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AGROECONOMIC EVALUATION OF AROMATIC AND MEDICINAL PLANTS USED FOR THE ENRICHMENT OF GRASSLANDS

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Abstract

The aim of this research was to clarify the successfulness of seeding medicinal plants in pasture. The trial was carried out in May 2016 in Latvia; soil – sod gleyic; pHKCl 5.7; organic matter content – 2.1 g kg^{-1}. The trial included two mixtures of seeds: the mixture "Country Horse 2122" contained nine species of medicinal plants in different proportions; the second mixture contained oregano and St. John's wort in equal parts. The seeds were sown in squares that were free from sward: "Country Horse 2122" in eight repetitions, and the mixture of oregano and St. John's wort in seven repetitions. In the trial, the influence of the mixture on the growth and development of plants was studied, the changes in botanical composition were established, and the installation costs were calculated. In the squares with the oregano and St. John's wort, more than 50% of plants were weeds. For "Country Horse 2122", the count of weeds was 4% in 2016 and 7% in 2017. The costs of seeds and manual work for the "Country Horse 2122" trial were 139 EUR per 100 m^2, and for the mixture of oregano and St. John's wort – 208 EUR per 100 m^2. The mixture "Country Horse 2122" can be recommended to farmers – it can be sown mechanized in lines. In that case, the costs can make about 250 EUR per ha, and the yield can be cut in the year of sowing.

Keywords: medicinal plants, grasslands, mixture of seeds.
JEL Codes: Q01, Q12, Q15.

Introduction

The sward composition of different grasslands consists of grasses, legumes, herbs, and mostly of shrubs and trees (Nagy et al., 1997). It is important to provide high quality pastures as well as to improve the productivity and health of livestock. All over the world, in addition to traditional pasture grass types, it is popular to interseed medicinal plants in order to treat animals medicinally for the prevention and treatment of livestock ailments (Nagy et al., 1997). Medicinal plants are described as plants with high microbiological characteristics and bactericidal and fungicidal effects (Sulzberger, 1995). For livestock, medicinal plants improve the lack of appetite and facilitate the digestive process of animals, boost their immune system, reduce inflammation, grow up milk secretion, etc. Also, medicinal plants are indicators of grassland biodiversity (Nagy et al., 1997).

Such species of medicinal plants as caraway (*Carum carvi* L.), chicory (*Cichorium intybus* L.), dandelion (*Taraxacum officinale* Web.), garden thistle (*Cirsium oleraceum* Scop.), garlic (*Allium sativum* L.), goldenrod (*Solidago virga-aurea* L.), great willowherb (*Epilobium* sp.), yarrow (*Achillea millefolium* L.), mead wort (*Filipendula ulmaria* L.), nettle (*Urtica dioica* L.), oregano (*Origanum vulgare* L.), sagewort (*Artemisia* sp. Willd.), primrose (*Primula* sp.), ribwort (*Plantago lanceolata* L.), St. John`s wort (*Hypericum perforatum* L.), tansy (*Tanacetum vulgare* L.), thyme (*Thymus* sp.), viola (*Viola* sp.), and more others are recommended in ethnoveterinary medicine (Antal and Csedo, 2004; Lkhagvatseren et al., 2010; Seidler-Lozykowska, 2009).

Scientific literature approves the positive effect of many medicinal plants on the health and productiveness of livestock. For example, wormwood (*Artemisia absinthium* L.) and yarrow (*Achillea millefolium* L.) can be used for the reduction of the urea content in milk of dairy cows (Mosimann et al., 2015). Oregano (*Origanum vulgare* L.) reduces gas emission in cows during the first third of lactation and has potential to be used as a feed additive for dairy cows (Kolling et al., 2018). Camomile (*Matricaria chamomilla* L.) and black caraway (*Nigella sativa* L.) can be used as natural growth promoters in ewe diets to improve milk yield and composition and lamb growth (El-Ghousein, 2010). Condensed tannins in the bark of Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) H. Karst.) and birch (*Betula pubescens* Ehrh.) can be utilized as a feed supplement for animal health (Steinshamn, 2014). The descriptions below give information about the most popular medicinal plants for the enrichment of grasslands in Northern Europe.

Yarrow (*Achillea millefolium* L.) is a flowering plant in the family *Asteraceae*. It is a common herb of both wet and dry areas, such as roadsides, meadows, fields and coastal places (Rubine and Eniņa, 2010). It has been introduced as a feed for livestock in places like New Zealand and Australia. Yarrow contains essential oils (terpenes, terpene alcohols and sesquiterpenes), vitamins C and K, carotenoids, resins, trace elements, bitters, phytoncides, stubborn substances. It is used in the case of upper respiratory tract inflammation as an anti-inflammatory agent, to improve digestion and appetite, to treat diarrhea and inflammation of digestive organs, and it also prevents intestinal gas accumulation. Yarrow has anti-inflammatory, bactericidal and anti-allergic effects (Jakovskis, 2007; Rubine and Eniņa, 2010; Brutāne et al., 2003).

Caraway (*Carum carvi* L.) is a biennial plant in the family *Apiaceae*. Caraway is distributed throughout practically all of Europe except the Mediterranean region. It is widely established as a cultivated plant. It has a

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pleasant aroma and burning bitter taste. Seeds and roots contain essential oils, and the most important compounds are D-carvone, D-limonene, caravel, and other terpenes and their derivatives. Seeds and roots also contain oils, proteins, flavonoids, tannins, coumarins, triterpenes, sitesterols, resinous substances, minerals, and other substances. Caraway is used to improve the function of digestive organs, it increases the secretion of the mammary gland and prevents bloating (Rubine and Eniņa, 2010; Brutāne et al., 2008).

Chicory (*Cichorium intybus* L.) is a somewhat woody, perennial herbaceous plant of the dandelion family *Asteraceae*. Chicory is grown as a forage crop for livestock. It is a wild, cold-resistant plant on roadsides in its native Europe (Rubine, Eniņa, 2010). Roots contain bitters, bitter glucosides, intibone, sugars, inulin, ascorbic acid, methoxycumarine, organic acids, phenol carboxylic acids, sesquiterpene lactones, proteins, resinous substances. Flowers contain flavonoids and vitamin C, but leaves contain bitters, vitamins, and minerals. Chicory has soothing, bactericidal, anti-inflammatory, analgesic and metabolic effects (Brutāne et al., 2003; Rubine and Eniņa, 2010, Brutāne et al., 2008).

Ribwort plantain (*Plantago lanceolata* L.) is a species of flowering plant in the plantain family *Plantaginaceae*. It is a common weed of cultivated land. It contains phenol carboxylic acids and their derivatives, flavonoids, carbohydrates, and fumaric acid, while its seeds contain oils, mucous membranes, and proteins; different phytosterols are found in the roots. The leaves have anti-inflammatory, spasmolytic, diuretic, secretintic and wound-healing effects (Rubine and Eniņa, 2010).

Oregano (*Origanum vulgare* L.) is a flowering plant in the mint family *Lamiaceae*. Oregano is a perennial herb, it is native to temperate Western and Southwestern Eurasia and the Mediterranean region (Rubine and Eniņa, 2010; Flečers, 2010). It has a mild scent and bitter taste. Oregano contains essential oils (consisting of phenols: thymol, carvacrol, cymom and various terpenes), flavonoids, tannins, bitters, triterpic acids, ascorbic acids, minerals (selenium, molybdenum, iron). Oregano has antimicrobial, antiviral and anticrescent effects. It improves digestion, intestinal peristalsis and biliary secretion (Rubine and Eniņa, 2010; Brutāne et al., 2008).

Common nettle (*Urtica dioica* L.) is a herbaceous perennial flowering plant in the family *Urticaceae*. It is native to Europe, Asia, northern Africa, and North America, and is introduced elsewhere. Common nettle cntains K, C, A and B vitamins. It also contains flavonoids, histamine, serotonin, choline, carotenoids, chlorophylls, triterpenes, sterols, glycoside urticanes, tannins, organic acids, pantothenic acid, formic acid, coumarins, and minerals copper, barium, selenium, strontium, molybdenum. Fast-acting active substances reduce inflammation and affect the overall metabolism. Common nettle stimulates tissue regeneration, tones up the stomach and intestinal tract (Tereško, 2014; Rubine and Eniņa, 2010).

For the enrichment of grasslands, it is important to use local medicinal plants in agrocenosis as they are adapted to the specific agroecological conditions and possible stress situations in a local environment (Sivicka, Zukauska, Adamovics, 2013). Also it is important to understand that cultivated medicinal plants keep the features of wild plants, which means that they have strong self-keeping abilities (unequal growing and seed ripening, self-seeding, a long vegetation period).

Medicinal plants should be cultivated in ecological conditions that are similar to natural environment (Žukauska, 2008). It is also important to provide the growing interrelationship between the natural biotope and the place of cultivation. The advantages of cultivated medicinal plants in comparison with the wild ones are: less admixtures, higher content of specific biochemical components, higher plant quality, and faster lifecycle of perennial plants.

The optimal temperature of growing medicinal plants is +20 – +25 °C per day and +10 – +15 °C per night (Žukauska, 2008). That is why, if the temperature is not appropriate, it is impossible to have a good yield of medicinal plants in field conditions. Successful cultivation of medicinal plants is possible only if agronomic practices are based on deep understanding of plants' biological and agroecological requirements.

Many medicinal plants have very small (from 0.3 to 2.5 mm in diameter) seeds (Sulzberger, 1995). It is recommended to saw seeds of medicinal plants not deeper than 2 cm. Also, the seeds of some species need to be sprouted in light conditions. There are two possibilities of growing medicinal plants:

- seeding into the field (plant biological features, seed quality, the level of soil cultivation, and meteorological conditions are important);
- seedlings are grown and planted out.

Many species need seed calibration, and scarification or stratification before sowing (Sulzberger, 1995). In Latvian agroclimatic conditions, sowing in autumn is similar to nature`s propagation. The seeds do not need to be stimulated, the seedlings will appear in the early spring. Bad meteorological conditions (frost, thaw, changes in temperature) may have a negative effect on the results. Being sown in the soil, the seeds can sprout after 2–6 years. This fact explains the uneven germination of different species in this mixture.

Planting of seedlings is preferable as medicinal plants are heat-loving. At the beginning of vegetation, plants are developing very slowly, and it is possible to provide optimal conditions for seedlings. This method will allow faster vegetation of medicinal plants in pasture conditions; however, in that case, the costs of plant material will be much more higher.

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In Latvia, there is a lack of practical research on the use of medicinal plants in cultivated grasslands. The aim of the present research was to clarify the successfulness of seeding medicinal plants in pasture.

Materials and methods

Plant Material and Growing Conditions

The trial was carried out in a pasture (sod gleyic soil, pH_{KCl} 5.7, organic matter content 2.1 g kg^{-1}) of the farm "Tīrumsīļi", Tirza civil parish, Gulbene municipality, Latvia, in May 2016. The trial included two mixtures of seeds.

The first mixture, "Country Horse 2122" (producer "Deutsche Saatveredelung"), contained nine species of medicinal plants:

- 7% yarrow (*Achillea millefolium* L.),
- 18% caraway (*Carum carvi* L.),
- 20% chicory (*Cichorium intybus* L.),
- 2% wild carrot (*Daucus carota* L.),
- 15% fennel (*Foeniculum vulgare* Mill.),
- 1% hedge bedstraw (*Gallium mollugo* L.),
- 10% parsley (*Petroselinum sativum* Hoffm.),
- 10% ribwort plantain (*Plantago lanceolata* L.),
- 17% salad burnet (*Sanguisorba minor* Scop.).

The second mixture contained:

- 50% oregano (*Origanum vulgare* L.),
- 50% St. John's wort (*Hypericum perforatum* L.).

The second mixture was produced manually, using seeds from Lithuania. After germination, it is recommended to observe the growing scheme of 45 × 60 cm for oregano and St. John's wort.

a) **b)**

Figure 1. Mixtures of seeds: a – "Country Horse 2122"; b – oregano and St. John's wort (photo by R. E. Artamonovs)

The seeds were sown in squares that were free from sward: "Country Horse 2122" in eight repetitions, and the mixture of oregano and St. John's wort in seven repetitions. The squares were established in a zigzag pattern. The area of one square was 4 m^2 for "Country Horse 2122" and 2 m^2 for the mixture of oregano and St. John's wort.

Figure 2. Plant growing scheme of the trial:
mixture "Country Horse 2122";
mixture of oregano and St. John's wort
(photo by R. E. Artamonovs)

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The recommended sowing norms were 1.5 kg ha^{-1} for "Country Horse 2122" and 2 kg ha^{-1} for oregano and St. John's wort.

In the trial, the influence of the mixture on the growth and development of plants was studied, the changes in botanical composition were established (22/08/2016 and 14/05/2016), and the installation costs were calculated. For the research of botanical composion, the components of mixtures were used as control.

Meteorological conditions

According to the data of the Latvian Environment, Geology and Meteorology Centre about Gulbene municipality, the average air temperature in 2016 was +14.3 °C in May, +16.8 °C in summer (0.2 degrees below the average in Latvia), and +4.9 °C in autumn (0.2 degrees below the average in Latvia); in November and December – -1.0 °C and -0.6 °C respectively (0.2 °C and 0.6 °C below the average in Latvia).

In 2017, the average air temperature was -4.2 °C in January (1.5 degrees below the average in Latvia), -3.4 °C in February (1.1 degrees below the average in Latvia), and +1.7 °C and +3.8 °C in March and April respectively (0.4 °C and 0.3 °C below the average in Latvia).

The amount of rainfall was 621.2 mm from May until December in 2016, and 96.4 mm from January until April in 2017. The smallest amount of precipitation was in May 2016 (13.9 mm), but the highest – in August 2016 (156.7 mm). As the beginning of June was very hot but the amount of rainfall was only 75.7 mm (twice lower than in July and August), the rainfall had a significant negative effect on seed germination. Comparing April 2016 to April 2017, the amount of rainfall in April 2016 was about three times higher than in April 2017.

The results suggest that meteorological conditions were not optimal for the cultivation of medicinal plants and for plant biomass production in the vegetation period of 2016–2017.

Results

For "Country Horse 2122", the first sprouts were observed on the 8th day after sowing; for oregano and St. John's wort – on the 21st day after sowing, and also in the further vegetation, plants developed much more slower than weeds. Figures 3 and 4 show the development of medicinal plants in June and August of 2016.

a) **b)**

Figure 3. Trial squares in June 2016: a – "Country Horse 2122"; b – oregano and St. John's wort (photo by R. E. Artamonovs)

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a) b)

Figure 4. Trial squares in August 2016: a – "Country Horse 2122"; b – oregano and St. John's wort (photo by R. E. Artamonovs).

The squares were checked after winter, on the 1st of May 2017. It was observed that the development of the plants of "Country Horse 2122" mixture started considerably earlier than that of other grasses. This means that medicinal plants of this mixture can be used as a source of the first vitamins for dairy cows. The winterhardiness of oregano and St. John's wort was also optimal.

a) b)

Figure 5. Trial squares in spring 2017: a – "Country Horse 2122"; b – oregano and St. John's wort (photo by R. E. Artamonovs)

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Table 1. Botanical composition of plants in the "Country horse 2122" mixture trial, %

Species	Control (components of mixture)	Results, on average	
		22/08/2016	14/05/2017
Achillea millefolium L.	7	8	7
Carum carvi L.	18	7	7
Cichorium intybus L.	20	14	14
Daucus carota L.	2	3	2
Foeniculum vulgare Mill.	15	9	7
Gallium mollugo L.	1	4	4
Petroselinum sativum Hoffm.	10	4	4
Plantago lanceolata L.	10	28	29
Sanguisorba minor Scop.	17	19	19
Other species:			
Barbarea arcuata Rchb.	-	-	1
Elytrigia repens L.	-	1	2
Equisetum arvense L.	-	1	1
Taraxacum officinale L.	-	-	1
Trifolium pratenese L.	-	2	2

Out of the total amount of plants for the mixture "Country Horse 2122", weeds made about 4% in 2016 and about 7% in 2017. Some species from the analysed mixture were characterized as root vegetables (chicory, wild carrot, parsley, parsnip). It is recommended to grow these species in separate squares. This makes the precious agrotechnics possible.

Out of the total amount of plants for squares with oregano and St. John's wort, weeds were about 53% in 2016 and about 55% in 2017 (Table 2).

Table 2. Botanical composition of plants in the oregano and St. John's wort mixture trial, %

Species	Control (components of mixture)	Results, on average	
		22/08/2016	14/05/2017
Origanum vulgare L.	50	29	28
Hypericum perforatum L.	50	18	17
Other species:			
Achillea millefolium L.	-	-	2
Artemisia absinthium L.		1	-
Barbarea arcuate Rchb.		-	2
Capsella bursa-pastoris (L.) Medik.		1	-
Galium aparine L.		6	5
Elytrigia repens L.		18	14
Equisetum arvense L.		2	3
Plantago lanceolata L.		4	5
Ranunculus acris L.		5	4
Rumex acetosella L.		-	2
Sanguisorba minor Scop.		2	2
Sonchus arvensis L.		4	1
Taraxacum officinale L.		-	1
Trifolium pratenese L.		10	13
Vicia cracca L.		-	1

Because of the small size of oregano and St. John's wort seeds, germination occurred very slowly. Also, the lack of humidity after sowing negatively influenced the germination process, which is why plant development proceeded considerably slower than that of weeds.

The last photofixation was made in June 2017. Figure 6 presents the appearance of squares on the 4th of June 2017.

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a) b)

Figure 6. Trial squares in June 2017: a – "Country Horse 2122"; b – oregano and St. John's wort (photo by R. E. Artamonovs)

The costs of seeds and manual work for the "Country Horse 2122" mixture trial were 44.48 EUR per 32 m^2 or 139 EUR per 100 m^2, and for the mixture of oregano and St. John's wort – 29.12 EUR per 14 m^2 or 208 EUR per 100 m^2. The costs include also land preparation (trimmering, taking off from the sward, aeration, grooving, sowing, the price of seed material, etc.).

Tables 3 and 4 present the costs of manual work for the trials of "Country Horse 2122" mixture and the mixture of oregano and St. John's wort.

Table 3. Costs of manual work for the "Country Horse 2122" mixture trial

Position	Total experimental area, m^2	Costs, EUR
Trimmering, taking off from the sward	32	35.20
Aeration, grooving, sowing		8.96
Seeds		0.32
Total		**44.48**

Table 4. Costs of manual work for the trial of oregano and St. John's wort mixture

Position	Total experimental area, m^2	Costs, EUR
Trimmering, taking off from the sward	14	15.40
Aeration, grooving, sowing		3.92
Seeds		9.80
Total		**29.12**

Tables 5 and 6 show the costs of mechanized work for the trials of "Country Horse 2122" mixture and the mixture of oregano and St. John's wort. The results suggest that mechanized work is profitable only if total area is at least 100 m^2.

Table 5. Costs of mechanized work for the "Country Horse 2122" mixture trial

Position	Total experimental area, m^2	Costs, EUR
Plowing Slipping Cultivation Sowing and slipping	100	125.00
Seeds		0.66
Total		**125.66**

Table 6. Costs of mechanized work for the trial of oregano and St. John's wort mixture

Position	Total experimental area, m^2	Costs, EUR
Plowing Slipping Cultivation Sowing and slipping	100	125.00
Seeds		70.00
Total		**195.00**

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The mixture "Country Horse 2122" can be recommended to farmers – it can be sown mechanized in lines, in which case, the costs will be about 250 EUR per ha, and the yield can be cut in the year of sowing. Due to the needs of specific growing conditions, the use of oregano and St. John's wort in grassland may cause problems (the development of plants is weak in the first year); also, these seeds are more expensive than those of the "Country Horse 2122" mixture. Besides, the lack of the seed material can be a problem in Latvia.

When freshly cut plants were fed to dairy cows, the animals consumed them eagerly. It was also observed that the medicinal plants did not negatively change the quality (taste, odour, and colour) of milk. On the 29th of September 2016, it was observed that dairy cows were interested in tasting the "Country – horse 2122" mixture plants regardless of the electric fence around the trial square. It is seen in Figure 7 that dairy cows managed to get under the electric fence to taste the medicinal plants.

Figure 7. Dairy cows interested in tasting the "Country horse 2122" mixture plants (photo by R. E. Artamonovs)

A SWOT analysis was prepared to establish the strengths, weaknesses, opportunities, and threats of growing medicinal plants and herbs in grassland.

The possible strengths are:
- enrichment of botanical composition of grasslands;
- possibility of using medicinal plants for phytotherapy, disease prevention, and treatment of animals;
- medicinal plants contain biologically active substances, including many minerals necessary for the development of animals and for the strengthening of their immunity;
- regeneration of plants, self-sowing;
- reduction of veterinary costs;
- medicinal plants cannot change the quality of other plants negatively.

The possible weaknesses are:
- lack of knowledge about growing medicinal plants in grasslands;
- lack of research about growing medicinal plants in meadows and pastures;
- difficult installation;
- low interest of farms;
- lack of specialized mixtures, the optimal composition should be produced by the growers themselves;
- provision of optimal conditions, specific requirements for growing (humidity, lighting, temperature, soil pH_{KCl}).

The possible opportunities are:
- a novelty in Latvia;
- enrichment of grasslands with medicinal plants can be developed in various farms, not only in organic ones;
- cultivation of medicinal plants in pastures and meadows can be practised also for beef cattle;
- possibilities of processing the medicinal plants in pellets (cooperation with specialized farms);
- development of production and marketing;
- possibility of preparing the mixtures for individual needs;
- education possibilites.

The possible threats are:
- low germination of medicinal plant seeds after sowing,
- significant influence of meteorological conditions on the development of medicinal plants,
- a relatively expensive installation,

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- a risk that animals will not eat medicinal plants,
- medicinal plants selected for grasslands can be toxic,
- costs of seeds / plant materials.

It is necessary to develop a more thorough methodology for the cultivation of medicinal plants in separate squares in pastures for increasing the livestock health and productivity in Latvia.

Conclusions

According to agroeconomic evaluation, the mixture "Country Horse 2122" can be recommended to farmers.

Because of the needs of specific growing conditions, the use of oregano and St. John's wort in grassland can be problematic in Latvian meteorological conditions.

The medicinal plants used in this research had no negative influence on the quality of milk; in contrast, dairy cows eagerly ate these plants.

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