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Quantification of Radiation Use Efficiency and Yield of Wheat as Influenced by Different Levels of Nitrogen and Water Stress under Semi-Arid Conditions of Faisalabad

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Abstract

Crop production is greatly influenced by water and nutrition stress in semi-arid areas. Nitrogen and water are two most important yield limiting factors which effect economic production of wheat. Drought initiates when large area of land suffers from absence of precipitation for temporary periods. Though, not only water scarceness but also low relative humidity and high temperature are other climate factors which induce drought condition. Whereas Effective nutrition (nitrogen) maintains crops metabolic activities and has the potential to lessen drought stress. According to study carried out to explore the influence of varying levels of potential soil moisture deficit (PSMD) and nitrogen, an experiment was planned at agronomy research area, University of Agriculture, Faisalabad. It was laid out in randomized complete block design (RCBD) with split plot arrangement, and replicated thrice. Two factors: potential soil moisture deficit levels (I_1: irrigation at 50 mm PSMD, I_2: irrigation at 75 mm PSMD and I_3: irrigation at 100 mm PSMD) were randomized in main plots, while sub plot nitrogen levels {control (No nitrogen), 50, 100 and 150 kg N ha^{-1}} were randomized. Adequate nitrogen application along with sufficient irrigation management gave highest yield. Under water deficit conditions adequate nitrogen application ameliorates the drought stress. Highest plant height (86.27 cm), number of productive tillers (320.0), grain·spike^{-1} (49.73), test weight (50.55 g) and grain yield (6.72 t·ha^{-1}) were observed with 75 mm PSMD and 150 kg·ha^{-1} application of nitrogen. While radiation use efficiency for dry matter accumulation of wheat ranged from 1.53 - 1.87 g·MJ^{-1} whereas, radiation use efficiency for grain yield ranged from 0.421 - 0.473 g·MJ^{-1}. Results revealed that highest RUE obtained I_3 (75 mm PSMD) and nitrogen application at 150 kg·ha^{-1}. Judicial application of irrigation and fertilizer not only boosts the yield but also saves resource and increases former output.

Keywords

Quantification, Potential Soil Moisture Deficit, Nitrogen, Wheat

1. Introduction

Wheat is a cereal crop cultivated worldwide as well as in Pakistan and is known as king of cereals. Due to its compatibility with wide-ranging climatic and soil conditions, it is being cultivated on large area around the global [1]. It has significant contribution in economic share as it accounts 1.9% share in GDP of Pakistan with 9.6% of value addition [2]. Also, it has the highest cropping area in the field crops with about 9.052 million ha grown in Pakistan.

Recent climate change is becoming a major threat for crop production due to its unprecedented behavior with more devastating effects in semi-arid tropics [3]. Climatic condition is to what extent and where wheat can be cultivated economically to feed the ever-increasing population. Water shortage is single most threatening factors for crops cultivation in most parts of world [4]. This situation is getting worse gradually and water shortage is predicted to enhance by 32% up to 2050 [5] coupled with climatic projections [6]. Pakistan is facing acute irrigation water shortage, which is very detrimental for crop production [7]. Growth, yield and quality of wheat grains are markedly influenced by climatic conditions [8]. Drought events and water scarcity reduce the area under wheat cultivation from 9.23 mha in 2016 to 9.0 mha in 2017 [2]. In Pakistan, wheat crop faces water deficit in December and January due to seasonal canal closure. This water drought requires re-scheduling of irrigation that may compensate the water stress with compromising grain yield [9].

Critical stages of wheat under water stress are booting, flowering and grain formation under Mediterranean climate [10]. Most critical stage of wheat under drought stress is grain-filling stage, water scarcity at this stage shorten rate of grain-filling, reduced the grain-filling period and ultimately results in yield reduction [11].

Different degrees of water stress affect differently to physiological and metabolic functions of plants such stomatal conductance, photosynthetic rate and transpiration rate [12]. Drought stress at stem elongation stage results in reduction of spikelet and kernel number significantly [13]. Drought stress after flowering stage negatively correlated with translocation of photosynthates from leaves to grains [10] [14]. Water stress significantly reduces wheat yield [15]. The amount of irrigation influences water use efficacy and grain production

[16]. Moreover, excessive application of irrigation water may not result in optimal economic output or higher yield. Thus, there is a definite demand for proper irrigation scheduling [17]. Water stress at tillering has shown linear decrease in RUE of cereal crops and deficit at lateral stages does not have significant effect on RUE [18]. Under water shortage, deficit irrigation is considered as suitable technique; it has further various practices such as potential soil moisture deficit approach (difference amongst irrigation plus rainfall and potential evapotranspiration) in which reduced amount of water is applied to crop without having any adverse impacts on crop yield [19]. Basic objective of PSMD is to enhance water productivity [20] [21]. Water deficit mostly affects post-tillering phases of wheat than initial period [22]. However, this effect is devastating with lower nitrogen application in the prior stages [23].

Nitrogen is an important nutrient required for plant advancement [24], together with water deficit, deficiency of nitrogen can also reduce grain's production and quality of crop [25]. Especially availability of water can influence growth and nutrient status in soil and nitrogen utilization from soil and artificial sources [26]. Increase in nitrogen levels enhances the leaf area duration and total dry matter [27] [28]. At cellular level, nitrogen enhances the size and number of cells, improves the radiation absorption efficiency and enhances plant's leaf area index [29]. In semi-arid and arid tropics wheat production greatly depends upon nitrogen application [30] [31].

Nitrogen uptake and utilization by plants and wheat are determined by factors including the activity and length of the root system, the nitrate uptake intensity, nitrate reductase activity, sink of grains, *N* losses due to soil characteristics and leaching and carbohydrate production [32]. Nitrogen content in leaves cell governs photosynthetic capacity of leaves, determination of Carbohydrate metabolism [33] and nitrogen uptake estimation can be evaluated by chlorophyll quantity [34] [35].

In semi-arid areas, mineralization of nitrogen is not adequate for cereals requirement while use of appropriate amount of nitrogen is mandatory for higher outputs [36]. Appropriate amount of application of nitrogen in dry land areas can enhance ability of plant to overcome water deficit stress [37]. Improved grain quality [38] and augmented grain yield of wheat was observed with increasing quantity of nitrogen [39]. Emam *et al.* [40] investigated that by increasing level of nitrogen in rainfed conditions, yield of wheat increased. Environmental protection and farm profitability can be achieved by appropriate use of nitrogen [41]. Positive effect on RUE of wheat was observed with optimum dose of nitrogen [42].

Thus, there is need to introduce new management strategies that can decrease the chance of drought and utilize the available irrigation water in efficiently [43]. It is needed to evolve new irrigation methods to enhance water use efficiency and productivity [44]. Therefore, current study was carried out to determine the suitable combination of potential soil moisture deficit and nitrogen, to obtain higher and economic wheat production.

2. Materials and Methods

2.1. Experimental Location and Soil

A field trial was carried out at student farm, University of Agriculture, Faisalabad (31˚25' North latitude and 73˚08' East longitude, with semi-arid environment). Before sowing, soil samples from depth of 0 - 15 and 15 - 30 cm were collected randomly from experimental area for soil analysis. Report of physico-chemical properties of soil was obtained from Soil Fertility Research Institute, Lahore (Table 1). Climatic condition of the experimental site for the duration of study is represented in (Figure 1).

2.2. Plant Material and Seed Bed Preparation

Galaxy-2013 cultivar of wheat was acquired from Ayub Agriculture Research Institute, Faisalabad. Seed bed was prepared by rotavating followed by two ploughings and planking to pulverize the soil. Line sowing was done with hand drill while maintaining 22.5 cm distance between rows using seed rate of 125 $kg \cdot ha^{-1}$.

2.3. Experimental Treatments and Design

Trial was arranged in randomized complete block design (RCBD) with split-plot arrangement and replicated thrice. There were two factors studied in the experiment. Factor which was randomized in main plot comprised of three levels of

Table 1. Results of soil analysis.

Parameter	Depth	pH	EC (dSm"1)	*N* (%)	P_2O_5 (ppm)	K_2O (ppm)	Organic Matter (%)	Sand (%)	Silt (%)	Clay (%)
Values	0 - 15 (cm)	8.1	4.2	0.057	20.5	290	1.36	22	19	59
	15 - 30 (cm)	8.3	4.5	0.062	16.6	260	1.24	19	17	64

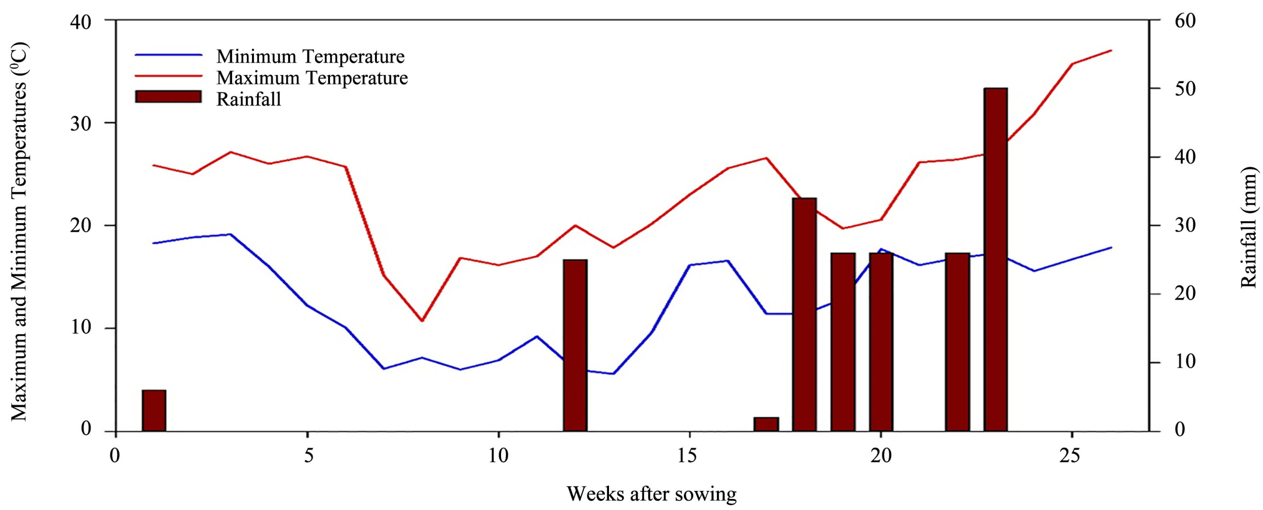

Figure 1. Meteorological data for cropping season (2015) University of Agriculture, Faisalabad.

potential soil moisture deficit (PSMD), *i.e.* I_1 = 50 mm PSMD, I_2 = 75 mm PSMD and I_3 = 100 mm PSMD. While, factor randomized in sub plot consist of four levels of nitrogen, *i.e.* control (No nitrogen), 50, 100 and 150 kg N ha^{-1} Total number of experimental plots was 36, as set of 12 treatments was replicated thrice.

2.4. Irrigation and Water Management

Canal water as well as tube well water was available to irrigate the experimental unit according to treatment requirement. Soil moisture status was monitored by using tensiometers. Nitrogen fertilizer application was done according to respective treatment in each experimental unit. While recommended dose of Phosphorous (*P*) and potassium (*K*) were applied immediately at the time of sowing. The sources of fertilizers were urea, single super phosphate and murate of potash for *N*, *P* and *K* respectively.

2.5. Measurements and Statistical Analysis

A standard model "CROPWAT" was applied to calculate penman potential evapotranspiration (PET). it was developed by Food and Agriculture Organization [45]. It computes the total amount of irrigation water applied to crop is equal to difference between summation of irrigation and precipitation and potential evapotranspiration (PET).

$$D = \sum ET_o - \sum (I + R)$$

ET_o can be calculated by following formula.

$$ET_o = E_{pan} \times K_p$$

E_{pan} = mean daily pan evaporation, K_p = pan coefficient.

Water stress was imposed on crop in early, middle and terminal stages of crop development and was continued for varying degree of time. Irrigations were applied at 50, 75 and 100 mm PSMD. Calculation of amount of water per are shown as under.

Irrigation depth = 50 mm = 0.05 m;

Area of net plot = 4.5 m × 1.5 m = 6.75 m^2;

As we know that, 1 m^3 = 1000 liters;

Irrigation for 50 mm (depth) = 337.5 liters;

Diameter of fountain (d) = 0.24 m;

Radius of fountain (r) = 0.12 m;

Fountain length = 25 cm = 0.25 m;

Fountain total area (πr^2) = 0.045 m^2;

Fountain total volume = A × L = 0.01125 m^3;

Required volume of irrigation water = 0.337 m^3;

Total fountain buckets needed for 50 mm PSMD=Required volume of irrigation water/total volume of fountain = 0.337/0.01125 = 30.

To maintain 50 mm PSMD per plot 30 fountain buckets were used.

Similarly, 45 fountain buckets for 75 mm PSMD and 60 buckets for 100 mm PSMD per plot were used.

Soil water content $= (W1 - W2/W2) \times 100$ where $W1$ = Mass of soil before drying and $W2$ = Mass of soil after drying.

Observation regarding productive tillers, plant height, grains·spike^{-1}, test weight, economic yield and total biomass accumulation were recorded according to standard criterion. While radiation using efficiency for total dry matter was computed as (RUE_{TDM}): TDM/Σ*Sa*, while, for grain yield was calculated as (RUE_{GY}) = Grain yield/Σ*Sa*.

Here TDM = total dry matter, *Sa* is equal to amount of intercepted photo synthetically active radiations (PAR) [46], as it can be calculated by multiplying *Fi* with *Si*, where "*Fi*" is fraction of intercepted radiations and "*Si*" is daily incident photosynthetically active radiation

$$Sa = Fi \times Si$$

here "*Fi*" can be calculated by Beer's law

$$Fi = 1 - exp(-k \times LAI)$$

K is a coefficient whose value for wheat is 0.4. Furthermore, for calculation of "*Si*" there is need to calculate solar radiations

$$Si = \text{Total } Rs/2$$

Rs is equal to solar radiations that can be calculated by

$$Rs = [a + b(n/N)] \times Ra$$

where, *a* and *b* are constants and have 0.25 and 0.5 values respectively, *n* is equal to actual sunshine hours whereas *N* is maximum possible sunshine hours and Ra is extra-terrestrial radiations. All recorded data was statistically analyzed by using fisher analysis of variance technique and difference among treatment's means was compared by least significance difference test at 5% level of probability [47].

3. Results and Discussion

The statistical analysis of the experiment representing the effect of different levels of Nitrogen and PSMD on the height of plant, productive tillers, numbers of grains·spike^{-1}, test weight, radiation use efficiency, total dry matter accumulation and economic yield is representing in **Table 2**. The effect of PSMD and nitrogen levels is represented in **Table 3**, while, interactive effects of PSMD and nitrogen levels on these parameters is represented in **Table 4**.

3.1. Plant Height

The statistical data concerning about the height of plant as affected by different levels of irrigations and different levels of nitrogen is shown in (**Table 3**). Study has shown that plant height influenced significantly due to different irrigation timing in addition to different delta of water. Moreover, a significant interaction of irrigation levels and Nitrogen application was also observed (**Table 4**). The results showed that irrigation level 75 mm PSMD and 150 kg N ha^{-1} gave the maximum 76.27 cm and 82.27 cm plant height respectively and least plant height 68.77 cm was noted in 100 mm PSMD and control *N* treatments (N_0) gave 59.40 cm plant height. I_2 treated plots gave maximum plant height because effective rainfall was maximum and adequate moisture supply was maintained throughout the all growth stages of crop. The results of our experiment are just like with the study of [48] [49] [50] [51]. High dose application of nitrogenous fertilizer increases the vegetative growth vigorously and our result synchronise with the finding of [52] [53].

Table 2. The mean squares of moisture deficits and nitrogen treatments regarding yield and yield components of wheat during 2014-15.

Source of variation	df	Plant height (cm)	Productive tillers m^{-2}	No. of grains·$spike^{-1}$	1000-grain weight (g)	Biological yield (t·ha^{-1})	Grain yield (t·ha^{-1})	RUE_{TDM} (g·MJ^{-1})	RUE_{GY} (g·MJ^{-1})
Replication (r)	2	981.67	10348.8	407.17	258.09	18.95	3.22	0.55	0.002
Irrigation (*I*)	2	249.25*	10766.6**	59.80**	205.37**	55.24**	9.99**	0.09*	2.05
Error a	4	4.611	15.8	2.59	1.231	0.39	0.32	0.003	0.001
Nitrogen (*N*)	3	896.36**	6266.5**	49.62**	138.24**	64.81**	16.2**	0.103*	2.63*
$I \times N$	6	13.31	1205.5**	5.33	2.66	1.84	0.36	0.002	0.07
Error b	18	5.47	30.1	1.51	0.78	0.69	0.12	0.002	0.001
Total	35								

Table 3. Response of yield and yield components of wheat to moisture deficits and nitrogen levels during 2014-15.

Treatments	Plant height (cm)	productive tillers m^{-2}	No. of grains·$spike^{-1}$	1000-grain weight (g)	Biological yield (t·ha^{-1})	Grain yield (t·ha^{-1})	RUE_{TDM} (g·MJ^{-1})	RUE_{GY} (g·MJ^{-1})
Irrigation levels (*I*)								
I_1	70.17^b	263.3^b	40.72^b	40.11^b	9.88^b	3.67^b	1.74^b	0.45^b
I_2	76.27^a	283.1^a	44.45^a	45.52^a	13.18^a	5.01^a	1.86^a	0.47^a
I_3	68.77^b	224.2^c	40.29^b	37.39^c	9.15^c	3.26^c	1.68^b	0.45^b
LSD (P = 0.05)	2.4	4.50	1.82	1.25	0.71	0.64	0.06	0.01
Nitrogen rates (*N*)								
N_0	59.40^d	221.5^c	39.23^d	36.63^d	7.13^d	2.39^d	1.62^d	0.44^c
N_1	69.04^c	262.0^b	40.90^c	39.27^c	10.57^c	3.50c	1.74^c	0.46^b
N_2	77.16^b	258.4^b	42.24^b	42.46^b	11.77^b	4.53^b	1.80^b	0.46^b
N_3	82.27^a	285.4^a	44.79^a	45.67^a	13.48^a	5.50^a	1.88^a	0.47^a
LSD (P=0.05)	2.31	5.43	1.21	0.87	0.82	0.34	0.04	0.43

Means sharing same letters did not differ significantly at P = 0.05. I_1: Irrigation at 50 mm potential soil moisture deficit; I_2: Irrigation at 75 mm potential soil moisture deficit; I_3: Irrigation at 100 mm potential soil moisture deficit; N_0: Control (No nitrogen); N_1: 50 kg N ha^{-1}; N_2: 100 kg N ha^{-1} and N_3: 150 kg N ha^{-1}.

Table 4. The response of yield and yield components of wheat to moisture deficits and nitrogen levels during 2014-15.

Treatments	Plant height (cm)	productive tillers m^{-2}	No. of grains·spike^{-1}	1000-grain weight (g)	Biological yield (t·ha^{-1})	Grain yield (t·ha^{-1})	RUE_{TDM} (g·MJ^{-1})	RUE_{GY} (g·MJ^{-1})
Interaction ($I \times N$)								
$I_1 \times N_0$	56.67 ± 10.2	232.33 ± 22.4^{f}	39.22 ± 6.5	35.44 ± 4.4	6.55 ± 1.0	2.19 ± 0.2	1.62	0.434
$I_1 \times N_1$	66.73 ± 9.5$^{(b)}$	254.4 ± 25.0^{de}	40.35 ± 6.5	37.69 ± 3.5	8.95 ± 1.0	3.24 ± 0.4	1.71	0.462
$I_1 \times N_2$	76.60 ± 9.2	264.36 ± 30.4^{c}	40.73 ± 5.8	42.06 ± 4.7	10.59 ± 1.1	4.00 ± 0.5	1.77	0.452
$I_1 \times N_3$	81.33 ± 10.1	302.03 ± 33.0^{b}	42.33 ± 6.0	45.23 ± 6.0	13.45 ± 1.6	5.25 ± 0.6	1.86	0.477
$I_2 \times N_0$	67.33 ± 12.6	247.7 ± 28.6^{e}	40.67 ± 5.0	40.67 ± 5.0	8.76 ± 0.6	2.93 ± 0.6	1.69	0.460
$I_2 \times N_1$	74.79 ± 8.6	269.36 ± 28.1^{c}	42.71 ± 6.4	43.37 ± 5.4	13.91 ± 2.6	4.44 ± 0.9	1.86	0.473
$I_2 \times N_2$	79.80 ± 8.8	295.0 ± 32.0^{b}	44.57 ± 5.4	47.24 ± 5.9	14.55 ± 2.3	5.93 ± 1.2	1.92	0.481
$I_2 \times N_3$	86.9 ± 8.2	320.0 ± 37.2^{a}	49.46 ± 8.5	50.79 ± 4.5	15.48 ± 1.4	6.72 ± 0.9	1.96	0.489
$I_3 \times N_0$	53.86 ± 8.1	184.59 ± 31.0^{h}	37.78 ± 4.4	33.78 ± 5.0	6.08 ± 0.8	2.04 ± 0.1	1.56	0.443
$I_3 \times N_1$	66.93 ± 7.0	262.3 ± 32.1^{cd}	39.65 ± 6.6	36.73 ± 3.4	8.84 ± 1.2	2.81 ± 0.5	1.66	0.447
$I_3 \times N_2$	75.40 ± 10.1	215.83 ± 24.2^{g}	41.40 ± 4.6	38.07 ± 4.1	10.17 ± 1.2	3.65 ± 0.3	1.71	0.452
$I_3 \times N_3$	78.20 ± 8.0	234.01 ± 30.4^{f}	42.13 ± 4.4	40.99 ± 3.9	11.50 ± 1.8	4.55 ± 0.7	1.81	0.466
LSD								
(P = 0.05)	4.01	9.4	2.11	1.51	1.42	0.05		

$^{(b)}$The data are presented as the means ± SD; Means sharing same letters did not differ significantly at P = 0.05.

3.2. Productive Tillers m^{-2}

Final economic yield is directly influenced by numbers of spike bearing tillers per unit area and its expresses the importance of productive tillers. In Table 3 data indicate that the PSMD and nitrogen levels and in Table 4 interaction of PSMD and nitrogen levels has significant impact (P > 0.05) on the total number of tillers (productive) per unit area. Maximum productive tillers (320.0) were recorded under 75 mm PSMD and 150 kg N ha^{-1} ($I_2 \times N_3$) treatment while, least (184.59) productive tillers were noted in 100 mm PSMD × control (0 N) ($I_3 \times N_0$) treated plots. Results of our experiment are analogous to those of Nisar *et al.*, [51] (2016). Khaliq, [52] (1999) reported that productive tillers in a unit area increased significantly with the rising application of nitrogen.

3.3. Grains per Spike and 1000 Grain Weight

Grain per spike were significantly (P ≤ 0.05) affected by PSMD and nitrogen level (Table 3) while their interactive effect was non-significant (Table 4). Maximum (P ≤ 0.05) grains per spike (44.45) were recorded under 75 mm PSMD irrigation treatments (I_2), while, (44.79) when 150 kg N ha^{-1} treatments (N_3) was applied. Least no of grains per spike (40.29) and (39.23) were recorded in I_1 (50 mm PSMD) and N_0 (0 nitrogen) treated plots. Low level of nitrogen and low PSMD reduced the grains per spike significantly.

In case of 1000 grain test weight PSMD levels and nitrogen level influenced significantly ($P \le 0.05$) (**Table 3**) but interaction of PSMD levels and nitrogen treatments didn't affect significantly (**Table 4**). Highest (45.52 g) 1000 grain weight was recorded under 75 mm PSMD (I_2) treatment, while, I_3 (100 mm PSMD) produced least test weight (37.39 g). Increasing water application increased grain weight [53] [54], but our result contradicts with these studies, judicial application of irrigation increases the total grain weight. This study has shown the same trend as of [51]. More nitrogen application also increased grain weight significantly and highest test weight (45.67 g) was recorded in N_3 (150 kg N ha^{-1}) and least (36.63 g) was noted in N_0 (control) treatment. These findings are in line with those of [48]. Similar research carried out by Lin *et al.* [55] and Shao *et al.* [56] shown that not more than three or four irrigations are necessary for gaining desired outcomes in case of wheat.

3.4. Biological Yield and Economic Yield

Biological yield is defined as "total biomass production per unit area by a crop". Biological yield depends upon characteristic like plant population in a unit area, height of the plants, total number of grains·spike^{-1} and test weight of grains. Alteration in any cultural practice, climatic factors or any other factor (fertilization, irrigation and pesticides) reflects alteration in biological produce of crop. The statistical data regarding the influence of irrigation (PSMD) and nitrogen levels on biological yield are presented in **Table 3**. Data shows that nitrogen levels significantly variate the biological yield as well as irrigation levels also produce significant difference among different treatments, while their interactive effect is non-significant ($P \le 0.05$). Maximum (13.18 t·ha^{-1}) biological yield was attained in the case of I_2 (75 mm PSMD) followed by 9.88 t·ha^{-1} in case of I_1 (50 mm PSMD) while, minimum (9.15 t·ha^{-1}) biological yield was recorded under I_3 (Irrigation at 100 mm PSMD) treatments. Reasons behind the maximum Biological yield in (I_2) was judicial use of irrigation resulted in better germination, proper stand establishment, maximum numbers of tillers per unit area, more plant height, less water stress to crop and higher water use efficiency [57]. Warraich *et al.* [50] reported that under water stress plants required more energy to extract water low soil moisture status.

The statistical data regarding impact of different nitrogen levels at total dry matter production of wheat are shown in **Table 3**. Highest biological yield (13.48 t·ha^{-1}) attained from N_3 (150 kg N per hectare) after that (11.77 tons per hectare) under N_2 (100 kg N per hectare), and least (7.13 t per hectare) biological yield was found in N_0 (control) treatments. Hussain, [49] (2006) and Ali, [58] (2009) observed that total biomass production will increase with increasing nitrogen application. The interaction of two factors was non-significant ($P \le 0.05$) on total biomass production (**Table 4**).

The pivot point of the research is to maximize the per unit economic yield (grain in case of wheat) to fulfill the human dietary requirement and to ensure food security. That's why different package of technologies is used to boost the profitability and economics of producers. Economic yield (grain in case of wheat) is product of collective response of yield component (total number of productive tillers unit area^{-1} × total number of grains·spike^{-1} × 1000 grain weight). Data about economic yield affected by various PSMD and nitrogen treatments is presented in **Table 3**. Statistical analysis for grain yield shows that PSMD levels and nitrogen treatment have significant impact. Maximum (5.01 t·ha^{-1}) grain yield was achieved from I_2 (75 mm PSMD) followed by grain yield (3.67 t·ha^{-1}) and least (3.26 t·ha^{-1}) from I_1 (50 mm PSMD) and I_3 (100 mm PSMD), respectively. Appropriate amount and at specific time, application of water increased the yield while un-judicial use or lower use of irrigation both reduced the wheat yield. Excessive irrigation application leads to lodging which ultimately reduced the grain yield. Zhang *et al.* [59] also declared that judicial application of water is necessary for maximum yield. Bunyolo, [60] stated that wheat yield will increase with increasing irrigation application while Lin, [57] reported that only 4 irrigations at critical growth stages is enough for obtaining economic wheat yield. Mubeen *et al.* [61] and Zarien *et al.* [62] findings revealed that judicial application of 4 irrigation at proper time gave maximum yield.

In case of nitrogen application uppermost grain yield (5.50 t·ha^{-1}) was gained from N_3 (150 kg N per hectare), followed by 4.53 t per hectare, 3.50 t per hectare and 2.39 t per hectare from treatments N_2 (100 kg N per hectare), N_1 (50 kg N per hectare) and N_0 (control), in that order (**Table 3**). Interactive effect of these factors did not affect the economic yield (**Table 4**). Hussain *et al.* [49] and Ali *et al.* [58] noticed that rising nitrogen level increases economic yield significantly.

Agarwal and Sinha, [63] stated the harmful effects of water scarcity on the seed yield of wheat. Drought stress before pollination is negatively correlated with seed yield. Demir and Shaw, [64] described that drought stress at pollination stage of maize plant reduced the seed yield up to half. The economic yield of wheat like other crops has constructive responses as chemical fertilizer application increased. Climatic and management practices (crop rotation, watering and drainage) factors are primarily significance in response of field crops to chemical fertilizers [32].

3.5. Radiation Use Efficiency (RUE)

RUE for total dry matter was found to be significantly changed with irrigation and nitrogen levels (**Table 3**), while their interaction found to be non-significant (**Table 4**). Regarding PSMD levels, RUE for TDM ranged from 1.68 - 1.86 g·MJ^{-1} and maximum RUE was found in I_2 (50 mm PSMD). Whereas, for nitrogen, it was highest (1. 88 g·MJ^{-1}) in N_3 (150 kg N ha^{-1}) and least (1. 62 g·MJ^{-1}) RUE eas observed in N_0 (control treatmnet). RUE for grain yield was maximum (0.47 g·MJ^{-1}) in case of I_2 (75 mm PSMD) among irrigation regimes and in nitrogen application, RUE_{GY} found be highest (0.47 g·MJ^{-1}) with 150 kg·ha^{-1} application of nitrogen, while interaction of irrigation and nitrogen levels effect RUE non-significantly. Whitfield, [65] stated RUE of wheat was reduced due to water stress. Calviglia *et al.* [42] found that RUE can be increased with higher levels of nitrogen but not significantly ($P \leq 0.05$).

4. Conclusion

Inadequate irrigation and precipitation limitation during the growth period of wheat hampered the yield and growth, so it is concluded that judicial fertilizer application under adequate PSMD condition can mitigate the yield losses. In case of drought inadequate *N* application diminishes the produce significantly. At early grain filling stage drought stress and low soil *N* contents lead to reduced *N* uptake and diminish the yield. Under such scenario, following yield response curve we can get maximum economic yield.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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