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Fakultät Agrarwissenschaften/ Institut für Kulturpflanzenwissenschaften/ Ernährungsphysiologie der Kulturpflanzen

Molekulare Mechanismen der Clusterwurzelbildung bei der weißen Lupine

Betreut durch Prof. Dr. Uwe Ludewig

GFL Jahrestagung – 02.02.2022

Philipp Olt

DFG Deutsche Forschungsgemeinschaft

Phosphatreserven sind begrenzt

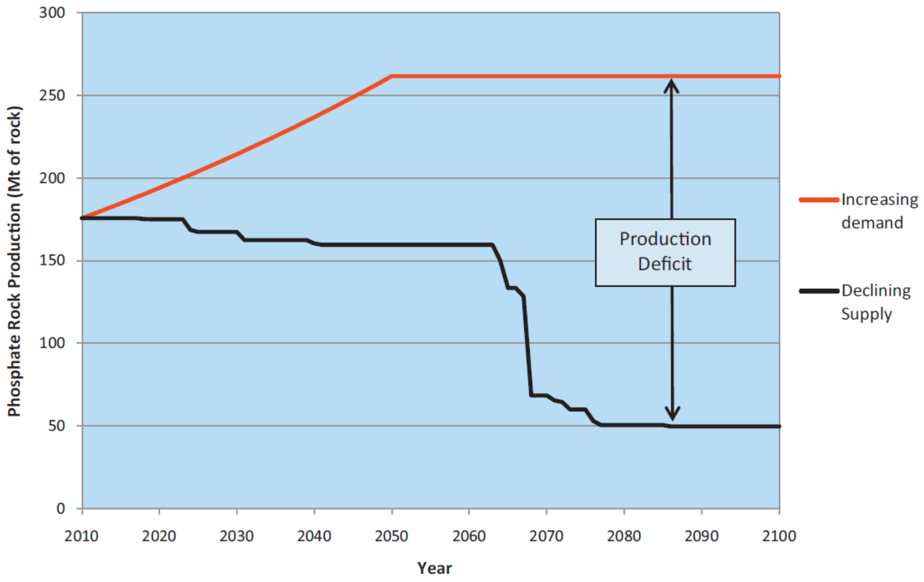
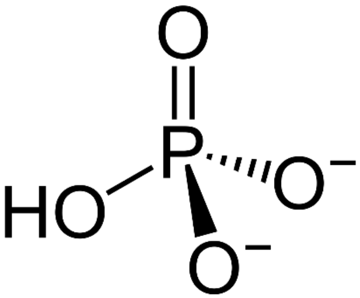


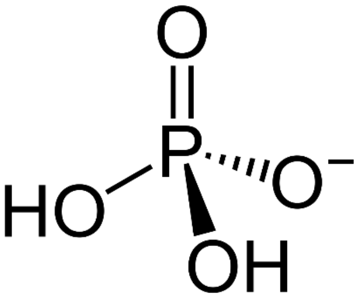
Fig. 6. Future phosphate rock production deficit as a result of rising demand and reserve depletion based on constant individual country extraction rates.

Cooper *et al.* 2011

Orthophosphat (P_i)

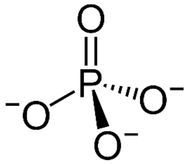


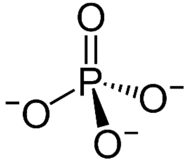
HPO_4^{2-}

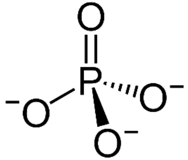


$H_2PO_4^{-}$

Schlecht lösliche Phosphate

$3\ Ca^{2+}$ + 2 

Al^{3+} + 

Fe^{3+} + 

und viele mehr…

https://upload.wikimedia.org/wikipedia/commons/thumb/0/0d/Hydrogenphosphat-Ion.svg/1217px-Hydrogenphosphat-Ion.svg.png
https://upload.wikimedia.org/wikipedia/commons/thumb/c/c8/Dihydrogenphosphat-Ion.svg/1217px-Dihydrogenphosphat-Ion.svg.png
https://de.wikipedia.org/wiki/Eisen(III)-phosphat#/media/File:Phosphate_anion.svg

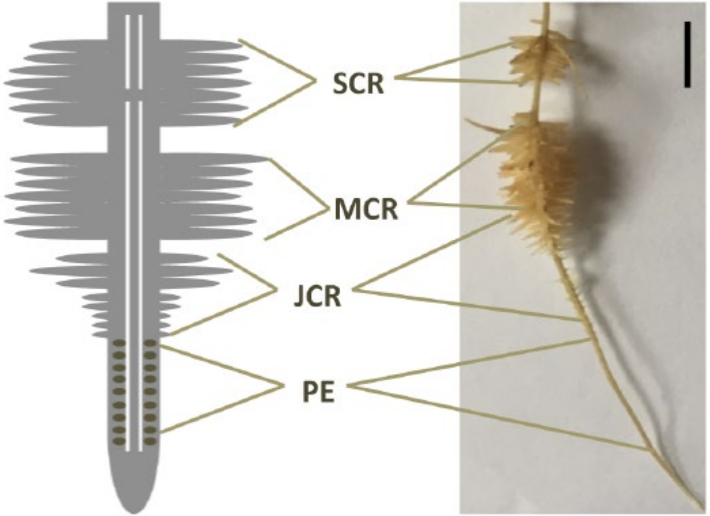
Clusterwurzeln (Proteoidwurzeln)

- Flaschenbürstenartige Ansammlung von Lateralwurzeln
- Reaktion auf Phosphat- (Pi) oder Eisen- (Fe) mangel

(Hagström *et al*. 2001, Neumann & Martinoia 2002, Skene 1998)

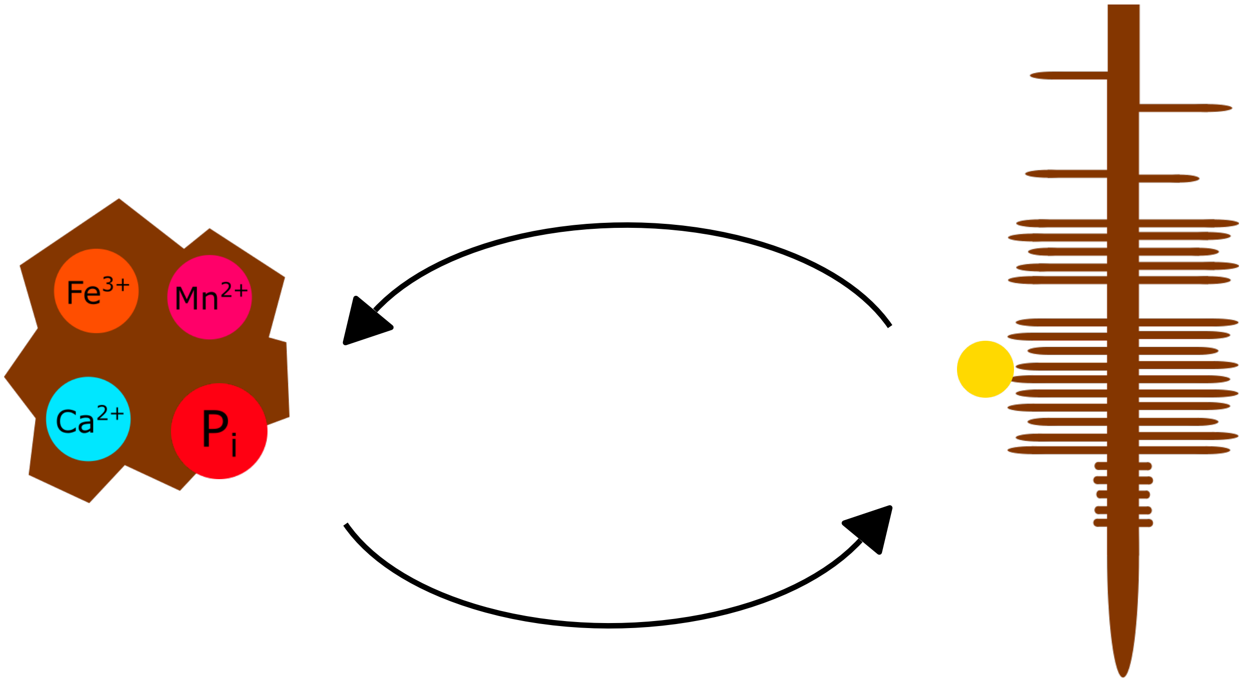
- Vergrößerte Oberfläche
- Exudation von organischen Säureanionen (Malat, Citrat)
- Ermöglichen das Lösen von schwer löslichem Phosphat im Boden(P)

(Gardner et al. 1983, Dinkelaker et al. 1997, Gilbert et al. 1999)



Zhou *et al*. 2018

Clusterwurzeln können schwer lösliche Phosphate lösen



Verschiedene Arten können Clusterwurzeln ausbilden

Table 1 Plant genera and species with proteoid-like root clusters.

Family	Genus	Species	Native geographical region	Reference
Proteaceae	*Adenanthos, Banksia, Conospermum, Dryandra, Franklandia, Grevillea, Hakea, Isopogon, Lambertia, Lomatia, Macadamia, Orites, Petrophile, Stirlingia, Strangea, Synaphea, Telopea, Xylomelum*	at least 200 species	most genera endemic in Australia, some genera also in Australasia, Central and South America	Purnell, 1960; Lamont, 1972b, 1982, 1993; Grinbergs et al., 1987; Grose, 1989; Handreck, 1991; Aitken et al., 1992; Grierson, 1992; Pate and Jeschke, 1993
	Aulax, Brabejum, Diastella, Faurea, Leucadendron, Leucospermum, Mimetes, Orothamnus, Paranomus, Protea, Serruria, Sorocephalus, Spatalla	at least 54 species	South Africa, all genera endemic	Lamont, 1983a; Lamont et al., 1984; Smith and Jooste, 1986
				geographic distribution of the Proteaceae: Johnson and Briggs, 1975
Casuarinaceae	*Casuarina*	*C. equisetifolia*		Gardner et al., 1982
		C. littoralis		
		C. obesa	Australia,	Reddell et al., 1986
		C. cunninghamiana	South East Asia, Pacific Islands	Khan, 1993
	Allocasuarina	*A. campestris*		Reddell et al., 1986
	Gymnostoma	*G. papuanum*		Racette et al., 1990
Mimosaceae	*Acacia*	*Acacia mucronata*	Australia	Sward, 1978
Fabaceae	*Lupinus*	*Lupinus albus*	Mediterranean region	Gardner et al., 1982a, b, 1983; Dinkelaker et al., 1989; Moraghan, 1991; Gerke et al., 1994
		Lupinus consentinii	Mediterranean region	Trinick, 1977; White and Robson, 1989
	Kennedia	*Kennedia*	Australia	Trinick, 1977; Brundrett and Abbott, 1991
	Viminaria	*Viminaria juncea*	Australia	Lamont, 1972c; Brundrett and Abbott, 1991; Walker and Pate, 1986
Myricaceae	*Myrica*	*Myrica cerifera* *M. gale*	North America	Louis et al., 1990, 1991; Crocker and Schwintzer, 1993
Moraceae	*Ficus*	*Ficus benjamina*	India	Rosenfield et al., 1990

(Dinkelaker *et al.*, 1995)

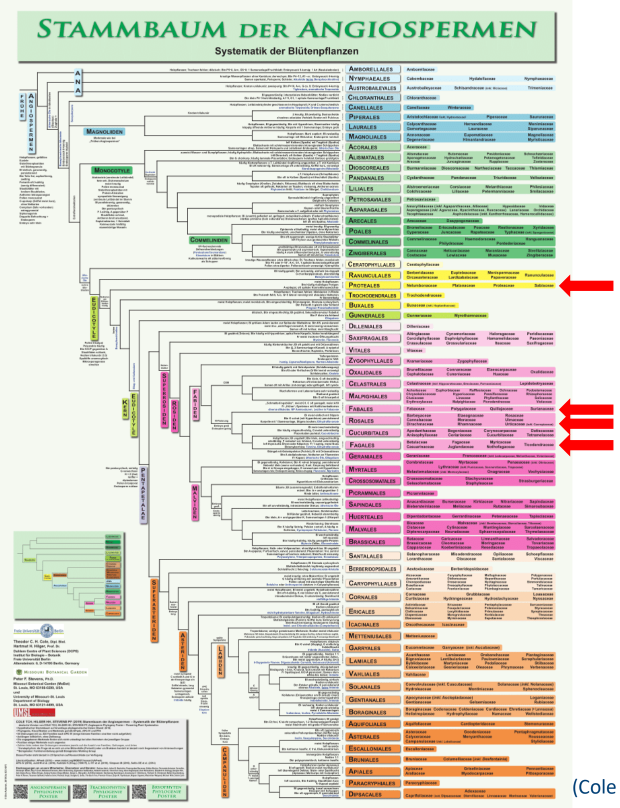
https://de.wikipedia.org/wiki/Macadamia#/media/Datei:Starr_080715-9233_Macadamia_integrifolia.jpg

https://flora-toskana.com/de/tropische-fruchtpflanzen/389-macadamia-integrifolia-macadamia-nuss-macadamiabaum.html

https://cdn.webshopapp.com/shops/159542/files/328938019/999x999x1/idorganics-macadamias.jpg

https://upload.wikimedia.org/wikipedia/commons/thumb/8/84/Allocasuarina_littoralis.jpg/220px-Allocasuarina_littoralis.jpg
https://bilder.t-online.de/b/89/43/04/66/id_89430466/610/tid_da/birkenfeige-im-royal-botanical-gardens-in-sri-lanka-ist-ein-besonders-grosser-ficus-benjamina-zu-sehen-.jpg
https://upload.wikimedia.org/wikipedia/commons/d/d6/Myrica_faya.jpg

Clusterwurzeln tauchen unabhängig von einander in verschiedenen Teilen des Stammbaums auf



(Cole *et al.*, 2021)

Nicht alle Lupinen können Clusterwurzeln ausbilden

	Cluster roots	References
Old World species[1]		
L. albus	Yes	Gardner et al., 1982
L. anatolicus	n.t.	
L. angustifolius	Yes/no	Egle et al., 2003; Hocking and Jeffery, 2004
L. atlanticus	Yes	Clements et al., 1993; Abdolzadeh et al., 2010
L. consentinii	Yes	Trinick, 1977
L. digitatus	Yes	Clements et al., 1993
L. hispanicus	Yes	Hocking and Jeffery, 2004
L. luteus	Yes	Hocking and Jeffery, 2004
L. mariae-josephi	n.t.	
L. micranthus	Yes	Clements et al., 1993; Abdolzadeh et al., 2010
L. palaestinus	Yes	Clements et al., 1993
L. pilosus	Yes	Clements et al., 1993
L. princei	Yes	Clements et al., 1993
L. somaliensis	Extinct	
New World species[2]		
L. arboreus	No	Skene and James, 2000
L. guadalupensis	No	Lambers et al., 2013
L. lepidus	Yes*	Lambers et al., 2012
L. mutabilis	Yes/no	Hocking and Jeffery, 2004; Pearse et al., 2006
L. polyphyllus	Yes	Razavi et al., 2017
L. sericeus	cho	Lambers et al., 2013
L. subcarinosus	No	Lambers et al., 2013
L. sulphureus	No	Lambers et al., 2013
L. texensis	No	Lambers et al., 2013

[1] All known Old World Lupinus species are listed.
[2] Only tested New World species are included.
n.t. indicates not tested; Yes, "cluster-like" root formation; cho, enhanced carboxylate release by roots; Yes/no, discrepancies between different studies.*

(Pueyo et al., 2021)

Modellorganismus: Weiße Lupine

- Weiße Lupine (*Lupinus albus* L.) (Fabaceae)
- Samen sind reich an Protein und Kohlenhydraten
- Gründüngungspflanze

Lupinen sind eine hochqualitative Proteinquelle

https://images-na.ssl-images-amazon.com/images/I/61dYAIPYfkL._SL1000_.jpg

https://www.femelle.ch/images/Kochen_Rezepte/Lupinen-Rezepte-660.jpg

https://img.chefkoch-cdn.de/rezepte/2499761392659386/bilder/665101/crop-360x240/lupinenkern-petersilien-salat.jpg

https://4.bp.blogspot.com/-WX_ldigaE7o/V6iIiE6YV6I/AAAAAAAAAB4/s1NQs2TFgSsaBCVM1cfQirGJBRYixA69QCEw/s1600/lupin%2Bchicken%2Bfeed.jpg

In gemäßigten Breiten hängt der landwirtschaftliche Erfolg der Lupinenkultur von der Anthraknoseresistenz ab

https://www.agric.wa.gov.au/sites/gateway/files/wide%20row%20bulk.jpg

https://precisionagricultu.re/wp-content/uploads/2018/02/crop-rotation1402-620x330.jpg

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Modellorganismus: Weiße Lupine

Genomsequenz:

nature COMMUNICATIONS

ARTICLE

https://doi.org/10.1038/s41467-019-14197-9 OPEN

High-quality genome sequence of white lupin provides insight into soil exploration and seed quality

Bárbara Hufnagel[1], André Marques[1,13], Alexandre Soriano[1], Laurence Marquès[1], Fanchon Divol[1], Patrick Doumas[1], Erika Sallet[2], Davide Mancinotti[3], Sébastien Carrere[2], William Marande[4], Sandrine Arribat[4], Jean Keller[5], Cécile Huneau[6], Thomas Blein[7], Delphine Aimé[8], Malika Laguerre[1], Jemma Taylor[9], Veit Schubert[10], Matthew Nelson[9,11], Fernando Geu-Flores[3], Martin Crespi[7], Karine Gallardo[8], Pierre-Marc Delaux[5], Jérôme Salse[6], Hélène Bergès[4], Romain Guyot[12], Jérôme Gouzy[2] & Benjamin Péret[1*]

White lupin (*Lupinus albus L.*) is an annual crop cultivated for its protein-rich seeds. It is adapted to poor soils due to the production of cluster roots, which are made of dozens of determinate lateral roots that drastically improve soil exploration and nutrient acquisition (mostly phosphate). Using long-read sequencing technologies, we provide a high-quality genome sequence of a cultivated accession of white lupin ($2n = 50$, 451 Mb), as well as de novo assemblies of a landrace and a wild relative. We describe a modern accession displaying increased soil exploration capacity through early establishment of lateral and cluster roots. We also show how seed quality may have been impacted by domestication in term of protein profiles and alkaloid content. The availability of a high-quality genome assembly together with companion genomic and transcriptomic resources will enable the development of modern breeding strategies to increase and stabilize white lupin yield.

Forschungsfragen

- Welche Signale lösen Clusterwurzeln aus?
- Welche Faktoren beeinflussen die Morphologie der Cluster?
- Wie funktionieren die Cluster?

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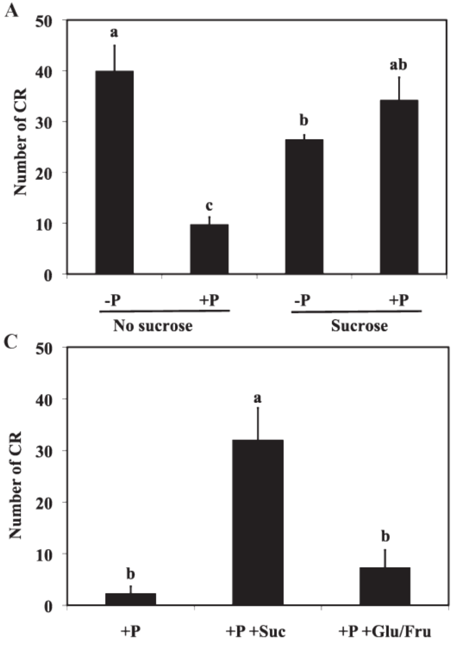
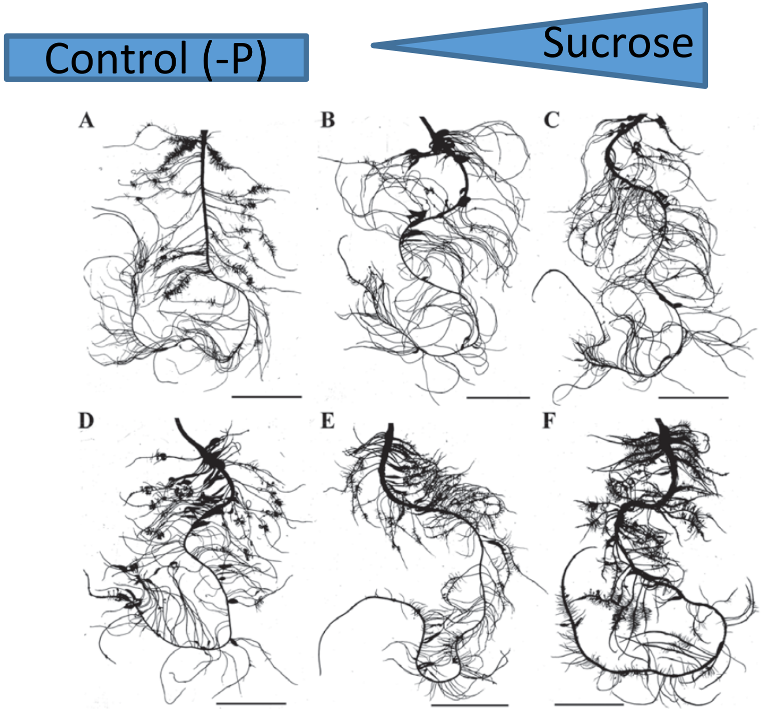
Saccharose löst Clusterbildung aus



(Wang *et al*. 2015)

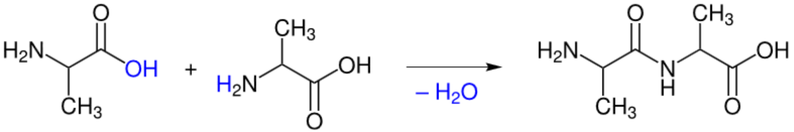


(Wang *et al*. 2015)

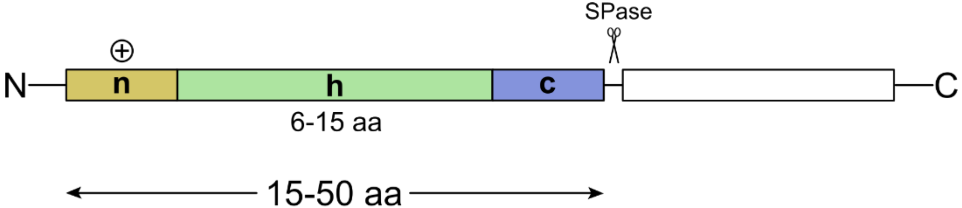
Peptide als Signalmoleküle

- Signalpeptide sind in vielen verschiedenen Bereichen der Entwicklung von Pflanzen beteiligt.

- Sie benötigen die Wahrnehmung durch spezielle Rezeptoren.
  (Butenko *et al*. 2009, De Smet *et al*. 2009, Murphy *et al*. 2012)



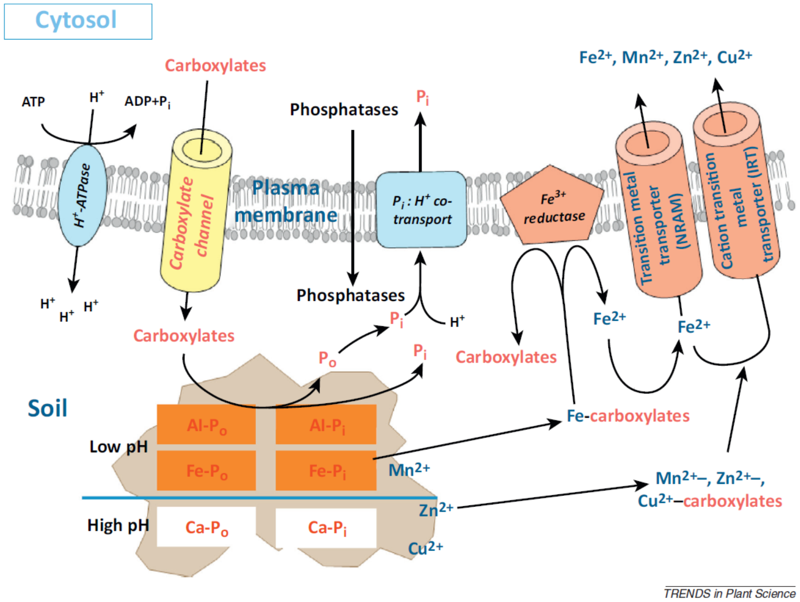
https://upload.wikimedia.org/wikipedia/commons/8/8d/Peptidbindung.svg



https://upload.wikimedia.org/wikipedia/commons/thumb/c/c6/Signal_sequence.svg/1920px-Signal_sequence.svg.png

https://www.ebi.ac.uk/pdbe/static/entry/1yk1_deposited_chain_front_image-800x800.png

Transportmoleküle in den Membranen haben einen Einfluss auf die Funktion der Cluster



(Lambers *et al*. 2015)

Zusammenfassung

- Clusterwurzeln sind eine Anpassung an Phosphormangel und können schlecht lösliche Phosphate wieder pflanzenverfügbar machen.
- Die weiße Lupine ist ein gut geeigneter Modellorganismus für Clusterwurzeln.
- Saccharose funktioniert als auslösendes Signal für die Clusterbildung.
- Signalpeptide könnten eine Rolle bei der Regulation der Morphologie von Clusterwurzeln spielen.

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Vielen Dank für Ihre Aufmerksamkeit!

https://lupein.ch/wp-content/uploads/2018/08/fullsizeoutput_123c.jpeg

Philipp Olt

Betreut durch Prof. Dr. Uwe Ludewig

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References

Butenko, M. A., Vie, A. K., Brembu, T., Aalen, R. B., & Bones, A. M. (2009). Plant peptides in signalling: looking for new partners. *Trends in plant science*, *14*(5), 255-263.

Cock, J. M., & McCormick, S. (2001). A large family of genes that share homology withCLAVATA3. *Plant physiology*, *126*(3), 939-942.

Cole, T. C. H., Hilger, H. H., Bachelier, J. B., Stevens, P. F., Goffinet, B., Shiyan, N. M., ... & Mosyakin, S. L. (2021). Spanning the Globe–The Plant Phylogeny Poster (PPP) Project. *Ukrainian Botanical Journal*, *78*(3), 235-241.

Cooper, J., Lombardi, R., Boardman, D., & Carliell-Marquet, C. (2011). The future distribution and production of global phosphate rock reserves. *Resources, Conservation and Recycling*, *57*, 78-86.

De Smet, I., Voß, U., Jürgens, G., & Beeckman, T. (2009). Receptor-like kinases shape the plant. *Nature cell biology*, *11*(10), 1166.

Dinkelaker, B., Hengeler, C., Neumann, G., Eltrop, L., & Marschner, H. (1997). Root exudates and mobilization of nutrients. *Trees: contributions to modern tree physiology*.

Gardner, W. K., Barber, D. A., & Parbery, D. G. (1983). The acquisition of phosphorus byLupinus albus L. *Plant and soil*, *70*(1), 107-124.

Gilbert, G. A., Knight, J. D., Vance, C. P., & Allan, D. L. (1999). Acid phosphatase activity in phosphorus-deficient white lupin roots. *Plant, Cell & Environment*, *22*(7), 801-810.

Hagström, J., James, W. M., & Skene, K. R. (2001). A comparison of structure, development and function in cluster roots of Lupinus albus L. under phosphate and iron stress. *Plant and Soil*, *232*(1-2), 81-90.

Lambers, H., Hayes, P. E., Laliberté, E., Oliveira, R. S., & Turner, B. L. (2015). Leaf manganese accumulation and phosphorus-acquisition efficiency. *Trends in plant science*, *20*(2), 83-90.

Murphy, E., Smith, S., & De Smet, I. (2012). Small signaling peptides in Arabidopsis development: how cells communicate over a short distance. *The Plant Cell*, *24*(8), 3198-3217.

Neumann, G., & Martinoia, E. (2002). Cluster roots–an underground adaptation for survival in extreme environments. *Trends in plant science*, *7*(4), 162-167.

Okamoto, S., Shinohara, H., Mori, T., Matsubayashi, Y., & Kawaguchi, M. (2013). Root-derived CLE glycopeptides control nodulation by direct binding to HAR1 receptor kinase. *Nature communications*, *4*, 2191.

Ohyama, K., Ogawa, M., & Matsubayashi, Y. (2008). Identification of a biologically active, small, secreted peptide in Arabidopsis by in silico gene screening, followed by LC-MS-based structure analysis. *The Plant Journal*, *55*(1), 152-160.

Pueyo, J. J., & Quiñones, M. A. Coba de la Peña T., Fedorova EE, Lucas MM (2021). *Nitrogen and phosphorus interplay in lupin root nodules and cluster roots. Front. Plant Sci*, *12*(644218), 10-3389.

Sattari, S. Z., Bouwman, A. F., Giller, K. E., & van Ittersum, M. K. (2012). Residual soil phosphorus as the missing piece in the global phosphorus crisis puzzle. *Proceedings of the National Academy of Sciences*, *109*(16), 6348-6353.

Skene, K. R. (1998). Cluster roots: some ecological considerations. *Journal of Ecology*, *86*(6), 1060-1064.

Tsikou, D., Yan, Z., Holt, D. B., Abel, N. B., Reid, D. E., Madsen, L. H., ... & Markmann, K. (2018). Systemic control of legume susceptibility to rhizobial infection by a mobile microRNA. *Science*, *362*(6411), 233-236.

Wang, Z., Shen, J., Ludewig, U., & Neumann, G. (2015). A re-assessment of sucrose signaling involved in cluster-root formation and function in phosphate-deficient white lupin (Lupinus albus). *Physiologia plantarum*, *154*(3), 407-419.

Zhang, B., Pan, X., & Anderson, T. A. (2006). MicroRNA: a new player in stem cells. *Journal of cellular physiology*, *209*(2), 266-269.

Zhou, Y., Sarker, U., Neumann, G., & Ludewig, U. (2018). The LaCEP1 peptide modulates cluster root morphology in Lupinus albus. *Physiologia plantarum*.