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"Increasing Crop Yield through Advanced Irrigation Technologies: World and Uzbekistan Experiences"

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Abstract: Chickpea (Cicer arietinum L.) is an important leguminous crop worldwide, especially in semi-arid regions. Efficient irrigation is crucial to maximize its yield and ensure food security. This article explores the advantages of modern irrigation technologies for chickpea cultivation, particularly drip irrigation. We discuss chickpea planting practices, phenological stages, various irrigation methods, and the benefits of drip irrigation in chickpea production. Furthermore, we synthesize global research findings with specific studies conducted in Uzbekistan, demonstrating the impact of improved irrigation on chickpea yield and water use efficiency. The discussion highlights the potential of these technologies to enhance productivity and contribute to sustainable agriculture.

Keywords: Chickpea, Irrigation, Drip Irrigation, Water Use Efficiency, Yield, Phenology, Sustainable Agriculture, Legumes

Methods: This article includes an analysis of studies conducted in foreign countries and their results, incorporating data from scientific databases (such as Scopus, Web of Science, OpenAI Scholar), relevant agricultural journals, and publications from research institutes. The information is gathered from a comprehensive review of the literature. Search terms include "chickpea," "irrigation," "drip irrigation," "water use efficiency," "yield," "phenology," and similar combinations. The analysis covers global research, particularly studies conducted in arid and semi-arid regions, as well as research conducted in Uzbekistan. The article includes a comparative analysis of chickpea yield, water consumption, and various irrigation methods.

Introduction: Chickpea (Cicer arietinum L.) is an important leguminous crop, a key food source, and a vital component of sustainable agricultural systems, particularly in arid and semi-arid regions. It is a protein-rich food source and contributes to soil fertility through nitrogen fixation [1-3]. However, chickpea cultivation is often limited by water scarcity and the variability of rainfall. In many regions, including Uzbekistan, farmers often rely on traditional flood irrigation or furrow irrigation, which can be inefficient and lead to water waste [4-5]. Effective irrigation methods, such as drip irrigation, offer significant advantages in maximizing water use efficiency and, consequently, increasing yield [6-9].

Chickpea belongs to the legume family and is a species of annual and perennial herbaceous plants; it is a leguminous grain crop. Its origin is Asia. The stem is herbaceous, upright, coarse, ribbed, hairy, and grows to a height of 30-70 cm. The leaves are compound, pinnate [10-13]. The flowers are bisexual, butterfly-shaped, and small. The fruit is a pod, containing 1-2, sometimes 3, seeds. The seed color varies, including white, pink, and dark yellow. Chickpeas are heat- and light-loving, and are a spring crop. Compared to other legumes, chickpeas are more drought- and salt-tolerant. The seeds germinate at temperatures between 2-5°C, and the plant grows slowly at low temperatures. The plant can tolerate frosts of up to -6 to -8°C during the growing season. Excess moisture can cause disease, and the flowers and fruit may drop. Chickpeas are self-pollinating [14-16]. The growing period lasts from 70 to 190 days. The seeds contain 19-33% protein, 4-7% fat, 0.2-4.0% ash, 48-61% nitrogen-free extractive substances, 2-12% fiber, vitamins, and amino acids. In one season, chickpea roots can fix 50-70 kg of nitrogen per hectare in the form of pure matter. They are typically planted in rows (row spacing of 45-60 cm) or broadcast (row spacing of 15 cm), sometimes sown at a depth of 5-10 cm [17-19].

According to GOST, both green and yellow chickpeas are suitable for consumption as raw, heat-treated, and canned products [20,23]. They are valued for their high content of vitamins and microelements, including beta-carotene; vitamins A, E, K, B group; iron; iodine; potassium; calcium; magnesium; sodium; zinc, and others. Rich in fiber, chickpeas improve intestinal function, have a beneficial effect during pregnancy, and help speed up recovery after illness [20-22].

The varieties developed by the Uzbekistan Grain Scientific Research Institute through repeated single selection have been adapted to the non-irrigated lands of Jizzakh, Kashkadarya, Syrdarya, Samarkand, Tashkent, and Surkhandarya regions. The flowers are white and large. The chickpea pods contain 1-2 seeds, which are twisted and white. The weight of 1000 seeds ranges from 372 to 305 grams. This medium-maturing variety takes 78-79 days from full germination to technical ripeness. The protein content is 24.3-26%. It is resistant to ascochyta blight. Drought-resistant, the chickpea pods do not split [21-23].

Results and Discussion. Chickpea planting and phenological observations: Chickpeas are typically planted in late autumn or early spring, depending on the climate, to adapt to moisture availability and avoid excessive heat stress. Phenological stages include germination, vegetative growth, flowering, chickpea pod formation, and ripening. The water requirements fluctuate during these stages; the reproductive stages are especially sensitive to water stress, which can significantly affect yield. Monitoring crop growth and utilizing phenological data are crucial for effective irrigation timing. In Uzbekistan, where water is scarce, correct timing is especially important. The planting time, method, and preparation work depend on the climate conditions and soil fertility of the region.

In autumn planting, chickpeas can be sown in warm climates during the autumn months (September-November). This planting allows the seeds to germinate during winter and start growing in spring. In spring planting, especially in cold climates, sowing is recommended during the spring months (February-April). In this case, it is important to protect the crop from spring frosts. In Uzbekistan, chickpeas are primarily planted in spring (late February to mid-April), but autumn planting is also practiced in some southern regions. When analyzing chickpea planting methods, sowing can be done in rows or broadcast, but the depth of sowing is also considered. One of the most common methods is row planting. Chickpea seeds are planted at a certain spacing (usually 40-60 cm between rows, 5-10 cm between plants). In broadcast planting, seeds are spread evenly and mixed with the soil. This method tends to be less effective. There is also a deep sowing method where seeds are planted at a depth of 4-8 cm, depending on soil type. However, in heavy soils, seeds should not be planted too deeply. Before planting, the soil is thoroughly plowed, loosened, and leveled. Organic fertilizers such as manure can be used to improve soil fertility. Prior to planting, seeds are treated with special preparations to protect them from diseases. After planting, the soil must be sufficiently moist, and the field is irrigated. Chickpea phenological observations involve tracking the growth and development stages of the plant and recording any changes. These observations allow for the proper timing of water and nutrient applications to increase yield. The main phenological stages of chickpeas include germination, vegetative growth, flowering, pod formation, and ripening. The germination process occurs within 7-14 days after planting. Soil temperature and moisture are crucial factors for successful germination. During vegetative growth, the plant develops leaves and stems. This phase lasts approximately 30-45 days, depending on climatic conditions. The plant grows rapidly, branches out, and accumulates green mass. After the vegetative phase, the flowering phase begins. Flowers appear on the plant's stems and branches. The flowering period lasts 15-20 days.

In the pod formation stage, chickpea pods start to form after flowering. At this stage, the plant requires more water and nutrients. The pods gradually increase in size, and the seeds inside begin to develop. The next stage is the ripening of chickpea pods, where they turn yellow or brown, and the seeds inside harden. During this phase, the plant’s water demand decreases. Once the pods are fully ripe, the crop is harvested.

Figure 1. Chickpea crop condition during growth and harvesting.

An irrigation plan is developed based on the plant’s growth and development stages. The demand for water is highest during the flowering and pod formation stages. The need for nutrients changes during different stages, and fertilizers are applied at the appropriate times. Diseases and pests often become active at specific stages of plant growth, and through monitoring, proper control measures can be planned. Phenological observations can also help estimate yield potential.

Traditional irrigation methods, such as flood irrigation and furrow irrigation, involve the use of large amounts of water, which leads to significant losses through runoff, deep percolation, and evaporation. These methods are particularly inefficient for crops like chickpeas, which are prone to root rot due to excess soil moisture. Furrow irrigation is still widely used but often results in uneven water distribution within fields. Drip irrigation, also known as micro-irrigation, delivers water directly to the root zone of plants through a network of pipes and emitters. This method has several advantages. Drip irrigation significantly reduces water loss and ensures that plants receive only the necessary amount of water. By keeping the soil surface dry, it also prevents the germination and growth of weeds, reducing competition for resources. Nutrients can be delivered through the drip irrigation system (fertigation), providing precise application and reducing leaching. By eliminating water stress, drip irrigation can significantly improve plant growth, flowering, pod formation, and ultimately, yield. Keeping the leaves dry reduces the likelihood of fungal diseases, which is a key factor in successful chickpea cultivation.

Given the increasing relevance of chickpea cultivation in Uzbekistan and its importance in the food industry, various research institutions are focusing on developing new, promising chickpea varieties. An analysis was conducted on data from six chickpea varieties cultivated in Uzbekistan. These varieties were created by research institutions such as the Irrigated Lands Scientific-Research Institute (G'allaorol Branch and Main Branch), Tashkent State Agrarian University (TashDAU), and Gulistan State University (GulDU). Most of the varieties belong to the Karneum and Euro-Asian groups, which indicates their large seed size and high yield potential.

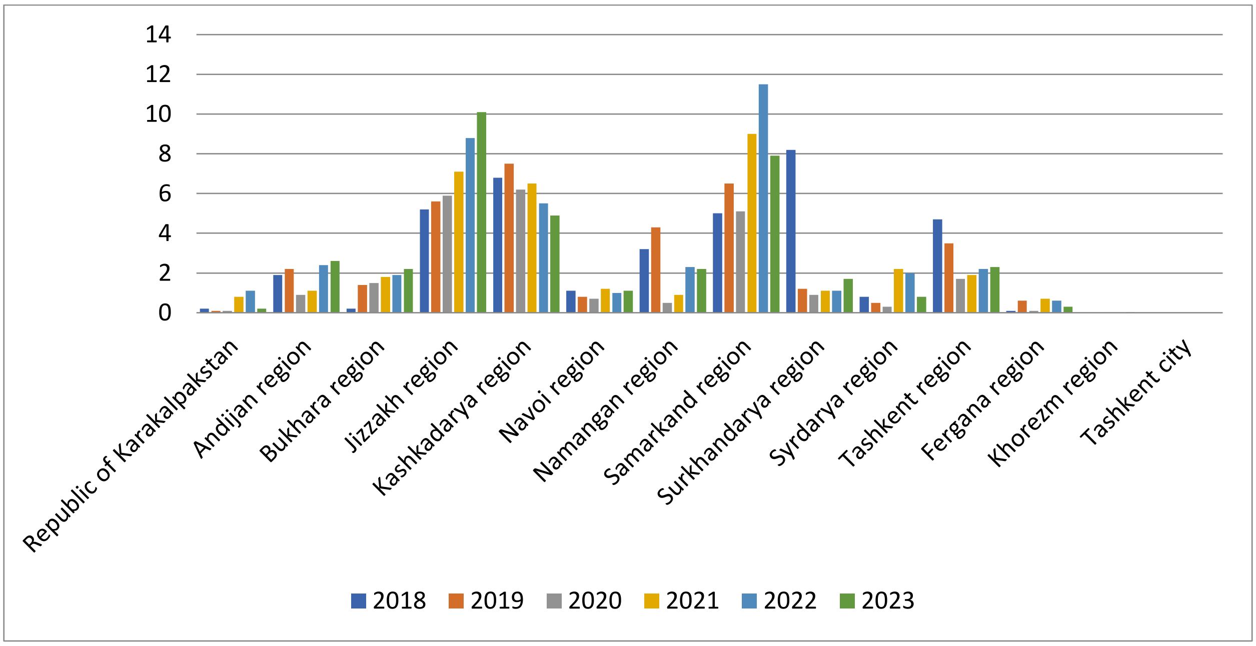
The morphological and biological characteristics of the varieties were analyzed as follows:

1. **Variety created by Ergashev N et al. (Variety 1):** This variety has a seed weight of 323.0-342.0 g, an average height of 42-50 cm, a vegetation period of 88-93 days, and an average yield of 7.1 s/ha. With a protein content of 27.5-28.1%, this variety is valuable for the food industry.
2. **Variety created by Eshmirzayev K et al. (Variety 2):** This variety has a seed weight of 258.6-292.3 g, a height of 45.0-48.0 cm, a vegetation period of 80-91 days, and a yield range of 7.2-11.5 s/ha. It stands out for its rapid growth and variability in yield.
3. **Variety created by Mannopova M et al. (Variety 3):** This variety has a seed weight of 485.0 g, a height of 75-78 cm, a vegetation period of 180-190 days, and a yield of 25.8 s/ha. It is characterized by large seeds and high yield but has a long vegetation period.
4. **Variety created by Atabayeva X et al. (Variety 4):** This autumn variety has a seed weight of 344-365 g, a vegetation period of 76-82 days in spring and 210 days in autumn. In dryland areas, it yields 4.2-6.4 s/ha, while in irrigated areas, it achieves 30.1 s/ha. This highlights the efficiency of autumn chickpea cultivation in irrigated conditions.
5. **Variety created by Mannopova M et al. (Variety 5):** This variety has a seed weight of 520.0 g, a height of 66-75 cm, a vegetation period of 122 days, and a yield of 36.6 s/ha. Its high yield and protein content (28.0%) are among its distinctive features.
6. **Variety created by Atabayeva X et al. (Variety 6):** This spring variety has a seed weight of 312-328 g and a vegetation period of 75-97 days. It yields 4.5-5.4 s/ha in dryland areas and 25.7 s/ha in irrigated areas, demonstrating its ability to perform well in irrigated conditions.

The analysis of the yield data shows that Varieties 5 (36.6 s/ha) and 4 (30.1 s/ha in irrigated areas) have the highest yields. In contrast, the yields were relatively lower in dryland areas. The varieties also differ in their vegetation periods, with Variety 2 (80-91 days) and Variety 6 (75-97 days) being early-maturing varieties. Varieties 3 (180-190 days) and 4 (autumn 210 days) have longer vegetation periods. All the varieties show a high protein content ranging from 26.6% to 28.1%, indicating their nutritional value [24].

International research highlights the advantages of drip irrigation in chickpea cultivation. Studies conducted in various regions (such as India, Australia, and Iran) show that drip irrigation can increase chickpea yields by 20-50% compared to traditional methods, depending on soil type, climate, and management practices. Drip irrigation can save 30-60% of irrigation water when compared to surface irrigation methods without reducing yields. The system delivers water directly to the plant's root zone through small droplets, preventing excessive evaporation, leaching, and runoff. In contrast, surface irrigation spreads water over the entire surface, leading to significant evaporation and seepage losses. Drip irrigation allows water to be applied precisely and in the correct amounts according to the plant's needs, preventing soil saturation and water wastage. Drip irrigation helps maintain soil moisture at a constant and optimal level. In surface irrigation, the soil can sometimes become overly wet or too dry. Drip irrigation only supplies water to the plant roots and keeps the surface dry, preventing weed germination and growth. Reduced weed growth decreases competition for water and nutrients. Chickpeas irrigated with drip systems often have improved seed size, uniform maturity, and higher protein content. Consistent water delivery to the root zone also prevents root rot diseases and waterlogging.

Several studies in Uzbekistan have focused on the impact of advanced irrigation systems on chickpea cultivation. Based on experimental results, a comparative analysis was conducted with international data. The studies show that, in Uzbekistan's conditions, drip irrigation improves water efficiency (yield per unit of water used) compared to traditional furrow irrigation. Under drip irrigation, chickpea yields significantly increase, often with reduced water consumption compared to furrow irrigation systems. Some studies report yield increases ranging from 20% to 40%. For example, a study conducted in Khorezm province showed a 30% increase in chickpea yield under drip irrigation compared to traditional systems. Drip irrigation can improve soil structure, reduce excess surface water, and enhance nutrient availability, which helps mitigate soil salinity issues.



Graph 1. Peas grown on farms of all categories.

The results of foreign and Uzbek studies confirm that the implementation of modern irrigation methods, especially drip irrigation, offers significant opportunities to increase chickpea productivity. Drip irrigation ensures the efficient use of water, which is crucial in arid and semi-arid regions with limited water resources. The high yields achieved through drip irrigation are related to the optimization of water delivery, reduced water stress, and better nutrient availability.

While traditional methods are easier to implement, their inefficiency leads to significant water wastage, making them unsustainable in the long run. This is especially important in Uzbekistan, where water scarcity is a major issue. The country's agriculture heavily depends on irrigation, and making irrigation as efficient as possible is critical for the future. The results indicate that the adoption of modern irrigation methods not only improves productivity and farmers' incomes but also contributes to the sustainable use of water resources.

Apart from irrigation, several other factors influence chickpea yield, and the following measures are recommended to optimize productivity:

1. **Selection of locally adapted chickpea varieties** that are resistant to local diseases.
2. **Timely planting** to ensure optimal growth and efficient use of available resources.
3. **Application of appropriate fertilizers** based on soil composition to ensure all necessary nutrients are available to the plants.
4. **Integrated pest and disease management strategies** to minimize crop damage.
5. **Proper soil management**, including avoiding soil compaction and improving soil structure, which enhances water infiltration and root health.

These measures, when combined with efficient irrigation systems like drip irrigation, can significantly improve chickpea production, especially in water-limited regions.

Conclusion: The article explored the advantages of modern irrigation technologies, particularly drip irrigation, in improving chickpea yield and water use efficiency. The evidence shows that switching from traditional furrow irrigation to drip irrigation can significantly improve not only yields but also the responsible use of water resources. Results from international contexts and specific research within Uzbekistan emphasize that the implementation of these technologies can lead to significant advances in chickpea production. These achievements are crucial for both food security and the economic sustainability of chickpea farming. Using advanced irrigation practices, along with other best management practices, is essential for optimizing chickpea production and ensuring sustainable agriculture in dryland and semi-arid areas of Uzbekistan and globally. Additional research is needed to optimize the application of these technologies in different agricultural systems. Research findings indicate that in Uzbekistan, chickpea varieties with various characteristics have been developed. Some varieties stand out for their early maturity, while others are distinguished by high yields. Furthermore, the existence of varieties suited for autumn and spring planting allows farmers to choose varieties that fit their specific region and conditions.

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