



# Proceeding Paper Can Long Photoperiods Be Utilized to Integrate Cichorium spinosum L. into Vertical Farms? <sup>+</sup>

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Abstract: Vertical farming is gaining attention for urban agriculture and sustainable food production, but mainstream crops may not be economically viable in this system, prompting a shift to high-value crops. This study explores the potential of *Cichorium spinosum* L. (spiny chicory), a wild edible green, for vertical farming. When cultivated on open field and greenhouses, spiny chicory tends to flower prior vernalization deeming the flowered plants unsalable, necessitating an investigation on its flowering responses. *C. spinosum* L. plants were cultivated and for 5 months in peat-filled pots, under low light (100 µmols m<sup>2</sup> s<sup>-1</sup>), and two photoperiods (10 and 15 h) with stable temperature (20 °C) and CO<sub>2</sub> level (400 ppm). No flowering occurred at the end of the first experiment, indicating that photoperiod, light intensity of 300 µmols m<sup>-2</sup> s<sup>-1</sup>, temperature between 25 and 30 °C, CO<sub>2</sub> levels of 350 to 400 ppm, and plant density of 100 plants m<sup>-2</sup>. At the end of the one-month cultivation the yield of the salable fresh weight was approximately 1.7–2 kg per m<sup>2</sup>. Moreover, gas exchange measurements were conducted to analyze CO<sub>2</sub> uptake and evapotranspiration. This study aims to enhance understanding of spiny chicory's flowering response and growth performance, providing valuable insights for cultivating this wild edible vegetable in vertical farming systems.

Keywords: vertical farming; photoperiod; spiny chicory; wild edible greens; underutilized crops

# 1. Introduction

Cultivation within vertical farms commonly involves the application of extended photoperiods and relatively low photosynthetic photon flux density (PPFD) ranging from 15 to 18 h and 180 to 300  $\mu$ mol m<sup>-2</sup> s<sup>-1</sup>, respectively. This practice seeks to reach the daily light integral (DLI) goals of certain crops by utilizing the energy-efficient attributes of lower PPFD levels, while maintaining high photosynthetic capacity over prolonged durations, thereby achieving optimum growth rates [1–4]. Despite the rapid expansion of the vertical farming sector, criticism often occurs due to the high energy use and increased carbon footprint compared to open field or greenhouse production [5–7], further emphasized by the fact that key businesses have faltered to sustain their growth and financial viability [8,9]. For this reason, novel crops characterized as "niche" that command elevated prices in the market compared to mainstream crops are progressively being incorporated into vertical farming systems [10,11]. This strategic integration aims to mitigate the considerable operational expenses and contribute significantly to the attainment of profitability.



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**Copyright:** © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). *Cichorium spinosum* L. (spiny chicory) is a wild edible plant that can be found near the sea, on rocks or coastal sand as well as rocky mountains of the Mediterranean basin [12,13]. Being part of the Mediterranean diet, *C. spinosum* L. has been gaining attention thanks to its rich phytonutrient content and anti-carcinogenic properties [14–16]. As a result, the commercial cultivation of *C. spinosum* L. has also been gaining attention. Extended photoperiods can potentially trigger flower initiation, subsequently inducing changes in the chemical composition of the leaves, flavor profile, and ultimately rendering the yield unmarketable [17]. As a result, it becomes imperative to ascertain the feasibility of *C. spinosum* L. cultivation within vertical farms, particularly under prolonged photoperiod conditions. Presently, the absence of documented research regarding the growth cycle of spiny chicory in controlled environments from seed to harvest deems the optimum conditions rather unclear.

Knowledge from *C. intybus* L., (chicory) could perhaps be implemented in the cultivation of *C. spinosum* L since these two are genetically similar, yet their morphological characteristics delimit the two species [18]. Unfortunately, studies on distinct varieties within the *Cichorium intybus* L. group have shown that chicory plants can either be of absolute or facultative cold requirements with regard to flowering. In addition, the prevailing temperature during various stages—ranging from seed production in maternal plants, seed storage, germination, and seedling cultivation-can hasten the processes of bolting and flowering [19–21]. It has been also suggested that high temperature (20–25 °C) could have a devernalization effect on chicory plants [21] but on the other hand, very high temperatures, (28-35 °C) could hasten flowering independently of vernalization [22,23]. It is unclear whether flowering initiation is attributed to temperature, light intensity, or their interaction. Since low temperatures are easy to avoid in vertical farms, flowering due to vernalization does not appear to be of primary concern. Conversely, C. intybus has been known to have an absolute long day requirement, therefore photoperiod is the primary determinant for triggering bolting and flowering [19]. In addition, the developmental stage of the plant has been suggested to contribute to its sensitivity to the interplay between low temperatures and extended photoperiods, highlighting the complexity of these regulatory mechanisms [19–25].

In order to clarify whether un-vernalized seeds can be used for the commercial cultivation of spiny chicory in vertical farms, two experiments were carried out. The first experiment took place in climate chambers and explored whether long days could initiate flowering under low light intensity. The second experiment applied the findings from the first and explored the commercial potential of spiny chicory when cultivated in a small-scale vertical farm while utilizing long photoperiod.

# 2. Materials and Methods

# 2.1. Cultivation Conditions

In the first experiment, sowing took place during May of 2020 inside polyester trays filled with TS 1 fine peat (Klasmann-Deilmann GmbH, Geest, Germany). Subsequently, the trays were placed in the glasshouse of the Laboratory of Vegetable Production's during the germination process. The moisture level of the substrate was checked daily and irrigation was administered manually. After 4 weeks, 30 seedlings per treatment were transplanted into individual 0.5 L pots containing peat and were relocated on 3 horizontal trays, inside each of the two climate chambers of the Laboratory of Ecology. Temperature, relative humidity, carbon dioxide concentration, and PPFD at the canopy level, were set to 20 °C, 65–60%, 400 ppm, and 70–80 µmol m<sup>-2</sup> s<sup>-1</sup>, respectively. For the experiment, the photoperiod was established at 10 h (short day, SD) within one chamber, and 15 h (long day, LD) in the other. The nutrient solution used was tailored for the cultivation of spiny chicory as recommended by the decision support system "NUTRISENSE DSS" and fertigation was administrated manually using syringes of different volumes depending on the stage of the plant. As a treatment, the photoperiod was set to 10 h (short day, SD) in one chamber

and 15 h (long day, LD) on the other. The plants were maintained inside the chambers for 7 months.

Flowering initiation was not observed in the first experiment, which led to the implementation of a 15 h photoperiod in the second experiment which was conducted from June to July of 2023 in an acclimated room with modular vertical farms at the Laboratory of Vegetable Production. In this experiment, sowing took place on rockwool sheets (AO Plug, Grodan, Roermond, the Netherlands) which were placed inside the horizontal layers of Vegeled trolleys (Colllasse SA, Seraing, Belgium). Before sowing, achenes were broken using a house blender and separated from the debris using a Fluid Bed Dryer (Endecotts Limited, London, UK). A month from sowing, seedlings were transplanted to plastic net pots and distributed to the 3 layers of the modular farm at a plant density of 100 plants per m<sup>2</sup>. The temperature, relative humidity, carbon dioxide concentration, photoperiod, and PPFD at the canopy level were set to 25–30 °C, 60–70%, 400 ppm, 15 h, and 300  $\mu$ mol m<sup>-2</sup> s<sup>-1</sup>. The nutrient solution recipe was designed using "NUTRISENSE DSS". EC and pH were checked daily and maintained at 1.5 to 2 (mS/cm) and 5.5 to 6.5, respectively.

#### 2.2. Measurements

In both experiments leaf gas exchange analysis was carried out one week prior to harvest using the LCpro T analyzer (ADC BioScientific, Hoddesdon, UK). The plants were then harvested and their leaf number (LN), leaf area (LA), fresh and dry weight (FW, DW) were measured using the LI-3100C (LI-COR, Inc., Lincoln, NE, USA) and a Mettler PE-3600 scale (Mettler Toledo LLC, Columbus, OH, USA).

#### 2.3. Statistical Analysis

All experimental data underwent One-Way ANOVA analysis employing the Statistica 12 software package for Windows (StatSoft Inc., Tulsa, OK, USA) for each experiment separately. Duncan's multiple range test was administered at a significance level of  $p \le 0.05$  for all measured variables.

#### 3. Results and Discussion

#### 3.1. Experiment 1: Does Extended Photoperiod Alone Induce Flowering in Chicorium spinosum L.?

In the first experiment, leaf area (LA), leaf fresh weight (FW), and leaf dry weight (DW) statistically differed between plants cultivated under long and short days, whereas leaf number (LN) and DW/FW did not show any significant differences. As seen in Table 1, plants that grew under LD conditions had increased LA, FW, and DW compared to plants grew under SD. This was expected, since increased daily light integrals are linked to increased yields [26]. Moreover, as seen in Table 2, leaf gas exchange was significantly affected only between the 460 and 920  $\mu$ mol m<sup>-2</sup> s<sup>-1</sup> range. Hence, CO<sub>2</sub> assimilation and transpiration were not affected within the light intensity range in which the plants were cultivated, regardless of the photoperiod treatment.

**Table 1.** Effect of photoperiod long (LD) and short (SD) on the agronomical characteristics, namely leaf number (LN), leaf area (LA), leaf fresh weight and dry weight (FW, DW), and their ration (DW/FW) of plants cultivated on peat inside a climate chamber.

Treatment	LN	LA (cm <sup>2</sup> )	FW	DW	DW/FW
LD	$15\pm1.14$	$123.57 \pm 13.82$ a	$6.04\pm0.72~\mathrm{a}$	$0.422\pm0.06~\mathrm{a}$	$6.91\% \pm 0.37\%$
SD	$14.7\pm0.74$	$76.19\pm5.73\mathrm{b}$	$3.3\pm0.25b$	$0.216\pm0.01~\text{b}$	$6.84\% \pm 0.50\%$
Statistical Significance	ns	*	*	*	ns

Means followed by different letters within a column are significantly different as determined by Duncan's test ( $p \le 0.05$ ; n = 10). Statistical significance is depicted with the symbol \*, while non-statistically significant difference with "ns" in the last row of the table.

Parameter	Treatment	0	46	92	184	460	920
E	LD	$0.32\pm0.03$	$0.25\pm0.02$	$0.21\pm0.02$	$0.22\pm0.02$	$0.29\pm0.04~b$	$0.43\pm0.05~\mathrm{b}$
	SD	$0.42\pm0.08$	$0.31\pm0.07$	$0.27\pm0.06$	$0.32\pm0.08$	$0.46\pm0.11$ a	$0.75\pm0.13~\mathrm{a}$
А	LD	$-0.01\pm0.04$	$1.42\pm0.15$	$1.67\pm0.21$	$2.4\pm0.33$	$3.64\pm0.56b$	$5.73\pm1.12\mathrm{b}$
	SD	$-0.13\pm0.23$	$1.6\pm0.43$	$1.99\pm0.55$	$3.4\pm1.04$	$5.69\pm1.42~\mathrm{a}$	$8.84 \pm 1.43~\mathrm{a}$
Statistical	E	ns	ns	ns	ns	*	*
Significance	А	ns	ns	ns	ns	*	*

**Table 2.** Leaf gas exchange (assimilation (A), and transpiration (E)) of spiny chicory plants cultivated under long (LD) and short (SD) photoperiods in a climate chamber.

Means followed by different letters within a column are significantly different as determined by Duncan's test ( $p \le 0.05$ ; n = 10). Statistical significance is depicted with the symbol \*, while non-statistically significant difference with "ns" in the last row of the table.

The low light intensity (70–80  $\mu$ mol m<sup>-2</sup> s<sup>-1</sup>), being slightly greater than the light intensity of the photosynthetic compensation point (around 50  $\mu$ mol m<sup>-2</sup> s<sup>-1</sup>) appeared to be the primary limiting factor in terms of growth. Moreover, it is suggested that the plants never surpassed the juvenile stage during the 7 months of the experiment. When cultivated in an open field, spiny chicory plants flower during May or June, depending on the ecotype, which could be a combination of developmental stage, vernalization, photoperiod, and temperature [27]. This supports findings from research on *Cichorium intybus* L. that suggest that the developmental stage exerts a significant influence on the sensitivity of the chicory to extended photoperiods [19–25].

# 3.2. Experiment 2: Yield and Photosynthetic Capacitly of Chicorium spinosum L. Cultivated Commercially in a Vertical Farm

In the second experiment, the plants grew rapidly. A yield of 17.65 g per plant was reached within 1 month of cultivation in the vertical farming system, as seen in Table 3. Through this cultivation design the yield is estimated to be around 1.7 Kg per m<sup>2</sup> per harvest. The increased light intensity was crucial for photosynthesis and plant development as it is also supported by the results from the leaf gas exchange analysis shown in Table 4. Moreover, flowering appeared to less than 4% of the plants, deeming the 15 h photoperiod and PPFD of 300  $\mu$ mol m<sup>-2</sup> s<sup>-1</sup>, a viable cultivation design for spiny chicory.

**Table 3.** Effect of photoperiod on the agronomical characteristics, namely leaf number (LN), leaf area (LA), leaf fresh weight and dry weight (FW, DW), and their ration (DW/FW) of plants cultivated on rockwool plugs, in horizontal layers of Vegeled trolleys inside a climate chamber.

Treatments	LN	LA (cm <sup>2</sup> )	FW (g)	DW	DW/FW
DLI- > 15-300	$20\pm1$	$346.56\pm29.69$	$17.65 \pm 1.34$	$1.29\pm0.1$	$7\%\pm0.24\%$
Values are mean of n =	30 followed b	y the standard error.			

**Table 4.** Leaf gas exchange (assimilation (A), and transpiration (E)) of spiny chicory plants cultivated on rockwool plugs, in horizontal layers of Vegeled trolleys inside a climate chamber.

Parameter	0	46	92	184	460	920
E	$1.07 \pm 0.07$ 1.03 ± 0.14	$1 \pm 0.09$	$0.92 \pm 0.09$ 3.04 ± 0.2	$0.9 \pm 0.09$ 5 59 ± 0.47	$1.07 \pm 0.08$ 11.25 ± 0.76	$1.49 \pm 0.07$ 15.8 ± 0.8
A	=1.03 ± 0.14	0.94 ± 0.10	3.04 ± 0.2	5.59 ± 0.47	$11.23 \pm 0.70$	$15.8 \pm 0.8$

Values are mean of n = 30 followed by the standard error.

Our results support that the cultivation of spiny chicory can be feasible in vertical farms and that the cultivation time can be drastically decreased compared to other agricultural systems. Petropoulos et al., [17,28] report preparing seedling for 90 days, while by breaking the achenes as reported above, the process was reduce to 30 days. In addition, the cultivation phase lasted for another 30 days, leading to a total of 60 days from seed to harvest, whereas Petropoulos et al., report 133 days after sowing (DAS). In other experiments conducted by our group, Ntatsi et al., had previously reported yields of less than 6 g per plant, after 56 days from transplanting in a floating raft hydroponic system [29]. Furthermore, Voutsinos et al., in other research conducted from our group on hydroponically cultivated spiny chicory, the yields were close to 9 g per plant after less than a month of cultivation [30]. These comparisons portray how vertical farming can decrease the time needed for crops to reach certain yields.

## 4. Conclusions

In conclusion, our study suggests that flowering initiation of non-vernalized and non-stressed *Cichorium spinosum* L. plants is primarily controlled by the developmental stage. Under very low PPFDs, the plant development is stagnant and plants fails to flower even after 7 months of cultivation under a 15 h photoperiod. When spiny chicory plants are cultivated in vertical farms, the 15 h photoperiod can be utilized since plants managed to reach high yields, in just 2 months from seed to harvest, while maintaining a flowering percentage of less than 4% of the population. Nevertheless, even though the cultivation of spiny chicory in vertical farms can greatly reduce the time needed to reach high yields, the profitability of such a system remains to be analyzed.

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#### References

- Kozai, T.; Niu, G. Plant factory as a resource-efficient closed plant production system. In *Plant Factory*; Elsevier: Amsterdam, The Netherlands, 2020; pp. 93–115. ISBN 9780128166918.
- Al-Kodmany, K. The Vertical Farm: A Review of Developments and Implications for the Vertical City. *Buildings* 2018, *8*, 24. [CrossRef]
- Gavhane, K.P.; Hasan, M.; Singh, D.K.; Kumar, S.N.; Sahoo, R.N.; Alam, W. Determination of optimal daily light integral (DLI) for indoor cultivation of iceberg lettuce in an indigenous vertical hydroponic system. *Sci. Rep.* 2023, *13*, 10923. [CrossRef] [PubMed]
- 4. Jin, W.; Formiga Lopez, D.; Heuvelink, E.; Marcelis, L.F.M. Light use efficiency of lettuce cultivation in vertical farms compared with greenhouse and field. *Food Energy Secur.* **2023**, *12*, 1–10. [CrossRef]
- 5. Blom, T.; Jenkins, A.; Pulselli, R.M.; van den Dobbelsteen, A.A.J.F. The embodied carbon emissions of lettuce production in vertical farming, greenhouse horticulture, and open-field farming in the Netherlands. *J. Clean. Prod.* **2022**, *377*, 134443. [CrossRef]
- van Delden, S.H.; SharathKumar, M.; Butturini, M.; Graamans, L.J.A.; Heuvelink, E.; Kacira, M.; Kaiser, E.; Klamer, R.S.; Klerkx, L.; Kootstra, G.; et al. Current status and future challenges in implementing and upscaling vertical farming systems. *Nat. Food* 2021, 2, 944–956. [CrossRef] [PubMed]
- Graamans, L.; Baeza, E.; van den Dobbelsteen, A.; Tsafaras, I.; Stanghellini, C. Plant factories versus greenhouses: Comparison of resource use efficiency. *Agric. Syst.* 2018, 160, 31–43. [CrossRef]
- Galonska, E.; Michaeli, O.; Galonska, G. Note from Infarm's Founders: Strategy Shift and Profitability at Infarm. Available online: https://www.infarm.com/news/note-from-infarm-s-founders-strategy-shift-and-profitability-at-infarm (accessed on 10 February 2023).
- Boekhout, R. The Industry Responds to AeroFarms' Bankruptcy News. Available online: https://www.verticalfarmdaily.com/ article/9536736/the-industry-responds-to-aerofarms-bankruptcy-news/ (accessed on 15 July 2023).

- 10. Van Gerrewey, T.; Boon, N.; Geelen, D. Vertical farming: The only way is up? Agronomy 2022, 12, 2. [CrossRef]
- 11. Hikosaka, S. Production of Value-Added Plants. In *Smart Plant Factory: The Next Generation Indoor Vertical Farms*; Kozai, T., Ed.; Springer: Singapore, 2018; pp. 325–351. ISBN 978-981-13-1065-2.
- 12. Kiers, A.M. Endive, Chicory, and their wild relatives. A systematic and phylogenetic study of *Cichorium* (Asteraceae). *Gorteria Dutch Bot. Arch. Suppl.* **2000**, *5*, 1–77.
- 13. Abusaief, H.M.A.A.R.; Husien, D.; Naby, A.A. Salinity tolerance of the flora halophytes to coastal habitat of Jarjr-oma in Libya. *Nat. Sci.* **2013**, *11*, 29–45.
- 14. Melliou, E.; Magiatis, P.; Skaltsounis, A.L. Alkylresorcinol derivatives and sesquiterpene lactones from *Cichorium spinosum*. J. *Agric. Food Chem.* **2003**, *51*, 1289–1292. [CrossRef]
- 15. Zeghichi, S.; Kallithraka, S.; Simopoulos, A.P. Nutritional Composition of Molokhia (*Corchorus olitorius*) and Stamnagathi (*Cichorium spinosum*). In *Plants in Human Health and Nutrition Policy*; KARGER: Basel, Switzerland, 2003; pp. 1–21.
- 16. Psaroudaki, A.; Dimitropoulakis, P.; Constantinidis, T.; Katsiotis, A.; Skaracis, G.N. Ten Indigenous Edible Plants: Contemporary Use in Eastern Crete, Greece. *Cult. Agric. Food Environ.* **2012**, *34*, 172–177. [CrossRef]
- 17. Petropoulos, S.A.; Fernandes, Â.; Vasileios, A.; Ntatsi, G.; Barros, L.; Ferreira, I.C.F.R.; Antoniadis, V.; Ntatsi, G.; Barros, L.; Ferreira, I.C.F.R. Chemical composition and antioxidant activity of *Cichorium spinosum* L. leaves in relation to developmental stage. *Food Chem.* **2018**, 239, 946–952. [CrossRef]
- 18. Gemeinholzer, B.; Bachmann, K. Examining morphological and molecular diagnostic character states of *Cichorium intybus* L. (Asteraceae) and *C. spinosum* L. *Plant Syst. Evol.* **2005**, 253, 105–123. [CrossRef]
- 19. Gianquinto, G.; Pimpini, F. Morphological and physiological aspects of phase transition in radicchio (*Cichorium intybus* L. var. silvestre Bischoff): The influence of temperature. *Adv. Hortic. Sci.* **1995**, *9*, 192–199.
- 20. Gianquinto, G. Morphological and physiological aspects of phase transition in radicchio (*Cichorium intybus* L. var. silvestre Bisch.): Influence of daylength and its interaction with low temperature. *Sci. Hortic.* **1997**, *71*, 13–26.
- Dielen, V.; Notté, C.; Lutts, S.; Debavelaere, V.; Van Herck, J.C.; Kinet, J.M. Bolting control by low temperatures in root chicory (*Cichorium intybus* var. *sativum*). *Field Crops Res.* 2005, 94, 76–85. [CrossRef]
- Mathieu, A.S.; Lutts, S.; Vandoorne, B.; Descamps, C.; Périlleux, C.; Dielen, V.; Van Herck, J.C.; Quinet, M. High temperatures limit plant growth but hasten flowering in root chicory (*Cichorium intybus*) independently of vernalisation. *J. Plant Physiol.* 2014, 171, 109–118. [CrossRef] [PubMed]
- Mathieu, A.S.; Périlleux, C.; Jacquemin, G.; Renard, M.E.; Lutts, S.; Quinet, M. Impact of vernalization and heat on flowering induction, development and fertility in root chicory (*Cichorium intybus* L. var. sativum). *J. Plant Physiol.* 2020, 254, 153272. [CrossRef]
- 24. Harrington, J.F.; Verkerk, K.; Doorenbos, J. Interaction of vernalization, photoperiod and light intensity in floral initiation of endive. *Neth. J. Agric. Sci.* **1959**, *7*, 68–74. [CrossRef]
- 25. Pimpini, F.; Gianquinto, G. The influence of climatic conditions and age of plant at transplanting on bolting and yield of chicory (*Cichorium intybus* L.) cv. rosso di chioggia grown for early production. *Acta Hortic.* **1988**, *229*, 379–386. [CrossRef]
- 26. Kelly, N.; Choe, D.; Meng, Q.; Runkle, E.S. Promotion of lettuce growth under an increasing daily light integral depends on the combination of the photosynthetic photon flux density and photoperiod. *Sci. Hortic.* **2020**, *272*, 109565. [CrossRef]
- 27. Papafilippaki, A.; Nikolaidis, N.P. Comparative study of wild and cultivated populations of *Cichorium spinosum*: The influence of soil and organic matter addition. *Sci. Hortic.* **2020**, *261*, 108942. [CrossRef]
- Petropoulos, S.; Fernandes, Â.; Karkanis, A.; Ntatsi, G.; Barros, L.; Ferreira, I.C.F.R. Successive harvesting affects yield, chemical composition and antioxidant activity of *Cichorium spinosum* L. *Food Chem.* 2017, 237, 83–90. [CrossRef] [PubMed]
- 29. Ntatsi, G.; Aliferis, K.A.; Rouphael, Y.; Napolitano, F.; Makris, K.; Kalala, G.; Katopodis, G.; Savvas, D. Salinity source alters mineral composition and metabolism of *Cichorium spinosum*. *Environ. Exp. Bot.* **2017**, *141*, 113–123. [CrossRef]
- 30. Voutsinos-Frantzis, O.; Ntatsi, G.; Karavidas, I.; Neofytou, I.; Deriziotis, K.; Ropokis, A.; Consentino, B.B.; Sabatino, L.; Savvas, D. Exploring the Simultaneous Effect of Total Ion Concentration and K:Ca:Mg Ratio of the Nutrient Solution on the Growth and Nutritional Value of Hydroponically Grown *Cichorium spinosum* L. *Agronomy* 2022, 12, 2214. [CrossRef]

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