

# **BIOACCUMULATION OF LEAD IN SOYBEANS GROWN IN NATURALLY POLLUTED SOILS**

**Ljupcho Mihajlov, Biljana Kovacevik, Natalija Markova Ruzdik, Vesna Zajkova Paneva**

**Faculty of Agriculture, Goce Delchev University, Stip**

**Republic of North Macedonia**



## Introduction

- Soybean (*Glycine max*), is an annual legume from the family Fabaceae;
- The benefits of soybeans are numerous:
- It is rich in protein and low in price and thus it is considered one of the most economically important beans for food industry;
- Additionally, it contains no starch and, therefore, is a good source of protein for diabetics.
- It is also an important soil-enriching crop, adding nitrogen to the soil by means of nitrogen-fixing bacteria.

## SOYBEAN COMPOSITION

36% PROTEIN

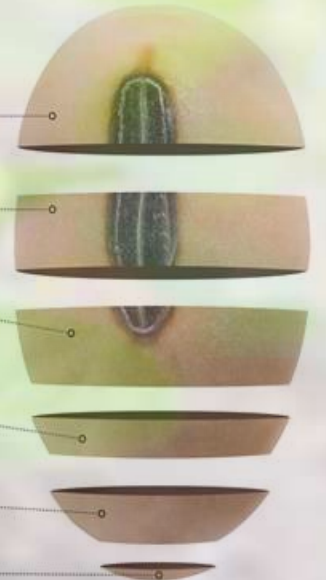
19% OIL

19% INSOLUBLE CARBOHYDRATE (FIBER)

9% SOLUBLE CARBOHYDRATE

13% MOISTURE

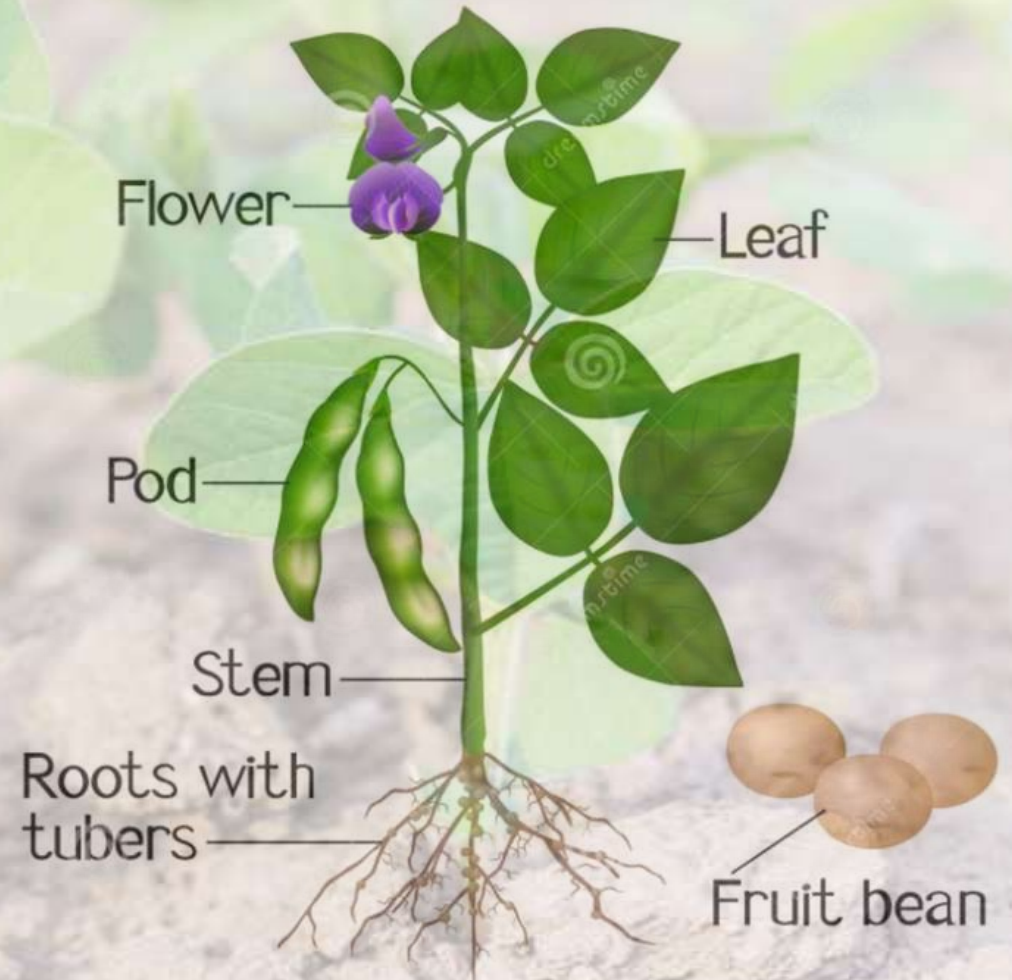
4% ASH (MINERALS)



Source: United Soybean Board

## Introduction

- Soybean is considered a good bioaccumulator of heavy metals from soil;
- Some authors even considered it as a remediation agent.
- In that case, the quality and the HM content in the seed could be an issue.
- Literature results are scattered.
- The purpose of our study was to investigate the ability of soybean to accumulate and translocate Pb in the plant parts (roots, shoots, leaves, pods, and seeds);



# Materials and methods

- The experiment was performed in a pot;
- Soil samples were collected from the naturally polluted soil with Pb from the top layer (25 cm depth) near the mining area of „Zletovo“.
- Soil quality was investigated before sowing the plants.
- Five different soybean varieties (Ilindenka, Pela, Avigea, Balkan, and Pavlikeni) with different vegetation periods were used in this study.
- Microwave digestion followed by the Q-ICP-MS analysis was used for the determination of Pb in different plant parts.



<b>Soybean variety</b>	<b>Origin</b>	<b>Mature group</b>	<b>Vegetation period</b>
Avigea	Bulgaria	0	100 days
Pela	Macedonia	0	100 days
Balkan	Serbia	I	120 days
Ilindenka	Macedonia	II	150 days
Pavlikeni	Bulgaria	II	150 days

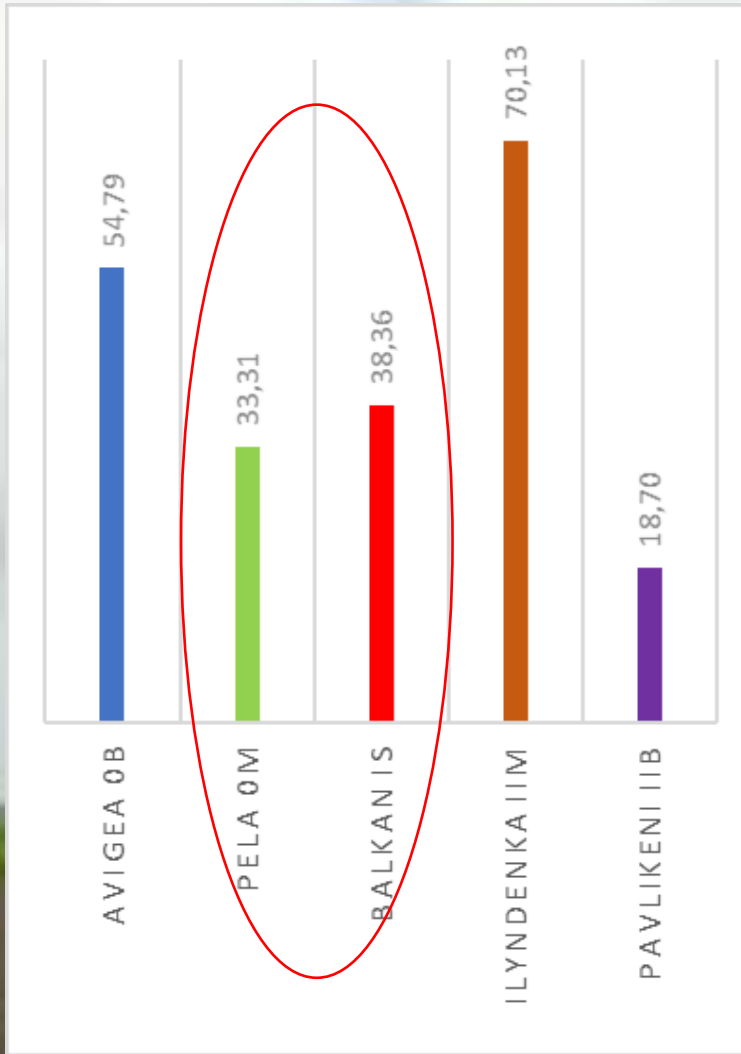
# Results



Table2. Soil quality from the Zletovo minning area

	Pb total ppm	Pb bioavailable ppm	pH	CEC cm/mo l	EC mS/cm	OM%	K2O mg/100g	P2O5 mg/100g	Loam %
soil	437	83.5	6.9	9.0	0.41	1.47	13.7	12.0	10.2
lgeo		4.6							

# Total Pb



## One-way ANOVA between groups

ANOVA						
Source of Variance	SS	df	MS	F	P-value	F crit
Between Groups	4742,668	4	1185,667	103,7500866	4,24233E-08	3,47805
Within Groups	114,2811	10	11,42811			
Total	4856,949	14				

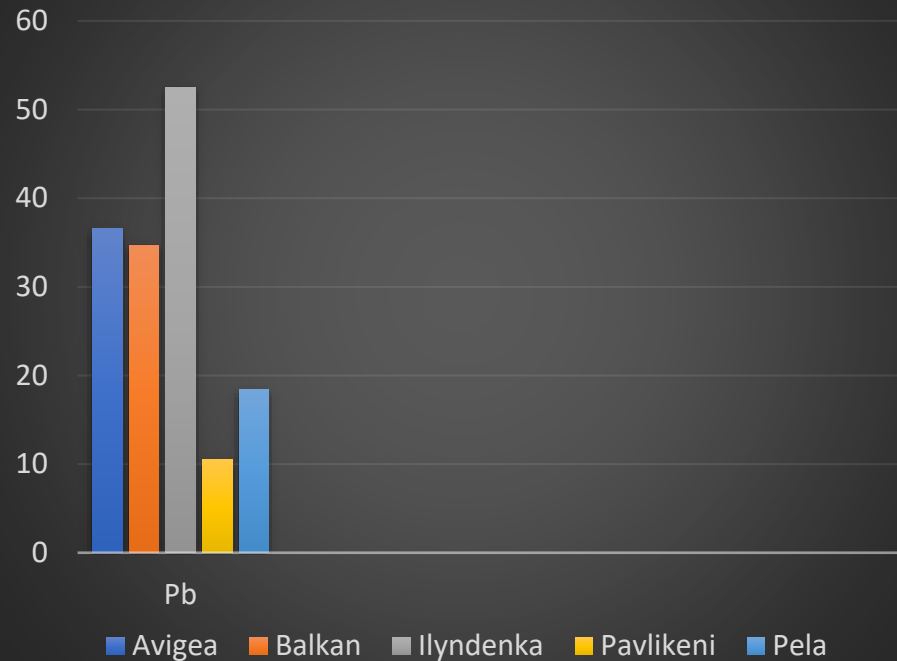
## Bonferroni-Adjustment $\alpha$ -crit = 0.01

t-Test	p
Avigea 0B/Pela 0M	0,002196
Avigea 0B/Balkan IS	0,006923
Avigea 0B/Ilyndenka IIM	0,010439
Avigea 0B/Pavlikeni IIB	0,000263
Pela 0M/Balkan IS	0,104192
Pela 0M/Ilyndenka IIM	0,000149
Pela 0M/Pavlikeni IIB	0,002154
Balkan IS/Ilyndenka IIM	0,000338
Balkan IS/Pavlikeni IIB	0,000998
Ilyndenka IIM/Pavlikeni IIB	3,3E-05

	Avigea	Balkan	Ilyndenka	Pavlikeni	Pela
<b>BAF</b>	0.66	0.46	0.84	0.22	0.40

# Roots

## Pb content in roots



## ANOVA single-factor analysis

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3254,77	4	813,6925	63,83224	4,42E-07	3,47805
Within Groups	127,4736	10	12,74736			
Total	3382,244	14				

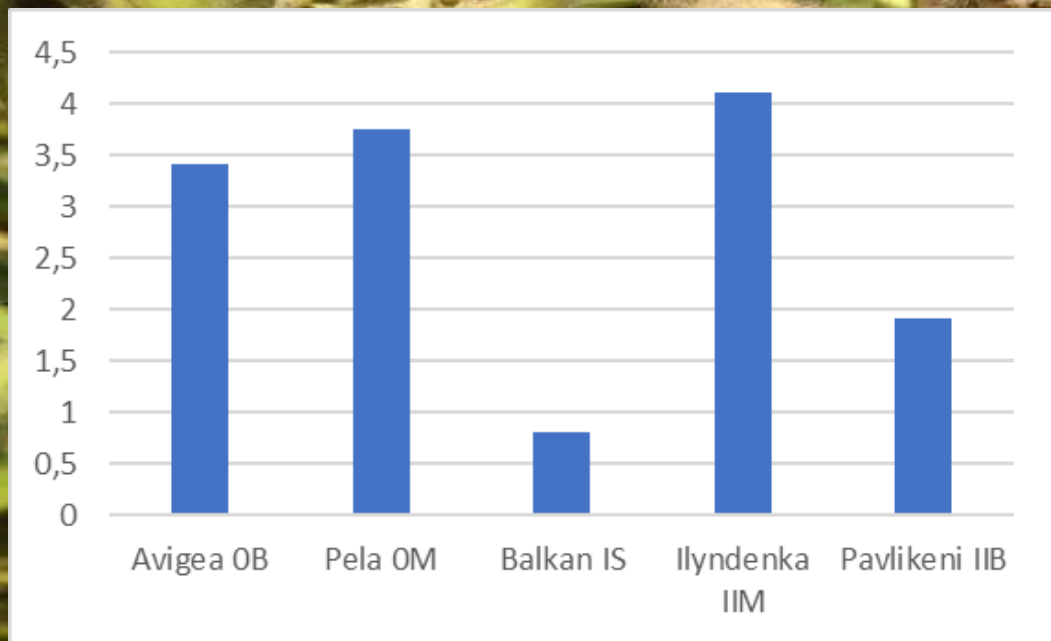
## Post-Hoc T-test for equal variances

t-Test	p
Avigea 0B/Pela 0M	6,19E-04
Avigea 0B/Balkan IS	0,2647
Avigea 0B/Ilyndenka IIM	0,0200
Avigea 0B/Pavlikeni IIB	4,59E-05
Pela 0M/Balkan IS	5,72E-04
Pela 0M/Ilyndenka IIM	0,0014
Pela 0M/Pavlikeni IIB	0,0074
Balkan IS/Ilyndenka IIM	0,0128
Balkan IS/Pavlikeni IIB	2,11E-05
Ilyndenka IIM/Pavlikeni IIB	5,30E-04

Table 3. The content of Pb (ppm) found in the roots of the investigated soybean varieties

Soybean variety	Avigea	Balkan	Ilyndenka	Pavlikeni	Pela
Pb roots	36.56±4.77	34.68±7.81	52.50±6.64	10.50±1.2	18.39±2.23
TA %	66,72	55,21	90,39	74,87	56,14

# Stem



## ANOVA single-factor analysis

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	23,185	4	5,79625	19,34189	0,000107	3,47805
Within Groups	2,996733	10	0,299673			
Total	26,18173	14				

## Post-Hoc T-test for equal variances

t-Test	p
Avigea OB/Pela OM	0,5557
Avigea OB/Balkan IS	0,000527
Avigea OB/Ilyndenka IIM	0,173689
Avigea OB/Pavlikeni IIB	0,026444
Pela OM/Balkan IS	0,00274
Pela OM/Ilyndenka IIM	0,550073
Pela OM/Pavlikeni IIB	0,032455
Balkan IS/Ilyndenka IIM	0,000598
Balkan IS/Pavlikeni IIB	0,037866
Ilyndenka IIM/Pavlikeni IIB	0,010911

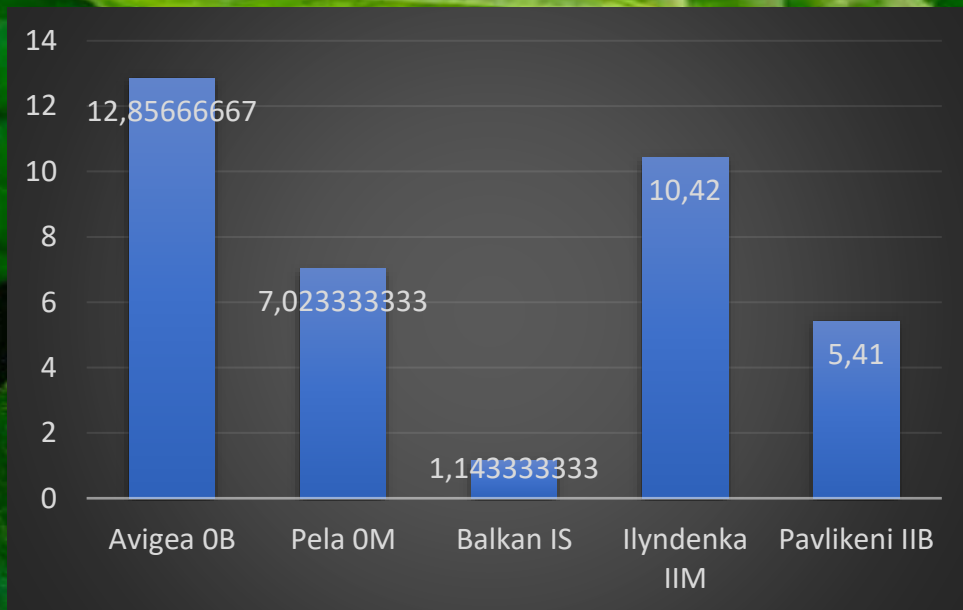
**Table 4. The content of Pb found in the shoots of the investigated soybean varieties**

Soybean variety	Avigea	Balkan	Ilyndenka	Pavlikeni	Pela
Pb / ppm	3.42±0.94	0.81±2.12	4.10±1.10	1.92±0.06	3.75±0.25
TA %	6,2	2,1	5,9	10,3	11,3

# Leaves

## ANOVA single-factor analysis

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	246,4175	4	61,60437	120,599	2,04E-08	3,47805
Within Groups	5,1082	10	0,51082			
Total	251,5257	14				



## Post-Hoc T-test for equal variances

t-Test	p
Avigea OB/Pela OM	0,0018
Avigea OB/Balkan IS	9,66E-05
Avigea OB/Ilyndenka IIM	0,0256
Avigea OB/Pavlikeni IIB	6,60E-04
Pela OM/Balkan IS	2,61E-04
Pela OM/Ilyndenka IIM	0,0012
Pela OM/Pavlikeni IIB	0,0376
Balkan IS/Ilyndenka IIM	7,41E-06
Balkan IS/Pavlikeni IIB	7,10E-04
Ilyndenka IIM/Pavlikeni IIB	1,82E-04

**Table 4. The content of Pb found in the leaves of the investigated soybean varieties**

Soybean variety	Avigea	Balkan	Ilyndenka	Pavlikeni	Pela
Pb / ppm	12.86±2.55	1.14±0.44	10.42±3.23	5.41±2.7	7.02±1.25
TA %	23,5	3	14,86	28,9	21,1

# Pods

## ANOVA single-factor analysis

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	21,42096	4	5,35524	41,25763	3,48E-06	3,47805
Within Groups	1,298	10	0,1298			
Total	22,71896	14				



## Post-Hoc T-test for equal variances

t-Test	p
Avigea OB/Pela OM	0,000724
Avigea OB/Balkan IS	0,842246
Avigea OB/Ilyndenka IIM	0,222011
Avigea OB/Pavlikeni IIB	0,009983
Pela OM/Balkan IS	0,001173
Pela OM/Ilyndenka IIM	0,003624
Pela OM/Pavlikeni IIB	0,000116
Balkan IS/Ilyndenka IIM	0,308427
Balkan IS/Pavlikeni IIB	0,017424
Ilyndenka IIM/Pavlikeni IIB	0,010303

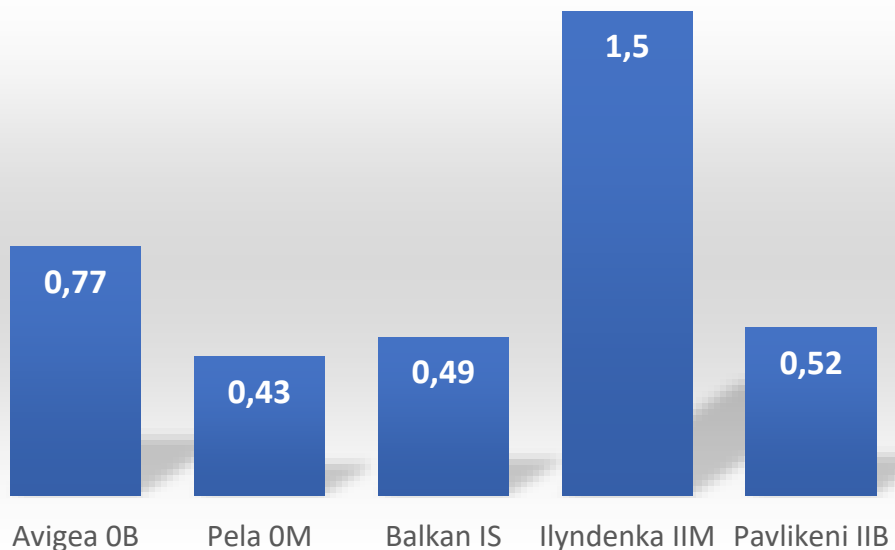
**Table 4. The content of Pb found in the pods of the investigated soybean varieties**

Soybean variety	Avigea	Balkan	Ilyndenka	Pavlikeni	Pela
Pb / ppm	1.18±0.14	1.24±0.24	1.66±0.36	0.35±0.02	3.90±0.14
TA%	2,1	3,2	2,4	1,9	11,7

# Seeds

## ANOVA single-factor analysis

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2,35644	4	0,58911	18,25	0,000137	3,47805
Within Groups	0,3228	10	0,03228			
Total	2,67924	14				



**MPL (EU) = 0.2 ppm**  
**MPL (FAO) = 0.1 ppm**

## Post-Hoc T-test for equal variances

t-Test	p
Avigea 0B/Pela 0M	0,079482
Avigea 0B/Balkan IS	0,110678
Avigea 0B/Ilyndenka IIM	0,018203
Avigea 0B/Pavlikeni IIB	0,236795
Pela 0M/Balkan IS	0,381707
Pela 0M/Ilyndenka IIM	<b>0,001756</b>
Pela 0M/Pavlikeni IIB	0,531024
Balkan IS/Ilyndenka IIM	<b>0,001744</b>
Balkan IS/Pavlikeni IIB	0,818154
Ilyndenka IIM/Pavlikeni IIB	<b>0,005394</b>

**Table 4. The content of Pb found in the seeds of the investigated soybean varieties**

Soybean variety	Avigea	Balkan	Ilyndenka	Pavlikeni	Pela
Pb / ppm	0.77±0.08	0.49±0.15	1.45±0.85	0.52±0.07	0.43±0.03
TA%	1,4	1,3	2,1	2,8	1,3

# Conclusion

- **There is a great diversity in soybeans regarding their ability to accumulate and translocate Pb;**
- **All investigated varieties have the greatest ability to store Pb in roots and the lowest ability to translocate it in the seed.**
- **Despite that the content of Pb in the seed exceeds the internationally established MRLs**
- **Although soybeans tolerate high concentrations of lead in neutral soils well, their cultivation in such soils is not recommended due to Pb concentrations in the seed that can exceed the MPL.**
- **There is a need for further research, especially on the ability of soybeans to accumulate Pb when grown in soils with lower concentrations, and how they behave in soils with different pH, especially in soils with higher pH, etc.**

**THANK  
YOU  
FOR  
YOUR  
ATTENTION**

