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Effect of Nitrogen Fertilization on Triticale Growth Under Rainfed and Supplemental Irrigation Systems

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Abstract

Two adjacent field studies were conducted in the fall of 2020-2021 at the Advancing Research Enabling Communities Center (AREC) at the American University of Beirut, Lebanon to examine the effect of various rates of nitrogen fertilizer on the growth and yield of triticale under rainfed and supplementary irrigation. Treatments were NPK, and various rates of nitrogen fertilizer. Results showed that supplementary irrigation alone significantly increased crop height, shoot dry weight, grain starch content, and grain yield, compared to the rain-fed regardless of nitrogen applications. The average grain yield of triticale under supplementary irrigation was 5.8 tons/ha while it was 4.9 tons/ha under rainfed conditions. A higher yield was obtained under supplementary irrigation than in the rainfed system regardless of the nitrogen application. Nitrogen at all tested rates increased the grain area of triticale under supplementary irrigation, compared to the same treatments under rainfed conditions. In conclusion, supplementary irrigation alone may give higher biomass and yield quantity and better grain quality than nitrogen fertilizer under rainfed conditions.

Keywords: Triticale; Nitrogen Fertilizer; Supplementary Irrigation; Rainfed; Drought Stress

Abbreviations: AREC: Advancing Research Enabling Communities Center; DAP: Days After Planting; RCBD: Randomized Complete Block Design; ICARDA: International Center for Agricultural Research in the Dry Areas; ANOVA: Analysis of Variance

Introduction

Triticale (x Triticosecale Wittmack) is a man-made hybrid, a cross of wheat (Triticum spp.) and rye (Secale cereale L). It combines favorable traits from both crops like growth and vigor, cold tolerance, and high protein [1]. It has greater drought, saline, and disease resistance than wheat and rye. Both forage and grain types of triticale are grown, but it is primarily used as feed for animals [2]. Algeria and Tunisia are the main triticale producers in the MENA region [3]. Water and nitrogen are the most limited resources for grain production in the MENA region. Both resources are overused in grain production, and they are no longer sustainable. The Beqaa plain in Lebanon is the leading county for rainfed cereal grain production but it is facing various challenges among them are the lack of sustainable water resources, a limited amount of precipitation (<500 mm/year), and the high exploitation of groundwater to an alarming decline of 15-20 meters in groundwater levels. Another critical challenge is the threat to water quality from the excessive use of agrochemicals such as nitrogen. Many studies showed that proper application of nitrogen is an important indicator that affects triticale growth and development. The objective of this study was to test the impact of various rates of nitrogen fertilizer on triticale growth under supplementary and rainfed conditions.

Materials and Methods

General Experimental Procedures

Two adjacent field experiments (1250 m2/each) were carried out simultaneously at the Advancing Research Enabling Communities Center (AREC) of the American University of Beirut, Lebanon during the fall 2020 and spring 2021 seasons. AREC is in the Northern Beqaa plain with an altitude of around 1000 m above sea level at 34° 54'N latitude and 36° 45'E longitude. The field soil is a deep silty clay loam with a pH of 7.36, EC of 245 µS/cm, ratio of nitrogen/nitrate of 50mg/kg and the and total percent nitrogen of 0.16%. In both the rainfed and supplementary fields, soil bed was done using a squared moldboard plow tracked by rotary tillage to break soil clods and incorporate materials thoroughly into the soil. Both procedures were done two weeks before sowing triticale seeds at a rate of 190 kg/ha. Seeds were planted on November 20, 2020, using a grain drill machine, which includes 24 furrow openers spaced 15 cm. After sowing triticale seeds, the Cambridge Roller machine was used. Treatments were controlled (0 nitrogen), NPK 15:15:15, and various rates of granular nitrogen fertilizer (40%). NPK was applied at 100 kg/ha as a single application of the whole amount while only 30% of all the nitrogen (N) treatments were added during planting (Table 1). The second nitrogen application included the rest of the quantity of nitrogen fertilizer (70%), 100 days after planting (DAP). Supplementary irrigation was done by a sprinkler system with a maximum flow rate of 1.9 m3/hr. at a pressure of 3.8 bar. The sprinklers were Rain Bird 14070H 3/4' (19mm) Full Circle, Brass Impact Sprinkler. Timing and duration of the supplementary irrigation were done according to the weather data station at AREC (Table 2). Soil moisture was estimated before and after each supplementary irrigation according to [4], Soil moisture by mass was calculated using the below equation:

Table 1: Fertilizer type, rates, application time, and amount (%), days after planting (DAP).

Treatment	Rate Kg/ha	Rate pure N/ha	Application 0 DAP 30%	Application 100 DAP 70%
C	0	0	0	0
NPK	100	15	100	0
N	40	16	12	28
N	80	32	24	56
N	120	48	36	84
N	160	64	48	112
N	200	80	60	140

C, Control; NPK, 15%N;15%P:15%K; N, granular nitrogen fertilizer (40%).

Table 2: Days after Planting (DAP), amount of rain precipitation (R), supplementary irrigation (S) and total amount of water (R + S)..

S	DAP	R (mm)	S (mm)	S Total (mm)
S1	148	346.6	51	397.6
S2	157	0	68	68
S3	172	0.5	51	51.5
Total	172	347.1	170	517.1

S1, first irrigation; S2, second irrigation; S3, third irrigation; R (mm), amount of precipitation from rain; S (mm), total amount of irrigation; S (mm) total amount of both precipitation from rain and supplementary irrigation.

$$\text{Soil Moisture by Mass} = (\text{Water weight}) / (\text{Microwave dry weight}) \times 100$$

Soil moisture and irrigation DAP and the amount of precipitation by supplemental irrigation are shown in (Table 3).

Experimental Measurements and Statistical Analyses

Experimental plots were arranged in a randomized complete block design (RCBD) with four replications for each experiment. Blocks were separated by 2.5m aisles. Each experiment was divided into 28 plots with an area of 21m^2/plot (6m length × 3.5m width). Each plot comprised 22 rows, 15 cm between rows, and 10cm within the row. The total pure planted area of each experiment, excluding aisles, was 588m2. The average triticale population was 12 plants/m2 in each experiment. The collected data included crop height (2 times), shoot dry weight, grain weight per m2, thousand-grain weight, grain analysis and morphology. The grain weight was done by threshing the collected spikes, while the grain weight was done for 1000 seeds. Both parameters were done at the International Center for Agricultural Research in the Dry Areas (ICARDA) in Lebanon. Briefly, spikes were threshed by winter Steiger thresher LD 350.A., cleaned by Kim seeds Cleaner MK3 and counted by Pfeuffer Contador. The grain morphology traits were measured by a specialized software (Grain scan) combined with a specialized seed scanner. Gain contents were analyzed in our laboratory by NIRS DS2500 at wavelength between 400 – 2500 nm (FOSS analytical solutions for food analysis and quality control). Statistical analyses for both experiments were done by IBM SPSS Statistics 25. Treatment means were compared using three-way ANOVA (analysis of variance) and for some parameters using two-

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way ANOVA. Regarding post-hoc analysis, the Bonferroni test was used. Differences were considered significant at α = 0.05. These analyses were done by depending on syntax code of SPSS software.

Results and Discussion

Except for the supplementary irrigation with nitrogen at a rate above 120 kg/ha, none of the treatments significantly increased crop height compared to control after 170 DAP (Figure 1). However, none of the treatments increased the crop height compared to the controls of both the supplementary and rainfed after 225DAP (Figure 2). Crop height in both the supplementary and rain fed conditions with or without nitrogen were similar. Martyniak [5] indicated that water requirement for wheat, barely, and triticale are between 293-314mm. In this experiment we believe that the amount of precipitation in the rainfed (347.10mm) could be sufficient for triticale growth and development. Supplementary irrigation had no significant effect on crop height over time. In addition, our soil analysis revealed a high level of nitrogen in the soil (>40mg/kg) during planting triticale. Bashour [6] reported that Nitrogen-Nitrates level above 40 mg/kg is considered high enough to support grain growth. All nitrogen treatments under both systems had no significant effect on triticale shoot dry weight after 170 DAP in comparison to the control (Figure 3). NPK was the most effective treatment in increasing dry weight of triticale shoots under rainfed conditions. High level of nitrogen significantly reduced triticale shoots dry weight in comparison to the control or with supplementary irrigation with nitrogen. Our results are consistent with that of Alagoz et al. [7], who found that limited water reduced triticale plant dry weight by 24%.

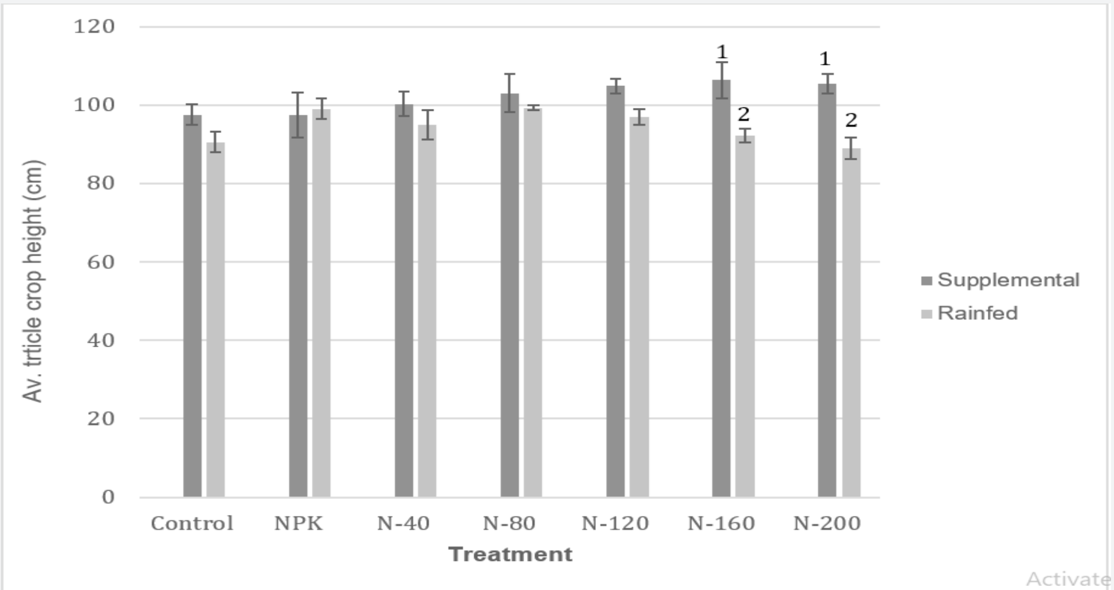

Figure 1: Average triticale crop height (cm) under rainfed and supplemental irrigation systems 170 days after planting date ± SE (n=80 plants). N-40 refers to 40 kg N /ha; N-80 refers to 80 kg N/ha; N-120 refers to 120 kg N/ha; N-160 refers to 60 kg N/ha, and N-200 refers to 200 kg N/ha. In the double bar chart refers to the significant difference between the same treatment under different systems (P < 0.05).

Supplementary irrigation alone or combined with nitrogen fertilizer at all rates significantly increased grain weight (Figure 4) and thousand-grain weight of triticale in comparison to all treatments under rainfed conditions (Figure 5). Supplementary irrigation alone was the most effective treatment in increasing the grain yield. The grain weight under both supplemental irrigation and rainfed conditions, excluding the nitrogen treatments, was 5816.33 kg/ha and 4914.29 kg/ha, respectively. Barati et al. [8] found that supplementary irrigation was the most influential factor affecting cereals' grain weight. Nitrogen had no effect on the grain weight under rain feed system [9]. The reason for decreasing the grain weight under rainfed compared to supplemental irrigation systems could be due to drought stress and high temperatures during the grain-filling period, as it generally appears under Mediterranean conditions [10]. Regarding the nitrogen requirement of triticale, triticale needs below the average nitrogen fertilizer than other cereal grains [11]. Therefore, over-fertilizing with nitrogen could lead to root growth and exudation impairment [12-14]. Our results are consistent with these studies because both adjacent fields of this experiment were planted with lentils in 2019. In other words, both adjacent experiments were already rich in nitrogen.

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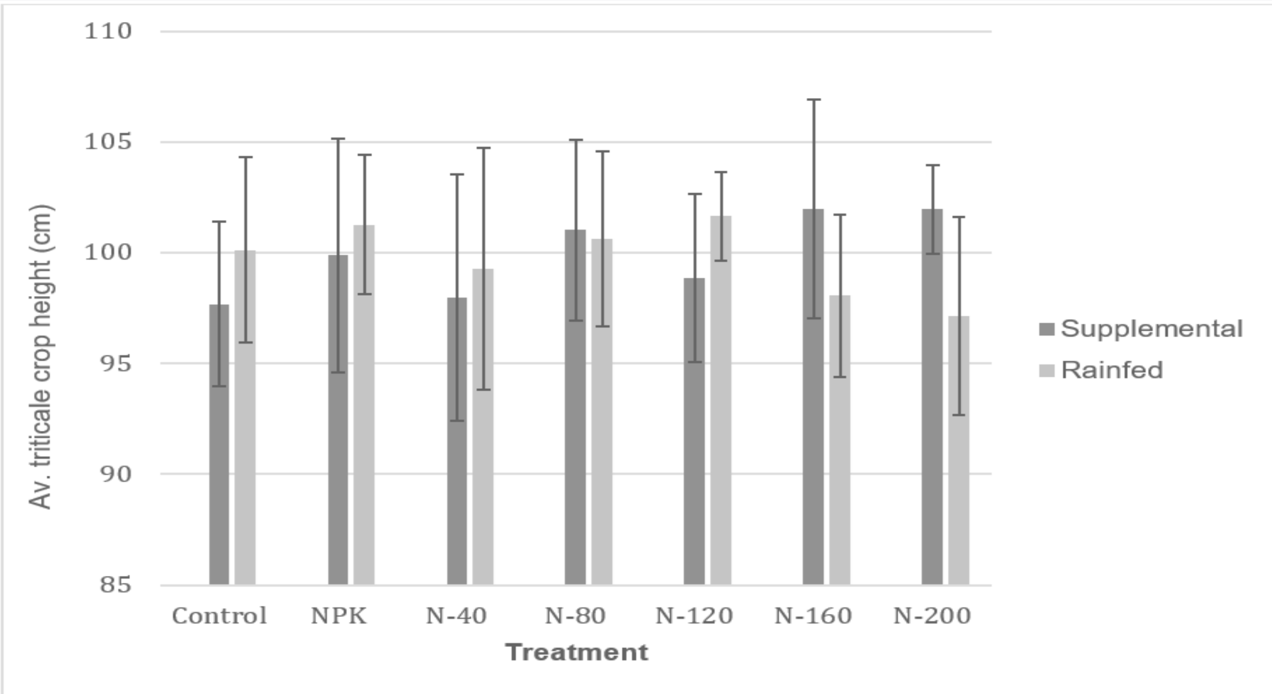

Figure 2: Average triticale crop height (cm) under rainfed and supplemental irrigation systems after 225 days after planting date ± SE (n=80 plants). N-40 refers to 40 kg N/ha; N-80 refers to 80 kg N/ha; N-120 refers to 120 kg N/ha; N-160 refers to 60 kg N/ha, and N-200 refers to 200 kg N/ha. In the double bar chart refers to the significant difference between the same treatment under different systems (P < 0.05)..

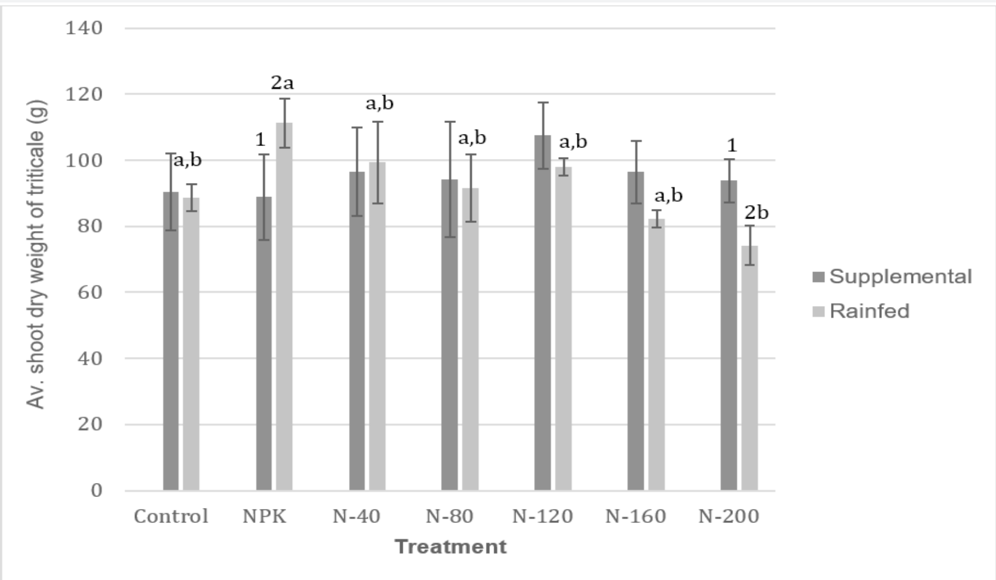

Figure 3: Average shoot dry weight (g) of triticale under rainfed and supplemental irrigation systems after 170 days after planting date ± SE (n=80 plants). N-40 refers to 40 kg N/ha; N-80 refers to 80 kg N/ha; N-120 refers to 120 kg N/ha; N-160 refers to 60 kg N/ha, and N-200 refers to 200 kg N/ha. 1 and2 in the double bar chart refers to significant difference between the same treatment under different systems (P < 0.05). a and b in the double bar chart refers to significant differences between different treatments under the same system (P < 0.05).

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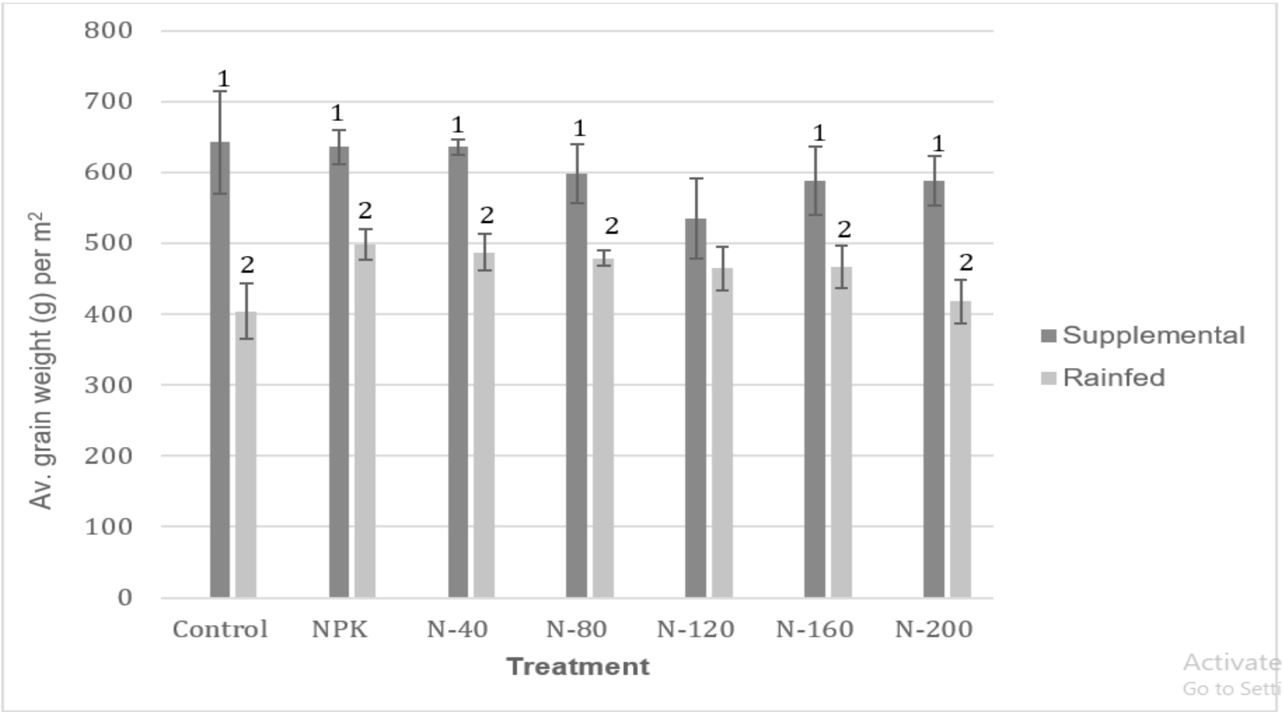

Figure 4: Average grain weight (g) of triticale per square meter under rainfed and supplemental irrigation systems ± SE (n= 4 m2). N-40 refers to 40 kg N/ha; N-80 refers to 80 kg N/ha; N-120 refers to 120 kg N/ha; N-160 refers to 60 kg N/ha, and N-200 refers to 200 kg N/ha. 1 and 2 in the double bar chart refers to significant differences between the same treatment under different systems (P < 0.05).

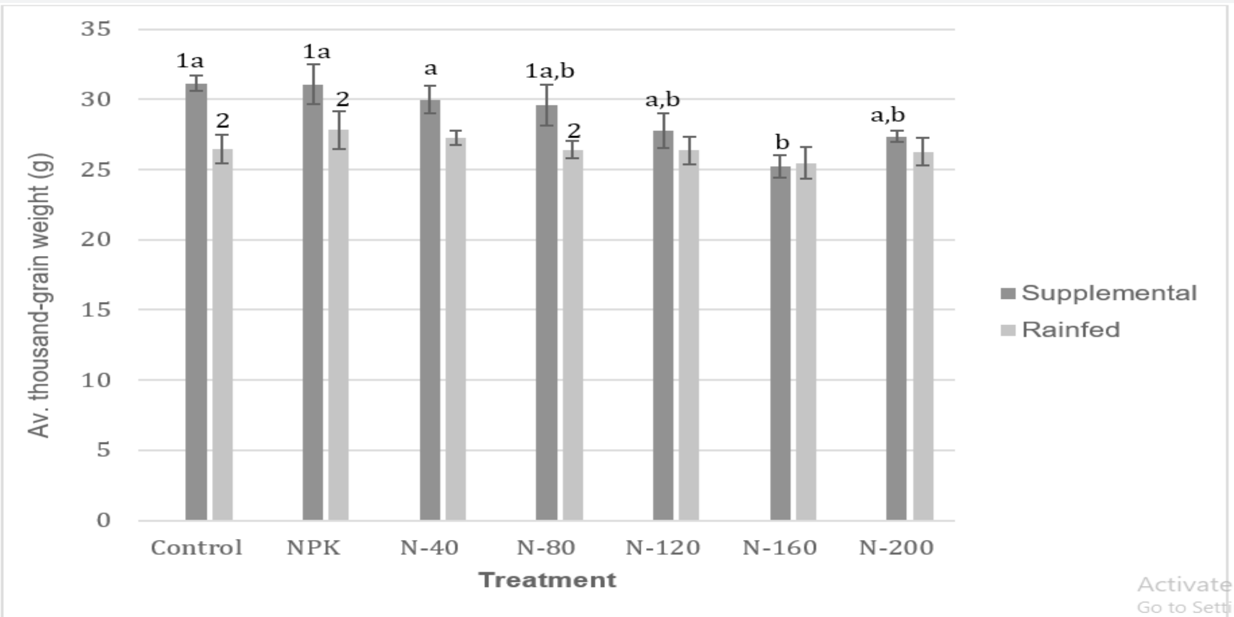

Figure 5: Average thousand-grain weight (g) of triticale under rainfed and supplemental irrigation systems ± SE (n= 4,000 seeds). N-40 refers to 40 kg N/ha; N-80 refers to 80 kg N/ha; N-120 refers to 120 kg N/ha; N-160 refers to 60 kg N/ha, and N-200 refers to 200 kg N/ha. 1 and 2 in the double bar chart refers to significant difference between the same treatment under different systems (P < 0.05). a and b in the double bar chart refers to significant difference between different treatments under the same system (P < 0.05).

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Grain protein content was higher in rainfed than in the supplementary irrigation (Figure 6). In general, most treatments under rainfed conditions recorded a higher protein content ratio than the same treatments under supplemental irrigation conditions. Addition of nitrogen at all tested rates did not enhance the grain protein content under rainfed conditions while they did under supplementary irrigation compared to their respective controls (Figure 5). Nitrogen at 160 kg/ha was the most effective treatment in increasing the grain protein content under supplementary irrigation in comparison to the control (Figure 6). It is interesting to note that unlike protein, the grain starch content was higher in supplementary irrigation than rainfed. Nitrogen at all tested rates had no significant effect on grain starch under both systems (Figure 7). We believe that the reason for higher protein content under rainfed for most treatments than the same under supplemental irrigation could be associated with the influence of water stress on the crop, which could activate the movement of nitrogen from the leaves to the grains, resulting in a boost in protein content in the grains [15,16]. Conversely, decreasing grain starch content in a drought situation is considered an obvious signal regarding the impact of drought on grain yield [17]. Studies by Flagella et al. [18] indicated that low grain starch content may lead to a negative effect on photosynthesis and thus reduce grain yield.

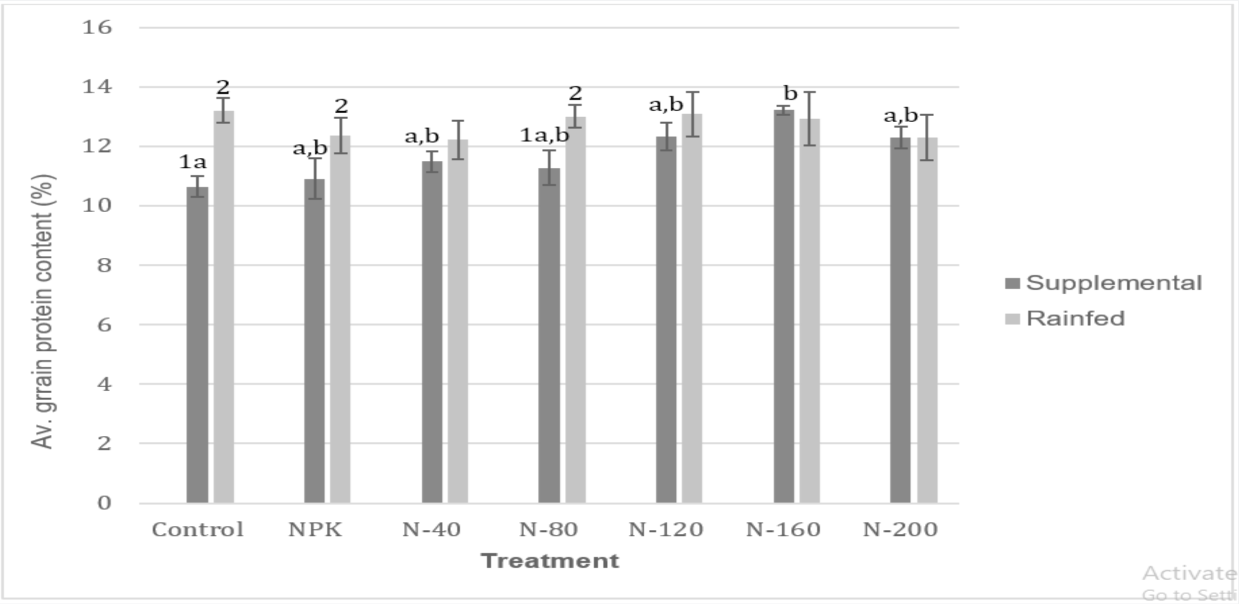

Figure 6: Average grain protein content (%) of triticale under rainfed and supplemental irrigation systems ± SE (n= 4,000 seeds). N-40 refers to 40 kg N/ha-1; N-80 refers to 80 kg N/ha; N-120 refers to 120 kg N/ha; N-160 refers to 60 kg N/ha, and N-200 refers to 200 kg N/ha. 1 and 2 in the double bar chart refers to significant difference between the same treatment under different systems (P < 0.05). a and b in the double bar chart refers to the significant difference between different treatments under the same system (P < 0.05).

Table 3: Days after planting (DAP), Soil moisture (SM) at soil depths of 30 and 50cm, supplementary irrigation days after planting (S DAP) in mm and Precipitation (mm).

DAP	SM % (30cm)	SM % (50cm)	S DAP	P mm
146	27.02	21.35	-	-
148	-	-	148	51
153	28.9	25.27		
157	-	-	157	68
158	29.97	34.21	-	-
172	-	-	172	51
174	28.5	28.27	-	-

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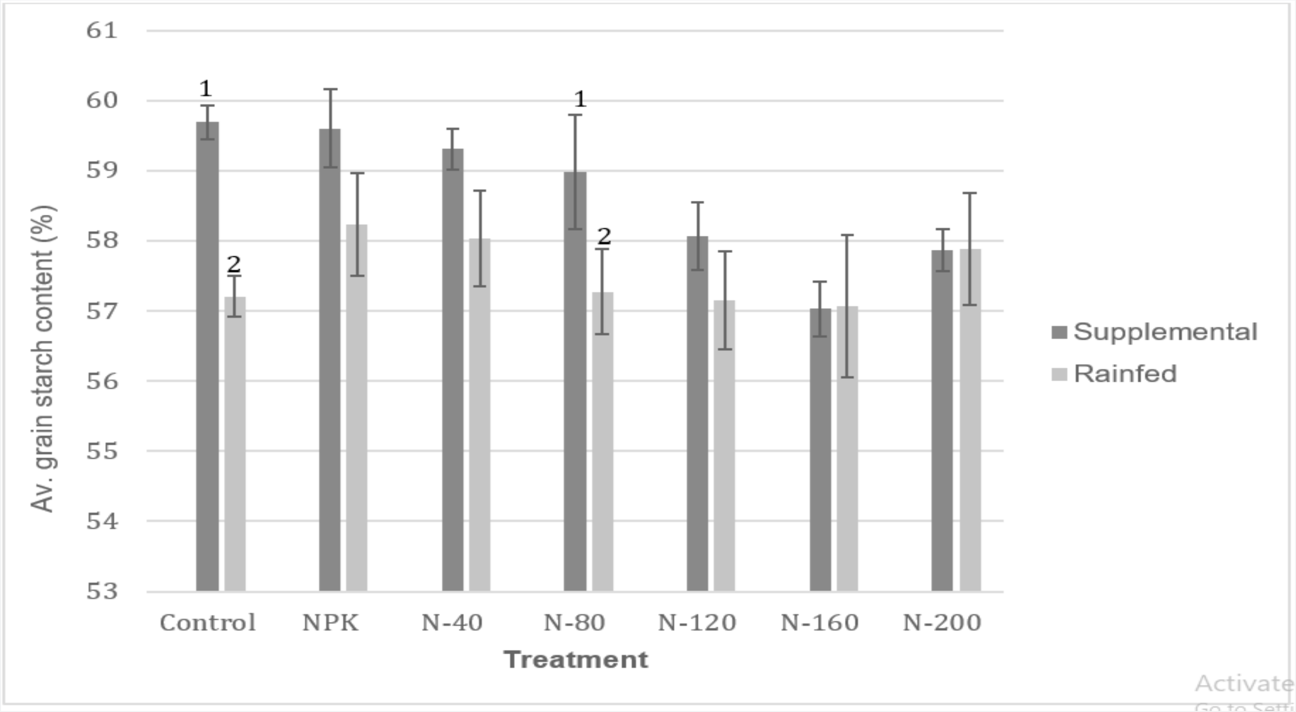

Figure 7: Average grain starch content (%) of triticale under rainfed and supplemental irrigation systems ± SE (n= 4,000 seeds). N-40 refers to 40 kg N/ha; N-80 refers to 80 kg N/ha; N-120 refers to 120 kg N/ha; N-160 refers to 60 kg N/ha, and N-200 refers to 200 kg N/ha. 1 and 2 in the double bar chart refers to significant differences between the same treatment under different systems (P < 0.05)

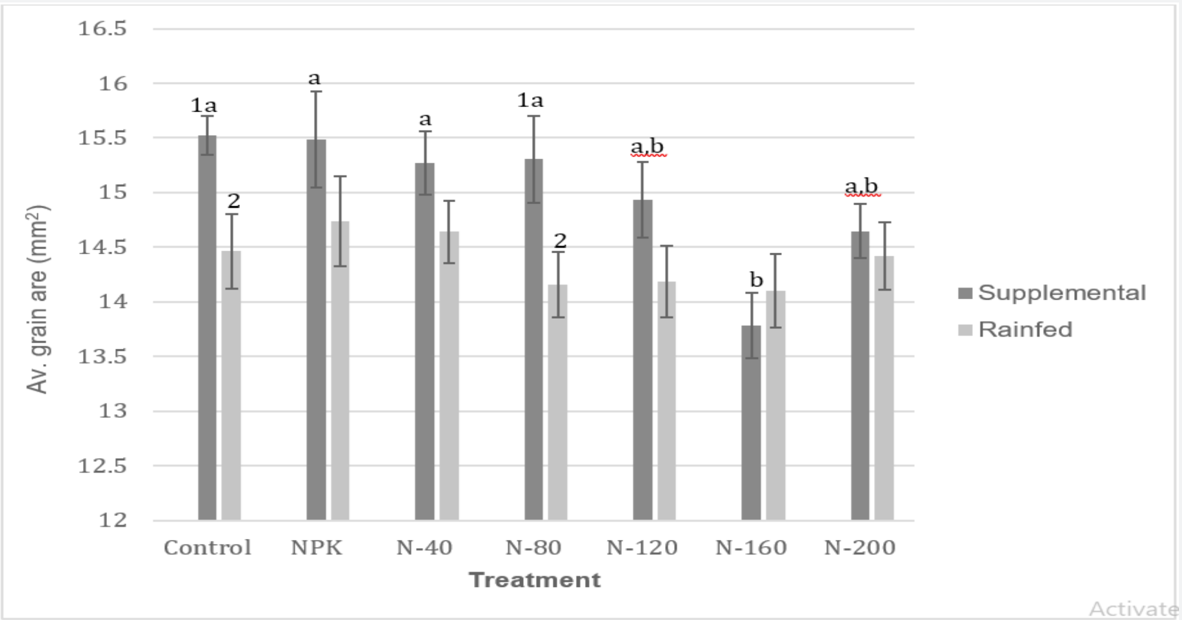

Figure 8: Average grain area (mm2) of triticale under rainfed and supplemental irrigation systems ± SE (n= 4,000 seeds). N-40 refers to 40 kg N/ha; N-80 refers to 80 kg N/ha; N-120 refers to 120 kg N/ha; N-160 refers to 60 kg N/ha, and N-200 refers to 200 kg N/ha. 1 and 2 in the double bar chart refers to significant differences between the same treatment under different systems (P < 0.05). a and b in the double bar chart refers to the significant difference between different treatments under the same system (P < 0.05).

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Nitrogen at all tested rates had no significant effect on grain area of triticale in comparison to the control under both irrigation systems (Figure 8). However, supplementary irrigation alone significantly increased the grain area in comparison to the rain fed condition. Our results show that morphological measurements of supplementary irrigation alone or with nitrogen were higher than under rainfed conditions. Previous studies indicated that grain size increased when the crops were irrigated compared to the same crops planted under rain fed conditions. Qi-hua et al. [19] showed that grain area, and grain perimeter of rice were significantly improved under irrigation system. Regarding the impact of nitrogen treatments on the grain morphological traits, results show that nitrogen did not increase the average of morphological grain traits in comparison to the control under supplemental irrigation.

Conclusion

Our results revealed that addition of nitrogen at various tested rates had no significant effect on grain yield on various growth parameters under supplementary and/or rainfed systems. There is a possibility that the soil is already rich with nitrogen or over-fertilized and thus nitrogen had no significant effect on growth parameters. Besides, the land of the experiment was planted with lentils the year before this study. This may cause an increase in the nitrogen level in the soil. Yet, supplementary irrigation alone was the most influential factor on triticale growth and yield quantity and quality compared to rainfed. This factor can pose a significant risk to triticale producers when it is not monitored and managed correctly, and thus sequential supplemental irrigation is highly recommended.

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