International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 2813-2821

Received: 01-07-2019
Accepted: 03-08-2019

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Effect of moisture stress in wheat (*Triticum aestivum* L.)

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Abstract
A field experiment on Effect of Moisture Stress in wheat (*Triticum aestivum* L.) was carried out at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *rabi* season of 2017-18. The four treatments consisted of depriving of irrigation in main plots *viz.*, I_1 : No stress (8 irrigation), I_2 : Depriving of irrigation at CRI stage (21 DAS), I_3 : Depriving of irrigation at flowering stage (65 DAS) and I_4 : Depriving of irrigation at grain formation stage (75 DAS) as well as four moisture stress management treatments in sub plot *viz.*, M_1 : Seed hardening with 2% $CaCl_2$, M_2 : Seed hardening with 2% CaCl2 + 0.5% KCl spray at 60 DAS, M3 : Seed hardening with 2% $CaCl_2$ + 3% Kaolin spray at 60 DAS and M_4 : Seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin spray at 70 DAS was laid out in split plot design with four replications in loamy sand soil. Growing of wheat crop without moisture stress (I_1) and seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin spray at 70 DAS recorded maximum values of growth parameters like plant height, dry matter per plant, number of tillers per meter row length, earhead length, number of leaves per plant, leaf length, leaf width and yield attributes like number of earhead per meter row length, number of grain per earhead, grain yield per plant and test weight. Application of irrigation without any stress (I_1) and seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin at 70 DAS (M_4) recorded significantly higher seed and straw yield over depriving of irrigation at CRI stage ($I_{2)}$ and seed hardening with 2% $CaCl_2$ only (M_1), respectively.

Keywords: Moisture, wheat, yield and growth

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important staple food crop of about one third population of the world as well as India. In India, it is grown since ancient times, evidences from Mohen-Jo-Daro excavations indicated that wheat was cultivated since more than 5000 years ago. This crop is mainly responsible for the green revolution and mitigating the problem of food insecurity in India. It is cultivated under diverse growing conditions of soil and climate. In India, it is the second most important food crop after rice. It is an excellent health-building food containing approximately 78% carbohydrates, 12% protein, 2% fat and minerals each and considerable amount of vitamins (Kumar *et al.*, 2011) [14]. About 80 to 85% of wheat grains are ground into flour and consumed in the form of chapaties. Soft wheat is used for making chapaties, bread, cake, biscuits, pastry and other bakery products. Hard wheat is used for manufacturing rawa, suji and sewaya. In areas where rice is a staple food grain, wheat is eaten in the form of puri and uppama. It is also used for making flakes and sweet meals like kheer and shira. Apart from food purposes, wheat grains have also industrial importance for manufacturing paste, alcohol, oil, gluten *etc*. Residues obtained after milling *i.e*. bran used as cattle feed. Wheat straw is utilized as a fodder for feeding the livestock during drought year and also useful in manufacturing mattresses, straw hats, paper and articles of art purpose. India has the largest area under wheat (30.6 million hectares) but ranks second in production (96.5 million tonnes) after China with the average productivity of 3154 kg/ha (GOI, 2016).

Among the various production inputs, judicious water use and balanced nutrients are considered as the two key inputs for making maximum contribution to crop productivity. Water is a structural constituent of plant cells and it maintains the cell turgor pressure. When plenty of water is available, cells are turgid and plants retain their structural form. Water accounts for the largest part of the body weight of an actively growing plant and it constitutes about 85-90 per cent of body weight of young plants and 20 to 50 per cent of older or mature plants. Water serves as a solvent of substances and a medium in plants allowing metabolic reactions to occur. Moreover, water is also helps in the germination of seeds, photosynthesis, transport of the minerals and nutrients and also maintains the plant structure. Agricultural productivity cannot be maintained without assured supply of moisture to the plant which is accomplished by irrigation. Deficit of irrigation at any critical growth stage can drastically reduce crop yield. So, it is very important to find out the depriving of irrigation at critical growth stage of wheat.

As irrigation water is scarce and costly input, its economic and scientific utilization and optimal allocation among the different crops grown becomes quite imperative. Wheat is highly sensitive to water stress during the crown root initiation (CRI) and flowering but excess irrigation may lead to heavy vegetative growth and shortening of reproductive period and ultimately decrease the yield. Thus, timing of the length of irrigation interval with the growth stages of crop might be reduced the number of irrigations and results in an economic crop yield. In principle, irrigation should be given while the soil water potential is still high enough to enable soil to supply water fast enough to meet the local atmospheric demands without placing the plants under stress that would reduce yield and quality of harvested crop. Although, a high water status throughout the growing season is necessary to maintain unimpaired crop growth and high economic yield, the imposition of some stress by longer irrigation intervals during vegetative or maturation by way of narrowing or widening IW/CPE ratio could attain similar economic yields as well as saving of irrigation water and improving water use efficiency. In general, irrigation is being scheduled on the basis of climatological approach (IW/CPE ratio) during entire period of crop irrespective of the stage of growth. But proper scheduling of irrigation is necessary at both vegetative and reproductive phases to maintain the optimum moisture regime for better growth and development of crop.

Drought is one of the most important biotic stress, which affect the growth and development of plant and also a major hindrance for higher productivity of crops under arid and semi arid conditions. Drought stress depends not only on the duration and intensity of water stress but also on the developmental phase at which the stress is occurred. Drought induces many morphological, physiological, genetical, biochemical and molecular responses in plants to develop tolerance mechanisms (Gholamin *et al.*, 2010) [8]. Some of these mechanisms of plant modified to acclimatize and survive under water stress condition are early maturity, development of plasticity, maintaining water uptake, reducing water loss by shedding leaves, reflection of excess sun rays, closing stomata, and reducing cuticular conductance, maintenance of turgor pressure, accumulation of amino acids like proline and glycine and synthesis of growth regulator.

Various drought management practices have been developed to cope up with the moisture stress condition and to increase the crop yield per unit amount of water used. Some of the important moisture stress management practices, which play key role in improving and sustaining crop production under moisture stress condition are seed hardening and antitranspirant resistant.

Seed hardening modifies the physiological and biochemical nature of seeds which are favourable for drought tolerance. Seed hardening with 2% $CaCl_2$ increased morpho-physiological traits like plant height, number of leaf lets, leaf dry matter and total dry matter accumulation, leaf area per plant and harvest index (Manjunath and Dhanoji, 2011) [16]. Moreover, seed hardening has been reported to induce drought resistance in plants and enhances the capacity of seeds to withstand dehydration and overheating. Other beneficial effects of seed hardening are better root growth, higher rate of photosynthesis and larger dry matter accumulation (Henckel, 1964) [11]. Potassium plays vital role under moisture stress condition by stimulating biological process in the plant cell such as enzymes activation, respiration, photosynthesis, chlorophyll synthesis, carbohydrate formation, water balance and stomata opening (Mesbah, 2009) [20]. The KCl foliar spray helps plant to maintain higher water potential as potassium plays important role in osmoregulation and thereby it increases osmotic potential of leaves, which causes reduction in loss of water from leaves. As most of the water absorbed by plants is lost by transpiration, reducing plant transpiration could conserve irrigation water and minimize plant water stress. So, that spraying of antitranspirant results in higher relative water content and water use efficiency (Mishra, 1996) [22]. The term antitranspirants refers to a series of compounds intended for reducing the transpiration loss of water occurring mainly through stomatal pores present on leaf surface or from plant surface (Plaut, 2007) [27].

Material and Methods

A field experiment on effect of moisture stress in wheat (*Triticum aestivum* L.) was carried out at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *rabi* season of 2017-18. The four treatments consisted of depriving of irrigation in main plots *viz.*, I_1 : No stress (8 irrigation), I_2 : Depriving of irrigation at CRI stage (21 DAS), I_3 : Depriving of irrigation at flowering stage (65 DAS) and I_4 : Depriving of irrigation at grain formation stage (75 DAS) as well as four moisture stress management treatments in sub plot *viz.*, M_1 : Seed hardening with 2% $CaCl_2$, M_2 : Seed hardening with 2% $CaCl_2$ + 0.5% KCl spray at 60 DAS, M_3 : Seed hardening with 2% $CaCl_2$ + 3% Kaolin spray at 60 DAS and M_4 : Seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin spray at 70 DAS was laid out in split plot design with four replications in loamy sand soil were tried in Split plot design with four replication. Wheat variety GW 451 was used as test crop. The details of treatments tested in the present investigation on effect of moisture stress in wheat (*Triticum aestivum* L.) are as follows:

Details of treatments

[A] Depriving of irrigation (I) (Main plot)

I_1: No stress (8 irrigations)
I_2: Depriving of irrigation at CRI stage (21 DAS)
I_3: Depriving of irrigation at flowering stage (65 DAS)
I_4: Depriving of irrigation at grain formation stage (75 DAS)

[B] Moisture stress management (M) (Sub plot)

M_1: Seed hardening with 2% CaCl2
M_2: Seed hardening with 2% CaCl2 + 0.5% KCl spray at 60 DAS
M_3: Seed hardening with 2% CaCl2+ 3% Kaolin spray at 60 DAS
M_4: Seed hardening with 2% CaCl2 + 0.5% KCl + 3% Kaolin spray at 70 DAS

Table 1: Treatment combinations

Sr. No.	Symbol	Depriving of irrigation	Moisture stress management
1.	T_1:I_1M_1	No stress (8 irrigations)	Seed hardening with 2% CaCl2
2.	T_2:I_1M_2	No stress (8 irrigations)	Seed hardening with 2% CaCl2 + 0.5% KCl spray at 60 DAS
3.	T_3:I_1M_3	No stress (8irrigations)	Seed hardening with 2% CaCl2 + 3% Kaolin spray at 60 DAS
4.	T_4:I_1M_4	No stress (8 irrigations)	Seed hardening with 2% CaCl2 + 0.5% KCl + 3% Kaolin spray at 70 DAS
5.	T_5:I_2M_1	Depriving of irrigation at CRI stage (21 DAS)	Seed hardening with 2% CaCl2
6.	T_6:I_2M_2	Depriving of irrigation at CRI stage (21 DAS)	Seed hardening with 2% CaCl2 + 0.5% KCl spray at 60 DAS
7.	T_7:I_2M_3	Depriving of irrigation at CRI stage (21 DAS)	Seed hardening with 2% CaCl2 + 3% Kaolin spray at 60 DAS
8.	T_8:I_2M_4	Depriving of irrigation at CRI stage (21 DAS)	Seed hardening with 2% CaCl2 + 0.5% KCl + 3% Kaolin spray at 70 DAS
9.	T_9:I_3M_1	Depriving of irrigation at flowering stage (65 DAS)	Seed hardening with 2% CaCl2
10.	T_{10}:I_3M_2	Depriving of irrigation at flowering stage (65 DAS)	Seed hardening with 2% CaCl2 + 0.5% KCl spray at 60 DAS
11.	T_{11}:I_3M_3	Depriving of irrigation at flowering stage (65 DAS)	Seed hardening with 2% CaCl2 + 3% Kaolin spray at 60 DAS
12.	T_{12}:I_3M_4	Depriving of irrigation at flowering stage (65 DAS)	Seed hardening with 2% CaCl2 + 0.5% KCl + 3% Kaolin spray at 70 DAS
13.	T_{13}:I_4M_1	Depriving of irrigation at grain formation stage (75 DAS)	Seed hardening with 2% CaCl2
14.	T_{14}:I_4M_2	Depriving of irrigation at grain formation stage (75 DAS)	Seed hardening with 2% CaCl2 + 0.5% KCl spray at 60 DAS
15.	T_{15}:I_4M_3	Depriving of irrigation at grain formation stage (75 DAS)	Seed hardening with 2% CaCl2 + 3% Kaolin spray at 60 DAS
16.	T_{16}:I_4M_4	Depriving of irrigation at grain formation stage (75 DAS)	Seed hardening with 2% CaCl2 + 0.5% KCl + 3% Kaolin spray

Note: Nitrogen will be applied through urea and phosphorus will be applied through DAP.

The observations of the study was growth parameters like plant height, dry matter per plant, number of tillers per meter row length, earhead length, number of leaves per plant, leaf length, leaf width and yield attributes like number of earhead per meter row length, number of grain per earhead, grain yield per plant and test weight recorded after complete sun drying, the bundles were weighed just before threshing to record biological yield with the help of balance. Net plot wise threshing and cleaning were done manually. The seed yield received from net plot wise recorded by weighing with the help of electronic balance up to two decimal. All dose of phosphorus (60 kg ha^{-1}) and half dose of nitrogen (60 kg ha^{-1}) were applied as basal dose at sowing time and remaining half dose of nitrogen (60 kg ha^{-1}) was applied in two equal split *i.e.* 25 and 45 DAS. The source of nitrogen and phosphorus was urea and DAP, respectively. Light planking was done after basal application of fertilizers. During the present investigation, wheat variety GW 451 was taken for the experimentation. This is the latest variety of wheat released by Main Wheat Research Station, Vijapur (Gujarat) during the year of 2015 for general cultivation. One hundred twenty kg seeds of wheat GW 451variety were treated with 2% $CaCl_2$ and sown on 15th November, 2017 to a depth of 4-5 cm by drilling keeping inter-row spacing of 22.5 cm between the two rows and lightly covered with the soil. There is an urgent need to concentrate the work on how best the productivity potential of wheat under moisture stress conditions can be enhanced by integrating suitable ameliorative measures to overcome the effect of moisture stress condition. But, the study on these aspects in managing the moisture stress in wheat is very meager and therefore, there is an urgent need to improve the productivity potential of wheat under receding soil moisture conditions.

Results and discussion

Growth

Effect of depriving of irrigation on plant height

Data outlined in Table 2 indicated that the plant height of wheat was significantly influenced due to different treatments of depriving of irrigation at 30, 60, 90 DAS and at time of harvesting. Significantly the tallest plant height of 40.38, 70.63, 89.72 and 94.72 cm was recorded by irrigating the wheat crop without no stress at 30, 60, 90 DAS and at harvest, respectively. In case of 30 DAS, the highest plant height was recorded in no stress of moisture was followed by depriving of irrigation at flowering and grain formation stages. Moreover, the plant height remained equal at depriving of irrigation at flowering stage and grain formation stage at 60 and 90 DAS and at the time harvest. The smaller plant height of 35.16, 64.32, 71.74 and 78.99 cm was recorded by depriving of irrigation at CRI stage of wheat at 30, 60, 90 DAS and at harvest, respectively.

The optimum moisture supplied under no stress treatment promoted the division and expansion of cell components and there by stem elongation which virtually increased the plant growth in terms of plant height and ultimately recorded tallest plants. Smaller plant height was observed under treatment of depriving of irrigation at CRI stage (I_2) might be due to reduction in cell enlargement and stem elongation.

Table 2: Effect of depriving of irrigation and moisture stress management on plant height of wheat

Treatments				Plant height (cm)			
				30 DAS	60 DAS	90 DAS	At harvest
A.	**Main plot : Depriving of irrigation (I)**						
	I_1	:	No stress (8 irrigation)	40.38	70.63	89.72	94.72
	I_2	:	Depriving of irrigation at CRI stage (21 DAS)	35.16	64.32	71.74	78.99
	I_3	:	Depriving of irrigation at flowering stage (65 DAS)	37.43	66.23	79.76	84.76
	I_4	:	Depriving of irrigation at grain formation stage (75 DAS)	36.22	65.92	76.48	81.16
S.Em.±				0.92	1.35	2.31	2.71
C.D. at 5%				2.94	4.33	7.40	8.68
C. V. (%)				9.85	8.11	10.12	11.51
B.	**Sub plot : Moisture stress management (M)**						
	M_1	:	Seed hardening with 2% $CaCl_2$	36.00	65.48	71.66	76.91
	M_2	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl at 60 DAS	36.98	66.48	75.87	81.00
	M_3	:	Seed hardening with 2% $CaCl_2$ + 3% Kaolin at 60 DAS	37.62	66.99	81.16	87.55
	M_4	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin at 70 DAS	38.59	68.14	89.01	94.16
S.Em.±				0.76	0.87	1.89	2.01
C.D. at 5%				NS	NS	5.42	5.77
Interaction (I × M)							
C.D. at 5%				NS	NS	NS	NS
C. V. (%)				8.13	5.23	9.52	9.47

Patil *et al*. (2014) [26] reported that the highest plant height of wheat crop was recorded byirrigating the crop at CRI +100 CPE over irrigation at CRI only. These results are also in agreement with those reported by Bramha *et al.* (2007), Patel *et al.* (2010) [25], Patel *et al.* (2010) [25], Verma *et al.* (2010) [35], Rafiei *et al.* (2011) [28], Aown *et al.* (2012) [4].

Effect of moisture stress management on plant height

Data presented in Table 2 indicated that the moisture stress management treatments failed to exert significant influence on plant height during 30 and 60 DAS but plant height at 90 DAS and at the time of harvest was significantly influenced by moisture stress management treatments. The seed hardening with 2% $CaCl_2$ along with spraying of 0.5% KCl and 3% Kaolin (M_4) registered significantly the tallest plant height of 89.01 cm and 94.16 cm at 90 DAS and at the time of harvesting, respectively. Seed hardening of wheat crop with 2% $CaCl_2$ recorded significantly smallest plant height of 71.66 and 76.91 cm during 90 DAS and at the time of harvesting, respectively.

The superior performance of seed hardening with 2% $CaCl_2$+ 0.5% KCl spray + 3% Kaolin spray treatment may be attributed to integrated moisture-stress management practices. Moreover, seed hardening with $CaCl_2$ might be promoted germination and quick establishment, spraying of KCl benefited crop by osmoregulation and application of kaolin as an antitranspirant avoided excess evapotranspiration which virtually increased the plant growth in terms of plant height. Aown *et al.* (2012) [4] revealed that foliar application of 1% potassium at all three critical growth stages improved the drought tolerance of plants and improved the growth parameters. These results are also in agreement with the findings of Manjunath and Dhanoji (2010), Laxminarayanappa *et al.* (2011) [16] and Kanwar *et al.* (2017) [12].

Effect of depriving of irrigation on number of tillers per meter row length

An investigation of data showed in Table 3 revealed that the number of tillers per meter row length was significantly influenced by different treatments of depriving of irrigation. Significantly the highest number of tillers per meter row length (156.6) was obtained when wheat crop was grown under no stress (I_1) and which was to the tune of 22.7, 12.2 and 16.3 per cent higher than that of depriving of irrigation at CRI stage (I_2), depriving of irrigation at flowering stage (I_3) and depriving of irrigation at grain formation stage (I_4), respectively. Moreover, depriving of irrigation at flowering stage (I_3) was remained at par with the depriving of irrigation at grain formation stage (I_4). Significantly the lowest number of tillers per meter row length (127.6) was recorded by the depriving of irrigation at CRI stage (I_2).

Bramha *et al.* (2007) reported that irrigations scheduled at five critical growth stages *viz*., crown root initiation (CRI) + tillering + late jointing + flowering + milk stage recorded higher number of effective tillers per meter row length as compared to control.

This might be owing to adequate availability of water and better conductive rhizosphere environment for higher uptake of nutrients which in turn boost the growth and development leading to more number of tillers per plants. The results are in close conformity with those of Kumar *et al.* (2013) [15], Singh *et al.* (2013) [31] and Tyagi *et al.* (2015) [34].

Effect of moisture stress management on number of tillers per meter row length

The data presented in Table 3 indicated the number of tillers per meter row length significantly influenced by the different moisture stress management practices. Significantly the highest number of tillers per meter row length (153.5) was obtained by seed hardening with 2% $CaCl_2$ along with spraying of 0.5% KCl and 3% Kaolin (M_4). Significantly the lowest number of tillers per meter row length was recorded under seed hardening with 2% $CaCl_2$ only (M_1). Seed hardening with 2% $CaCl_2$ along with spraying of 0.5% KCl and 3% Kaolin (M_4) recorded 8.3, 14.7 and 20.6 per cent higher number of tillers per meter row length than that of seed hardening with 2% $CaCl_2$+ spray of 3% Kaolin (M_3), seed hardening with 2% $CaCl_2$+ spray of 0.5% KCl (M_2) and seed hardening with 2% $CaCl_2$ (M_1), respectively. Bramha *et al.* (2007) found that spraying of 6% kaolin at 49 and 69 DAS recorded higher number of effective tillers per meter row length as compared to control.

Table 3: Effect of depriving of irrigation and moisture stress management on number of tillers per meter row length of wheat

Treatments				Number of tillers per meter row length
A.	**Main plot : Depriving of irrigation (I)**			
	I_1	:	No stress (8 irrigation)	156.6
	I_2	:	Depriving of irrigation at CRI stage (21 DAS)	127.6
	I_3	:	Depriving of irrigation at flowering stage (65 DAS)	139.6
	I_4	:	Depriving of irrigation at grain formation stage (75 DAS)	134.7
S.Em.±				3.61
C.D. at 5%				11.53
C. V. (%)				10.36
B.	**Sub plot : Moisture stress management (M)**			
	M_1	:	Seed hardening with 2% $CaCl_2$	127.5
	M_2	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl at 60 DAS	133.8
	M_3	:	Seed hardening with 2% $CaCl_2$ + 3% Kaolin at 60 DAS	141.7
	M_4	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin at 70 DAS	153.5
S.Em.±				3.05
C.D. at 5%				8.74
Interaction (I × M)				
C.D. at 5%				NS
C. V. (%)				8.76

The increase in number of tillers per meter row length was probably due to effects of seed hardening treatments on photosynthetic activity and tissue hydration and enabling the plant to resist soil moisture stress more efficiently (Henckel, 1964) [11]. (Mesbah, 2009) [20] reported that potassium plays vital role under moisture stress condition by stimulating biological process in the plant cell such as enzymes activation, respiration, photosynthesis, chlorophyll synthesis, carbohydrate formation, water balance and also stomata opening. Spraying of antitranspirant on wheat leaves increased nitrate reductase activity and reduced the transpiration rate at flowering stage, which resulted in higher number of tillers per meter row length. (Singh, 2007) [32]. The results are also in close conformity with those of Suryakant *et al.* (2001) [33] and Ansari *et al.* (2012) [3].

Effect of depriving of irrigation on earhead length

Data presented in Table 3 revealed that the earhead length significantly influenced by different treatments of depriving of irrigation. Significantly the highest earhead length (9.04 cm) was obtained under no stress condition (I_1). The per cent increase in earhead length under no moisture stress the (I_1) was 20.6, 13.0 and 26.0 over depriving of irrigation at grain formation stage (I_4), depriving of irrigation at flowering stage (I_3) and depriving of irrigation at CRI stage (I_2), respectively. Moreover, the depriving of irrigation at flowering stage (I_3) was at par with the depriving of irrigation at grain formation stage (I4). Significantly the lowest earhead length (7.17 cm) was recorded by the depriving of irrigation at CRI stage (I_2). Growing of wheat crop without moisture stress provides adequate moisture to the plant throughout the growing period of the crop which ultimately increased the photosynthesis activity of the plant leading to more translocation of phostosynthates from source to sink resulting in higher earhead length (Naseri *et al.* 2010). Sarkar *et al.* (2013) [30] reported that the highest earhead length was recorded by the application of five irrigations over four, three, two, one and no irrigation of wheat. The results are also in close conformity with findings of Singh *et al.* (2013) [31] and Krishna *et al.* (2017) [31].

Effect of moisture stress management on earhead length

The perusal data presented in Table 3 revealed that the earhead length was significantly influenced by moisture stress management. Significantly the highest earhead length (8.81 cm) was recorded by seed hardening with 2% $CaCl_2$ + spray of 0.5% KCl and 3% kaolin (M_4) and it was followed by seed hardening with 2% $CaCl_2$ + spray of 3% kaolin (M_3) and seed hardening with 2% $CaCl_2$+ spray of 0.5% KCl (M_2). Seed hardening with 2% $CaCl_2$+ spray of 0.5% KCl and 3% kaolin at 70 DAS (M_4) increased the earhead length to the magnitude of 9.0, 16.1 and 21.9 over seed hardening with 2% $CaCl_2$ + spray of 3% kaolin (M_3), seed hardening with 2% $CaCl_2$ + spray of 0.5% KCl (M_2) and seed hardening with 2% $CaCl_2$ (M_1), respectively. Significantly the lowest earhead length (7.23 cm) was recorded under the treatment of seed hardening with 2% CaCl2 only (M_1). Mesbah, (2009) [20] reported that potassium plays vital role under moisture stress condition by stimulating biological process in the plant cell such as enzymes activation, respiration, photosynthesis, chlorophyll synthesis, water balance and also stomata opening. Spraying of antitranspirant on wheat leaves increased photosynthesis, nitrate reductase activity and reduced the transpiration rate at flowering stage which ultimately resulting in higher earhead length. Patil *et al.* (2014) [26] reported that the seed hardening with CaCl2 + mycorrhizae + KCl + kaolin spray recorded the highest earhead length as compared to no moisture stress management. The results are also in close conformity with those of Meena *et al.* (2013) [19].

Effect of depriving of irrigation on number of leaves per plant

Data presented in Table 4 revealed that the number of leaves per plant significantly influenced by different depriving of irrigation. Significantly higher number of leaves per plant (22.6) was recorded by no moisture stress condition (I_1) and it was followed by depriving of irrigation at flowering stage (I_3) and grain formation stage (I_4). The minimum number of leaves per plant (17.9) was recorded by depriving of irrigation at CRI stage (I_2). The higher number of leaves per plant might be due to the higher plant height (Table 4) and favorable growth of wheat crop by the adequate availability of moisture which ultimately resulted in fully turgid and higher number of green leaves per plant. Jiotode *et al.* (2002) observed that scheduling of irrigation at 40 mm CPE in maize recorded higher number of leaves per plant over 60 and 80 mm CPE due to better water use. The present findings are also in accordance with the findings of Patil *et al.* (2014) [26] and Kumar *et al.* (2012) [3].

Table 4: Effect of depriving of irrigation and moisture stress management on number of leaves per plant of wheat

Treatments				Number of leaves per plant
A.	**Main plot : Depriving of irrigation (I)**			
	I_1	:	No stress (8 irrigation)	22.6
	I_2	:	Depriving of irrigation at CRI stage (21 DAS)	17.9
	I_3	:	Depriving of irrigation at flowering stage (65 DAS)	20.0
	I_4	:	Depriving of irrigation at grain formation stage (75 DAS)	18.7
S.Em.±				0.41
C.D. at 5%				1.32
C. V. (%)				8.31
B.	**Sub plot : Moisture stress management (M)**			
	M_1	:	Seed hardening with 2% $CaCl_2$	18.1
	M_2	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl at 60 DAS	19.0
	M_3	:	Seed hardening with 2% $CaCl_2$ + 3% Kaolin at 60 DAS	20.2
	M_4	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin at 70 DAS	22.0
S.Em.±				0.39
C.D. at 5%				1.13
Interaction (I × M)				
C.D. at 5%				NS
C. V. (%)				7.95

Effect of moisture stress management on number of leaves per plant

The data presented in Table 4 revealed that effect of moisture stress management had significant influence on the number of leaves per plant. Seed hardening with 2% $CaCl_2$ + 0.5% KCl and 3% kaolin spray (M_4) recorded significantly higher number of leaves per plant (22.0) and it was followed by seed hardening with 2% $CaCl_2$ + spray of 3% kaolin (M_3) and seed hardening with 2% $CaCl_2$ + 0.5% KCl spray (M_2). Seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% kaolin spray recorded 21.54 per cent higher number of leaves per plant than that of seed hardening with 2% $CaCl_2$ only (M_1). Seed hardening with $CaCl_2$ (2%) (M_1) recorded significantly minimum number of leaves per plant (18.1). This might be due to more plant height (Table 4) and more number of tillers per plant (Table 4) Laxminarayanappa *et al.* (2011) [16] found that seed hardening with 2% $CaCl_2$ recorded significantly higher number of leaflet per plant as compared to rest of the treatments. The results are also in close conformity with those of Manjunath and Dhanoji (2010).

Interaction effect

The interaction effect of depriving of irrigation and moisture stress management on plant height, number of leaves per plant, earhead length, number of tillers per meter row length was found non-significant.

Yield

Effect of depriving of irrigation on grain yield

The data regarding grain yield per hectare as influenced by depriving of irrigation and moisture stress management are summarized in Table 5. Significantly the highest grain yield (4401 kg/ha) was obtained by growing of wheat crop under no stress of moisture (I_1) and it was to the magnitude of 17.5, 16.5 and 38.6 per cent higher than that of depriving of irrigation at grain formation stage (I_4), depriving of irrigation at flowering stage (I_3) and depriving of irrigation at CRI stage (I_2), respectively. Depriving of irrigation at flowering stage of wheat (I_3) was remained at par with the depriving of irrigation at grain formation stage (I_4). Significantly the lowest grain yield (3175 kg/ha) was obtained under depriving of irrigation at CRI stage (I_2). The remarkable increase in grain yield with the optimum moisture supplies might be attributed due to favorable effect on yield attributes *viz.*, number of earhead per meter row length), number of grains per earhead and grain yield per plant and test weight Brahma *et al.* (2007) [7] reported that irrigations scheduled at five critical growth stages *viz.*, crown root initiation (CRI), tillering, late jointing, flowering, milk stage resulted in significantly higher grain yield over one, two and three irrigations but was on par with four irrigations scheduled at CRI, tillering, late jointing, milk stage. These findings are in agreement with the findings of Afzal Ahmed (2016) [2], Mahmud *et al.* (2016) [17], Mishra and Kushwaha (2016) [21].

Effect of moisture stress management on grain yield

The data furnished in Table 5 revealed that the grain yield per hectare significantly influenced by moisture stress management. Significantly the highest grain yield (4329 kg/ha) was obtained under treatment of seed hardening with 2% $CaCl_2$ + spray of 0.5% KCl and 3% kaolin (M_4) and it was to the tune of 14.2, 20.4 and 27.9 per cent higher than that of seed hardening with 2% $CaCl_2$ and 3% kaolin spray (M_3), seed hardening with 2% $CaCl_2$ + 0.5% KCl spray (M_2) and seed hardening with 2% $CaCl_2$ (M1), respectively. Seed hardening with 2% CaCl2 + 3% kaolins pray (M_3) was remained at par with seed hardening with 2% $CaCl_2$ and 0.5% KCl spray (M_2). Significantly the lowest grain yield (3386 kg/ha) was obtained under treatment of seed hardening with 2% $CaCl_2$ (M_1). The increase in grain yield was probably due to beneficial effects of seed hardening treatments which might be increased the water absorbing capacity of seeds, photosynthetic activity and tissue hydration there by enabling the plant to resist soil moisture stress more efficiently (Henckel, 1964) [11]. Potassium plays vital role under moisture stress condition by stimulating biological process in the plant cell such as enzymes activation, respiration, photosynthesis, chlorophyll synthesis, water balance and stomata opening (Mesbah, 2009) [20]. Moreover, Singh (2007) [32] reported that spraying of antitranspirant on wheat leaves increased nitrate reductase activity and reduced the transpiration rate at flowering stage which resulted in higher grain yield per hectare. Gul *et al.* (2011) [10] reported that the higher grain yield was recorded by spraying of 0.5% N + 0.5% K + 0.5% Zn solution (twice) as compared to control. These findings are also in agreement with Khan *et al.* (2016) [13].

Table 5: Effect of depriving of irrigation and moisture stress management on grain yield of wheat

Treatments				Grain yield (kg/ha)
A.	**Main plot : Depriving of irrigation (I)**			
	I_1	:	No stress (8 irrigation)	4401
	I_2	:	Depriving of irrigation at CRI stage (21 DAS)	3175
	I_3	:	Depriving of irrigation at flowering stage (65 DAS)	3779
	I_4	:	Depriving of irrigation at grain formation stage (75 DAS)	3745
		S.Em.±		171.6
		C.D. at 5%		549.1
		C. V. (%)		18.1
B.		**Sub plot : Moisture stress management (M)**		
	M_1	:	Seed hardening with 2% $CaCl_2$	3386
	M_2	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl at 60 DAS	3595
	M_3	:	Seed hardening with 2% $CaCl_2$ + 3% Kaolin at 60 DAS	3790
	M_4	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin at 70 DAS	4329
		S.Em.±		86.6
		C.D. at 5%		248.5
		Interaction (I × M)		
		C.D. at 5%		NS
		C. V. (%)		9.17

Effect of depriving of irrigation on straw yield

A perusal of data revealed that straw yield per hectare was significantly influenced by depriving of irrigation (Table 6) Significantly the highest straw yield (6401 kg/ha) was obtained by growing of wheat crop under no stress of water (I_1) and it was to the magnitude of 9.6, 9.0 and 23.7per cent higher than that of depriving of irrigation at grain formation stage (I_4), depriving of irrigation at flowering stage (I_3) and depriving of irrigation at CRI stage (I_2), respectively. Depriving of irrigation at flowering stage of wheat (I_3) was remained at par with depriving of irrigation at grain formation stage (I_4). Significantly the lowest straw yield (5175 kg/ha) was obtained under depriving of irrigation at CRI stage (I_2). Higher straw yield under no stress of moisture might be due to better vegetative growth in terms of dry matter per plant, plant height and number of tillers per plant which obviously resulted into more straw yield. Tyagi *et al.* (2015) [34] reported that four irrigations gave significantly higher grain and straw yield as compared to control. These findings are in agreement with findings of Nayak *et al.* (2015) [24] and Salunkhe *et al.* (2015) [29].

Effect of moisture stress management on straw yield

An appraisal of results in Table 6 showed that the effect of moisture stress management on straw yield per hectare was significant. Significantly the highest straw yield (6375 kg/ha) was obtained under the treatment of seed hardening with 2% $CaCl_2$ + spray of 0.5% KCl and 3% kaolin (M_4) which was to the tune of 9.2, 13.0 and 17.4 per cent higher than that of seed hardening with 2% $CaCl_2$ and spray of 3% kaolin (M_3), seed hardening with 2% $CaCl_2$ + 0.5% KCl (M_2) and seed hardening with 2% $CaCl_2$ (M_1), respectively. Seed hardening with 2% $CaCl_2$ + spray of 3% kaolin (M_3) was remained at par with seed hardening with 2% $CaCl_2$ and 0.5% KCl (M_2). Significantly the lowest grain yield (5432 kg/ha) was obtained under treatment of seed hardening with 2% CaCl2 (M_1). This might be due to the more growth and yield attributing characters like plant height, number of tillers per plant, number of leaves per plant, leaf length and leaf width The yield production capacity is directly proportional to the photosynthetic activity of plant and which is largely depends upon dry matter accumulation in leaf, leaf area index and leaf area duration which also plays important role in determining the capacity of the plants in trapping solar energy for photosynthesis. Nateghi *et al.* (2013) [23] observed that the highest straw yield was recorded by the application of 3.25% kaolin as compared to without spraying. These findings are in agreement with findings of Badukale *et al.* (2015) [5] and Amal *et al*. (2011) [2].

Table 6: Effect of depriving of irrigation and moisture stress management on straw yield of wheat

Treatments				Straw yield (kg/ha)
A.	**Main plot : Depriving of irrigation (I)**			
	I_1	:	No stress (8 irrigation)	6401
	I_2	:	Depriving of irrigation at CRI stage (21 DAS)	5175
	I_3	:	Depriving of irrigation at flowering stage (65 DAS)	5872
	I_4	:	Depriving of irrigation at grain formation stage (75 DAS)	5838
S.Em.±				161.8
C.D. at 5%				517.5
C. V. (%)				11.11
B.	**Sub plot : Moisture stress management (M)**			
	M_1	:	Seed hardening with 2% $CaCl_2$	5432
	M_2	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl at 60 DAS	5641
	M_3	:	Seed hardening with 2% $CaCl_2$ + 3% Kaolin at 60 DAS	5836
	M_4	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin at 70 DAS	6375
S.Em.±				82.96
C.D. at 5%				236.8
Interaction (I × M)				
C.D. at 5%				NS
C. V. (%)				5.67

Effect of depriving of irrigation on harvest index

A perusal of data outlined in the Table 7 revealed that the harvest index was significantly influenced by depriving of irrigation. Significantly the highest harvest index (40.6) was obtained under the treatment of no stress of moisture (I_1) and which was increased to the tune 4.3, 3.8 and 7.4 per cent higher than that of depriving of irrigation at grain formation stage (I_4), depriving of irrigation at flowering stage (I_3) and depriving of irrigation at CRI stage (I_2), respectively. Depriving of irrigation at flowering stage of wheat (I_3) was remained at par with the depriving of irrigation at grain formation stage (I_4). Significantly the lowest test weight (37.8) was obtained under treatment of depriving of irrigation at CRI stage (I_2). This might be due to the sufficient water applied in the reproductive phase leading to more amount of assimilates diverted towards the sink and which ultimately provided larger ratio of grain to biological yield. Idnani and Kumar (2012) [3] reported that irrigation at CRI stage + 100 mm CPE registered significantly highest grain yield, straw yield and harvest index over the irrigation at CRI stage only in wheat. These findings are in agreement with findings of Bhari and Sah (2013) [6].

Table 7: Effect of depriving of irrigation and moisture stress management on harvest index of wheat

Treatments				Harvest index (%)
A.	**Main plot : Depriving of irrigation (I)**			
	I_1	:	No stress (8 irrigation)	40.6
	I_2	:	Depriving of irrigation at CRI stage (21 DAS)	37.8
	I_3	:	Depriving of irrigation at flowering stage (65 DAS)	39.1
	I_4	:	Depriving of irrigation at grain formation stage (75 DAS)	38.9
S.Em.±				0.47
C.D. at 5%				1.49
C. V. (%)				4.77
B.	**Sub plot : Moisture stress management (M)**			
	M_1	:	Seed hardening with 2% $CaCl_2$	38.1
	M_2	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl at 60 DAS	38.8
	M_3	:	Seed hardening with 2% $CaCl_2$ + 3% Kaolin at 60 DAS	39.2
	M_4	:	Seed hardening with 2% $CaCl_2$ + 0.5% KCl + 3% Kaolin at 70 DAS	40.3
S.Em.±				0.27
C.D. at 5%				0.79
Interaction (I × M)				
C.D. at 5%				NS
C. V. (%)				2.81

Effect of moisture stress management on harvest index

An appraisal of results, presented in Table 7 showed that the effect of moisture stress management was on harvest index was found significant. Significantly the highest harvest index (40.3) was obtained under the treatment of seed hardening with 2% $CaCl_2$ + 0.5% KCl and 3% kaolin spray (M_4) and it was followed by seed hardening with 2% $CaCl_2$ + 3% kaolin spray (M_3) and seed hardening with 2% $CaCl_2$ + 0.5% KCl spray (M_2). Significantly lowest harvest index (38.1) was obtained under treatment seed hardening with 2% $CaCl_2$ (M_1).

Interaction effect

An appraisal of data in Table 7 indicated that the interaction effect of depriving of irrigation and moisture stress management did not exert any significant influence on the grain yield, straw yield and harvest index.

Conclusion

In light of results obtained from present investigation, it can be concluded that growing of wheat crop without moisture stress and seed hardening with 2% CaCl2 along with 0.5% KCl and 3% Kaolin spray at 70 DAS was recorded the maximum growth and yield.

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