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German chamomile performance after stubble catch crops and response to nitrogen fertilization

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ABSTRACT

Pharmaceutical companies have a growing demand for herb raw material, including German chamomile (*Chamomilla recutita* (L.) Rauschert), produced according to the rules of Good Agricultural Practices (GAP) for medicinal plants. These rules, among others, require limitation of the application of mineral fertilizers and pesticides. Catch crops can improve soil fertility and reduce weed infestation for subsequent crops. The aim of this study was to evaluate the effect of stubble catch crops and different nitrogen doses on anthodia and herb yield, and content and yield of essential oil from a diploid and tetraploid cultivar of German chamomile. In the 3-year experiment, two chamomile cultivars were grown – Mastar (2n) and Dukat (4n). They were sown after ploughing legume mixture or buckwheat (*Fagopyrum esculentum* Moench) stubble catch crops; nitrogen fertilization rates were 0, 30, 60, and 90 kg N ha^{-1}. It was found that fertilization with 60 and 90 kg N ha^{-1} reduced chamomile weed infestation to a greater extent than the use of catch crops. The highest yield of anthodia was obtained after the application of the highest nitrogen rate. The herb and oil yield from herb were highest after the application of 60 kg N ha^{-1}. Cultivation of Dukat after a legume catch crop allowed for a reduction in nitrogen fertilizer rate from 90 to 60 kg N ha^{-1} without a decrease in anthodium yield. Buckwheat catch crop inhibited the growth of chamomile. A higher yield of anthodia was collected from the cultivar Dukat, but the essential oil content was higher in anthodia of Mastar. The content of chamazulen in essential oil from anthodia was 17.7 and 17.2%, α-bisabolol 23.0 and 21.1%, respectively, from Mastar and Dukat. The essential oil from herb contained mainly farnesene and en-in-dicycloether. The requirements of Good Agricultural Practices in chamomile cultivation can be met by the application of legume stubble catch crops, choice of suitable cultivar, and by adopting the nitrogen rate appropriate for the aim of cultivation.

1. Introduction

Chamomilla recutita L. Rausch. (syn. *Matricaria chamomilla* L., family Asteraceae), known as German chamomile, belongs among the oldest known medicinal plants. Its pharmaceutical materials are inflorescences (anthodia, flower heads). Also herb is purchased, which can be used for the production of herbal teas or in veterinary medicine. Medicinal properties of the species are determined mainly by its essential oil. The essential oil is composed of about 40 components, of which chamazulen and α-bisabolol show the strongest anti-inflammatory activity (Orav et al., 2010). Essential oil is accumulated in all organs of chamomile, although the greatest amounts occur in inflorescences. Its content in inflorescences ranges from 0.25 to 2.0% and it depends on the genotype, cultivation conditions, and developmental stage, with the highest concentration occurring in the full flowering plant (Gosztola et al., 2010; Pirzad et al., 2006; Salamon, 2007; Seidler-Łożykowska, 2000, 2003, 2010; Singh et al., 2011). Essential oil is obtained from fresh or dried anthodia or herb by distillation with steam.

Due to a growing demand from the pharmaceutical, cosmetic, and food industries for high-quality herbal raw materials, breeding work is undertaken in order to obtain appropriate cultivars. At later stages, research is necessary on developing agricultural practices to show the potential of new cultivars. Most chamomile cultivars derive from Europe, particularly in the centre and east (Franke et al., 2005). There are diploid cultivars (e.g. Bohemia, Bona, Promyk, and the new Mastar) as well as tetraploid (e.g. Lutea, Goral, Złoty Łan, and the new Dukat). The cultivars differ from each other with regard to height of plants, size of flower heads, and content as well as composition of essential oil (Azizi et al., 2007; Letchamo, 1993; Salamon, 2004; Seidler-Łożykowska, 2000, 2003).

Herbal companies are interested in buying large amounts of material with uniform quality. Such material can be obtained only from field crops. Currently the field production of medicinal plants

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must be carried out in accordance with the rules of Good Agricultural Practices for medicinal plants (Anonim, 2006; Demarco et al., 1999). According to these rules, in medicinal crop cultivation it is necessary to reduce mineral fertilizers and pesticides. The fertilization recommendations developed in the previous century, based on many authors, are given by Franke et al. (2005). Those recommendations in relation to the most yield-forming component – nitrogen – place the rates from 20 to 80 kg N ha^{-1}, with the most often stated rate being 40–50 kg N ha^{-1}. Some authors, however, claim that a high productivity and profitability of herbal crops can be achieved by application of nitrogen in doses higher than 90 kg N ha^{-1}. An additional argument is that higher doses reduce weed infestation by stimulating herbal crops development (Mordalski and Kordana, 2002). Although chamomile is a common weed, it is also easily exposed to weed infestation (Kucharski and Mordalski, 2007). Currently, there are only a few herbicides intended for application in herbal crops, and no preparation registered in Poland to control weeds in chamomile. Consequently, various agricultural practices must be directed towards limitation of weed pressure. One of the methods may be cultivation of a catch crop for ploughing in. The useful species for such type of crops are legumes, particularly fast growing cultivars of pea (*Pisum sativum* L.) and common vetch (*Vicia sativa* L.). Their lavish growth enables suppression of weed development in autumn while additionally enriching the soil with nitrogen that is available for the successive crop (Wilczewski et al., 2007). Some plant species left on the surface or mixed with the surface layer of soil may limit germination and growth of many weed species (Perez, 1990). This group includes buckwheat which secretes phenolic substances with strong allelopathic properties (Mioduszewska et al., 2013). It was proved that ploughing in buckwheat or even its harvest residue limits the germination and growth of various weed species (Stupnicka-Rodzynkiewicz et al., 2004; Xuan et al., 2005). It cannot be expected that catch crops will eliminate weed infestation, but if they reduce it the weeds will be easier to control mechanically. Chamomile responds positively to strip cultivation (Surmacz-Magdziak and Wiśniewski, 2007), which facilitates mechanical weed control.

In the present research hypothesis it was assumed that properly selected species of plants grown as a stubble catch crop may contribute to an improvement in the management of a field under chamomile by reducing the rate of nitrogen fertilization and making weed control easier. A mixture of legumes or buckwheat in a pure stand should meet these criteria. A stubble catch crop of legumes enriches soil nitrogen and it can also replace herbicides that should be used before establishing the plantation. Buckwheat in turn secretes into the soil phenolic substances that inhibit weed growth, also after ploughing in. Due to the morphological and developmental differentiation of di- and tetraploid chamomile cultivars, they were expected to respond differently to the applied agricultural practices.

The aim of this study was to evaluate the effect of growing stubble catch crops and of varied nitrogen fertilization on anthodium and herb yield, as well as the content, and yield of essential oil from diploid and tetraploid cultivars of German chamomile.

2. Materials and methods

2.1. Location and scheme of the field experiment

The subject of this study was two cultivars of German chamomile: diploid 'Mastar' and tetraploid 'Dukat' developed in the Institute of Natural Fibres and Herbal Plants in Poznań (Poland). The study was carried out based on a three-factorial field experiment established at the Research Station Mochełek (53°13′ N, 17°51′ E) owned by the University of Technology and Life Sciences in Bydgoszcz. The experiment was established in the split-plot split-block design with four replications.

Experimental factors were:

1. Stubble catch crop: buckwheat, legumes (field pea + common vetch), without a catch crop (control).
2. Chamomile cultivars: Mastar (2n), Dukat (4n).
3. Nitrogen fertilization: 0, 30, 60, and 90 kg N ha^{-1}.

The plot area was 9.0 m^2. Field study was conducted from August 2008 to July 2011.

2.2. Soil conditions and fertilization with Ca, P, and K

Soil at Mochełek is a fine-sandy loam, mixed mesic, ustic, typic hapludalf with pH 6. The soil has a high abundance of potassium and phosphorus, and is moderate in magnesium. Liming at a rate of 1.5 t ha^{-1} in the form of calcium carbonate had been used under the previous crop or before sowing the catch crop. Mineral fertilizers were applied under pre-sow ploughing at rates of 70 kg P_2O_5 ha^{-1}, 80 kg K_2O ha^{-1}.

2.3. Stubble catch crops

The previous crop was spring barley. In 2008 catch crops were sown on 10 August, in 2009 on 13 August, and in 2010, due to unfavourable weather conditions, catch crops were sown on 25 August. Seeding rate amounted to: buckwheat (cv. Emka) – 100 kg ha^{-1}, legume mixture (pea cv. Bohun 135 kg ha^{-1} + vetch cv. Jaga 25 kg ha^{-1}) – 160 kg ha^{-1}. Harvest of plants cultivated as the catch crop was performed in the middle of October. Mineral nitrogen content in the aboveground mass yield of catch crops was determined with the Kjeldahl method.

2.4. Sowing chamomile and fertilization with nitrogen

Sowing of chamomile was performed in the third week of October in 2008 and in 2009, and in the fourth week of October in 2010. In accordance with personal communication with the breeder, seeding rate of cv. Mastar was 2.0 kg ha^{-1} and cv. Dukat 2.5 kg ha^{-1} (because of greater 1000 seed weight); row spacing was 30 cm. Seeds for each plots were weighed out and sown by hand. Chamomile seeds germinate in light and, therefore, they were not covered with soil but only pressed with a roller.

Pre-sowing nitrogen fertilization at rates 20 and 30 kg N ha^{-1} were applied only in plots where the two highest fertilization levels were planned, i.e. 60 and 90 kg N ha^{-1}, respectively. The balance of the rate was applied in spring, directly after the start of growth. In plots where 30 kg N ha^{-1} was planned, the whole rate was spread in spring. Nitrogen was applied in the form of ammonium nitrate.

2.5. Weed infestation

Quantitative assessment of weed infestation was made in the second half of April. It was performed on each plot using frames of 2 m × 0.5 m. Moreover, in 2011 a gravimetric evaluation was performed. Weeds were counted and then cut out, dried at 60 °C, and their aboveground dry mass was determined. After the assessment of weed infestation, weeds from interrows were removed using a weeding machine, whereas weeds growing in rows were removed by hand.

2.6. Harvest of anthodia and herb

The harvest of anthodia and herb was performed separately: