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Research Article

IMPACT OF WATERING LEVELS ON SOYBEAN (*Glycine max* L.) GROWTH AND PRODUCTIVITY

Habibullah Poya[1], Rahmatullah Kazimi[2]*

[1]*Daikundi Institute of Higher Education, Faculty of Agriculture, Department of Agronomy, Nili, Afghanistan*
[2]*Daikundi Institute of Higher Education, Faculty of Agriculture, Department of Horticulture, Nili, Afghanistan*

Corresponding Author:
kazimirahmatullah@dhei.edu.af

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ABSTRACT. The present investigation was carried out to assess impact of water scarcity conditions on soybean (*Glycine max* L.) growth and yield. The experiment was done at Faculty of Agriculture, Kabul University, Afghanistan during the period of 2021 and 2022. The experimental farm having an elevation of 1971 meters above mean sea level, the farm is situated at 34°N latitude and 69°E longitude. The experiment consisted of five replications and four treatments according to randomized completely-block design. The treatments included I0 control, I_1 (431 mm), I_2 (526.9 mm), and I_3 (622.7 mm). The characteristics that have been considered were plant height, leaf count, branch count, pod count, length of pod, number of seeds per plant, 100-seed weight, and grain production per hectare. The gathered data were subjected to an analysis of variance (ANOVA) and used the STAR package application. The least significant difference (LSD) with a probability of 5% was employed to compare each treatment. The combined findings of 2021 and 2022 showed that there were some notable variations across the treatments, I_3 levels of irrigation represented the best across all variables examined, and have been enough water for the growth and development of soybeans, and enough water around the roots of the plants made enough nutrients available to the plants. This is why there were significant differences between the treatments and I_3, which have the best performance.

***Keywords**: Irrigation regimes, vegetative traits, protein, grain, Glycine max L*

INTRODUCTION

Comparing the nutrient content of soybeans (*Glycine max* L.) to animals, it is referred to as the "miracle golden bean" of the millennium. According to Openshaw & Hadley [1], the soybean seed has 41% protein, 21% oil, and 11% soluble carbohydrates. The nutritional richness and marketability of soybeans have made them a highly renowned crop in Afghanistan. According to current research, soybeans are utilized in Afghanistan in a variety of ways to improve the nutrition of people and animals as they are well-suited to growing circumstances in most regions of the nation [2]. Soybeans were first introduced in Afghanistan in 1970. But unfortunately, due to the bad security situation, it was stopped and have forgotten for three decades. Fortunately, in 2003, the Korea Institute, with a background in nutrition science, came to Afghanistan to research practical methods of combating malnutrition among women and children, which had the highest mortality rate. This institute identified soybeans as a good source of protein to reduce malnutrition in Afghanistan and emphasized on its cultivation [3].

Soybean growth is highly dependent on moisture availability throughout crucial growth phases since the crop is susceptible to high and low soil moisture levels. Thus, there is a clear correlation between the irrigation levels and crop development and production [4]. A crucial component that may also be a productivity constraint for crops is irrigation water. Water is currently the most valuable resource on the planet, even in Afghanistan, and a shortage of it will create a challenging issue. The amount and duration of irrigation is dependent on the developmental stage of the soybean, which establishes the daily crop water need, the soil's ability to retain water in the root zone, and the local meteorological circumstances. Conserving water is becoming a critical component of agricultural output, hence, it is crucial to have a thorough grasp of the ideal amount of water needed for different crops in order to manage the limited water resources wisely. With irrigation, soybean output may be significantly boosted, and the profitability can be raised in areas with low soil moisture levels. Soybean crops have demonstrated a 1.5 m depth of water retention, suggesting a degree of tolerance to restricted irrigation [5].

Some parts of the world, including Afghanistan experiences drought each year, devastatingly impacting agriculture productivity, and the prolonged droughts are not able to withstand soybean crops. The lack of water during blooming or pod elongation significantly decreased crop production [6]. The moisture content of the soil has an impact on water usage efficiency (WUE), WUE is higher during periods of water scarcity (drought or deficit irrigation regime) [7]. The phrase irrigation water use efficiency (IWUE) was coined as the restrictive definition of water use effectiveness does not address the function of irrigation. IWUE is more suited for agronomic practice as it takes into account how different irrigation schedules might affect production [8].

The objective of this experiment was to clarify the impact of various watering levels on the vegetative characteristics of soybeans.

MATERIALS AND METHODS

This experiment was carried out in agronomic research area of Faculty of Agriculture, Kabul University in the growing seasons of 2021 and 2022. This research consists of four treatments such as I0 control, I_1 was 431.1 mm at nine times, I_2 was 526.9 mm at eleven times, and I_3 was 622.7 mm at thirteen times. and five replications with Randomized completely block design. The sample chemical characteristics of the soil from the fields are shown in Table 1.

Table 1. *Chemical properties of initial soil.*

Seasons	pH	EC (ds/m)	Total – N (%)	P_2O_5 (ppm)	Soil – Texture			Classification
					Sand (%)	Silt (%)	Clay (%)	
2021	8.20	0.234	0.017	23.7	63.9	18	18.08	Sandy loam
2022	8.3	0.203	0.096	25.8	62.7	19.09	18.2	Sandy loam

Source: Soil Department of Agriculture Research Institute of Afghanistan (ARIA)

The plot was two by two meters. The seeds were planted at distance of 60 cm between the rows and 14.6 cm between the plants during the period of May 13, 2021, and May 13, 2022 directly. The yield contributing characteristics were noted, and the data was investigated by the STAR's application method for analysis of variance. The least significant difference test was used at the level of 5% confidence to examine differences in treatment means.

Long-term climate averages suggest that the study location has an arid, dry climate with a typical yearly temperature of 25C and 45 mm of precipitation throughout the plant development seasons. Table 2 provides average temperatures and precipitation of grown plants.

Table 2. *Meteorological data during the period of investigation (2021 and 2022)*

Months	Total precipitation (mm)		Temperature (C^o)	
	2021	2022	2021	2022
May	29.1	31.3	14.9	26.4
June	0	0.5	19.6	31.7
July	4.7	1.35	21.6	34.3
August	8.0	5.5	22.8	33.1
September	0.0	0.0	16.1	30.1

Source: Afghanistan Meteorological Department

Selection and preparation of field

The plot with rectangular form with uniform fertilizer and the same topography as well was selected for the experiment. The experimental plot was firstly plowed, and the field was then harrowed and leveled appropriately. All the stubble was removed, and then the field was laid out. The two beds with 60cm width and 220cm length were made, and 50 cm distance between the two plots as well.

Plant sowing

The seeds of soybean were grown to a depth of 4 cm and a distance of 14.6 cm from each other on both sides of the ridge (60 cm width) directly to the reciprocal of the beds on 13th May 2020 and 13th May 2021. Thus, 30 plants were grown on a ridge, or 60 plants in each plot. Seed rate depends on the seed index, germination, and planting date. Generally, 75 – 100 kg of seed per hectare is recommended.

Soybean cultivar

The variety which have been used in this research is Stine 3300. According to the findings of different studies, the variety Stine 3300 among other varieties is well-adapted to cold regions like Kabul, Logar, Bamyan, Ghazni, etc.

Statistical Analysis

ANOVA, which was used in the analysis of my data, has a wide range of uses in research across various fields, from natural sciences to medicine and industrial research. The ANOVA technique was used to analyze data because it is a powerful and essential tool for multiple groups and categories. It can help us determine whether or not there are any significant differences between the means of independent variables. Hence, we can easily see the difference between the independent variables.

RESULT AND DISCUSSION

Vegetative Parameters

According to the findings, plant height, plant leaf count, and branch per plant were significantly impacted by water levels. Plant height is related to the division of cells and development, which rely on physiological processes in the presence of water supply (Fig 1).

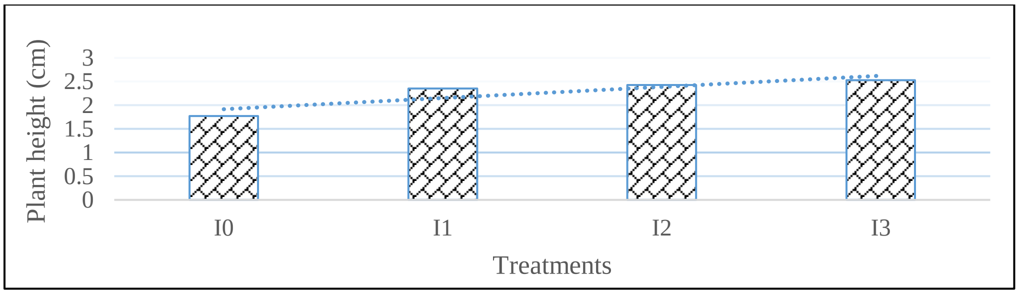

Fig. 1. *Effect of different levels of treatments on Plant height (cm).*

Plant height may be significantly influenced by watering levels due to increased nutrient availability of adequate moisture in the root zone of soybeans. This outcome is consistent with the findings of [9], that showed irrigation periods had an impact on soybean height during growth. According to other Studies, insignificant changes in the plant heights of chickpea and French beans with varying irrigation rates [10, 11].
An essential factor in assessing the production efficacy of leguminous agricultural plants is the number of leaves per plant. The information showed a substantial variation in the number of leaves per plant for every treatment. The results are clear when the minimal value of 51.6 with I0 to the considerably largest number of leaves per plant of 127.4 with I_3 have been compared (Fig 2).

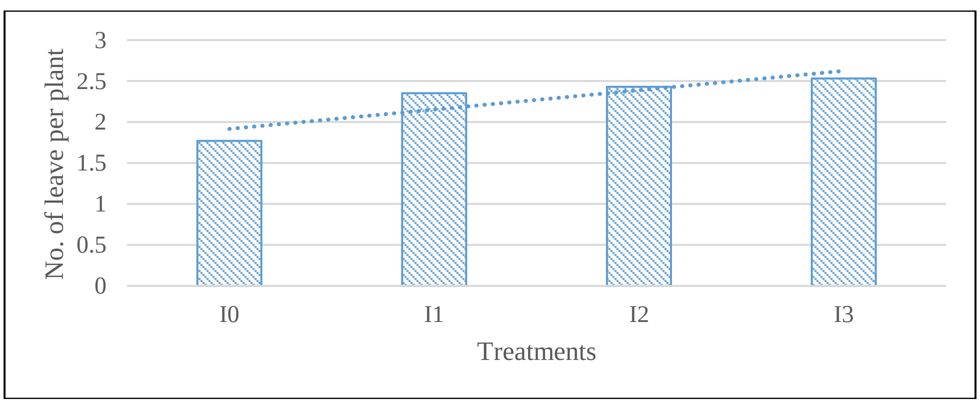

Fig. 2. *Effect of different levels of treatments on number of leaves per plant.*

Watering levels impacted the number of leaves per plant considerably, this effect may be attributed to better morphological characteristics such as branch count and leaf per plant,

which are directly correlated with leaf area/plant and shoot ultimate dry matter weight. This result is consistent with the findings of [12]. According to [13], plants with greater water supplies had more leaves overall, which produced more leaf area per plant.
Another crucial factor in assessing the production performance of leguminous agricultural plants is the number of branches per plant. The data showed that the number of branches per plant varied significantly across all treatments. Compared to the lowest value of 2.02 with I0, the significantly most significant number of branches per plant 6.7 was observed at I_3. Increased morphological characteristics, such as plant height, led to more pods per plant, which in turn produced greater branches (Table 3) and (Fig 3).

Table 3. *Effect of different levels of treatments on soybean parameters.*

Treatments	No. of leaves plat^{-1} at maturity	No. of braches plant^{-1} at maturity	Plant height (cm) at maturity	No. of pod plant^{-1}	No. of seeds pod^{-1}
I_0	51.60^{d}	2.02^{c}	28.33^{d}	24.43^{d}	1.77^{c}
I_1	111.00^{c}	5.21^{b}	57.97^{c}	67.80^{c}	2.35^{b}
I_2	117.70^{b}	5.31^{b}	65.54^{b}	78.35^{b}	2.43^{ab}
I_3	127.40^{a}	6.76^{a}	77.04^{a}	99.94^{a}	2.53^{a}
CV	5.37	13.57	2.73	8.58	7.50
$LSD_{0.05}$	4.983	0.596	1.425	5.286	0.155

The findings agree with the results which have been released by [14]. According to research which has been done on beans, it showed that low levels of soil moisture might be the result of a decrease in nutritional element absorption that resulted in a decrease in the number of branches produced, which discouraged the physiological processes required for plant growth [15].

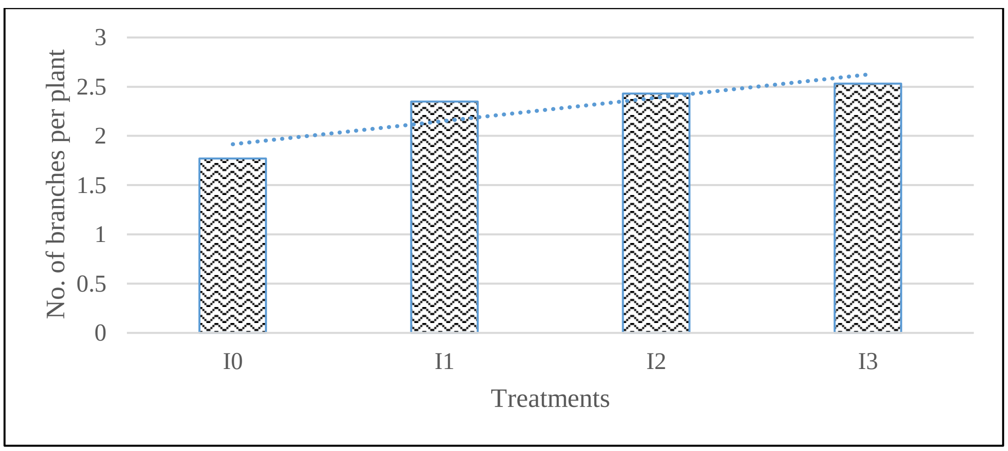

Fig. 3. *Effect of different levels of treatments on number of branches per plant.*

Grain yield parameters

The findings demonstrated that all grain production variables (number of pod per plants, number of seeds per plants, pod length (cm), weight of 100 seeds, and grain yield per ha) were significantly impacted by the amount of water. Crop production is directly impacted by the quantity of pod per plant, which is the yield contributing component. The data showed that the quantity of pods per plant varied across all treatments significantly. Pod count per plant was significantly greater with I_3 treatment at 99.9, compared to lowest levels with I0 at 24.43. Water shortage caused decrease of plant pods, which negatively impacted the growth of plant's reproductive organs. Stress during the vegetative stage inhibited the growth of branches that bear the fruit, which eventually reduced the quantity of pods per plant. This outcome is consistent with the research done by [16, 17], which have found that the height of soybean plants was impacted by watering levels (Fig 4).

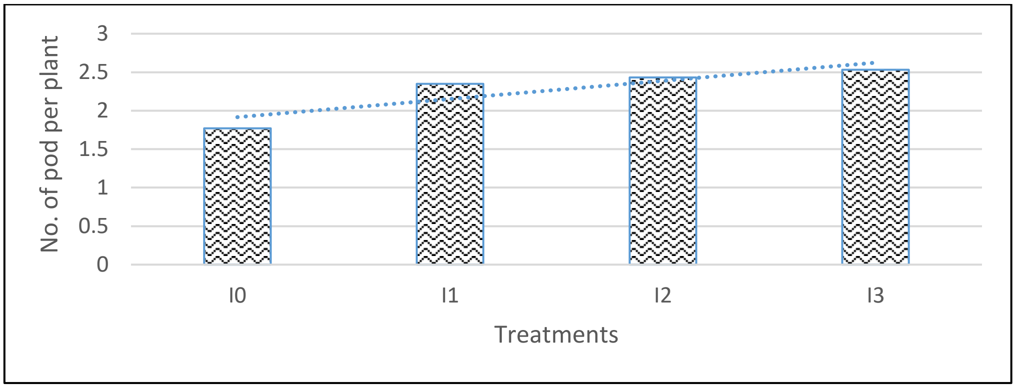

Fig 1. *Effect of different levels of treatments on number of pod per plant.*

The number of seeds per pod is thought to be a significant element that affects the yields in leguminous crops directly. The data clearly showed that there was a large variation in the amount of seeds per pod. In comparison to the lowest number of seeds per pod 1.77 with I0 treatment, the significantly largest number of seeds per pod 2.53 was seen with I3 treatment. The negative impact of irrigation stress on the assimilation production caused the notable change in the quantity of seeds per pod. There were fewer seeds per pod because irrigation stress decreased the crop plant's photosynthetic activity, which lowered the amount of photosynthesis. This outcome is true with the findings published by [18, 19]. Furthermore, [20, 21] found that throughout the reproductive phase of mung beans, there was a decrease in the quantity of seeds per pod (Fig 5).

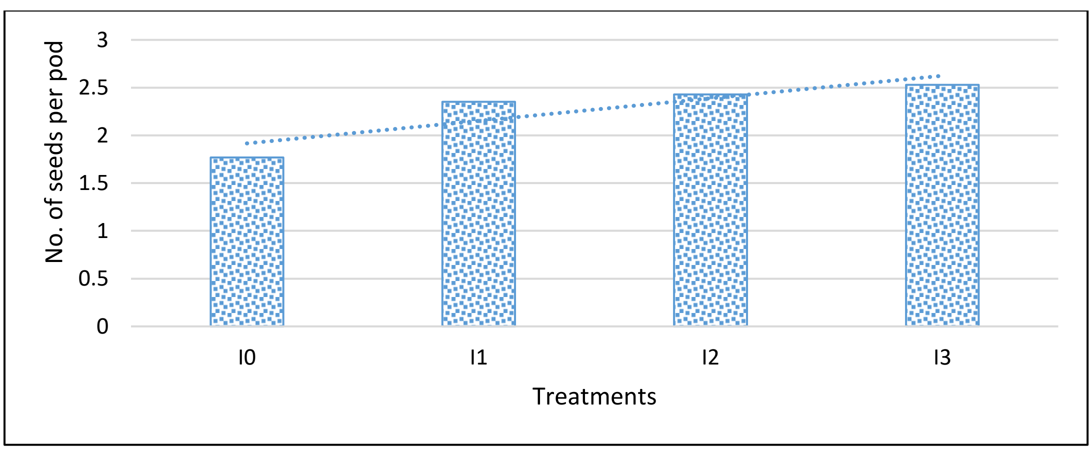

Fig 2. *Effect of different levels of treatments on the number of seeds per pod.*

Legume crop output is influenced by a variety of factors, one of which is the total quantity of seeds per plant. The data clearly showed that the quantity of seeds per plant varied considerably depending on the watering level. With I_3 treatment, the number of seeds per plant was significantly greater at 247.6, compared to the lowest number of seeds per plant with I0 treatment, which was 35.41. The number of pods per plant and seeds per pod vary, which might explain the variance in the quantity of seeds per plant. This outcome is in agreement with findings of [18]. According to studies of [22], early dryness had minimal impacts on quantity of seed per plant, but shortage of water during a pod-filling stage, it dropped by 20% (Fig 6).

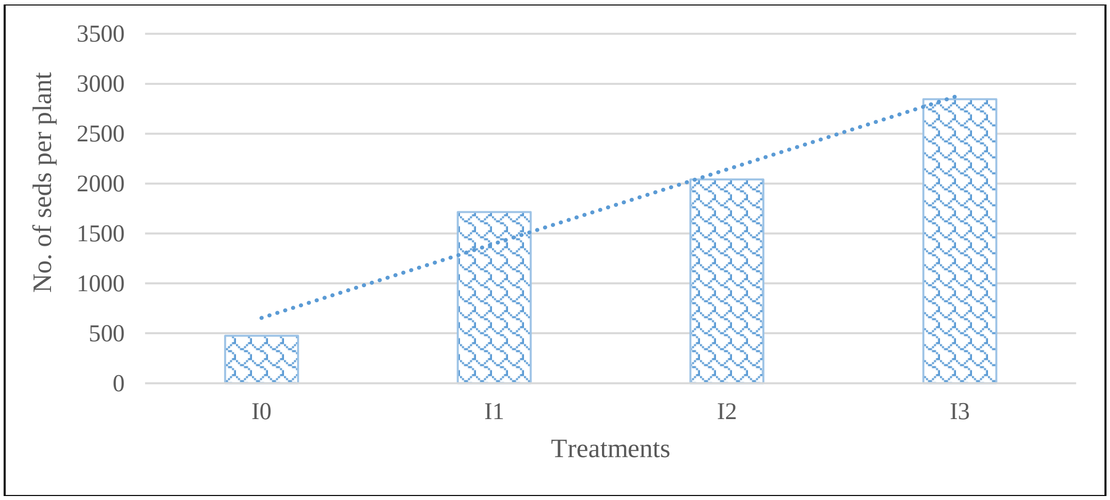

Fig 3. *Effect of different levels of treatments on number of seeds per plant.*

Leguminous crops' productivity is largely dependent on the length of their pods. The statistics clearly showed that the various irrigation levels had a major impact on pod length. In comparison to the lowest pod length of 2.09 with I0 treatment, the significantly largest pod length of 4.13 was seen with I_3 treatment. Water shortage during pod formation may be the cause of the difference in pod length. This outcome is consistent with the observations and findings of [23] that showed varying levels of irrigation affected the length of the French bean pod (Fig 7).

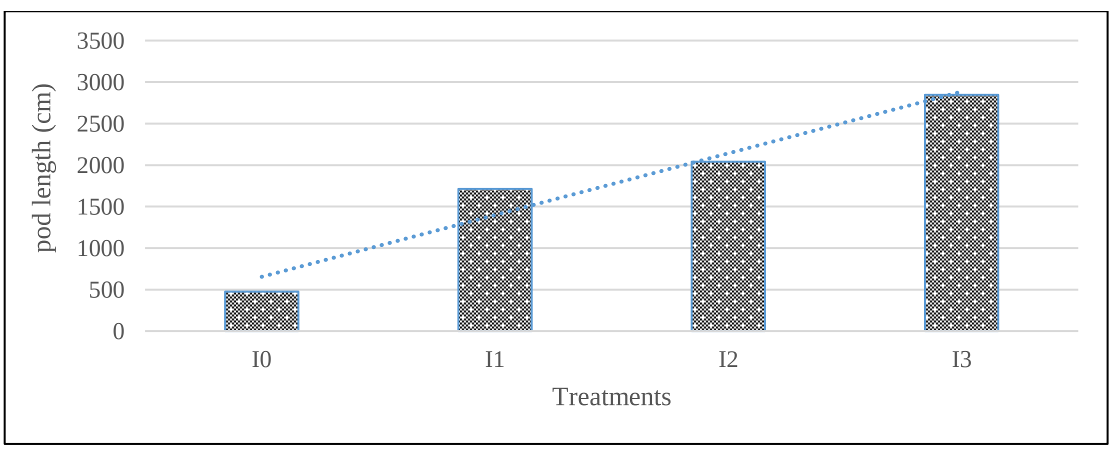

Fig 4. *Effect of different levels of treatments on pod length.*

The ultimate yield of any crop is directly impacted by the seed weight. Data indicated that irrigation stress had a highly significant impact at different development stages. In comparison to the lowest 100 seed weight of 3.9gr with I0 treatment, the significantly greatest 100 seed weight of 10.41gr was noted with I_3 treatment (Fig 8). The weight loss of 100 seeds may have been resulted from the seeds fully under stressful circumstances. This outcome is consistent with the research conducted by [24]. Additionally, watering throughout the blooming and pod development stages boosted the mung beans 1000-seed weight [25].

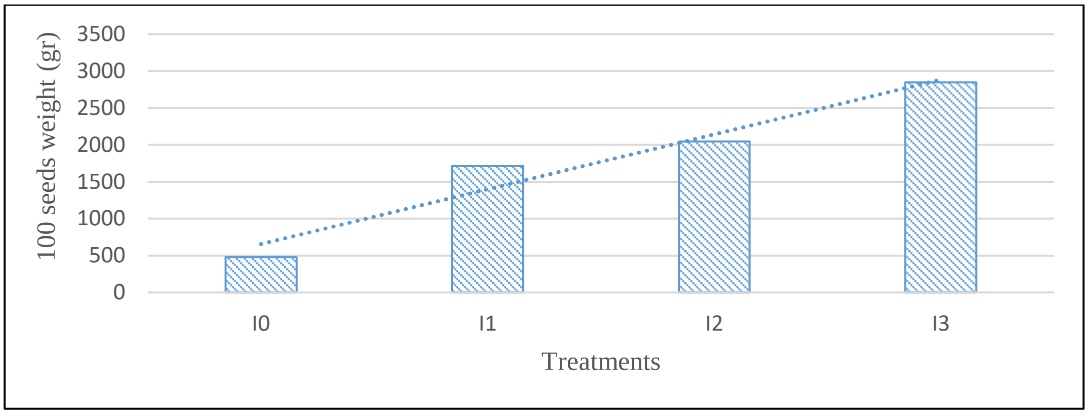

Fig 5. *Effect of different levels of treatments on 100 seeds weight (gr).*

The total effect of different yield components in each set of environmental variables is called yield. Therefore, any change in them is likely to result in a change in seed yield. The data clearly showed that the seed production was greatly impacted by various watering levels. Notably, treatment with I_3 produced a maximum seed yield of 2845.23 kg per ha, whereas treatment with I0 produced a minimum seed yield of 476.07 kg per ha (Table 4 & Fig 9). There also have been reports on reductions of soybean crop production due to water stress [26, 27]. This study also confirms the results of [28], which have found that irrigation frequency significantly affects soybean growth and production.

Table 4. *Effect of different levels of treatments on soybean parameters.*

Treatments	No. of seeds plant^{-1}	Pod length (cm)	100 seeds weight (gr)	Grain yield ha^{-1} (kg)
I_0	35.41^{d}	2.09^{c}	3.89^{c}	476.07^{d}
I_1	168.87^{c}	3.97^{b}	9.39^{b}	1714.30^{c}
I_2	193.16^{b}	4.06^{ab}	9.57^{b}	2042.60^{b}
I_3	247.65^{a}	4.13^{a}	10.41^{a}	2845.23^{a}
CV	8.72	4.03	6.07	9.48
$LSD_{0.05}$	12.80	0.130	0.460	152.75

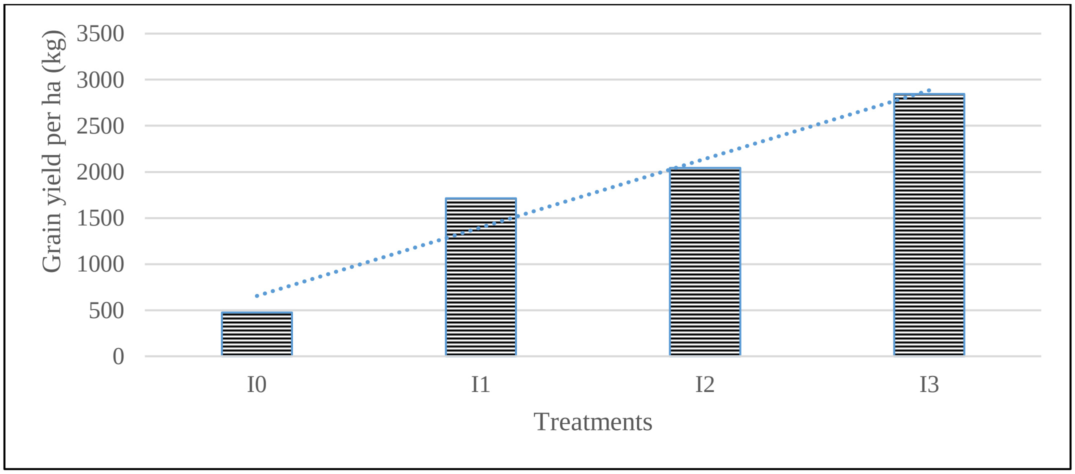

Fig 6. *Effect of different levels of treatments on grain yield per ha (kg).*

Water Use Efficiency (WUE)

Crop productivity regarding water, also referred to as crop water use efficiency (WUE), measures the economic yield obtained per unit of water utilized. The amount of irrigation water provided to the soil affected the overall amount of water used by soybeans. Between 431.1mm and 622.7mm of water was used overall. I4 treatment had the highest overall water usage (622.7 mm), while I_1 treatment had the lowest (431.1 mm). The following given in kg m^3 is the calculation made using of equation according to [29].

Water Use Efficiency (WUE) = Y/A.I.W.

Eqn. 1

Where: WUE: Water Use Efficiency (kg/m^3), Y: Grain Yield (kg/ha), A.I.W: Applied Irrigation Water (m^3/ha)

The findings indicated that there was a substantial ($P<0.05$) variation in water consumption efficiency when different watering levels were taken into account. The efficiency of water utilization varied between 0.3852 and 0.4509 kg m^3. The watering level that yielded the maximum water use efficiency was thirteen times (I_3). However, the treatments with the highest watering level (I_1) of nine times had the lowest water usage effectiveness. WUE increased as watering levels raised but decreased when watering levels are fully reduced. Increasing irrigation water reduced the amount of soil water that was depleted. While [30] discovered that the maximum water use efficiency with one irrigation was greater than two or three watering levels in French beans. [31] observed enhanced water use efficiency when increasing irrigation frequency, whereas [32] found that water use efficiency and irrigation water use efficiency values decreased when watering amount increased (Table 5).

Table 5. Effect of different levels of treatments on water use efficiency (WUE)

Treatments	Water applied + Effective rainfall (m^3 ha^{-1})	Water use efficiency (kg m^{-3})
I_0	0.0000	0.00000
I_1	4400.3	0.3852[b]
I_2	5358.6	0.3817[b]
I_3	6316.9	0.4509[a]

This experiment has been done in Kabul environmental condition and might not generalize in other regions; hence our recommendation is to create any further research according to impact of watering levels on growth and productivity of soybean (*Glycine max* L).

CONCLUSION

Various levels of irrigation were shown to have a substantial impact on soybean growth and production after two experimental seasons. Reducing irrigation levels led to a progressive decrease in soybean growth and production. Applying irrigation level (I3) treatment resulted in the greatest seed production. However, when irrigation was not provided, (I_0) produced the smallest seed yield. The treatments differed significantly in terms of water use efficiency as well, I_3 (thirteen-times irrigation) had the greatest water use efficiency. Therefore, based on the results, it can be said that in order to grow soybeans with a larger grain yield under the climate of Kabul, additional irrigation is necessary, particularly during the vegetative, blooming, and pod-filling stages. As researchers, we worked for two seasons on the water required for soybeans under the Kabul climatic conditions; We suggest that soybean needs about 622.7 mm for better growth and performance that should be considered.

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