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ORIGINAL ARTICLE

Prospects of medicinal herbs management in reclaimed minelands of Ukraine

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The rocks of Nikopol manganese ore basin are represented with Neogenic and Paleogenic sediments. After realization of the stage of mine-technical reclamation loess-like and red-brown loams appear on the dump surface. Taking into biological specialty of most species of medicinal herbs, it can be assuming, some of them need culture on the humus rich soil to form the feedstock of stable quality, others can be successfully grown on pour leached soils, generally known as loess-like loams coming on the surface. Numerous types of medicinal herbs were tested in *situ* on the reclaimed mine land. From the comparison of the results with the defined permissible concentration limits, it was concluded that the levels of trace element contents in the locally available medicinal plants under investigation fall around the permissible range except for *German chamomile* (*Matricaria chamomilla*), *Dwarf everlast* (*Helichrysum arenarium*), *Motherwort* (*Leonurus cardiac*) and St John's-wort (*Hypericum perforatum*) with regard to its extremely high Cu and Mn content.
Key words: reclaimed mine land; medicinal herbs; trace elements

Introduction

Land area of the world is occupied by degraded land. Plantation of herbal plants at degraded land can help to save the diversity of these herbal plants and simultaneously will help to minimize the pressure on crop lands and reclaim the degraded land of the country (Kudesia et al, 2009). The waste lands and problematic soils can be also made cultivable lands with selection of suitable remunerative herbal plants. Medicinal plant cultivation may seem highly attractive but it has certain limitations that should not be overlooked while venturing into its cultivation (Kalaichelvi & Swaminathan, 2009). Meantime anthropogenic processes, involving the organic manure, synthetic fertilizers, industrial residues and lime upon exposer contribute various amounts of heavy metals to the ecosystem (Khan et al., 2002; Martins et al., 2008; Rehman et al., 2002).

That is why WHO suggested that medicinal plants used as ingredients of herbal formulation (teas, tinctures, etc.), should be checked for the presence of heavy metals (WHO 1998). The heavy metals contents of herbal teas are variable due to the factors like differences between the plants species, geographical area and exposure to different pollution sources (Muntean et al., 2016). Heavy metal uptake by the plants is therefore a main pathway of metal transfer from sediments and water to the food web. The metal uptake by the plant is determined by metal mobility and bioavailability (Gajalakshmi et al., 2012).

But the mechanism of the toxic metal absorption processes is still unclear. Some heavy metals at low levels are essential micronutrients for plants, but in higher concentrations they may cause metabolic disorders and growth inhibition as well, for some of the medicinal plant species (Masarovicova, Kral'ova, 2007). It is suggested that pharmaco-vigilance must be done to improve the quality, safety and efficacy of herbal drugs not only during their growth, but also during their sampling, processing and storage by traditional healers in order to avoid heavy metal contamination. Everyone involved in traditional herbal medicine should be sensitized to heavy metal contamination risk to improve the quality, safety, and efficacy of herbal drugs (Kofi et al, 2013).

The animal and human body requires both the metallic and the non-metallic elements within certain permissible limits for growth and good health. Therefore, the determination of element compositions in food and related products is essential for understanding their nutritive importance (Jabeen et al., 2010; Moses et al., 2008; Kostić et al., 2011). Today, there are a lot of scientific interests for the development of plant products as dietary supplements (Franz et al., 2011; Miroddi et al., 2013). Although the effectiveness of medicinal plants is mainly associated with their constituents such as essential oils and secondary metabolites, it is considered that prolonged intake can cause health problems if the heavy metals like Pb, Cd, Zn, Ni and other impurities are above the threshold concentrations (Stanojkovic-Sebica et al., 2015) .Up to 1220 species of the Ukrainian wild medicinal plants are of limited economic importance.

More than 50% of them have widespread geographical distribution but grow scattered or occasionally, and though there are no destructive impacts on their habitats their populations do not supply raw material for production of, e.g. medicine (Minarchenko, 2011). Although feedstock supplies of numerous species of wild herbs had significantly reduced recently due to intensive agricultural exploration of soils.

Around 50 % of the bulk medicinal herbs feedstock is represented by systematically cultured plants. Medicinal herbs culturing allows increasing significantly the pool of the feedstock for medicinal purposes (Country report, 2016). Among the reasons, requiring the expansion of medicinal herbal feedstock production following should be named: a) depletion of the wild herbs resources; b) necessity of production cost reduction due to high production cost of the herbal feedstock; c) technical complications with preparation of the large volumes of the feedstock; d) steadily increasing demand on herbal feedstock.

It should be mentioned that rocks of Nikopol manganese ore basin are represented with Neogenic and Paleogenic sediments. After mine rock biomelioration process on the second stage the dump surface is covered with black soil (Kharytonov, Resio, 2013). Phyitoindication estimation of soil conditions is discussed in a number of papers (Zhukov, 2015; Zhukov et al., 2016a; Zhukov et al., 2016b). It can be assumed that the part of reclaimed lands in this mining region could be used for medicinal herbs culturing.

Due to this in-depth study of medicinal s herbs productivity on different types of reclaimed lands is required. The main criterion of successful culturing in such conditions is the absence of the risk of herbal mass contamination with heavy metals (Kharytonov, 2007). Thus, different, regarding soil requirements, types of medicinal herbs were tested in *situ* on the reclaimed mine dump of mine-processing plant in Nikopol manganese ore basin. Most of these medicinal herbs species were detected during observation of natural plant covering of the dumps. The purpose of the study is to define the possibility of medicinal herb feedstock production using different types of reclaimed lands.

Material and methods

During experiments in the Pokrovsky land reclamation station, medicinal herbs for which both above and underground parts are used as feedstock were tested. To study the reaction of different species of medicinal herbs microfield trials were established. General scheme of artificial soil profiles creation is presented in Fig. 1.

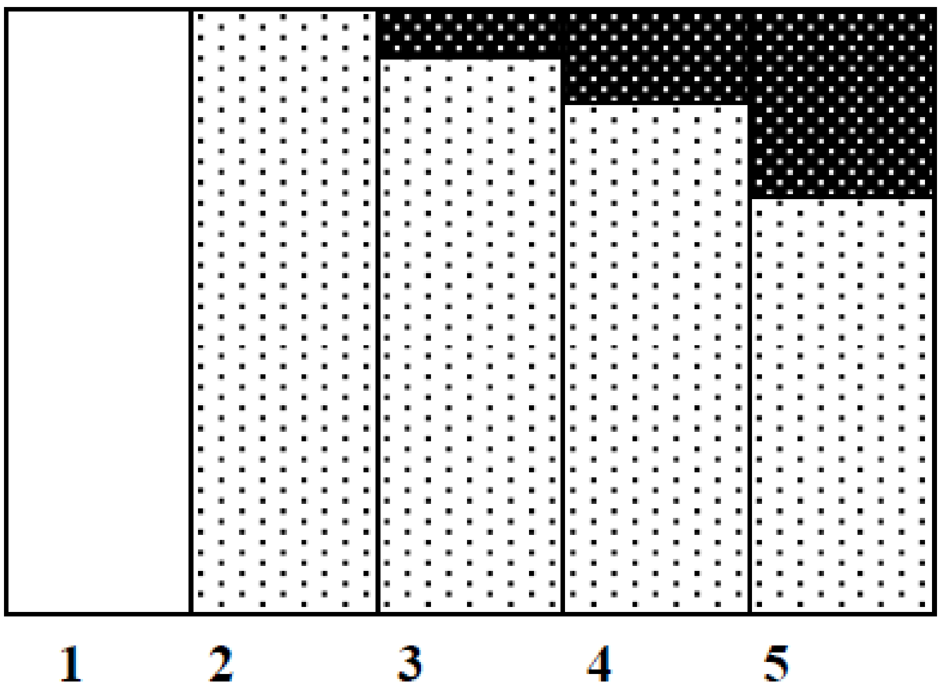

Fig. 1. General scheme of artificial soil profiles creation

Two profiles of the long-term plant meliorated rocks are shown in Fig. 2.

Loess loam Mix of Red-Brown Loam and Clay

Fig. 2. Artificial Profiles of Rocks after Long-Term Plant Melioration

30-cm stratum of black soil was created in the surface of dump consisting in mix loess and red-brown loams and red-brown clay (# 3 in Fig.1). Experiment plots were established both on black soil cover of 30 cm thickness and loess like loam (without topsoil, #2 in Fig. 1) with fertilizers application in dosage $N_{80}P_{80}K_{80}$ during seeding and $N_{40}P_{40}$ for transmitting seedings and without fertilizers in three replications. Total plot area was 10 sq. m.

The following plant species were chosen for the field experiments: *Marsh mallow* (*Althaea officinalis*), *Braunton's milkvetch* (*Astragalus brauntonii*), *Tooth pickweed* (*Ammivisnaga*), *Valerian* (*Valeriana officinalis*), *St John's-wort* (*Hypericum perforatum*), *English marigold* (*Calendula officinalis*), *German chamomile* (*Matricaria chamomilla*), *Dalmatian pellitory* (*Tanacetum cinerariifolium*), *Dwarf everlast* (*Helichrysum arenarium*), *Motherwort* (*Leonurus cardiac*), *Common madder* (*Rubiatinctorum*), *Wallflower* (*Erysimum*), *Broadleaf plantain* (*Plantago major*), *Field restharrow* (*Ononisar vensis*), *Common sage* (*Salvia officinalis*) and others.

Most of chosen species are perennial herbs. During the first year they grow slowly and can be harvested on the zonal soils only on the second year. Application of fertilizers was aimed to achieve harvesting mass within first year.

5 g of soil sample was extracted by shaking with 50 ml of *1 N HCl* and letting stand for one day (Kharytonov et al., 2004). Trace element concentrations were determined by comparison with prepared standards provided by the Laboratory of Standard Solutions, Physical-Chemical Institute, Odessa, using a Saturn 3 atomic absorption-spectrophotometer (North Donetz Engineering Design Bureau, Ukraine) using standard methods of flame spectrophotometry.

After drying in the air and next in a drier at 103ºC until to the constant weight, plant material was thoroughly ground in laboratory mill. Prior to analyses, herbs were stored in paper bags in a dry and aerated place. To determine mineral elements contents samples weighing 2 g were combusted in a muffle furnace at 450°C by means of drying method and then dissolved in 5 ml 6N spectral purity hydrochloric acid. Determination of trace elements contents in obtained mineralizers were made by means of flame using a spectrophotometer AAS (Germany). The obtained data on chemical properties of the soil studied represent the arithmetic means of three replicates of each sampling, their ranges and standard deviations values.

Results and discussion

According to the harvesting efficiency all studied plants could be divided on the three groups. First group is presented with medicinal herbs very sensitive to the fertility of reclaimed lands. Data on the productivity of plants referred to the first group (highly demanding to soil fertility) are shown in Table 1. The influence of mineral fertilizers on the productivity of the medicinal herbs was additional parameter that was studied.

Table 1. Productivity of herbal plants highly demanding to soil fertility, ton/ha

Species	Black topsoil		Loess like loam	
	Control	NPK	Control	NPK
Immortelle (Helichrysum arenarium)	0.760±0.040	1.060±0.070	0.090±0.004	0.410±0.008
English marigold (Calendula officinalis)	0.920±0.050	1.030±0.050	0.160±0.006	0.660±0.012
Mother wort (Leonurus cardiac)	2.730±0.060	3.930±0.080	0.450±0.010	0.670±0.007
Common madder (Rubiatinctorum)	1.390±0.040	1.460±0.070	0.160±0.004	0.20±0.005
Wall flower (Erysimum)	18.0±0.050	19.90±0.070	8.90±0.050	10.60±0.050

During second year of growth on the black topsoil obtained productivity for these species was varying from 0.76 to 2.73 ton/ha. Application of the fertilizes allowed to obtain biomass gain on 15-65 % higher than for plants on same substrate without fertilizers. *Dwarf everlast* (*Helichrysum arenarium*) and *Motherwort* (*Leonurus cardiac*) had the strongest response on fertilizers introduction. Second group – medicinal herbs with moderate demand to the fertility of reclaimed soils. Data on second group (mezotrophs) productivity are represented in Table 2.

Table 2. Productivity of medicinal herbs with moderate demand to the soil fertility, ton/ha

Species	Black topsoil		Less like loam	
	Control	NPK	Control	NPK
St John's - wort (Hypericum perforatum)	2.350±0.060	2.380±0.080	1.650±0.050	2.290±0.050
Broadleaf plantain (Plantago major)	2.230±0.050	3.350±0.090	1.090±0.050	2.080±0.040
German chamomile (Matricaria chamomilla)	0.580±0.004	0.840±0.008	0.240±0.015	0.490±0.003

The strongest response on fertilizers introductions was observed for *Broadleaf plantain* in the second group. Biomass on the topsoil with fertilizers increased in 1.5 times and in 2 times on the loess like loam. Third group is medicinal plants with low demand to the fertility of reclaimed soils. Data on the third group (evrytrophs) are represented in Table 3.

Table 3. Productivity of medicinal plants with low demand to the soil fertility, ton/ha

Species	Black topsoil		Less like loam	
	Control	NPK	Control	NPK
Astragalus (Astragalus brauntonii)	2.350±0.057	2.420±0.062	2.080±0.035	1.950±0.040
Marsh mallow (Althaea officinalis)	1.830±0.036	2.050±0.065	0.860±0.014	1.010±0.010
Ammi dental (Ammi visnaga)	1.210±0.016	1.310±0.010	0.950±0.02	1.020±0.015
The harrow plow (Ononisarvensis)	0.560±0.005	0.60±0.005	0.860±0.015	1.440±0.012
Dalmatian pellitory (Tanacetum cinerariifolium)	2.530±0.066	3.130±0.075	0.930±0.013	1.050±0.009
Common sage (Salvia officinalis)	16.90±0.037	18.10±0.035	14.90±0.018	16.03±0.012

Results of micro-field trials with application of mineral fertilizers on black soil and loess loam had proved ability of the plants of this group to compensate for essential nutrients. The strongest response for *NPK* introduction was observed for field rest harrow (*Ononi sarvensis*). Data on heavy metal content in black soil and plant meliorated rocks are shown in Table 4.

Table 4. Heavy metals content in the soil and rocks, mg·kg^{-1}

Substrata	Co	Ni	Pb	Mn	Zn	Cu	Fe	Cr
Black soil	4.88±0.30	8.40±0.40	16.60±0.90	535.0±17.0	62.0±8.0	8.30±0.40	1747±73.0	3.0±0.20
Loess like loam	5.56±0.20	7.90±0.50	13.800±0.40	343.0±20.0	81.0±8.10	6.60±0.20	1283±71.0	3.10±0.20
Red-brown loam	5.68±0.10	8.43±0.10	12.20±0.50	348.0±7.0	28.30±2.40	6.80±0.20	1243±34.0	3.0±0.20
Red-brown clay	6.85±0.30	11.30±0.30	12.60±0.07	467.0±7.0	35.0±36.0	8.57±0.30	1848±108.0	3.80±0.10

Analysis of the content of microelements in soil and rocks indicates that the data obtained are comparable. Results of analysis of ash extracts of medicinal herbs are given in the Table 5.

It is known that 200-400 mg·kg^{-1} DM of Fe content at herbs is considered as the excess (Kabata-Pendias, Mukherjee, 2007). Results achieved from the study indicate that Fe levels in some herbs exceed the physiological limits for plants.

The permissible limit set by FAO / WHO for edible plants for copper was 3.00 mg·kg^{-1} (Jabeen et al., 2010).

After comparison of metal limit in the studied plants with those proposed by FAO/WHO (FAO/WHO, 1984) it was found that all plants accumulated Cu above this limit.

The highest copper content levels were detected for English marigold (*Calendula officinalis*), *German chamomile* (*Matricariachamomilla*), *Dwarf everlast* (*Helichrysumarenarium*), *Motherwor*t (*Leonurus cardiac*) and *St John's-wort* (*Hypericumperforatum*).

According to obtained data, the highest concentration of manganese (> 90 *mg·kg^{-1}*) is detected in German chamomile (*Matricaria chamomilla*), Dwarf everlast (*Helichrysum arenarium*), Motherwort (*Leonurus cardiac*).

Zinc in concentration more than 30 mg·kg^{-1} was detected only in English marigold (*Calendula officinalis*), German chamomile (*Matricaria chamomilla*) and Motherwort (*Leonurus cardiac*).

However, it did not exceed 500 mg·kg^{-1} DM (described as a toxic concentration for plants) in any studied material (Kabata-Pendias, Mukherjee, 2007).

The zinc concentration in the studied plants ranges between 11 mg·kg^{-1} to 32 mg·kg^{-1} compared to 27.4 mg·kg^{-1} permissible limit set by FAO/WHO in edible plants. Thus the concentration of Zn in the studied plants is around the normal range for the element excluding Motherwort (*Leonurus cardiac*). The cobalt and nickel concentrations in the studied plants were around the normal range for the element.

Magnesium concentration of 2000 mg·kg^{-1} in plants is commonly regarded as the minimum "safe" dietary concentration for adequate animal health (Little, D.A., 1982). This provides that all studied plants can be used to compensate magnesium deficiency in animals.
At the same time magnesium concentrations in the plants grown on loess like loam exceeded on 15-50 % the amounts of above ground mass for black soil, excluding English marigold (*Calendula officinalis*) and Motherwort (*Leonurus cardiac*).

Table 5. Trace elements content (mg·kg^{-1}) in medicinal plants, grown on black topsoil and phytomeliorated loess loam

Species	Soil	Co	Ni	Mn	Zn	Cu	Fe	Mg
Field restharrow	Black topsoil	2.0±0.12	2.4±0.3	22.0±0.8	14.0±1.2	12.0±0.7	438.8±42	8895±452.0
(Ononis arvensis)	Loess loam	3.0±0.2	2.7±0.4	28.0±1.4	11.0±1.0	12.0±0.8	655.4±55	10990±517
Marsh mallow	Black topsoil	4.0±0.3	2.6±0.3	42.0±2.5	19.0±8.7	12.0±1.5	479.7±44	13192±570
(Althaea officinalis)	Loess loam	4.0±0.3	3.1±0.3	24.0±1.1	20.0±1.7	18.0±2.0	404.0±39	19997±971
Valerian	Black topsoil	4.0±0.2	4.2±0.2	89.0±4.0	21.0±2.5	11.0±0.9	927.0±85	5499±233
(Valeriana officinalis)	Loess loam	5.0±0.3	4.6±0.3	60.0±5.0	22.0±2.7	15.0±1.5	992.0±97	9797±504
English marigold	Black topsoil	6.9±0.3	2.8±0.1	84.0±3.5	33.0±2.5	27.0±2.5	740.6±96	14292±610
(*Calendula officinalis*)	Loess loam	6.0±0.3	3.2±0.4	60.0±3.4	37.0±4.5	18.0±1.5	510.9±67	13497±560
German chamomile	Black topsoil	7.0±0.4	4.4±0.3	203±10.0	32.0±2.0	21.0±2.1	624.7±49	10495±505
(*Matricaria chamomilla*)	Loess loam	6.0±0.3	4.8±0.3	161±9.5	31.0±2.5	21.0±2.2	662.9±57	11198±630
Dwarfeverlast	Black topsoil	5.0±0.2	2.6±0.1	128.0±6.0	26.0±1.5	17.0±0.9	414.9±40	9498±470
(*Helichrysum arenarium*)	Loess loam	5.0±0.3	3.7±0.3	98.0±4.7	27.0±2.5	24.0±1.9	381.9±39	12498±712
Motherwort	Black topsoil	7.0±0.2	3.2±0.1	149±8.7	36.0±2.0	32.0±3.5	752.9±59	28595±1550
(*Leonurus cardiac*)	Loess loam	8.0±0.6	4.7±0.3	88.0±5.4	32.0±2.2	25.0±2.6	591.8±40	26689±1350
St John's-wort	Black topsoil	3.0±0.2	1.5±0.04	76±4.4	21.0±1.5	26.0±2.0	329.0±28	6700±210
(*Hypericum*per foratum)	Loess loam	2.0±0.3	1.7±0.3	51.0±2.1	22.0±2.7	21.0±2.5	242.0±20	7500±250
Braunton's milkvetch	Black topsoil	5.0±0.2	3.6±0.3	83.0±4.1	26.0±2.9	14.0±0.9	352.9±19	14394±492
(Astragalus brauntonii)	Loess loam	5.0±0.3	4.4±0.5	75.0±3.7	23.0±3.0	17.0±1.5	291.9±18	16495±510

Conclusions

Growing of the medicine plants feedstock on the loess like loam can provide sufficient productivity for plants referring to highly and moderate demand to substrate fertility. The strongest response on fertilizers introduction was observed for Dwarf everlast (*Helichrysum arenarium*), Motherwort (*Leonurus cardiac*) and Broadleaf plantain (*Plantago major*).
The concentration (mg·kg^{-1}) of the elements in the plants studied was found to be as follows: manganese (22 to 203), iron (242 to 992), copper (12 to 32), zinc (11 to 37), cobalt (2 to 8), nickel (1.7 to 4.8) and magnesium (5499 to 26689).

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