disadvantages that are associated with the difficulty of securing absorption materials or in terms of the high cost of the materials used. Therefore, it is advisable to conduct more experiments in order to identify new materials that can be used and accessed easily and at lower costs.

References

1. Agafonov, D.V., Sibirjakov, R.V. Filtrujushhij sorbent dlja ochistki vody ot nefteproduktov // Patent 2045334 RF. 1995. BI. № 10.
2. Osobennosti ochistki vody ot nefteproduktov s ispol'zovaniem neftjanyh sorbentov, fil'trujushhih materialov i aktivnyh uglej. [Jelektronnyj resurs].− Rezhim dostupa: http://elib.sfu-kras.ru/handle/2311/2187 (data obrashhenija 05.09.2015)
3. Absalan, G., Asadi, M., Kamran, S., Sheikhian, L., Goltz, D.M., 2011. Removal of reactive red-120 and 4-(2-pyridylazo) resorcinol from aqueous samples by Fe3O4 magnetic nanoparticles using ionic liquid as modifier. J. Hazard. Mater. 192, pp.476–484.
4. Bokovikova, T.N., Stepanenko, S.V., Kapustjanskaja, Zh.V., Marchenko, L.A., Dvadnenko, M.V., Privalova, N.M., Efimenko, S.A. Sposob ochistki neftesoderzhashhih stochnyh vod //Patent na izobretenie RUS № 2333158 20.12.2006.
5. N.B. Singh, Garima. N, Sonal. A, Rachna // Water purification by using Adsorbents: A Review. − 2018. − № 2. − P.193-194.

УДК 633/635:632.934

SUSTAINABLE INTENSIFICATION OF CROP PRODUCTION: INTERCROPPING

Negassi Berhane Teklesenbet, *PhD student, Department of crop production and Meadow Ecosystems, RSAU-MAA named after K.A. Timiryazev, berhaneteklesenbet2@gmail.com*

Shitikova Alexandra Vasilievna, *Doctor of Agricultural Sciences, Professor, Head of the Department of Crop Production and Meadow Ecosystems, RSAU-MAA named after K.A. Timiryazev, plant@rgau-msha.ru*

Feopentova Svetlana Vladimirovna, *Senior Lecturer, Department of Foreign and Russian Languages, RSAU-MAA named after K.A. Timiryazev, sfeopentova@mail.ru*

Abstract: *Intercropping is currently a common method of diversifying crop production in world practice, based on the cultivation of two or more genotypes or types of crops simultaneously on the same piece of land. The most common benefit of intercropping is higher yields through judicious use of the available growth resources by component crops. Combining legumes and grains improves soil fertility and health through symbiotic biological nitrogen fixation with bacteria. In addition, the combination of legume crops reduces cost of production by reducing* *the amount of fertilizer. However, intercropping has some limitations: it is believed that crop yields may be reduced due to competition and allelopathic effects among species.*

Keywords: *intercropping, soil fertility, nitrogen fixation, complementarity*

Relevance: Climate change tends to reverse the progress made in the struggle against hunger and malnutrition and increases the risks to global food security in general and to poor countries and populations below the poverty line in particular. There is general agreement that food production must increase to meet global needs, such as dietary changes needed to ensure efficient use of food to prevent malnutrition and obesity, prevent further expansion of agricultural land, and this must be done in a sustainable manner. Crop production intensification systems that can adapt to climate change and meet the dietary and economic needs of people is a pressing issue that needs to be addressed immediately. It is recommended to strengthen local food crops and crop systems that are deeply rooted in the dietary and social habits of residents, while maintaining sustainable production to meet the growing needs of the world's population [1].

The needs of a growing population will require an increase in crop production. Demand for food and energy is growing rapidly and will continue to grow as the world's population and average income rise. In 2019, the total world population was 7.7 billion and is expected to grow to 8.5 billion, 9.7 billion and 10.8 billion respectively by 2030, 2050 and 2100 respectively. By 2030, the total annual need for cereals for human consumption and animal feed will be 2.8 billion tons per year. Compared to demand from 2005 to 2007, total global demand for all agricultural commodities and cereals is estimated to grow by 1.1% and 0.9% per year, respectively, until 2050 [2].

The Green Revolution in the second half of the 20th century was extremely successful because it led to a rapid increase in food supplies without a significant increase in area or food prices. Traditional methods of increasing crop production have relied heavily on synthetic fertilizers and pesticides, but they have also damaged the environment, endangered human and wildlife health, and caused global climate catastrophes. Developing methods that produce enough food and maintain the quality of the environment and the economic well-being of people are some of the most important challenges of the twenty-first century. Thus, agriculture began to move towards finding new methods to increase productivity while maintaining higher levels of production and environmental quality, which is called sustainability [3].

Sustainable development aims to meet the needs of current generations while maintaining the needs of future generations, social well-being and environmental quality. The main goals of sustainable development in agriculture are environmental and ecological health, economic profitability, social, and economic equity. Polyculture (intercropping) cropping is one of the ways to intensify crop production to ensure sustainable agriculture. Thus, the purpose of this article is to consider the importance of agricultural intensification in terms of resource use efficiency and related methods for measuring the effectiveness of intercropping.

Intercropping is a form of farming system that involves growing two or more different species of crops simultaneously on a plot of land. This is a unique approach compared to other methods used by farmers to enrich the diversity of cropping systems such as crop rotation, insect strips and buffer plants. Intercropping involves the cultivation of two or more genotypes or types of crops simultaneously for a certain period of time. The use of legumes as part of crop diversification methods have expanded the scope for increasing food production without negative environmental impacts, opening up new opportunities for further research, extension work and policy on cropping systems. Crop diversity in which different species or types of crops are grown in rotation in different seasons within the same calendar year, is an important approach to building resilience [4].

Intercropping system contributes a greater yield stability on a given plot of land through the judicious use of available crop growth resources by component crops. Growing legumes together with cereals increases soil fertility through biological nitrogen fixation with the help of bacterial association and supports soil conservation through more ground cover than growing alone. Intercropping reduces the risk of pest infestation and improves forage quality by increasing the yield of crude protein from the forage. It reduces the cost of production and provides insurance against total crop failure or volatile market prices for the commodity, especially in areas prone to severe weather conditions such as frost, droughts and floods. Moreover, it provides physical support to climbing crops and lodging susceptible crop species. Thus, intercrop (polyculture) ensures greater financial and environmental stability than monocultural cropping.

Depending on the species' combination, competition for nutrients, water, and light, as well as allelopathic effects between crops, can lead to lower yields. Reducing competition can be achieved by choosing appropriate crops, adjusting planting rates and cropping geometry. When climatic and environmental conditions are unfavorable, intercropping reduces the chance of a complete crop failure. Precipitation is the most important climatic component for crop development, which directly affects crop yields. The largest part of the world's arable land (60%- 600 million hectares) is situated in developing countries where 40% of it is in the zone of moisture deficient with low rainfall. Unacceptable practices such as deforestation, intensive livestock and crop production, as well as land-use changes (predominance of monocultures) etc. have exacerbated soil degradation in many parts of the world to the extent that 47% of soils are currently degraded.

A broad term used to express the impact of efficient resource use in intercropping systems is complementarity. Complementarity refers to the sharing of resources, reducing competition between species. There are two ways of resource complementarity that describe how combined plants use resources more efficiently in a mixture than when they are grown individually: resource sharing and facilitation (*figure A and B*).

Legumes in intercropping can increase crop yields under low soil nitrogen conditions as they compete less fiercely for soil nitrogen than other plant species. They can provide up to 15% additional nitrogen to non-legumes through biological nitrogen fixation (BNF). Cereal-legume blends may include systems in which both species have comparable phenology but incomparable morphology, or conversely, opposite phenology and morphology which leads to niche complementarity in time and/or space. Intercropping aims to exploit complementary and beneficial interactions between species to increase catch and resource use efficiency, productivity and profit per unit of land. Diversification of on-farm crops through intercropping can improve yields and stability of agricultural production in the event of seasonal fluctuations and climate change, as different species respond

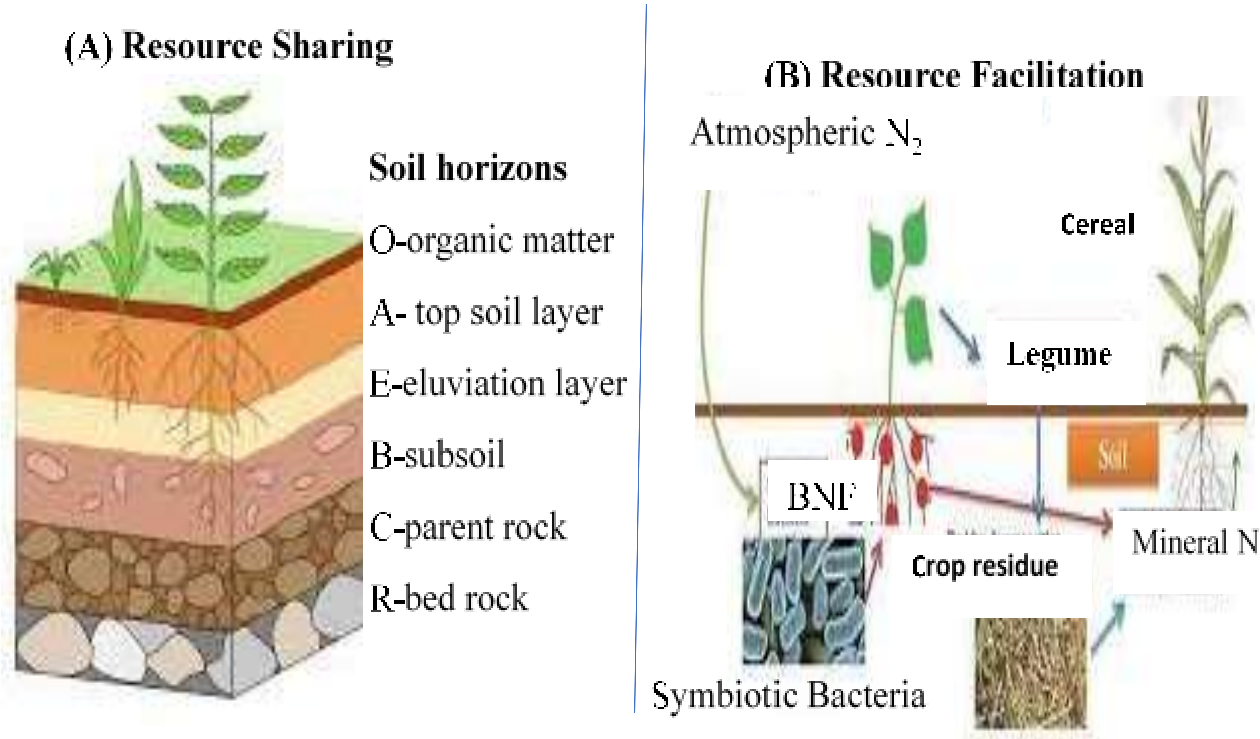

Figure. Resource complementarity in legume-cereal intercropping

differently to different environmental conditions. For example, when monocots and dicots are combined and grown together in polyculture, the harvested dry matter yield is higher than when they grow separately, indicating that intraguild (intraspecific) competition is more intense than interspecific competition. Growing of shallow rooted along with deep rooted species is characterized by more efficient use of limited resources: water and nutrients (e.g., nitrogen), which leads to higher rates of total nitrogen utilization and leads to higher productivity in polycultures [5].

Recent advances in agronomy, especially intercropping, have led to more efficient land use through the successful selection of crop species with complementarities for space, radiation, and input requirements. It has been observed that in cereal-legume interfacing systems, legumes with a shorter, denser canopy are more efficient at absorbing solar energy compared to a monoculture. Intercropping can increase the productivity of land, yields and profits through more efficient use of one or more resources in time and space. According to biodiversity studies, 79% of intercropping systems produced biomass at a rate that was on average 1.7 times greater than monoculture.

The legume intercropping system is an interesting method of producing green forage biomass with higher quantitative and qualitative characteristics for livestock and increasing incomes. Legumes, due to their higher protein content, tend to increase the nutritional value and quality of feed and cereals due to their higher lignin content than legumes, increase acid detergent lignin, decrease neutral detergent fiber, and increase crude protein content in legume forages.

Conclusions: The Green Revolution largely depends on synthetic agrochemicals to increase crop production and adversely affected both the environmental quality and health of living organisms. Intercropping aims to exploit complementary and beneficial interactions between species to increase resource use efficiency, productivity, profit per unit of land and maintains high level of environmental quality.

Cereal-legume intercropping includes species with comparable phenology but incomparable morphology, or, opposite phenology and morphology which leads to niche complementarity in time and/or space. It produces higher quality and quantity of green forage biomass and improves the nutritional value of feed.

References

1. Giller KE et al. The future of farming: Who will produce our food? // Springer. 2021 Vol. 13. P. 1073–1099.

2. Doubi BTS et al. Existing competitive indices in the intercropping system of Manihot esculentaCrantz and Lagenaria siceraria (Molina) standley // J Plant Interact. Taylor and Francis Ltd., 2016. Vol. 11, No. 1. P. 178–185.

3. Weih M., Mínguez MI, Tavoletti S. Intercropping Systems for Sustainable Agriculture // Agriculture (Switzerland). MDPI, 2022. Vol. 12, no. 2.

4. United Nations Department of Economic and Social Affairs; Population Division. World Population Prospects 2019, Highlights. 2019.

5. Gebru H. A Review on the Comparative Advantages of Intercropping to Mono-Cropping System // Journal of Biology, Agriculture and Healthcare. 2015. Vol. 5, № 09. P. 1–13.