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Foliar application of potassium and restricted irrigation improved the growth and yield of wheat under rainfed condition of Bhal region

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Abstract
Foliar application of potassium increases the drought tolerance in the wheat crop with restricted irrigation, keeping in the view, a field experiment effect of foliar K application for improving wheat yield and water productivity under restricted irrigation condition was conducted at Agricultural Research station, Anand Agricultural University, Dhandhuka, *Bhal* region of Gujarat under conserved soil moisture condition with restricted irrigation in the *Rabi* season of 2021-22 with the objective to reduce moisture stress and to enhance the yield potential of wheat by using potash sprays. Inadequate moisture during the sensitive stages will cause substantial reduction in yield. The experiment was laid out in three replication with nine treatments in split plot design. They are (A). Irrigation levels, I_1: One irrigation at CRI stage, I_2: Two Irrigation at CRI and flowering stage, I_3: Three irrigation at CRI, late jointing and milking stage. (B). Foliar K application, F_1: Control (Water spray), F_2: 2% K foliar application at tillering (40-45) and jointing (60-65 DAS), and K_3: 4% K foliar application at tillering (40-45) and jointing. The result indicated that due to irrigation management plant height at harvest (70.56 cm), length of ear (7.12), biological yield (7751 kg/ha) and grain yield (3367 kg/ha) was found significant with I_3 treatment rest of parameters found non- significant with irrigation levels. Further data indicate from K foliar application, the plant height at harvest (71.51 cm), no of ear head sq. m. (295.44), length of ear (7.17), no, of grain per ear (32.68), test weight (44.03), biological yield (7112 kg/ha) and grain yield (3244 kg/ha) were recorded superior with K_3 Treatment (4% K foliar application at tillering (40-45) and jointing) whereas, plant height, no of ear head (sq. m) no, of grain per ear, biological yield and grain yield found at par with F_2 treatments Overall, it was observed that the foliar potassium fertilization and restricted irrigation increased the growth, yield attributes and grain yield.

Keywords: Foliar spray, potassium, irrigation, wheat

Introduction
Wheat is one of the two main crops grown in India and ever since the Green Revolution it has played a critical role for both national and global food security. Globally, India is the second largest producer of wheat, exporting 0.2 million tons annually and contributing 13% of the wheat supply (ANN 2014). Wheat (*Triticum aestivum*, L.) is one of the major cereal crops cultivated to meet the food demand of the burgeoning population. The cultivation of wheat has also been symbolic of green revolution, self-sufficiency in food production. In India, it is the second most important food crop after rice in terms of its importance and role in food security. In global level, wheat also ranked second after rice crop in food grain production and it was grown in 220.4 million hectare area with the production of 768.49 million tonnes (FAOSTAT, 2020) [13]. In term of global level wheat production India stand second position after china. In India wheat grown on 30.55 million hectare area with production of 107.18 million tonnes and productivity 3508 kg/ha (Sharma *et al.*, 2020) [20]. In India, Gujarat state gets seventh position in wheat production after Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Bihar and Rajasthan. In term of percentage, it accounts more than 4% of total production of the wheat in the country (Anon., 2020) [3]. In Gujarat, it is cultivated about 7.7 thousand hectare area with the production of 23.95 million tonnes and having productivity of 3082 kg ha^{-1} (Anon., 2019) [2] & (Choudhary *et al.*, 2018) [10]. Potassium is an essential element for plants and has an important role such as enzyme activation, protein synthesis, ion absorption and transport, photosynthesis and involves the respiration process as a regulator of stomata and the maintenance of turgor and osmotic equilibrium (Wiedenhoeft, 2006; Barker and Pilbeam, 2007) [23, 8].

Besides various adaptive mechanisms; potassium (K) sprayed under drought condition can improve the tolerance of crop plants to various types of abiotic stresses, and it also improved subsequent growth and yield. Mengel and Kirkby (2001) [16] reported that K improves physiological processes by the regulation of turgor pressure and photosynthesis; translocation of cations and enzymes activation, while, Cakmak (2005) [9] also observed that plant suffering from drought stress required more internal K. Water helps in cell enlargement due to turgor pressure and cell division which ultimately increase the growth of plant. Water is essential for the germination of seeds, growth of plant roots, and nutrition and multiplication of soil organism. Water is also essential for the transportation of nutrients and sugars from the soil to the plants. Irrigation recommended for wheat crop in accordance to their critical stages are namely at crown root initiation (21 DAS), tillering stage (40-45 DAS), jointing (60-65 DAS), flowering (80-85 DAS), milking (100-105 DAS) and dough stage (115-120 DAS). Irrigation given at crown root initiation stage is very important for successful growth of wheat and it has a great impact on higher grain yield (Randhawa *et al*., 2004). Limited irrigation an impotent tool of crop grown under conserved soil moisture condition due to limited irrigation yield increase up to 20 to 25% of in Bhal region of Gujarat and it also vary from crop to crop. Limited irrigation improves soil health because high number of irrigation in Bhal area of Gujarat damage soil heath. Hence, Foliar application of potassium and restricted irrigation an important factor for wheat crop at critical stages of crop in Bhal region of Gujarat for higher crop production (Choudhary *at el*., 2023) [11].

Materials and Methods

Site description

A field experiment was conducted at Agricultural Research Station, Anand Agricultural University, Dhandhuka, Bhal and Coastal Zone of Gujarat in Ahmedabad district at 22^0 22' North Latitude and 71^0 59' East Longitude during rabi season 201-22. The climate of this region is semi-arid and sub-tropical. Monsoon commences by the second week of June and retreats by middle of September with an average rainfall of 625.5 mm received entirely from the south-west monsoon currents. Crop was sown under conserved soil moisture condition.

Field layout and treatment levels

Experiment was carried out in Split plot design in three replications with nine treatments. In main plot, apply three irrigation *viz*; (A). Irrigation levels, I_1: One irrigation at CRI stage, I_2: Two Irrigation at CRI and flowering stage, I_3: Three irrigation at CRI, late jointing and milking stage, whereas, in sub-plot foliar application of potassium was apply (B). Foliar K application, F_1: Control (Water spray), F_2: 2% K foliar application at tillering (40-45) and jointing (60-65 DAS), and K_3: 4% K foliar application at tillering (40-45) and jointing. The wheat variety GW 451 was sown in third week of November with seed rate of 90 kg/ha at 20 cm spacing row to row. The plot size is**:** Gross: 1.80 m x 8 m = 14.40 sq. m. (9 rows) and Net size is 1.40 m x 7 m = 9.80 sq. m. (7 inner rows x 7 m long). Fertilizer applies as per the recommended dose of fertilizer. The growth, yield and yield attributes examine by randomly selecting five plants form each experimental plot, leaving the two border rows on the rows direction and half meter on opposite direction of the plot of wheat

Results and Discussion

(A) Effect of Irrigation levels (I)

Plant population

Numerically higher number of plant stand/sq m at harvest was found with I_3 Treatment (Three irrigation at CRI, late jointing and milking stage) (84.44) but, overall data was found no-significant in case of I_1 & I_2 treatment 85.11, 83.89 respectively.

Plant height at harvest

An examination of the data revealed that irrigation levels differed significantly in their plant height at maturity stage. Significantly higher plant height (cm) was recorded with treatment I_3 treatment (Three irrigation at CRI, late jointing and milking stage) being statistically at par I_2 treatments (Two Irrigation at CRI and flowering) (66.24 cm) which is 70.56 cm. This might be due to good establishment of roots, adequate moisture supply in soil which made higher nutrient mobilization and uptake and better condition for cell division and cell enlargement, which ultimately increased the plant height and plant spread. The results are in close conformity with the findings of Yadav and Singh (2014) [25] and Singh *et al*., (1980) [22].

No of ear head

It is apparent from the data given in Table 1.0 that the irrigation levels did not significantly influenced effective ear head (sq. m) but numerically higher number ear head (sq. m) was recorded with I_3 treatment (Three irrigation at CRI, late jointing and milking stage) which is 288.36. Whereas, $I_1$and I_2 treatment have 284.44 and 279.78 ear head (sq. m) respectively.

Physiological maturity

Data presented in Table 1.0, The maximum days to maturity (118.22) attend numerically with I_3 treatment (Three irrigation at CRI, late jointing and milking stage), it was statistically at par with I_2 treatment (114.0). Water is an elementary constituent of plant cell and their adequate supplies enhance cell division and as well as cell elongation. Therefore, optimum availability of water with two or three irrigations to wheat might have improved the photosynthetic area of plants that cumulatively contributed to higher plant height, effective tillers and anthesis and physiological maturity (Days after seeding). The results of this study are in close conformity by Sharma *et al*., (2020) [20] and Mer *et al*., (2014) [17]

Ear length (cm)

A perusal of data (Table 2.0) fingered out significant influence of irrigation levels on ear length (cm) of wheat. Application of three irrigation (I_3 treatment) gave significantly higher ear length (7.12) over I_1 treatment (6.48) and found statistically at par with two irrigation (I_2 treatment) (6.82). Due to K_2O spray Overall improvement in plant growth, vigour and production of photosynthates owing to increased availability, absorption and translocation of nutrient in plants. Sarkar *et al.* (1999) [19]

No of grain ear

The analysis of variance of data indicated that irrigation levels had significant effect on grain per ear. Data clearly indicated

(Table 2.0) that I_3 treatment (Three irrigation at CRI, late jointing and milking stage) were recorded significantly higher data (34.65) in front of I_1 treatment (28.89) and found statistically at par with I_2 treatment (two irrigation). Lin and Danfeng (2003) [15] also reported that improvement of growth and yield attributing characters were associated with enhancement of potassium level in plant due to foliar application of K.

Test weight (g)
It was clear from (Table no 2.0) the results that I_3 treatments have numerically higher test weight (g) of wheat. Application of thee irrigation (42.33) being at par with I_2 (40.77) and I_1 (40.41). These finding are closely confirm with Afzal A. and Kumar R. (2015) [6].

Biological yield (kg/ha)
Data further revealed from Table no 2.0 indicated that significantly higher bio yield (7751 kg/ha) was obtain from I_3 treatment (Three irrigation at CRI, late jointing and milking stage) over I_1 treatment (5973 kg/ha). Whereas, I_2 treatment (Two Irrigation at CRI and flowering) found statically at par with I_3 treatment.

Grain yield (kg/ha)
Data pertaining to grain yield of wheat as influenced by varying levels of restricted irrigation are presented in Table 2.0. A close perusal of the results shows that application three irrigation (I_3 treatment) produced significantly higher grain yield (3367 kg ha^{-1}) over one irrigation (I_1 treatment) (2696 kg ha^{-1}) which is being at par with two irrigation (I_2 treatment) (2968 kg ha^{-1}). Aown *et al.,* (2012) [26] reported that foliar application of K under drought at any critical crop growth stage significantly increased wheat grain yield.

(B) K_2O foliar spray
Plant population
Data indicated in table 1.0 shows that plant population was found non -significant with both treatment of potassium foliar spray. The numerically higher data was recorded with K_3 treatment (4% K application at tillering and jointing) 87.67 over Control F_1 treatment (Water spray) 279.78.

Plant height at harvest
Data further revealed that (Table 1.0) significantly higher plant height (cm) were recorded with K_3 treatment (4% K application at tillering and jointing) 71.51 over the control and which is found at par with K_2 treatment 66.27 (2% K application at tillering (40-45) and jointing (60-65 DAS). This might be due to the involvement of potassium in cell division and cell expansion as well as the positive influence of potassium on water and nutrient uptake, thus creating the cell turgor necessary for growth, resulting in higher plant height. (Shivashankar and Singh, 2022) [21].

No of ear head
The analysis of variance of data indicated (Table no 1.0) that potassium levels for foliar had significant effect on number of ear head. A critical examination of data further manifested that 4% foliar (K_3 treatment) application of K_2O recorded significantly higher number of ear head (295.44 sq.m.) over the control. Potassium is on the key macro element which is needed by crop. It has many functions in plant to perform in plants, as enzyme activation (involved in the processes of metabolism, photosynthesis starch synthesis, reduction of nitrate, reduces loss of water, nutrients and water uptake, counters climate effect (Cui *et al*., 2022) [12]

Physiological maturity
Data presented in Table 1.0, the maximum days to maturity (118.56) attend numerically with F_3 treatment (4% K application at tillering and jointing) and it was statistically at par with F_2 treatment (114.22). Its might be due to reduces the water stress and increase the photosynthesis and also improve the source to sink ratio and crop attend the maximum days to maturity and ultimately increase the seed production.

Ear length (cm)
A perusal of data (Table 2.0) fingered out significant influence of potassium spray on ear length (cm) of wheat. Application of 4% K application at tillering and jointing (K_3 treatment) gave significantly higher ear length (7.17) over water spray control (6.53). Aown *et al*., (2012) [26] reported foliar application of K improved the grain yield and other yield components. The foliar application of K was more effective at flowering.

No of grain ear
Data clearly indicated (Table 2.0) that due to foliar spray K_2O there was a significant improvement in the grains per ear, wherein; application of K_2O foliar spray (K_3 treatment) (32.68) recorded appreciably grains per ear over K_1 treatment (29.11) and being at par with treatment K_2 (31.43).

Test weight (g)
Data pertaining to test weight of wheat as influenced by due to potassium foliar spray are presented in Table 2.0. A perusal of the data also exhibited that foliar spray of potassium 4% at tillering and jointing (K_3 treatment) significantly increased the test weight (44.03) of wheat over water spray (38.43) (K_1 treatment). Whereas, K_3 treatment found at par with K_2 treatment (41.06) in case of K_2O foliar spray. However, few studies have explored the mechanisms and effects of foliar application of potassium on morphophysiological and agronomic characteristics, and whether these substances actually lead to an increase in production.

Biological yield (kg/ha)
Data further from Table no 2.0 indicated that significantly higher bio yield (7112 kg/ha) was obtain from K_3 treatment (4% K application at tillering and jointing) as compare to K_1 treatment (Water spray). K application is directly related to photosynthesis, as they increase the transpiration and stomatal conductance of irrigated plants and mitigate the effects on plants under stress. It has been suggested that plants mineral nutrient status plays a vital role in improving the resistance of plant to stress conditions (Yadov, 2006) [24]

Grain yield (kg/ha)
Data presented in Table no 2.0 sharply indicated that grain yield (3244) of wheat significantly higher recorded spray with 4% K at tillering and jointing (F3 treatment) over the control (2764). Whereas F_2 treatment (2% K application at tillering (40-45) and jointing (60-65 DAS) produced 3024 kg/ ha grain yield which found at par with F_3 treatment. foliar application of K improved the grain yield and other yield components.

The foliar application of K was more effective at flowering stage under water stress than other stages and improved the spike length and number of grains per spike, ultimately increase the grain yield of wheat. Aown *et al.,* (2012) [26]. It was indicated by many investigators that potassium played a key role in the osmotic adjustment (Stomatal opening) of plants under water stress and yield may be improved due to foliar potassium application to plants (Foyer *et al.,* 2002) [14].

Table 1: Effect of levels of irrigation and spray of potassium on plant population, plant height no. of ear head and maturity days of wheat

Treatments	Plant stand at harvest (sq. m)	Plant height at harvest (cm)	No of ear head (Sq. m.)	Physiological maturity (days after seeding)
Irrigation levels				
I_1	85.11	65.42	279.78	110.33
I_2	83.89	66.24	284.44	114.00
I_3	87.44	70.56	288.36	118.22
S.Em+	2.68	0.89	5.00	2.76
CD (P = 0.05)	NS	3.48	NS	NS
CV%	9.40	3.95	5.29	7.24
K_2O foliar spray				
K_1	85.11	64.43	276.11	109.78
K_2	83.67	66.27	280.67	114.22
K_3	87.67	71.51	295.44	118.56
S.Em+	1.15	1.69	4.83	2.37
CD (P = 0.05)	NS	5.21	14.89	NS
CV%	4.05	7.53	5.10	6.23

Table 2: Effect of levels of irrigation and spray of K_2O on yield & yield attributes of wheat

Treatments	Ear length (cm)	No of grain /ear	Test weight (g)	Biological yield (kg. ha.)	Grain yield (kg. ha.)
Irrigation levels					
I_1	6.48	28.89	40.41	5973	2696
I_2	6.82	29.68	40.77	7248	2968
I_3	7.12	34.65	42.33	7751	3367
S.Em+	0.11	0.99	0.86	202	83
CD (P = 0.05)	0.43	3.91	NS	795	324
CV%	4.83	9.60	6.30	8.69	8.23
K_2O foliar spray					
K_1	6.53	29.11	38.43	6901	2764
K_2	6.73	31.43	41.06	6958	3024
K_3	7.17	32.68	44.03	7112	3244
S.Em+	0.15	0.50	0.72	192	73
CD (P = 0.05)	0.46	1.55	2.22	591	226
CV%	6.54	4.86	5.25	8.23	7.30

Conclusion

The values for all the growth, yield & yield components of wheat markedly increased with the application of restricted irrigation at CRI, late jointing and milking stage along with 4% foliar spray of potassium at tillering (40-45) and jointing (60-65 DAS) stages.

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