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MEDICINAL PLANT CROPS - IMPORTANT SOURCE OF HIGH VALUE-ADDED PRODUCTS

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Abstract

Medicinal and aromatic plants play a central role, not only as traditional medicines used in many cultures but also as raw materials for other bio-based products.
Economical feasibility is the main interest to bring a species in cultivation but it is also a substantial limitation as long as sufficient raw material can still be obtained at a lower price from wild-harvest. The number of medicinal and aromatic plant species currently in formal cultivation for commercial production does not exceed a few hundred world-wide (FAO). Cultivation can also have conservation impacts, as some wild species are being over-exploited. Medicinal plant production through cultivation, for example, can reduce the extent to which wild populations are harvested, but, on the other hand, it also may lead to environmental degradation and loss of genetic diversity. A limiting factor for starting new crops is represented by climate changes which already causes major environmental effects. The selection of a vegetal species to be introduced into cultivation should be justified by the growing requirements correlated to the trends in climate change, multi-purpose potential of the plant - a variety of products based on current uses and future projections, various types (herb, seeds, fruits, leaves, flowers, roots) of raw material for industrial use and an important market demand.
In this review are presented the main biologically active herbal constituents, applicative potential (as medicines, cosmetics, insecticides, allelochemicals, food additives and dyes), prospects to widen the range of the feedstock for understudy industrial uses, restricting factors that inhibit broader industrial use of the biomass feedstock, prospects and recommendations to use bio-based products.

Key words*: medicinal plants, cultivation, biomass, bio-based products.*

INTRODUCTION

In the last years there was recorded an increasing need for industrial products from renewable resources. Many farmers are interested in adding value to their existing crops by utilizing agricultural waste material or by converting crops to new uses. The international market for herbal products is estimated to be of US$ 62 billion, and it is estimated to grow to US$ 5 trillion by the year 2050 (Purohit and Vyas, 2004).
The largest global markets for medicinal and aromatic plants (MAPs) are China, France, Germany, Italy, Japan, Spain, the UK and the USA. Japan has the highest *per capita* consumption of botanical medicines in the world.
Within the EU, Germany is by far the largest importer with 235,644,913 $ trade value in 2013 (9.2% out of total imports) and also the largest exporter with 550,141,676 $ (5.5% out of total exports). (COMTRADE)
Herbal/traditional self-treating remedies are increasingly popular in Romania, due to consumers' increasing awareness about the possible harming effects of long-term self-medication using standard OTC drugs. In 2013, value growth reached 14%, after a 20% rise in 2012 (Euromonitor International, 2014).
For successful large scale cultivation of MAPs, high quality raw material should be produced using low input cultivation methods so that it can compete in the international market and with plants collected in the wild (Lubbe and Verpoorte, 2011).
Scientists widely agree that global climate change is already causing major environmental effects, such as changes in the frequency and intensity of precipitation, droughts, heat waves

and wildfires; rising sea level; water shortages in arid regions; new and larger pest outbreaks afflicting crops and forests. Phenological changes will alter growing seasons, ecosystem production, population-level interactions and community dynamics. Projections (for 2071–2100) show a general reduction in summer soil moisture over most of Europe, significant reductions in the Mediterranean region, and increases in the north-eastern part of Europe. Soil degradation, together with prolonged drought periods and increased numbers of fires, leading to marginalisation and even land abandonment, is already contributing to an increased risk of desertification. Current trends and future scenarios depict an increase in the demand for water in agriculture, potentially increasing competition for water. Crop management will have to be adapted in order to try to avoid crucial development stages sensitive to water-stress (flowering, grain filling, etc.) occurring during generally dry periods.(Impacts of Europe's changing climate — 2008 indicator-based assessment, European Environment Agency)

The selection of a herbal species to be introduced into cultivation should be justified by the growing requirements correlated to the trends in climate change, multi-purpose potential of the plant - a variety of products based on current uses and future projections, various types (herb, seeds, fruits, leaves, flowers, roots) of raw material for industrial use and an important market demand. Cultivation provides a more stable production base and greater control over quality, but requires investment in management, training, equipment and labour, which makes financing an issue. Cultivation provides an option to regenerate endangered species and is more able to become certified organic as they can better control production, provide traceability and input supply records.

A key issue in manufacturing herbal products and medicines is standardization, the process of producing herbal extracts or phytochemicals in which product potency is guaranteed through consistency in active compound content level. This process requires high knowledge in phytochemical analysis and process technology to ensure the quality assurance required.

Product value increases in the following order: fresh material < dried powder <non-standardized extract < freeze/spray dried extract < standardized extract <phytomedicine.

This review aims to present the applicative potential of MAPs, prospects to widen the range of the feedstock for understudy industrial uses, restricting factors that inhibit broader industrial use of the biomass feedstock, recommendations to use bio-based products.

MATERIALS AND METHODS

Literature review

Studies were identified by conducting electronic searches of PubMed, Science Direct and Scopus from 2000 to the end of 2015. More than 100 papers related to utilization of herbs, herbal extracts or herbal products in various industrial areas were consulted.

RESULTS AND DISCUSSIONS

Potential applications of herbal raw material

Plants produce an enormous variety of natural products with highly diverse structures. These products are commonly termed “secondary metabolites” in contrast to the “primary metabolites” which are essential for plant growth and development (Springob and Kutchan, 2009). A simple classification of secondary metabolites includes tree main groups: terpenes (such as plant volatiles, cardiac glycosides, carotenoids and sterols), phenolics (such as phenolic acids, coumarins, lignans, stilbenes, flavonoids, tannins and lignin) and nitrogen containing compounds (such as alkaloids and glucosinolates) (Agostini-Costa et al., 2012).

In addition to their physiological function in plants, natural products also have a strong impact on human culture and have been used throughout human history as condiments, pigments, and pharmaceuticals (Springob and Kutchan, 2009). Many herbal species can be used for multiple purposes and discovery of new and valuable compounds is in progress.

For example, aromatic plants not only serve as condiments and as important resources in the perfume and cosmetic industries, but have gained wide popularity now in aromatherapy

(Bakksli et al., 2008; Perry and Perry, 2006). Many spices, seasonings, condiments, and perfumes are made using essential oils that function as insect toxins in plants but are relatively harmless to humans. Examples include peppermint and spearmint (*Mentha* spp.), basil (*Ocimum* spp.), oregano (*Origanum* spp.), rosemary (*Rosmarinus* spp.), sage (*Salvia* spp.), savory (*Satureja* spp.), thyme (*Thymus* spp.), black pepper (*Piper* spp.), cinnamon (*Cinnamomum* spp.), and bay leaf (*Laurus* spp.). Citronella, an essential oil isolated from lemon grass (*Cymbopogon citratus*) also contains high limonoid levels and has become a popular insect repellent in the United States due to its low toxicity in humans and biodegradable properties. Although it is toxic in large quantities, it has been used medicinally by humans in small amounts as a pupil dilator and antidote for some nerve gas poisonings. Capsaicin and related capsaicinoids produced by members of the genus *Capsicum* are the active components of chili peppers and produce their characteristic burning sensation in hot, spicy foods (Adeyemi, 2011).

Celery (*Apium graveolens* L. var. *dulce* DC.; Apiaceae) is an important vegetable crop. Apigenin, a flavone isolated from celery which has been used to dye wool, has been shown to possess remarkable anti-inflammatory, antioxidant and anti-carcinogenic properties (Patel et al., 2007).

It is worthy to mention the various applicative potential of terpene compounds. Farnesene is a sesquiterpene widely used by perfume industry due to its beautiful smell, mainly in cosmetics preparation such as masks and powders. In addition, this molecule is utilized during beer brewing since contributes significantly to their aroma. Aldehydes comprise another group of compounds with commercial applications either as precursors for the production of oxo-alcohols (used in detergents), or are produced in a small scale (less than 1000 tons/year) in order to be used as ingredients by perfumes and flavors industries. In this respect, the sesquiterpenic aldehyde α-sinensal was identified as potential isolation target (Evergetis and Haroutounian, 2014).

The monoterpene cymene is widely used either as precursor for the synthesis of *p*-cresol or as important intermediate by the pharmaceutical, food and agrochemical industries for the production of various fungicides, pesticides and flavoring agents (Selvaraj et al., 2002).

Pharma industry

The importance of plants as a source of new drug molecules is illustrated by the fact that, in the past 20 years, 28% of new drug entities were either natural products or derived from them as semi-synthetic derivatives (Chin et al., 2006). New therapeutic strategies based on natural compounds are targeted to cardiovascular diseases, infectious diseases, diabetes, obesity, cancer and allergy. There are a wide range of medicinal preparations: tea (infusions or decoction), tinctures, glycerolates, medicinal oils, essential oils, compresses or plasters, eye washes, balsams, cataplasms, as well as a great number of pharmaceutical forms: tablets, capsules, syrups, ointments, hydrophilic gels, eye-drops (colliriums), nasal sprays and drops.

The herbal medicinal market in Europe is currently affected by changes of the regulatory environment. There are great differences between Member States in the definition and categorization of herbal medicines. A single medicinal plant may be defined as a food, a functional food, a dietary supplement or a herbal medicine in different countries, depending on the regulations applying to foods and medicines in each country. The general intention is to harmonize the regulation of medicinal products, food and other consumer goods at centralized European level but difficulties come from the heterogeneity of the starting material itself (chemical composition, natural variability, diverse sources), the heterogeneity of plant preparations (plant part used, type of preparation, manufacturing process), and the lack of accurate quality/safety data for often non-standardized low price products (Peschel, 2007).

Plants have also proven to be a major source for the discovery of modern drugs, particularly in the cancer field (Young, 2005). Of 155 small molecules developed as anti-cancer drugs worldwide from the 1940s to the present time, 72.9% are naturally-inspired, with 47% being either the natural products or semi-synthetic derivatives (Newman and Cragg, 2007).

Anti-tumor pentacyclic alkaloid camptothecin (CPT) from the wood and bark of *Camptotheca acuminata* Decne. (Cornaceae) (Li and Adair, 1994), the terpene paclitaxel (Taxol®) from the bark of Pacific yew (*Taxus brevifolia* Peattie) (Wani et al., 1971; Wall and Wani, 1995), vinblastine and vincristine, two well-known antimitotic cancer drugs used to treat Hodgkin's lymphoma and acute childhood lymphoblastic leukemia, respectively are isolated from *Catharanthus roseus* (also known as *Vinca rosea* L., family Apocynaceae); etoposide and teniposide, two semi-synthetic analogs of podophyllotoxin, an aryltetrainlactone cyclolignan isolated from *Podophyllum peltatum* rhizomes (Itokawa et al., 2008), are potent DNA TOPII cancer drugs used for small cell lung and testicular cancers and lymphomas/leukemias; likewise the water-soluble etoposide phosphate (also known as etopophos) is used for refractory testicular cancer and small cell lung cancer. Natural compounds are effective also in other medical areas: betulinic acid, a lupane triterpenoid isolated from *Syzygium claviflorum* (Roxb.) Wall. ex A.M. Cowan & Cowan (Myrtaceae) is used in the semi-synthesis of dimethyl succinyl betulinic acid currently used in anti-AIDS clinical trials (Itokawa, 2008); coumarin suksdorfin isolated from *Lomatium suksdorfii* J. M. Coult. & Rose (Apiaceae) is an anti-HIV (human immunodeficiency virus) compound, with semi-synthetic analogs currently being tested in clinical trials; the alkaloid galantamine (Razadyne®/Razadyne® ER,formerly known as Reminyl) from *Galanthus woronowii* Losinsk. (Amaryllidaceae) and related genera, including *Narcissus* L., (Cherkasov and Tolkachev, 2002) is used for the treatment of mild to moderate Alzheimer's disease; shikimic acid, a precursor for the antiviral drug Tamiflu® is isolated from the most common hardwood species in the southeastern United States, *Liquidambar styraciflua* L., known as sweetgum (Hamamelidaceae) (Li et al., 2005), making this species a promising pharmaceutical crop.

A new pharmaceutical niche was developed in the last years, drugs for veterinary use. Considering the potential harm of veterinary drug treatments on the environment and human health and in some cases their limited efficacy, disease management has to be concentrated on harmless, preventive and lasting methods. Recently, increasing attention is being paid to the use of plant products for disease control in aquaculture as an alternative to chemical treatments. Plant products have been reported to stimulate appetite and promote weight gain, to act as immunostimulant and to have antibacterial and anti-parasitic (virus, protozoans, monogeneans) properties in fish and shellfish aquaculture (Raverter et al., 2014).

Cosmetics

According to the *Organic Monitor*, a research and consulting company specialised in global organic and related-product industries, natural and organic products were estimated to account for 3% of all personal care products sales in Europe in 2009. While this is a relatively small percentage, it showed an annual growth rate of 20% (Antignac et al., 2011).

In the last years a new concept has developed – cosmeceutics -cosmetic products that include ingredients designed not only to enhance the appearance but to also have a positive physiological effect at the cellular level. The portfolio of new products is diversified: men's grooming products, anti-aging products, spa-at-home, detoxification products. A novelty in this area is the use of vegetal stem cells in antiaging formulation. A recent study shows that cosmetic industry based on natural products could be very profitable (Katsikis, 2009). Beyond this, the safety assessment of botanicals is more complex and associated with a higher degree of uncertainty than that of conventional ingredients. Given that novel botanical ingredients of personal care products may contain unknown substances with novel toxicological properties, new approaches to their safety assessment are needed (Antignac et al., 2011).

Dyes, colorants

There is an increasing development of new natural compounds able to substitute chemical additives for food and beverage industry. These compounds are used as antioxidants or colorants. For example, Naturex France has developed an extensive range of extracts which naturally protect food products against oxidation and therefore extend their shelf life as

well as a wide range of special coloring formulations made by natural pigments like carotenoids, curcuminoids, chlorophylls and anthocyanins. Some of the most known natural dyes used worldwide are: alizarin and lawsone, which belong to quinones, the main chemical components of madder and henna, different catechin structures belonging to tannins found in green tea, delphinidine, quercetin and mercetin with anthocyanin structure, a subgroup of flavonoids, the main components of saffron dye and curcumin, a carotenoid, the main component of turmeric (approved naturally derived food colorant in European Union – E100) (Alihosseini and Sun, 2008).
Natural colorants used in textile industry are popular due to their softer color shades, naturalness, deodorizing/anti-cancer properties and harmonizing natural shades (Mirjalili et al., 2011). Moreover, they prove a strong antibacterial activity (Ghaheh et al., 2014).
Only a limited number of plant species exhibit the potential for large-scale production. Method for obtain and purify compounds and stability studies must be developed.

Insecticides
An analysis of more than 20000 papers on botanical insecticides from 1980 to 2012 indicates a major growth in the number of papers published annually (61 in 1980 to 1207 in 2012), and their proportion among all papers on insecticides (1.43% in 1980 to 21.38% in 2012) (Isman and Grieneisen, 2014) which reflects the increasing interest of scientists concerning this subject, correlated with market needs. More than 1500 species of plants have been reported to have insecticidal value, and many more exist. Although compared with modern synthetics the plant substances are relatively less effective, their relatively safe nature has resulted in the opening up of a new vision in plant insecticides research (Kumar et al., 2011).
They are often called "environmentally friendly" due to their reduced toxicity to humans, fast and complete degradation in the environment and low-risk for resistance and selective properties for non-target organisms (Schmutterer, 1995). The most known natural insecticides are pyrethrins which come from certain species of chrysanthemums, azadirachtin from neem tree and limonene and linalool which are volatile molecules obtained from some vegetal species.

Allelochemicals
Limited research on isolation/extraction, characterization/synthesis or formulation of allelochemicals and their use in pest management in medicinal plantations showed that plant-derived products can be effective alternatives to synthetic pesticides in existing cropping systems (Gahukar, 2012).
It was showed that 3-O-monoglucoside of oleanolic acid secreted to the soil by *Calendula* species possesses very strong allelophatic properties in relation to the dicotyledons and weaker activity to the monocotyledons (Ruszkowski et al., 2004).
Plant sesquiterpenes comprise a large class of natural products with a number of biological activities, including some with interesting herbicidal and allelopathic potentials (Abdelgaleil et al., 2009; Saad et al., 2012).Sorghum releases a substantial amount of phenolic lipids including sorgoleone, a 3-penta-decatriene benzoquinone that is the primary source of the allelopathy properties of sorghums (Netzly and Butler, 1986). Juglone is an allelochemical present in walnut (*Juglans* spp) and it represses the growth of many weed species.

Food additives
Addition of natural antioxidants and antimicrobials to meat and meat products is one of the important strategies in development of healthier and novel meat products. In this regard several studies utilizing herbs, spices, fruits and vegetable extracts, and have shown that addition of these extracts to raw and cooked meat products decreased lipid oxidation, improved color stability and total antioxidant capacities which are important characteristics for shelf stable meat products. The major active components/phytochemicals responsible for the antioxidant activity of plant derivatives are polyphenols, flavonoids, phenolic diterpenes and tannins (Zhang et al., 2010). Moreover, the essential oils of herbs and spices are widely known for their strong antioxidant, antimicrobial and antifungal activities in foods (Hygreeva et al., 2014).

There are very few natural antimicrobials that can be used as direct replacements for existing preservatives owing to their lower effectiveness, higher cost and product organoleptic quality deterioration. Further, if a natural antimicrobial with potential as a food preservative can be shown to be sufficiently effective in foods, it will need regulatory approval before it can be used as a food additive (Negi, 2012).

Some of them are already approved for use in EU countries: E392 – rosemary extract as antioxidant and by Food and Drug Administration (USA): Alfalfa extract, herb and seed**;** Arnica flower extract **i**n alcoholic beveragesonly**,** Damiana leaves,Dandelion root andfluid extract,Sage (Greek and Spanish),Savory (winter or summer)**,** Tagetes (marigold) oil**;** Psyllium seed husk for frozen desserts, etc

Prospects to widen the range of the feedstock for understudy industrial uses, restricting factors that inhibit broader industrial use of the biomass feedstock

Many herbal compounds still await to be discovered or to be applied in various directions. By biotechnology and molecular methods, the yield and quality of valuable compounds can be increased. The majority of medicinal plants have yet to be utilized on a large scale. One of the main reasons for this is the chemical variability inherent in plant-derived therapeutics (Gorelick and Bernstein, 2014). A good example would be the natural variation of *Echinacea* within a species which have a tremendous effect on final product quality. This diversity might be due to genetic and environmental differences including variety, cultivation regions, harvest time, and cultivation or processing conditions. Even in germplasm that has been in cultivation for many years, there is still considerable phytochemical variation between individual plants. It was proved that cloned plants derived by division of the roots of individual plants in cultivated populations are very uniform and are one method for selecting and producing high-performance cultivars from exceptional plants (Arnason et al., 2002).

Cultivation also opens up the possibility of using biotechnology to solve problems like species misidentification, genetic and phenotypic variability, variability and instability of extracts, toxic components and contaminants. Further, by biotechnology and chemical (semi)synthesis, some gaps are overcomed. For example, it is known that the early production of paclitaxel relied on the bark of Pacific yew, with a limited supply of this nonrenewable source. The yield of paclitaxel from the yew bark is tremendously low; with 3,000 yew trees being needed to harvest enough bark to produce 1 kg of paclitaxel (Elbehri, 2005). Currently, paclitaxel can be produced by semi-synthesis using 10-deacetylbaccatin III (10-DAB) (Newmann and Cragg, 2004) and other baccatins isolated from needles of European yew (*T. baccata* L.) and other yew species.

Controlled growth systems also make it feasible to manipulate of phenotypic variation in the concentration of medicinally important compounds. The aim is to increase potency, reduce toxin levels and increase uniformity and predictability of extracts. By bringing herbs into cultivation, traditional and biotechnological plant-breeding techniques can be applied at the genetic level to improve yield and uniformity, and to modify potency or toxicity (Canter et al., 2005).

Pharmaceutical and other specialty crops are the starting point for a wide range of products: essential oils, human and veterinary drugs, herbal health products, inks, colorants and dyes, perfumes, beauty products, novel plant protection products and also a range of intermediate products from which the above are manufactured.

If we are referring to the cultivation technology and management, there are some restricting factors that should be taken into account.

It is clear that feedstock and quality of raw material strongly depend on weather conditions. As regards crop management, there are some stages that require investments and special attention, especially as size of cultivated area increases: watering during dry season (especially in the case of *Mentha piperita*, irrigation is a limiting factor), weed and pest control, harvest (the crop must be harvest on the right time, in the case of essential oil production harvesting should not be carried out in too hot weather and very windy conditions as significant volumes of oil can be lost

through evaporation and also the numbers of harvests per year greatly influence yield, and composition of oil). Moreover, the raw material has to be free of components that are toxic for animals and humans – mycotoxins, heavy metals or xenobiotics (pesticides and other chemicals) and these problems could be avoided if appropriate facilities for storage and drying are available and also if good cultivation practices are complied. Mechanized work in cultivation process, whenever is possible will increase productivity and diminish labor work (for example, peppermint harvesting can be done with special machines whose productivity is high, thereby reducing labor consumption per hectare from 20 workers to 1 ha to 0.5 ha / hour mechanized harvesting). The essential oils production requires highly focused farm practices, field maintenance and more technical support.

As regards processing methods, it is clear that a processed material will increase the value of the good.

Since herbal drugs, extracts and herbal medicinal products are multicomponent systems, they present difficulties in separating and analyzing the right compound. Contrary to most synthetic drugs, plant- and plant derived material involves the (quantitative) determination of one or two components, normally only present in small quantities against a huge background of others. In the case of detection of adulterated oils or extracts, analytical study is a must; that is why modern analytical methods should be developed.

Adequate processing methods conduct to herbal products of higher yield, lower operating costs, and faster production times. The separation of the interesting compound mostly leads to the high price of the compounds. Usually, vegetal active principles works together in a synergic way and there is no need to develop many extraction steps. Only in a few cases one compound is of interest (artemisinin, silymarin, etc). Innovative and efficient (both from economical and scientific point of view) methods such as Supercritical Fluid Extraction (SFE) where supercritical fluids such as carbon dioxide under high pressure need to be developed.

Herbal products can be sold in a variety of forms such as capsules, tablets, tea bags, extracts, essential oils, etc. and packaging plays an important role to attract consumers. Products diversity is an important issue for a company; new products come from new technologies and new equipment but also must be correlated to consumers needs and targeted marketing campaign. Volatile oil, capsules or tablets require very high and high production costs unlike tea which requires medium production costs and give high incomes. To extend the product portfolio, there is a need for investments in appropriate equipment for extraction, processing and packing herbal products.

As regards economical aspects, the import of cheap and poor quality products and raw materials (especially from countries with low labor costs such as China and India) is a very common issue; the product price (and not the product quality) is the most important factor that affects buying decision for many market segments. Sometimes medicinal herbs are purchased, refined, repackaged and re-exported to other EU member countries or some producers choose to use encapsulated dried and milled plants as selective extracts or some choose to sell adulterated essential oils. For example, lavender oil is often adulterated by acetylated lavandin, aspic, synthetic linalool, linalyl acetate; caraway oil is adulterated by addition of *d*-limonene obtained as by products from the extraction of carvone or from orange oil; synthetic compounds are also added into oils - synthetic linalool in coriander oil and synthetic citral in lemongrass oil (Singhal et al., 1997).

CONCLUSIONS

At present, of the 70,000 species of medicinal plants in the world still primarily harvested in the wild, most have not been cultivated as crops. For example, of the 3,000 species of medicinal plants being traded in the world, 70-80% originate from wild-collections (Schippmann et al., 2006), and only 900 have commercial cultivation underway or in development (Mulliken and Inskipp, 2006). Some 15,000 medicinal plant species may be threatened with extinction (Hawkins, 2008).

The strategy for sustainable use of MAP has two main components: regulation of collection

of medicinal plants from the wild to protect biodiversity and promotion of cultivation to meet demand and provide new income opportunities to farmers.

There are several ways in which plant science can address future demand in this area, as it was stated by The European Plant Science Organization in 2005: first, this can be done by optimising the profile and possibly increasing the content of active components of the raw material itself. A second opportunity lies in the better preservation of these phytochemicals during crop maturation, post-harvest treatment and storage. Third, the factors that play a major role in bioactivity during processing should be at least maintained and possibly enhanced.

Consumers preferences has changed towards the use of 'natural' over synthetic products and the trend will remain; still, the consumers must understand that the quality is more important than price. A critical examination of bioactive plant products has to cover analytical aspects, absorption, bioavailability and molecular functionality. The industry should speculate this trend and diversify the product portfolio as well as ecological farming has an ascending trend.

New applications should be investigated; phytotherapy in veterinary medicine is a domain which needs further study as well as development of natural products for agriculture. Environmentally friendly alternative practices for crop protection is a key issue in modern agriculture. Utilizing allelopathic plants to suppress the weed infestation is the most cost-effective and environment-friendly method of weed control. Also, the domain of food preservatives based on medicinal plants should be deepened.

As regards MAPs for pharmaceutical purposes, it is important to develop stable molecular markers which assure without doubt the quality of herbal medicines and to conduct clinical trials in Europe in order to comply with regulatory requirements for product registration, especially in Germany and France which regulate botanical products mainly as drugs. Examples of companies that perform clinical trials are BionoricaArzneimittel, Dr.Willmar Schwabe Pharmaceuticals, Lichtwer Pharma AG, Madaus AG, Max Zeller Sohne AG, and Schaper & Brümmer GmbH.

The perspectives are encouraging, as in the past 20 years, completely new markets were created for herbal- based products upon scientific support.

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