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Invasive Plant Biomass as a Source of Lipids for Bioeconomy

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***Abstract* – Invasive plants can be considered as a significant environmental problem: a direct threat to biodiversity but also affecting the productivity of agriculture forestry as well as human and animal health. Considering the threats by invasive plants European as well as other countries put efforts into invasive plant spreading control and eradication of existing populations. Invasive plant biomass at the same time can be a valuable resource for bioeconomy. The study aims to evaluate the possibilities of using invasive plant biomass as a source of biologically and pharmacologically active substances – lipids and fatty acids. Invasive plants common in North Europe have been studied: lupine, Canadian goldenrod and Japanese, Bohemian and Sakhalin knotweeds. For extraction traditionally used solvents were compared with green (low toxicity, biogenic origin) solvents and the good performance of the environmentally friendly solvents has been demonstrated. Bohemian knotweed exhibits higher proportions of certain fatty acids such as linoleic acid and eicosanic acid in comparison to other species. Japanese knotweed, on the other hand, generally displays intermediate levels for most fatty acids but stands out with distinct peaks in components such as linolenic acid. In contrast, Sakhalin knotweed dominates in several fatty acids including palmitic acid which highlights its unique biochemical profile. Thus, invasive plants can serve as valuable resources of biologically active compounds for differing applications and their biomass biorefinery can serve as a resource thus supporting invasive plant eradication efforts.**

***Keywords* – Bioeconomy; extraction; fatty acids; invasive plants; lipids.**

Nomenclature	
FA	Fatty acids
FAME	Fatty acid methyl esters
GC-MS	Gas chromatography-mass spectrometry
BSTFA	N,O-bis(trimethylsilyl)trifluoroacetamide
TMCS	Trimethylchlorosilane

1. INTRODUCTION

Invasive plants are a significant risk to biodiversity, agricultural production and forestry, as well as human health, thus requiring control of their spreading and eradication of already established populations [1]. Invasive plants degrade ecosystem services, reduce crop yields, increase management costs, reduce grazing value and have other adverse impacts [2]. Global economic costs of plant invasion were estimated to be ~4 billion USD per year [3].

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Eradication of invasive plants can be achieved using chemical and biological control methods and habitat management efforts [4], [5]. As a problem can be considered sometimes low efficiency of removal methods and the need for safe utilization of plant biomass [6]. The European Union has established regulations aimed at invasive plant spreading control and eradication outlining species of highest risk prevention measures and management and eradication activities [7].

Two problems are limiting the efficiency of existing invasive plant control and eradication activities: 1) knowledge of invasive plant composition and understanding of factors behind their invasiveness; 2) knowledge of their biomass safe utilization possibilities [8]. At the same time invasive plant biomass can be utilized using it as a resource for bioeconomy – as a source of energy, substances for diverse applications, fibers and other materials [9], [10]. This approach for invasive plant biomass utilization can help to transform invasive plant biomass into valuable resources and can make plant eradication economically beneficial or at least cover plant control efforts.

An important group of biomolecules are lipids, represented by triglycerides, fatty acids, terpenes, sterols and other groups of substances [11]. Invasive plant lipids contribute to their chemical defences, can affect soil enzymes and act as allelopathic chemicals inhibiting the growth of native plants [12]. Invasive plant lipids can contribute to environmental stress (salinity and temperature changes) tolerance of invasive plants [13]. Composition of lipids in invasive plants common in North Europe has not been much studied.

The study aims to evaluate the possibilities of using invasive plant biomass as a source of biologically and pharmacologically active substances – lipids and fatty acids to support plant eradication efforts.

2. MATERIALS AND METHODS

2.1. Materials

Reference standard substances were purchased from Sigma-Aldrich Chemie Ltd. (Steinheim, Germany) of analytical grade. 0.5 M trimethylphenylammonium hydroxide solution in methanol for GC derivatization were purchased from the same producer. A standard solution containing a mixture of C_4-C_{24} fatty acid methyl esters (FAMEs) with purity ≥99.0 % was acquired from Sigma-Aldrich Chemie Ltd. The used solvents: dichloromethane, chloroform, hexane, methyl tert-butyl ether, ethyl acetate and dimethyl carbonate were of HPLC, GC grade (Sigma-Aldrich, France).

2.2. Plant Material and General Extraction Procedure

Invasive plants Lupine (*Lupinus polyphyllus* L.), Canadian goldenrod (*Solidago canadensis* L.) and knotweeds (*Reynoutria japonica. R. sachalinensis. R. bohemica*) plants and their parts (leaves, stems, flowers, seeds, roots) were sampled in the summer/autumn of 2023, 2024 in the vicinity of Riga (Latvia) and Jēkabpils district (Latvia). Plant biomass was dried for 24 hours in an oven at 60 ºC, and milled using a laboratory cutting mill (Fritsch Pulverisette 15) to a particle size <1 mm. Dried and ground parts of the plant were weighed into Whatman extraction thimbles and extracted with CH_2Cl_2 (180 mL) in a Soxhlet extractor for 6 hours (1 cycle/70 sec). Dry extracted lipids were derivatized according to the ASTM D5974–96 method and further transesterified fatty acids were analysed by GC-MS.

2.3. Gas Chromatography-Mass Spectrometry

Chromatographic analyses were performed using a GC (Perkin Elmer, Clarus 580) coupled to a quadrupole MS (Clarus SQ 8 C) ESI source. The carrier gas (helium, 99.999 % purity) had a programmed flow rate of 1.0 mL min^{-1} with a 1:4 split ratio (10 mL min^{-1}). The source was operated in the positive ion mode with an electron energy voltage of 70 kV. The total ion current mode was set in the m/z range 25–480, but the ion multiplier current was set to 1700 V with a scan time of 0.2 s (625 scans sec^{-1}). The system was controlled by the "TurboMass Ver6.0.0" software and data processing was performed using the NIST MS 2.2 Library (FairCom Corp. USA) software. Free fatty acids composition was separated using an Omegawax 250 capillary column with a polyethylene glycol stationary phase (30 m × 0.25 mm, 0.25 µm film thickness). The column temperature program began at 75 °C (held for 2.0 min) increased to 130 °C (20 °C min^{-1}), then to 205 °C (4 °C min^{-1}) and finally to 230 °C (2.9 °C min^{-1}), with a hold time of 14.88 min (total analysis time 48 min). The MS ion source temperature and transfer line temperature were 230 °C and 260 °C, respectively. The sample injector temperature was adjusted to 230 °C.

3. Results and Discussions

To analyse lipid and especially fatty acid composition, three invasive plants, abundant in Northern, and Central Europe and elsewhere were selected: Lupine (*Lupinus polyphyllus* Lindl.), Canadian goldenrod (*Solidago canadensis* L.) and knotweeds (*Reynoutria japonica, R. sachalinensis, R. bohemica*) and their parts (leaves, stems, flowers, seeds and roots). For extraction of lipids from these plants efficiency of traditionally [14] used solvents (hexane, chloroform, dichloromethane) were compared with so-called "green solvents" (ethyl acetate, dimethyl carbonate, methyl tert-butyl ether (Table 1). For research purposes solvents such as dichloromethane, and chloroform can be recommended considering the highest yields of extractives, but "green solvent" efficiency demonstrate potential of their use to obtain lipids from invasive plants in preparative scale.

Table 1. Yields of Lipids (mg g^{-1}) from Leaves of Invasive Plants: Solvent Impact

Leaves	Chloroform	Hexane	Dimethyl carbonate	Methyl-t butyl ether	Dichloromethane	Ethyl acetate
R. japonica	21.8	9.1	13.1	10.7	11.3	15.1
L. polyphyllus	34.2	16.7	20.5	17.2	23.5	25.4
S. canadensis	43.2	19.7	28.6	19.7	31.9	23.5

Lipid yields in studied invasive plants and their parts (roots, stems, leaves, blooms, seeds) significantly differ (Fig. 1). The results obtained show that the highest yield of lipids has been found in seeds (86 mg g^{-1}), followed by leaves (40 mg g^{-1}), blooms (21 mg g^{-1}) and stems (10 mg g^{-1}). The lowest yield of lipids was found in roots.

An important group of lipids are fatty acids [14] and thus this group of substances in studied invasive plants were analysed in detail. A comparative analysis of fatty acid profiles from different knotweed species (*R. japonica, R. sachalinensis, R. bohemica*) reveals both commonalities and distinct variations across the samples. The data show that the fatty acid composition of the leaves of different knotweed species is very similar (Table 2). The highest mass of free fatty acids is found in *R. sachalinensis* (3.607 mg kg^{-1}), but in *R. japonica* and *R. bohemica*), it is lower – 2.153 and 2.416 mg kg^{-1} of biomass. In all samples, significant amounts of ester-forming fatty acids such as C16:0, C14:0, C18:0, C18:1n-9, and C12:0 were

also detected, confirming the findings of other studies regarding knotweed as a significant and enduring natural source of bioactive carotenoids [15].

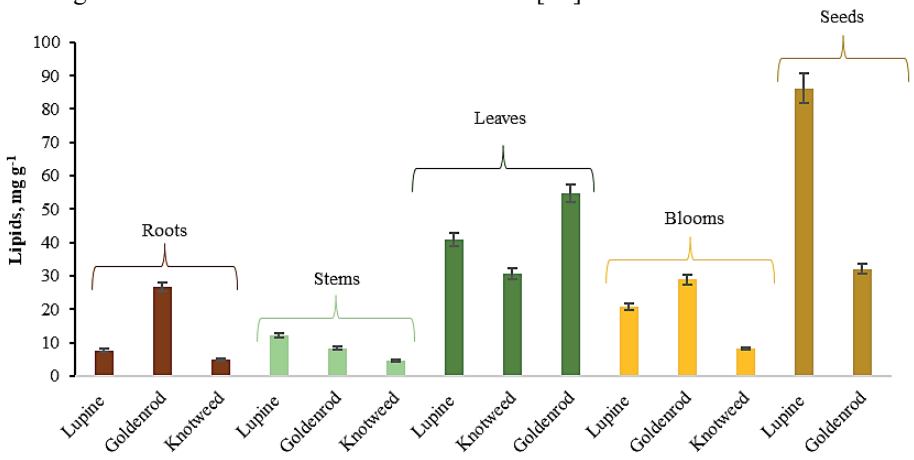

Fig. 1. The concentration of lipids in the different parts of Lupine, Knotweed and Goldenrod (*L. polyphyllus, S. canadensis, Reynoutria* spp.)

One of the dominant polyunsaturated fatty acids is C18:3n-3, which can significantly improve drought resilience for plants as it helps maintain saturation [16]. The highest amount of fatty acid found in this group is C18:2n-6, which can serve as one of the indicators in plants under stress [17]. In contrast to the *R. bohemica, R. japonica* and *R. sachalinensis* sample fatty acid profile, characterized by the presence of C16:1n-3 (Δ12c), which could significantly decrease under drought conditions [16] and C16:1n-5 (Δ11c), which has potential for use as pheromones [18]. *R. sachalinensis* is unique for its fatty acid C17:1n-8 (Δ9c), which possesses high added value [19]. Various plant species free fatty acid compositions were compared; *Reynoutria* spp. was used as a reference alongside the chosen invasive species, *L. polyphyllus, S. canadensis* for further study (Tables 3, Annex Table S1, S2).

Among the analysed plant species, *Reynoutria* spp. exhibited the highest FA diversity, with a total of 37 identified FAs. Within the *Reynoutria* spp. species, *R. bohemica* demonstrated the greatest diversity (36 FAs), while *R. japonica* had the lowest (33 FAs). In comparison, Lupine extracts contained 29 distinct FAs, whereas *L. polyphyllus* was characterized by 28 different FAs. The number of detected fatty acids (FAs) in this study is considerably higher than those reported in the existing literature. For instance, in *L. polyphyllus* seeds, only 14 to 19 FAs have been identified [20]. Additionally, no comprehensive fatty acid analysis for *S. canadensis* could be found in the available literature. The literature provides information on the fatty acid (FA) composition of *L. polyphyllus* seeds, which primarily consists of oleic, linoleic, and linolenic acids, with palmitic and stearic acids also present in significant amounts [20]. However, a comparison with the detected FA composition in *L. polyphyllus* leaves reveals notable differences. For instance, oleic acid, which dominates in the seeds, was not detected in the leaves, while palmitic and stearic acids were found to be the dominant FAs instead. Similar to *Reynoutria* spp., the majority of the free fatty acid mass in *L. polyphyllus* leaves is composed of linolenic acid. However, similar to the findings reported in the literature regarding *L. polyphyllus* seeds, the proportion of unsaturated fatty acids in the leaves is also close to 75 % [21].

TABLE 2. CONTENT OF FREE FATTY ACIDS IN THE LEAVES OF *L. POLYPHYLLUS* AND *S. CANADENSIS*

Omega name	**Common name**	**Content of free fatty acids, µg kg^{-1} DW**	
		L. polyphyllus	***S. canadensis***
(CLA) C18:3n-3 (Δ9c11t15c)	c9t11c15-Octadecatrienoic acid (18:3) (CLA)	20.7± 0.2	130.0 ± 1.0
C20:1n-9 (Δ11c)	11-Eicosenoic acid	<LOQ	6.9 ± 0.4
C16:1n-5 (Δ11c)	11-Hexadecenoic acid	<LOQ	2.9 ± 0.2
C20:1n-7 (Δ13c)	13-Eicosenoic acid	3.3 ± 0.0	19.0 ± 2.0
C16:1n-3 (Δ13c)	13-Hexadecenoic acid	146.0 ± 1.0	26.3 ± 1.1
C17:1n-10 (Δ7c)	7-Heptadecenoic acid	68.2 ± 2.0	38.2 ± 3.1
C16:1n-9 (Δ7c)	7-Hexadecenoic acid	5.7 ± 0.2	8.2 ± 0.8
C16:1n-7 (Δ9c)	9-Hexadecenoic acid	6.6 ± 0.1	10.2 ± 0.5
C9:0 (diacid)	Azelaic acid	19.9 ± 0.2	14.0 ± 1.4
C22:0	Behenic acid	85.3 ± 3.9	104.0 ± 4.3
C4:0 3-OH	3-Hydroxy butanoic acid	1.6 ± 0.3	<LOQ
C10:0	Capric acid	5.0 ± 0.3	<LOQ
C20:1n-[6-9] (Δ14-11t)	[14]–[11]-Eicosenoic acid	86.9 ± 0.8	640.1 ± 10.0
C21:0	Heneicosanoic acid	10.5 ± 0.3	17.3 ± 2.1
C26:0	Hexacosanoic acid	85.0 ± 3.2	19.0 ± 2.0
C12:0	Lauric acid	28.2 ± 0.8	8.3 ± 0.7
C18:2n-6 (Δ9c12c)	Linoleic acid	782.0 ± 7.9	1250.1 ± 40.0
C18:3n-3 (Δ9t12t15t)	Linolenic acid	4470.0 ± 70.3	3140.0 ± 50.4
C17:0	Margaric acid	23.2 ± 0.2	29.9 ± 0.8
C14:0	Myristic acid	96.4 ± 2.0	123.0 ± 5.5
C19:0	Nonadecanoic acid	3.6 ± 0.1	11.9 ± 0.6
C9:0	Nonanoic acid	1.7 ± 0.0	5.3 ± 0.5
C9:0 9-oxo	9-Oxo-nonanoic acid.	7.8 ± 0.6	2.0 ± 0.1
C16:0	Palmitic acid	1896.0 ± 1.2	1003.0 ± 20.2
C25:0	Pentacosanoic acid	24.8 ± 2.1	19.4 ± 1.1
C15:0	Pentadecanoic acid	12.6 ± 0.1	23.4 ± 3.3
C18:0	Stearic acid	326.0 ± 3.9	205.3 ± 3.8
C8:0 (diacid)	Suberic acid	3.3 ± 0.2	<LOQ
C24:0	Tetracosanoic acid	84.7 ± 0.4	106.2 ± 3.6
C23:0	Tricosanoic acid	27.4 ± 1.2	40.3 ± 3.0
(CLA) C18:2n-7 (Δ11c13t)	(CLA) 11-trans.13-cis-octadecadienoate	2.8 ± 0.1	8.0 ± 0.1

TABLE 3. CONTENT OF FREE FATTY ACIDS IN THE LEAVES OF *REYNOUTRIA* SPP

Omega name	Content of free fatty acids, μg kg^{-1}		
	R. bohemica	***R. japonica***	***R.sachalinensis***
(CLA) C18:2n-7 (Δ10t12c)	1.4 ± 0.1	3.7 ± 0.1	<LOQ
(CLA) C18:2n-7 (Δ11c13t)	1.4 ± 0.1	<LOQ	1.4 ± 0.1
C20:1n-9 (Δ11c)	32.4 ± 0.6	17.0 ± 1.3	3.5 ± 0.1
C20:1n-7 (Δ13c)	3.2 ± 0.1	2.7 ± 0.2	8.3 ± 0.6
C16:1n-3 (Δ13c)	8.5 ± 0.9	11.2 ± 0.4	21.8 ± 1.1
C16:3n-3 (Δ7c10c13c)	3.9 ± 0.1	3.7 ± 0.1	67.0 ± 0.2
C17:1n-7 (Δ7c)	6.6 ± 0.1	6.9 ± 0.203	<LOQ
C16:1n-9 (Δ7c)	3.7 ± 0.1	3.1 ± 0.2	5.1 ± 0.3
18:3n−3 (Δ9t12t15t)	3.2 ± 0.1	2.9 ± 0.1	4.4 ± 0.1
C16:1n-7 (Δ9c)	8.1 ± 0.6	4.3 ± 0.2	12.1 ± 1.1
C9:0 (diacid)	15.9 ± 0.9	17.1 ± 0.9	34.0 ± 0.7
C22:0	46.9 ± 1.2	30.6 ± 1.5	114.3 ± 0.8
C10:0	4.0 ± 0.1	4.1 ± 0.3	3.5 ± 0.1
C8:0 (diacid)	1.2 ± 0.1	0.9 ± 0.0	1.3 ± 0.1
C18:1n-7 (Δ11t)	16.2 ± 0.6	9.4 ± 0.1	27.3 ± 0.6
C20:0	38.7 ± 0.7	33.0 ± 1.0	65.1 ± 0.9
C18:1n-9 (Δ9t)	298.6 ± 6.8	204.3 ± 5.5	227.8 ± 9.3
C21:0	4.2 ± 0.5	4.5 ± 0.6	5.3 ± 0.1
C26:0	83.4 ± 0.6	98.6 ± 1.6	92.1 ± 5.6
C12:0	42.0 ± 1.4	44.7 ± 2.6	25.2 ± 0.4
C18:2n-6 (Δ9c12c)	265.1 ± 21.2	228.1 ± 0.3	495.1 ± 29.7
C18:3n-3 (Δ9t12t15t)	662.0 ± 11.4	517.9 ± 6.9	1190.0 ± 60.3
C17:0	6.6 ± 0.1	9.2 ± 0.1	11.1 ± 0.4
C14:0	64.5 ± 1.6	57.5 ± 1.3	87.0 ± 2.6
C19:0	2.0 ± 0.1	2.2 ± 0.1	2.2 ± 0.1
C9:0	2.2 ± 0.1	2.2 ± 0.0	3.6 ± 0.1
C9:0 9-oxo	1.7 ± 0.1	2.4 ± 0.1	5.0 ± 0.1
C16:0	610.1 ± 8.8	642.7 ± 10.9	864.9 ± 9.1
C25:0	15.0± 0.9	11.7 ± 1.0	25.7 ± 0.8
C15:0	5.2 ± 0.3	4.5 ± 0.2	10.3 ± 0.2
C18:0	60.1 ± 0.3	81.7 ± 1.3	84.3 ± 0.7
C8:0 (diacid)	1.5 ± 0.1	1.9 ± 0.0	1.5 ± 0.1
C24:0	78.4 ± 6.8	72.7 ± 4.6	139.6 ± 10.3

4. CONCLUSION

Invasive plants Lupine (*Lupinus polyphyllus* Lindl.), Canadian goldenrod (*Solidago canadensis* L.) and knotweeds (*Reynoutria japonica, R. sachalinensis, R. bohemica*) and their parts (leaves, stems, flowers, seeds and roots) are a rich source of lipids and they can be with reasonable yield produced using "green solvents". Lipid yields in studied invasive plants and their parts (roots, stems, leaves, blooms, seeds) significantly differ and the highest yield of lipids has been found in seeds (86 mg g^{-1}), followed by leaves, blooms and stems, but the lowest yield of lipids was found in roots. A comparative analysis of fatty acid profiles from different knotweeds reveals both commonalities and distinct variations across the samples. The data show that the fatty acid composition of the leaves of different species is very similar. Some found polyunsaturated fatty acids are a factor significantly improving drought resilience for plants as they help to increase drought resilience. *Reynoutria* spp. contains unique components that define their own biochemical profiles, highlighting the potential of knotweed as a significant natural resource for diverse applications. *L. polyphyllus* and *S. canadensis* also have a similar composition when compared to *Reynoutria* spp., however, the proportions of various fatty acids differ more.

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ANNEX

TABLE S1. CONTENT OF FREE FATTY ACIDS IN *S. CANADENSIS*

Omega name	Content of free fatty acids, µg kg^{-1}			
	Stems	**Roots**	**Seeds**	**Flowers**
(CLA) C18:2n-7 (Δ11t13c)	2.9 ± 0.2	6.7 ± 0.3	<LOQ	7.1 ± 0.6
(CLA) C18:3	4.6 ± 0.3	5.0 ± 0.5	3.9 ± 0.3	29.3 ± 0.8
20:3n-3 (Δ11c14c17c)	8.8 ± 0.8	2.2 ± 0.3	3.8 ± 0.0	5.4 ± 0.4
C20:1n-9 (Δ11c)	1.6 ± 0.0	5.2 ± 0.5	28.0 ± 2.3	20.4 ± 0.7
C20:1n-7 (Δ13c)	2.3 ± 0.2	5.3 ± 0.5	3.7 ± 0.2	7.6 ± 0.9
ai C18:0	2.4 ± 0.2	7.0 ± 0.7	<LOQ	<LOQ
C17:0n-7	0.8 ± 0.3	9.7 ± 0.1	10.7 ± 0.8	27.3 ± 1.1
C16:0n-7	1.6 ± 0.2	3.4 ± 0.3	4.5 ± 0.3	1.9 ± 0.2
C16:1n-7 (Δ9c)	1.2 ± 0.0	7.2 ± 0.4	5.2 ± 0.1	6.6 ± 0.5
C9:0 (diacid)	20.4 ± 1.0	25.1 ± 2.1	33.0 ± 3.3	26.0 ± 3.1
C22:0	16.5 ± 0.8	41.0 ± 4.4	106.0 ± 2.2	138.0 ± 3.4
C20:1n-[6-9] (Δ14-11t)	21.1 ± 1.2	33.0 ± 2.2	68.9 ± 0.8	110.1 ± 1.8
C21:0	3.9 ± 0.2	3.4 ± 0.5	12.0 ± 1.3	16.1 ± 0.8
C26:0	24.2 ± 2.7	4.2 ± 0.5	62.7 ± 3.6	60.0 ± 3.4
C12:0	0.9 ± 0.1	2.2 ± 0.1	35.8 ± 4.4	42.1 ± 0.7
C18:2n-6 (Δ9c12c)	390.3 ± 7.7	820.3 ± 60.0	297.1 ± 8.1	1570.1 ± 59.7
C18:3n-3 (Δ9t12t15t)	143.8 ± 4.4	150.0 ± 10.4	84.6 ± 4.7	750.2 ± 19.6
C17:0	17.4 ± 0.7	29.9 ± 0.8	25.0 ± 1.1	24.9 ± 1.6
C14:0	15.3 ± 0.5	8.4 ± 0.1	221.2 ± 4.3	711.0 ± 1.7
C19:0	3.5 ± 0.3	5.8 ± 0.3	24.8 ± 3.6	5.6 ± 0.8
C9:0	0.9 ± 0.0	1.3 ± 0.0	8.3 ± 0.3	4.9 ± 0.3
C9:0 9-oxo	7.2 ± 0.8	13.7 ± 1.1	1.2 ± 0.8	2.7 ± 0.4
18:1 cis-9	26.7 ± 1.6	67.7 ± 9.0	83.0 ± 4.3	315.7 ± 3.3
C16:0	459.4 ± 3.4	1260.0 ± 161.0	649.9 ± 30.1	980.0 ± 10.4
C25:0	7.4 ± 0.7	14.3 ± 0.6	30.2 ± 2.6	27.0 ± 2.6
C15:0	12.4 ± 0.2	47.1 ± 3.2	18.1 ± 1.1	24.0 ± 2.0
C18:0	35.7 ± 1.1	67.2 ± 8.0	208.0 ± 2.6	280.4 ± 5.3
C24:0	31.4 ± 0.8	81.8 ± 6.6	133.0 ± 8.3	205.5 ± 4.4
18:1 *trans*-11	9.0 ± 0.9	25.0 ± 1.7	17.7 ± 1.8	19.8 ± 0.4
C23:0	15.0 ± 1.3	27.4 ± 2.8	27.5 ± 3.3	31.0 ± 1.1

TABLE S2. CONTENT OF FREE FATTY ACIDS IN *L. POLYPHYLLUS*

Omega name	**Content of free fatty acids, μg kg^{-1}**			
	Stems	**Roots**	**Seeds**	**Flowers**
(CLA) C18:2n-7 (Δ11c13t)	1.8 ± 0.0	4.3 ± 0.2	24.0 ± 8.1	7.7 ± 0.2
(CLA) C18:3n-3 (Δ9c11t15c)	2.7 ± 0.0	3.5 ± 0.3	279.8 ± 5.4	40.1 ± 0.7
C20:1n-7 (Δ13c)	2.9 ± 0.0	1.6 ± 0.0	36.0 ± 2.2	9.7 ± 0.9
C16:1n-3 (Δ13c)	6.1 ± 0.0	1.5 ± 0.0	<LOQ	4.2 ± 0.2
22:3n-3 (Δ13c16c19c)	1.9 ± 0.0	15.8 ± 0.0	45.7 ± 0.8	5.9 ± 0.1
C17:1n-10 (Δ7c)	3.1 ± 0.0	6.2 ± 0.0	35.4 ± 0.5	<LOQ
C16:1n-9 (Δ7c)	2.2 ± 0.0	3.4 ± 0.0	17.3 ± 2.2	5.4 ± 0.3
C17:1	1.3 ± 0.2	2.8 ± 0.1	<LOQ	2.8 ± 0.1
C16:1n-7 (Δ9c)	<LOQ	8.5 ± 0.2	94.0 ± 1.7	4.1 ± 0.4
C9:0 (diacid)	14.2 ± 0.5	29.3 ± 0.6	21.4 ± 0.7	20.3 ± 0.3
C22:0	45.3 ± 0.1	25.2 ± 0.8	271.1 ± 6.0	192.4 ± 1.6
C18:1n-7 (Δ11t)	4.2 ± 0.3	128.7 ± 5.0	948.6 ± 100.4	8.5 ± 0.4
C20:1n-[6-9] (Δ14-11t)	27.9 ± 0.9	22.7 ± 0.5	164.1 ± 1.7	153.5 ± 5.5
C18:1n-9 (Δ9t)	11.1 ± 0.7	71.0 ± 0.3	12 050.0 ± 769.5	73.8 ± 1.1
C21:0	3.6 ± 0.2	6.2 ± 0.7	26.1 ± 1.4	16.7 ± 2.2
C26:0	15.1 ± 0.5	5.9 ± 0.2	22.5 ± 0.6	38.8 ± 4.3
C18:2n-6 (Δ9c12c)	1.6 ± 0.0	760.4 ± 26.2	20 054.0 ± 820.0	133.2 ± 2.2
C18:3n-3 (Δ9t12t15t)	15.1 ± 0.4	337.6 ± 10.4	4984.2 ± 304.3	167.4 ± 3.3
C17:0	13.7 ± 0.4	10.8 ± 0.4	21.9 ± 0.7	10.1 ± 0.3
C14:0	10.5 ± 0.3	9.9 ± 0.2	39.5 ± 0.9	17.9 ± 0.3
C16:0	414.0 ± 3.4	556.6 ± 1.5	6754.0 ± 620.0	1004.0 ± 10.3
C25:0	14.4 ± 1.3	10.9 ± 0.7	20.9 ± 0.3	16.3 ± 1.0
C15:0	6.14 ± 0.0	10.8 ± 0.5	16.7 ± 0.5	13.5 ± 1.5
C18:0	70.4 ± 0.3	70.6 ± 1.1	672.4 ± 32.2	211.4 ± 1.4
C24:0	29.1 ± 0.3	30.9 ± 0.1	133.4 ± 10.2	121.4 ± 10.0
C23:0	19.5 ± 0.2	20.6 ± 0.4	66.4 ± 4.4	24.3 ± 0.8