

INFLUENCE OF DIFFERENT IRRIGATION METHODS ON YIELD AND WATER PRODUCTIVITY OF MUNGBEEN

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Abstract

Background There is substantial variation in crop yields and corresponding water productivity of different crops as well as for the same crop grown in different parts of the world. Soil moisture is the supremely critical and greatly mutable component of the crop root zone environs. Therefore, water must be used wisely and efficiently by adopting water conservation technologies to enhance crop yield as well as water productivity.

Methodology A research experiment was piloted to compare water use efficiency and crop yield (Mungbean) by using three different irrigation methods i.e. flood vs sprinkler irrigation via center-pivot system vs sprinkler irrigation via hose reel.

Results the No. of branches produced under central pivot system were minimum (12.3 ± 1.1), but pod length was greater than other treatments and No. of grains pod-1 were statistically similar to other treatments. The grain yield of mungbean grown under different water application methods was not vary statistically, however was slightly higher under flood irrigation. The water productivity was 0.41 kg m⁻³, 0.41 kg m⁻³ and 0.38 kg m⁻³ for flood, central pivot system and for hose reel treatment, respectively.

Conclusion Grain yield and water efficiency of different treatments were statistically similar to each other, however center-pivot irrigation system has an advantage to utilize input(s) efficiently with control of weed infestation.



1. INTRODUCTION

Food security remains one of the most tenacious global challenges of the 21st century, with increasing concerns due to rising population, land degradation, and climatic variability (FAO, 2022). Ensuring consistent food production for a growing population requires innovative and sustainable agricultural practices, especially in regions with limited natural resources. In this context, legume crops, particularly pulses like mungbean (*Vigna radiata*), play a pivotal role. They are an affordable and essential source of plant-based protein, vital amino acids, dietary fiber, vitamins, and micronutrients, thereby contributing significantly to human nutrition and the fight against malnutrition (pp.200–213.) (Giller, K.E.,).

Legumes are also recognized for their agro-ecological benefits. They enhance soil fertility and structure through biological nitrogen fixation (BNF) in symbiosis with *Rhizobium* spp., promote beneficial microbial associations such as mycorrhizae, and reduce dependency on chemical nitrogen fertilizers (Mafongoya, P.L) (Hedley, M., 2001). Furthermore, as low-input crops, legumes are economically viable for resource-poor farmers and contribute to sustainable cropping systems, especially in semi-arid and marginal environments (Zahran, H.H., 2023) (Singh, B., Rani). Given these attributes, increasing legume production is considered a strategic approach to achieve the United Nations Sustainable Development Goals (SDGs), particularly SDG 2: Zero Hunger (UN, 2022).

Water scarcity, however, is a critical barrier to legume productivity, particularly in arid and semi-arid regions where rainfall is erratic and irrigation efficiency is poor (IWMI, 2022). In Pakistan, agriculture accounts for approximately

90% of total freshwater use, yet inefficient irrigation practices result in massive water losses—estimated at 37 million acre-feet (MAF) annually (Ali, M., Hussain). Of this, 12 MAF is lost in the conveyance system, including main canals, distributaries, minors, and over 58,500 watercourses (Hasan, M.M). Moreover, water use efficiency remains suboptimal, with less than 40% of irrigation water effectively utilized at the crop root zone (Qureshi, A.S.,).

Conventional flood irrigation, the most common method in Pakistan, is associated with substantial water wastage due to percolation, evaporation, and surface runoff. It also promotes waterlogging, salinization, and inefficient nutrient uptake (Ashraf, M). Therefore, there is a growing interest in adopting modern pressurized irrigation systems, such as sprinkler irrigation using center pivot and hose reel technologies, which apply water more uniformly and at controlled rates (Jalota, S.K) (Tiwari, S. and Mal, B.C., 2022). These systems have demonstrated potential in improving water productivity (kg yield per cubic meter of water used), enhancing crop performance, and conserving water in both rainfed and irrigated settings (Keller, A., Sackler) (Wichelns, D.).

Despite these advantages, limited studies have directly compared the agronomic response and water productivity of legumes under different irrigation methods in the Pakistani context. Mungbean, as a short-duration crop with relatively shallow roots, is particularly responsive to optimized irrigation scheduling (Khan, S.A). Understanding how sprinkler systems perform in comparison to flood irrigation in terms of yield, water use efficiency, and physiological traits is



essential for developing resilient and resource-efficient cropping systems (Rashid, H) (Ahmad, N., Jamil, M. and Zia, M., 2022).

Therefore, this trial was designed to estimate and equate the effects of three irrigation methods—flood irrigation, sprinkler irrigation via center pivot, and sprinkler irrigation via hose reel—on the growth, yield, and water productivity of mungbean. The outcomes of this research are expected to provide insights into more efficient irrigation strategies and contribute to water-smart legume production in water-scarce regions.

2. MATERIALS AND METHODS

A field trial was performed at Water Management Research Farm, Renala Khurd, Okara, Pakistan (30° 50' 44.9" N; 73° 32' 84.3" E). This region has the climate characteristics of plains. The study area is categorized by semi-arid climate; where > 80% of the downpours during the monsoon season (June to September). Temperature escalations > 50 °C (122 °F) in the summer whereas in winter the lowest temperature recorded is as low as freezing point. The soil is a loam with 7.9 pH. The 15-mm soil layer contains 0.62% organic matter, 7.3 ppm available P, and 100 ppm available K.

Experimental materials and design

The mungbean variety NM-2016 was sown as a test crop. Di-ammonium phosphate (DAP) @ 1 bag/acre was applied as basal doze. Three water treatments, i.e. flood (common practice), sprinkler irrigation with center-pivot system and sprinkler irrigation with hose reel were applied throughout crop period. The layout was designed as Randomized Complete Block Design (RCBD). The yield and yield related attributes were measured at the time of physiological maturity in triplicates. All

the data acquired was statistically analyzed using STATISTIX 8.1. Turkeys HSD (Honestly Significance Difference) test was used to compare treatments.

Water productivity

Water productivity was calculated as given below:

$$\text{Water Productivity (kg m}^{-3}\text{)} = \frac{\text{Grain Yield (kg)}}{\text{water applied (m}^3\text{)}}$$

3. RESULTS AND DISCUSSION

Growth- and growth-related attributes

The application of different irrigation methods had a notable impact on the vegetative growth characteristics of mungbean, including plant height, number of branches per plant, and number of pods per plant (Table1).

- Plant Height:** The highest plant height (40.8 ± 2.8 cm) was observed in the flood irrigation treatment, followed closely by sprinkler irrigation with central pivot (40.1 ± 2.7 cm), and hose reel sprinkler irrigation (39.9 ± 2.8 cm). Although the differences were relatively small, flood irrigation produced slightly taller plants. This may be due to more consistent moisture availability around the root zone, promoting elongation growth.
- Number of Branches per Plant:** The highest number of branches per plant (22.7 ± 1.5) was recorded under sprinkler irrigation with hose reel, which significantly outperformed the central pivot method (12.3 ± 1.1). The flood irrigation method resulted in an intermediate number of branches (20.3 ± 2.1). The superior branching under the hose reel system may be attributed to moderate and evenly distributed



moisture that supports lateral growth and shoot development.

- **Number of Pods per Plant:** Mungbean plants irrigated with the hose reel system also produced the highest number of pods per plant (37.0 ± 1.6), compared to 31.7 ± 1.7

under flood irrigation and 30.7 ± 1.6 under central pivot sprinkler irrigation. Increased pod production under the hose reel treatment reflects the positive influence of optimal water distribution and reduced water stress on reproductive development.

Table 1: Growth- and growth-related attributes of Mungbean grown under different irrigation methods

Treatments/Parameters	Plant Height (cm)	No. of Branches Plant ⁻¹	No. of pods Plant ⁻¹
Flood irrigation	40.8±2.8	20.3±2.1	31.7±1.7
Sprinkler irrigation with central pivot	40.1±2.7	12.3±1.1	30.7±1.6
Sprinkler irrigation with Hose Reel	39.9±2.8	22.7±1.5	37.0±1.6

Values are Mean± SD and average of three replications.

Yield-Related Attributes (Table 2)

Irrigation methods also influenced pod length, pod diameter, and number of grains per pod, which are direct determinants of mungbean yield.

- **Pod Length:** The longest pods (10.4 ± 1.6 cm) were obtained under flood irrigation, followed by the central pivot sprinkler system (8.38 ± 1.5 cm). The shortest pods (2.30 ± 0.5 cm) were produced under hose reel irrigation, which appears inconsistent with its high pod number. This could indicate a trade-off between pod quantity and size under hose reel conditions, possibly due to higher competition among reproductive sinks.

- **Pod Diameter:** Hose reel irrigation produced the thickest pods (0.41 ± 0.05 mm), followed by central pivot (0.35 ± 0.07 mm), while flood irrigation resulted in the thinnest pods (0.29 ± 0.04 mm). Increased pod diameter under hose reel irrigation may be linked to more uniform water availability that supports proper seed filling despite shorter pod length.
- **Number of Grains per Pod:** All treatments produced a similar number of grains per pod, with flood irrigation and hose reel irrigation both recording 10.7 grains, while central pivot recorded slightly fewer (10.3). These differences were minimal and may not be statistically significant, indicating that irrigation method had limited influence on seed set per pod.



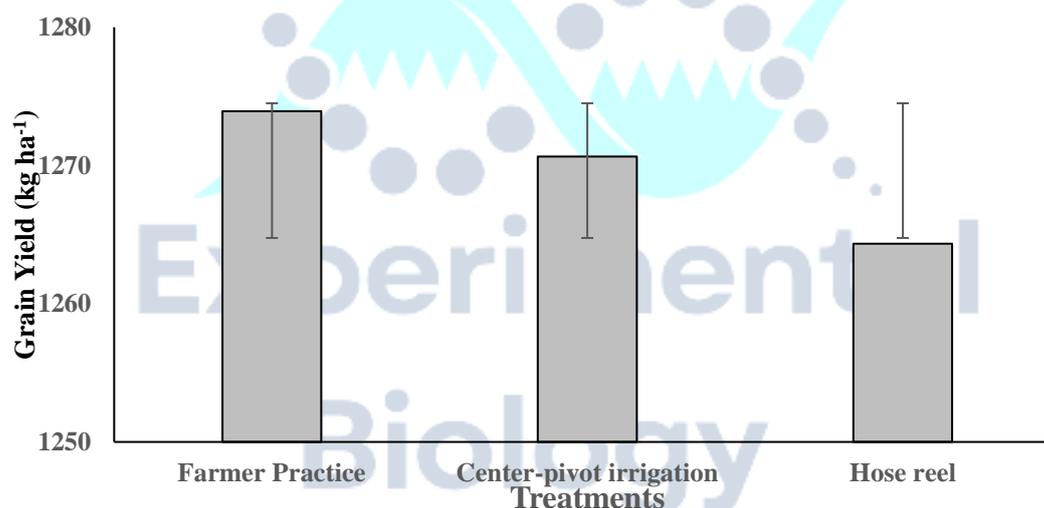
Table 2: Yield related attributes of Mungbean grown under different irrigation methods

Treatments/Parameters	Pod Length (cm)	Pod Diameter (mm)	No. of Grains Pod ⁻¹
Flood irrigation	10.4±1.6	0.29±0.04	10.7±0.09
Sprinkler irrigation with central pivot	8.38±1.5	0.35±0.07	10.3±1.11
Sprinkler irrigation with Hose Reel	2.30±0.5	0.41±0.05	10.7±1.08

Grain yield, harvest index and water productivity

The grain yield of mungbean grown under different water application methods/systems was not differed significantly (Figure 1). Since yields were not affected by water application methods, it seems that other yield components must have

compensated (Asaduzzaman et al., 2008)), but this compensation was not detectable statistically. The harvest index of treatment 1, in which flood irrigation was applied, was found maximum in our experiment (Figure 2). However, the economic part of mungbean remained statistically significant.

**Figure 1:** Grain yield of mungbean under different irrigation methods

The water productivity (WP) was also calculated by dividing grain yield to water applied during crop growth period. The water productivity was 0.41 kg m⁻³, 0.41 kg m⁻³ and 0.38 kg m⁻³ for flood irrigation, center-pivot system and for hose reel treatment,

respectively. The results clearly state that WP under center-pivot system was similar to WP under flood irrigation with optimum use of water, less weed infestation and efficient utilization of fertilizers and other inputs.

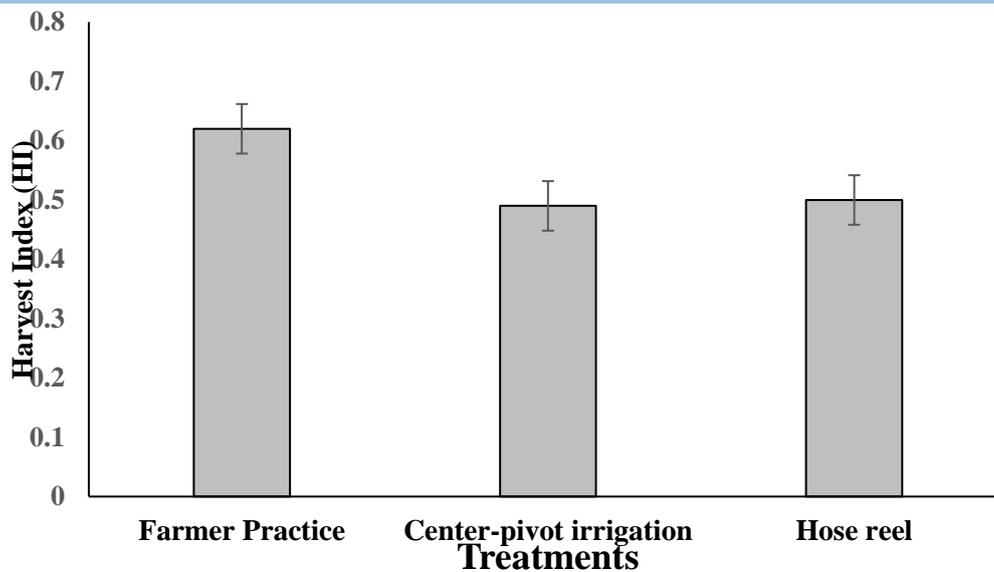


Figure 2: Harvest index of mungbean under different irrigation methods

4. CONCLUSION

Flood irrigation favored plant height and pod length, sprinkler irrigation with hose reel was more effective in enhancing branch formation, pod number, and pod diameter—traits that are closely linked with higher reproductive efficiency and total yield. These results suggest that hose reel sprinkler systems may offer a more water-efficient and productive irrigation strategy for mungbean cultivation under suitable field conditions, especially where water conservation is a priority. Grain yield and water productivity of different treatments were statistically similar to each other, hence central pivot system has advantage to utilize input(s) efficiently with control of weed infestation without compromising the yield.

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Conflict of Interest

Authors declared there is no conflict of interest.

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