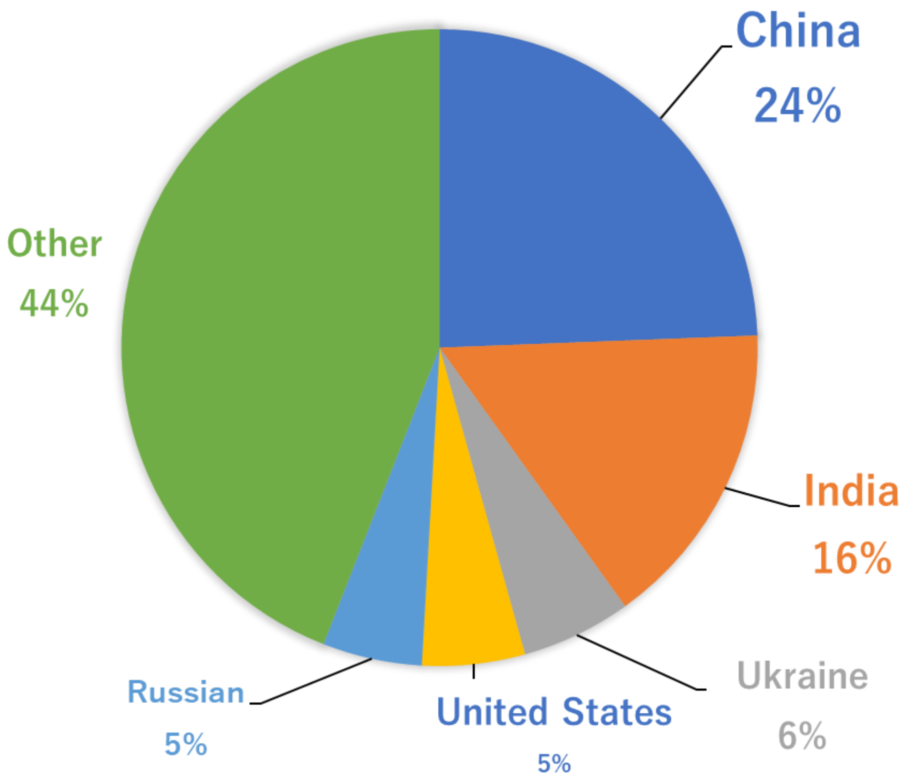
新技術説明会
New Technology Presentation Meetings!

革新的ウイルスフリー種苗生産技術

長岡技術科学大学　技術科学イノベーション系
准教授　牧　慎也

2026年6月18日

Global context: Potato Production



FAOSTAT（2023年）

データ引用元 https://www.yasainavi.com/graph/worlddata/item=potatoes

順化

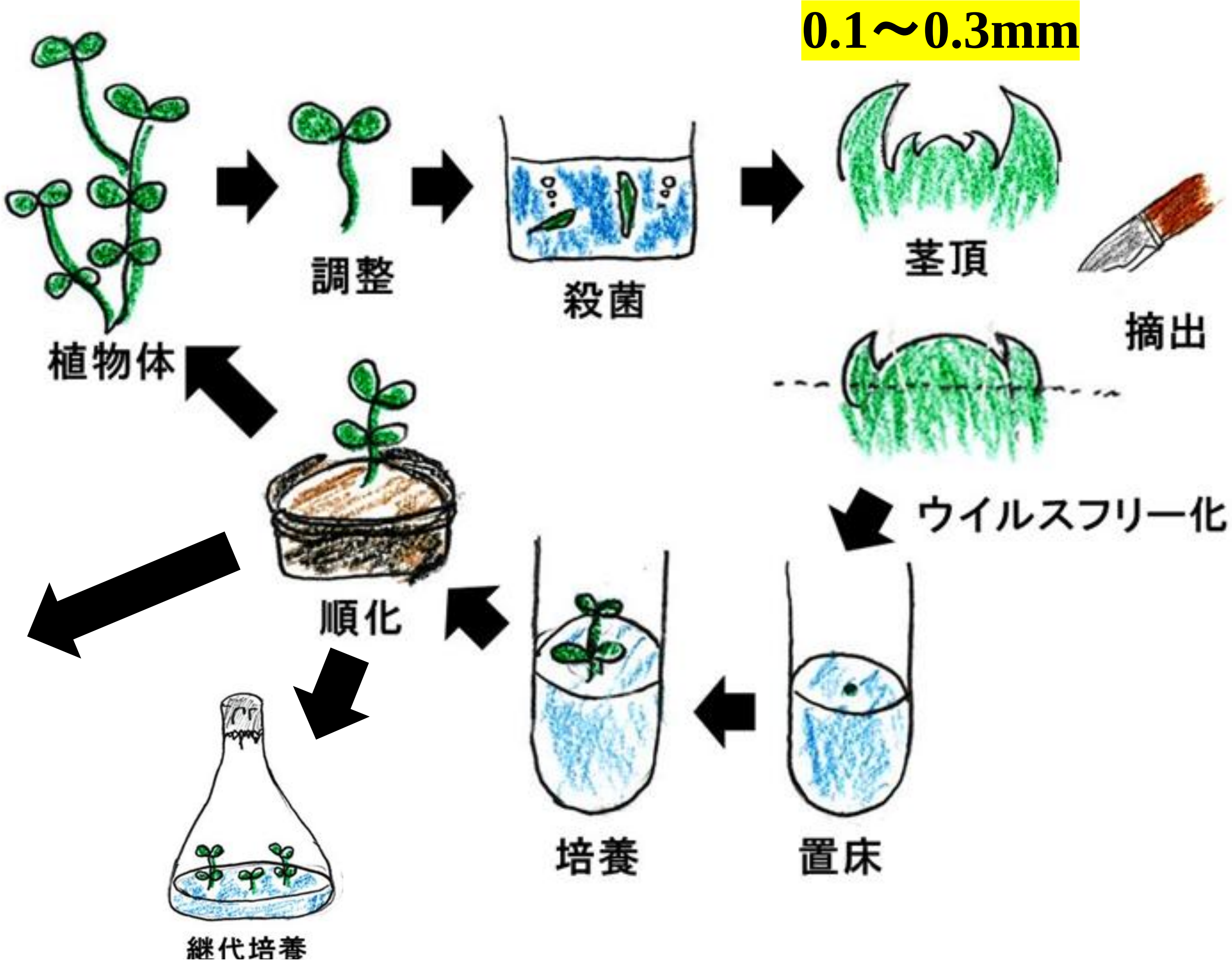


Figure Strategy of the sterilization method

クリーンベンチ作業

人工気象器

▲ウイルスフリークローン植物体の培養

ウイルスフリー種苗

MS medium

		調製濃度	使用量	最終濃度	使用量
		[mg/100mL]	1/2MS[mL]	1/2MS[mg/L]	1/2 +2.5Mesos[mL]
A	NH_4NO_3	8250	10	825	10
B	KNO_3	9500	10	950	10
C	$CaCl_2$・2H2O	4400	10	440	15
D	KH_2PO_4	850	10	85	15
H	$MgSO_4$・7H2O	3700	10	370	15
E	$MnSO_4$・4H2O	223	10	22.3	10
	$ZnSO_4$・7H2O	86		8.6	
	CuSO4・5H2O	0.25		0.025	
F	H_3BO_3	62	10	6.2	10
	KI	8.3		0.83	
	Na_2MoO_4・$2H_2O$	2.5		0.25	
	$CoCl_2$・$6H_2O$	0.25		0.025	
G	FeSO4・7H2O	278	10	27.8	10
	Na_2-EDTA	373		37.3	
Vitamin	Nicotinic acid	500	1	5	1
	Pyridoxine	50		0.5	
	Thiamine	300		3	
寒天	寒天	—	8.0g	8.0g/L	8.0g
ショ糖	砂糖		30g	30g/L	30g
pH	5.7				
容量	1L				

USDA Corvallis OR

Cryopreservation

A solution to the problem of ion confounding in experimental biology

To the editor: Understanding ion-specific effects is a central theme of biology. But because ions are generally manipulated through the use of salts, the complication of 'ion confounding' is introduced. Ion confounding occurs when the ion(s) of interest are covaried with the covaried ion associated with the salts used; that is, changing the concentration of a single cation or anion using a single salt results in a simultaneous change in the associated co-ion. If the concentration of an ion is not varied independently, then the main effect associated with that ion is indistinguishable from or confounded with, the effect(s) caused by changing the concentrations of the other ions. Identifying ion confounding requires converting reported salt formulations, including ions introduced via pH adjustments, to corresponding ion concentrations. If there are deviations of ion type and/or concentration other than those specified by the experimental design, then ion confounding has occurred. Ion confounding is extremely common in disciplines that study ion-specific effects, but is particularly apparent in plant nutrition studies, as the complex mineral-ion mixtures used are the primary nutritive source of these organisms (**Table 1**)[1].

To avoid ion confounding, it is necessary to be able to calculate a salt mix, or 'recipe', that achieves any given ionic formulation. This can be easily solved as a linear programming problem that optimizes the allocation of mixture components (the ions) from a set of salts. The linear function, presented as a minimization, can be used to determine the types and concentrations of salts, acids and bases to achieve a particular ionic solution:

$$\text{minimize} \qquad c_1X_1 + c_2X_2 + \ldots + c_nX_n \qquad (1)$$

where c is a known weighting coefficient, and X is the unknown amount of an individual salt,

$$\text{subject to} \quad a_{i1}X_1 + a_{i2}X_2 + \ldots + a_{in}X_n \; \{\leq, =, \geq\} \; b_i \quad (i = 1, 2, \ldots m)$$

$$X_1, \ldots X_n \geq 0$$

where a are known coefficients of ion proportionality for each salt X that contributes an ion defined by the target ion concentration b; a non-negative constraint ensures positive values. Equation (1) results in a list of the type and amount of salts to achieve the exact ion concentrations specified by b (**Supplementary Methods** online). A software application for making these calculations and generating associated pipetting tables is available from the authors.

Equation (1) provides the means to generate exact solutions of complex ion mixtures. Thus, ions can and should be manipulated as independent factors in statistically valid experiments (**Supplementary Note** online). The overarching impact of ion confounding is that our understanding of ion-specific effects on biological processes is primarily based on flawed experimental designs. This implies that the most basic ion-specific effects on biological responses have never been properly characterized (**Supplementary Discussion** online). The approach presented here provides the means to overcome this fundamental hindrance to valid experimental study of ion-specific effects.

Table 1 | Ion confounding of the hydroponic nutrient solutions

Solution	pH	NO_3^-	PO_4^{3-}	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}
Control	4.44	15	1	6	5	2	2.05
Lacking N	4.51	0[a]	1	**5**	**2.5**	2	**6.55**
Lacking PO_4^{3-}	4.54	**14**	0[a]	6	**4**	2	2.05
Lacking K^+	4.43	**10**	1	0[a]	**5.5**	2	2.05
Lacking Ca^{2+}	4.45	**5**	1	6	0[a]	2	2.05
Lacking Mg^{2+}	4.44	**14**	1	**10**	**4**	0[a]	**1.55**
Lacking SO_4^{2-}	4.27	**18**	1	**7**	**4**	2	0[a]

Ion confounding is illustrated by calculating the ion concentrations of the popular salt formulations developed by Hoagland and Arnon[1] for determining ion-specific effects on hydroponically grown plants. When the formulations are viewed in this manner the confounding becomes clear. For example, the formulation 'lacking Mg^{2+}' does not just change the [Mg^{2+}] as would be required to determine the effect(s) of this ion, but compared to the control solution ion levels also changes the [NO_3^-], [K^+], [Ca^{2+}] and [SO_4^{2-}]. Consequently, the measured responses cannot be attributed to Mg^{2+} alone, but will be a product of the combined changes of multiple ions; the Mg^{2+} main effect is now confounded with the effect(s) of the covaried ions. Only major mineral ions are shown; Cl^-, Fe^{2+}, Zn^{2+} and Cu^{2+} are also confounded. pH calculated using MINEQL+ ver 4.5 (Environmental Research Software, Hallowell, Maine, USA) chemical equilibrium modeling system. Ion levels are in mM. Confounded ions are in bold.

[a]Ions being varied.

Note: Supplementary information is available on the Nature Methods website.

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1. Hoagland, D.R. & Arnon, D.I. The water-culture method for growing plants without soil. *Univ. Calif. Coll. Agric. Exp. Stn. Circ.* **347**, 1–39 (1938).

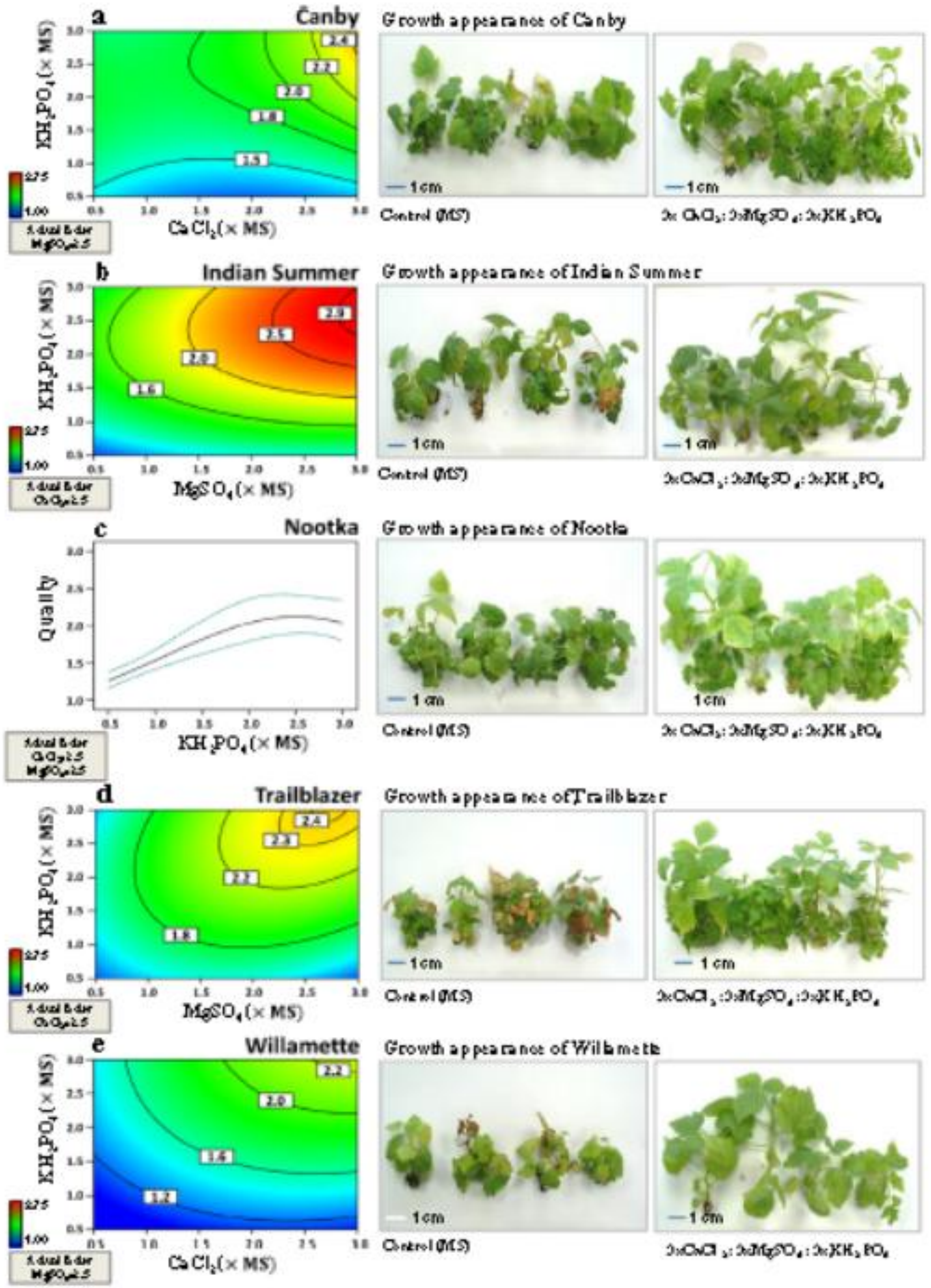


Figure 1. Optimized quality graphs of five cultivars of red raspberries grown on medium containing varying concentrations of the three mesos components. Shoot quality ratings (1 = poor (*dark blue*), 3 = good (*red*)) as related to significant mesos factors (graph) and shoot growth appearance (photographs) on standard MS medium as compared to an improved mesos treatment (Trt. 13). (*a*) Canby (*b*) Indian Summer (*c*) Nootka (*d*) Trailblazer (*e*) Willamette. The graph for Nootka (*c*), which had a single significant factor, has a *solid response line* with confidence levels (*dotted lines*) indicated.

In Vitro Cell.Dev.Biol.—Plant (2015) 51:648–658

Acta Physiol Plant (2015) 37:1-10

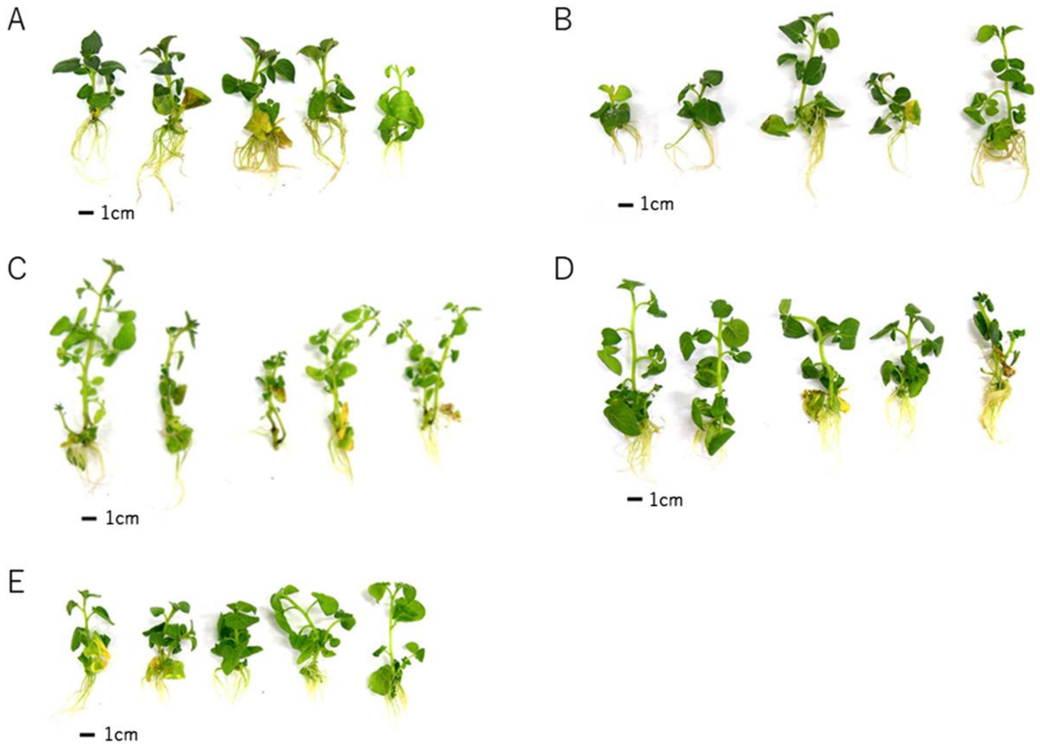


Figure 1. Samples of harvested plantlets of ‘Nishiyutaka,’ cultured on the following media: A: 1.0× Murashige and Skoog (MS), B: 1.5×MS, C: 2.0×MS, D: 2.5×MS, E: 3.0×MS.

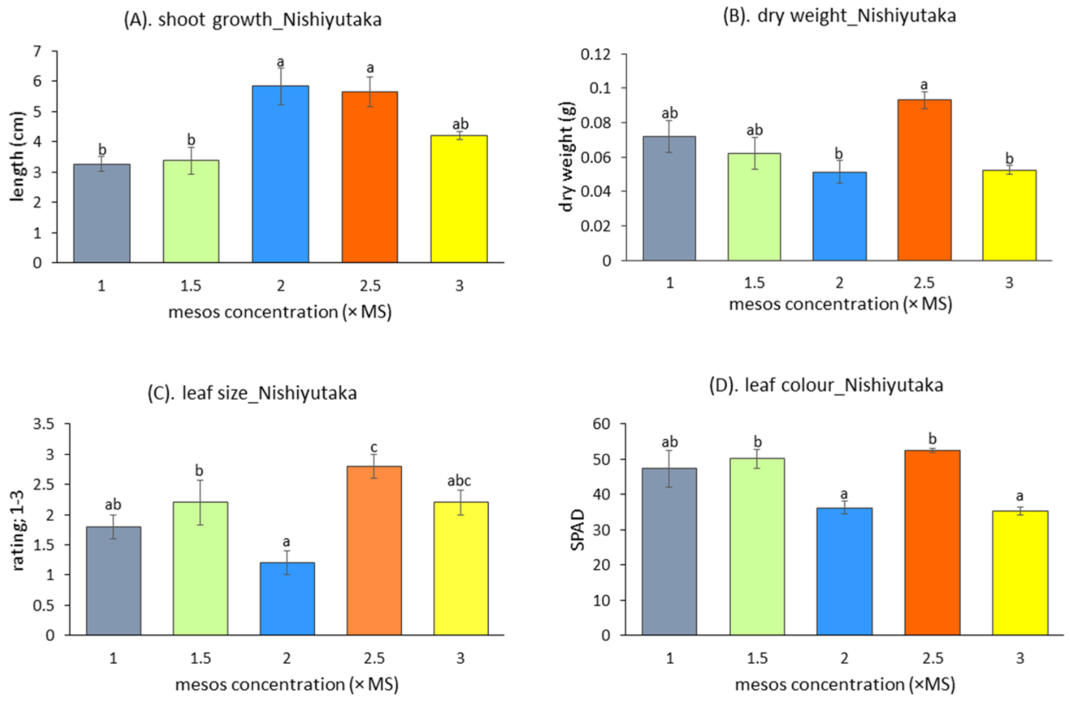


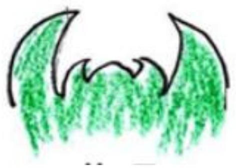
Figure 2. Shoot length, dry weight, leaf size, and leaf colour of ‘Nishiyutaka’ on increasing mesos concentrations. Data represents mean±standard error (SE). Different lowercase letters represent statistically significant differences (p≤0.05), n=10.

Plant Biotechnology 38, 401–408 (2021)

＜現在の種苗生産方法＞

ウイルス感染・線虫感染リスク
ジャガイモ品質低下

ウイルスフリークローン苗


成長点


in vitro（試験管増殖）


マイクロチューバー作製

増殖
ミニチューバー作製

基本種

農水省　種苗管理センター　１１道県

原原種
増殖

原種
増殖

採種

長島町
配布
増殖？

（北海道・宮崎・長崎）
線虫被害？

農水省
植物防疫所
毒：安全性

＜革新的低エネルギー種苗培養システム＞

ウイルスフリークローン苗

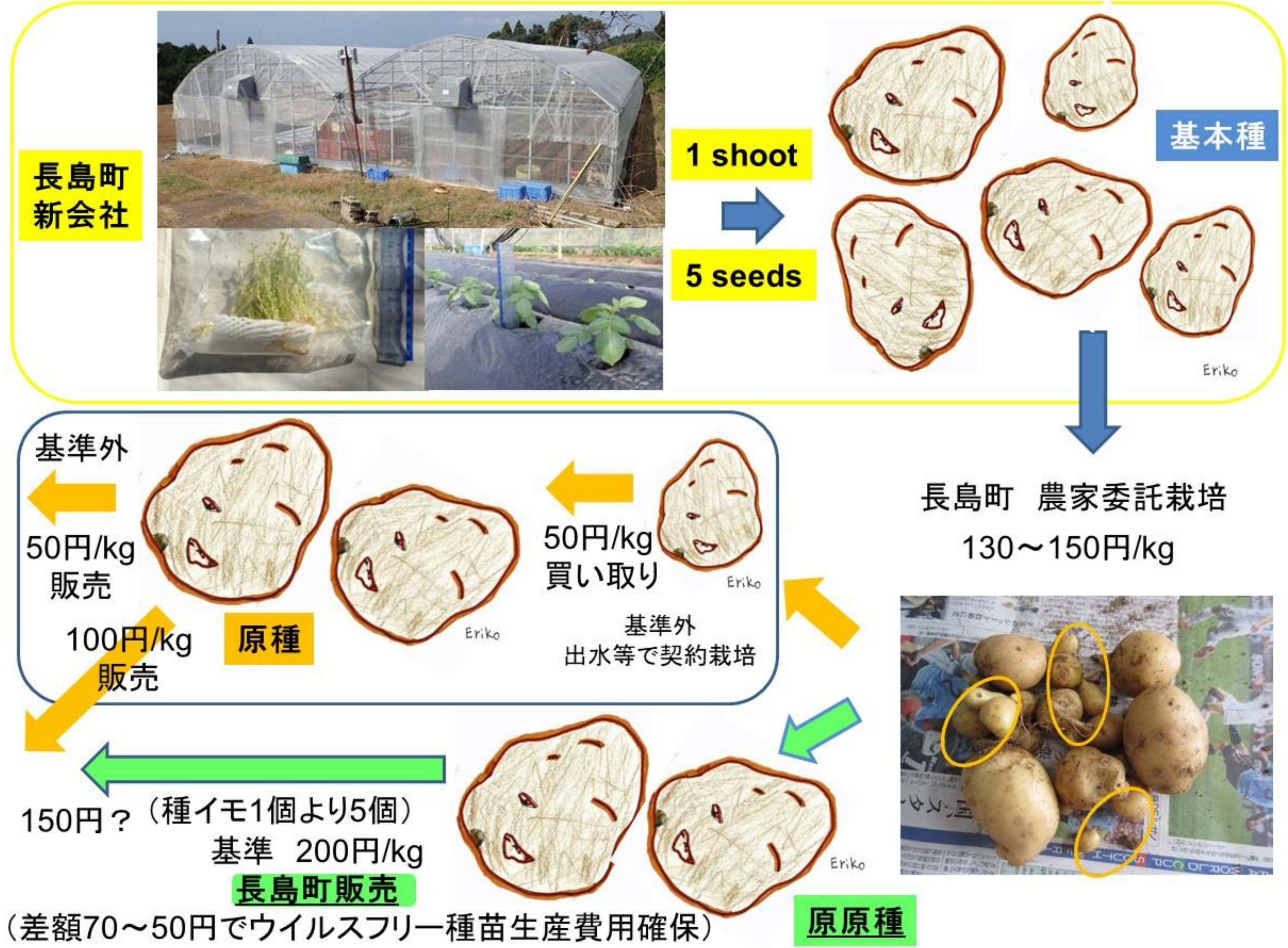
成長促進培養法

期間短縮による低コスト化

直接
植える

原原種?
配布

ウイルスフリー
種イモ生産



長岡技術科学大学
Nagaoka University of Technology

発芽･発根力の違い

サツマイモが地球上から消える日が来る！？

基腐病汚？

＜従来法＞

(クローン苗) → 切返 → 切返 → クローン苗 → 栽培？ → 発芽？ → 培養苗？

5000円／ポット

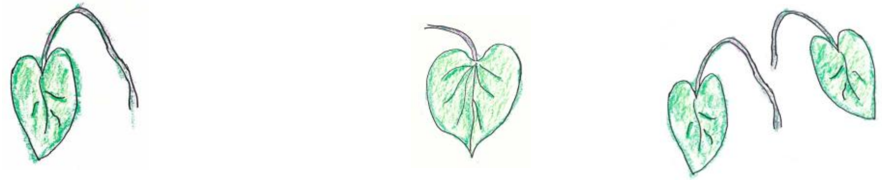
200円／本

3年 種芋？

種芋滅菌機　70%減？

＜革新的種苗生産法＞

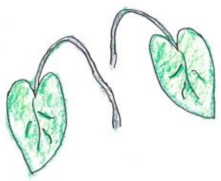
クローン苗 → 切返 → 切返 →



・革新的種苗生産技術(さつまいも編)

／1本クローン苗当たり

1本 クローン苗 ➡ 50本？ 切返 ➡ 500本？ 切返 ➡



研究課題

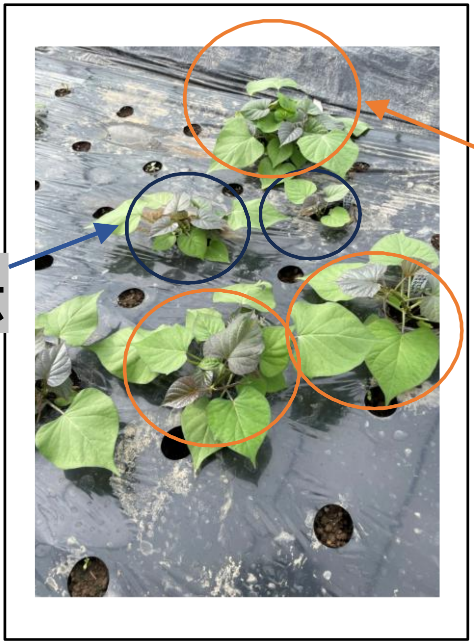
・*in green*での増殖技術の確立

（ジャガイモ種苗のように1本が100本以上になるような技術開発）

温度？
光？
➡ 増殖要因？

ミネラル×、植物ホルモン×

慣行法



M 式
長岡技術科学大学開発
革新的種苗生産技術

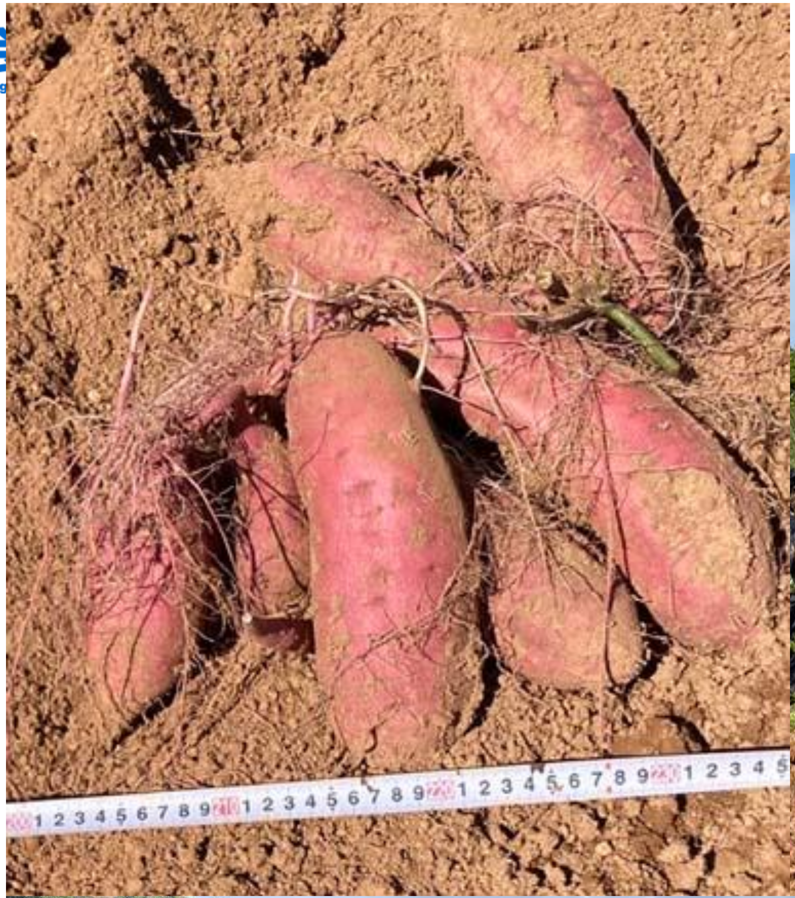
慣行法枯死！

真夏

真冬

冷房暖房・人工光源（LED）施設不要

20240511



実用化に向けた課題

現在、ジャガイモ種芋については、実用化レベル研究開発は実施済。バイオスティミュラント技術により、植物病を防ぐ完全無農薬ジャガイモ生産技術を実証試験中

サツマイモに関しては、色素系遺伝子発現について、基礎的研究を実施中（MASP　STEP1　原田隆大）。

今後、更に実験データを取得し、重要特許を複数取得する。

企業への期待

種芋、サツマイモ種苗等　ウイルスフリー種苗　販路を確立している企業、あるいは一緒に世界展開を進めていただける企業との共同研究を希望。

また、農業分野への世界展開を考えている企業には、本技術の導入が有効と思われる。

本技術に関する知的財産権

発明の名称	：栄養繁殖性植物の増殖方法および栽培方法
特許番号	：特許第7652408号
出願人	：長岡技術科学大学
発明者	：牧　慎也

産学連携の経歴

2022年度　MASP　STEP1事業に採択　牧　慎也
2026年度　MASP　STEP1事業に採択　原田　隆大
2028年-　　　　　　大学発ベンチャー設立予定

お問い合わせ先

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