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Drought Priming and Subsequent Irrigation Water Regimes Enhanced Grain Yield and Water Productivity of Wheat Crop

Inayatullah Katohar [1,†], Rajesh Kumar Soothar [1,†], Farman Ali Chandio [1,2], Mashooque Ali Talpur [1], Shakeel Ahmed Soomro [1], Ashutus Singha [3], Li Bin [4,*] and Muhammad Uris Mirjat [1]

[1] Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam 70060, Pakistan; inayatullahkatohar5@gmail.com (I.K.); rk_engr195@yahoo.com (R.K.S.); fachandio@sau.edu.pk (F.A.C.); matalpur@sau.edu.pk (M.A.T.); ssoomro@sau.edu.pk (S.A.S.); mumirjat@sau.edu.pk (M.U.M.)

[2] Inti International University, Persiaran Perdana BBN, Putra Nilai, Nilai Negri Sembilan 71800, Malaysia

[3] Department of Irrigation and Water Management, Sylhet Agricultural University, Sylhet 3100, Bangladesh; ashutus.iwm@sau.ac.bd

[4] College of Optical, Mechanical and Electrical Engineering, Zhejiang Agriculture and Forestry University, Hangzhou 311300, China

* Correspondence: libin_zafu@hotmail.com

† These authors contributed equally to this work.

Abstract: The most important factor impacting wheat production is water stress that occurs during the reproductive growth stage. Therefore, the plant responses and water productivity as affected by drought priming were investigated during Rabi seasons 2021 and 2022. The field trials were conducted in the research field of the Department of Irrigation and Drainage, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam. The Hamal-BNS wheat variety was subjected to differing irrigation water regime levels (40%, 50% and 60% of soil water holding capacity, SWHC) after being subjected to drought priming, irrigation water recovery (water closure period) and drought priming. There were six treatments: (1) DPP-40 (drought priming plants at 40% of SWHC), (2) DPP-50, (3) DPP-60, (4) CTP-40 (controlled treated plants at 40% of SWHC), (5) CTP-50 and (6) CTP-60. During the experiment period, soil moisture content was significantly affected by the different treatments at various growth stages of wheat. The results indicated that winter wheat pre-exposed to drought priming attained a stress imprint that improved the subsequent deficit water levels which occurred during the later plant growth stage as demonstrated by the progress of test weight, grain yield, plant level water use efficiency and irrigation water use efficiency as well as relative yield compared to CTP-50 (control treatment). Under the irrigation water regime levels during the post-anthesis period, primed wheat plants sustained grain yield and higher relative yield than wheat plants without priming due to the better irrigation water regime for drought-primed wheat plants. Similarly, primed wheat plants consumed 18.3% less irrigation water as compared to non-primed plants, which significantly increased plant level WUE and irrigation WUE and decreased dry biomass and root development of drought-primed wheat plants. Therefore, to conserve fresh water for other field crops and increase water productivity in the Sindh province, it is recommended that drought priming is used during the early growth period of wheat plants as a successful irrigation method.

Keywords: drought priming; irrigation water regime; plant growth; grain yield; water productivity

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1. Introduction

For the wellbeing of ecosystems and human development, water is a crucial resource. It is also essential for alleviation of poverty, development of gender justice and its contribution to energy and food security. However, significant water-related issues like scarcity, flooding, droughts, pollution, a lack of supply and sanitation, the permanent loss of ecosystems, and the loss of ecosystem services affect billions of people worldwide. According to scientific estimates, 80% of the world's population is directly or indirectly vulnerable to serious threats to the security of their water supply [1]. However, with 70% of global water usage going to agriculture, this industry is the biggest water consumer in the world [2]. Due to water demand from rapid industrialization and rapid population increase, food output is largely regulated by water availability in almost all regions of the world [3]. Keeping the existing rates of agricultural water usage efficiency unchanged, it is predicted that an incremental 5700 km^3 of fresh water will be needed each year to meet the required food needs in 2050. Moreover, two-thirds of all freshwater withdrawals are used by agriculture, which is the world's largest user of the resource [4].

In Pakistan, the usual surface availability of water at canal heads is 127.5 BCM; however, during the past years, it has fluctuated between 120.5 and 116.0 BCM [5]. Since there are now no significant advancements being achieved regarding water supplies, the future appears uncertain. Because the country's water storage capacity is so low, even after an exceptionally wet rainy season and flooding, there will be a water shortage in the winter [6]. It is currently experiencing a severe irrigation water deficit; farmers who are struggling with this issue have reduced yields, lower household incomes, and are food insecure. Pakistan's governmental and commercial sectors must make investments in water management for irrigation to preserve crop yield, which is crucial for household security and the eradication of poverty [7]. Due to inadequate management, outdated technology, and poor irrigation scheduling, which lower crop productivity and WUE, Pakistan's limited water resources are being rapidly drained [8]. It is a significant challenge to maintain the usual supply of water for crops that have high water demands. As a result, irrigated agriculture must use novel strategies that focus on eco-friendly technologies to overcome the problems of shortage of water [9].

Significant risks to the production of wheat are emerging in many areas of the world due to salinity and drought, which are the primary causes of impeded plant development and growth [10–13]. More food and fiber are needed due to the growing population, which is being satisfied by expanding irrigated agriculture. As a result, Pakistan's water resources are under more strain. Therefore, it is essential to improve management and utilization of the available water resources at all sizes, including catchment, irrigated region, farm and field scales. It is typically expensive, time-consuming and challenging to manage water on a large scale. In contrast, field-scale water management is typically more affordable, doable and practicable, and it can also be put into effect quickly. It is crucial to enhance water management at the field level by implementing more practical and successful strategies including irrigation planning and preparing for drought.

The primary abiotic stress caused by drought is a decrease in plant water status, which leads to a reduction in photosynthesis, an increase in oxidative stress, growth restriction, and ultimately a decline in wheat production. It has been proven that drought priming during the vegetative growth stage of wheat could enhance tolerance to drought stress at grain filling. However, drought priming implemented during the vegetative growth stage in wheat crops is untested. A major factor impairing global metabolism, growth and biomass production of plants is drought [14,15]. Future climate projections forecast a surge in drought frequency and severity along with rising temperatures [16]. In areas with limited water supplies, drought is the greatest restriction that causes a significant loss in production.

Wheat (*Ttritium aestivum* L.) is a crucial grain crop on a global scale. It is considered to be one of the most significant crops for producing staple food. It is reportedly extremely vulnerable to drought stress, which frequently happens at the post-anthesis phase, resulting in substantial yield penalties [17]. Wheat production could be considerably reduced by drought stress that occurs during grain filling; however, drought-tolerant types could continue to lose less grain yield than drought-stressed types [18]. This yield reduction is mostly caused by the occurrence of photosynthesis during the drought [19,20]. The main objective of this research based on the above facts is that this research examined the effect of subsequent irrigation water regimes on plant growth, drought priming at the vegetative stage and water productivity of wheat.

2. Materials and Methods

The field experiments were carried out at the experimental station of the Department of Irrigation and Drainage, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam (Figure 1). The experimental soil is classified as silt clay loam, with a pH of 8.3, soil electrical conductivity ($EC_{1:5}$) of 2.1 dS m^{-1}, soil bulk density of 1.19 g cm^{-1}, soil porosity of 41%, soil moisture content of 18.9% and field capacity of 44% up to a depth of 1–160 cm.

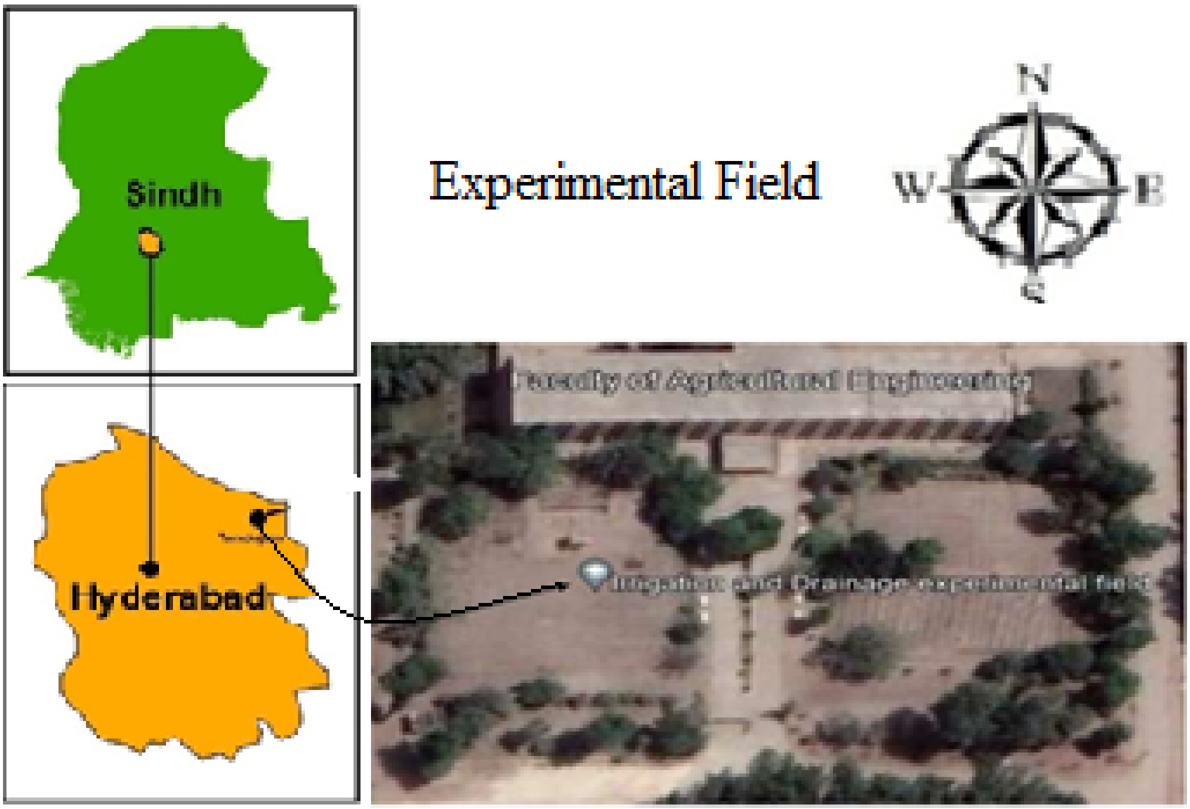

Figure 1. Bird's eye view of the experimental site.

2.1. Treatment and Experimental Setup

The trials were based on a completely randomized design that included drought priming and three levels of irrigation water regimes under a basin irrigation method. Before treatments, wheat crop was irrigated at 50% of soil water holding capacity (SWHC). The drought priming plant (DPP) regime was initiated after forty days of sowing by withholding irrigation water for thirty days. Likewise, the control treated plants (CTP) received 50% SWHC irrigation. However, all treatments were performed at 50% SWHC for recovery of single irrigation water after drought priming stress and then plants were subsequently irrigated at water regime levels of 40%, 50% and 60% of SWHC. The detailed experimental treatments are described in Figure 2. The experimental layout and setup are shown in Figure 3. Each treatment had three replicates. A total of 18 subplots with an average field size of 3 m by 4 m were prepared for this experiment. In order to maintain the environmental conditions in the experiment area, a buffer zone was provided around the irrigated field and was planted with the same crop. In this study, a popular variety of Hamal wheat was selected and broadcasting method was used for seed sowing under all designed treatments. However, as per recommendations, fertilizer doses were applied.

<table>
<tr><td colspan="3">Early plant growth stage</td><td>Heading stage to maturity</td><td rowspan="3">Treatment</td></tr>
<tr><td>Control condi-
tion</td><td>Drought priming</td><td>Recovery</td><td rowspan="2">Subsequent stress</td></tr>
<tr><td>40 days</td><td>30 days</td><td>Full irrigation</td></tr>
<tr><td rowspan="6">50% of SWHC</td><td rowspan="3">Drought priming plants (DPP)</td><td rowspan="6">50% of soil water holding capacity</td><td>DPP-40</td><td>T1</td></tr>
<tr><td>DPP-50</td><td>T2</td></tr>
<tr><td>DPP-60</td><td>T3</td></tr>
<tr><td rowspan="3">Control treated plants (CTP)</td><td>CTP-40</td><td>T4</td></tr>
<tr><td>CTP-50</td><td>T5</td></tr>
<tr><td>CTP-60</td><td>T6</td></tr>
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Figure 2. Treatments during the experimental period.

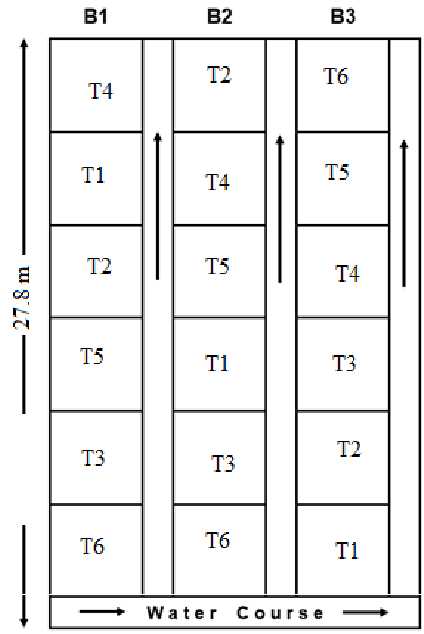

Figure 3. Experimental plot layout and setup for field experiment.

2.2. Irrigation Plan and Measurements

The amount of soil moisture depletion determines the irrigation timing, and each irrigation application was at 40%, 50% and 60% of SWHC throughout each treatment plan. The CROPWAT model was used to calculate the frequency and irrigation depth for the wheat crop. The depth of irrigation water to crop was measured using a flow meter. In order to supply the required depth of irrigation water under all replicates, the treatment plots for the wheat were determined empirically using the following equation given by Isrealson et al. [21].

$$QT = 28\ AD$$

where Q = Discharge required (lps), T = Time of application (hours), A = Area to be irrigated (hectares), and D = Depth of irrigation to be applied (cm).

Meteorological parameter data of solar radiation, precipitation, wind speed, relative humidity and air temperature were collected from the nearest Agro-meteorological station. CROPWAT Version 8.0 was used to run the CROPWAT model on average meteorological data from the previous 10 years. The amount of irrigation water used from the first to the last growth stage is shown in Table 1.

Table 1. Volume of irrigation water applied and total water consumed in the treatments during the base period of the wheat crop.

Treatment		Irrigation (mm)	Total Water Consumed	
			(mm)	(m^3 ha^{-1})
DPP-40	1	292	292	2920
DPP-50	2	294	294	2940
DPP-60	3	296	296	2960
CTP-40	4	358	358	3580
CTP-50	5	360	360	3600
CTP-60	6	362	362	3620

2.3. Data Collection and Analysis

At the different depths of 0–20, 20–40, 40–60, 60–80 and 80–100 cm, the soil samples were collected to determine soil moisture storage before and after each irrigation application during the crop period. Plant height was determined regularly on different days after sowing. At physiological maturity, different plant parameters were recorded, then the plants were harvested and divided into biomass and grain yields, as well as relative yield [22,23]. The plants' roots developed differently as a result of water stress and this was assessed by sampling roots from a 20 cm × 30 cm area at 0–30 cm depth of soil profile immediately after the crop was harvested. The soils were removed from the roots before the roots were dried for 60 h at 75 °C to acquire their dry mass. In order to calculate root density, the dry weight of the root sample was divided by the sampling area. The above-ground dry biomass divided by the total amount of water consumed was used to compute plant water use efficiency (WUEp). Similarly, irrigation water use efficiency (IWUE) for all treatments was calculated by total used divided by total grain.

2.4. Statistical Analysis

Field-collected data were examined statistically using ANOVA techniques following the completely randomized design with three replicates. The corrections were performed in terms of soil, crop growth and water productivity using Excel with SPSS software (SPSS version 20.0, IBM Corporation, New York, NY, USA).

3. Results

3.1. Soil Moisture Content (SMC)

The data regarding SMC under drought priming at the vegetative stage and subsequent different water regime levels are shown in Figure 4. The average SMC was significantly affected at different days after wheat sowing during the experimental period. The results showed that the highest SMC (16.6%) was found in CTP-60 (controlled treatment plants) up to 0–100 cm followed by 14.3%, 12.8%, 11.8%, 15.7%, 14.7% under the DPP-40, DPP-50, DPP-60, CTP-40 and CTP-50, respectively. The highest SMC value was observed under CTP-40 whereas the minimum was 11.8% under DPP-60 treatment. The drought-primed plants had lower SMC than the plants without drought priming throughout the experimental period.

3.2. Plant Height

Before drought priming, plant height was non-significantly affected under all the experimental plots (up to 40 days after sowing). During the 2021 and 2022 growing seasons, primed plants had considerably lower average plant heights than plants without priming at the vegetative phase under drought conditions after treatments had begun (Figure 5). After water recovery, compared with primed plants, non-primed wheat plants still had significantly higher plant height. However, 66 days after seeding, non-primed wheat plants grew much taller than the primed plants. This was due to the ensuing drought stressors. Similarly, the control wheat plant heights ranked as CTP-40 (113.1 cm) > CTP-50 (112.3 cm)

> CTP-60 (111.5 cm), whereas the plant height of wheat with DPP (drought priming plants) treatment was ranked as DPP-40 (95.8 cm) > DPP-60 (95.2 cm) > DPP-50 (93.0 cm). The greater plant height (113.1 cm) was observed at 118 days under CTP-60, whereas the lowest plant height of 93.0 cm was observed at 118 days under DPP-50.

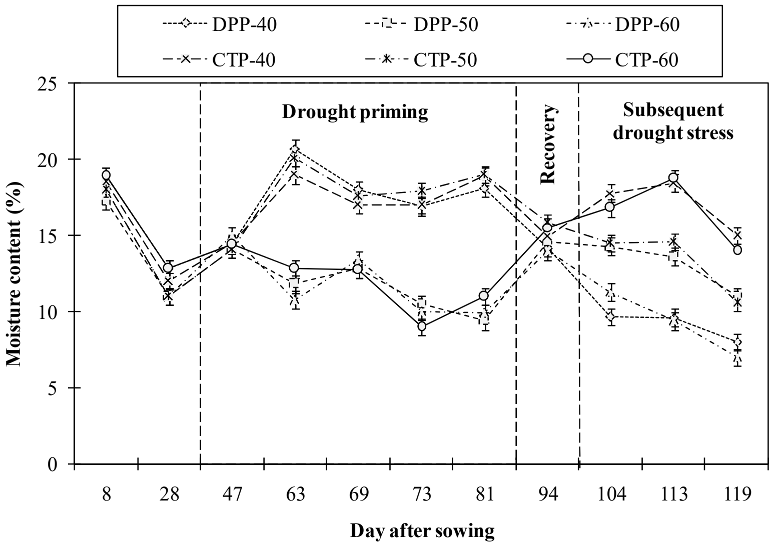

Figure 4. Mean temporal variation of soil moisture content at 0–100 cm soil depth under different treatments throughout the growing seasons.

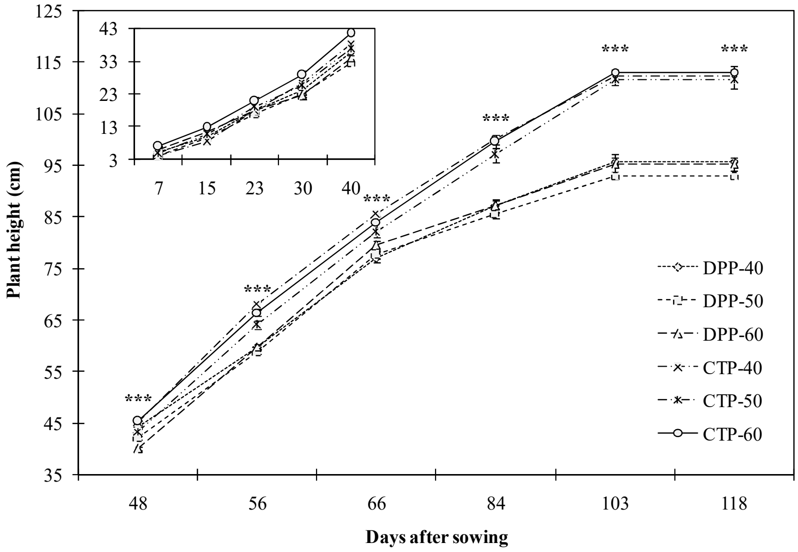

Figure 5. Mean plant height of wheat crop as affected by different treatments throughout the growing season. DPP-40, DPP-50, DPP-60, CTP-40, CTP-50 and CTP-60 indicate the treatments, respectively. The values are means ± SE (n = 3). The small bars are standard error. *** Indicates significant differences among the treatments according to Duncan's multiple range test at $p \leq 0.001$ level.

3.3. Spike Length, Grains per Spike^{-1} and Grain Weight per Spike^{-1}

The spike length, number of grains per spike^{-1} and grain weight per spike^{-1} of the wheat crop were significantly affected by the different treatments (drought priming at vegetative stage and subsequent different water regime levels) as shown in Figure 6. The results clearly show that the maximum spike length of wheat was 12.8 cm under CTP-50, whereas the minimum spike length was 10.9 cm under the treatment of DPP-60. Similarly, the mean spike length of wheat decreased by 8%, 12%, 15%, 1% and 3% under DPP-40, DPP-50, DPP-60, CTP-40 and CTP-60, respectively, compared to control treatment. Compared with controlled treatment plants, the values of spike length under drought priming plants' treatments were significantly lower (Figure 6a).

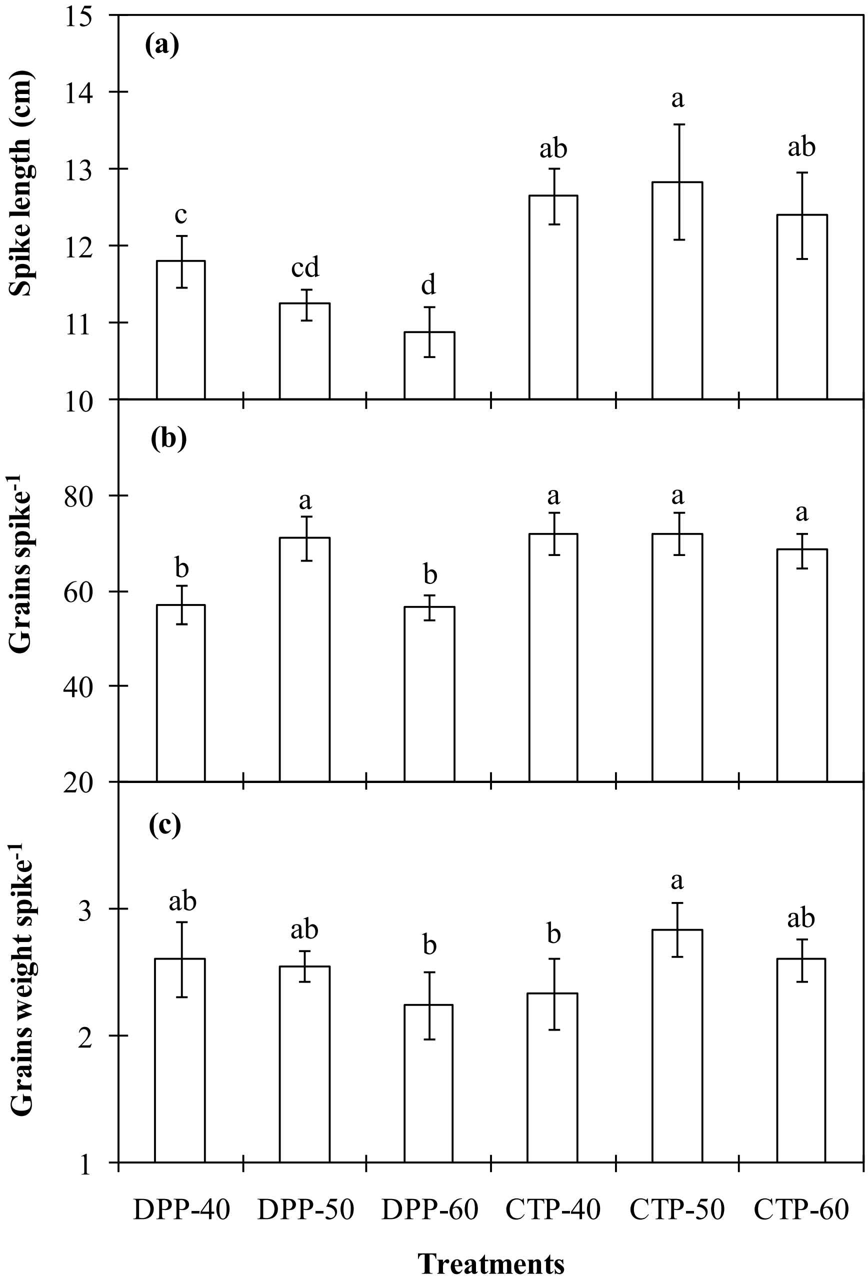

Figure 6. Mean spike length (**a**), grains per spike (**b**), and grain weight per spike (**c**) of wheat crop as affected by different treatments. DPP-40, DPP-50, DPP-60, CTP-40, CTP-50 and CTP-60 indicate the treatments, respectively. The values are means ± SE (n = 3). The small bars are standard error. Different letters indicate significant differences among the treatments according to Duncan's multiple range test at $p \leq 0.05$ level.

Similarly, the maximum number of grains per spike^{-1} length was determined to be 72.1 under CTP-50, whereas the minimum grains per spike^{-1} length was 57.1 under the treatment of DPP-40 (Figure 6b). Similarly, the grains per spike^{-1} length decreased by 21%, 1%, 21% and 5% under DPP-40, DPP-50, DPP-60 and CTP-60, respectively, compared to control treatment and CTP-40 treatment. However, the maximum grain weight per spike^{-1} was 2.84 g under CTP-50, whereas the minimum grain weight per spike^{-1} was 2.25 g under the treatment of DPP-60. Similarly, the grain weight per spike^{-1} decreased by 8%, 10%, 21%, 18% and 8% under DPP-40, DPP-50, DPP-60, CTP-40 and CTP-60, respectively, compared to control treatment (Figure 6c). The tillers meter^{-2} was non-significantly affected by the different treatments as shown in Figure 7a.

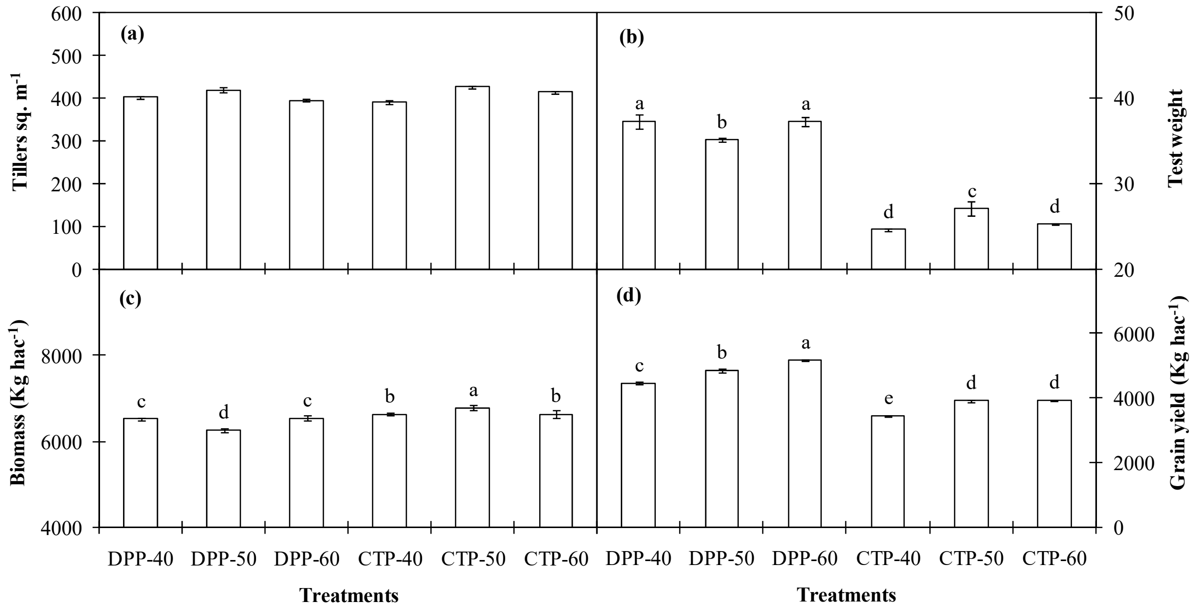

Figure 7. Mean tillers square m^{-1} (**a**), test weight (**b**), biomass (**c**), and grain yield (**d**) of wheat crop as affected by different treatments. DPP-40, DPP-50, DPP-60, CTP-40, CTP-50 and CTP-60 indicate the treatments, respectively. The values are means ± SE (n = 3). The small bars are standard error. Different letters indicate significant differences among the treatments according to Duncan's multiple range test at $p \leq 0.05$ level.

3.4. Yield Components of Wheat

The test weight, dry biomass and seed yield of the wheat crop was significantly affected by different treatments (Figure 7). The test weight of wheat grain increased by 37%, 30%, 37%, 9% and 7% under DPP-40, DPP-50, DPP-60, CTP-40 and CTP-60, respectively, compared to control treatment (Figure 7b). Moreover, Figure 5c shows that the highest dry biomass yield recorded was higher (6790 kg ha^{-1}) under CTP-50 treatment whereas the minimum dry biomass (6260 kg ha^{-1}) was recorded under CTP-50 treatment. Similarly, the dry biomass of wheat grain decreased by 4%, 8%, 4%, 2% and 2% under DPP-40, DPP-50, DPP-60, CTP-40 and CTP-60, respectively, compared to control treatment. Compared to CTP (controlled treatment plants), the values of dry biomass yield of DPP (drought treatment plants) was higher.

As shown in Figure 7d, the highest grain yield (5163 kg ha^{-1}) was in DPP-60 whereas the lowest grain yield (3347 kg ha^{-1}) was in CTP-40 treatment. It was observed that compared with CTP (controlled treatment plants), the values of grain yield under DPP (drought priming plants) treatment were higher. Similarly, the grain yield of wheat increased by 14%, 24%, 32% and 1% under DPP-40, DPP-50, DPP-60 and CTP-60, respectively, and decreased 12% under CTP-40 treatment compared to control treatment.

3.5. Root Development and Relative Yield

At harvesting stage, the root development of wheat grain was affected significantly by the different treatments (Figure 8). The findings exhibit that the root dry biomass of wheat grain decreased by 35%, 40%, 43%, 7% and 6% under DPP-40, DPP-50, DPP-60, CTP-40 and CTP-60, respectively, compared to control treatment. The interactions between subsequent soil water stress and drought priming were found for root dry biomass and grain yield of wheat crop (Figure 9). Similarly, relative yield of wheat grain was affected significantly by different treatments (Figure 10). The findings exhibit the maximum relative yield of wheat grain (1.32) was recorded under DPP-60 whereas the minimum relative yield (0.88) was found under CTP-40 treatment. Similarly, the relative yield of wheat grain increased by 14%, 24%, 32%, 12% and 2% under DPP-40, DPP-50, DPP-60, CTP-40 and CTP-60, respectively, in contrast with control treatment.

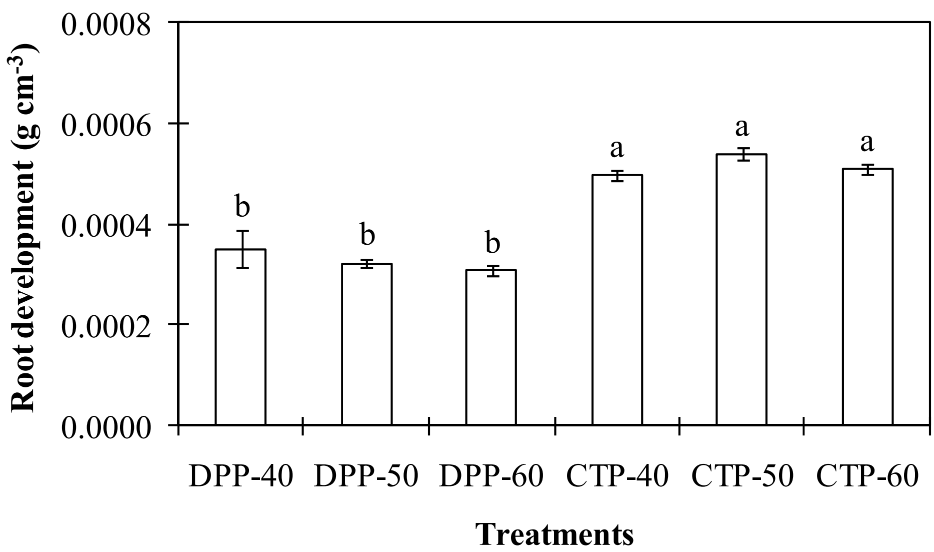

Figure 8. Mean root development of wheat crop as affected by different treatments. The values are means ± SE (n = 3). The small bars are standard error. Different letters indicate significant differences among the treatments according to Duncan's multiple range test at $p \leq 0.05$ level.

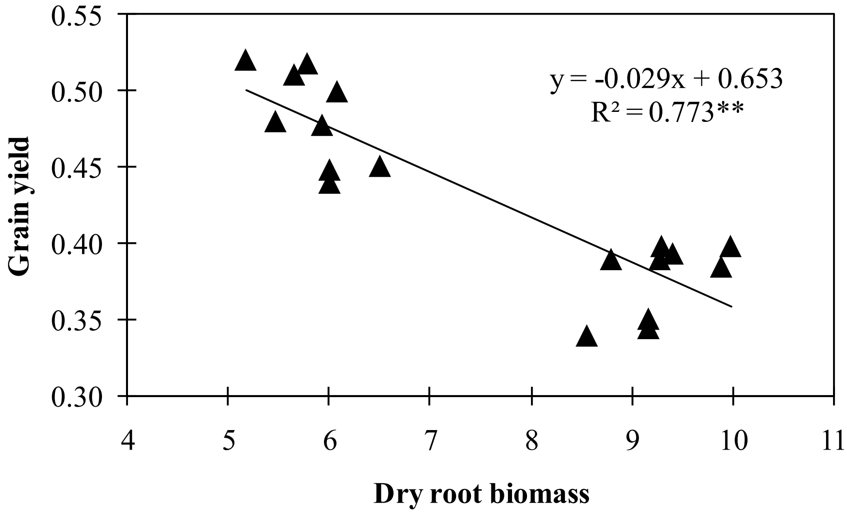

Figure 9. Simple correlation analysis between wheat yield and dry root biomass. ** = Significant at $p < 0.01$.

3.6. Water Productivity

The plant level water use efficiency (WUEp) and irrigation water use efficiency (IWUE) of wheat crop at the harvesting stage was significantly affected by the different treatments (Figure 11). The findings demonstrated the WUEp increased by 18%, 13%, 17%, 2% and 3% under DPP-40, DPP-50, DPP-60, CTP-40 and CTP-60, respectively, in contrast to control treatment. It was noticed that, compared with CTP, the plant levels under DPP were higher (Figure 11a). However, the maximum IWUE (1.74 kg m^{-3}) was recorded in DPP-60 whereas the minimum IWUE (0.96 kg m^{-3}) was found under the treatment of CTP-40. Similarly, the IWUE increased by 41%, 52%, 60% and 1% under DPP-40, DPP-50, DPP-60 and CTP-60, respectively, and decreased 11% under CTP-40 treatment in contrast to control treatment.

As compared with CTP, it was also noticed that the irrigation water use efficiency under DPP was higher (Figure 11b).

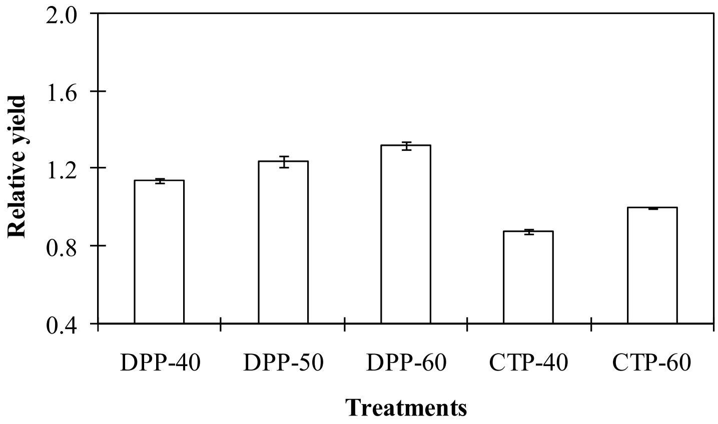

Figure 10. Mean relative yield of wheat crop as affected by different treatments. DPP-40, DPP-50, DPP-60, CTP-40 and CTP-60 indicate the treatments, respectively. The values are means ± SE (n = 3). The small bars are standard error.

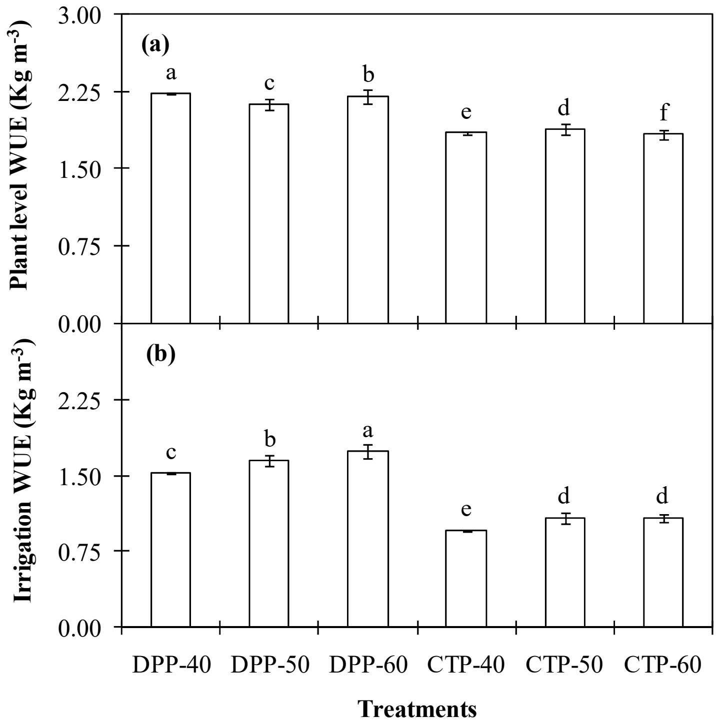

Figure 11. Mean plant level water use efficiency (WUE) (**a**) and irrigation water use efficiency (WUE) (**b**) of wheat crop as affected by different treatments. DPP-40, DPP-50, DPP-60, CTP-40, CTP-50 and CTP-60 indicate the treatments, respectively. The values are means ± SE (n = 3). The small bars are standard error. Different letters indicate significant differences among the treatments according to Duncan's multiple range test at $p \leq 0.05$ level.

4. Discussion

Drought is the primary abiotic stress that reduces plant water status, hinders photosynthesis, causes oxidative stress, limits growth, and ultimately lowers crop yields. In the water-scarce zones where drought is the greatest limitation, future climate projections forecast a rise in drought severity and frequency together with increasing temperature, which would result in significant yield loss [16].

4.1. Soil Moisture Dynamics in the Root Zone of Wheat Crop

In Pakistan, there is a Warabandi system of water rotation periods which affect the soil moisture uptake of winter wheat. Among the different treatments, it was shown that the soil moisture content was higher under controlled treatment plants (CTP) at 0–100 cm soil depth as compared to DPP (drought priming plants) treatments. At DPP-40, the SMC was recorded as 14.3%. The recorded data are shown in Figure 4. Moreover, as compared to the DPP treatments, the SMCs ranked as 16.6% under CTP-40 > 15.7% under CTP-50 > 14.7% under CTP-60 > 14.3% under DPP-40 > 12.8% under DPP-50 > 11.8% under DPP-60 treatment. The results revealed that the SMCs were lower in DPP as compared to CTP. In comparison to the treatments after priming, the ensuing drought stresses at the later growth stage substantially enhanced. The fact that there were substantial interactions between the initial drought and the subsequent soil water stress showed that the effects of the initial drought differed depending on the soil water regime. However, under the same subsequent soil water levels, the dry biomass was lower in primed plants and higher in non-primed plants. Nevertheless, plants that had been primed used far less water overall. As a result, as contrasted to unprimed plants, the primed plants produced considerably more biomass. Our results coincide with Tankari et al.'s study [24]. According to Tankari et al. [24], when plants were subjected to drought priming, the average soil water content decreased from 24% to 10% in primed plants to roughly 24% for non-primed plants of both kinds. For both kinds, primed plants had more soil water than unprimed plants.

4.2. Effect of Various Treatments on Wheat Crop Plant Development and Yield

In 25 wheat cultivars, drought stress significantly decreased plant height, spike length, and grain production per spike [25]. The plant growth parameters were continuously recorded around every 10 days during the study period. Figures 5 and 6 show that the plant height and growth parameters were significantly improved with controlled treatment plants as compared to the drought priming plants. Moreover, as compared to the DPP treatments, the highest parameters recorded were for plant height under CTP-60, spike length under CTP-50, grains per spike under CTP-50 and grain weight per spike under DPP-50. Similarly, the minimum plant growth parameters recorded were for plant height under DPP-60, spike length under DPP-60, grains per spike under DPP-60 and grain weight per spike under DPP-60. This shows that all plant growth parameters were lower in DPP-60 treatments and higher in CTP-50 and CTP-60. Our results coincide with Abid et al.'s [26], who found that the plant growth parameters under controlled treatment plants were higher and lower in drought priming plant treatments due to less availability of moisture and tolerance.

The number of productive tillers per plant is a key yield indicator since it shows how well plants can wear spikes. The better production potential is represented by a high number of productive tillers per plant. The minimum numbers of tillers per square meter and test weight, biomass and grain yield were found under CTP-40, DPP-50 and CTP-40, respectively (Figure 7). This shows that almost all plant yield components were lower in CTP-40 and higher in DPP-60 and CTP-50 treatment. Compared with DPP treatments, the dry biomass was increased in CTP. Our findings coincide with Wang et al.'s [17], who reported that despite the drought stress in grain filling, drought primed plants had much larger grain yields than controlled treatment plants. This was mostly because these plants had significantly more kernels overall. Seed priming considerably raises wheat crop output despite moisture stress conditions, according to several additional investigations on wheat crops utilizing different chemical compounds. According to a recent study, primed seeds retain the memory of previous droughts and pass it on to the following generation, giving future generations the ability to tolerate drought [27]. Therefore, based on criteria related to yield features, it may be inferred that seed priming increases seed yield by promoting early reproductive growth and more basal distribution to the growing grains.

4.3. Effect of Different Treatments on Water Productivity of Wheat Crop

Under different treatments, the irrigation water use efficiency (IWUE) had a favorable relationship with yield components [28]. In the present study, the results of IWUE and WUEp were significantly the highest (2.23 kg/cm^3) under DPP-40 treatment and (1.74 kg/cm^3) under DPP-60 (Figure 11). According to Singha et al. [29], drought priming dramatically increases WUEp because of significantly increased dry biomass as compared to non-primed plants under subsequent stress; however, primed plants' water use also improved. From Figure 11a, the WUEp was significantly improved with DPP (drought priming plants) treatments as compared to CTP. Our findings coincided with the findings of Singha et al. [29] and Tankari et al. [24]. Because primed plants underwent further water stress and had considerably drier biomass than unprimed plants, they discovered that drought priming dramatically improved WUEp. Additionally, the improved WUEp was mostly due to an enhancement in photosynthesis, as further evidenced by the plants having much more leaf under drought priming. Therefore, enhancing crop IWUE under a changing climate through drought priming at an early growth stage should be seen as a viable technique to maximize agricultural sustainability and food security. Based on the results, it is hoped that such creative knowledge would point the way for future studies aimed at enhancing wheat's synchronous drought and tolerance.

5. Conclusions

Drought primed wheat plants reached a stress imprint that improved the subsequent irrigation water regime levels at later plant growth stages as demonstrated by the progress of test weight, grain yield, WUEp and IWUE as well as relative yield under subsequent irrigation water regime level in contrast with non-primed wheat crop. During the post-anthesis period, under the irrigation water regime levels, primed wheat plants sustained grain yield and higher relative yield than non-primed wheat crops because of a better irrigation water regime for drought priming wheat plants. Similarly, primed wheat plants consumed 18.3% less irrigation water in contrast with non-primed plants, which significantly enhanced plant level WUE and irrigation WUE for primed wheat plants. Our experimental results show that drought priming during the early growth period of wheat plants may be a promising irrigation strategy to mitigate subsequent irrigation water regime levels and save fresh water for other field crops in the Sindh province.

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