of radiation, and energy particles created in the decay process are used in healthcare, agriculture, and sports, and are widely used in science and basic research [2]. Radioactive exposure can improve the quality and productivity of agricultural products with insects, pests and disease management. Radioisotopes can also be used to study soil properties to monitor the emission and utilization of necessary nutrients from soil by plants [3]. Radioisotopes used as labels can be used by scientists to measure the exact nutrient and water requirements of crops under specific conditions. Radiation is used in agriculture for illustration, and radioisotopes and controlled radiation are used to improve food crops [4], preserve food, determine groundwater resources, disinfect medical supplies, analyze hormones, X-ray pipelines, control industrial processes, and study environmental pollution [5]. Radiation is used to make high-performance polymeric materials. Radiation can cause some molecules to cross-link, forming giant molecules with higher heat resistance, chemical resistance, and mechanical properties [5]. The effective use of fertilizers is very important since not only [6] is it an expensive process, but for many countries, this means a lot of foreign currency spending of improper use of fertilizers can cause huge losses and may damage the environment [7]. Therefore, it is essential to the maximum amount of fertilization fertilizer that can enter the plant. Due to improper placement, incorrect timing and other reasons, the minimum was lost [8]. Fertilizers are labeled with radioactive isotopes (for example 32 phosphorus) or stable isotopes. For example, Nitrogen 15, provides a way to determine how much fertilizer has absorbed the damage caused and the damage to the environment. Nitrogen ^{15} can also be provided directly Evaluation of fixed nitrogen content in the field atmosphere condition [9].

Phosphorus^{-32} is used in plant science to track the fertilizer absorption of plants from roots to leaves. When fertilizers labeled with phosphorus 32 are applied to plants in a hydroponic manner or through water in the soil, the amount of phosphorus used can be mapped from the emitted beta radiation [10]. Irradiation can preserve the nutrients in food and kill the microorganisms that destroy them. Preservation technology exposes food to electron beams or gamma rays, a type of high-energy light that is stronger than X-rays used by doctors to take pictures of the inside [11]. Irradiation does not change the appearance or taste of food. Chemical fertilizers are expensive, and improper use can cause water pollution [12]. Therefore, the effective use of fertilizer has attracted the attention of developing and developed countries [13]. It is important to get as much fertilizer as possible into the plants and minimize the damage to the environment. Fertilizers "labeled" with specific isotopes (such as nitrogen 15 or Phosphorus^{-32}) provide a way to find out how much the plant has absorbed and lost, so that fertilizer use can be better managed [14]. Using N-15 can also assess how much nitrogen the root bacteria in the soil and beans have fixed from the air [15].

Recent studies on radioisotopes have also shown that for many crops, supplying plant nutrients through leaves is faster and more effective than applying them in the soil. For example, it has been found that up to 10% of nutrients that are hardly absorbed by the roots can be absorbed up to 90% when applied to leaves [16]. It has been found experimentally that nutrient absorption by leaves not only occurs during the day, but also at night [17]. Although the isotope technology, not only can determine the amount of nutrients absorbed by the plant, but also give people the opportunity to understand the movement of the plant and the location of its accumulation [18]. In plants, most of the radioactive phosphorus has been used in this type of research, and the results show that the nutrient is absorbed faster than expected. Radioisotopes and radiation are used for mutation induction [19]. The mutation is a sudden genetic mutation of the genetic factor organ on the chromosome of an organism. Using radiation to induce genetic variation is a potentially valuable tool in agriculture. We have been able to prove with certainty that radiation can produce changes in genetically modified tissues, and these changes are useful for plant improvement [20].

At present, the application of radioisotopes in agriculture is more extensive than in any other scientific fields, and their applications enable us to solve many agricultural problems more accurately in a shorter time [21]. Therefore, radioisotopes have become an important help for scientists who solve agricultural problems [22]. In addition, radiotracers and energy sources consume become indispensable to all complex agronomic research issues. Radioisotopes and radiation provide us the opportunity to clear away mysterious events that were once in the nutrition and growth of plants and the evolution of new crop varieties [23]. They help us eliminate accidental factors that have adverse effects on plants in different ways. In agriculture [24], radioisotopes are used for the nutritional research of major and minor elements, milk production, and the research of photosynthesis mechanism. Plant protection, plant pathology, the role of pesticides, the absorption of fertilizers, the migration of ions in the soil, and the preservation of plants and food. In order to determine the correct nutrients for plants, we need to know the exact soil-plant relationship and the factors involved [25]. The production of radioisotopes through nuclear reactors and other atomic devices has increased the use of radioisotopes in agriculture. In order to obtain higher yields from the soil by applying fertilizers, one must determine the fertility status of the soil, which seems to be non-productive. Radioactive phosphorus is used in most studies to determine the status of soil P (Figure 1). Through this research, some problems can be solved, such as the comparison of various fertilizers, particle size, placement, application time, dosage, plant absorption and the effect of the applied fertilizer on the soil.

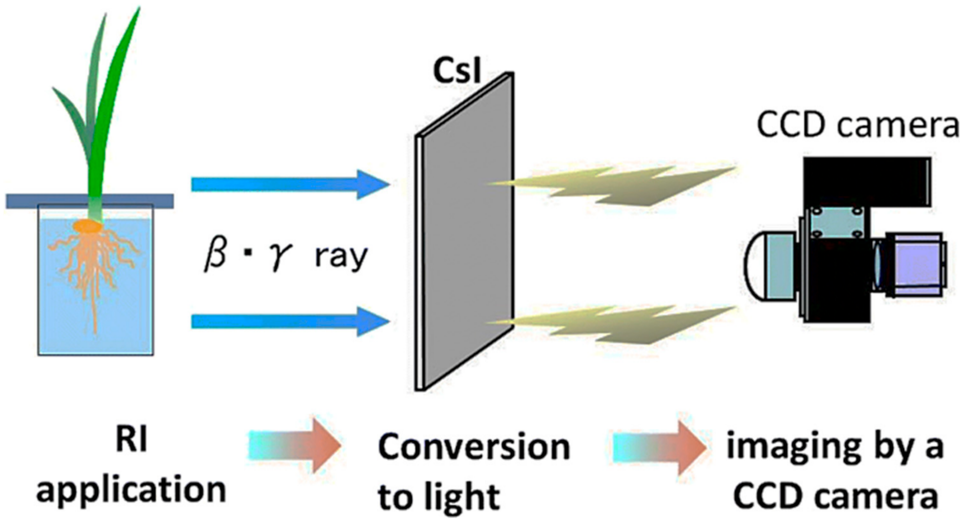

Figure 1. Schematic illustration of the real-time imaging system. After the application of the radioisotopes to the plant, the radiation of the radioisotopes coming out from the plant was converted to light by a scintillator deposited on FOS (Fiber Optic Plate). Then, the light was introduced to a highly sensitive CCD camera to produce the radiation profile image. Since the light intensity is very weak and the sensitivity of the camera is high, initially, everything was kept in dark to protect the camera. Then, a plant box was prepared where only the above-ground part of the plant was illuminated by light and the plant box was sealed tightly to prevent the leakage of light. Now a chamber is prepared and the light was off when the CCD camera is on. Two imaging systems were prepared; one is for macroscopic and microscopic samples. To image an entire plant, from root to shoot, the macroscopic imaging system is used and for microscopic imaging, a modified fluorescent microscope is used to obtain three images simultaneously, light, fluorescent and radioisotope images. This schematic is reproduced from the study by Nakanishi [26].

2. Application of Radioactive Tracers in Agricultural Chemistry

The radioactive materials released by the accident have many direct harmful effects on plants, animals and their environment [27]. In the first two months after the accident, this problem of direct deposition on plants is of the greatest concern since radioactive iodine decomposes rapidly. After the initial stage of sedimentation, a growing concern is the contamination of plants by absorbing radioactive materials such as cesium and strontium from the soil to the roots of the soil [28]. In the first few years after the accident, due to factors such as weathering and decay, the content of radioactive substances in agricultural animals and plants declined rapidly, but the level of radioactivity continued to decline afterwards, but at a slower rate [29]. In order to restore the soil used for cultivation, scientists and farmers are trying to find a way to eliminate radiation in the soil. They used various expensive methods to find a solution to the radioactive problem in areas with high planting rates [30]. The solution is the sunflower plant, which is a super-accumulating plant with an effective mechanism to absorb nutrients, water, minerals and certain radioisotopes (such as strontium and cesium) from the soil. Sunflower is also very attractive since it grows well and can quickly produce large amounts of biomass [31]. Compared with many other crops, it can adapt too many different climates and can grow without much management.

3. Sunflower in Field Extracts Radioisotopes from the Soil

These radioisotopes mimic some of the nutrients normally absorbed by plants. Therefore, plants do not actually distinguish between these radioactive isotopes and some naturally absorbed nutrients in the soil, such as potassium and calcium [32]. The goal is for sunflowers to concentrate the radioactivity in the soil (which is quite low in concentration) to a higher concentration in the plant material. The plant material needs to be treated by transferring specific pollutants or radioisotopes from silica from the soil to the carbon-based substance in the aluminosilicate matrix (difficult to handle) in the soil [33]. This is actually the connection between the sunflower and the discovered nuclear power plant. So far, growing sunflowers is the best solution to remove radioactive isotopes from the soil, but scientists need to find new agricultural techniques to achieve better results. Since radioisotopes act as plant nutrients, strontium is very similar to calcium and is easily absorbed by plants, while cesium acts similar to potassium, which is fixed on soil particles and is difficult to remove from the soil [34]. At the site of the Fukushima nuclear disaster, sunflowers could only remove 0.5% of radioactive cesium from the soil [35]. The role of the sunflower as the most effective and non-invasive means to eliminate nuclear radiation is not yet fully understood, but the inherent prospects and possibilities of plant biology are constantly being revealed. Sunflowers are an international symbol of nuclear disarmament. This is another subtle sign that few gardening activities can change the world. Abnormal isotopes can be used to help understand chemical and biological processes in plants [36]. There are two reasons for this: (1) the radioisotope is chemically the same as other isotopes of the same element and will be replaced in a chemical reaction; (2) the element can be easily detected by a Geiger counter or other similar radioactive form of equipment. Example: Inject a phosphate solution containing radioactive phosphorus 32 into the roots of plants. Since phosphorus 32 behaves the same as phosphorus 31, which is the more common and non-radioactive form of the element, plants use phosphorus 32 in the same way [37]. Then, a Geiger counter was used to detect the movement of radioactive phosphorus 32 throughout the plant. This information helps scientists understand the detailed mechanisms of how plants use phosphorus for growth and reproduction [38].

Radioisotope, also known as radio-isotope, radionuclide or radionuclide, refers to any one of several substances with different masses of the same chemical element, its nuclear is unstable, and spontaneously with α, β and Gamma rays emit energy and dissipate excess energy [39]. Radioisotopes, also known as radioisotopes, radionuclides or radionuclides, are substances of several different qualities of the same chemical element. The nucleus is unstable and passes through α, β, and gamma rays [40]. Each chemical element has one or more radioactive isotopes. For example, hydrogen is the lightest element and has three isotopes with mass numbers 1, 2, and 3. However, only hydrogen 3 (tri) is a radioactive isotope [41]. The other two are stable. More than 1,800 radioactive isotopes of various elements are known. Some of them are found in nature [42]. The rest are artificially produced as direct products of nuclear reactions, or indirectly produced as radioactive offspring of these products. Each "maternal" radioisotope will eventually be decomposed into one or at most several stable isotope "daughters" unique to the parent [43]. There are several sources of radioisotopes. Some radioisotopes exist in the form of ground radiation. For example, the radioactive isotopes of radium, the uranium that naturally occur in rocks and soil. Uranium and or are also present in water [44]. The air is produced by the radioactive decay of radium. Organic materials usually contain small amounts of radiocarbon and potassium [45]. Cosmic radiation from the sun and other stars is the source of background radiation on the earth. Humans also produce other radioisotopes through nuclear reactions, which can lead to unstable combinations of neutrons and protons [46]. One way to artificially induce nuclear trans is to bombard stable isotopes with alpha particles. Here, a brief treatment of radioactive isotopes follows (for full treatment, see isotope: Radioactive isotopes) [47]. Each chemical element has one or more radioactive isotopes. For example, hydrogen, the lightest element, has three isotopes with mass numbers 1, 2, and 3 [48]. However, only hydrogen 3 (tri) is a radioisotope, and the other two are stable. More than 1000 radioactive isotopes of various elements are known. About 50 of them are found in nature. The rest are artificially produced as direct products of nuclear reactions, or indirectly produced as radioactive offspring of these products [49].

4. Radio-isotopic Determining the Function of Fertilizers in Different Plants

This article reviews the principles of tracer technology and its application in agriculture and related sciences [50], involving radioactive counting, synthesis of radiolabeled compounds and their applications in analysis, metabolism and biology [51]. Use in synthesis problems Barley field, which has benefited from the use of fertilizer, is well known and has demonstrated how nuclear technology can play a major role in innovating weapons capabilities and energy [52]. As we all know, thanks to the use of the power of radioisotopes, the agricultural sector has made tremendous progress [53]. In 1964, the United Nations Food and Agriculture Organization (FAO) and the International Atomic Energy Agency (IAEA) established the Joint Department of Atomic Energy for Food and Agriculture. The purpose of this joint department is to coordinate research projects related to the use of isotopes and radiation in the fields of plant breeding, soil fertility, irrigation and crop growth, and chemicals in food. This article will explore how to use radiation to improve plant nutrition in fertilizers and produce seed variants, both of which have created higher efficiency in the industry [54]. Plant nutrition uses fertilizers in agriculture to increase soil fertility, thereby increasing crop yields. The study showed a picture of a large wheat field, which may have produced such high crop yields due to the use of fertilizers [55]. For many countries, the use of fertilizers is very expensive, and incorrect use will result in a waste of money/resources and may damage the environment [56]. Radioisotopes are very useful in estimating the amount of phosphorus and nitrogen available in the soil, which helps determine the amount of phosphate and nitrogen fertilizer that should be applied to the soil [57]. In this process, fertilizers P-32 and N-15 labeled with radioisotopes are used to determine how much fertilizer the plants absorb and lose fertilizer to the environment [58]. The goal is to obtain higher grain yields from chemical fertilizers by optimizing absorption. Radioisotopes can also be used to study the characteristics of the soil to monitor the uptake and use of essential nutrients by plants from the soil [59]. By using radioisotopes as labels, scientists can measure the exact nutrient and water requirements of crops under specific conditions [60]. This is especially useful in drought and water-poor areas.

Another major impact of radiation in agriculture is the use of radiation to induce genetic changes to improve crop variation and mutation breeding [61]. As part of the plant breeding method, a method using radiation-induced genetic changes has been established [62]. By applying a certain dose of gamma rays or neutron irradiation, it is possible to produce mutations, thereby creating crop varieties that are more resistant to disease, tolerate harsh conditions, and that show increased yield and shorter growth time [63]. Approximately 1800 crop plants have been developed through the use of radiation-induced mutations, which is economically important [64]. A successful example is in Hungary, where they tried to develop a new rice variety resistant to rice blast, which is a harmful rice disease [65]. They first tried to test a type of French rice, but due to the different climates between Hungary and France, the French rice was ripened too late in Hungary to obtain the best crop yield [66]. Thousands of these French seeds were irradiated with varying amounts of gamma rays in an attempt to mature early [67]. One variety died three weeks earlier than the non-irradiated female, so the seed was selected for propagation in Hungary. It was released in 1976 and put into commercial use under the trade name Nucleoryza. In conclusion, radioisotopes can be applied in a variety of ways to solve many problems in the agricultural industry and improve industry efficiency [68]. These applications are especially important for resource-poor developing countries or regions (such as California, where water resources are limited due to drought) and for protecting natural resources while responding to food security challenges [69]. Radioactive tracers are substances containing radioactive atoms that can be detected and measured more easily. (Radioactivity is the property of certain elements that spontaneously emit energy in the form of particles or waves through the decomposition of their nuclei) [70]. For example, it is possible to create a water molecule in which one of the two hydrogen atoms is hydrogen. Radioactive tri (hydrogen 3) atom [71]. The behavior of this molecule is almost the same as that of ordinary water molecules [72]. The main difference between tri-containing tracer molecules and normal molecules is that the tracer molecules continuously emit radiation that can be detected by a Geiger counter or some other type of radiation detector [73].

5. Agricultural Applications of Radioactive Tracers

Radioisotopes can be used to help understand chemical and biological processes in plants [74]. A Geiger counter is then used to detect the movement of the radioactive phosphorus-32 throughout the plan, Chromic phosphate P 32 is used to treat cancer or related problems [75]. It is put by catheter into the pleura (sac that contains the lungs) or into the peritoneum (sac that contains the liver, stomach, and intestines) [76] to treat the leaking of fluid inside these areas that is caused by cancer. By utilizing radioactive phosphorus researchers have prevailed in recognizing soil phosphorus and manure phosphorus taken by plants [77]. Radioisotopes such as Fe, Mn, K, Ca, N, Rb, C, Cs, Si, Sr, and other large-scale and miniature components have additionally been utilized by laborers to discover their development in various sorts of soils and furthermore their situation in various parts of the world [78]. The radioisotope technique is entirely dependable and supportive in deciding the richness level of soil [79]. Hence, the use of radioactive components in horticulture has gotten enormous significance in deciphering specific parts of soil richness and other many-sided issues [80,81]. Radioisotopes have likewise helped the examination of the impact of such factors as development, water system techniques and time on the root arrangement of plants [82]. Ongoing investigations with radioisotopes have likewise shown that with many harvests, the supply of plant supplements through the leaves is more speedy and compelling than the application in soil [83]. For instance, it has been found that a supplement, which is not really retained up to 10% by root, can be consumed up to 90% when applied on leaves [84]. Tentatively, it has been observed that the ingestion of supplements by leaves happens during the day time as well as in the evening time [85]. Through isotope procedure it is conceivable not exclusively to decide the measure of supplements that are taken by plants, it offers the chance to be aware of their development and their places of amassing [86]. In plants, for the most part, radio-phosphorus has been utilized for this sort of examination work and the outcomes have shown that the retention speed of this supplement was more than normal [87]. Radioisotopes and radiation is utilized in transformation acceptance. Transformation is an abrupt heritage [88] change of the genetic elements and organs on the chromosomes of the life forms [89]. The work of radiation to actuate genetic variations is a helpful apparatus of likely worth in horticulture [90]. We have had the option to show convincingly that [91], radiation changes can be achieved in the association of the inherited make-up that is helpful in plant improvement [92,93]. Radioisotopes and ionizing radiations are incalculable incentives for acquiring knowledge into biological propensities for bugs [94]. With the guidance of radioisotopes, we can discover populace thickness the development rate during various phases of the existence cycle, methods of dispersal, development and movement, flight range sleeping spots, egg living destinations connected to hunters, parasites, taking care of mating propensities and infection transmission and so on [95]. Ongoing examinations on radioisotopes have additionally shown that for some, crops, providing plant supplements through leaves is quicker and more compelling than applying them in the dirt [96]. For instance, it has been determined that up to 10% of supplements that are not really consumed by the roots can be assimilated up to 90% when applied to leaves [97]. It has been found tentatively that supplement ingestion by leaves happens during the day, yet in addition around evening time [98]. Through isotope innovation, not exclusively can decide the measure of supplements consumed by plants, yet additionally offer individuals the chance to comprehend the development of plants and the area of their gathering [99,100]. In plants, a large portion of the radioactive phosphorus has been utilized in this sort of examination [101], and the outcomes show that the supplement is ingested quicker than anticipated. Radioisotopes and radiation are utilized for change enlistment [102]. Change is an abrupt hereditary transformation of the hereditary variable organ on the chromosome of a creature [103,104].

Utilizing radiation to prompt hereditary variety is a possibility [105], significant apparatus in the table records some normally happening radioactive isotopes [106].

Author Contributions: Conceptualization, A.L.S.; resources and validation, F.K.S.; T.J.; formal analysis, S.I.; writing—review and editing, A.H., A.L.S. All authors have read and agreed to the published version of the manuscript.

Funding: This work did not receive any funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Most of the data are available in all Tables and Figures of the manuscripts.

Conflicts of Interest: The authors declare that there is no conflict of interest in the article.

References

1. Belchenko, S.A.; Torikov, V.E.; Shapovalov, V.F.; Belous, I.N.; Dronov, A. Technology of cultivation of fodder crops in conditions of radioactive contamination and their impact on the content of heavy metals and cesium-137. *Bull. Bryansk State Agric. Acad.* **2016**, *2*, 58–67.
2. Shpakov, A.S.; Bychkov, G. Field feed production, the state and tasks of scientific support. *Feed Prod.* **2010**, *10*, 3–9.
3. Pan, B.; Lam, S.K.; Mosier, A.; Luo, Y.; Chen, D. Ammonia volatilization from synthetic fertilizers and its mitigation strategies: A global synthesis. *Agric. Ecosyst. Environ.* **2016**, *232*, 283–289. [CrossRef]
4. Adhikari, T.; Gowda, R.C.; Wanjari, R.H.; Singh, M. Impact of Continuous Fertilization on Heavy Metals Content in Soil and Food Grains under 25 Years of Long-Term Fertilizer Experiment. *Commun. Soil Sci. Plant Anal.* **2020**, *52*, 389–405. [CrossRef]
5. Wang, B.; Chu, C.; Wei, H.; Zhang, L.; Ahmad, Z.; Wu, S.; Xie, B. Ameliorative effects of silicon fertilizer on soil bacterial community and pakchoi (*Brassica chinensis* L.) grown on soil contaminated with multiple heavy metals. *Environ. Pollut.* **2020**, *267*, 115411. [CrossRef] [PubMed]
6. Mahesh, M.; Thomas, J.; Kumar, K.A.; Bhople, B.S.; Saresh, N.V.; Vaid, S.K.; Sahu, S.K. Zeolite farming: A sustainable agricultural prospective. *IJCMAS* **2018**, *7*, 2912–2924. [CrossRef]
7. Nakhli, S.A.A.; Delkash, M.; Bakhshayesh, B.E.; Kazemian, H. Application of zeolites for sustainable agriculture: A review on water and nutrient retention. *Water Air Soil Pollut.* **2017**, *228*, 464. [CrossRef]
8. Siyal, A.L.; Fozia, K.S.; Tahira, J. Yield from genetic variability of bread wheat (*Triticum aestivum* L.) genotypes under water stress condition: A case study of Tandojam, Sindh. *Pure Appl. Biol.* **2021**, *10*, 841–860. [CrossRef]
9. Ren, X.; Xiao, L.; Qu, R.; Liu, S.; Ye, D.; Song, H.; Wu, W.; Zheng, C.; Wu, X.; Gao, X. Synthesis and characterization of a single phase zeolite A using coal fly ash. *RSC Adv.* **2018**, *8*, 42200–42209. [CrossRef]
10. Doni, S.; Gispert, M.; Peruzzi, E.; Macci, C.; Mattii, G.B.; Manzi, D.; Masini, C.M.; Grazia, M. Impact of natural zeolite on chemical and biochemical properties of vineyard soils. *Soil Use Manag.* **2020**, *37*, 832–842. [CrossRef]
11. Zwolak, A.; Sarzyńska, M.; Szpyrka, E.; Stawarczyk, K. Sources of soil pollution by heavy metals and their accumulation in vegetables: A review. *Water Air Soil Pollut.* **2019**, *230*, 164. [CrossRef]
12. Gholamhoseini, M.; Ghalavand, A.; Khodaei-Joghan, A.; Dolatabadian, A.; Zakikhani, H.; Farmanbar, E. Zeolite-amended cattle manure effects on sunflower yield, seed quality, water use efficiency and nutrient leaching. *Soil Till. Res.* **2013**, *126*, 193–202. [CrossRef]
13. Chen, T.; Wilson, L.T.; Liang, Q.; Xia, G.; Chen, W.; Chi, D. Influences of irrigation, nitrogen and zeolite management on the physicochemical properties of rice. *Arch. Agron. Soil Sci.* **2017**, *63*, 1210–1226. [CrossRef]
14. Sun, Y.; He, Z.; Wu, Q.; Zheng, J.; Li, Y.; Wang, Y.; Chen, T.; Chi, D. Zeolite amendment enhances rice production, nitrogen accumulation and translocation in wetting and drying irrigation paddy field. *Agric. Water Manag.* **2020**, *235*, 106126. [CrossRef]
15. Awasthi, M.K.; Wang, Q.; Ren, X.; Zhao, J.; Huang, H.; Awasthi, S.K.; Lahori, A.H.; Li, R.; Zhou, L.; Zhang, Z. Role of biochar amendment in mitigation of nitrogen loss and greenhouse gas emission during sewage sludge composting. *Bioresour. Technol.* **2016**, *219*, 270–280. [CrossRef] [PubMed]
16. Wang, Q.; Awasthi, M.K.; Ren, X.; Zhao, J.; Li, R.; Wang, Z.; Wang, M.; Chen, H.; Zhang, Z. Combining biochar, zeolite and wood vinegar for composting of pig manure: The effect on greenhouse gas emission and nitrogen conservation. *Waste Manag.* **2018**, *74*, 221–230. [CrossRef]
17. Floros, G.D.; Kokkari, A.I.; Kouloussis, N.A.; Kantiranis, N.A.; Damos, P.; Filippidis, A.A.; Koveos, D.S. Evaluation of the natural zeolite lethal effects on adults of the bean weevil under different temperatures and relative humidity regimes. *J. Econ. Entomol.* **2018**, *111*, 482–490. [CrossRef]
18. Siyal, A.L.; Ali, G.C.; Nasiruddin, S.; Jay, K.S.; Tahira, J.; Fozia, K.S.; Muhammad, S.C. Screening of Wheat Genotypes for Morphological, Physiological and Phenological Traits under Climatic Condition. *Eur. J. Biol. Biotechnol.* **2021**, *2*, 87–91. [CrossRef]
19. Stavi, I.; Rahamim, S.; Gidon, R.; Judith, L. Ancient to Recent-Past Runoff Harvesting Agriculture in Recharge Playas of the Hyper-Arid Southern Israel. *Water* **2017**, *9*, 991. [CrossRef]

20. Arnáez, J.; Lana-Renault, N.; Lasanta, T.; Ruiz-Flaño, P.; Castroviejo, J. Effects of farming terraces on hydrological and geomorphological processes. A review. *Catena* **2015**, *128*, 122–134. [CrossRef]
21. Kosmowski, F. Soil water management practices (terraces) helped to mitigate the 2015 drought in Ethiopia. *Agric. Water Manag.* **2018**, *204*, 11–16. [CrossRef] [PubMed]
22. Wen, Y.; Kasielke, T.; Li, H.; Zhang, B.; Zepp, H. May agricultural terraces induce gully erosion? A case study from the Black soil region of northeast China. *Sci. Total Environ.* **2020**, *750*, 141715. [CrossRef] [PubMed]
23. Sabir, M. The Terraces of the Anti-Atlas: From Abandonment to the Risk of Degradation of a Landscape Heritage. *Water* **2021**, *13*, 510. [CrossRef]
24. Brandolini, P.; Cevasco, A.; Capolongo, D.; Pepe, G.; Lovergine, F.; Del Monte, M. Response of Terraced Slopes to a Very Intense Rainfall Event and Relationships with Land Abandonment: A Case Study from Cinque Terre (Italy). *Land Degrad. Dev.* **2017**, *29*, 630–642. [CrossRef]
25. Gao, Y.; Ma, M.; Yang, T.; Chen, W.; Yang, T. Global atmospheric sulfur deposition and associated impaction on nitrogen cycling in ecosystems. *J. Clean. Prod.* **2018**, *195*, 1–9. [CrossRef]
26. Nakanishi, T.M. What you can see by developing real-time radioisotope imaging system for plants: From water to element and CO_2 gas imaging. *J. Radioanal. Nucl. Chem.* **2018**, *318*, 1689–1695. [CrossRef] [PubMed]
27. Vermien, C.; Smolder, R.; McLaughlin, M.J.; Degryse, F. Model-based rationalization of sulphur mineralization in soils using 35S isotope dilution. *Soil Biol. Biochem.* **2018**, *120*, 1–11. [CrossRef]
28. Carciochi, W.D.; Divito, G.A.; Fernández, L.A.; Echeverría, H.E. Sulfur affects root growth and improves nitrogen recovery and internal efficiency in wheat. *J. Plant Nutr.* **2017**, *40*, 1231–1242. [CrossRef]
29. Gourav, N.K.S.; Shrama, R.P.; Sharma, G.D. Vertical distribution of sulfur fractions in a continuously fertilized acid alfisol under maize-wheat cropping system. *Commun. Soil Sci. Plant Anal.* **2018**, *49*, 923–933.
30. Sedlář, O.; Balík, J.; Kulhánek, M.; Černý, J.; Matěchová, M.; Suran, P. Crop sulfur status in relation to soil sulfur determined using anion exchange membranes and Mehlich 3. *J. Plant Nutr.* **2021**, *44*, 1563–1570.
31. Balík, J.; Kulhánek, M.; Černý, J.; Sedlář, O.; Suran, P. Soil organic matter degradation in long-term maize cultivation and insufficient organic fertilization. *Plants* **2020**, *9*, 1217. [CrossRef] [PubMed]
32. Sharma, M.K.; Kumar, M. Sulphate contamination in groundwater and its remediation: An overview. *Environ. Monit. Assess.* **2020**, *192*, 74. [CrossRef] [PubMed]
33. Goswami, D.; Thakker, J.N.; Dhandhukia, P.C. Portraying mechanics of plant growth promoting rhizobacteria (PGPR): A review. *Null* **2016**, *2*, 1127500. [CrossRef]
34. Backer, R.; Rokem, J.S.; Ilangumaran, G.; Lamont, J.; Praslickova, D.; Ricci, E.; Subramanian, S.; Smith, D.L. Plant growth-promoting rhizobacteria: Context, mechanisms of action, and roadmap to commercialization of biostimulants for sustainable agriculture. *Front. Plant Sci.* **2018**, *9*, 1473. [CrossRef] [PubMed]
35. Siyal, A.L. Effect of bio fertilizer in addition with phosphorus on the growth of maize (*zea mays* L.). *Intern. J. Adv. Res.* **2017**, *5*, 527–532. [CrossRef]
36. Housh, A.B.; Powell, G.; Scott, S.; Anstaett, A.; Gerheart, A.; Benoit, M.; Waller, S.; Powell, A.; Guthrie, J.M.; Higgins, B.; et al. Functional mutants of *Azospirillum brasilense* elicit beneficial physiological and metabolic responses in *Zea mays* contributing to increased host iron assimilation. *ISME J.* **2021**, *15*, 1505–1522. [CrossRef] [PubMed]
37. Zhang, X.; Kong, X.; Zhou, R.; Zhang, Z.; Zhang, J.; Wang, L.; Wang, Q. Harnessing perennial and indeterminant growth habits for ratoon cotton (Gossypium spp.) cropping. *Ecosyst. Health Sustain.* **2020**, *6*, 1715264. [CrossRef]
38. Sarfraz, Z.; Iqbal, M.S.; Pan, Z.; Jia, Y.; He, S.; Wang, Q.; Qin, H.; Liu, J.; Liu, H.; Yang, J.; et al. Integration of conventional and advanced molecular tools to track footprints of heterosis in cotton. *BMC Genom.* **2018**, *19*, 776. [CrossRef] [PubMed]
39. Veres, A.; Wyckhuys, K.A.; Kiss, J.; Tóth, F.; Burgio, G.; Pons, X.; Avilla, C.; Vidal, S.; Razinger, J.; Bazok, R. An update of the Worldwide Integrated Assessment (WIA) on systemic pesticides. Part 4: Alternatives in major cropping systems. *Environ. Sci. Pollut. Res.* **2020**, *27*, 29867–29899. [CrossRef]
40. Siyal, A.L.; Toheed, G.M.; Fawad, S.; Fozia, K.S.; Tahira, J.; Fida, H.M.; Nasiruddin, S.; Imtiaz, H.B.; Akbar, H. Climate Change: Impacts on the Production of Cotton in Pakistan. *Eur. J. Agric. Food Sci.* **2021**, *3*, 97–100. [CrossRef]
41. Kamunda, C.; Mathuthu, M.; Madhuku, M. An Assessment of Radiological Hazards from Gold Mine Tailings in the Province of Gauteng in South Africa. *Int. J. Environ. Res. Public Health* **2016**, *13*, 138. [CrossRef] [PubMed]
42. Winde, F.; Wade, P.; van der Walt, I.J. Gold tailings as a source of waterborne uranium contamination of streams—The Koekemoerspruit (Klerksdorp goldfield, South Africa) as a case study. Part 1: Uranium migration along the aqueous pathway. *Water SA* **2004**, *30*, 219–226. [CrossRef]
43. Winde, F.; Stoch, E.J. Threats and opportunities for post-closure development in dolomitic gold mining areas of the West Rand and Far West Rand—A hydraulic view Part 3: Planning and uncertainty—Lessons from history. *Water SA* **2010**, *36*, 83–88. [CrossRef]
44. Tufail, M. Radium equivalent activity in the light of UNSCEAR report. *Environ. Monit. Assess.* **2012**, *184*, 5663–5667. [CrossRef] [PubMed]
45. Cai, Y.; Kim, E. Sustainable Development in World Trade Law: Application of the Precautionary Principle in Korea-Radionuclides. *Sustainability* **2019**, *11*, 1942. [CrossRef]
46. Aseeva, A. (Un) Sustainable Development (s) in International Economic Law: A Quest for Sustainability. *Sustainability* **2018**, *10*, 4022. [CrossRef]

47. Tedsen, E.; Homann, G. Implementing the Precautionary Principle for Climate Engineering. *Carbon Clim. Law Rev.* **2013**, *7*, 90–100. [CrossRef]
48. Wagner, M. Taking Interdependence Seriously: The Need for a Reassessment of the Precautionary Principle in International Trade Law. *Cardozo J. Int. Comp. Law* **2011**, *20*, 713–769.
49. Morris, M. The Precautionary Principle: Good for Environmental Activists, Bad for Business. *J. Bus. Adm.* **2010**, *9*, 1–24.
50. Ansari, A.H.; Wartini, S. Application of Precautionary Principle in International Trade Law and International Environmental Law: A Comparative Assessment. *J. Int. Trade Law Policy* **2014**, *13*, 19–43. [CrossRef]
51. Fattore, C. Interest Group Influence on WTO Dispute Behaviour: A Test of State Commitment. *J. World Trade* **2012**, *46*, 1261–1280. [CrossRef]
52. Mba, C. Induced Mutations Unleash the Potentials of Plant Genetic Resources for Food and Agriculture. *Agronomy* **2013**, *3*, 200–231. [CrossRef]
53. Tester, M.; Langridge, P. Breeding technologies to increase crop production in a changing world. *Science* **2010**, *327*, 818–822. [CrossRef]
54. Hertel, T.W.; Burke, M.B.; Lobell, D.B. The poverty implications of climate-induced crop yield changes by 2030. *Glob. Environ. Change* **2010**, *20*, 577–585. [CrossRef]
55. McCouch, S. Diversifying selection in plant breeding. *PLoS Biol.* **2004**, *2*, 1507–1512. [CrossRef]
56. Mba, C.; Guimaraes, P.; Ghosh, K. Re-orienting crop improvement for the changing climatic conditions of the 21st century. *Agric. Food Secur.* **2012**, *1*, 7. [CrossRef]
57. Till, B.J.; Jankowicz-Cieslak, J.; Sagi, L.; Huynh, O.A.; Utsushi, H.; Swennen, R.; Terauchi, R.; Mba, C. Discovery of nucleotide polymorphisms in the Musa gene pool by Ecotilling. *Theor. Appl. Genet.* **2010**, *121*, 1381–1389. [CrossRef]
58. Sai, H.; Howell, T.; Nitcher, R.; Missirian, V.; Watson, B.; Ngo, K.J.; Lieberman, M.; Fass, J.; Uauy, C.; Tran, R.K.; et al. Discovery of Rare Mutations in Populations: TILLING by Sequencing. *Plant Physiol.* **2011**, *156*, 1257–1268. [CrossRef]
59. Uccelli, L.; Martini, P.; Cittanti, C.; Carnevale, A.; Missiroli, L.; Giganti, M.; Bartolomei, M.; Boschi, A. Therapeutic Radiometals: Worldwide Scientific Literature Trend Analysis (2008–2018). *Molecules* **2019**, *24*, 640. [CrossRef] [PubMed]
60. McDevitt, M.R.; Sgouros, G.; Sofou, S. Targeted and Nontargeted α-Particle Therapies. *Annu. Rev. Biomed. Eng.* **2018**, *20*, 73–93. [CrossRef] [PubMed]
61. Qaim, S.M.; Spahn, I. Development of novel radionuclides for medical applications. *J. Label. Comp. Radiopharm.* **2018**, *61*, 126–140. [CrossRef] [PubMed]
62. Müller, C.; Van der Meulen, N.P.; Benešová, M.; Schibli, R. Therapeutic Radiometals Beyond 177Lu and 90Y: Production and Application of Promising alpha-Particle, beta-Particle, and Auger Electron Emitters. *J. Nucl. Med.* **2017**, *58*, 91S–96S. [CrossRef]
63. Aghevlian, S.; Boyle, A.J.; Reilly, R.M. Radioimmunotherapy of cancer with high linear energy transfer (LET) radiation delivered by radionuclides emitting α-particles or Auger electrons. *Adv. Drug Deliv. Rev.* **2017**, *109*, 102–118. [CrossRef] [PubMed]
64. Osanai, M.; Hirano, D.; Mitsuhashi, S.; Kudo, K.; Hosokawa, S.; Tsushima, M.; Iwaoka, K.; Yamaguchi, I.; Tsujiguchi, T.; Hosoda, M.; et al. Estimation of Effect of Radiation Dose Reduction for Internal Exposure by Food Regulations under the Current Criteria for Radionuclides in Foodstuff in Japan Using Monitoring Results. *Foods* **2021**, *10*, 691. [CrossRef] [PubMed]
65. Hamada, N.; Ogino, H.; Fujimichi, Y. Safety regulations of food and water implemented in the first year following the Fukushima nuclear accident. *J. Radiat. Res.* **2012**, *53*, 641–671. [CrossRef]
66. Irving, L.J. Carbon Assimilation, Biomass Partitioning and Productivity in Grasses. *Agriculture* **2015**, *5*, 1116–1134. [CrossRef]
67. Poorter, H.; Niklas, K.J.; Reich, P.B.; Oleksyn, J.; Poot, P.; Mommer, L. Biomass allocation to leaves, stems and roots: Meta-analysis of interspecific variation and environmental control. *New Phytol.* **2012**, *193*, 30–50. [CrossRef] [PubMed]
68. Myers, S.S.; Zanobetti, A.; Kloog, I.; Huybers, P.; Leakey, A.D.B.; Bloom, A.J.; Carlisle, E.; Dietterich, L.H.; Fitzgerald, G.; Hasegawa, T.; et al. Increasing CO_2 threatens human nutrition. *Nature* **2014**, *510*, 139–142. [CrossRef] [PubMed]
69. Studer, R.A.; Christin, P.A.; Williams, M.A.; Orengo, C.A. Stability-activity tradeoffs constrain the adaptive evolution of RubisCO. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 2223–2228. [CrossRef] [PubMed]
70. Sudo, E.; Suzuki, Y.; Makino, A. Whole plant growth and N utilization in transgenic rice plants with increased or decreased Rubisco content under different CO_2 partial pressures. *Plant Cell Physiol.* **2014**, *55*, 1905–1911. [CrossRef] [PubMed]
71. Khaembah, E.N.; Irving, L.J.; Thom, E.R.; Faville, M.J.; Easton, H.S.; Matthew, C. Leaf Rubisco turnover in a perennial ryegrass (*Lolium perenne* L.) mapping population: Genetic variation, identification of associated QTL, and correlation with plant morphology and yield. *J. Exp. Bot.* **2013**, *64*, 1305–1316. [CrossRef] [PubMed]
72. Gelbart, W.Z.; Johnson, R.R. Molybdenum Sinter-Cladding of Solid Radioisotope Targets. *Instruments* **2019**, *3*, 11. [CrossRef]
73. Stolarz, A.; Kowalska, J.A.; Jasinski, P.; Janiak, T.; Samorajczyk, J. Molybdenum targets produced by mechanical reshaping. *J. Radioanal. Nucl. Chem.* **2015**, *305*, 947–952. [CrossRef] [PubMed]
74. Stolarz, A. Target preparation for research with charged projectiles. *J. Radioanal. Nucl. Chem.* **2014**, *299*, 913–931. [CrossRef] [PubMed]
75. Bénard, F.; Buckley, K.R.; Ruth, T.J.; Zeisler, S.K.; Klug, J.; Hanemaayer, V.; Vuckovic, M.; Hou, X.; Celler, A.; Appiah, J.P.; et al. Implementation of Multi-Curie Production of ^{99m}Tc by Conventional Medical Cyclotrons. *J. Nucl. Med.* **2014**, *55*, 1017–1022. [CrossRef]
76. Sklairova, H.; Cisterno, S.; Cicoria, G.; Marengo, M.; Palmieri, V. Innovative Target for Production of Technetium-99m by Biomedical Cyclotron. *Molecules* **2019**, *24*, 25. [CrossRef] [PubMed]

77. Matei, L.; McRae, G.; Galea, R.; Niculae, D.; Craciun, L.; Leonte, R.; Surette, G.; Langille, S.; St. Louis, C.; Gelbart, W.; et al. A new approach for manufacturing and processing targets used to produce ^{99m}Tc with cyclotrons. *Mod. Phys. Lett. A* **2017**, *32*, 1740011. [CrossRef]
78. Braccini, S.; Alves, F. Special Issue "Instruments and Methods for Cyclotron Produced Radioisotopes". *Instruments* **2019**, *3*, 60. [CrossRef]
79. Kreller, M.; Pietzsch, H.J.; Walther, M.; Tietze, H.; Kaever, P.; Knieß, T.; Füchtner, F.; Steinbach, J.; Preusche, S. Introduction of the New Center for Radiopharmaceutical Cancer Research at Helmholtz-Zentrum Dresden-Rossendorf. *Instruments* **2019**, *3*, 9. [CrossRef]
80. Nesteruk, K.P.; Ramseyer, L.; Carzaniga, T.S.; Braccini, S. Measurement of the Beam Energy Distribution of a Medical Cyclotron with a Multi-Leaf Faraday Cup. *Instruments* **2019**, *3*, 4. [CrossRef]
81. Do Carmo, S.J.; de Oliveira, P.M.; Alves, F. Simple, Immediate and Calibration-Free Cyclotron Proton Beam Energy Determination Using Commercial Targets. *Instruments* **2019**, *3*, 20. [CrossRef]
82. Steyn, G.F.; Anthony, L.S.; Azaiez, F.; Baard, S.; Bark, R.A.; Barnard, A.H.; Beukes, P.; Broodryk, J.I.; Conradie, J.L.; Cornell, J.C.; et al. Development of New Target Stations for the South African Isotope Facility. *Instruments* **2018**, *2*, 29. [CrossRef]
83. Sitarz, M.; Jastrzębski, J.; Haddad, F.; Matulewicz, T.; Szkliniarz, K.; Zipper, W. Can We Extract Production Cross-Sections from Thick Target Yield Measurements? A Case Study Using Scandium Radioisotopes. *Instruments* **2019**, *3*, 29. [CrossRef]
84. Vaudon, J.; Frealle, L.; Audiger, G.; Dutillly, E.; Gervais, M.; Sursin, E.; Ruggeri, C.; Duval, F.; Bouchetou, M.L.; Bombard, A.; et al. First Steps at the Cyclotron of Orléans in the Radiochemistry of Radiometals: 52Mn and 165Er. *Instruments* **2018**, *2*, 15. [CrossRef]
85. Costa, P.; Metello, L.F.; Alves, F.; Duarte Naia, M. Cyclotron Production of Unconventional Radionuclides for PET Imaging: The Example of Titanium-45 and Its Applications. *Instruments* **2018**, *2*, 8. [CrossRef]
86. Zhuravlev, I. Titanium Silicates Precipitated on the Rice Husk Biochar as Adsorbents for the Extraction of Cesium and Strontium Radioisotope Ions. *Colloids Interfaces* **2019**, *3*, 36. [CrossRef]
87. Singh, B.; Tomar, R.; Tomar, R.; Tomar, S. Sorption of homologues of radionuclides by synthetic ion exchanger. *Microporous Mesoporous Mater.* **2011**, *142*, 629–640. [CrossRef]
88. Abdel Rahman, R.; Ibrahim, H.; Hung, Y. Liquid Radioactive Wastes Treatment: A Review. *Water* **2011**, *3*, 551–565. [CrossRef]
89. Strelko, V.; Milyutin, V.; Gelis, V.; Psareva, T.; Zhuravlev, I.; Shaposhnikova, T.; Milgrandt, V.; Bortun, A. Sorption of cesium radionuclides onto semicrystalline alkali metal silicotitanates. *Radiochemistry* **2015**, *57*, 73–78. [CrossRef]
90. Vincent, T.; Vincent, C.; Guibal, E. Immobilization of Metal Hexacyanoferrate Ion-Exchangers for the Synthesis of Metal Ion Sorbents—A Mini-Review. *Molecules* **2015**, *20*, 20582–20613. [CrossRef] [PubMed]
91. Suzui, N.; Tanoi, K.; Furukawa, J.; Kawachi, N. Recent Advances in Radioisotope Imaging Technology for Plant Science Research in Japan. *Quantum Beam Sci.* **2019**, *3*, 18. [CrossRef]
92. Kanno, S.; Arrighi, J.-F.; Chiarenza, S.; Bayle, V.; Berthomé, R.; Péret, B.; Javot, H.; Delannoy, E.; Marin, E.; Nakanishi, T.M.; et al. A novel role for the root cap in phosphate uptake and homeostasis. *Elife* **2016**, *5*, e14577. [CrossRef]
93. Sugita, R.; Kobayashi, N.I.; Hirose, A.; Tanoi, K.; Nakanishi, T.M. Evaluation ofin vivodetection properties of ^{22}Na, ^{65}Zn, ^{86}Rb, ^{109}Cd and ^{137}Cs in plant tissues using real-time radioisotope imaging system. *Phys. Med. Biol.* **2014**, *59*, 837–851. [CrossRef] [PubMed]
94. Sugita, R.; Kobayashi, N.I.; Hirose, A.; Ohmae, Y.; Tanoi, K.; Nakanishi, T.M. Nondestructive real-time radioisotope imaging system for visualizing ^{14}C-labeled chemicals supplied as CO_2 in plants using Arabidopsis thaliana. *J. Radioanal. Nucl. Chem.* **2013**, *298*, 1411–1416. [CrossRef]
95. Sugita, R.; Sugahara, K.; Kobayashi, N.I.; Hirose, A.; Nakanishi, T.M.; Furuta, E.; Sensui, M.; Tanoi, K. Evaluation of plastic scintillators for live imaging of ^{14}C-labeled photosynthate movement in plants. *J. Radioanal. Nucl. Chem.* **2018**, *318*, 579–584. [CrossRef]
96. Sugita, R.; Kobayashi, N.I.; Hirose, A.; Saito, T.; Iwata, R.; Tanoi, K.; Nakanishi, T.M. Visualization of Uptake of Mineral Elements and the Dynamics of Photosynthates in Arabidopsis by a Newly Developed Real-Time Radioisotope Imaging System (RRIS). *Plant Cell Physiol.* **2016**, *57*, 743–753. [CrossRef] [PubMed]
97. Sugita, R.; Kobayashi, N.I.; Hirose, A.; Iwata, R.; Suzuki, H.; Tanoi, K.; Nakanishi, T.M. Visualization of how light changes affect ion movement in rice plants using a real-time radioisotope imaging system. *J. Radioanal. Nucl. Chem.* **2017**, *312*, 717–723. [CrossRef]
98. Nussaume, L.; Kanno, S.; Javot, H.; Marin, E.; Nakanishi, T.M.; Thibaud, M.-C. Phosphate Import in Plants: Focus on the PHT1 Transporters. *Front. Plant Sci.* **2011**, *2*, 83. [CrossRef]
99. Kanno, S.; Cuyas, L.; Javot, H.; Bligny, R.; Gout, E.; Dartevelle, T.; Hanchi, M.; Nakanishi, T.M.; Thibaud, M.-C.; Nussaume, L. Performance and Limitations of Phosphate Quantification: Guidelines for Plant Biologists. *Plant Cell Physiol.* **2016**, *57*, 690–706. [CrossRef]
100. Sugita, R.; Kobayashi, N.I.; Hirose, A.; Tanoi, K.; Nakanishi, T.M. Visualization of Ion Transport in Plants. In *Agricultural Implications of the Fukushima Nuclear Accident (III): After 7 Years*; Nakanishi, T.M., O'Brien, M., Tanoi, K., Eds.; Springer: Singapore, 2019; pp. 221–231.
101. McKay, R.M.L.; Palmer, G.R.; Ma, X.P.; Layzell, D.B.; McKee, B.T.A. The use of positron emission tomography for studies of long-distance transport in plants: Uptake and transport of 18F. *Plant Cell Environ.* **1988**, *11*, 851–861. [CrossRef]

102. Nakamura, S.-I.; Suzui, N.; Nagasaka, T.; Komatsu, F.; Ishioka, N.S.; Ito-Tanabata, S.; Kawachi, N.; Rai, H.; Hattori, H.; Chino, M.; et al. Application of glutathione to roots selectively inhibits cadmium transport from roots to shoots in oilseed rape. *J. Exp. Bot.* **2013**, *64*, 1073–1081. [CrossRef] [PubMed]
103. Hu, P.; Yin, Y.-G.; Ishikawa, S.; Suzui, N.; Kawachi, N.; Fujimaki, S.; Igura, M.; Yuan, C.; Huang, J.; Li, Z.; et al. Nitrate facilitates cadmium uptake, transport and accumulation in the hyperaccumulator Sedum plumbizincicola. *Environ. Sci. Pollut. Res.* **2013**, *20*, 6306–6316. [CrossRef] [PubMed]
104. Suzui, N.; Yin, Y.-G.; Ishii, S.; Sekimoto, H.; Kawachi, N. Visualization of zinc dynamics in intact plants using positron imaging of commercially available 65Zn. *Plant Methods* **2017**, *13*, 40. [CrossRef] [PubMed]
105. Kawachi, N.; Yin, Y.-G.; Suzui, N.; Ishii, S.; Yoshihara, T.; Watabe, H.; Yamamoto, S.; Fujimaki, S. Imaging of radiocesium uptake dynamics in a plant body by using a newly developed high-resolution gamma camera. *J. Environ. Radioact.* **2016**, *151*, 461–467. [CrossRef] [PubMed]
106. Singh, B.; Singh, J.; Kaur, A. Applications of radioisotopes in agriculture. *Int. J. Biotech. Bioeng. Res.* **2013**, *4*, 167–174.