Review

MODERN PEA SOWING TECHNOLOGIES: EFFICIENCY, PRECISION, AND SUSTAINABILITY IN CONTEMPORARY AGRICULTURE

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Abstract: The protein content and quality of pea seeds are strongly influenced by cultivation practices and processing methods. Soil fertility, stress conditions, and harvest timing affect protein synthesis and amino acid profiles. Post-harvest treatments can enhance or degrade protein digestibility and nutritional value. Optimized agronomic and processing strategies are essential to ensure high-quality pea protein for human consumption. Pea sowing represents a crucial stage in the agricultural process, and the use of modern sowing technologies has brought significant improvements in the efficiency and sustainability of this process. Seeders, equipped with advanced depth and seed distribution control systems, enable uniform and efficient sowing, reducing resource waste. These modern technologies not only support more efficient resource management but also contribute to environmental protection by reducing the need for chemical treatments and improving soil structure. Additionally, the sowing process helps combat pests and diseases by ensuring even plant distribution, making them more resilient. Although implementing these technologies may involve high initial costs, the long-term economic and ecological benefits make them a valuable investment in agriculture. This chapter explores the impact of modern seeders on contemporary agriculture, highlighting the advantages and challenges associated with their use.

1. Introduction

Pea seeds (Pisum sativum) represent a highly valuable component of the human diet due to their rich nutritional profile. They are an excellent source of plant-based protein, containing approximately 23–25% protein by dry weight, with a favorable amino acid composition rich in lysine but limited in methionine, making them complementary to cereal grains in mixed diets. The high protein digestibility (over 85%) enhances their nutritional efficiency [1]. In addition to protein, pea seeds are a good source of complex carbohydrates, primarily starch and dietary fiber, contributing to glycemic regulation and satiety. Total dietary fiber ranges from 8 to 11 g/100 g dry matter, including both soluble fibers, which support blood glucose and cholesterol control, and insoluble fibers, which promote digestive health. The seeds are low in fat (typically <2%), and the lipid fraction is predominantly unsaturated. Peas also provide a range of micronutrients, including iron, phosphorus, potassium, magnesium, zinc, and B vitamins such as folate and thiamine, contributing to metabolic function and cellular health. Their low glycemic index and absence of cholesterol make them suitable for diabetic and cardiovascular health-oriented diets. Furthermore, peas are free of gluten and represent a hypoallergenic protein source, increasingly used in functional foods and plant-based formulations. These attributes underscore the role of pea seeds as a sustainable and nutritionally dense ingredient in diverse human diets.

The quality of pea seeds for human consumption is closely linked to agronomic practices throughout the cultivation cycle. Factors such as seed selection, sowing time, soil fertility, irrigation management, and pest control directly affect nutrient accumulation, seed composition, and the presence of anti-nutritional factors. Optimal planting density and timely sowing ensure uniform growth and efficient nutrient uptake, which enhances protein synthesis and starch deposition. Soil quality and the availability of essential macro- and micronutrients—particularly nitrogen, phosphorus, and zinc—play critical roles in determining protein content and amino acid balance [2]. The application of biofertilizers and integrated nutrient management can further improve seed nutritional density while maintaining environmental sustainability. Crop management practices such as weed control, disease prevention, and use of biostimulants contribute to healthier plants, reducing physiological stress that could compromise seed quality. Excessive use of chemical inputs, on the other hand, can lead to pesticide residues or reduced soil microbial activity, negatively impacting food safety and nutrient bioavailability. Harvesting at optimal maturity is essential to ensure proper seed hardness, protein concentration, and storage quality. Post-harvest handling, including drying and storage, also influences the preservation of vitamins and prevention of fungal contamination. In sum, sustainable and precise crop management practices are essential to maximize both the yield and the nutritional quality of pea seeds intended for food applications [3].

The protein content and quality of pea seeds are determined not only by genetic factors but also by environmental conditions and agricultural management during cultivation. Soil fertility—particularly nitrogen availability—directly influences the biosynthesis of storage proteins such as legumin and vicilin. Practices that enhance soil health, such as crop rotation with legumes, use of organic fertilizers, and microbial inoculants (e.g., Rhizobium spp.), can improve nitrogen fixation and protein yield. Abiotic stresses such as drought, excessive heat, or nutrient deficiencies during flowering and seed development can lead to reduced protein accumulation and altered amino acid profiles. Harvest timing is also critical: premature or delayed harvesting may reduce protein concentration or promote degradation of functional proteins [4].

Post-harvest processing—especially drying, dehulling, and thermal treatments—further affects protein quality. Excessive heat during drying or cooking can cause denaturation of proteins, reducing solubility and digestibility, while moderate thermal treatment may improve the nutritional value by inactivating anti-nutritional factors like trypsin inhibitors. Milling and fractionation can concentrate protein but may result in the loss of certain amino acids or micronutrients if not carefully controlled. Innovative processing techniques, such as air classification, fermentation, or enzymatic hydrolysis, are increasingly used to enhance protein bioavailability and functional properties for use in plant-based food formulations. Overall, the preservation of high protein content and quality in peas requires integrated attention to cultivation, harvesting, and processing parameters tailored for food-grade applications [5].

Pea (fig.1) is a widely cultivated legume crop, known not only for its nutritional value but also for its agronomic benefits. One of its major advantages lies in its ability to enrich the soil with nitrogen due to the presence of nodule-forming, nitrogen-fixing bacteria on its roots, which reduces the need for synthetic nitrogen fertilizers [1].

Fig. 1 - Pea (Pisum sativum L.) [2]

Population statistics indicate a substantial rise in the global population, projected to reach 10 billion by 2050. As a result, the global challenges of energy and water scarcity, food security, and climate change are expected to intensify [3,4,5]. In the context of modern agriculture, food systems exert increasing pressure on ecosystems [6]. Balancing ecosystem protection with the need to provide sustainable nutrition for the global population has become a critical concern in recent years [7]. Over the past decades, there has been a growing global trend towards the production and consumption of environmentally friendly food, cultivated in clean areas without the use of mineral fertilizers, pesticides, or other synthetic inputs [8,9].

Automation and software programs are transforming legume production, increasing efficiency, precision, and sustainability. Advanced technologies such as sensors, IoT devices, and autonomous machinery help monitor and manage every stage of crop development. Soil sensors provide real-time data on moisture, temperature, and nutrient levels, enabling precise irrigation and fertilization. Drones equipped with multispectral cameras survey fields, identifying stressed areas and enabling targeted interventions.

Automated planters and harvesters reduce labor demands and ensure uniform crop establishment and collection. GPS-guided tractors allow for precision field operations, reducing overlap and optimizing resource use. Variable rate technology (VRT) adjusts input application rates according to field variability, improving productivity and reducing environmental impact.

Software platforms integrate data from multiple sources, offering farmers centralized dashboards to monitor operations and make informed decisions. Farm management systems track planting schedules, input use, weather forecasts, and yield predictions. Decision support systems use AI algorithms to recommend pest control actions, planting dates, or optimal harvest windows based on predictive models.

Greenhouse vegetable production benefits from environmental control software, which automates temperature, humidity, lighting, and CO_2 levels. In hydroponics and aquaponics, automation ensures balanced nutrient delivery and water quality. Robotics are increasingly used for transplanting, weeding, and selective harvesting, especially in high-labor-intensity crops.

Machine learning models process data from previous seasons to improve future planning and risk assessment. Cloud-based platforms enable remote monitoring and collaboration among producers, agronomists, and suppliers.

The integration of automation and software programs not only increases operational efficiency but also supports sustainable practices by minimizing waste and optimizing inputs. As digital agriculture evolves, legume production is becoming more resilient, profitable, and climate-smart.

Fig. 2 - Start Analyzing & Visualizing your data with HortControl Software [10]

HortControl is the central software to setup your experiments and to store and manage data locally on a site. Within seconds after the scan, the plant parameters sets can be visualized and analyzed with the HortControl tool box [10].

The production of high-quality agricultural products remains a top priority within the crop industry [11,12]. At the same time, preserving soil fertility, ensuring ecological purity, and promoting resource conservation are equally important goals [13,14,15]. Achieving these objectives requires the adoption of adaptive cropping systems [16], which rely on the renewable resources of biological communities—such as plant and microbial systems—to supply essential nutrients to plants and enhance their stress resilience [17]. In this context, legume agrocenoses formed in symbiosis with nodule bacteria represent a fundamental element of organic farming, as these systems exhibit mutual compatibility and functional complementarity.

Pea is cultivated for both green pods and mature seeds [18]. The pods are slightly aromatic, sweet, and crispy, and notably lack pod parchment [19]. In India, for instance, pea is typically grown as a winter vegetable in the northern plains and as a summer vegetable in hilly regions. It is commonly consumed fresh, canned, processed, or dehydrated. India remains the largest producer and importer of leguminous crops [20].

From a nutritional standpoint, pea is an excellent food for human consumption, whether used as a vegetable or in soups. The immature seeds found in green pods are especially popular for these uses. Additionally, pea herbage harvested shortly after pod picking serves as a valuable green fodder for livestock [21].

Field peas are among the leading grain legumes for both food and forage due to their rich and balanced amino acid profile. Pea seeds contain approximately 22–24% total protein, 1.5% fat, 55% nitrogen-free extractives, and 6–8% crude fiber. They are also a vital source of lysine—an essential amino acid—present in concentrations 3–4 times higher per kilogram than in cereal grains [22,23].

Pea is cultivated across nearly all regions of the world and plays a significant role in the human diet [24]. It holds particular importance in vegetarian and vegan nutrition, where its high protein content helps individuals meet their dietary protein requirements in the absence of meat and dairy products [25,26]. Sowing date and cultivar selection are key management strategies for optimizing both seed yield and protein content [27]. Numerous studies [28,29] have reported that early sowing increases yield, while delayed sowing leads to reductions.

In recent years, catch crops have gained attention due to their positive impact on soil health. They improve the physical and biological properties of soil [30,31] and reduce the risk of eutrophication caused by nutrient leaching [32,33]. Within cropping systems dominated by cereals, selecting appropriate species for catch crops is essential. Legume crops are particularly desirable in this role due to their beneficial effects on soil chemistry and structure [34,35], though they do require early sowing to be effective [36].

2. Materials and methods

Sowing peas is a fundamental task in the cultivation technology of this vegetable, having a significant impact on the uniformity of germination, plant density, and, ultimately, on the yield. Pea (Pisum sativum L.) is a leguminous plant distinguished by its relatively large, spherical, and fragile seeds, characteristics that require the use of specially designed sowing machines to prevent seed damage.

Regarding the sowing period, it must be carefully chosen to match the specific climatic and moisture conditions of each region. Sowing is usually done in early spring, between March and April, when the soil reaches a temperature of at least 4–5°C. Early sowing is essential for uniform crop development, and delaying sowing can lead to reduced yields and the emergence of pest risks.

For sowing peas, mechanical seeders are generally used, which allow for the uniform distribution of seeds. These seeders are equipped with dosing systems that regulate the amount of seed, considering the specific characteristics of pea seeds. Typically, a sowing depth of 4–6 cm is recommended, ensuring good root development and uniform germination.

The seeders are equipped with opener discs that allow for easy penetration into the soil, even in high humidity conditions. These seeders are extremely useful for working in heavy soils or soils with plant residues, which can complicate sowing.

Regarding sowing density, it is adjusted based on the purpose of the crop – for green pod production or for dry bean production. In general, seed rates range between 170–250 kg/ha, depending on the type of pea and soil conditions. The final plant density usually reaches approximately 90–110 plants per square meter. For sowing aimed at green pod production, narrower rows are recommended to ensure quick soil coverage and reduce weed growth.

Another important aspect in pea sowing technology is the precise monitoring of the distance between seeds. Distribution errors can severely affect the uniformity of the crop and lead to a low yield. Modern precision seeders are equipped with monitoring sensors that constantly control the seed flow and adjust the dosing to ensure uniform distribution. This allows for reducing the error to below 10%, resulting in uniform germination and a well-established crop.

Modern seeders are equipped with ISOBUS and GPS control systems, which allow precise operation of the machinery, even in large farms. These technologies enable users to control sowing speed, record accurate data on operations performed, and adjust sowing parameters in real-time, significantly improving sowing efficiency.

Regarding sowing speed, it plays a crucial role in achieving maximum yield. Typically, sowing is done at a speed of about 4–7 km/h. Higher speeds can lead to uneven seed distribution and seed damage, while speeds that are too low can extend working time and affect sowing quality. Modern seeders are equipped with damping systems that help maintain the stability of the machinery even at high speeds.

As for soil preparation before sowing, it is important for the soil to be properly prepared. A preliminary pass with a combiner or adjustable-tooth harrow is recommended to break up solid soil structures and create a fine seedbed.

Finally, choosing the right seeder is not just about technical specifications but also the cost-benefit ratio. Modern seeders, equipped with state-of-the-art technologies, may initially seem expensive, but the advantages they bring—such as reduced seed loss, increased crop uniformity, and higher work efficiency—justify the investment, especially for medium and large farms. These machines allow for optimized fuel consumption and reduce the number of passes across the field, which lowers operating costs and increases long-term profitability.

3. Results

This chapter presents modern seeding machine models used in agricultural crop sowing, with a focus on their ability to successfully incorporate pea seeds. While these machines are primarily designed for cereal crops, their technical configurations—such as precise depth control, advanced seed distribution systems, and the ability to sow seeds of various sizes—make them suitable for sowing legumes, including peas.

Peas are typically sown in rows with a spacing of 12–15 cm, and the seeders discussed below, thanks to their versatility and adjustable technical parameters (such as pressure on the coulters, seed dosage, disc diameter, etc.), can ensure uniform seed distribution and consistent sowing depth. This results in optimal conditions for germination and crop development.

Therefore, the seeders presented in this chapter—METRO MEGA by Maschio Gaspardo, SUP 400 DIAMANT by Mecanica Ceahlău, and PREMIA 9000 TRC by Kuhn—can be successfully used for pea cultivation, offering efficient and reliable solutions for farms aiming to achieve uniform emergence and high yields.

3.1. METRO MEGA Seeder – MASCHIO GASPARDO

The Italian company Maschio Gaspardo manufactures the METRO MEGA seeder (fig. 3), a high-capacity agricultural equipment created by combining four SC MARIA seeder modules that operate synchronously in parallel. This configuration is made possible by a towed frame with foldable sides, which reduces the transport width to just 6 meters, thus facilitating the movement of the machinery on public roads.

Fig. 3 - METRO MEGA Seeder [37]

The seeder retains the functional characteristics of the models it is derived from, including:

- Mechanical transmission with three cams in an oil bath,
- Compartmented hopper for the simultaneous distribution of seeds and fertilizers,
- Double disc furrows, equipped with adjustable compression springs.

Technical specifications – METRO MEGA:

- Working width: 12 m
- Number of rows: 88
- Row spacing: 13.6 cm
- Seed hopper capacity: 1,320 l
- Fertilizer tank capacity: 1,080 l
- Transport width: 6 m
- Required power: ≥ 240 HP
- Weight: ≥ 9,200 kg

3.2. SUP 400 DIAMANT Seeder – MECANICA CEAHLĂU

Produced by the Romanian company Mecanica Ceahlău, the SUP DIAMANT range of cereal seeders is designed for row sowing and includes two models with working widths of 3 m and 4 m. These seeders are equipped with a Norton gearbox featuring 72 speeds, allowing for fine adjustment of seed rates. The triple distributor enables the application of very small seeds (e.g., rapeseed, clover, alfalfa) at rates as low as 2 kg/ha.

The SUP 400 DIAMANT seeder (fig. 4) offers multiple advantages:

- Adjustable double-disc coulters for depths up to 8 cm
- Large hopper capacity
- Telescopic markers with spherical discs
- Packing wheels included as standard
- Rapid switch between small and standard seed types
- Triple distributor for a wide range of crops

Optionally, it can be equipped with: covering tines, packing chains, systems for shutting off two or three rows, and simultaneous fertilizer application.

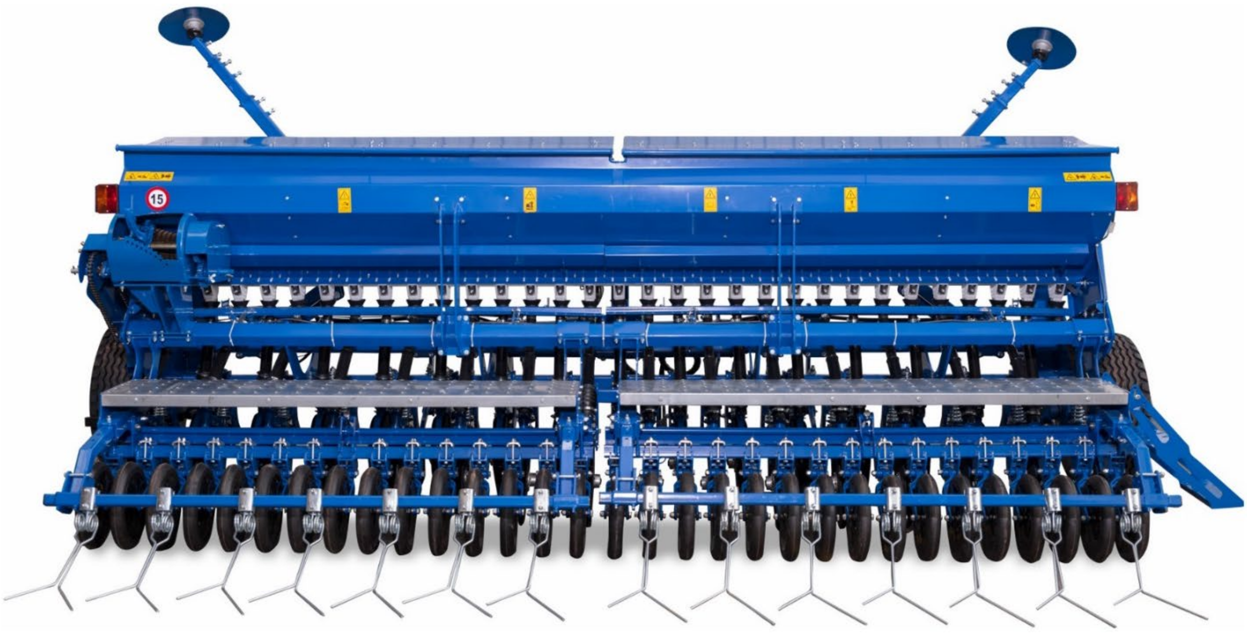

Fig. 4 – SUP 400 DIAMANT Seeder [38]

Technical Specifications – SUP 400 DIAMANT:

- Equipment type: mounted, category II ISO
- Required power: 120–140 HP
- Working width: 4 m
- Number of rows: 31
- Row spacing: 13 cm

- Seed distribution: triple spiked roller
- Seeding rate adjustment: 72-speed gearbox
- Seed hopper capacity: 1,260 L
- Coulter type: double disc, 370 mm diameter
- Productivity: 1.4–2.8 ha/h
- Working speed: 5–10 km/h
- Dimensions (L x W x H): 2.46 x 4.6 x 1.62 m
- Weight: 2,100 kg

3.3. PREMIA 9000 TRC Seeder – KUHN (France)

The French company Kuhn manufactures the PREMIA 9000 TRC seeder (fig. 5), a mechanical model designed for large farms using medium-capacity tractors. It is a towed, foldable seeder without a soil preparation unit, with a working width of 9 meters and a transport width of only 3.5 meters.

Fig. 5 - The mechanical seed drill PREMIA 9000 TRC [39]

It is a combined seeder for both seeds and fertilizer, distributed simultaneously in the same row (60% of the hopper for seeds, 40% for fertilizer). The machine is equipped with 4 HELICA dosing units, allowing distributions between 1.5 and 300 kg/ha, for all types and sizes of seeds.

The dosing is ensured by helicoidal rollers, mechanically driven by lateral drive wheels and cam variators, maintaining a constant flow, independent of the travel speed. The components are mostly made of stainless steel for an extended service life.

4. Discussions

Sowing peas is a crucial step in the cultivation technology of this vegetable, and choosing the right technologies for sowing plays a decisive role in the success of the crop. Over the decades, the continuous development of sowing machinery has led to the implementation of increasingly precise solutions, which not only improve yields but also contribute to more sustainable resource management.

Modern sowing machines, such as precision seeders equipped with advanced mechanical systems, allow for uniform seed distribution, which is essential for achieving a uniform crop. Compared to traditional seeders, these technologies are much more efficient, reducing the risks of seed distribution errors and providing much stricter control over the sowing depth.

An important aspect to mention is the impact that precision sowing has on economic and ecological efficiency. Modern seeders, equipped with GPS and ISOBUS technologies, enable precise operation and the recording of relevant data for each field lot. This not only optimizes fuel consumption and reduces operating costs but also allows for better monitoring of sowing parameters. This efficiency translates into resource savings, including reduced seed and fertilizer consumption.

Additionally, the implementation of these technologies aligns with the general trend in agriculture to reduce environmental impact. Modern seeders can precisely adjust the amount of seeds distributed, reducing waste and ensuring optimal plant density. This can contribute to improving soil health and more efficient nutrient use. Furthermore, the fact that these machines are more efficient in soil processing, especially in humid conditions or heavy soils, helps reduce erosion and maintain soil structure in the long term.

At the same time, precision sowing helps address another important aspect of modern agriculture: pest and disease management. A uniform sowing reduces the risk of plant overcrowding, which can attract pests or promote disease development. Moreover, by better controlling plant density, the need for chemical treatments can be reduced, thus supporting organic farming and minimizing the impact on biodiversity.

Another relevant aspect concerns the adaptability of modern seeders to different soil and climate conditions. Although sowing technologies are highly advanced, it is important for farmers to understand and choose the right type of seeder based on the specifics of the land they are working with. For example, seeders that allow for depth adjustment are essential in areas with denser soils or plant residues. Furthermore, these seeders can be configured to sow more sensitive crops, such as peas, which require gentle handling of the seeds.

Regarding the size of the machinery, large-scale seeders, such as the METRO MEGA or DIAMANT models, enable fast and efficient operation on large farms, significantly impacting productivity per unit area. However, the initial costs of such equipment can be high, and the purchase decision must be made based on the size of the farm and its specific needs. In this regard, a careful cost-benefit analysis is essential, considering long-term savings in fuel, maintenance, and seed conservation.

Sowing peas with modern technologies, such as precision seeders, plays a fundamental role in today's agriculture, contributing both to improved yields and supporting ecological and sustainable practices. The efficiency of these machines, combined with the responsible use of resources and their adaptability to varying field conditions, makes these technologies a valuable investment for farmers worldwide. However, to maximize the benefits of these technologies, it is important for farmers to be educated and have access to relevant information that enables them to make informed decisions when selecting the right equipment and to understand their long-term impact on the environment and the economy.

5. Conclusions

Modern seeding technologies have brought a significant leap in the efficiency and sustainability of agriculture, and pea seeding is no exception. The use of seeders equipped with advanced seed dosing systems, seeding depth control, and GPS monitoring allows for uniform and precise sowing, with a direct impact on the growth and development of the crop. This leads to higher and more consistent yields, reduced seed loss, and more efficient resource management, particularly fuel and fertilizers.

Furthermore, modern seeders reduce the risks associated with seed damage, providing a constant and uniform sowing flow. These technologies also support ecology by limiting the use of chemical inputs and improving soil structure. The implementation of such technological solutions contributes to healthier and more resilient crops, which, ultimately, supports the increase in agricultural productivity and sustainability.

However, high initial costs and the need to adapt the technology to the specific conditions of each farm remain significant challenges for the widespread adoption of precision seeders. Nevertheless, the long-term benefits — resource savings, higher yields, and environmental protection — make these technologies a valuable investment for medium and large farms.

In conclusion, pea sowing using modern seeders represents an important direction for the future of agriculture, providing innovative solutions that improve not only production efficiency but also the long-term sustainability of agricultural activities. The adoption of these technologies will play a crucial role in achieving global objectives related to food security, environmental protection, and responsible resource use.

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References

1. Ansabayeva, A. **(2023)**. Cultivation of peas, Pisum sativum L. in organic farming. Caspian Journal of Environmental Sciences, 21(4), 911-919.
2. Global Bean. https://www.globalbean.eu/publications/common-pea/ (accessed on **09 04 2025**)
3. Eltohamy, K.M., Taha, M.F. Use of Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to Assess the Levels of Phosphorus and Cadmium in Lettuce. **(2024)**. In Plant Chemical Compositions and Bioactivities; Springer: New York, NY, USA; pp. 231–248.
4. Maja, M.M., Ayano, S.F. **(2021)**. The Impact of Population Growth on Natural Resources and Farmers' Capacity to Adapt to Climate Change in Low-Income Countries. Earth Syst. Environ., 5, 271–283.
5. Taha, M.F., Mao, H., Zhang, Z., Elmasry, G., Awad, M.A., Abdalla, A., Mousa, S., Elwakeel, A.E., Elsherbiny, O. **(2025)**. Emerging Technologies for Precision Crop Management Towards Agriculture 5.0: A Comprehensive Overview. Agriculture.; 15(6):582. https://doi.org/10.3390/agriculture15060582
6. Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., et al. **(2019)**. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet, Volume 393, Issue 10170, 447 – 492, DOI: 10.1016/S0140-6736(18)31788-4. Epub 2019 Jan 16.
7. Röös, E., Bajzelj, B., Weil, Ch., Andersson, E., Bossio, D., Line, J. **(2021)**. Gordon Global Food Security. 28: 100487 Serekpayev, N, Popov, V, Stybayev, G, Nogayev, A & Ansabayeva, A 2016, Agroecological aspects of chickpea growing in the dry steppe zone of Akmola region, northern Kazakhstan. Biosciences Biotechnology Research Asia, 13: 1341-1351. DOI: 10.13005/bbra/2275.
8. Wu, D., Wei, Z., Qu, F., Mohamed, TA., Zhu, L., Zhao, Y., Jia, L., Zhao, R., Liu, L., Li, P. **(2020)**. Effect of Fenton pretreatment combined with bacteria inoculation on humic substances formation during lignocellulosic biomass composting derived from rice straw. Bioresource Technology, 303: 122849, https://doi.org /10.1016/j.biortech.2020.122849.
9. Nassif, WG., Lagenean, FHS., Al-Taai, OT. **(2023)**. Impact of vegetation cover on climate change in different regions of Iraq. Caspian Journal of Environmental Sciences, 21: 333-342.
10. PHENOSPEX. https://phenospex.com/ (accessed on **09 04 2025**)
11. Kantarbayeva, EE., Shayakhmetova, AS., Koshen, BM., Zholamanov, KK. **(2017)**. The density of planting and the productivity of corn in the context of forest-steppe zone of northern Kazakhstan. Asian Journal of Microbiology, Biotechnology & Environmental Sciences, 19: 116-120.

12. Kuldybayev, N., Dutbayev, Y., Lozowicka, B., Iwaniuk, P., Slyamova, A., Tsygankov, V. **(2021)**. Effects of root rot in soybean cultivars with diverse susceptibility to the disease on plant physiology, yield, amino acids, and mycotoxins profile in climatic conditions of kazakhstan. OnLine Journal of Biological Sciences, 21: 312-321.
13. Bekezhanov, D., Kopbassarova, G., Rzabay, A., Nessipbayeva, I., Aktymbayev, K. **(2021)**. Environmental and legal regulation of digitalization of environmental protection. Journal of Environmental Management and Tourism, 12: 1941–1950.
14. Al- Abbasi, SHAH., Altaef, AQ., AL-Samarraie, M., Al-Naqib, ATH., Al-Majmaei, AAM. **(2022)**. Collection and diagnosis of some wild plants in the vicinity of Samarra University, Iraq. Caspian Journal of Environmental Sciences, 20: 437-440.
15. Yesmagulova, BZ., Assetova, AY., Tassanova, ZB., Zhildikbaeva, AN., Molzhigitova, DK. **(2023)**. Determination of the degradation degree of pasture lands in the west Kazakhstan region based on monitoring using geoinformation technologies. Journal of Ecological Engineering, 24: 179-187.
16. Aipeisova, S., Utarbayeva, N., Maui, A., Kazkeev E., Baubekova, A. **(2023)**. Fabaceae Lindl. species in the floristic composition of the aktobe floristic district. International Journal of Environmental Studies, 80: 1076-1087, DOI: 10.1080/00207233.2022.2136851.
17. Serekpayev, N., Popov, V., Stybayev, G., Nogayev, A., Ansabayeva, A. **(2016)**. Agroecological aspects of chickpea growing in the dry steppe zone of Akmola region, northern Kazakhstan. Biosciences Biotechnology Research Asia, 13: 1341-1351. DOI: 10.13005/bbra/2275.
18. Kaur, R., Kondal, P., Singh, N., Maurya, V., Sharma, A., Kumar, R. **(2024)**. Effect of spacing and sowing dates on growth, yield and quality of pea (Pisum sativum L.). Int. J. Res. Agron., 7(2), 238-251.
19. Chauhan, A., Sharma, A. **(2021)**. Genetic Diversity in Edible Podded Pea (Pisum sativum var. saccharatum). Indian Journal of Agricultural Sciences. 34(2):301-304
20. Shakya, K., Chettri, MK., Sawidis, T. **(2008)**. Impact of heavy metals (copper, zinc, and lead) on the chlorophyll content of some mosses. Archives of Environmental Contamination and Toxicology. Apr; 54:412-421.
21. Temel, Y., Kucukler, S., Yıldırım, S., Caglayan, C., Kandemir, FM. **(2020)**. Protective effect of chrysin on cyclophosphamideinduced hepatotoxicity and nephrotoxicity via the inhibition of oxidative stress, inflammation, and apoptosis. Naunyn-Schmiedeberg's archives of pharmacology. Mar; 393:325-337.
22. Bocianowski, J., Księżak, J., Nowosad, K. **(2019)**. Genotype by environment interaction for seeds yield in pea (Pisum sativum L.) using additive main effects and multiplicative interaction model. Euphytica, 215, 191.
23. Amantayev, B., Shelia, V., Kipshakbayeva, G., Shestakova, N., Gordeyeva, Y., Kulzhabayev, Y., ... & Hoogenboom, G. **(2024)**. Effect of Fertilizer, Sowing Date, and Seeding Rate on Biomass and Yield of Pea (Pisum savitum L.) Grown Under Dry Steppe and Steppe Conditions. Agriculture, 14(12), 2367.
24. Sümer, F. Ö. **(2024)**. The Effects of Sowing Date and Cultivars on Yield and Quality of Pea. preprints.org. doi: 10.20944/preprints202401.1660.v1
25. Rasskazova, I., Kirse-Ozolina, A. **(2020)**. Field pea Pisum sativum L. as a perspective ingredient for vegan foods: A review. Research for Rural Development, 35: p. 125-131.
26. Dahl, W.J., Foster, L.M., Tyler, R.T. **(2012)**. Review of the health benefits of peas (Pisum sativum L.). British Journal of Nutrition, 108(S1): p. S3-S10.
27. Turner, N.C. **(2004)** Agronomic options for improving rainfall-use efficiency of crops in dryland farming systems. Journal of Experimental Botany. 55(407): p. 2413-2425.
28. Tavakkoli, A.R., Oweis, T.Y. **(2004)** The role of supplemental irrigation and nitrogen in producing bread wheat in the highlands of Iran. Agricultural water management. 65(3): p. 225-236.
29. Photiades, I., Hadjichristodoulou, A. **(1984)**. Sowing date, sowing depth, seed rate and row spacing of wheat and barley under dryland conditions. Field crops research. 9: p. 151-162.
30. Piotrowska, A., Wilczewski, E. **(2012)**. Effects of catch crops cultivated for green manure and mineral nitrogen fertilization on soil enzyme activities and chemical properties. Geoderma, 189–190, 72–80.

31. Zimny, L., Wacławowicz, R., Malak, D. **(2005)**. Changes in selected physical properties of soil as a result of differentiated organic and mineral nitrogen fertilization. Fragm. Agron., 1, 664–677.
32. Eichler, B., Zachow, B., Bartsch, S., Köppen, D., Schnug, E. **(2004)**. Influence of catch cropping on nitrate contents in soil and soil solution. Landbauforsch. Völkenrod, 54, 7–12.
33. Wilczewski, E., Sokół, B., Nowicki, R., Jug, I., Pietrzykowski, K., Gałęzewski, L. **(2023)**. Response of Field Pea and Common Vetch, Grown as a Catch Crop, on the Sowing Method. Agriculture, 13(1), 3; https://doi.org/10.3390/agriculture13010003.
34. Wilczewski, E., Piotrowska-Długosz, A., Lemańczyk, G. **(2015)**. Properties of Alfisol and yield of spring barley as affected by catch crop. Zemdirb. Agric., 102, 23–30.
35. Wanic, M., Żuk-Gołaszewska, K., Orzech, K. **(2019)**. Catch crops and the soil environment—A review of the literature. J. Elem., 24, 31–45.
36. Zaniewicz-Bajkowska, A., Rosa, R., Kosterna, E., Franczuk, J. **(2013)**. Catch crops for green manure: Biomass yield and macroelement content depending on the sowing date. Acta Sci. Pol. Agric., 12, 65–79.
37. Maschio Gaspardo. https://www.maschiogaspardo.com/ro/web/romania/metro-mega (accessed on **08 04 2025**)
38. Mecanica Ceahlau. https://mecanicaceahlau.ro/produse/semanatoare-paioase-sup-400-diamant/ (accessed on **08 04 2025**)
39. Kuhn. https://www.kuhn.com/en/crop/seed-drills/trailed-seed-drills/trailed-min-till-mechanical-seed-drills/premia-9000-trc (accessed on **09 04 2025**)