ISSN:0975-1459
Journal of Pharmaceutical Sciences and Research
www.jpsr.pharmainfo.in

Ecological significance of winter camelina in biological agriculture

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Abstract

Oilseed crops, including winter camelina (Camelina Sativa) are of great importance for human nutrition, feeding livestock, industry, construction, medicine, pharmacy and perfumery. They are an important source of complete protein contained in cake and meal.

With the purpose of studying the biological capabilities of winter camelina in biological agriculture, the influence of growth stimulants on crop germination, growth, development were studied, as well as cultivation of the new crop for the Republic together with beans – annual Persian clover (Trifolium resupinatum L.). Also its accumulating ability to extract heavy metals from the soil and to reduce the number of weeds was determined.

The experiments were performed in the mountain area of North Ossetia at the altitude of 1,400 m above sea level and in foothills at the altitude of 600 m above sea level. Growth stimulants were biopreparation pharmaiodine and p-amino-benzoic acid (PABA). To reduce soil toxicity, winter camelina was sown together with winter annual Persian clover. The results of the experiments showed that combined use of growth stimulants increased germination rate by 13-15%, plant height - by 4-5 cm, and winter hardiness - by 3-4%.

After joint sowing of winter camelina and Persian clover, the decreased content of heavy metals (lead, copper, zinc, nickel) was observed in soil.

Phytoextractive properties of winter camelina had been detected as a hyper-accumulator plant that could reduce soil toxicity 30 days after sowing. Essential oils contained in the seeds of camelina inhibited germination of many weeds, which allowed not only recommending this crop as soil keeper, but also ensuring high quality product in organic agriculture.

Keywords: fertility rehabilitation, growth stimulation, annual clover, oilseed crops, heavy metals.

INTRODUCTION

Disruption of the crop rotation systems leads to sharp deterioration of soil fertility, phytosanitary situation, increase in the level of soil fatigue, anthropogenic and technogeneous effect. Such disruption results in sharply reduced crops' yield. Crops of perennial grasses that improve soil fertility and reduce its toxicity [1, 2, 3] are significantly reduced.

To enhance the biodiversity of plants that accumulate heavy metals from the soil and have high competitive ability in weed control, it is necessary to introduce new species with the phytoextraction ability to suppress weeds' growth in the crop rotation system, reduce weed infestation of crops and enrich soil with organic substances [2, 3].

The interest in camelina is due to the lucky combination of high yield of the seeds (up to 2.0 t/ha and more) and high oil content (40-42%). Camelina oil is used for food and diet nutrition, and as technical oil for making linseed oil and biodiesel fuel, in medicine, pharmacy and perfumery. After heat treatment, camelina cake may be used for feeding the livestock and poultry. The agronomical value of camelina is in the fact that it is undemanding to soils, tolerates well soil and air drought, can provide the yield of seeds and oil in a wide range of conditions. Like rape, camelina has two forms of life – spring and winter [4, 5, 6, 7].

The growth regulators, bacterial products and micronutrients in the form of complexes and complexonates of metals (chelates) are used more and more widely. Substances of this class have high physiological activity at low concentrations in plants. They easily fit into the technology of crop cultivation, especially cultivation in the conditions of insufficient content of microelements in soil [8, 9, 10].

Recently, researchers from many countries have been actively discussing the new biological method of decontaminating contaminated soils and water bodies as a decent alternative to the traditional treatment method that is based on the use of the biological productivity of organisms. In general, this method is called "bioremediation". Phytoremediation is a method of treatment based on the use of green plants [11,12,13].

Phytoremediation (treatment and remediation of soils using plants) belongs to cost-effective and environmentally justified extensive methods used in the conditions of pollution with heavy metals. One of the phytoremediation method varieties, phytoextraction, consists in removing heavy metals from contaminated soils by long-term cultivation of plants.

The phytoextraction properties of winter camelina in the mountainous areas of North Ossetia-Alania have been additionally studied, as well as inhibition of many weed seeds' germination, which will reduce the chemical load on the agricultural ecosystems.

For assessing the biological features of winter camelina in the mountainous areas of North Ossetia-Alania, advisability of its cultivation, developing scientifically-based effective technologies of cultivation of this crop in the crop rotation system, several problems of plan growth stimulation in pure and mixed sowing have been solved, accumulating the features of this important crop in the crop rotation system.

CONDITIONS AND METHODS OF RESEARCH

The research was performed in 2015-2017 in the experimental area of the Department of Agronomy at the Faculty of the Gorsky State Agrarian University located in the mountain meadow subalpine zone of the Fiagdon pit within the Northern slope of the Central Caucasus between the Rocky and Lateral ridges, at the altitude of 1,400 meters above sea level (settlement Kurtat), and at the experimental base of the North Caucasian Research Institute of the Mountain and Foothill Agriculture of the Vladikavkaz Scientific Center of RAS in the Piedmont zone on leached black soil (at the altitude of 600 meters above sea level). Despite the specificity of the mountain soils in the Fiagdon pit (high content of crushed stone, shallow bedding of gravel and bedrock, significant washing ability, weak water-holding

characteristics), they provide necessary amount of nutrients, moisture and air to the plants.

During the experiment, the influence of biopreparations pharmaiodine and PABA was studied separately and in a mixture. One of the variants was mixed sowing of winter camelina + Persian clover.

Biopreparation pharmaiodine features high antimicrobial activity against gram-positive and gram-negative bacteria, the entire range of phytopathogenic viruses; at higher concentrations, it is efficient against fungal pathogens, various fungi, viruses and bacteria; it is also designed to fight plant diseases.

PABA is a non-toxic group B vitamin-like compound, also known as vitamin H_1 or vitamin B_{10}. PABA is an activator of phenotypic activity; it increases the immunity of plants and their adaptive properties.

Persian clover (Trifolium resupinatum L.) is an annual plant that is a great predecessor, since it can accumulate biological nitrogen in soil in the range between 150 and 180 kg/ha, which makes it reasonable to sow it mixed with winter camelina. The plot area was 10 m^2. The experiment was repeated three times. Arrangement was consequent.

In the experiment, winter camelina of Karat grade was used; it features increased tolerance to pathogens, higher resistance to lodging, and uniform plant height, flowering and ripening vigor. In the second experiment, winter camelina was studied as a crop that accumulated heavy metals (lead, zinc, copper, nickel). To accelerate cleaning and reclamation of contaminated lands, winter camelina and Persian clover were sown separately and in a mixture.

Chemical analyses were performed at the North Ossetian Republican Station of Agrochemical Service on a flame-absorption spectrophotometer. After harvesting winter wheat (late June – early July), crop residues (straw) were sprinkled with potassium humate, and plowed into the soil; the land was prepared for sowing the small-seeded annual Persian clover. This variety of clover was sown in August, which allowed to accumulate within the 30-40 days of its growth part of the nitrogen for sowing winter camelina, which was placed in interrow spacings (50-60 cm) of Persian clover.

The next year, in the third week of April, both crops reached the phase of budding and maximum development. The green mass was mowed and plowed into the soil. Then the soil was prepared for corn to be sown for grain on May 10.

The choice of camelina in the crop rotation system was due to the fact that its seeds contained significant amounts of phosphoric acid (3-4% in the ash), and sufficient amount of sulfur. In the initial period of development, camelina plants require nitrogen fertilizers. Winter camelina is enriched with biological nitrogen by the nodule bacteria of annual Persian clover sown in the mixture in a single period (3rd decade of August). Clover can accumulate biological nitrogen in the range between 120 and 150 kg/ha, which is quite sufficient for normal development of winter camelina.

Camelina itself has high allelopathic properties due to high content of flavonoids, which are growth inhibitors for many weeds. Rutin, the flavonoid glycoside contained in camelina, inhibits germination of seed of competing weed species in the soil. Essential oils contained in the seeds of camelina are disinfectants of antimicrobial action. In the seeds of camelina, phenolic compounds are in the form of aglycones and glycosides that inhibit growth of seeds of many weed species.

Seeds of Persian clover also contain free flavonoids (quercetine), which are not antagonist of flavonoids of camelina, and consequently, mixed sowing of camelina and clover increases the effect on the weeds, and inhibits their development. Productivity of both crops increases due to the favorable mutual influence of these plants' root excretions.

RESULTS

Seed treatment with growth regulators allows to change the rate of plants' growth and development, increase productivity, improve seeds' quality, and stimulate plants' resistance to stresses and pathogens.

During the observations, growth stimulants had significant influence on germination and growth of winter camelina.

The germination vigor was quite high in all studied variants, and varied in the range between 78.6 and 80.1%. It was the maximum in the variant of the joint use of biopreparations of pharmaiodine and PABA – 80.1%, which exceeded the reference by 7.8%. The variant with joint sowing of winter camelina and Persian clover was slightly inferior (79.4%).

In the observations, the rate of winter camelina seed germination increased with the use of growth stimulants. The variant with the use of PABA had the lowest efficiency. Germination in this variant, compared to the reference, increased only by 2.3%. The use of pharmaiodine had more significant effect on germination – 86.2%, which was higher than in the reference by 12.8%. The highest seed germination rate was in the variant with the joint use of biopreparations pharmaiodine and PABA – 91.0%, which was 16.8% higher than in the reference. The variant with joint sowing of winter camelina and Persian clover was slightly inferior (88.9%).

By the criteria for assessing growth vigor according to GOST 9671-87, the seeds treated with growth stimulants had strong sprouts 1.9-2.4 cm long (according to GOST, they are to be not less than 1.5 cm). The longest sprouts were found in the variants with joint sowing of winter camelina and Persian clover, and the joint use of biopreparations pharmaiodine and PABA – 2.4-2.3 cm, which exceeded the reference by 0.8 and 0.7 cm, respectively. These variants were also characterized by the maximum weight of 100 sprouts - 0.89 and 0.81 g, respectively, which exceeded the reference by 0.22 and 0.20 g, respectively.

The observations showed that with the use of growth stimulants, plant height increased (on day 20).

The highest were the plants of winter camelina in the variant of joint sowing with Persian clover – 13.4 cm, they were somewhat inferior to the plants in the variant with the joint use of biopreparations pharmaiodine and PABA – 12.5 cm. Both variants exceeded the reference in this indicator by 5.2 and 4.3 cm, respectively. Due to Persian clover's ability to accumulate biological nitrogen in the root system, plant height increased.

The maximum diameter of the root neck was noted in the variants with seeds treated by both pharmaiodine and PABA, and joint sowing of winter camelina and Persian clover - 8.7 and 8.6 mm, which exceeded the reference by 2.6 and 2.5 mm, respectively. This influenced the general winter hardiness of winter camelina, the percentage of overwintering of which in these two variants was the highest, and amounted to 93.6 and 91.1%, which exceeded the reference by 5.0 and 2.5%, respectively.

Thus, the joint use of biopreparations pharmaiodine and PABA had the most significant influence on formation of winter camelina agrocenosis in autumn and winter.

Recently, researchers from many countries have been actively discussing the new biological method of decontaminating contaminated soils and water bodies as a decent alternative to the traditional treatment method that is based on the use of the biological productivity of organisms. [12, 13]. In general, this method is called "bioremediation". The results are shown in Table 1.

Table 1. Changes in soil toxicity after sowing accumulator plants of winter camelina and Persian clover

Variants	Heavy metals' content in the soil, mg/kg			
	Pb	Cu	Zn	Ni
Reference	92.6	12.8	52.0	39.8
Winter camelina	61.2	10.2	48.0	30.6
Persian clover	57.2	9.3	48.0	30.5
Winter camelina+Persian clover	41.6	7.1	39.0	26.3
Maximum permissible concentrations (MPC)	32.0	6.8	35.0	20.0

This technology is much cheaper, compared to the traditional cleaning methods, it features efficiency and relative simplicity (using traditional methods), and does not harm the environment. According to some estimates, the cost of cleaning soil by phytoextraction is about US$ 0.05 per 1 m^3 of soil, while the cost of traditional methods of cleaning is US$10 to 1,000 per 1 m^3 of soil. After harvesting, the contaminated plant biomass should be disposed of.

The data in the table show that among the studied variants, winter camelina has the highest phytoextracting properties, which allows to reduce the content of heavy metals in soil within 30 days after sowing: lead by 31.4, copper by 2.6, zinc by 4.0, and nickel by 9.2 mg/kg of soil, or by 33.9%, 20.3%, 7.7% and 23.1%, respectively, which is an indicator of high storage capacity of both crops.

CONCLUSION

1. The introduction of new crop, winter camelina, in the mountain and foothill conditions contributes to increasing the biodiversity in crop production and reduction of pesticide load on the agrocenosis.

2. The presowing treatment of seeds with growth stimulants – pharmaiodine and PABA - at the concentration of 0.1% ensured the increasing of growth processes indicators: germination vigor - by 16.3-17.1%, germination - by 12.8-15.5%, weight of 100 sprouts – by 0.13-0.22 g, sprout length - by 0.3-0.8 cm, plant height - by 1.3-5.2 cm, and root diameter in the end of autumn vegetation - by 1.1-2.5 mm. The highest indicators were found in the plants in the variant with the joint use of pharmaiodine and PABA.

3. The presowing seed treatment with growth stimulants increased winter hardiness of plants by 1.3-1.7%.

4. Phytoextraction properties of winter camelina as a hyper-accumulator plant capable of reducing the content of heavy metals in soil 30 days after sowing were revealed: lead - by 31.4, copper - by 2.6, zinc – by 4.0, and nickel – by 9.2 mg/kg of soil, or by 33.9%, 20.3%, 7.7% and 23.1%, respectively.

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