

**EFFECT OF MOISTURE STRESS AND IT'S MANAGEMENT
PRACTICES ON GROWTH AND YIELD OF WHEAT
(*Triticum aestivum* L.)**

by

Miss. Deshmukh Nikita Trimbak

(Reg. No. 016/003)

A Thesis submitted to the
**MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA**

in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRONOMY



DEPARTMENT OF AGRONOMY

**POST GRADUATE INSTITUTE
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2018

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I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institution
for a Degree or
Diploma

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The assistance and help received during the course of this investigation have been duly acknowledged.

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(N.T. Deshmukh)

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LIST OF ABBREVIATIONS

$^{\circ}\text{C}$	: Degree Celsius
@	: At the rate
%	: Per cent
B: C ratio	: Benefit Cost ratio
CD	: Critical Difference
cm	: Centimeter (s)
CO_2	: Carbon dioxide
CPE	: Cumulative pan evaporation
Cv.	: Cultivar
CRI	: Crown root initiation
DAS	: Days after sowing
dSm^{-1}	: DeciSeimens per meter
EC	: Electrical conductivity
ETc	: Crop evapotranspiration
ETo	: Reference evapotranspiration
<i>et al.</i>	: And others (etalli)
etc	: Excetera (and so on)
Even.	: Evening
FC	: Field capacity
Fig.	: Figure
FYM	: Farm yard manure
g	: Gram (s)
ha.	: Hectare
hrs.	: Hours
<i>i.e.</i>	: Id est (that is)
K	: Potassium
Kc	: Crop coefficient
KNO_3	: Potassium nitrate
Ky	: Yield response factor
l	: Litre

Met.week	:	Metrological week
Morn.	:	Morning
MOP	:	Murate of potash
N	:	Nitrogen
NS	:	Non-significant
P	:	Phosphorous
PE	:	Pan evaporation
PWP	:	Permanent wilting point
`	:	Rupees
RH	:	Relative humidity
S.Em.	:	Standard error of means
VAM	:	Vascular arbuscular mycorrhizae
viz.,	:	Videlicet (Namely)

ABSTRACT

EFFECT OF MOISTURE STRESS AND IT'S MANAGEMENT PRACTICES ON GROWTH AND YIELD OF WHEAT (*Triticum aestivum* L.)

By

Miss. Nikita Trimbak Deshmukh

A candidate for the degree of
MASTER OF SCIENCE (AGRICULTURE)
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2018

Research Guide	:	Dr. A.D. Tumbare
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A field experiment on “Effect of moisture stress and it’s management practices on growth and yield of wheat” was carried out during the *rabi* season of 2016-17 at Post Graduate Institute Research farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar Maharashtra (India).

The soil of experimental field was clay loam in texture, low in soil available nitrogen (228.94 kg ha⁻¹), medium in phosphorus (14.82 kg ha⁻¹) and high in available potassium (383.60 kg ha⁻¹) and 0.54 % organic carbon. The soil was slightly alkaline in reaction (pH 8.10) with 0.26 dSm⁻¹ electrical conductivity. The physical properties of soil viz., bulk density (1.24 g cm⁻³), field capacity (35.28 %) and permanent wilting point (18.25 %) indicates that the soil was moisture retentive.

The experiment was laid in split plot design with three replications. The treatment consist of six irrigation regimes as main plot treatments viz., I₁- Irrigation at crown root initiation stage; I₂- Irrigation at tillering stage; I₃- Irrigation at flowering stage; I₄- Irrigation at crown root initiation + tillering stage; I₅- Irrigation at crown root initiation + tillering + flowering stage and I₆- Irrigation at crown root initiation + tillering + flowering + milk stage and four sub-plot treatments viz., S₁- Control; S₂- vascular arbuscular mycorrhizae soil application @ 10 kg ha⁻¹; S₃- Foliar spray of 1 % KNO₃ spray at flowering and S₄- vascular arbuscular mycorrhizae soil application @ 10 kg ha⁻¹ + foliar spray of 1 % KNO₃ spray at flowering.

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1% KNO₃ at flowering recorded significantly higher growth attributes viz., plant height (92.70 cm), number of tillers meter⁻¹ row length (139), number of leaves plant⁻¹ at 56 DAS (17.87), dry matter meter⁻¹ row length

(406.73 g) and yield attributes *viz.*, number of grains panicle⁻¹ (68.67) and 1000 grain weight (36.67 g).

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1% KNO₃ at flowering recorded significantly higher grain yield (41 q ha⁻¹) and straw yield (53.98 q ha⁻¹). However, under limited availability of irrigation water scheduling of one irrigation at tillering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1% KNO₃ at flowering registered maximum grain (21.67 q ha⁻¹) and straw yield (28.56 q ha⁻¹) than scheduling of one irrigation to wheat crop at crown root initiation or flowering stage without any moisture stress management practices.

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1% KNO₃ at flowering to the wheat crop recorded significantly maximum total chlorophyll content (55.99 %), photosynthetic rate (34.90 μ mol CO₂ m⁻² s⁻¹), CO₂ concentration (380.25 μ mol CO₂ m⁻² s⁻¹), stomatal conductance (0.95 m mol m⁻² s⁻¹) and transpiration rate (8.81 m mol H₂O m⁻² s⁻¹) at 56 days after sowing. Whereas, scheduling of one irrigation to wheat crop at flowering stage without any moisture stress management practices (control) recorded significantly maximum stomatal resistance (4.33 μ mol m⁻² s⁻¹) and leaf temperature (30.75°C) at 84 days after sowing than rest of the treatment combinations.

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1% KNO₃ at flowering recorded significantly maximum protein content (12.35 %) and minimum glutenin (25.15 %) and lysine content (2.15 %) in wheat grain.

The crop water use of water increased with increase in number of irrigations. Maximum consumptive use (40.11 cm) of water was registered with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage coupled with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage.

The crop water use efficiency was increase with decrease in number of irrigations. Scheduling of one irrigation to wheat crop at crown root initiation coupled with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded maximum crop water use efficiency (208.24 kg ha⁻¹ -cm) than rest of the treatment combinations.

The maximum field water use efficiency ($96.30 \text{ Kg ha}^{-1}\text{-cm}$) was observed with scheduling of one irrigation to wheat crop at tillering stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage.

Among the treatment combinations, scheduling of one irrigation to wheat crop at tillering stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage registered maximum water productivity (0.96 kg m^{-3}) than rest of the treatment combinations.

Based on one season experiment, it could be concluded that scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 per cent potassium nitrate (KNO_3) at flowering stage recorded higher grain yield. However, under limited availability of irrigation water, scheduling of one irrigation at tillering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 per cent potassium nitrate (KNO_3) at flowering stage found suitable for maximum yield and monetary benefits.

1. INTRODUCTION

Wheat (*Triticum* spp.) belongs to the genus *Triticum* of the Poaceae (*Gramineae*) family originally from the Levant region of the Near East and Ethiopian Highlands, but now cultivated worldwide. The three species of wheat namely, *Triticum aestivum* (bread wheat), *Triticum durum* (macaroni wheat) and *Triticum dicoccum* (Emmer or Khapli wheat) grown on commercial basis in the Indian subcontinent from pre-historic times.

Wheat is a very adaptable crop and is grown under the wide range of soil and climatic conditions. The crop is most successfully grown between latitude of 57° N to 47° S (Billie, 1995). In India it is grown mostly in the plains where as in the hills it is cultivated in mountainous region of North India and Nilgiris and Palani hills in South India.

Wheat is consumed by human beings in form of flour for making chapaties, semolina and pasta products. It is also used for preparation of bread, biscuits, cookies, cracks, noodles, dalia, maida, vermicelli, etc. Wheat straw is also used for the animal feed as fodder and for packaging materials. Wheat contains nearly 70 % carbohydrates, 12 % protein, 1.7 % fat, 2.7 % minerals, 2% fiber and 12% moisture (Gupta *et al.*, 2002).

Wheat (*Triticum aestivum* L.) is one of the most important staple food crop of about one third population of world and is the common source of carbohydrate and protein. World's total wheat production was 754 million tonnes. India's share in global wheat production was recorded at 12.98 percent in year 2016-17 (Anon., 2016).

India's total cultivated area under wheat is 30.23 million ha with production of 93.50 million tonnes and average productivity of 3093 kg ha⁻¹. The leading state of wheat growing in India are Uttar Pradesh, Punjab, Madhya Pradesh, Haryana, Rajasthan, Bihar, Gujarat, Maharashtra, West Bengal and Himachal Pradesh. Among the states Uttar Pradesh holds first position in production of wheat (26.87 million tonnes). Maharashtra's total area under wheat is 0.63 million ha with production of 0.76 million tonnes and average productivity of 1205 kg ha⁻¹ (Anon., 2016).

Irrigation scheduling is one of the important managerial activities and affects the effective and efficient utilization of water by crops. It determines the process to decide when to irrigate the crops and how much water to apply. It optimizes agricultural production with minimizing yield loss due to water shortage and improving performance and sustainability of any irrigation system through conserving water. Scheduling of irrigation based on critical growth stages (crown root, tillering, flowering and dough stage) in wheat has been practical approach to the farmers. The impact of limited irrigation on crop yield and WUE depends on the growth stage and most sensitive stage vary region to region due to regional variability in environment and agronomic practices (Singh *et al.*, 2006a).

Under limited supply of water, irrigation schedule should be for the best adopted utilization for available quantity of water. Hamid Nawaz *et al.*, (2015) recommended that where only one irrigation was possible, scheduled at crown root initiation stage (20-25 days after sowing), where two irrigation are available, first irrigation should be given at crown root initiation stage and second at flowering stage, where three irrigation are possible, first irrigation should be given at crown root initiation, second at late jointing (boot) and third at milking stage. These recommendations strongly stress the importance of irrigation at CRI stage. It has been found that each week delay in first irrigation from crown root initiation stage results in yield reduction of 2-3 quintal per hectare.

Moisture stress is one of the most important abiotic 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. Moisture stress depends not only on the duration and intensity of water stress, but also on the developmental phase at which the stress is occurred. Plant growth and yield is the function of potential of the environment and its management. Once the potential of the environmental factors is understood, through management techniques efforts have to be made to provide the best possible growing conditions to achieve potential yields. Various agro-techniques or cultural practices developed on ecological principles help to manipulate agro ecosystem to ensure, minimum intra-specific and interspecific competition for the resources (Ahlawat and Rana, 1998).

Moisture stress induces many morphological, physiological, genetical, biochemical and molecular responses in plants to develop tolerance mechanisms (Gholamin *et al.*, 2010). 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 betaine and synthesis of growth regulator.

Various moisture stress 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. The Vascular Arbuscular Mycorrhizae (VAM) and potassium nitrate (KNO_3) plays dominant role in the moisture stress management practices.

The vascular arbuscular mycorrhizae are fungi that colonize roots of a large number of plant species, enhancing host drought resistance, modifying soil-plants water relations and increasing water absorption capacity, enhance drought tolerance to plants by tapping a large volume of soil, mobilization of scarce nutrient sources. Mycorrhizae can bind soil particles into larger aggregates, necessary for a stable and porous physical structure of soil (O'keefe and Sylvia, 1992).

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 in leaves and regulation of stomata opening as well as direct effect on the disease resistance (Mesbah, 2009). 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.

There is an urgent need to concentrate the work on how best the productivity potential under moisture stress conditions can be enhanced by integrating suitable ameliorative measures to overcome the effect of moisture stress due to which there is a great reduction in the productivity potential. There are certain avenues to improve the productivity potential under receding soil moisture condition like seed hardening technique, mycorrhizae application and foliar nutrition to induce moisture

stress tolerance in crop plants. But, the study on integrating these aspects in managing the moisture stress in wheat is very meager and therefore, there is a scope to improve the production potential of wheat under receding soil moisture conditions by integrating moisture stress management practices. Therefore, an attempt has been made in this experiment to integrate the compatible and suitable moisture stress management practices to overcome the problem of moisture stress with following objectives-

1. To study the effect of moisture stress on growth and yield of wheat.
2. To study the effect of moisture stress management practices on growth and yield of wheat.
3. To study the water use efficiency under moisture stress and it's management practices.
4. To study the economics of wheat under moisture stress and it's management practices.

2. REVIEW OF LITERATURE

The literature pertaining to various irrigation regimes moisture stress management practices, water use efficiency and economic aspects has been review in relation to growth and yield of wheat crop and presented in this chapter under the following sub heads:

2.1 Effect of moisture stress on growth and yield

Dhaka (2003) carried out an experiment at Agronomy Research Area of the C.C.S. Haryana Agricultural University, Hisar (Haryana) during *rabi* seasons of 2001-02 and 2002-03 and showed that water stress during reproductive phase in I_2 and vegetative phase in I_3 caused significant reduction in yield and yield attributes during both years. When compared with normal irrigation (I_1), limited irrigation upto 65 DAS (I_2) reduced the number of grains spike⁻¹, 1000 grain weight, grain yield, straw yield and harvest index by 10.0, 28.0, 19.7, 4.2 and 14.3 per cent, respectively. The similar trend was observed where crop was exposed to water stress during vegetative phase by supplying irrigation only after 85 DAS in I_2 except the fact that reduction in straw yield was comparatively more than the grain yield as evident from slight increase in harvest index. The trend observed under restricted irrigation in comparison to normal irrigation was quite explicit.

Parihar and Tiwari (2003) conducted an experiment on wheat at Indira Gandhi Agricultural University, Raipur (Chattisgarh) in clay soil (p^H 7.3). The treatment consisted of different irrigation levels (0.6, 0.9, 1.2 and 0.9/1.2 IW : CPE) with 6.0 cm depth of irrigation water to wheat. They indicated that the highest grain yield was produced with 0.9 IW : CPE which was at par with 1.2 IW : CPE. Higher grain yield was the result of higher number of effective tillers, grains spike⁻¹ and test weight.

Saren *et al.*, (2004) reported that four irrigations applied at crown root initiation, tillering, flowering and grain development stages resulted in maximum plant height (96.64 cm), dry matter accumulation (563.85 g m⁻²), leaf area index (2.95) and crop growth rate (13.55 g m⁻² day⁻¹) of wheat on sandy loam soil.

Ranjita *et al.*, (2007) conducted a field experiment at Main Agricultural Research Station, Dharwad, University of Agricultural Sciences, Dharwad (Karnataka) to

determine the effect of irrigation schedules, mulch and antitranspirant on growth, yield and economics of wheat. Irrigations scheduled at five critical growth stages *viz.*, crown root initiation + tillering + late jointing + flowering + milk stage resulted in significantly higher grain yield (2545 kg ha^{-1}) over one, two and three irrigations but was on par with four irrigations scheduled at crown root initiation + tillering + late jointing + milk stage. Increase in yield was due to higher number of effective tillers per metre row length, number of grains per ear and 1000 grain weight. Plant height, total dry matter production per metre row length were higher in frequently irrigated treatments. Grain yield was highest (2215 kg ha^{-1}) in treatment receiving kaolin spray over control but was on par with straw mulch. Growth and yield attributing characters differed significantly due to the application of straw mulch and antitranspirant.

Akram (2011) conducted a field experiment at Research Area of Department of Crop Physiology, University of Agriculture, Faisalabad (Pakistan) to determine the sensitivity of wheat to water stress and changes in water relations and yield of wheat (*Triticum aestivum* L.) under water stress conditions applied at different growth stages. The experiment comprised of two wheat cultivars and four water stress treatments, maintained by withholding water at tillering, anthesis, and at both stages. Water stress caused reduction in leaf relative water contents, water potential, osmotic potential, turgor potential, growth and yield components of both the wheat cultivars. The results indicated that high value of relative water contents were associated with increased yield and yield components. Consecutive stresses at both growth stages caused severe reduction in yield and yield components in both cultivars of wheat.

Ibrahim *et al.*, (2012) tested the effect of fertigation regimes on wheat grown in sandy soil in two field experiments in Egypt. The results showed that the highest yield and the highest water use efficiency (WUE) was obtained under irrigation application using 1.2 and 0.8 ET_c, respectively with fertigation application in 80% of application time in both growing seasons. The highest yield reduction and the lowest WUE under the tested climate change scenarios were obtained from farmer irrigation. It can be concluded that irrigating wheat grown in sandy soil with an amount of either 1.0 or 0.8 of ET_c with fertigation application in 80% of application time recommended to enhance growth and yield.

Idnani and Kumar (2012) conducted field experiment during *rabi* season of 2007-08 and 2008-09 at IARI, New Delhi and reported that among sowing methods, FIRBS planting and among irrigation scheduling, irrigation at crown root initiation stage + 100 mm CPE registered significantly highest plant height, leaf area index, dry matter accumulation at 90 days after sowing, number of effective tillers per meter row length, ear length, test weight, grain yield (4.76 t ha^{-1}), straw yield (11.03 t ha^{-1}), harvest index, net return and benefit: cost ratio (3.07) and the highest water use efficiency ($158.5 \text{ kg ha}^{-1} \text{ -mm}$).

Sarkar *et al.*, (2013) studied timing and the extent of water deficit in a field experiment on wheat (Cv. Shatabdi) for three consecutive years from 2003-04 through 2005-06 at Jamalpur area. The effects of number and timing of irrigation application on yields were investigated under variable soil moisture condition in the root zone of different treatments. Eight deficit irrigations, including one no stress and one rainfed treatments were selected to subject the crop to various degrees of soil water deficit at different stages of crop growth. Measured amount of irrigation water was applied as per schedule prescribed for a particular treatment. Grain yield, biomass, harvest index and water productivity were reasonably affected by deficit irrigation. Other yield contributing parameters like 1000-grain weight, grains spike⁻¹ and spike length were also affected by different levels of deficit irrigation. The highest water productivity (2.02 kg m^{-3}) was observed in treatment which was irrigated only once at crown root initiation stage although the yield was comparatively low. The crown root initiation stage was found the most sensitive to water stress. Water stress at vegetative stage also reduced the yield considerably.

Keyvan and Soheil (2013) conducted an experiment at Research Farm of Islamic Azad University located in Kermanshah (Iran) during 2010-11. The main plots were allocated to four different irrigation regimes : I₁- full irrigation (irrigation during growth period after 40 % depletion of soil moisture) I₂ - drought stress at the start of anthesis stage through the grain filling stage with irrigation after 80 % depletion of soil moisture; I₃ - drought stress at the start of anthesis stage through the ripening stage with irrigation after 80% depletion of soil moisture; and I₄ - drought stress at the start of grain filling stage through the ripening with irrigation after 80% depletion of soil moisture. The

subplots were allocated to three Cultivars treatments of C₁ (Roshan- Back Cross), C₂ (Karaj 1) and C₃ (Mrvdasht). The results showed that with increasing drought stress grain yield, biological yield, harvest index and water use efficiency decreased but evapotranspiration efficiency (ETE) was increased. Under control (I₁) conditions, WUE mean was 1.27 kg m⁻³ for all cultivars, but equal to 1.11, 0.91 and 0.73 kg m⁻³ for stress treatments I₂, I₃, and I₄, respectively. The highest and lowest harvest index and water use efficiency were observed for Roshan-Back Cross cultivar and Mrvdasht cultivar under well-watering, respectively.

Aradhna Kumari *et al.*, (2014) conducted an experiment in the laboratory and pot culture, Division of Plant Physiology, Indian Agricultural Research Institute, Pusa (New Delhi) during the rabi (winter) seasons of 2010–11 and 2011–12 to evaluate eight wheat (*Triticum aestivum* L.) genotypes. Moisture stress in laboratory experiment was induced by polyethylene glycol- 6000 (PEG-6000) (0, 15 and 20 %), with three replications to study germination related traits of wheat genotypes. All the genotypes showed decrease in biomass, grain yield, 1,000 grain weight and harvest index under water stress condition, but decline was more severe in case of PBW-343, HD-2733, PBW-373 and HD-2967 as compared to C-306, HD-2987, HD-3016 and NI-3039.

Shahid and Hari Ram (2017) conducted the field experiment at the Punjab Agricultural University, Ludhiana (Punjab) and reported that increase in the irrigation frequency significantly increased the dry matter accumulation and leaf area index at 120 DAS. Significantly higher plant height, tiller density and effective tillers were recorded with four irrigations as compared to no and two irrigations and were statistically at par with three irrigations. The highest tiller count was recorded under three irrigations which was statistically at par with four irrigations. The highest biological yield was recorded with four irrigations and was significantly better than three, two and no irrigations. Grain yield recorded was highest under four irrigations and was statistically at par with grain yield under three irrigations.

2.2 Effect of moisture stress management practices on growth and yield of wheat

Govindan and Thirumurugan (2000) recorded effect of the foliar application of K fertilizer on the yield and yield components of green gram cv. VBN-1

was investigated during *kharif* 1999 at Madurai (Tamil Nadu). The treatment included foliar sprays of 0.5 or 1.0 % KCl or KNO₃ and their combinations, all applied at the initiation of flowering and 15 days after the first spray. All treatments recorded significantly higher yield and yield components over the untreated control. Among the different treatments, 1.0 % KCl + 1.0 % KNO₃ recorded the highest values for plant height at harvest (48.6 cm), leaf area index at 60 days after sowing (6.83), dry matter production at harvest (2783 kg ha⁻¹), number of pods per plant (20.6), pod length (8.12 cm), number of grains per pod (10.77), 100-grain weight (4.0 g), grain yield (777 kg ha⁻¹) and benefit:cost ratio (2.53).

Al-Karaki *et al.*, (2004) conducted field experiment at U.S. Department of Agriculture and Texas Tech. University and reported that biomass and grain yields were higher in mycorrhizal than non mycorrhizal plots irrespective of soil moisture and *Glomusetunicatum* inoculated plants generally had higher biomass and grain yields than those colonized by *G. mosseae* under either soil moisture condition. The mycorrhizal plants had higher shoot P and Fe concentrations than non-mycorrhizal plants at all samplings regardless of soil moisture conditions. The improved growth, yield and nutrient uptake in wheat plants demonstrate the potential of mycorrhizal inoculation to reduce the effects of drought stress on wheat grown under field conditions in semiarid areas of the world.

Moinuddin and Goswami (2004) conducted field experiment at AICRP on Water Management, Bidhan Chandra Krishi Viswavidyalaya, P.O. Gayespur, Nadia (West Bengal) and reported that the soil moisture stress at crown root initiation, tillering and flowering stage reduced the grain yield by 25.9, 8.2 and 12.5 % respectively over control. Foliar spray of potassium sulphate was effective in improving the grain yield by 6.5–9.1 %. Plant growth parameters like plant height and tillering were significantly reduced under water deficit at CRI and tillering stages. Grain filling was affected by stress at flowering but length of panicle and grain number remained unaffected at tillering and flowering. Crop sensitivity to phenological water stress in sandy loam soil was in the order of crown root initiation > flowering > tillering stage.

Solaimalai and Subburamu (2004) conducted study at Krishi Vigyan Kendra Tamil Nadu Agricultural University, Vriddhachalam on seed hardening for field

crops. Quality seeds along with other improve package of practices play a vital role in improving productivity of crops under rainfed condition. Seed hardening is a practice adopted to make crop plants resistant to soil moisture stress. NaCl, Na₂SO₄, KCl, MgSO₄, KH₂PO₄, K₂SO₄, CaCl₂, Na₂HPO₄, nitric acid, succinic acid, auxins, CCC, Jalshakti, triazoles, cow's urine and cow's extract were used as a seed hardening chemicals. Hardening of seedling resulting from pre-sowing treatment is due to the number of physio-chemical changes within the cytoplasm. Pre-sowing seed hardening with different chemicals improve seed viability as well as vigour, root length, root shoot ratio and yield of rainfed crops.

Huixing Song (2005) conducted experiment at School of Life Science, Southwest University, Chongqing (China) on effects of VAM on host plant in the condition of drought stress and its mechanism and summarizes effects of VAM on morphology, metabolism and protective adaptation of host plants in the condition of drought stress. Mechanism that VAM can enhance resistance of drought stress in host plant may include many possible aspects *viz* VAM improves the properties of soil in rhizosphere; VAM enlarges root areas of host plants and improve its efficiency of water absorption; VAM enhances the absorption of P and other nutritional elements and then improves nutritional status of host plant; VAM activates defence system of host plant quickly; VAM protects against oxidative damage generated by drought; VAM affects the expressions of genetic material.

Ranjita *et al.* (2007) conducted a field experiment at Main Agriculture Research Station, University of Agricultural Sciences, Dharwad (Karnataka) to determine the effect of irrigation schedule, mulch and antitranspirant on growth, yield and economics of wheat. They reported that grain yield was highest (2215 kg ha⁻¹) in treatment receiving kaolin spray over control but was on par with straw mulch. Growth and yield attributing characters differed significantly due to the application of straw mulch and antitranspirant.

Khan *et al.*, (2006) conducted field experiment at Potohar Region of Punjab and reported that the highest biological yield recorded by foliar application of KCl along with nitrogen. The response of foliar potash application on Chakwal-86 wheat variety was significant among the different treatments. Both sources of potash i.e. KNO₃

and KCl are equally effective in increasing yield and can be helpful in achieving maximum realizable yield.

Ahmed and Hoda (2008) conducted a field experiment at Main Agriculture Research Station, University of Agricultural Sciences, Dharwad (Karnataka) and reported that at water stress and rewatering, the mycorrhizal inoculation significantly increased the contents of some metabolites (proline; free amino acids; total soluble and crude proteins; total carbohydrate; total soluble and insoluble sugars) in wheat plants and enhanced the activities of some antioxidant enzymes such as peroxidase (POX) and catalase (CAT) as compared with stressed control, especially at heading stage of plant growth. The overall results, suggest that mycorrhizal colonization of wheat plants could improve the osmotic adjustment response, enhance its defense system and alleviate oxidative damage of cell viability. The cumulative effects increased the plant tolerance to drought.

Qiang and Ying (2009) conducted an experiment at Philippines Agricultural University and reported that vesicular arbuscular mycorrhizae (VAM) seedlings exhibited greater growth characteristics (fresh and dry weights and leaf area) compared with non-VAM seedlings under drought stress and non-drought stress conditions. Concentrations of P, K and Ca in the leaves and concentrations of P, Ca and Fe in the roots were higher in VAM than in non-VAM seedlings subjected to either non-drought stress or drought stress conditions. VAM colonization also increased leaf concentrations of Fe and Zn and root concentrations of K and Mg in seedlings under stress conditions. The improved nutrient uptake in colonized seedlings demonstrates the potential of VAM symbiosis to enhance drought resistance in citrus.

Akram *et al.*, (2009) conducted experiment at CCS Haryana Agricultural University, Hisar (Haryana) and reported that salt stress adversely affected the growth, yield components, gas exchange, water relations and also caused nutrient imbalance in sunflower plants. However, foliar-application of different sources of potassium improved shoot and root fresh and shoot dry weights, grain yield, 100-grain weight, photosynthetic rate, transpiration rate, stomatal conductance, water-use efficiency, relative water content and leaf and root K⁺ concentrations of sunflower plants grown under saline conditions.

Abbas Zareian *et al.*, (2014) conducted field experiment during growing season of 2011-12 at Seed and Plant Certification and Registration Research Institute (SPCRI), Karaj (Iran) in order to evaluate the effects of drought stress and potassium foliar application on grain yield, its components and some physiological traits of three wheat (*Triticum aestivum* L.) cultivars. The experimental treatments included three irrigation regimes; normal, mild stress (water withhold at the grain filling phase) and severe stress (water withhold at the ear emergence phase); potassium foliar treatments included, 0, 1.5 % and 3.0 % K₂O applications and three wheat cultivars (Marvdasht, Pishtaz and WS-82-9). Results showed that relative water content and net photosynthesis were significantly decreased by drought stress. These traits showed significant increase by increasing potassium foliar application. Further results also indicated that water stress through withholding at the ear emergence and grain filling phases reduced grain yield and its components. Foliar application of potassium at the rate of 3.0 % K₂O gave the highest values of all studied wheat characters followed by 1.5 % K₂O as compared with control treatment. It is concluded that maximum values of grain yield could be achieved from wheat cultivar WS-82-9 giving normal irrigation and sprayed with 3.0 % K₂O.

Kumar *et al.*, (2011) conducted an experiment and reported that the mycorrhizal inoculation improved yield attributes, yields and grain quality and the effect was compounded when fungal inoculation was preceded by seed priming (soaking of seed overnight in water). The yield attributes *viz.*, number of spikes m⁻² and grains spike⁻¹ were increased by 38.1 % and 54.7 % in PBW-343 and 43.4 % and 65.8 % in WH-1021, respectively due to fungal inoculation of primed seed over unprimed seed without inoculum. The respective grain yield was 25.8 and 19.1 % higher in PBW-343 and WH-1021. The protein content and wet gluten in the grains was improved significantly with fungi inoculation. After the harvest, the per cent mycorrhizal infection on the roots of WH-1021 were increased by more than two fold when primed seeds inoculated with fungi as compared to unprimed seeds.

Al-Asbahi (2012) conducted an experiment to study the gene expression pattern in shoots of wheat seedlings sprayed with the fungal culture filtrate. He reported an increase in the level of mRNA of arbuscularmycorrhizal protein comparing with

control. The over expression of this protein in wheat tissues might contribute in initiation of arbuscularmycorrhizal fungi colonization in wheat tissues.

Hasanpouret *et al.*, (2012) conducted an experiment at the Agricultural and Natural Resources Research Center of Tehran Province (Iran) in 2010-11 in wheat and reported that inoculation of microorganisms such as mycorrhizal fungi and *Azotobacteris* an effective and advantageous strategy for qualitative and quantitative yield of wheat. Inoculation with these biofertilizers promoted early flowering, long grain filing period, late maturity period, high number of grains per spikelet and short spike length for increasing yield under drought conditions

Sujatha *et al.*, (2013) conducted a field experiment at Department of Seed Science and Technology, Agricultural College and Research Institute, Madurai (T.N.) on pre-sowing seed hardening of wheat seeds with water and solutions of halide salts and growth regulating compounds to induce early germination, better root and seedling growth and increased yield has been employed by several workers. Seed hardening has been investigated by those concerned with problem of mitigating seed germination and seedling emergence under problematic field conditions. Hence, seed hardening is one of the physiological pre-sowing seed management practice given to seeds to resist drought or saline/sodic soils to boost up the yield and is also being practiced from time immemorial owing to the better performance among the agriculturists.

Patil *et al.*, (2014) conducted a field experiment during winter season of 2010-11 and 2011-12 at Agronomy Research Farm, CCS Haryana Agricultural University, Hissar (Haryana) to study integrated moisture stress management in wheat (*Triticum aestivum* L.). The treatment consisted of 4 moisture regimes in main plots, *viz.* irrigation at crown root initiation+ 100 mm cumulative pan evaporation(CPE), crown root initiation + 150 mm CPE, crown root initiation + 200 mm CPE and CRI only, and 6 moisture stress management practices in sub plots, *viz.*, no moisture stress management, seed hardening (SH) by CaCl_2 , SH + KCl spray, SH + mycorrhizae application + KCl spray, SH + mycorrhizae application + KCl spray + kaolin spray and pusa hydrogel application. Significantly the highest plant height, number of tillers, leaf area index, leaf area duration, dry matter accumulation and crop growth rate were recorded with irrigation at crown root initiation + 100 mm CPE over irrigation at crown root initiation

only. Similarly significantly highest grain yield, straw yield, harvest index, spikes m^{-2} , spike length, spikeletsspike $^{-1}$, grains spike $^{-1}$, grain weight spike $^{-1}$, test weight and net returns were recorded with crown root initiation + 100 mm CPE over irrigation at crown root initiation only. The treatment SH + mycorrhizae + KCl spray + kaolin spray recorded significantly highest plant height, number of tillers, leaf area index, leaf area duration, dry matter accumulation, crop growth rate, spikes m^{-2} , spikeletsspike $^{-1}$, spike length, grains spike $^{-1}$, grain weight spike $^{-1}$ and test weight over irrigation at crown root initiation only. Significantly the highest grain yield and straw yield as well as net returns were recorded in SH + mycorrhizae + KCl spray + kaolin spray over irrigation at crown root initiation only.

2.3 Effect of moisture stress and its management practices on water use efficiency

Sun *et al.* (2006) reported that with increasing ET, the irrigation requirements of winter wheat increases but excessive amounts of irrigation could decrease grain yield, WUE and WUEi. These results indicate that excessive irrigation might not produce greater yield or optimal economic benefit thus suitable irrigation schedules must be established. Irrigation experiments were conducted during different growing stages of winter wheat (*Triticum aestivum* L.) at Luancheng agro-ecology systems station of the Chinese Academy of Sciences during 1999-2000, 2000-01 and 2001-02 to identify suitable irrigation schedules for winter wheat. The aim was also to develop relationships between seasonal amounts of irrigation and yield, water-use efficiency (WUE), irrigation water-use efficiency (WUEi), net water-use efficiency (WUEet) and evapotranspiration (ET). A comparison of irrigation schedules for wheat showed that for maximum yield in the NCP, 300mm is an optimal amount of irrigation, corresponding to an ET value of 426mm.

Wajid *et al.*, (2007) under taken study on wheat in semi arid regions of Punjab was to see the effects of cultivars and irrigation regimes on water use efficiencies calculated for total water applied and crop evapotranspiration. Four irrigation i.e. I_0 = control, I_1 = irrigation up to stem elongation, I_2 = irrigation from stem elongation to maturity and I_3 = full irrigation treatments based on soil moisture deficit were applied to each cultivar. Irrigation treatments were managed to induce a range of drought from full

irrigation to nil irrigation from emergence to physiological maturity. Relationship between grain yield and ET was observed and concluded that for each mm of crop ET 3.27 g m^{-2} TDM was produced. Inqlab-91 increased yield by 10.7% over MH-97. Fully irrigated crop produced 93.18% higher yield over control treatment. In treatments where drought was imposed before or later anthesis, the primary cause of reduced efficiencies was a decrease in intercepted light which ultimately reduced its efficiency into economic part.

Mohammad *et al.*, (2007) conducted an experiments at the Research Farm of NWFP Agricultural University, Peshawar, Pakistan with one wheat variety, four irrigation intervals i.e. three weeks (W_3), four weeks (W_4), five weeks (W_5) and six weeks (W_6) and two pan levels i.e. equal to pan evaporation (P_1) and half of the pan evaporation (P_2) using randomized complete block design. Results of yield and its components indicated that there was significant effect of irrigation intervals on grain yield, number of grain per spike, grain weight per spike, number of tillers per plant and visual lodging percentage. There was no difference in yield and yield components when the crop was irrigated according to the full evaporation (P_1) and half pan evaporation (P_2). The highest water use efficiency ($8.01 \text{ kg ha}^{-1}\text{-mm}$) was obtained when crop was irrigated after five weeks interval. It could be concluded that for maximum yield of wheat the crop may be irrigated after five weeks interval.

Ranjita *et al.*, (2007) conducted a field experiment during *rabi* season of 2004-05 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka). There were 15 treatment combinations consisting of 5 main plots of irrigation schedules (I_1 = One irrigation at crown root initiation, I_2 = Two irrigations at crown root initiation + Flowering stage, I_3 = Three irrigations at crown root initiation + Late jointing + Milk stage, I_4 = Four irrigations at crown root initiation + Tillering + Late jointing + Milk stage, I_5 = Five irrigations at crown root initiation + Tillering + Late jointing + Flowering + Milk stage) and 3 sub plots (M_0 = Control, M_1 = Mulch (finger millet straw @ 6 t ha^{-1}), M_2 = Antitranspirant (kaolin @ 6% w/v)). Highest WUE ($10.74 \text{ kg ha}^{-1}\text{-mm}$) was observed in I_1 irrigation schedule closely followed by I_2 , I_3 , I_4 and I_5 (8.89 , 7.86 , 7.79 and $6.99 \text{ kg ha}^{-1}\text{-mm}$) respectively. The lowest WUE was noticed in I_5 ($6.99 \text{ kg ha}^{-1} \text{ mm}^{-1}$) irrigation schedule. The WUE was highest in treatment receiving

single irrigations at crown root initiation stage mainly due to conservative water use, which indicates the efficient water use at lower frequency of irrigation.

Yadav and Ramdeo (2008) conducted a field experiment at AICRP on Water Management Research Station, Rajasthan Agril. University, Sriganganagar (Rajasthan) on wheat under two irrigation regimes (0.8 and 1.0 IW/CPE with 5.5 cm depth of irrigation water and reported maximum consumptive use with scheduling of irrigation at 0.8 IW/CPE ratio than 1.0 IW/CPE.

Mesbah (2009) were conducted two field experiments at Al-Hussein Society for Reclaiming and Cultivating (Egypt) during 2007-08 and 2008-09 growing seasons, to study the effect of irrigation regimes (1350, 1600 and 1850 m fed⁻¹) and different treatments spraying with potassium (1, 2, 3 % and control, 48 kg K fed⁻¹ as soil application) on yield, yield components and water use efficiency of wheat (Giza-168 cultivar). Results indicated that the differences between irrigation regimes for leaf area index, plant height, number of tillers plant⁻¹, number of spikelets spike⁻¹, spike length, 100-grain weight, harvest index in first season only, water use efficiency and grain yield per fed were significant in the two seasons. Irrigation wheat plants with 1850 m fed⁻¹ gave the highest values for all studied traits except harvest index and water use efficiency. On the other hand, irrigation with 1350 m fed⁻¹ gave the highest values for water use efficiency only, in the two seasons. The interaction between irrigation regimes and spraying with potassium were significant for all studied traits except leaf area index and harvest index in the second season, plant height, number of tillers plant⁻¹, number of spikelet's spike⁻¹, spike length in the first and second seasons. Irrigation wheat plants with 1600 m fed⁻¹ and foliar application of 2 or 3% potassium gave the highest values of most studied attributes. The differences between foliar spraying of 1% potassium and the control treatment were significant, while, the differences between the control treatment and 2 or 3% potassium spray were insignificant of most studied attributes. Also, results show that, irrigation wheat plants until 1600 m fed⁻¹ in critical stages of wheat and sprayed with 2 % potassium increased the grain yield fed⁻¹ components and water use efficiency under new reclaimed conditions.

Ibrahim *et al.*, (2012) tested the effect of fertigation regimes on wheat grown in sandy soil in two field experiments in Egypt. The results showed that the

highest yield and the highest water use efficiency (WUE) was obtained under irrigation application using 1.2 and 0.8 of ET_c, respectively with fertigation application in 80% of application time in both growing seasons. The highest yield reduction and the lowest WUE under the tested climate change scenarios were obtained from farmer irrigation.

Sami *et al.*, (2013) analyzes the effects of different water application levels on agronomic parameters and water use efficiency of a durum wheat (*Triticum durum* Desf. Var. Karim.) cultivar under the Mediterranean climatic conditions in Central Tunisia. Field experiment was conducted at the Higher Institute of Agronomy of Chott Meriem during the growing season 2011-12. The irrigation treatments were full irrigation (T₁) corresponding to 100% of predetermined irrigation water levels, (T₂) 75% of full irrigation and (T₃) 50% of full irrigation. Results concerning water use efficiency revealed that T₁ and T₃ was 1.72 and 1.6 kg m⁻³, respectively. T₂ with 1.43 kg m⁻³ resulted in lowest water use efficiency. The results achieved in this study showed that irrigating winter wheat with continuously providing only 50 % of the crop water requirements in semi arid climate in Tunisia could result in high efficient irrigation water use.

Hari Ram *et al.*, (2013) conducted a field experiment at the Punjab Agricultural University, Ludhiana (Punjab) for three years (2008–09, 2009–10 and 2010–11) to study the effect of four irrigation treatments with irrigations applied at critical growth stages and four rates of rice straw mulching on the grain yield and water use efficiency of wheat in North-west India. The irrigation treatments were irrigations at crown root initiation (I₁) and boot stage (I₂); crown root initiation, tillering and boot stage (I₃); irrigations at crown root initiation, tillering, boot stage and milk stage (I₄); and irrigations at crown root initiation, tillering, jointing, boot stage and milk stage (I₅). Mulch application included no mulch (M₀) and 2 t ha⁻¹ (M₁), 4 t ha⁻¹ (M₂), and 6 t ha⁻¹ (M₃). The result indicate that WUE increased as mulching increased for the I₂, I₃, and I₄ treatments, but not for the I₅ treatment. The increase in water use efficiency with the I₅ treatment compared to no mulch was observed at the M₂ treatment only and no further increase occurred thereafter.

Jayswal *et al.*, (2016) conducted study on wheat crop in Saurashtra to find out the effect of irrigation regimes on crop yield and water use efficiency. Five treatments

were adopted i.e. 0.6 ETc, 0.8 ETc, 1.0 ETc, 1.2 ETc and control. Irrigation was applied at 10 to 12 days interval as per the treatments, in control treatment 60 mm fixed depth of irrigation was applied. Significantly the higher grain yield (2808.65 kg ha⁻¹) and dry matter (3990.76 kg ha⁻¹) were attained for control crop. The grain water use efficiency and dry matter water use efficiency were found non-significant.

Al-Molhem (2016) conducted an experiment at the Agricultural and Veterinary Research Station of King Faisal University, Hofuf, (Saudi Arabia) for three irrigation water regimes in wheat Cv- Bro bread, viz. 100 %, 80 % and 60 % ETc were used over three successive seasons (2009-10, 2010-11 and 2011-12). Data were collected on different parameters pertaining to crop agronomic and yield attributes viz. plant population and height, number of tillers, leaf area index (LAI), number of spikelets and grains spike⁻¹, 1000-grains weight, harvest index (HI) and total grain yield as well as water use efficiency (WUE). Obtained results revealed that, watering regime of 60 % ETc was statistically ($P \leq 0.05$) inferior in terms of almost all the prescribed parameters. 100 % and 80 % ETc watering regimes were statistically similar in comparison to their corresponding treatments in all seasons. In addition, the obtained results showed that averaged of watering regime viz., 100 %, 80 % and 60 % ETc were 2.90, 2.73 and 2.03 t ha⁻¹, respectively. WUE was recorded the highest values (0.42) at 80% ETc watering regime, whereas the lowest (0.36) at 100 % ETc.

Gameh *et al.* (2017) conducted field experiments at Shandaweel Agricultural Research Station during the three winter successive seasons (2012-13, 2013-14 and 2014-15) to find out the effect of different dates and irrigation regimes on growth, yield and consumptive use of three wheat varieties under Sohag governorate conditions. Three bread wheat cultivars (Shandaweel-1, Giza-168 and Sids-12) were cultivated in two different sowing dates (20th November and 5th December) under three irrigation intervals treatments of 21, 28 and 35 days. The results revealed the average water consumptive use by wheat plants were 2094.48 for I₁, 1883.46 for I₂ and 1564.15 for I₃ m³ fed⁻¹ at the first sowing date (20th Nov.) while it was 2123.93 for I₁, 1811.49 for I₂, and 1606.19 for I₃ m³ fed⁻¹ for the second sowing date (5th Dec.). The irrigation water use efficiency was higher with using the irrigation treatment every 35 days. It was 0.53, 0.54, and 0.61 kg m⁻³ for the first sowing date (20th November) and it was 0.64, 0.68, and 0.68 kg m⁻³ for the

second sowing date (5th Dec.) by using the irrigation interval treatment at 21, 28, and 35 days, respectively.

Rajanna *et al.*, (2017) conducted field experiment during *rabi* (winter) seasons of 2012–13 and 2013–14 at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar (Haryana) reported that wheat planted on bed (FIRBS) and irrigation applied at CRI + IW:CPE = 0.90 evidenced significantly higher grain yield by 12–19 % and took more days from spike initiation to anthesis, anthesis to milk stage and milk to maturity during 2012–13 and 2013–14 crop seasons. WUE (144.6 and 155.4 kg ha⁻¹-cm) and IWP (4.3 and 4.5 kg m⁻³) perceived highest under bed planting by using lower total consumptive use of water (35.71 and 35.45 cm) during the respective crop seasons. Thus the CU was around 6–12 % lower under FIRBS as compared to other crop establishment techniques. Application of irrigation at CRI + IW:CPE = 0.75 resulted in highest WUE (129.0 and 140.0 kg ha⁻¹-cm) and IWP (4.2 and 4.4 kg m⁻³) with minimum water used (37.41 and 36.22 cm) during 2012–2013 and 2013–2014, respectively in contrast to other two moisture regimes.

Elias Meskeluet *al.*, (2017) carried out field experiment at Melkassa Agricultural Research Center, Ethiopia to establish optimum moisture stress threshold level for improving water productivity of irrigated wheat under limited water resource scenario. Seven moisture levels (100 % ET_C, 85 % ET_C, 70 % ET_C, 60 % ET_C, 50 % ET_C, 40 % ET_C, and 30 % ET_C) were imposed on wheat (*Triticum aestivum* L.) variety Kekeba as a treatment. It was found out that grain yield reduced with increased stress, whereas WUE was increased with stress level increased. The highest grain yield of 4559.0 kg ha⁻¹ and WP of 1.86 kg m⁻³ were obtained at 100% ET_C and 30 %, respectively. Moreover, 85 % ET_C and 70 % ET_C treatments showed no significant variation with 100% ET_C in grain yield. However, WUE observed at 70% ET_C treatment was significantly higher than 100% ET_C treatment. Grain yield obtained at 40% ET_C was significantly higher than that obtained at 30 % ET_C though WUE of both treatments were statistically similar. Therefore, wheat could be irrigated at 70 % ET_C to increase WUE without a significant grain yield reduction. Moreover, it could also be irrigated at 40% ET_C in areas where WUE is top priority with a compromise in grain yield reduction.

2.4 Effect of moisture stress and its management practices on nutrient uptake

Sarma *et al.* (2007) conducted field experiment during the winter seasons of 2000–01 and 2001–02 at CCS, Haryana Agriculture University Hisar (Haryana). Where wheat (*Triticum aestivum* L.) grown at 2 irrigation levels, viz., adequate irrigation and limited irrigation and 10 levels of nutrients. Wheat crop under adequate irrigation one each at crown-root initiation, late tillering, late jointing, flowering and milk stages recorded better growth, yield attributes, grain and straw yields and higher consumptive use of water and nutrient uptake. Application of $187.5 \text{ kg N ha}^{-1} + \text{FYM (10 t ha}^{-1})$ and $150 \text{ kg N ha}^{-1} + \text{FYM (10 t ha}^{-1}) + \text{Azotobacter}$ recorded significantly higher growth, grain and straw yields of wheat, nutrient uptake and available Nitrogen. The content of organic carbon and available phosphorus in soil increased and the bulk density and pH decreased in all the integrated nutrient management practices involving FYM (10 t ha⁻¹). Thus, on integrating FYM (10 t ha⁻¹) + *Azotobacter* with 187.5 and 150 kg N ha^{-1} or FYM (10 t ha⁻¹) with $187.5 \text{ kg N ha}^{-1}$, productivity and monetary returns can be increased by maintaining or improving the residual soil-fertility status after the harvest of wheat crop.

Coventry *et al.*, (2011) conducted an experiment at CSS Haryana Agricultural University, Hisar (Haryana), where 4 irrigation schedule treatments were split with nitrogen management treatments involving a 2-way or 3-way split of N fertiliser with the rice–wheat system. The application of extra N fertilizer with the non rice–wheat rotations produced no additional grain yield with an increase in the N-fertilizer input beyond 150 kg N ha^{-1} , although protein and N-content increased incrementally.

Tiwari *et al.*, (2016) conducted field experiment during the winter (*rabi*) season of 2010-11 on silty loam soil at Faizabad (Uttar Pradesh), to develop suitable dose of customized fertilizers (CF) and moisture regime for wheat (*Triticum aestivum* L.) crop. Productivity of grain and straw of wheat increased with increasing level of nutrient. Highest grain yield (53.13 q ha^{-1}) was recorded under the application of NPK 150 : 75 : 40 which was accounted increases of 18.22, 14.55 and 10.88 per cent more yield than F₁, F₄ and F₆ treatment respectively.

2.5 Effect of moisture stress and its management practices on physiological studies

Subbian *et al.* (2000) indicated that during seed hardening process, several physiological and biochemical changes occur *viz.*, changes in the properties of colloids and the hydrophobic colloids change to hydrophilic, the viscosity of protoplasm and plasticity of plasma lemma increases, increase in osmotic potential which will helps in drought withstanding capacity, activation of enzymes and rate of respiration and synthetic activity increases, increased levels of nucleo-proteins and organic phosphorus, increased in the activity of RNA and rate of protein synthesis, smaller epidermal and stomatal cells and increased total absorbing surface of the root system.

Dhaka (2003) carried out an experiment at Agronomy Research Area of the C.C.S. Haryana Agricultural University, Hisar (Haryana) during *rabi* seasons of 2001-02 and 2002-03. The main plot treatments comprised of six combinations of two dates of sowings (Timely sowing on 20th November and Late sowing on 25th December) and three irrigation levels (I₁ - Normal schedule of six irrigations at 22, 45, 65, 85, 105 and 120 DAS, I₂ - irrigation during vegetative phase up to 65 DAS only and I₃ - irrigation during reproductive phase after 85 DAS only) where as the six genotypes (PBW-343, WH-711, NIAW-34, UP-2338, RAJ-3765 and HD-2428) and showed that water stress during reproductive phase in I₂ hastened the maturity, reduced the duration of grain filling and grain maturation. Conversely, water stress during vegetative phase in I₃ hampered the crown root development, reduced the tillering, leaf area, biomass accumulation and ultimately the sink size. On the other hand the proper sink development and its realization under favourable moisture regime in I₁ resulted in much higher yield.

Abbas Zareian *et al.*, (2014) conducted field experiment during growing season of 2011-12 at Seed and Plant Certification and Registration Research Institute (SPCRI), Karaj (Iran) in order to evaluate the effects of drought stress and potassium foliar application on grain yield, its components and some physiological traits of three wheat (*Triticum aestivum* L.) cultivars. The experimental treatments included three irrigation regimes; normal, mild stress (water withhold at the grain filling phase) and severe stress (water withhold at the ear emergence phase); potassium foliar treatments included, 0, 1.5 % and 3.0 % K₂O applications and three wheat cultivars (Marvdasht,

Pishtaz and WS-82-9). Relative water content (RWC) and net photosynthesis were measured after grain filling stage. Results showed relative water content and net photosynthesis were significantly decreased by drought stress. These traits showed significant increase by increasing potassium foliar application. Foliar application of potassium at the rate of 3.0 % K_2O gave the highest values of all studied wheat characters followed by 1.5 % K_2O as compared with control treatment.

Wajid *et al.*, (2011) studied twelve wheat cultivars of diverse characters and origin at Sindh Agriculture University, Tandojam (Pakistan). The experiment was laid-out in factorial design with two treatments (non-stress and stress at anthesis) and three replications during crop season 2007-08. The cultivars TD-1, SKD-1 and Sarsabz showed minimum reduction in physiological as well as yield characters in stress at anthesis, however low to high reductions were observed in stress conditions as compared to non-stress. Correlations among morphological, physiological and morpho-physiological traits such as plant height, grains per spike, seed index, grain yield per plant, harvest index, relative water content, stomatal conductance, leaf area and spike fertility were generally reliable indicators for screening drought tolerant wheat cultivars and potentially with higher yields.

Ashinie *et al.*, (2011) conducted an experiment in a lathhouse at Sinana Agricultural Research Center (SARC) during the 2006-07 main season in Bale Zone of Oromia Region, Ethiopia on wheat to assess the differential morpho-physiological response to stimulated water deficit and to determine the relationship between some of these morphological and physiological traits and yield components of eighteen durum wheat genotypes grown in pots under lathhouse condition. Water deficit significantly affected gas exchange and chlorophyll fluorescence parameters. It reduced the net photosynthesis rate (P_n), transpiration rate (E) and stomatal conductance (g_s) measured both at anthesis and grain-filling stages. Similarly, the value of initial fluorescence (F_o) was increased while variable fluorescence (F_v), maximum fluorescence (F_m) and optimum quantum yield fluorescence (F_v/F_m) were decreased under water deficit. RWC of the leaves was decreased by 36.7% while SLA increased by 12.6% due to moisture stress relative to the well-watered control.

2.6 Effect of moisture stress and its management practices on quality studies

Kattimani *et al.*, (1996) conducted a field experiment on wheat at University of Agricultural Sciences, Dharwad (Karnataka) under three levels of irrigation, I₁ – at CRI, I₂ – at CRI + boot leaf stage and I₃ – at 9 to 10 days interval. They reported that irrigation decrease protein content in grain with increase in grain yield. The maximum protein content in wheat grain was recorded at I₁ level of irrigation.

Patil *et al.*, (2003) conducted a field experiment at Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) under three irrigation levels (1, 2 and 3 number of irrigations) to wheat and reported that increase in the grain protein content with increase in irrigation but it was significant upto 2 irrigations. Protein content at 2 and 3 irrigation was at par each other.

Guler (2003) evaluated at Agricultural University Ankara, (Turkey), from 1993 to 1995 the responses of three cultivars of durum wheat to four irrigation regimes [no irrigation or irrigation applied at three growth stages (sowing, jointing and anthesis)], 1000-kernel weight and test weight increased with irrigation at all three stages, whereas irrigation at sowing and jointing resulted in high pigmentation and protein values. When irrigation was applied at sowing and jointing, but not at anthesis, with water stress occurring only at grain filling, the quality of the grain was positively affected.

Onyibe (2005) conducted field experiment at Irrigation Research Stations of the Institute for Agricultural Research, Kadawa in the Sudan Savanna of Nigeria to study the effect of irrigation regime (60, 75 and 90 % Available Soil Moisture (ASM) on the growth and yield of two recently introduced wheat cultivars (Sietecerros and Pavon-76). The result revealed that increase of irrigation regime from 60 to 90 per cent ASM did not significantly affect most of the growth, yield and yield parameters evaluated in the study. Each increase in irrigation regime however increased days to maturity, water use and thermal time but decreased water use efficiency. Pavon-76 produced superior grain yield than Siete ceros only in one season. Pavon-76 had a higher LAI, more tillers and spikes m⁻² and larger grain size, but had shorter plants, lower grain weight and grain number spike⁻¹ and matured earlier than Sietecerros. Irrigation level of 60 per cent ASM is recommended for both varieties in the Sudan savanna ecology. At this ASM the

highest water use efficiency of 4.0-4.8 kg ha⁻¹-mm was obtained and grain yield was not significantly compromised. Grain yield was more strongly correlated with grain weight per spike than with grain number per spike.

Zhao *et al.*, (2008) conducted a field experiment on wheat with 4 irrigation regimes (0.6, 0.8, 1.0 and 1.2 IW/ CPE) with 7 cm depth of water and reported that protein content in wheat grain increased with increase in irrigation regimes while gluten content decreased with increase in irrigation regimes. They also recorded higher protein content with treatment 1.0 IW/CPE ratio while higher gluten content was recorded due to treatment 0.6 IW/CPE ratio.

El Tahir *et al.*, (2011) was conducted a field experiment for two consecutive winter seasons (2008-09 and 2009-10) at the Demonstration Farm, College of Agricultural Studies, Sudan University of Science and Technology, to study the effect of different irrigation intervals on growth, yield, yield components and water use efficiency of wheat (*Triticum aestivum* L.). Wheat cultivar Condor was grown with different irrigation intervals namely every 7, 10, 14, 21 and 28 days. The results showed highly significant differences in treatments effects on biomass, straw and grain yield, harvest index, water use efficiency and protein content. In general irrigation every 7 and 10 days gave the highest protein content, grain, straw yield and field water use efficiency. But for economics aspect irrigation every 10 days is recommended. Irrigation at every 14 days have no remarkable effect, on the other hand irrigation every 21, and 28 days must be avoided under this semi-arid condition.

Coventry *et al.*, (2011) conducted an experiment at CSS Haryana Agricultural University, Hisar (Haryana). The treatment comprises 4 irrigation schedule treatments were split with nitrogen management treatments involving a 2-way or 3-way split of N fertilizer with the rice–wheat system. The results indicates that with all 4 rotations the highest protein level was achieved (range 11.8–12.5 %) with this 3-way N application split. Grain yield increased in a step-wise manner as additional irrigation was implemented with all rotations and the highest protein outcomes were achieved with the least irrigations. The application of extra N fertilizer with the non rice–wheat rotations produced no additional grain yield with an increase in the N-fertilizer input beyond 150 kg N ha⁻¹, although protein and N-content increased incrementally.

Nazarli and Faraji (2011) conducted an experiment at Department of Agronomy and Plant Breeding, Urmia University, Urmia (Iran) and reported that the irrigation regimes had significant effect on proline content, soluble sugars and ascorbate peroxidase (APX) activity, but no significant differences were detected among irrigation regimes for catalase (CAT) activity. Limited irrigation increased proline concentration and total soluble sugars in leaves. Results indicated that the highest proline content (12 $\mu\text{mol/g DW}$), total soluble sugars (49 mg/g DW) and APX activity (42 $\mu\text{mol min}^{-1} \text{g}^{-1} \text{FW}$) were related to irrigation at 25 % of field capacity. They concluded that proline and soluble sugar levels were increased in wheat leaves under deficit irrigation regimes.

Hamid *et al.*, (2012) conducted field experiment at Isfahan Province, Iran and found the differences between irrigation after 70 mm and 90 mm evaporation were not significant with the exception of wet gluten. Delay in irrigation from 70 mm to 90 mm evaporation, significantly increases wet gluten. Irrigation after 110 mm evaporation significantly reduced the grain yield, yield components and wet gluten. However delay in irrigation from 70 mm to 90 mm evaporation significantly increased grain protein percentage. Wheat irrigated after 90 mm cumulative pan evaporation not only save about 22 per cent in irrigation water with no significant loss in yield but also grain protein per cent increased by 1.7 per cent.

Mir Reza *et al.*, (2013) carried out the field experiment in 2010-11 at Agricultural Research and Natural Resources Center of Varamin, Iran. Main plots were three irrigation treatments contains of (normal irrigation, non-irrigation at start of flowering stage (severe stress) and non-irrigation at start of grain filling stage (light stress)), and sub plots were four levels of seed inoculations with biofertilizers (no inoculation, inoculation with mycorrhiza fungus, inoculation with *Azotobacter* bacterium and coinoculation with mycorrhiza fungus plus with *Azotobacter* bacterium). The results showed the effect of drought stress during reproductive stage was significant on all traits, except for plant height and peduncle length. The grain yield decreased by 16 and 30 per cent for light and severe stress, respectively. The highest protein and phosphorus yield were obtained with mycorrhiza fungus inoculation treatment in normal irrigation condition.

Ngwako and Mashiq (2013) conducted an experiment at Department of Agricultural Research Station, Sebele, during the winter in 2009 and reported that irrigation significantly affected days to maturity, number of tillers, number of grains per spike and grain yield. Irrigation throughout the growth stages increased number of tillers, number of grains per spike, grain yield, harvest index and grain protein by 20.58, 26.07, 42.72, 16.71 and 3.31 per cent, respectively over no irrigation.

2.7 Effect of moisture stress and its management practices on economic studies

Singh *et al.*, (2003) conducted an experiment at Rajasthan Agricultural University, Bikaner (Rajasthan) in sandy loam soil (pH 8.1). The treatment consist of three irrigation regimes (0.6, 0.8 and 1.0 IW/CPE) with 6.0 cm depth of irrigation and four N levels (90, 120, 150 and 180 N kg ha⁻¹). They revealed that 1.0 IW/CPE with 150 N kg ha⁻¹ treatment combination recorded significantly highest net monetary returns (₹ 12279 ha⁻¹) and benefit : cost ratio (2.3) than rest of the treatment combinations.

Kibe and Singh (2003) conducted a field experiment at IARI, New Delhi in sandy soil (pH 7.5) with 4 irrigation levels (0, 1, 2 and 4 irrigations) at critical growth stages. The result revealed that, progressive increase in irrigation from 0 to 4 increased the wheat yield and yield attributes significantly. The grain (3962.5 kg ha⁻¹) and straw yield (6808.5 kg ha⁻¹) was highest with 4 irrigations. Benefit : cost ratio was also highest with 4 irrigations.

Sarkar (2005) conducted an experiment at Bidan Chandra Krishi Vishwvidyalaya, Gayeshpur (West Bengal) in loamy soil (pH 6.75). The treatment consisted of 3 levels of irrigation (0.8, 1.0 and 1.2 IW : CPE with 5.0 cm depth of irrigation water) and 3 levels of N, P₂O₅ and K₂O ha⁻¹. He reported that yield responded significantly with irrigation and recorded highest grain and straw yield when irrigated with 1.2 IW : CPE than their reduced levels. Benefit : Cost ratio were also responded significant to irrigation.

Singh *et al.*, (2006) conducted a field experiment at College of Agriculture, GB Pant University of Agriculture and Technology, Pantnagar (U.P) during *rabi* season of 2004-05 on wheat (*Triticum aestivum* L.) crop variety PBW-343 to study the effect of irrigation scheduling on wheat NPK concentration, uptake and yield sown

with the help of Pantnagar Zero Ferti Seed Drill. Four different irrigation schedules based on pan evaporation (mm/day) were replicated six times in a randomized block design. It was observed that significant increase in grain yield was recorded due to increased IW:CPE ratios. The highest yield (40.1 q ha^{-1}) and Benefit : Cost ratio was obtained when irrigation water supplied at IW:CPE ratio of 1.2.

Zameer Khan *et al.*, (2006) conducted field experiment at NARC, Islamabad and Tamman Multan Area of District Chakwal, Pakistan to compare the effect of K (KNO_3 and KCl) sources as foliar application at different growth stages of wheat. The treatments were (1) Control (No spray); (2) K- 0.5% solution (as KNO_3); (3) N and K- 0.5% and 0.2 % solution (as KCl+ Urea); (4) K- 0.5% solution (as KCl); (5) N- 0.2 % solution as Urea. Biological yield of wheat improved significantly with N and K application. The study proved that both sources of potash i.e. KNO_3 and KCl are equally effective in increasing wheat yield and can be helpful in achieving maximum realizable yield. Foliar application of potash at critical stages can be helpful in to realize optimum economic yield.

El Tahir *et al.*, (2011) was conducted a field experiment for two consecutive winter seasons (2008-09 and 2009-10) at the Demonstration Farm, College of Agricultural Studies, Sudan University of Science and Technology, to study the effect of different irrigation intervals on growth, yield and water use efficiency of wheat (*Triticum aestivum* L.). Wheat cultivar-Condor was grown with different irrigation intervals namely every 7, 10, 14, 21 and 28 days. The results showed that irrigation every 7 and 10 days gave the highest protein content, grain, straw yield and field water use efficiency, but for economics aspect irrigation every 10 days is recommended. Irrigation at every 14 days have no remarkable effect, on the other hand irrigation every 21, and 28 days must be avoided under this semi-arid condition.

Mekkei *et al.*, (2014) conducted an experiment at the Agricultural Experiment and Research Station, Faculty of Agriculture, Cairo University, Egypt to study the effect of irrigation regime (I_1 : full 5 irrigation, I_2 : skipping 2nd irrigation, I_3 : skipping 3rd irrigation, I_4 : skipping 4th irrigation and I_5 : skipping 5th irrigation) on yield and quality of five wheat cultivars. Results showed that skipping irrigation at various growth stages significantly decreased plant height, number of tillers m^{-2} , number of

spikes m^{-2} , spike length, 1000-kernel weight, grain, straw and biological yields, harvest index and Benefit : Cost ratio in both seasons.

Patil *et al.*, (2014) conducted field experiment during winter (*rabi*) season of 2010–11 and 2011–12 at CCS Agricultural University, Hisar (Haryana), to study integrated moisture stress management in wheat. The treatments consisted of 4 moisture regimes in main plots, *viz.*, irrigation at crown-root initiation (CRI) + 100 mm cumulative pan evaporation (CPE), crown-root initiation + 150 mm CPE, CRI + 200 mm CPE and CRI only, and 6 moisture-stress management practices in sub plots, *viz.*, no moisture stress-management, seed hardening (SH) by CaCl_2 , SH + KCl spray, SH + mycorrhizae application + KCl spray, SH + mycorrhizae + KCl spray + kaolin spray and Pusa hydrogel application. The result indicated that significantly highest grain and straw yields as well as net returns were recorded in SH + mycorrhizae + KCl spray + kaolin spray over irrigation at CRI only.

Sana *et al.*, (2014) carried out field experiment to investigate the effect of different irrigation schedules on growth and yield performance of wheat varieties assessment in district Awaran Balochistan during *rabi* 2012-13. Three wheat varieties i.e. Sassui, TD-1 and Raskoh-2005 were evaluated for their performance against three irrigation schedules i.e. five irrigations (1st 25 DAS and subsequent irrigations at 15 days interval), four irrigations (1st 30 DAS and subsequent irrigations at 20 days interval) and three irrigations (1st 35 DAS and subsequent irrigations at 25 days interval). The results showed that interaction of five irrigations and wheat variety Sassui proved optimum for obtaining maximum grain yield ($7444.70 \text{ kg ha}^{-1}$) and Benefit : Cost ratio.

3. MATERIAL AND METHODS

The present experiment entitled “Effect of moisture stress and its management practices on growth and yield of wheat” was carried out at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri during 2016-17. The details of the material used and methods adopted during the course of investigation are described in this chapter under following subheads.

3.1 Details of experimental material

3.1.1 Experimental site

An experiment was carried out at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, District. Ahmednagar (Maharashtra) during *rabi* season of 2016-17.

3.1.2 Physical and chemical properties of soil

The topography of experimental field was levelled and having good drainage. The experimental soil was clay loam in texture. In view to know the initial fertility status of the soil, representative soil samples were collected from experimental site from 0-30 cm depth randomly. The soil sample were analyzed in PG student's laboratory for determination of soil physical and chemical properties by using standard analytical methods and are presented in Table 3.1.

From the data (Table 3.1) it could be seen that the experimental soil was low in available nitrogen ($228.94 \text{ kg ha}^{-1}$), medium in phosphorus (14.82 kg ha^{-1}) and high in potassium (383.6 kg ha^{-1}). The soil organic carbon content, pH and EC was 0.54 per cent 8.10 and 0.26 dSm^{-1} , respectively. The physical properties of soil *viz.*, bulk density (1.24 g cm^{-3}), field capacity (35.28 %) and permanent wilting point (18.25 %) indicates that the soil was good in water retention capacity.

3.1.3 Climatic conditions

A. General

Geographically the Post Graduate Institute Research Farm, MPKV, Rahuri situated at $19^{\circ} 23'$ and $19^{\circ} 38'$ N latitude and between $74^{\circ} 39'$ and $74^{\circ} 65'$ S longitude. The average altitude is 511 m above mean sea level. Climatologically, this area falls in the semi-arid tract with average annual rainfall of 520 mm received in the 15 to 45 days.

Table 3.1. Physical and chemical properties of experimental site

S.N.	Particulars	Value	Method adopted	Reference/s
A.	Physical properties			
1.	Particle size distribution (%)			
i.	Coarse sand (%)	7.60	International pipette	Piper (1966)
ii.	Fine sand (%)	11.60		
iii.	Silt (%)	38.42		
iv.	Clay (%)	42.38		
2.	Textural class	Clay loam		
B.	Soil moisture constants			
3.	Field capacity (%)	35.28	Pressure plate apparatus	Richards (1947)
4.	Permanent wilting point (%)	18.25		
5.	Bulk density (g cm ⁻³)	1.24	Core sampler	Dastane (1972)
C.	Chemical properties			
1.	Soil pH (1:2.5 soil : water)	8.10	Potentiometry	Piper (1966)
2.	EC (dSm ⁻¹)	0.26	Conductometry	
3.	Organic carbon (%)	0.54	Wet oxidation	Nelson and Sommer (1982)
4.	Available nitrogen (kg ha ⁻¹)	228.94	Alkaline permanganate	Subbiah and Asija (1956)
5.	Available phosphorus (kg ha ⁻¹)	14.82	NaHCO ₃ (0.5M) pH 8.5 (Ascorbic acid)	Watanable and Olsen (1965)
6.	Available potassium (kg ha ⁻¹)	383.60	Flame photometer	Knudsen <i>et al.</i> (1982)

Table 3.2. Analytical methods for plant analysis

Sr. No.	Particulars	Method adopted	Reference
	Grain analysis		ICC-159 (1995)
1.	Protein content (%)	NIR spectrometer	
2.	Glutein content (%)	NIR spectrometer	
3.	Lysine content (%)	NIR spectrometer	

The rainfall is concentrated during monsoon months from June to October from South-West monsoon which is nearly 80 per cent of total rainfall, while the rest from North-East monsoon (October-November). The distribution of rainfall is erratic and uncertain.. The tract is under the rain shadow area lying on eastern sides of Western Ghats, agro-climatically falls under scarcity zone of Maharashtra.

In order to have an idea about the climatic conditions prevailed during the experimentation period (October 2016 to March 2017), The data on weekly means of meteorological weather parameters *viz.*, maximum and minimum temperature, relative humidity, sunshine hrs, wind velocity, rainfall and pan evaporation were obtained from Meteorological Observatory located at Water Management Project, Mahatma Phule Krishi Vidyapeeth, Rahuri and presented in Table 3.3.

B. Nature of season during experimental period (2016-17)

Data on weekly means of meteorological parameters during the experimental period of 2016-17 indicates that there was no rainfall during the crop growth period. The maximum and minimum temperature ranged from 26.5⁰C to 39.9⁰C and 8.7⁰C to 21.5⁰C, respectively. The weekly morning mean relative humidity at morning was between ranged 33 to 87 per cent, while evening mean relative humidity ranged 15 to 71 per cent. The maximum relative humidity (87 %) was observed during 40th meteorological week at morning hours, whereas the minimum relative humidity (15 %) was noticed during 12th and 13th meteorological week at evening hours. The bright sunshine hours ranged between 6.7-10.7 hr. The wind velocity was ranged between 0.3-2.5 kmph, throughout the crop growth period.

In general, weather during the period of experiment was favourable for growth and production of wheat.

3.1.4 Cropping history of experimental plot.

Cropping history of experimental plot for previous three years are presented in Table 3.4.

Table 3.3. Meteorological data for the year 2016-17

Met. Week	Temp.(⁰ C)		Humidity (%)		Sun shine (hrs)	Wind velocity (km hr. ⁻¹)	Rain fall (mm)	Rainy days	Evp. (mm day ⁻¹)
	Max.	Min.	Morn.	Even.					
October-2016									
40	28.6	21.5	87	71	7.9	0.8	0.0	0.0	3.3
41	31.6	20.6	80	53	7.1	0.7	0.0	0.0	4.1
42	31.6	17.2	67	34	8.1	0.4	0.0	0.0	4.5
43	31.4	16.4	66	36	9.1	0.3	0.0	0.0	4.7
November-2016									
44	30.1	13.6	51	41	9.5	0.4	0.0	0.0	4.6
45	29.6	11.7	52	25	9.5	0.4	0.0	0.0	4.2
46	29.5	12.6	64	41	7.5	0.5	0.0	0.0	3.7
47	29.1	10.1	56	27	9.3	0.6	0.0	0.0	3.9
48	30.2	10.5	62	26	8.8	0.5	0.0	0.0	4.9
December-2016									
49	28.9	11.2	64	34	8.6	1.0	0.0	0.0	3.9
50	28.7	11.7	52	37	7.8	1.1	0.0	0.0	4.0
51	29.2	10.2	54	34	9.3	0.4	0.0	0.0	4.1
52	29.4	8.7	57	29	9.5	0.4	0.0	0.0	4.5
January -017									
01	29.3	9.3	57	34	9.6	0.4	0.0	0.0	4.2
02	26.5	8.9	61	34	9.4	1.0	0.0	0.0	3.9
03	28.8	13.5	68	39	6.7	1.0	0.0	0.0	4.1
04	31.0	13.0	62	30	9.5	1.1	0.0	0.0	4.2
February-2017									
05	31.3	12.8	59	28	9.9	1.1	0.0	0.0	4.4
06	31.7	13.6	59	32	9.5	1.2	0.0	0.0	4.9
07	32.3	13.9	53	26	9.7	1.9	0.0	0.0	5.6
08	34.6	13.8	45	21	10.7	1.8	0.0	0.0	6.5
09	34.6	14.0	41	15	8.5	1.2	0.0	0.0	6.6
March-2017									
10	32.8	13.9	47	23	9.1	1.6	0.0	0.0	7.8
11	33.0	13.6	33	17	9.2	2.5	0.0	0.0	7.0
12	36.1	17.2	38	15	9.1	2.4	0.0	0.0	8.1
13	39.9	21.0	41	15	7.9	1.1	0.0	0.0	8.5

Table 3.4. Cropping history of experimental plot

Sr. No.	Year	Season		
		<i>Kharif</i>	<i>Rabi</i>	Summer
1.	2013-2014	Maize	Onion, potato	Fallow
2.	2014-2015	Maize	Onion, potato	Fallow
3.	2015-2016	Maize	Wheat	Fallow
4.	2016-2017	Present investigation.		

3.2 Experimental methods

3.2.1 Treatment details

The experiment consists of 24 treatment combinations with six main plot treatments of irrigation regimes and four sub-plot treatments of moisture stress management practices. The treatments were replicated three times in split plot design. The plan of layout used to carry out research is given in Fig. 3.1. The details of the treatment and symbols used during research work are presented in Table 3.5.

Table 3.5. Details of treatment and symbols used

Sr. No	Treatment	Symbol
A.	Main plot treatment : Irrigation regimes	
1.	Irrigation at CRI stage	I ₁
2.	Irrigation at tillering stage	I ₂
3.	Irrigation at flowering stage	I ₃
4.	Irrigation at CRI + tillering stage	I ₄
5.	Irrigation at CRI + tillering + flowering stage	I ₅
6.	Irrigation at CRI + tillering + flowering + milk stage	I ₆
B.	Sub plot treatment : Moisture stress management practices	
1.	Control	S ₁
2.	Soil application of VAM @ 10 kg ha ⁻¹	S ₂
3.	Foliar spray of 1 % KNO ₃ at flowering	S ₃
4.	Soil application of VAM @ 10 kg ha ⁻¹ + Foliar spray of 1 % KNO ₃ at flowering	S ₄

3.2.2 Experimental details

- | | |
|------------------------------------|---|
| 1. Variety | Phule Samadhan |
| 2. Spacing | 22.5 cm (row to row) |
| 3. Seed rate | 100 kg ha ⁻¹ |
| 4. Recommended dose of fertilizers | 120:60:40 N,P ₂ O ₅ ,K ₂ O kg ha ⁻¹ |
| 5. Plot size | Gross : 3.00 m x 2.70 m
Net : 2.75 m x 2.25 m |

Design – Split plot

Replications – Three (3)

3.3 Details of cultivation practices :

3.3.1 Preparation of field

The field was prepared by ploughing with tractor followed by one harrowing. The soil was brought to fine tilth and then the layout of experiment was done manually. The plan of experimental layout is given in Fig.3.1.

3.3.2 Application of FYM

The well decomposed farmyard manure (FYM) was applied common to all the treatments @ 10 t ha⁻¹ before sowing of the crop.

3.3.3 Seed material

The wheat seed cv. Phule Samadhan was procured from the office of the Chief Scientist (seed), Breeder Seed Production Unit, Mahatma Phule Krishi Vidyapeeth, Rahuri. The characteristics of wheat cultivar is as under.

Sr. No.	Particulars	Details
1.	Crop and variety	Wheat (Phule Samadhan)
2.	Release by	MPKV, Rahuri
3.	Year of Release	2016
4.	Plant height (cm)	90-100
5.	Maturity Period (days)	100-115
6.	Average weight of 1000 grains (g)	40-43
7.	Yield potential (q ha ⁻¹)	46.12 (irrigated)
8.	Other characters	i. Early maturity. ii. Bold seeded. iii. Rust resistant. iv. Good quality for chapatti.

3.3.4 Seed treatment

Wheat seeds were treated with biofertilizers i.e. *Azotobactor* and PSB @ 250 g per 10 kg of seeds before sowing.

3.3.5 VAM application

The Vascular Arbuscular Mycorrhizae (VAM) culture was applied @ 10 kg ha⁻¹ before sowing. The VAM culture was first mix with well decomposed farmyard manure and applied in the line of wheat seed at the time of sowing.

3.3.6 Sowing

The wheat was sown by line sowing with 22.5 cm line spacing on 10th November 2016.

3.3.7 Gap filling

Gap filling was done in wheat on 28-11-2016 in order to maintain optimum plant population.

3.3.8 Fertilizer application

The recommended dose of fertilizers (120:60:40 kg ha⁻¹) was applied through urea (46 % N), single super phosphate (16 % P₂O₅) and muriate of potash (60 % K₂O). The half dose N and full dose of P₂O₅ and K₂O was applied at the time of sowing as basal dose, while the remaining half dose of N was applied as per treatment on 11-12-2016 (I₁, I₄, I₅ and I₆), 30-12-2016 (I₃) and 19-01-2017(I₅) as top dressing.

3.3.9 Irrigation

First common irrigation was applied immediately after sowing (@ 7.5 cm depth) and second common irrigation was applied subsequently after seven days (@ 7.5 cm depth) to ensure better germination. Thereafter the irrigations were applied as per the treatment by using following formula.

$$\text{Time (Sec.)} = \frac{\text{Area (m}^2\text{)} \times \text{Depth of irrigation (m)}}{\text{Discharge (lit/sec.)}}$$

3.3.10 Cultural operations

The schedule of various cultural operations carried out during the course of investigation are presented in Table 3.6.

3.3.11 Plant protection

No plant protection measures were undertaken as there was no incident of any insect, pest or diseases taken during the period of experimentation.

3.3.12 Weeding

In order to keep the experimental plot free from weeds two hand weedings were carried out on 03-12-2016 and 24-12-2016 in experimental field.

Table 3.6 Schedule of cultural operations carried out during the experimental period

Sr No	Field operations	Frequency	Date of operation
A.	Preparatory tillage		
1.	Ploughing	1	11-10-2016
2.	Harrowing	1	18-10-2016
B.	FYM application	1	23-10-2016
C.	Preparation of layout	1	05-11-2016
D.	Basal dose of fertilizers	1	09-11-2016
E.	Application of VAM	1	10-11-2016
F.	Sowing	1	10-11-2.16
G.	Top dressing of nitrogen	3	10-12-2016, 30-12-2016 and 19-01-2017
H.	Post sowing operations		
1.	Gap filling	1	22-11-2016
2.	Weeding	2	03-12-2016 and 24-12-2016
3.	Irrigation at CRI	1	10-12-2016
4.	Irrigation at tillering	1	29-12-2016
5.	Irrigation at flowering	1	18-01-2017
6.	Irrigation at CRI + tillering stage	2	10-12-2016 and 29-12-2016
7.	Irrigation at CRI + tillering + flowering stage	3	10-12-2016, 29-12-2016 and 20-01-2017
8.	Irrigation at CRI + tillering + flowering + milk stage	4	10-12-2016, 29-12-2016, 20-01-2017 and 03-02-2017
9.	Foliar spraying of 1% KNO ₃ at flowering	1	14-01-2017, 17-01-2017, 20-01-2017, 27-01-2017, 04-02-2017 and 08-02-2017
H.	Harvesting	6	17-02-2017, 20-02-2017, 25-02-2017, 02-03-2017, 08-03-2017 and 12-03-2017
I.	Threshing	6	18-02-2017, 21-02-2017, 26-02-2017, 03-03-2017, 09-03-2017 and 13-03-2017

3.3.13 Harvesting

Harvesting of wheat crop was done as per the treatments. The treatments where only one irrigation was applied were harvested earlier i.e. on 17-02-2017 (I₁), 20-02-2017 (I₂) and 25-02-2017 (I₃). Subsequently the treatment I₄, I₅ and I₆ were harvested on 02-03-2017, 08-03-2017 and 12-03-2017 respectively.

3.3.14 Threshing and winnowing

The crop was threshed plot wise with the help of mini thresher and grain yield per plot was recorded accordingly. The threshed seeds were winnowed, cleaned and stored separately for future quality studies.

3.4 Details of observations

3.4.1 Sampling techniques

The various biometric observations of wheat were recorded in per meter row length. The 5 lines were selected in each net plot, bamboo pegs along with tags were fixed at both side of each row for easy identification. The periodical growth observations were recorded on these plants starting from 28 days after sowing. These selected plants were further used for recording the yield contributing characters. The details of the observations recorded during the period of investigation are presented in Table 3.7.

Table 3.7 Biometric observation for wheat

Sr. No	Particulars	Procedure/ formula	Frequency	Sample size	Period
A	Growth Studies				
1	Plant count	Plant count was recorded from each net plot for initial and final plant count.	2	Per meter row length	At 15 DAS and at harvest
2	Plant height (cm)	The plant height was measured from the ground level to the last fully opened leaf till ear emergence. At harvest it was measured from ground level up to the bottom of ear.	4	5 plants	28,56,84 DAS and at harvest
3	Number of leaves plant ⁻¹	The numbers of green leaves were counted from the ground level to the last fully opened leaf for each treatment	4	5 plants	28,56,84 DAS and at harvest
4	Leaf area plant ⁻¹ (dm ²)	The leaf area was measured by using the instrument Leaf Area Meter from each treatment.	4	5 plants	28,56,84 DAS and at harvest

Table 3.7 contd....

Sr. No	Particulars	Procedure/ formula	Frequency	Sample size	Period
5	No. of tillers	Number of tillers were counted from per meter row length from each net plot.	4	Per meter row length	28,56,84 DAS and at harvest
6	Dry matter (g/ meter row length)	Sample plants of 1 meter row length from each treatment were cut from the base and then oven dried at 60°C till the constant weight was obtained and expressed as dry matter per meter row length.	2	Per meter row length	At harvest
B. Yield studies					
1	Number of spikelets panicle ⁻¹	Number of spikelets per panicle were recorded from randomly selected five panicle from each treatment.	1	5 panicle	At harvest
2	Length of panicle (cm)	Length of panicle was recorded with the help of scale from randomly selected five panicles from each treatment and work out the mean length of panicle and expressed in cm.	1	5 panicle	At harvest
3	Number of grains panicle ⁻¹	Five panicle from each treatment were collected and separated all the grains from the panicle, then counted all the grains and work out the average number of grains per panicle.	1	5 panicle	At harvest
4	Weight of grains panicle ⁻¹ (g)	The number of grains obtained from five panicles from each treatment were weighed on electronic balance and work out mean grain weight per panicle and expressed in grams.	1	5 panicle	At harvest
5	1000 grain weight (g)	Thousand grains were counted from randomly drawn composite grain sample from each treatment and recorded the weight of grains by using electronic balance and expressed in grams.	1	Composite sample	At harvest
6	Grain yield plot ⁻¹ (kg)	Treatment wise the net plots were harvested and threshed separately after cleaning the grains weight was recorded by using electronic balance and expressed in kilograms	1	Net plot	At harvest

Table 3.7 contd....

Sr. No	Particulars	Procedure/ formula	Frequency	Sample size	Period
7	Straw yield plot ⁻¹ (kg)	After separating the grains from each net plots, the remaining straw was weighed by using electronic balance and recorded the weight and expressed in kilograms.	1	Net plot	At harvest
C	Quality studies				
1	Protein (%)	The protein content in wheat grain was analyzed with the help of NIR Spectrometer from each treatment and expressed in per cent.	1	Composite	At harvest
2	Glutein (%)	Theglutein content in wheat grain was analyzed with the help of NIR Spectrometer from each treatment and expressed in per cent.	1	Composite	At harvest
3.	Lysine (%)	The lysine content in wheat grain was analyzed with the help of NIR Spectrometer from each treatment and expressed in per cent.	1	Composite	At harvest
D	Physiological observations				
1	Photosynthetic rate ($\mu \text{ mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)	Physiological parameters were recorded by using portable photosynthesis system LI-COR make LI- 6400XT periodically at an interval of 28 days after sowing. The observations were recorded between 11.00-13.00 hrs at every observation. Principle:- Portable photosynthesis system (IRGA) are used for the measurement of a wide range of hetero atomic gas molecules including CO ₂ , H ₂ O, NH ₃ , CO, SO ₂ , N ₂ O, NO and gaseous hydrocarbons like CH ₃ . Hetero atomic molecules have characteristic absorption spectrum in the infrared region. Therefore absorption of radiation by a specific hetero atomic molecule is directly proportional to its concentration in an air sample.	4	5 plants	28,56,84 and at harvest
2	Transpiration rate ($\text{m mol H}_2\text{O m}^{-2} \text{ s}^{-1}$)		4	5 plants	28,56,84 and at harvest
3	Stomatal conductance ($\text{m mol m}^{-2} \text{ s}^{-1}$)		4	5 plants	28,56,84 and at harvest
4	Leaf temperature (°C)		4	5 plants	28,56,84 and at harvest
5	Stomatal resistance ($\mu \text{ mol m}^{-2} \text{ s}^{-1}$)		4	5 plants	28,56,84 and at harvest
6	CO ₂ concentration ($\mu \text{ mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)		4	5 plants	28,56,84 and at harvest

Table 3.7 contd....

Sr. No	Particulars	Procedure/ formula	Frequency	Sample size	Period
E	Soil studies				
1.	Field capacity (%)	Soil samples were collected and field capacity was calculated with the help of pressure plate apparatus.	1	Net plot	At harvest
2.	Permanent wilting point (%)	Soil samples were collected and permanent wilting point was calculated with the help of pressure plate apparatus.			
3.	Bulk density (g cm ⁻³)	Soil samples were collected and bulk density was calculated with the help of core sampler.			
4.	pH	Soil sample were collected at the depth of 0-30 cm from each replication plot before and after harvest of each crop. After air drying the samples were grinded in wooden mortal and pistil in order to study the effect of moisture stress on various physical and chemical properties of soil during experimentation.			
5.	EC (dSm ⁻¹)				
6.	OC (%)				
7.	Available N, P, K				
F	Economic evalution				
1.	Consumptive use (cm)	$CU = \sum_{i=1}^n \frac{M_{1i} - M_{2i}}{100} \times BDi \times Di$ Where as, CU = Consumptive use (cm) n = Number of layers considered in root zone M_{1i} = Soil moisture percentage at first sampling in ith layer M_{2i} = Soil moisture percentage at second sampling in ith layer BDi = Bulk density of ith soil layer (g cm⁻³) Di = Depth of ith soil layer			
2.	Crop water use efficiency (kg ha ⁻¹ -cm)	$= \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Crop evapotranspiration (cm)}}$			
3.	Field water use efficiency (kg ha ⁻¹ -cm)	$= \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Total water requirement (cm)}}$			
4.	Water productivity (kg m ⁻³)	$= \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Water applied (m}^{-3}\text{)}}$			

Table 3.7 contd....

Sr. No	Particulars	Procedure/ formula	Frequency	Sample size	Period
5.	Yield response factor (Ky coefficient)	$\left(\frac{Y_a}{Y_x} \right) = K_y \left(\frac{ET_a}{ET_x} \right)$ Whereas, Y_x = Maximum yield Y_a = Actual yield ET_x = Maximum evapotranspiration ET_a = Actual evapotranspiration K_y = Yield response factor			
G	Economic evaluation				
1.	Cost of cultivation (` ha ⁻¹)	The cost of cultivation of wheat crop was worked out by considering the prevailing prices of inputs as given in appendix-I			
2.	Gross monetary return (` ha ⁻¹)	Gross monetary return was worked out by considering the prevailing prices of the farm produce (output).			
3.	Net monetary return (` ha <sup>-1</sup>)	= Gross monetary returns (` ha ⁻¹ ) - Cost of cultivation (` ha ⁻¹)			
4.	B:C ratio.	$= \frac{\text{Gross monetary returns (` ha}^{-1}\text{)}}{\text{Cost of cultivation (` ha}^{-1}\text{)}}$			

3.5 Statistical analysis

Data recorded on various growth and yield attributes, yield of crops were statistically analyzed by using the standard method of split plot design for main and sub plot treatment of wheat. The F test of significance was used for testing the null hypothesis and appropriate standard error of mean (SEm. ±). Treatment effects were worked out on basis of critical difference (C.D) at 5 per cent probability level (Panse and Sukhatme, 1967). The data was also present in tabular form with suitable graphical illustrations and figures at appropriate places.

4. RESULTS AND DISCUSSION

4.1 Plant population

The plant population of wheat as influenced by different treatments are presented in Table 4.1. The mean plant population of wheat was 45.47 and 111.7 in per meter row length at initial and at harvest, respectively.

Effect of irrigation regimes:

The initial plant population of wheat was not influenced significantly due to different irrigation regimes. This indicates that the plant population was uniform in all the treatments of irrigation regimes. However the final plant population was found significant due to different irrigation regimes. The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher plant population at harvest than rest of the irrigation regimes. Whereas significantly minimum plant population was observed in scheduling of one irrigation to wheat crop at flowering stage alone than rest of the irrigation regimes. The higher number of irrigations maintain the optimum moisture level at root rhizosphere of crop throughout growth period which increase the survival percentage of tillers. Whereas where only one irrigation was applied at critical growth stages the survival percentage of tillers were minimum as there was moisture stress in root rhizosphere in most of the growing period. These results are in accordance with Onyibe (2005) and Al-Molhem (2016).

Effect of moisture stress management practices

The initial plant population in wheat was not influenced significantly due to different moisture stress management practices. However, the final plant population was differed significantly due to different moisture stress management practices. The soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage received significantly higher plant population than rest of the management practices. Significantly minimum plant population was observed in control treatment than rest of the moisture stress management practices.

Table 4.1 Plant population of wheat as influenced by different treatment

Treatment	Plant Population m ⁻¹ row length	
	Initial	Final
Irrigation regimes (I)		
I ₁ : Irrigation at CRI stage	45	97
I ₂ : Irrigation at tillering stage	45	100
I ₃ : Irrigation at flowering stage	45	94
I ₄ : Irrigation at CRI + tillering stage	46	118
I ₅ : Irrigation at CRI + tillering + flowering stage	45	127
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	46	132
S.Em. ±	0.53	0.03
CD at 5 %	NS	0.11
Moisture stress management (S)		
S ₁ : Control	44	104
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	45	110
S ₃ : 1 % KNO ₃ spray at flowering	45	114
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	45	117
S.Em. ±	0.30	0.03
CD at 5 %	NS	0.08
Interaction (I x S)		
Between two sub plot means at same level of main plot means		
S.Em. ±	0.74	0.07
CD at 5 %	NS	0.20
Between two main plot means at same level of sub plot means		
S.Em. ±	0.83	0.07
CD at 5 %	NS	0.21
General Mean	45.47	111.72

Table 4.1a. Interaction effect between irrigation regime and moisture stress management practices on plant population in wheat at harvest

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	93.0	97.0	90.0	110.0	118.0	120.0
VAM (soil appl. @ 10 kg ha ⁻¹)	97.0	96.0	97.0	118.0	123.0	134.0
1 % KNO ₃ spray at flowering	104.0	97.3	94.0	120.0	131.0	138.0
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	109.0	99.0	96.0	124.0	137.0	139.0
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.07			0.07		
CD at 5 %	0.20			0.21		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

This might be because of vascular arbuscular mycorrhizae enhances drought tolerance in plants by tapping a large volume of soil, mobilized scarce nutrient sources and modify the root environment where as KNO₃ maintains the water potential in plant which helps to increase the survival percentage of tillers. These results was similar with those observed by Saren *et al.*, (2004) and Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of final plant population in wheat.

Scheduling of four irrigations at crown root initiation + tillering + flowering + milk stage to wheat along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher plant population than rest of the treatment combinations. Significantly minimum plant population was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.1 a).

4.2 Plant height

The plant height of wheat as influenced by different treatments are presented in Table 4.2 and graphically depicted in Fig. 4.1. The mean plant height of wheat was 33.63, 56.57, 81.34 and 81.38 cm at 28, 56, 84 DAS and at harvest, respectively.

Effect of irrigation regimes

The plant height in wheat was influenced significantly due to different irrigation regimes at all the crop growth stages except 28 DAS. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher plant height at all the crop growth stages than rest of the irrigation regimes. However, it was at par with scheduling of three irrigations to wheat

Effect of moisture stress management practices

The plant height in wheat was influenced significantly due to different moisture stress management practices at all the crop growth stages except 28 DAS. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher plant height at all crop growth stages than rest of the management practices. However, it was at par with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing alone and foliar spray of 1 % KNO₃ at flowering alone at 56 DAS. Significantly minimum plant height was observed in control treatment at all the crop growth stages than rest of the moisture stress management practices. Plant height at soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage was higher because of vascular arbuscular mycorrhizae helps to maintain the water potential in soil, where as potassium nitrate maintains the osmotic potential in plants which increases cell division, cell multiplication and cell enlargement which in turn helps to increase in plant height. These results are in accordance with Dhaka (2003) and Al-Karaki *et al.*, (2004).

Table 4.2 Periodical plant height of wheat as influenced by different treatment

Treatment	Plant height(cm)			
	At 28 DAS	At 56 DAS	At 84 DAS	At harvest
Irrigation regimes (I)				
I ₁ : Irrigation at CRI stage	33.56	55.77	76.19	76.25
I ₂ : Irrigation at tillering stage	33.55	53.76	78.12	78.17
I ₃ : Irrigation at flowering stage	33.58	50.08	74.68	74.72
I ₄ : Irrigation at CRI + tillering stage	33.56	57.78	82.19	82.21
I ₅ : Irrigation at CRI + tillering + flowering stage	33.76	59.94	86.03	86.04
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	33.79	62.08	90.83	90.86
S.Em. $\pm$	0.08	0.68	0.42	0.41
CD at 5 %	NS	2.14	1.31	1.30
Moisture stress management (S)				
S ₁ : Control	33.59	54.45	78.99	79.03
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	33.66	57.09	80.53	80.55
S ₃ : 1 % KNO ₃ spray at flowering	33.62	56.86	81.83	81.85
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	33.65	57.87	84.01	84.12
S.Em. $\pm$	0.07	0.50	0.30	0.30
CD at 5 %	NS	1.43	0.86	0.85
Interaction (I x S)				
Between two sub plot means at same level of main plot means				
S.Em. $\pm$	0.17	1.22	0.73	0.73
CD at 5 %	NS	3.49	2.10	2.09
Between two main plot means at same level of sub plot means				
S.Em. $\pm$	0.17	1.25	0.76	0.75
CD at 5 %	NS	3.70	2.24	2.23
General Mean	33.63	56.57	81.34	81.38

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices on plant height was found to be significant in respect of plant height of wheat at 56 DAS, 84 DAS and at harvest.

At 56 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher plant height than rest of the treatment combinations, however it was at par with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with foliar spray of 1 % KNO₃ at flowering stage alone and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing alone as well as scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage and foliar spray of 1 % KNO₃ at flowering stage. Significantly minimum plant height was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.2a).

At 84 days after sowing scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher plant height than rest of the treatment combinations. However, it was at par with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with foliar spray of 1 % KNO₃ at flowering stage alone. Significantly minimum plant height was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.2 b). Almost similar trend was observed at harvesting stage in respect of plant height (Table 4.2 c).

Table 4.2a. Interaction effect between irrigation regimes and moisture stress management practices on plant height (cm) of wheat at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	53.25	52.35	48.52	55.58	56.10	60.88
VAM (soil appl. @ 10 kg ha ⁻¹)	58.13	53.14	49.58	59.50	60.25	61.92
1 % KNO ₃ spray at flowering	55.30	54.28	50.55	57.53	61.25	62.25
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	56.38	55.25	51.68	58.52	62.15	63.25
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	1.22			1.25		
CD at 5 %	3.49			3.70		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.2b Interaction effect between irrigation regime and moisture stress management practices on plant height (cm) of wheat at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	72.75	76.25	72.17	79.25	84.25	89.25
VAM (soil appl. @ 10 kg ha ⁻¹)	75.92	77.25	74.24	80.25	85.25	90.25
1 % KNO ₃ spray at flowering	76.92	78.62	75.58	82.25	86.35	91.25
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	79.17	80.37	76.75	87.00	88.25	92.55
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.73			0.76		
CD at 5 %	2.10			2.24		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.2c Interaction effect between irrigation regime and moisture stress management practices on plant height (cm) of wheat at harvest

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	73.01	76.25	72.17	79.25	84.25	89.25
VAM (soil appl. @ 10 kg ha ⁻¹)	75.92	77.25	74.24	80.25	85.25	90.25
1 % KNO ₃ spray at flowering	76.92	78.62	75.58	82.25	86.35	91.25
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	79.17	80.57	76.90	87.07	88.32	92.70
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.73			0.75		
CD at 5 %	2.09			2.23		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

4.3 Number of tillers m⁻¹ row length

The number of tillers m⁻¹ row length in wheat as influenced by different treatments are presented in Table 4.3 and graphically depicted in Fig.4.2. The mean of number of tillers m⁻¹ row length in wheat were 197.90, 112.94 and 111.72 at 56, 84 DAS and at harvest, respectively.

Effect of irrigation regimes

The number of tillers in wheat was influenced significantly due to different irrigation regimes at all the crop growth stages. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher number of tillers at all the crop growth stages than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum number of tillers m⁻¹ row length at all crop growth stages than rest of the irrigation regimes. This might be because of high moisture content at all growth stages increases photosynthetic activities there by increases number of tillers in wheat crop. Similar results were observed by Parihar and Tiwari (2003) and Saren *et al.*, (2004).

Table 4.3 Periodical number of tillers m^{-1} row length in wheat as influenced by different treatment

Treatment	Number of tillers /m row length		
	At 56 DAS	At 84 DAS	At harvest
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	195.67	98.75	97.12
I ₂ : Irrigation at tillering stage	197.00	102.25	100.52
I ₃ : Irrigation at flowering stage	186.50	96.33	94.52
I ₄ : Irrigation at CRI + tillering stage	200.50	119.00	118.54
I ₅ : Irrigation at CRI + tillering + flowering stage	200.75	127.58	127.31
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	207.00	133.75	132.15
S.Em. $\pm$	0.07	0.32	0.03
CD at 5 %	0.21	1.00	0.11
Moisture stress management (S)			
S ₁ : Control	191.17	105.83	104.67
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	202.00	112.39	110.83
S ₃ : 1 % KNO ₃ spray at flowering	194.00	115.33	114.06
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	204.44	118.22	117.33
S.Em. $\pm$	0.06	0.28	0.03
CD at 5 %	0.16	0.80	0.08
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. $\pm$	0.14	0.68	0.07
CD at 5 %	0.39	1.96	0.20
Between two main plot means at same level of sub plot means			
S.Em. $\pm$	0.14	0.67	0.07
CD at 5 %	0.40	1.97	0.21
General Mean	197.90	112.94	111.72

Table 4.3a Interaction effect between irrigation regime and moisture stress management practices on number of tillers m⁻¹ row length of wheat at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	190.0	191.0	180.0	196.0	190.0	200.0
VAM (soil appl. @ 10 kg ha ⁻¹)	200.0	201.0	190.0	202.0	205.0	213.0
1 % KNO ₃ spray at flowering	192.0	193.0	179.0	199.0	200.0	200.0
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	200.6	203.0	196.0	205.0	208.0	214.0
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.14			0.14		
CD at 5 %	0.39			0.40		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.3b. Interaction effect between irrigation regime and moisture stress management practices on number of tillers of wheat at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	95.0	97.0	92.0	111.0	119.0	121.0
VAM (soil appl. @ 10 kg ha ⁻¹)	99.3	98.0	99.0	119.0	124.0	135.0
1 % KNO ₃ spray at flowering	105.0	99.0	96.0	121.0	132.0	139.0
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	110.0	101.0	98.0	125.0	135.3	140.0
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.68			0.67		
CD at 5 %	1.96			1.97		

Table 4.3c. Interaction effect between irrigation regime and moisture stress management practices on number of tillers of wheat at harvest

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	93.0	97.0	90.0	110.0	118.0	120.0
VAM (soil appl. @ 10 kg ha ⁻¹)	97.0	96.0	97.0	118.0	123.0	134.0
1 % KNO ₃ spray at flowering	104.0	97.3	94.0	120.0	131.0	138.0
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	109.0	99.0	96.0	124.0	137.0	139.0
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.07			0.07		
CD at 5 %	0.195			0.199		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Effect of moisture stress management practices

The number of tillers m⁻¹ row length in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher number of tillers m⁻¹ row length at all crop growth stages than rest of the moisture stress management practices. Significantly minimum number of tillers m⁻¹ row length at all the crop growth stages was observed in control treatment than rest of the moisture stress management practices. The higher number of tillers m⁻¹ row length at soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be because vascular arbuscular mycorrhizae creates favorable water balance in root rhizosphere and supply optimum quantity of nutrients which in turn helps to increase number of tillers m⁻¹ row length in wheat. These results are similar to those reported by Moinuddin and Goswami (2004) and Huixing Song (2005).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of number of tillers m^{-1} row length at all the crop growth stages.

At 56 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage recorded significantly higher number of tillers m^{-1} row length than rest of the treatment combinations. Significantly minimum number of tillers m^{-1} row length was observed with scheduling of one irrigation at flowering stage along with control treatment than rest of the treatment combinations (Table 4.3a).

At 84 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage recorded significantly higher number of tillers m^{-1} row length than rest of the treatment combinations. However, it was at par with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with foliar spray of 1 % KNO_3 at flowering stage alone. Significantly minimum number of tillers m^{-1} row length was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.3b).

At harvest scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage recorded significantly higher number of tillers m^{-1} row length than rest of the treatment combinations. Significantly minimum number of tillers m^{-1} row length was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.3c).

Table 4.4 Periodical number of leaves per plant of wheat as influenced by different treatment

Treatment	Number of leaves plant ⁻¹		
	At 28 DAS	At 56 DAS	At 84 DAS
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	11.80	14.63	3.27
I ₂ : Irrigation at tillering stage	11.25	15.53	3.26
I ₃ : Irrigation at flowering stage	11.24	14.34	3.24
I ₄ : Irrigation at CRI + tillering stage	11.77	16.14	3.31
I ₅ : Irrigation at CRI + tillering + flowering stage	11.74	16.18	3.33
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	12.01	16.28	3.39
S.Em. ±	0.01	0.27	0.02
CD at 5 %	NS	0.86	0.05
Moisture stress management (S)			
S ₁ : Control	11.29	14.65	3.12
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	11.90	15.89	3.16
S ₃ : 1 % KNO ₃ spray at flowering	11.40	15.19	3.32
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	11.96	16.33	3.60
S.Em. ±	0.01	0.29	0.01
CD at 5 %	0.01	0.84	0.03
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. ±	0.01	0.72	0.0271
CD at 5 %	NS	2.05	0.077
Between two main plot means at same level of sub plot means			
S.Em. ±	0.01	0.68	0.0279
CD at 5 %	NS	1.97	0.082
General Mean	11.64	15.52	3.30

Table 4.4a. Interaction effect between irrigation regime and moisture stress management practices on number of leaves plant⁻¹ of wheat at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	12.33	14.81	13.04	16.32	15.63	15.77
VAM (soil appl. @ 10 kg ha ⁻¹)	15.70	15.90	15.25	15.64	16.58	16.24
1 % KNO ₃ spray at flowering	14.77	15.15	14.14	17.00	14.83	15.25
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	15.71	16.27	14.91	15.59	17.67	17.87
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.72			0.68		
CD at 5 %	2.05			1.97		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.4b. Interaction effect between irrigation regime and moisture stress management practices on number of leaves plant⁻¹ of wheat at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	3.21	3.08	3.05	3.11	3.12	3.15
VAM (soil appl. @ 10 kg ha ⁻¹)	3.14	3.10	3.08	3.16	3.21	3.25
1 % KNO ₃ spray at flowering	3.27	3.29	3.29	3.32	3.35	3.40
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	3.47	3.56	3.52	3.64	3.65	3.75
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.0271			0.0279		
CD at 5 %	0.077			0.082		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

4.4 Number of leaves plant⁻¹

The number of leaves plant⁻¹ in wheat as influenced by different treatments are presented in Table 4.4. The mean number of leaves plant⁻¹ in wheat were 11.64, 15.52 and 3.30 at 28, 56 and 84 DAS, respectively.

Effect of irrigation regimes

The number of leaves plant⁻¹ in wheat was influenced significantly due to different irrigation regimes at all the crop growth stages except 28 DAS. Among the irrigation regimes scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher number of leaves plant⁻¹ at all the crop growth stages than rest of the irrigation regimes. However, it was at par with scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage and scheduling of two irrigations to wheat crop at crown root initiation + tillering as well as scheduling of one irrigations to wheat crop at tillering stage at 56 days after sowing. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum number of leaves plant⁻¹ at all the crop growth stages than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher number of leaves plant⁻¹ at all the crop growth stages, this might be because of frequent application of irrigation at all the critical growth stages of crop which increase the internode numbers and length of internode resulted in increasing number of leaves plant⁻¹. These results were accordance with by Onyibe (2005) and Akram (2011).

Effect of moisture stress management practices

The number of leaves plant⁻¹ in wheat was influenced significantly due to different moisture stress management practices at all crop growth stages except 28 DAS. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher number of leaves plant⁻¹ at all crop growth stages than rest of the moisture stress management practices. However, it was at par with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing alone at 56 DAS. Significantly minimum number of leaves plant⁻¹ at all the crop growth stages was observed in control treatment than rest of the moisture stress management practices. The higher number of leaves plant⁻¹ with soil

application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be because of vascular arbuscular mycorrhizae increases water absorption capacity and KNO₃ stimulates biological processes in plant cell such as enzyme activation, respiration and chlorophyll synthesis which increases number and length of internodes. These results were in accordance with Al-Karaki *et al.*, (2004) and Ranjita *et al.*, (2007).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of number of leaves plant⁻¹ at 56 and 84 DAS, respectively.

At 56 days after sowing scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher number of leaves plant⁻¹ than rest of the treatment combinations. However, it was at par with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing alone, scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage, scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing alone, scheduling of two irrigations to wheat crop at crown root initiation + tillering along with foliar spray of 1 % KNO₃ at flowering stage alone, scheduling of two irrigations to wheat crop at crown root initiation + tillering along with control treatment, scheduling of one irrigations to wheat crop at tillering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage and scheduling of one irrigations to wheat crop at tillering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing alone. Significantly minimum number of leaves plant⁻¹ were observed with scheduling of

one irrigation at crown root initiation and control treatment than rest of the treatment combinations (Table 4.4a).

At 84 days after sowing scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher number of leaves plant⁻¹ than rest of the treatment combinations. Significantly minimum number of leaves plant⁻¹ was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.4b).

4.5 Leaf area plant⁻¹

The leaf area plant⁻¹ of wheat as influenced by different treatments are presented in Table 4.5. The mean leaf area plant⁻¹ in wheat was 1.04, 1.45 and 1.16 dm² at 28, 56 and 84 DAS, respectively.

Effect of irrigation regimes

The leaf area plant⁻¹ in wheat was influenced significantly due to different irrigation regimes at all the crop growth stages except 28 DAS. Among the irrigation regimes scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher leaf area plant⁻¹ at all the crop growth stages except 28 DAS than rest of the irrigation regimes. However, it was at par with scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage, scheduling of two irrigations to wheat crop at crown root initiation + tillering stage, scheduling of one irrigation to wheat crop at tillering stage at 56 and 84 DAS. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum leaf area plant⁻¹ at all the crop growth stages than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher leaf area plant⁻¹ at all the crop growth stages, this might be because of availability of high moisture content in soil accelerates the physiological process of crops. Similarly, increased plant height and total number of leaves per plant may also have resulted in increased leaf area plant⁻¹. This results are in conformity with those reported by Ranjita *et al.*, (2007) and Indani and Kumar (2012).

Table 4.5 Periodical leaf area in wheat as influenced by different treatment

Treatment	Leaf area plant ⁻¹ (dm ²)		
	At 28 DAS	At 56 DAS	At 84 DAS
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	1.07	1.41	1.13
I ₂ : Irrigation at tillering stage	1.02	1.45	1.15
I ₃ : Irrigation at flowering stage	1.02	1.40	1.12
I ₄ : Irrigation at CRI + tillering stage	1.05	1.46	1.18
I ₅ : Irrigation at CRI + tillering + flowering stage	1.04	1.47	1.18
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	1.05	1.49	1.19
S.Em. ±	0.01	0.01	0.02
CD at 5 %	NS	0.03	0.05
Moisture stress management (S)			
S ₁ : Control	1.05	1.42	1.14
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	1.04	1.43	1.15
S ₃ : 1 % KNO ₃ spray at flowering	1.03	1.46	1.16
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	1.04	1.48	1.17
S.Em. ±	0.01	0.01	0.01
CD at 5 %	NS	0.03	0.02
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. ±	0.03	0.02	0.03
CD at 5 %	NS	NS	0.09
Between two main plot means at same level of sub plot means			
S.Em. ±	0.03	0.02	0.03
CD at 5 %	NS	NS	0.10
General Mean	1.04	1.45	1.16

Table 4.5a. Interaction effect between irrigation regime and moisture stress management practices on leaf area (dm²) in wheat at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	1.15	1.19	1.10	1.12	1.13	1.16
VAM (soil appl. @ 10 kg ha ⁻¹)	1.14	1.13	1.13	1.16	1.22	1.18
1 % KNO ₃ spray at flowering	1.11	1.12	1.11	1.21	1.13	1.19
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	1.12	1.15	1.16	1.20	1.17	1.30
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.033			0.034		
CD at 5 %	0.097			0.102		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Effect of moisture stress management practices

The leaf area plant⁻¹ in wheat was influenced significantly due to different moisture stress management practices at 56 and 84 DAS and non significant at 28 DAS. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher leaf area plant⁻¹ than rest of the moisture stress management practices. However, it was at par with foliar spray of 1 % KNO₃ at flowering stage at 56 DAS. Significantly minimum leaf area plant⁻¹ was observed in control treatment than rest of the moisture stress management practices. Leaf area plant⁻¹ at soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage was higher because vascular arbuscular mycorrhizae and KNO₃ increases water absorption capacity which stimulates biological processes in plant cell thereby increases leaf area plant⁻¹. These findings confirm the results of Al-Karaki *et al.*, (2004) and Aradhana Kumari *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of leaf area plant⁻¹ at 84 DAS.

At 84 days after sowing scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher leaf area plant⁻¹ than rest of the treatment combinations. However, it was at par with scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage coupled with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing as well as scheduling of two irrigations to wheat crop at crown root initiation + tillering along with foliar spray of 1 % KNO₃ at flowering stage. Significantly minimum leaf area plant⁻¹ was observed with scheduling of one irrigation at flowering stage along with control treatment than rest of the treatment combinations (Table 4.5a).

4.6 Total chlorophyll content

The total chlorophyll content in wheat leaves as influenced by different treatments are presented in Table 4.6 and graphically depicted in Fig.4.3. The mean total chlorophyll content in wheat leaves was 44.10, 50.97 and 30.65 % at 28, 56 and 84 DAS, respectively.

Effect of irrigation regimes

The total chlorophyll content in wheat leaves was influenced significantly due to different irrigation regimes at all the crop growth stages. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher total chlorophyll content in wheat leaves at all the crop growth stages than rest of the irrigation regimes. However, it was at par with scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage and scheduling of two irrigations to wheat crop at crown root initiation + tillering stage as well as scheduling of one irrigation to wheat crop at tillering stage at 56 days after sowing. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum total chlorophyll content in wheat leaves at all the crop growth stages than rest of the irrigation regimes.

Table 4.6 Periodical total chlorophyll content in wheat leaves as influenced by different treatment

Treatment	Total chlorophyll content (%)		
	At 28 DAS	At 56 DAS	At 84 DAS
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	43.87	50.53	30.60
I ₂ : Irrigation at tillering stage	43.45	51.13	30.03
I ₃ : Irrigation at flowering stage	43.06	49.21	29.76
I ₄ : Irrigation at CRI + tillering stage	44.37	51.40	30.67
I ₅ : Irrigation at CRI + tillering + flowering stage	44.48	51.57	31.12
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	45.36	51.96	31.72
S.Em. $\pm$	0.03	0.29	0.03
CD at 5 %	0.11	0.90	0.09
Moisture stress management (S)			
S ₁ : Control	43.12	49.98	30.23
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	44.03	50.97	30.51
S ₃ : 1 % KNO ₃ spray at flowering	44.20	51.24	30.82
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	45.05	51.69	31.04
S.Em. $\pm$	0.03	0.24	0.02
CD at 5 %	0.08	0.69	0.07
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. $\pm$	0.07	0.59	0.06
CD at 5 %	0.18	1.69	0.16
Between two main plot means at same level of sub plot means			
S.Em. $\pm$	0.07	0.59	0.06
CD at 5 %	0.19	1.72	0.17
General Mean	44.10	50.97	30.65

Table 4.6a. Interaction effect between irrigation regime and moisture stress management practices on total chlorophyll content (%) in wheat leaves at 28 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	42.96	42.50	41.68	43.11	43.35	44.12
VAM (soil appl. @ 10 kg ha ⁻¹)	43.86	43.25	43.65	44.11	43.96	45.35
1 % KNO ₃ spray at flowering	44.11	43.95	42.67	45.25	44.25	45.95
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	44.56	44.11	44.26	45.00	46.00	46.35
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.07			0.07		
CD at 5 %	0.18			0.19		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.6b. Interaction effect between irrigation regime and moisture stress management practices on total chlorophyll content (%) in wheat leaves at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	50.12	49.72	46.75	50.85	50.65	51.86
VAM (soil appl. @ 10 kg ha ⁻¹)	50.35	50.65	50.12	50.99	51.56	52.15
1 % KNO ₃ spray at flowering	50.65	50.89	49.75	51.19	51.96	50.88
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	50.99	51.12	50.35	52.59	52.12	55.99
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.59			0.59		
CD at 5 %	1.69			1.72		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.6c Interaction effect between irrigation regime and moisture stress management practices on total chlorophyll content (%) in wheat leaves at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	30.43	29.65	29.25	30.12	30.65	31.25
VAM (soil appl. @ 10 kg ha ⁻¹)	29.65	29.99	30.35	30.45	30.99	31.65
1 % KNO ₃ spray at flowering	29.99	30.12	30.65	30.98	31.21	31.99
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	30.15	30.35	30.98	31.12	31.62	32.00
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.06			0.06		
CD at 5 %	0.165			0.169		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

This might be because of high moisture content at all the critical growth stages helps to solubilize the available nutrients in soil which increases the various metabolic processes in plants thereby increasing total chlorophyll content in wheat leaves. These results are in the line of Wajid *et al.*, (2011) and Abbas Zarein *et al.*, (2014).

Effect of moisture stress management practices

The total chlorophyll content in wheat leaves was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher total chlorophyll content in wheat leaves at all crop growth stages than rest of the management practices. However, it was at par with foliar spray of 1 % KNO₃ at flowering stage at 56 DAS. Significantly minimum total chlorophyll content in wheat leaves at all the crop growth stages was observed in control treatment than rest of the moisture stress management practices. The higher total chlorophyll content in wheat leaves at soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be because of vascular arbuscular mycorrhizae solubilizes the scarce nutrients along with

major and micronutrients which increases the nitrogen concentration in leaves thereby increases the total chlorophyll content. These results are in accordance with Govindan and Thirumurugan (2000) and Dhaka (2003).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of total chlorophyll content at 28, 56 and 84 DAS.

At 28 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher total chlorophyll content in wheat leaves than rest of the treatment combinations. Significantly minimum total chlorophyll content in wheat leaves was observed with scheduling of one irrigation at flowering stage along with control treatment than rest of the treatment combinations (Table 4.6a).

At 56 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher total chlorophyll content in wheat leaves than rest of the treatment combinations. Significantly minimum total chlorophyll content in wheat leaves was observed with scheduling of one irrigation at flowering stage along with control treatment than rest of the treatment combinations (Table 4.6b).

At 84 days after sowing scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher total chlorophyll content in wheat leaves than rest of the treatment combinations. However, it was at par with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with foliar spray of 1 % KNO₃ at flowering stage alone. Significantly minimum total chlorophyll content in wheat leaves was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.6c).

4.7 **Photosynthetic rate**

The photosynthetic rate as influenced by different treatments are presented in Table 4.7 and graphically depicted in Fig.4.4. The mean photosynthetic rate of wheat was 12.70, 32.08 and 26.88 $\mu \text{ mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ at 28, 56 and 84 DAS, respectively.

Effect of irrigation regimes

The photosynthetic rate in wheat was influenced significantly due to different irrigation regimes at all the crop growth stages except 28 DAS. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher photosynthetic rate at all the crop growth stages than rest of the irrigation regimes. However, it was at par with scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage at 56 DAS and at 84 DAS as well as scheduling of two irrigations to wheat crop at crown root initiation + tillering stage. Significantly minimum photosynthetic rate was observed with scheduling of one irrigation to wheat crop at flowering stage than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher photosynthetic rate at all the crop growth stages, this might be because of availability of higher moisture content at all the crop growth stages increase the transpiration rate there by increases the carbon dioxide intake. These results are confirm the findings of Ranjita *et al.*, (2007) and Ashinie *et al.*, (2011).

Effect of moisture stress management practices

The photosynthetic rate in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher photosynthetic rate at all crop growth stages than rest of the management practices. However, it was at par with foliar spray of 1 % KNO₃ at flowering stage as well as soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing at 56 and 84 DAS. Significantly minimum photosynthetic rate at all the crop growth stages was observed in control treatment than rest of the moisture stress management practices.

Table 4.7 Periodical photosynthetic rate in wheat as influenced by different treatment

Treatment	Photosynthetic rate ($\mu\text{mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$)		
	At 28 DAS	At 56 DAS	At 84 DAS
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	12.74	31.07	26.79
I ₂ : Irrigation at tillering stage	12.38	31.26	26.70
I ₃ : Irrigation at flowering stage	12.51	30.96	26.00
I ₄ : Irrigation at CRI + tillering stage	12.66	32.63	26.91
I ₅ : Irrigation at CRI + tillering + flowering stage	12.92	32.72	27.28
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	12.98	33.10	27.58
S.Em. $\pm$	0.14	0.46	0.21
CD at 5 %	NS	1.46	0.66
Moisture stress management (S)			
S ₁ : Control	12.57	31.32	26.42
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	12.70	32.55	26.79
S ₃ : 1 % KNO ₃ spray at flowering	12.48	31.86	26.98
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	13.05	32.66	27.31
S.Em. $\pm$	0.10	0.29	0.14
CD at 5 %	NS	0.84	0.42
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. $\pm$	0.25	0.72	0.35
CD at 5 %	NS	2.07	1.02
Between two main plot means at same level of sub plot means			
S.Em. $\pm$	0.26	0.78	0.37
CD at 5 %	NS	2.31	1.10
General Mean	12.70	32.08	26.88

Table 4.7a. Interaction effect between irrigation regime and moisture stress management practices on photosynthetic rate ($\mu \text{ mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) in wheat leaves at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	31.14	32.02	28.00	32.21	31.92	32.64
VAM (soil appl. @ 10 kg ha ⁻¹)	33.03	32.10	31.76	31.77	32.40	32.42
1 % KNO ₃ spray at flowering	28.47	32.04	31.86	32.32	34.00	32.44
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	31.65	31.92	32.21	34.22	32.57	34.90
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.72			0.78		
CD at 5 %	2.07			2.31		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.7b. Interaction effect between irrigation regime and moisture stress management practices on photosynthetic rate ($\mu \text{ mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) in wheat leaves at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	26.77	26.37	24.75	26.61	27.05	26.99
VAM (soil appl. @ 10 kg ha ⁻¹)	26.27	26.57	26.84	26.75	27.24	27.07
1 % KNO ₃ spray at flowering	26.47	26.87	26.68	26.95	27.35	27.58
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	26.51	27.00	26.87	27.34	27.49	28.67
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.35			0.37		
CD at 5 %	1.02			1.10		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Photosynthetic rate at soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage was higher because vascular arbuscular mycorrhizae and KNO₃ increases water potential in plant which solubilize the essential plant nutrients which helps to increase number and size of leaf for maximum absorption of intercepted Photosynthetic Active Radiation (PAR) resulted in increase of photosynthetic rate. These results are in the line of Abbas Zarein *et al.*, (2014) and Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of photosynthetic rate at 56 and 84 DAS.

At 56 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher photosynthetic rate than rest of the treatment combinations. However, it was at par with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with control treatment, scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage, scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage along with foliar spray of 1 % KNO₃ at flowering stage and scheduling of two irrigations to wheat crop at crown root initiation + tillering along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage as well as scheduling of one irrigation to wheat crop at crown root initiation stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing. Significantly minimum photosynthetic rate was observed with scheduling of one irrigation to wheat crop at flowering stage and control treatment than rest of the treatment combinations (Table 4.7 a).

At 84 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of

vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher photosynthetic rate than rest of the treatment combinations. Significantly minimum photosynthetic rate was observed with scheduling of one irrigation to wheat crop at crown root initiation along with control treatment than rest of the treatment combinations (Table 4.7b).

4.8 CO₂ concentration

The CO₂ concentration as influenced by different treatments are presented in Table 4.8 and graphically depicted in Fig. 4.4. The mean CO₂ concentration in wheat was 328.23, 346.24 and 317.04 μ mol CO₂m⁻²s⁻¹ at 28, 56 and 84 DAS, respectively.

Effect of irrigation regimes :

The CO₂ concentration in wheat was influenced significantly due to different irrigation regimes at all the crop growth stages. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher CO₂ concentration at all the crop growth stages than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum CO₂ concentration at all the crop growth stages than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher CO₂ concentration at all the crop growth stages, this might be because of increasing the soil moisture availability in root rhizosphere increases the soil water potential thereby increasing moisture absorption capacity of plant resulted in accelerate the transpiration for more intake of CO₂. Similar results were observed by Shahid and Hari Ram (2017).

Effect of moisture stress management practices

The CO₂ concentration in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher CO₂ concentration at all crop growth stages than rest of the management practices. Significantly minimum CO₂ concentration was observed in control treatment at all the crop growth stages than rest of the moisture stress management practices.

Table 4.8 CO₂ concentration in wheat leaves as influenced by different treatment

Treatment	CO ₂ concentration(μ mol CO ₂ m ⁻² s ⁻¹)		
	At 28 DAS	At 56 DAS	At 84 DAS
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	321.03	336.01	306.55
I ₂ : Irrigation at tillering stage	325.33	342.16	317.05
I ₃ : Irrigation at flowering stage	317.05	331.06	301.52
I ₄ : Irrigation at CRI + tillering stage	330.78	346.87	321.03
I ₅ : Irrigation at CRI + tillering + flowering stage	335.94	358.60	325.33
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	339.27	362.74	330.78
S.Em. $\pm$	0.09	0.09	0.15
CD at 5 %	0.28	0.29	0.46
Moisture stress management (S)			
S ₁ : Control	313.06	338.30	300.53
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	324.00	342.15	314.01
S ₃ : 1 % KNO ₃ spray at flowering	335.86	348.52	322.82
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	340.01	355.98	330.81
S.Em. $\pm$	0.07	0.08	0.11
CD at 5 %	0.21	0.22	0.32
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. $\pm$	0.18	0.19	0.27
CD at 5 %	NS	0.54	0.77
Between two main plot means at same level of sub plot means			
S.Em. $\pm$	0.19	0.19	0.28
CD at 5 %	NS	0.55	0.81
General Mean	328.23	346.24	317.04

Table 4.8a. Interaction effect between irrigation regime and moisture stress management practices on CO₂ concentration (μ mol CO₂ m⁻² s⁻¹) in wheat leaves at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	330.20	335.25	325.25	340.25	348.62	350.25
VAM (soil appl. @ 10 kg ha ⁻¹)	332.25	339.62	330.25	345.35	350.25	355.20
1 % KNO ₃ spray at flowering	336.25	345.25	332.50	349.52	362.35	365.25
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	345.35	348.52	336.25	352.35	373.17	380.25
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.19			0.19		
CD at 5 %	0.54			0.55		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.8b. Interaction effect between irrigation regime and moisture stress management practices on CO₂ concentration (μ mol CO₂ m⁻² s⁻¹) in wheat leaves at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	289.36	302.35	280.33	305.62	310.25	315.25
VAM (soil appl. @ 10 kg ha ⁻¹)	302.35	315.25	300.25	319.62	321.35	325.25
1 % KNO ₃ spray at flowering	310.25	321.35	305.25	326.36	333.48	340.25
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	324.25	329.25	320.25	332.50	336.25	342.35
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.27			0.28		
CD at 5 %	0.77			0.81		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

The soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage registered maximum value of CO₂ concentration might be because of vascular arbuscular mycorrhizae and KNO₃ maintains water balance in soil and plant which helps to increase leaf area and transpiration rate which in turn increases CO₂ concentration. These results are in accordance with those reported by Ranjita *et al.*, (2007) and Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of CO₂ concentration in wheat leaves at 56 and 84 DAS.

At 56 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher CO₂ concentration than rest of the treatment combinations. Significantly minimum CO₂ concentration was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.8 a). Almost similar trend was observed at 84 DAS in respect of CO₂ concentration in wheat (Table 4.8 b).

4.9 Stomatal conductance

Stomatal conductance in wheat as influenced by different treatments are presented in Table 4.9 and graphically depicted in Fig. 4.4. The mean stomatal conductance of wheat was 0.17, 0.71 and 0.30 m mol m⁻² s⁻¹ at 28, 56 and 84 DAS, respectively.

Effect of irrigation regimes

The stomatal conductance in wheat leaves was influenced significantly due to different irrigation regimes at all the crop growth stages except at 28 DAS. Among the irrigation regimes scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher stomatal conductance in wheat leaves at all the crop growth stages than rest of the irrigation regimes. However, it was at par with scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage at 56 and 84 DAS.

Table 4.9 Stomatal conductance in wheat as influenced by different treatment

Treatment	Stomatal conductance ($\text{m mol m}^{-2} \text{s}^{-1}$)		
	At 28 DAS	At 56 DAS	At 84 DAS
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	0.15	0.68	0.28
I ₂ : Irrigation at tillering stage	0.14	0.69	0.29
I ₃ : Irrigation at flowering stage	0.13	0.67	0.26
I ₄ : Irrigation at CRI + tillering stage	0.16	0.73	0.30
I ₅ : Irrigation at CRI + tillering + flowering stage	0.21	0.74	0.36
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	0.23	0.75	0.37
S.Em. $\pm$	0.04	0.03	0.019
CD at 5 %	NS	0.01	0.02
Moisture stress management (S)			
S ₁ : Control	0.13	0.68	0.27
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	0.19	0.70	0.30
S ₃ : 1 % KNO ₃ spray at flowering	0.14	0.71	0.32
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	0.21	0.73	0.34
S.Em. $\pm$	0.03	0.03	0.02
CD at 5 %	NS	0.02	0.03
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. $\pm$	0.07	0.05	0.05
CD at 5 %	NS	0.01	0.02
Between two main plot means at same level of sub plot means			
S.Em. $\pm$	0.08	0.06	0.05
CD at 5 %	NS	0.02	0.03
General Mean	0.17	0.71	0.30

Table 4.9a Interaction effect between irrigation regime and moisture stress management practices on stomatal conductance ($\text{m mol m}^{-2}\text{s}^{-1}$) in wheat leaves at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	0.65	0.79	0.57	0.88	0.65	0.62
VAM (soil appl. @ 10 kg ha^{-1})	0.79	0.77	0.62	0.77	0.77	0.66
1 % KNO_3 spray at flowering	0.64	0.65	0.63	0.66	0.87	0.68
VAM (soil appl. @ 10 kg ha^{-1}) + 1 % KNO_3 spray at flowering	0.65	0.77	0.64	0.67	0.68	0.95
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.05			0.06		
CD at 5 %	0.01			0.02		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.9b. Interaction effect between irrigation regime and moisture stress management practices on stomatal conductance ($\text{m mol m}^{-2}\text{s}^{-1}$) in wheat leaves at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	0.29	0.26	0.23	0.28	0.29	0.30
VAM (soil appl. @ 10 kg ha^{-1})	0.28	0.27	0.26	0.29	0.50	0.31
1 % KNO_3 spray at flowering	0.29	0.28	0.27	0.30	0.31	0.32
VAM (soil appl. @ 10 kg ha^{-1}) + 1 % KNO_3 spray at flowering	0.28	0.29	0.30	0.31	0.32	0.54
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.05			0.05		
CD at 5 %	0.02			0.03		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum stomatal conductance in wheat leaves at all the crop growth stages than rest of the irrigation regimes. This might be because of high moisture content at all the critical growth stages helps to increase the water potential of plant cells which increases the turgor pressure of plant cells and opens stomata thereby increases stomatal conductance. Similar results were reported by Huixing Song (2005) and Wajid *et al.*, (2011).

Effect of moisture stress management practices

The stomatal conductance in wheat leaves was influenced significantly due to different moisture stress management practices at all the crop growth stages except at 28 DAS. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher stomatal conductance in wheat leaves at all crop growth stages than rest of the management practices. However, it was at par with foliar spray of 1 % KNO₃ at flowering stage at 56 DAS. Significantly minimum stomatal conductance in wheat leaves at all the crop growth stages was observed in control treatment than rest of the moisture stress management practices. These results were in accordance with Govindan and Thirumurugan (2000) and Wajid *et al.*, (2011).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of stomatal conductance at 56 and 84 DAS.

At 56 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher stomatal conductance in wheat leaves than rest of the treatment combinations. Significantly minimum stomatal conductance in wheat leaves was observed with scheduling of one irrigation at flowering stage along with control treatment than rest of the treatment combinations (Table 4.9a). Almost similar trend was observed at 84 DAS (Table 4.9 b).

4.10 Transpiration rate

The transpiration rate in wheat as influenced by different treatments are presented in Table 4.10 and graphically depicted in Fig.4.5. The mean transpiration rate in wheat was 3.55, 7.93 and 2.54 m mol H₂O m⁻²s⁻¹ at 28, 56 and 84 DAS, respectively.

Effect of irrigation regimes

The transpiration rate in wheat was influenced significantly due to different irrigation regimes at all the crop growth stages. Among the irrigation regimes scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher transpiration rate at all the crop growth stages than rest of the irrigation regimes. However, it was at par with scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage at 28 and 56 DAS and scheduling of two irrigations to wheat crop at crown root initiation + tillering stage as well as scheduling of one irrigation to wheat crop at tillering stage at 56 DAS. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum transpiration rate at all the crop growth stages than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher transpiration rate at all the crop growth stages, this might be because of application of frequent irrigation at critical growth stages increase the number and size of leaves. These results confirm the findings of Shahid and Hari Ram (2017).

Effect of moisture stress management practices

The transpiration rate in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher transpiration rate at all crop growth stages than rest of the management practices. However, it was at par with foliar spray of 1 % KNO₃ at flowering stage alone as well as soil application of vascular arbuscular mycorrhizaeculture @ 10 kg ha⁻¹ at sowing alone at 56 DAS. Significantly minimum transpiration rate was observed in control treatment at all the crop growth stages than rest of the moisture stress management practices.

Table 4.10. Transpiration rate in wheat as influenced by different treatment

Treatment	Transpiration rate ($\text{m mol H}_2\text{O m}^{-2} \text{ s}^{-1}$)		
	At 28 DAS	At 56 DAS	At 84 DAS
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	3.52	7.72	2.40
I ₂ : Irrigation at tillering stage	3.33	7.80	2.50
I ₃ : Irrigation at flowering stage	3.27	7.65	2.29
I ₄ : Irrigation at CRI + tillering stage	3.59	8.06	2.60
I ₅ : Irrigation at CRI + tillering + flowering stage	3.75	8.08	2.70
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	3.83	8.28	2.77
S.Em. $\pm$	0.03	0.17	0.01
CD at 5 %	0.09	0.54	0.03
Moisture stress management (S)			
S ₁ : Control	3.40	7.68	2.41
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	3.57	8.07	2.50
S ₃ : 1 % KNO ₃ spray at flowering	3.55	7.88	2.58
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	3.68	8.09	2.68
S.Em. $\pm$	0.03	0.11	0.01
CD at 5 %	0.09	0.33	0.02
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. $\pm$	0.07	0.28	0.01
CD at 5 %	NS	0.60	0.02
Between two main plot means at same level of sub plot means			
S.Em. $\pm$	0.07	0.30	0.02
CD at 5 %	NS	0.87	0.03
General Mean	3.55	7.93	2.54

Table 4.10a. Interaction effect between irrigation regime and moisture stress management practices on transpiration rate (m mol H₂O m⁻² s⁻¹) in wheat at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	7.57	7.49	7.32	7.80	7.72	7.80
VAM (soil appl. @ 10 kg ha ⁻¹)	7.68	7.58	7.80	8.12	8.13	8.50
1 % KNO ₃ spray at flowering	7.63	8.03	7.63	8.07	8.13	8.27
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	7.96	8.11	7.90	7.83	8.14	8.81
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.28			0.30		
CD at 5 %	0.60			0.87		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.10b. Interaction effect between irrigation regime and moisture stress management practices on transpiration rate (m mol H₂O m⁻²s⁻¹) in wheat at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	2.25	2.30	2.15	2.45	2.55	2.65
VAM (soil appl. @ 10 kg ha ⁻¹)	2.25	2.35	2.45	2.55	2.65	2.75
1 % KNO ₃ spray at flowering	2.35	2.40	2.55	2.65	2.75	2.80
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	2.40	2.55	2.65	2.75	2.84	2.87
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.01			0.02		
CD at 5 %	0.02			0.03		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Transpiration rate at soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage was higher because vascular arbuscular mycorrhizae and KNO₃ maintains moisture content in soil and plant which increases leaf area resulted in increase transpiration rate. These results are in the line of Huixing Song (2005) and Ranjita *et al.*, (2007).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of transpiration rate in wheat at 56 and 84 DAS.

At 56 days after sowing, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher transpiration rate than rest of the treatment combinations. However, it was at par with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing alone as well as scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with foliar spray of 1 % KNO₃ at flowering stage alone. Significantly minimum transpiration rate was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.10 a).

At 84 days after sowing scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher transpiration rate than rest of the treatment combinations. Significantly minimum transpiration rate was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.10 b).

4.11 Stomatal resistance

Stomatal resistance in wheat as influenced by different treatments are presented in Table 4.11 and graphically depicted in Fig.4.5. The mean stomatal resistance in wheat was 6.78, 1.44 and 3.42 $\mu \text{mol m}^{-2} \text{s}^{-1}$ at 28, 56 and 84 DAS respectively.

Effect of irrigation regimes

The stomatal resistance in wheat was influenced significantly due to different irrigation regimes at all the crop growth stages. Among the irrigation regimes, scheduling of one irrigation to wheat crop at flowering stage recorded significantly higher stomatal resistance at all crop growth stages than rest of the irrigation regimes. However, it was at par with scheduling of one irrigation to wheat crop at crown root initiation at 28 and 84 DAS. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly minimum stomatal resistance at all the crop growth stages than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly higher stomatal resistance, this might be because of lower water potential in plant decreases turgor pressure of guard cells which partially closes the stomata thereby increases stomatal resistance. Similar results were observed by Dhaka (2003) and Abbas Zarein *et al.*, (2014).

Effect of moisture stress management practices

The stomatal resistance in wheat was influenced significantly due to different moisture stress management practices at all the crop growth stages. Control treatment exhibited significantly higher stomatal resistance at all crop growth stages than rest of the management practices. Significantly minimum stomatal resistance was observed with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage than rest of the moisture stress management practices. Stomatal resistance in control treatment exhibited significantly higher stomatal resistance at all crop growth stages than rest of the management practices because lower water potential in plant cells decreases turgor pressure of guard cells which causes closing of stomata. These results are in accordance with those reported by Khan *et al.*, (2006) and Ranjita *et al.*, (2007).

Table 4.11 Stomatal resistance of wheat as influenced by different treatments

Treatment	Stomatal resistance ($\mu\text{mol m}^{-2} \text{s}^{-1}$)		
	At 28 DAS	At 56 DAS	At 84 DAS
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	7.36	1.49	3.51
I ₂ : Irrigation at tillering stage	6.94	1.43	3.63
I ₃ : Irrigation at flowering stage	7.72	1.56	3.86
I ₄ : Irrigation at CRI + tillering stage	6.49	1.39	3.39
I ₅ : Irrigation at CRI + tillering + flowering stage	6.34	1.38	3.09
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	5.74	1.36	3.05
S.Em. $\pm$	0.28	0.07	0.10
CD at 5 %	0.58	0.09	0.20
Moisture stress management (S)			
S ₁ : Control	7.60	1.53	3.71
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	7.02	1.48	3.40
S ₃ : 1 % KNO ₃ spray at flowering	6.54	1.39	3.38
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	5.92	1.37	3.20
S.Em. $\pm$	0.20	0.05	0.07
CD at 5 %	0.57	0.04	0.08
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. $\pm$	0.48	0.12	0.18
CD at 5 %	NS	0.06	0.09
Between two main plot means at same level of sub plot means			
S.Em. $\pm$	0.50	0.13	0.19
CD at 5 %	NS	0.07	0.08
General Mean	6.78	1.44	3.42

Table 4.11a Interaction effect between irrigation regime and moisture stress management practices on Stomatal resistance ($\mu\text{mol m}^{-2}\text{s}^{-1}$) in wheat leaves at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	1.55	1.59	1.68	1.39	1.44	1.52
VAM (soil appl. @ 10 kg ha ⁻¹)	1.59	1.37	1.61	1.36	1.28	1.36
1 % KNO ₃ spray at flowering	1.56	1.58	1.39	1.52	1.29	1.27
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	1.36	1.47	1.56	1.49	1.47	1.16
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.12			0.13		
CD at 5 %	0.06			0.07		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.11b Interaction effect between irrigation regime and moisture stress management practices on Stomatal resistance ($\mu\text{mol m}^{-2}\text{s}^{-1}$) in wheat leaves at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	3.77	3.85	4.33	3.57	3.45	3.33
VAM (soil appl. @ 10 kg ha ⁻¹)	3.85	3.70	3.57	3.45	2.56	3.23
1 % KNO ₃ spray at flowering	3.70	3.57	3.45	3.33	3.23	3.13
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	3.57	3.41	3.33	3.23	3.13	2.51
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.18			0.19		
CD at 5 %	0.09			0.08		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of stomatal resistance at 56 and 84 DAS.

At 56 days after sowing, scheduling of one irrigation to wheat crop at flowering stage and control treatment recorded significantly higher stomatal resistance than rest of the treatment combinations. Significantly minimum stomatal resistance was observed with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage than rest of the treatment combinations (Table 4.11a). Similar trend was observed at 84 days after sowing (Table 4.11b).

4.12 Leaf temperature

Leaf temperature in wheat as influenced by different treatments are presented in Table 4.12 and graphically depicted in Fig.4.5. The mean leaf temperature in wheat was 31.72, 25.33 and 31.43°C at 28, 56 and 84 DAS, respectively.

Effect of irrigation regimes :

The leaf temperature in wheat was influenced significantly due to different irrigation regimes at all the crop growth stages. Among the irrigation regimes scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly minimum leaf temperature at all the crop growth stages than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly higher leaf temperature at all the crop growth stages than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly higher leaf temperature at all the crop growth stages, this might be because of lower moisture content in plant decreases reflectance of light from leaves which is increasing leaf temperature in plants. Similar results were observed by Wajid *et al.*, (2011) and Ashinie *et al.*, (2011).

Table 4.12 Leaf temperature of wheat as influenced by different treatments

Treatment	Leaf temperature (°C)		
	At 28 DAS	At 56 DAS	At 84 DAS
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	28.85	25.53	31.09
I ₂ : Irrigation at tillering stage	29.22	25.93	31.27
I ₃ : Irrigation at flowering stage	30.14	26.45	33.08
I ₄ : Irrigation at CRI + tillering stage	28.30	25.28	31.18
I ₅ : Irrigation at CRI + tillering + flowering stage	27.80	24.49	31.11
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	26.22	24.29	30.85
S.Em. ±	0.08	0.01	0.11
CD at 5 %	0.25	0.02	0.34
Moisture stress management (S)			
S ₁ : Control	29.81	25.77	32.48
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	28.24	25.51	30.75
S ₃ : 1 % KNO ₃ spray at flowering	28.22	25.22	31.92
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	27.21	24.81	30.57
S.Em. ±	0.04	0.02	0.11
CD at 5 %	0.12	0.01	0.31
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. ±	0.10	0.01	0.27
CD at 5 %	0.30	0.02	0.77
Between two main plot means at same level of sub plot means			
S.Em. ±	0.12	0.01	0.26
CD at 5 %	0.36	0.03	0.75
General Mean	31.72	25.33	31.43

Table 4.12a Interaction effect between irrigation regime and moisture stress management practices on Leaf temperature (°C) in wheat at 28 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	29.01	29.22	30.58	28.13	27.28	26.25
VAM (soil appl. @ 10 kg ha ⁻¹)	28.58	29.13	30.22	28.02	27.01	26.11
1 % KNO ₃ spray at flowering	28.22	29.18	30.11	27.58	26.59	25.33
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	28.24	28.22	29.33	27.24	26.23	25.14
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.10			0.12		
CD at 5 %	0.30			0.36		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.12b Interaction effect between irrigation regime and moisture stress management practices on Leaf temperature (°C) in wheat at 56 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	26.12	26.35	26.96	25.85	24.90	24.45
VAM (soil appl. @ 10 kg ha ⁻¹)	26.62	26.23	25.95	25.45	24.45	24.35
1 % KNO ₃ spray at flowering	26.32	26.12	25.15	25.12	24.35	24.25
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	25.89	25.01	24.89	24.68	24.25	24.12
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.01			0.01		
CD at 5 %	0.02			0.03		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.12c. Interaction effect between irrigation regime and moisture stress management practices on Leaf temperature (°C) in wheat at 84 DAS

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	33.98	32.42	35.00	32.12	31.89	31.35
VAM (soil appl. @ 10 kg ha ⁻¹)	30.25	31.62	32.85	31.37	31.35	31.23
1 % KNO ₃ spray at flowering	33.14	31.12	32.12	30.85	30.85	30.55
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	32.25	29.90	31.35	30.38	30.35	25.00
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.27			0.26		
CD at 5 %	0.77			0.75		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Effect of moisture stress management practices

The leaf temperature in wheat was influenced significantly due to different moisture stress management practices. The significantly minimum leaf temperature at all the crop growth stages was observed with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage than rest of the moisture stress management practices. Control treatment exhibited significantly higher leaf temperature at all crop growth stages than rest of the management practices. However, it was at par with foliar spray of 1 % KNO₃ at flowering stage at 28 DAS. These results are in accordance with those reported by Abbas Zareian *et al.*, (2014) and Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of leaf temperature in wheat at 28, 56 and 84 DAS.

At 28 days after sowing, scheduling of one irrigation to wheat crop at flowering stage along with control treatment recorded significantly higher leaf

temperature than rest of the treatment combinations. Significantly minimum leaf temperature was observed with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage than rest of the treatment combinations (Table 4.12 a). Similar trend were observed at 56 DAS (Table 4.12 b) and 84 DAS (Table 4.12 c) in respect of leaf temperature in wheat.

4.13 Dry matter meter⁻¹ row length

The dry matter of wheat meter⁻¹ row length as influenced by different treatments are presented in Table 4.13 and graphically depicted in Fig.4.6. The mean dry matter of wheat meter⁻¹ row length at harvest was 328.39 g meter⁻¹ row length.

Effect of irrigation regimes

The dry matter in wheat meter⁻¹ row length was influenced significantly due to different irrigation regimes. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher dry matter meter⁻¹ row length than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum dry matter meter⁻¹ row length than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher dry matter meter⁻¹ row length might be because of frequent irrigation at critical growth stages accelerate the growth of the crop and also increases dry matter production of crop. These results are in conformity with those observed by Saren *et al.*, (2004) and Ranjita *et al.*, (2007).

Effect of moisture stress management practices

The dry matter in wheat meter⁻¹ row length was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher dry matter meter⁻¹ row length than rest of the moisture stress management practices. Significantly minimum dry matter meter⁻¹ row length was observed in control treatment than rest of the moisture stress management practices.

Table 4.13 Yield attributes of wheat as influenced by different treatment

Treatment	Yield attributes of wheat					
	Dry matter m ⁻¹ row length (g)	Length of panicle (cm)	No. of spikelets Panicle ⁻¹	No. of grains Panicle ⁻¹	Weight of grains Panicle ⁻¹ (g)	1000 grain weight (g)
Irrigation regimes (I)						
I ₁ : Irrigation at CRI stage	309.68	10.87	53.58	50.75	2.57	30.79
I ₂ : Irrigation at tillering stage	311.42	11.02	56.92	53.00	2.70	31.03
I ₃ : Irrigation at flowering stage	304.32	9.67	51.67	45.33	2.41	29.97
I ₄ : Irrigation at CRI + tillering stage	329.65	11.52	62.67	57.25	2.85	31.54
I ₅ : Irrigation at CRI + tillering + flowering stage	340.13	11.68	66.83	61.00	3.07	31.93
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	375.49	11.93	68.17	63.50	3.28	32.85
S.Em. ±	0.97	0.37	2.38	0.21	0.03	0.19
CD at 5 %	2.77	1.17	7.51	0.67	0.09	0.60
Moisture stress management (S)						
S ₁ : Control	315.60	10.67	58.00	51.78	2.40	30.39
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	323.10	10.91	58.89	53.89	2.64	30.97
S ₃ : 1 % KNO ₃ spray at flowering	331.86	11.22	59.78	56.28	2.86	31.35
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	343.23	11.67	63.22	58.61	3.35	32.69
S.Em. ±	0.97	0.12	1.29	0.12	0.11	0.15
CD at 5 %	2.77	0.35	3.70	0.35	0.32	0.43
Interaction (I x S)						
Between two sub plot means at same level of main plot means						
S.Em. ±	2.37	0.30	3.16	0.30	0.27	0.37
CD at 5 %	6.80	NS	NS	0.86	NS	1.06
Between two main plot means at same level of sub plot means						
S.Em. ±	2.30	0.45	3.63	0.34	0.24	0.37
CD at 5 %	6.72	NS	NS	1.00	NS	1.10
General Mean	328.39	11.12	59.97	55.14	2.81	31.35

Table 4.13a. Interaction effect between irrigation regime and moisture stress management practices on dry matter (g) of wheat at harvest

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	306.33	302.07	300.07	315.03	325.03	345.07
VAM (soil appl. @ 10 kg ha ⁻¹)	305.22	306.07	302.10	325.10	335.07	365.07
1 % KNO ₃ spray at flowering	308.75	315.17	305.03	335.07	342.03	385.10
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	318.40	322.37	310.07	343.40	358.40	406.73
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	2.37			2.30		
CD at 5 %	6.80			6.72		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

The maximum dry matter accumulation in soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be because of vascular arbuscular mycorrhizae and KNO₃ helps to maintain water balance in root rhizosphere throughout the growth period which causes vigorous growth of the crop and helps to increase dry matter production. These results were in accordance with Huixing Song (2005) and Khan *et al.*, (2006).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of dry matter meter⁻¹ row length.

Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher dry matter meter⁻¹ row length than rest of the treatment combinations. Significantly minimum dry matter meter⁻¹ row length was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.13 a).

4.14 Length of panicle

The length of panicle of wheat as influenced by different treatments are presented in Table 4.13. The mean length of panicle of wheat at harvest was 11.12 cm.

Effect of irrigation regimes

The length of panicle in wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher length of panicle than scheduling of one irrigation to wheat crop at flowering stage and at par with rest of the irrigation regimes except scheduling of one irrigation at flowering stage. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum length of panicle than rest of the irrigation regimes. Similar results were reported by El Tahir *et al.*, (2011) and Al-Molhem (2016).

Effect of moisture stress management practices

The length of panicle in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher length of panicle than rest of the moisture stress management practices. Significantly minimum length of panicle was observed in control treatment than rest of the moisture stress management practices. The higher length of panicle at soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be because of vascular arbuscular mycorrhizae and KNO₃ maintains favourable water balance in plant which helps to increase photosynthetic activities and translocates more photosynthates towards panicle which in turn increases length of panicle. These results are in line of those reported by Patil *et al.*, (2004) and Al-Karaki *et al.*, (2004).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was significant in respect of length of panicle in wheat.

4.15 Number of spikelets panicle⁻¹

The number of spikelets panicle⁻¹ in wheat as influenced by different treatments are presented in Table 4.13. The mean number of spikelets panicle⁻¹ of wheat at harvest was 59.97.

Effect of irrigation regimes

The number of spikelets panicle⁻¹ in wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher number of spikelets panicle⁻¹ than rest of the irrigation regimes. However, it was at par with scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage as well as scheduling of two irrigations to wheat crop at crown root initiation + tillering stage. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum number of spikelets panicle⁻¹ than rest of the irrigation regimes. The maximum number of spikelets panicle⁻¹ in scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage might be due to irrigation applied at each critical growth stages of the crop helps to increase the total biomass of crop and translocates more photosynthates towards panicle which in turn increases spikelets panicle⁻¹. These results are similar to those reported by Khan *et al.*, (2006) and Akram (2011).

Effect of moisture stress management practices

The number of spikelets panicle⁻¹ in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher number of spikelets panicle⁻¹ than rest of the management practices. However, it was at par with foliar spray of 1 % KNO₃ at flowering stage alone. Significantly minimum number of spikelets panicle⁻¹ was observed in control treatment than rest of the moisture stress management practices.

The higher number of spikelets panicle⁻¹ at soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be due to vascular arbuscular mycorrhizae and KNO₃ maintains favourable water balance in plant which helps to increase photosynthetic activities and

translocates more photosynthates towards the reproductive part (sink) which in turn increases number of spikelets panicle⁻¹. Similar results are reported by Moinuddin and Goswami (2004) and Huixing Song (2005).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be non significant in respect of number of spikelets panicle⁻¹ in wheat.

4.16 Number of grains panicle⁻¹

The number of grains panicle⁻¹ in wheat as influenced by different treatments are presented in Table 4.13. The mean number of grains panicle⁻¹ in wheat was 55.14 at harvest.

Effect of irrigation regimes

The number of grains panicle⁻¹ in wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher number of grains panicle⁻¹ than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum number of grains panicle⁻¹ than rest of the irrigation regimes. These results are in accordance with those reported by Ranjita *et al.*, (2007) and Qiang and Ying (2009).

Effect of moisture stress management practices

The number of grains panicle⁻¹ in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher number of grains panicle⁻¹ than rest of the moisture stress management practices. Significantly minimum number of grains panicle⁻¹ was observed in control treatment than rest of the moisture stress management practices. Similar results were observed by Moinuddin and Goswami (2004) and Huixing Song (2005).

Table 4.13b Interaction effect between irrigation regime and moisture stress management practices on number of grain panicle⁻¹

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	47.00	50.00	41.67	55.00	58.00	59.00
VAM (soil appl. @ 10 kg ha ⁻¹)	50.00	52.00	43.67	56.00	60.00	61.67
1 % KNO ₃ spray at flowering	52.00	54.00	47.00	58.00	62.00	64.67
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	54.00	56.00	49.00	60.00	64.00	68.67
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.30			0.34		
CD at 5 %	0.86			1.00		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of number of grains panicle⁻¹ in wheat.

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher number of grains panicle⁻¹ than rest of the treatment combinations. Significantly minimum number of grains panicle⁻¹ was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.13 b).

4.17 Weight of grains panicle⁻¹

The weight of grains panicle⁻¹ as influenced by different treatments are presented in Table 4.13. The mean weight of grains panicle⁻¹ in wheat was 2.81 g.

Effect of irrigation regimes

The weight of grains panicle⁻¹ in wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher weight of grains panicle⁻¹ than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum weight of grains panicle⁻¹ than rest of the irrigation regimes. This might be due to application of irrigation at all the critical growth stages of the crop helps to increase the dry matter accumulation, physiological processes thereby increases translocation of photosynthates from source sink i.e. grain. These results are in conformity with those reported by Dhaka (2003) and Khan *et al.*, (2006).

Moisture stress management practices

The weight of grains panicle⁻¹ in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher weight of grains panicle⁻¹ than rest of the moisture stress management practices. Significantly minimum weight of grains panicle⁻¹ was observed in control treatment than rest of the moisture stress management practices. The maximum weight of grains panicle⁻¹ with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage increase the weight of grain might be because of optimum irrigation provided to each critical growth stage which favour for increasing the nutrient availability throughout the crop growth period reflected in increase in total biomass and translocation of photosynthates towards reproductive part i.e. grain. These results are in line with those reported by Huixing Song (2005) and Patil *et al.*, (2014).

Intreaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be non significant in respect of grains weight panicle⁻¹.

Table 4.13c. Interaction effect between irrigation regime and moisture stress management practices on 1000 grain weight (g) of wheat

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	30.45	30.68	28.00	30.96	31.03	31.25
VAM (soil appl. @ 10 kg ha ⁻¹)	30.68	30.96	30.45	31.12	31.26	31.35
1 % KNO ₃ spray at flowering	30.96	31.12	30.65	31.29	31.96	32.12
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	31.05	31.35	30.79	32.80	33.47	36.67
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.37			0.37		
CD at 5 %	1.06			1.10		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

4.18 1000 grain weight

The 1000 grain weight of wheat as influenced by different treatments are presented in Table 4.13. The mean 1000 grain weight of wheat was 31.35 g.

Effect of irrigation regimes :

The 1000 grain weight in wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher 1000 grain weight than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum 1000 grain weight than rest of the irrigation regimes. Similar results were observed by Ranjita *et al.*, (2007) and Kumar *et al.*, (2011).

Effect of moisture stress management practices

The 1000 grain weight in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher 1000 grain weight than rest of the moisture stress management practices. Significantly minimum 1000 grain weight was observed in

control treatment than rest of the moisture stress management practices. These results were similar to those reported by Khan *et al.*, (2006) and Akram *et al.*, (2009).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of 1000 grain weight.

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher 1000 grain weight than rest of the treatment combinations. Significantly minimum 1000 grain weight was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.13c).

4.19 Grain yield (q ha⁻¹)

The grain yield of wheat as influenced by different treatments are presented in Table 4.14 and graphically depicted in Fig.4.7. The mean grain yield of wheat was 24.94 q ha⁻¹.

Effect of irrigation regimes

The grain yield of wheat was influenced significantly due to different irrigation regimes. The grain yield of wheat was increased linearly with increase in number of irrigations at critical growth stages. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher grain yield than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum grain yield than rest of the irrigation regimes. The grain yield obtained with one irrigation at crown root initiation and one irrigation at tillering stage was 2.28 and 4.95 per cent higher than scheduling of one irrigation at flowering stage. Whereas the grain yield obtained with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage was 40.51 and 12.74 per cent higher than scheduling of two irrigations to wheat crop at crown root initiation + tillering stage.

Table 4.14 Grain yield, straw yield and harvest index of wheat as influenced by different treatment

Treatment	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)	Biological yield (q ha ⁻¹)	Harvest index (%)	Per cent reduction in yield over I ₆
Irrigation regimes (I)					
I ₁ : Irrigation at CRI stage	16.65	21.93	38.58	33.61	57.33
I ₂ : Irrigation at tillering stage	17.69	23.30	40.99	35.04	54.66
I ₃ : Irrigation at flowering stage	15.76	20.75	36.51	32.42	59.61
I ₄ : Irrigation at CRI + tillering stage	27.77	36.57	64.34	43.38	28.83
I ₅ : Irrigation at CRI + tillering + flowering stage	32.74	43.10	75.84	47.32	16.09
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	39.02	51.37	90.39	51.46	-
S.Em. ±	0.12	0.17	0.25	0.20	-
CD at 5 %	0.36	0.55	0.80	0.62	-
Moisture stress management (S)					
S ₁ : Control	23.44	31.93	54.31	39.28	-
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	24.25	33.10	56.18	40.33	3.46*
S ₃ : 1 % KNO ₃ spray at flowering	25.14	33.38	58.24	40.74	7.25*
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	26.92	35.45	62.37	41.80	14.84*
S.Em. ±	0.09	0.13	0.22	0.12	-
CD at 5 %	0.27	0.37	0.64	0.36	-
Interaction (I x S)					
Between two sub plot means at same level of main plot means					
S.Em. ±	0.23	0.32	0.55	0.31	-
CD at 5 %	0.66	0.92	1.58	0.88	-
Between two main plot means at same level of sub plot means					
S.Em. ±	0.23	0.33	0.54	0.33	-
CD at 5 %	0.68	0.96	1.58	0.98	-
General Mean	24.94	32.84	57.78	40.54	-

* Increase in yield over control

The maximum yield reduction of 59.61 per cent was observed when one irrigation was applied to wheat crop at flowering stage, 57.33 per cent reduction with one irrigation applied at crown root initiation stage and 54.66 per cent reduction with one irrigation at tillering stage as compared to four irrigations applied to wheat crop at crown root initiation + tillering + flowering + milk stage. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher grain yield might be because of high moisture content at all growth stages increases number of tillers, number of spikelets panicle⁻¹, number of grains panicle⁻¹ and weight of grains panicle⁻¹ reflected on grain yield of wheat. Similar results were observed by El Tahir *et al.*, (2011) and Ibrahim *et al.*, (2012).

Effect of moisture stress management practices

The grain yield of wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher grain yield than rest of the moisture stress management practices. The grain yield obtained with soil application of vascular arbuscular mycorrhizae (VAM) @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage was 14.84 per cent higher than control treatment. While soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing alone and foliar spray of 1 % KNO₃ at flowering stage alone registered 3.46 and 7.25 per cent higher grain yield than control treatment. Significantly minimum grain yield was observed in control treatment than rest of the moisture stress management practices. The higher grain yield of wheat in soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be because vascular arbuscular mycorrhiza enhancing the drought resistance by tapping large volume of soil increasing water absorption capacity and mobilization of scarce nutrients which increase the growth and yield attributes *viz.*, plant height, dry matter accumulation, number of tillers, number of spikelets panicle⁻¹, number of grains panicle⁻¹, grain weight panicle⁻¹ and 1000 grain weight which finally resulted in increase in grain yield of wheat crop. These results are in line with those reported by Ranjita *et al.*, (2007) and Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of grain yield of wheat.

Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher grain yield than rest of the treatment combinations. Significantly minimum grain yield was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations. The grain yield obtained with one irrigation either at crown root initiation, tillering stage or flowering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded more grain yield than application of one irrigation at any stage without moisture stress management practices (Table 4.14 a).

4.20 Straw yield

The straw yield of wheat as influenced by different treatments are presented in Table 4.14 and graphically depicted in Fig.4.7. The mean straw yield of wheat was 32.84 q ha⁻¹.

Effect of irrigation regimes

The straw yield of wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher straw yield than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum straw yield than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher straw yield than rest of the irrigation regimes, this might be because of frequent application of irrigation water as per the need of crop at most important critical growth stages favors to increase nutrient availability resulted in increase the total biomass of the crop. Similar results were reported by Ranjita *et al.*, (2007) and Keyvan and Soheil (2013).

Table 4.14a. Interaction effect between irrigation regime and moisture stress management practices on grain yield ($q\ ha^{-1}$) of wheat

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	15.19	15.67	14.08	27.22	31.25	37.25
VAM (soil appl. @ 10 $kg\ ha^{-1}$)	15.67	15.99	15.51	27.45	32.25	38.62
1 % KNO_3 spray at flowering	16.64	17.45	16.32	27.99	33.25	39.20
VAM (soil appl. @ 10 $kg\ ha^{-1}$) + 1 % KNO_3 spray at flowering	19.10	21.67	17.12	28.44	34.20	41.00
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.23			0.23		
CD at 5 %	0.66			0.68		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.14b Interaction effect between irrigation regime and moisture stress management practices on straw yield ($q\ ha^{-1}$) of wheat

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	19.99	20.63	18.54	35.84	41.35	49.05
VAM (soil appl. @ 10 $kg\ ha^{-1}$)	20.63	21.06	20.42	36.14	42.46	50.85
1 % KNO_3 spray at flowering	21.91	22.97	21.48	36.85	43.78	51.61
VAM (soil appl. @ 10 $kg\ ha^{-1}$) + 1 % KNO_3 spray at flowering	25.17	28.53	22.55	37.44	45.03	53.98
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. $\pm$	0.32			0.33		
CD at 5 %	0.92			0.96		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Effect of moisture stress management practices

The straw yield of wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher straw yield than rest of the moisture stress management practices. Significantly minimum straw yield was observed in control treatment than rest of the moisture stress management practices. The maximum straw yield of wheat in soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be because of vascular arbuscular mycorrhizae and KNO₃ helps to maintain moisture content in root rhizosphere which increases plant height and number of tillers as well as yield attributes there by increases straw yield. These results are in accordance with those reported by Mesbah *et al.*, (2009) and Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of straw yield of wheat.

Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher straw yield than rest of the treatment combinations. Significantly minimum straw yield was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.14b).

4.21 Biological yield

The biological yield of wheat as influenced by different treatments are presented in Table 4.14. The mean biological yield of wheat was 57.78 q ha⁻¹.

Effect of irrigation regimes

The biological yield of wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher biological yield than rest of the irrigation regimes. Scheduling of one irrigation to

wheat crop at flowering stage recorded significantly minimum biological yield than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher biological yield might be because of higher grain and straw yield of wheat. Similar results were reported by Akram (2011) and Shahid and Hari Ram (2017).

Effect of moisture stress management practices

The biological yield of wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher biological yield than rest of the management practices. Significantly minimum biological yield was observed in control treatment than rest of the moisture stress management practices. The biological yield in soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be because of higher growth and yield attributes of wheat. These results are in line of those reported by Mesbah *et al.*, (2009) and Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of biological yield.

Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher biological yield than rest of the treatment combinations. Significantly minimum biological yield was observed with scheduling of one irrigation at crown root initiation stage and control treatment than rest of the treatment combinations (Table 4.14c).

4.22 Harvest index

The harvest index of wheat as influenced by different treatments are presented in Table 4.14. The mean harvest index was 40.54 %.

Table 4.14c. Interaction effect between irrigation regime and moisture stress management practices on biological yield (q ha⁻¹)

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	35.18	36.30	32.63	63.06	72.40	86.30
VAM (soil appl. @ 10 kg ha ⁻¹)	36.30	37.05	35.93	63.59	74.71	89.47
1 % KNO ₃ spray at flowering	38.55	40.42	37.80	64.84	77.03	90.81
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	44.27	50.20	39.67	65.88	79.23	94.98
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.55			0.54		
CD at 5 %	1.58			1.58		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.14d. Interaction effect between irrigation regime and moisture stress management practices on harvest index

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	32.54	34.13	29.00	43.08	46.30	50.61
VAM (soil appl. @ 10 kg ha ⁻¹)	32.86	33.78	33.82	43.09	47.01	51.42
1 % KNO ₃ spray at flowering	34.01	34.01	33.60	43.50	47.68	51.66
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	35.03	38.23	33.28	43.82	48.27	52.13
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.31			0.33		
CD at 5 %	0.88			0.98		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Effect of irrigation regimes :

The harvest index of wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher harvest index than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum harvest index than rest of the irrigation regimes, this might be because of maximum photosynthates were translocated from source (vegetative part) to sink (grain) resulted in higher proportion of economic yield compared to total biomass. Similar results were observed by Indani and Kumar (2012) and Sarkar *et al.*, (2013).

Effect of moisture stress management practices

The harvest index in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher harvest index than rest of the moisture stress management practices. Significantly minimum harvest index was observed in control treatment than rest of the moisture stress management practices. The higher harvest index in soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be due to higher economic obtained from total biomass. Similar results were reported by Mesbah *et al.*, (2009) and Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of harvest index.

Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher harvest index than rest of the treatment combinations. However, it was at par with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with foliar spray of 1 % KNO₃ at flowering stage alone and soil application of vascular arbuscular mycorrhizae culture @

10 kg ha⁻¹ at sowing alone. Significantly minimum harvest index was observed with scheduling of one irrigation at crown root initiation stage and control treatment than rest of the treatment combinations (Table 4.14d).

4.23 Grain quality

The grain quality of wheat as influenced by different treatments are presented in Table 4.15 and graphically depicted in Fig. 4.8. The mean of protein, glutenin and lysine content in wheat was 11.15, 26.58 and 2.40 %, respectively.

Effect of irrigation regimes

The grain quality in wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly higher protein content (11.82 %) and minimum glutenin (25.79 %) and lysine content (2.22 %) than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage recorded significantly minimum protein content (10.77 %) and maximum glutenin (28.27 %) and lysine content (2.61 %) than rest of the irrigation regimes. These results are in accordance with those reported by Kattimani *et al.*, (1996) and Gular, M. (2003).

Moisture stress management practices

The grain quality in wheat was influenced significantly due to different moisture stress management practices. Application of vascular arbuscular mycorrhizae culture in soil @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher protein content (11.66 %) and minimum glutenin (25.82 %) and lysine content (2.30 %) than rest of the management practices. Significantly minimum protein content (10.79 %) and maximum glutenin (27.34 %) and lysine content (2.49 %) was observed in control treatment than rest of the moisture stress management practices. Similar results were observed by Patil *et al.*, (2003) and Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be significant in respect of protein, glutenin and lysine content in wheat grains.

Table 4.15 Grain quality in wheat as influenced by different treatments

Treatment	Quality Parameters		
	Protein content (%)	Gluten content (%)	Lysine content (%)
Irrigation regimes (I)			
I ₁ : Irrigation at CRI stage	10.76	27.12	2.52
I ₂ : Irrigation at tillering stage	10.95	26.38	2.48
I ₃ : Irrigation at flowering stage	10.77	28.27	2.61
I ₄ : Irrigation at CRI + tillering stage	11.29	26.03	2.30
I ₅ : Irrigation at CRI + tillering + flowering stage	11.33	25.91	2.27
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	11.82	25.79	2.22
S.Em. $\pm$	0.01	0.04	0.01
CD at 5 %	0.04	0.12	0.02
Moisture stress management (S)			
S ₁ : Control	10.79	27.34	2.49
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	10.92	26.85	2.44
S ₃ : 1 % KNO ₃ spray at flowering	11.24	26.32	2.37
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	11.66	25.82	2.30
S.Em. $\pm$	0.01	0.03	0.01
CD at 5 %	0.03	0.09	0.02
Interaction (I x S)			
Between two sub plot means at same level of main plot means			
S.Em. $\pm$	0.028	0.08	0.02
CD at 5 %	0.080	0.224	0.06
Between two main plot means at same level of sub plot means			
S.Em. $\pm$	0.027	0.08	0.02
CD at 5 %	0.081	0.229	0.05
General Mean	11.15	26.58	2.40

Table 4.15a. Interaction effect between irrigation regime and moisture stress management practices on protein content (%) in wheat grain

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	10.32	10.45	10.12	11.52	10.96	11.35
VAM (soil appl. @ 10 kg ha ⁻¹)	10.63	10.85	10.32	10.99	11.12	11.63
1 % KNO ₃ spray at flowering	10.99	11.13	10.65	11.19	11.53	11.95
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	11.13	11.35	12.00	11.45	11.69	12.35
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.028			0.027		
CD at 5 %	0.080			0.081		

* CRI = Crown root initiation, T = Tillering, F = Flowering, M = Milk stage

Table 4.15b Interaction effect between irrigation regime and moisture stress management practices on gluten content (%) in wheat grain

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	28.23	26.98	29.85	26.45	26.32	26.21
VAM (soil appl. @ 10 kg ha ⁻¹)	27.62	26.45	28.65	26.32	26.12	25.95
1 % KNO ₃ spray at flowering	26.65	26.12	27.36	25.99	25.96	25.85
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	25.99	25.96	27.20	25.35	25.25	25.15
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.08			0.08		
CD at 5 %	0.224			0.229		

Table 4.15c Interaction effect between irrigation regime and moisture stress management practices on lysine (%) content in wheat grain

Moisture stress management	Irrigation regime*					
	CRI	T	F	CRI + T	CRI + T + F	CRI + T + F + M
Control	2.61	2.65	2.72	2.28	2.35	2.30
VAM (soil appl. @ 10 kg ha ⁻¹)	2.55	2.51	2.67	2.36	2.30	2.22
1 % KNO ₃ spray at flowering	2.52	2.45	2.55	2.30	2.22	2.20
VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	2.41	2.32	2.48	2.25	2.20	2.15
Sources	Between two sub plots means at same level of main plot means			Between two main plots means at same level of sub plot means		
S.Em. ±	0.02			0.02		
CD at 5 %	0.06			0.05		

Protein content

Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly higher protein content (12.35 %) than rest of the treatment combinations. Significantly minimum protein content (10.12 %) was observed with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations. The protein content with scheduling of one irrigation at crown root initiation or tillering or flowering stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage received more protein content than scheduling of one irrigation at any stage without any moisture stress management practices (Table 4.15 a).

Glutein content

Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly minimum glutein content (25.15 %) than rest of the treatment combinations. Significantly maximum glutein content (29.85 %) was observed in wheat

grain with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations (Table 4.15b).

Lysine content

Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded significantly minimum lysine content (2.15 %) than rest of the treatment combinations. Significantly maximum lysine content (2.72 %) was observed in wheat grain with scheduling of one irrigation at flowering stage and control treatment than rest of the treatment combinations, However it was at par with scheduling of one irrigation to wheat crop at flowering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing alone (Table 4.15 c).

4.24 Soil chemical properties and available nutrients

The soil chemical properties and available nutrients as influenced by different treatments are presented in Table 4.16. The mean soil pH, EC, organic carbon, soil available nitrogen, phosphorus and potassium was 8.10, 0.26 dSm⁻¹, 0.57 %, 224.94 kg ha⁻¹, 14.82 kg ha⁻¹ and 332.81 kg ha⁻¹, respectively.

Effect of irrigation regimes

The soil pH, EC, organic carbon, soil available nitrogen, phosphorus and potassium were not influenced significantly due to different irrigation regimes.

Effect of moisture stress management practices :

The soil pH, EC, organic carbon, soil available nitrogen, phosphorus and potassium were not influenced significantly due to different moisture stress management practices.

Interaction (I x S)

The interaction between irrigation regimes and moisture stress management practices was found to be non significant in respect of soil pH, EC, organic carbon, soil available nitrogen, phosphorus and potassium.

Table 4.16 Soil chemical properties and available nutrients as influenced by different treatments after harvest of wheat

Treatment	Soil chemical properties			Soil available nutrients		
	pH	EC (dSm ⁻¹)	Organic carbon (%)	Nitrogen (kg ha ⁻¹)	Phosphorus (kg ha ⁻¹)	Potassium (kg ha ⁻¹)
Irrigation regimes (I)						
I ₁ : Irrigation at CRI stage	8.20	0.28	0.55	212.33	15.39	334.30
I ₂ : Irrigation at tillering stage	8.21	0.26	0.56	228.61	15.30	328.21
I ₃ : Irrigation at flowering stage	8.19	0.26	0.58	228.74	14.75	318.09
I ₄ : Irrigation at CRI + tillering stage	8.19	0.29	0.57	230.11	15.11	340.01
I ₅ : Irrigation at CRI + tillering + flowering stage	8.17	0.27	0.60	226.51	14.90	332.47
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	8.20	0.25	0.54	226.49	14.23	343.79
S.Em. ±	0.01	0.01	0.03	6.06	0.85	18.05
CD at 5 %	NS	NS	NS	NS	NS	NS
Moisture stress management (S)						
S ₁ : Control	8.20	0.28	0.55	228.14	15.92	339.49
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	8.18	0.27	0.56	228.73	15.39	320.94
S ₃ : 1 % KNO ₃ spray at flowering	8.20	0.26	0.58	216.76	13.95	329.49
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	8.18	0.25	0.58	228.23	14.52	341.33
S.Em. ±	0.01	0.01	0.02	4.58	0.53	6.95
CD at 5 %	NS	NS	NS	NS	NS	NS
Interaction (I x S)						
Between two sub plot means at same level of main plot means						
S.Em. ±	0.02	0.03	0.05	11.22	1.29	17.02
CD at 5 %	NS	NS	NS	NS	NS	NS
Between two main plot means at same level of sub plot means						
S.Em. ±	0.02	0.03	0.06	11.45	1.41	23.31
CD at 5 %	NS	NS	NS	NS	NS	NS
General Mean	8.10	0.26	0.57	228.94	14.82	332.81
Initial status of soil	8.01	0.26	0.54	228.94	14.82	383.60

4.25 Moisture studies

The consumptive use efficiency, water use efficiency and water productivity were estimated and presented in Table 4.17.

4.25.1 Consumptive use

The consumptive use of water was increased with increase in number of irrigations. Maximum consumptive use (40.11 cm) of water was registered with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage coupled with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage. This might be because of more number of irrigations were applied at all the critical growth stages of crop along with soil application of vascular arbuscular mycorrhizae culture at sowing and foliar spray of 1 % KNO₃ which enhance the drought tolerance capacity of crop as well as increase the moisture absorption capacity. The minimum consumptive use (8.51 cm) was observed where only one irrigation was applied at crown root initiation or tillering stage or flowering stage along with moisture stress management practices. The scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage with different moisture stress management practices was found second in rank in respect of consumptive use of water in wheat crop (Table 4.17). Similar results are reported by Sun *et al.*, (2006) and Wajid *et al.*, (2007).

4.25.2 Crop water use efficiency

The crop water use efficiency was increased with decrease in number of irrigations. Scheduling of one irrigation to wheat crop at crown root initiation coupled with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded maximum crop water use efficiency

Table 4.17 Crop water use efficiency, field water use efficiency and water productivity in wheat as influenced by different treatments

Treatment	Consumptive use (cm)	Water applied* (ha-cm)	Yield (kg ha ⁻¹)	Crop water use efficiency (kg ha ⁻¹ -cm)	Field water use efficiency (kg ha ⁻¹ cm)	Water productivity (kg m ⁻³)
I ₁ S ₁	8.51	22.50	1518.58	178.45	62.49	0.62
I ₁ S ₂	8.75	22.50	1567.04	179.09	69.65	0.70
I ₁ S ₃	8.79	22.50	1663.97	189.30	73.95	0.74
I ₁ S ₄	9.17	22.50	1909.53	208.24	84.87	0.85
I ₂ S ₁	13.02	22.50	1567.04	120.36	69.65	0.70
I ₂ S ₂	13.16	22.50	1599.35	121.53	71.08	0.71
I ₂ S ₃	13.53	22.50	1744.75	128.95	77.54	0.78
I ₂ S ₄	13.67	22.50	2166.67	158.50	96.30	0.96
I ₃ S ₁	13.36	22.50	1408.33	105.41	67.59	0.68
I ₃ S ₂	13.43	22.50	1550.89	115.48	68.93	0.69
I ₃ S ₃	13.66	22.50	1631.66	119.45	72.52	0.73
I ₃ S ₄	13.73	22.50	1712.44	124.72	76.11	0.76
I ₄ S ₁	17.12	30.00	2722.00	159.00	90.73	0.91
I ₄ S ₂	17.17	30.00	2745.00	159.87	91.50	0.92
I ₄ S ₃	17.21	30.00	2799.00	162.64	93.30	0.93
I ₄ S ₄	18.47	30.00	2843.67	153.96	94.79	0.95
I ₅ S ₁	27.87	37.50	3125.00	112.13	83.33	0.83
I ₅ S ₂	28.11	37.50	3225.00	114.73	86.00	0.86
I ₅ S ₃	28.25	37.50	3325.00	117.70	88.67	0.89
I ₅ S ₄	29.84	37.50	3420.00	114.61	91.20	0.91
I ₆ S ₁	38.69	45.00	3725.00	96.28	82.78	0.83
I ₆ S ₂	38.87	45.00	3862.00	99.36	85.82	0.86
I ₆ S ₃	39.94	45.00	3920.00	98.15	87.11	0.87
I ₆ S ₄	40.11	45.00	3925.00	97.86	87.22	0.87

* Initially two common irrigations (7.5 cm depth) were applied to all treatments

(208.24 kg ha⁻¹-cm) than rest of the treatment combinations. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing along with control treatment recorded minimum crop water use efficiency (93.26 kg ha⁻¹-cm). Among the treatment combinations, the scheduling of one irrigation at crown root initiation and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage registered higher crop water use efficiency (208.24 kg ha⁻¹-cm) followed by scheduling of one irrigation at flowering stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage. The higher crop water use efficiency might be because of maximum grain yield was obtained with minimum quantity of irrigation water (Table 4.17). These results are in conformity with those reported by Yadav and Ramdeo (2008) and Mesbah (2009).

4.25.3 Field water use efficiency

The maximum field water use efficiency (96.30 kg ha⁻¹-cm) was observed with scheduling of one irrigation to wheat crop at tillering stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage followed by scheduling of two irrigations to wheat crop at crown root initiation + tillering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage (96.79 kg ha⁻¹-cm). The higher field water use efficiency might be because of the vascular arbuscular mycorrhizae helps to enhance water absorption capacity of crop as well as increase the nutrient availability, similarly the foliar spray of KNO₃ helps to stimulates enzyme activation, carbohydrate formation increase the water balance in leaves and regulation of stomatal opening and closing. Minimum field water use efficiency registered with scheduling of one irrigation to wheat crop at crown root initiation without any moisture stress management practices than rest of the treatment combinations (Table 4.17). These results are in accordance with those reported by Sun *et al.*, (2006) and Wajid *et al.*, (2007).

4.25.4 Water productivity (kg m^{-3})

Among the treatment combinations, scheduling of one irrigation to wheat crop at tillering stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage registered maximum water productivity (0.96 kg m^{-3}) followed by scheduling of two irrigations to wheat crop at crown root initiation + tillering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage (0.95 kg m^{-3}).

Table 4.18. The observed and predicted yield of wheat

Treatment	Consumptive use (cm)	Observed yield (kg ha^{-1})	Predicted yield (kg ha^{-1})
I ₁ : Irrigation at CRI stage	8.80	1664.78	1591.11
I ₂ : Irrigation at tillering stage	13.34	1769.45	1948.34
I ₃ : Irrigation at flowering stage	13.54	1575.83	1964.08
I ₄ : Irrigation at CRI + tillering stage	17.49	2777.42	2274.69
I ₅ : Irrigation at CRI + tillering + flowering stage	28.51	3273.75	3142.20
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	39.40	3858.00	3998.79

Table 4.19. Yield response factor (Ky coefficient) in wheat

Treatment	1-ETa/ETx	1-Ya/Yx	Ky
I ₁ : Irrigation at CRI stage	0.78	0.56	0.72
I ₂ : Irrigation at tillering stage	0.66	0.54	0.82
I ₃ : Irrigation at flowering stage	0.65	0.59	0.91
I ₄ : Irrigation at CRI + tillering stage	0.44	0.28	0.63
I ₅ : Irrigation at CRI + tillering + flowering stage	0.27	0.15	0.56

The minimum water productivity (0.62 kg m^{-3}) was observed with scheduling of one irrigations to wheat crop at crown root initiation stage without any adoption of moisture stress management practices i.e. control treatment. Higher water productivity might be due to production of higher grain yield with minimum quantity of water. The water productivity obtained with scheduling of four irrigation to wheat crop at

critical growth stages and three irrigations at critical growth stages are almost identical without adoption of any moisture stress management practice (Table 4.17). These results are line of Ranjanna *et al.*, (2017) and Elias Meskelu *et al.*, (2017).

4.25.5 Water production function

The water production function were derived by using the consumptive use and observed yield of wheat. It could be seen from the data presented in table 4.18 that the linear production function ($Y = 898.287 + 78.6855X$) fits well as the coefficient of determinant value was higher ($R^2=0.89$) than quadratic and power functions. This indicates that as the consumptive use increases the grain yield of wheat increases. The predicted yield obtained by using linear equation and observed yield are graphically depicted in Fig.4.10

4.25.6 Yield response factor (Ky coefficient)

The Ky coefficient indicate that the relative yield reduction is related to the corresponding relative reduction in evapotranspiration. The values of Ky coefficient are presented in Table 4.19 and graphically depicted in Fig. 4.9. From the data in Table 4.19 it could be seen that maximum value of Ky coefficient was observed scheduling of one irrigation at flowering stage (0.91) as compared to scheduling of one irrigation at crown root initiation stage (0.72) and scheduling of one irrigation at tillering stage (0.82). Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage registered minimum value of Ky coefficient (0.56).

4.26 Economics of wheat

The economics of wheat crop was worked out in terms of gross monetary returns, net monetary returns and benefit : cost ratio and presented in Table 4.20.

4.26.1 Cost of cultivation (` ha⁻¹)

The cost of cultivation as influenced by different treatments are presented in Table 4.20. The mean of cost of cultivation of wheat was ` 51260.46 ha⁻¹.

Effect of irrigation regimes

The cost of cultivation in wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded higher cost of cultivation than rest of the irrigation regimes. Scheduling of one irrigation to

wheat crop at crown root initiation stage recorded minimum cost of cultivation than rest of the irrigation regimes. The higher cost of cultivation might be because of higher cost required for application of irrigation water at all critical growth stages of crop. Similar results were observed by Kibe and Singh (2003) and Sarkar (2005).

Effect of moisture stress management practices

The cost of cultivation in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited higher cost of cultivation than rest of the moisture stress management practices. Minimum cost of cultivation was observed in control treatment than rest of the moisture stress management practices. The higher cost of cultivation might be because of cost required for vascular arbuscular mycorrhizae culture and foliar spray of KNO₃ at flowering. These results are in accordance with those reported by Zameer Khan *et al.*, (2006) and Patil *et al.*, (2014)

4.26.2 Gross monetary returns (₹ ha⁻¹)

The gross monetary returns as influenced by different treatments are presented in table 4.20. The mean of gross monetary returns in wheat was ₹ 70396 ha⁻¹.

Effect of irrigation regimes

The gross monetary returns in wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage obtained significantly higher gross monetary returns than rest of the irrigation regimes. Scheduling of one irrigation to wheat crop at flowering stage obtained significantly minimum gross monetary returns than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage obtained significantly higher gross monetary returns might be because of higher grain yield which in turn increases gross monetary returns. These results are in the line of Singh *et al.*, (2003) and Mekkei *et al.*, (2014).

Table 4.20. Economics of wheat as influenced by different treatment

Treatment	Cost of cultivation (` ha<sup>-1</sup>)	Gross monetary returns (` ha⁻¹)	Net monetary returns (` ha⁻¹)	B : C ratio
Irrigation regimes (I)				
I ₁ : Irrigation at CRI stage	50308	62212	11904	1.24
I ₂ : Irrigation at tillering stage	50765	62888	12123	1.24
I ₃ : Irrigation at flowering stage	50871	61308	10437	1.21
I ₄ : Irrigation at CRI + tillering stage	51105	70488	19382	1.38
I ₅ : Irrigation at CRI + tillering + flowering stage	51896	80362	28465	1.55
I ₆ : Irrigation at CRI + tillering + flowering + milk stage	52616	85121	32504	1.62
S.Em. ±	15.31	1319.30	1315.49	-
CD at 5 %	48.24	4157.18	4145.20	-
Moisture stress management (S)				
S ₁ : Control	50332	68742	18410	1.36
S ₂ : VAM (soil appl. @ 10 kg ha ⁻¹)	51210	69968	18757	1.36
S ₃ : 1 % KNO ₃ spray at flowering	50973	70833	19859	1.39
S ₄ : VAM (soil appl. @ 10 kg ha ⁻¹) + 1 % KNO ₃ spray at flowering	52524	72043	19518	1.37
S.Em. ±	12.50	211.22	211.59	-
CD at 5 %	35.85	605.81	606.87	-
Interaction (I x S)				
Between two sub plot means at same level of main plot means				
S.Em. ±	30.62	517.38	518.28	-
CD at 5 %	NS	NS	NS	-
Between two main plot means at same level of sub plot means				
S.Em. ±	30.62	1393.31	1389.96	-
CD at 5 %	NS	NS	NS	-
General Mean	51260	70396	19136.	1.37

Effect of moisture stress management practices

The gross monetary returns in wheat was influenced significantly due to different moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage exhibited significantly higher gross monetary returns than rest of the management practices. Significantly minimum gross monetary returns was obtained in control treatment than rest of the moisture stress management practices. The higher gross monetary returns in soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage might be because of optimum moisture content was maintain in root rhizosphere throughout crop growth period which increases grain yield there by increases gross monetary returns. Similar results were observed by Patil *et al.*, (2014) and Ranjanna *et al.*, (2017).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be non significant in respect of gross monetary returns.

4.26.3 Net monetary returns

The net monetary returns as influenced by different treatments are presented in Table 4.20. The mean of net monetary returns in wheat was ` 19136.46 ha⁻¹.

Effect of irrigation regimes

The net monetary returns in wheat was influenced significantly due to different irrigation regimes. Among the irrigation regimes scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage obtained significantly higher net monetary returns than rest of the irrigation regimes and at par with scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage. Scheduling of one irrigation to wheat crop at flowering stage obtained significantly minimum net monetary returns than rest of the irrigation regimes. Scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage obtained significantly higher net monetary returns might be because of high moisture content increases grain yield with minimum cost of cultivation which in turn increases net monetary returns. These results are similar to those reported by Mekkei *et al.*, (2014).

Effect of moisture stress management practices

The net monetary returns in wheat was influenced significantly due to different moisture stress management practices. Foliar spray of 1 % KNO_3 at flowering stage exhibited significantly higher net monetary returns than rest of the moisture stress management practices and at par with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage. Significantly minimum net monetary returns was obtained in control treatment than rest of the moisture stress management practices. Similar results were observed by Patil *et al.*, (2014).

Interaction (I x S)

The interaction effect between irrigation regimes and moisture stress management practices was found to be non significant in respect of net monetary returns.

4.26.4 B : C ratio

The B:C ratio of different treatments are presented in Table 4.20. The mean of B:C ratio of wheat was 1.37.

Effect of irrigation regimes

Among the irrigation regimes, scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded higher B:C ratio than rest of the irrigation regimes. Scheduling of three irrigations to wheat crop at crown root initiation + tillering + flowering stage found second in rank. Scheduling of one irrigation to wheat crop at flowering stage recorded minimum B:C ratio than rest of the irrigation regimes. Similar results were observed by Zameer Khan *et al.*, (2006) and El Tahir *et al.*, (2011).

Moisture stress management practices

Foliar spray of 1 % KNO_3 at flowering stage recorded higher B:C ratio than rest of the moisture stress management practices. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage found second best treatment in respect of B : C ratio. Minimum B:C ratio was observed in control treatment as well as soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing than rest of the moisture stress management practices. These results are in accordance with Patil *et al.*, (2014) and Sana *et al.*, (2004).

5. SUMMARY AND CONCLUSIONS

5.1 Summary

The field investigation entitled, “Effect of moisture stress and its management practices on growth and yield of wheat” was conducted at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) during 2016-17.

The finding emerged from the present investigation are summarized as below with appropriate sub headings.

5.1.1 Effect of irrigation regimes

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly maximum growth attributes viz., plant height (90.86 cm), number of tillers meter⁻¹ row length (132.75), number of leaves plant⁻¹ at 56 DAS (16.28), leaf area plant⁻¹ at 56 DAS (1.49 dm²), dry matter meter⁻¹ row length (375.49 g) and yield attributes viz., length of panicle (11.93 cm), number of spikelets panicle⁻¹ (68.17), number of grains panicle⁻¹ (63.50), weight of grains panicle⁻¹ (3.28 g) and 1000 grain weight (32.85 g) as compared to rest of the irrigation regimes.

The maximum and significantly higher grain yield (39.02 q ha⁻¹) and straw yield (51.37 q ha⁻¹) was recorded with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage than rest of the irrigation regimes.

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly maximum total chlorophyll content (51.96 %), photosynthetic rate (33.10 μ mol CO₂ m⁻² s⁻¹), CO₂ concentration (362.74 μ mol CO₂ m⁻² s⁻¹) stomatal conductance (0.73 m mol m⁻² s⁻¹) and transpiration rate (8.28 m mol H₂O m⁻² s⁻¹) at 56 days after sowing. Where as scheduling of one irrigation to wheat crop at flowering stage recorded significantly maximum leaf temperature (33.08 °C) and stomatal resistance (3.86 μ mol m⁻² s⁻¹) a than rest of the irrigation regimes.

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly maximum protein content (11.82 %) and minimum gluten (25.79 %) and lysine content (2.22 %) than rest of the irrigation regimes. However, scheduling of one irrigation at crown root initiation or tillering or flowering stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage received more protein content than scheduling of one irrigation at any stage without any moisture stress management practices

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly maximum gross monetary returns (85121 ` ha<sup>-1</sup>), net monetary returns (32504 ` ha⁻¹) and B : C ratio (1.62).

5.1.2 Effect of moisture stress management practices

The soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1% KNO₃ at flowering to the wheat crop recorded significantly maximum growth attributes viz., plant height (84.12 cm), number of tillers meter⁻¹ row length (117.33), number of leaves plant⁻¹ at 56 DAS (16.33), leaf area plant⁻¹ at 56 DAS (1.48 dm²), dry matter meter⁻¹ row length (343.23 g) and yield attributes viz., length of panicle (11.67 cm), number of spikelets panicle⁻¹ (63.22), number of grains panicle⁻¹ (58.61), weight of grains panicle⁻¹ (3.35 g) and 1000 grain weight (32.69 g) than rest of the moisture stress management practices and control treatment.

The soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing+ foliar spray of 1% KNO₃ at flowering to wheat crop recorded significantly higher grain yield (26.92 q ha⁻¹) and straw yield (35.45 q ha⁻¹) than soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing or foliar spray of 1 % KNO₃ at flowering alone and control treatment.

The soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing+ foliar spray of 1% KNO₃ at flowering to the wheat crop recorded significantly maximum total chlorophyll content (51.69 %), photosynthetic rate (32.50 µ mol CO₂ m⁻² s⁻¹), CO₂ concentration (355.98 µ mol CO₂ m⁻² s⁻¹), stomatal conductance (0.73 m mol m⁻² s⁻¹), transpiration rate (8.09 m mol H₂O m⁻² s⁻¹) at 56 days after sowing, whereas control treatment recorded significantly maximum stomatal resistance

($3.71 \mu \text{ mol m}^{-2} \text{ s}^{-1}$) and leaf temperature (32.48°C) at 84 DAS than rest of the moisture stress management practices.

The soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1% KNO_3 at flowering to the wheat crop recorded significantly maximum protein content (11.66 %) and minimum glutenin (25.82 %) and lysine content (2.30 %) than rest of the moisture stress management practices and control treatment.

The soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering to wheat crop obtain significantly maximum gross monetary returns ($72043 \text{ ` ha}^{-1}$ ), where as foliar spray of 1 %  $\text{KNO}_3$  at flowering stage alone obtained significantly higher net monetary returns ( $19859 \text{ ` ha}^{-1}$) and B : C ratio (1.39) than rest of the moisture stress management practices.

5.1.3 Interaction between irrigation regimes and moisture stress management practices

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1% KNO_3 at flowering recorded significantly higher growth attributes viz., plant height (92.70 cm), number of tillers meter^{-1} row length (139.00), number of leaves plant^{-1} at 56 DAS (17.87), dry matter meter^{-1} row length (406.73 g) and yield attributes viz., number of grains panicle^{-1} (68.67) and 1000 grain weight (36.67 g).

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing+ foliar spray of 1 % KNO_3 at flowering recorded significantly higher grain yield (41 q ha^{-1}) and straw yield (53.98 q ha^{-1}). However, under limited availability of irrigation water scheduling of one irrigation at tillering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering registered maximum grain (21.67 q ha^{-1}) and straw yield (28.56 q ha^{-1}) than scheduling of one irrigation to wheat crop at crown root initiation or flowering stage without any moisture stress management practices.

The yield obtained with scheduling of one irrigation either at crown root initiation, tillering or flowering stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage was 25.74, 38.28 and 21.59 per cent higher than scheduling of one irrigation at crown root initiation, tillering and flowering stage, respectively without any moisture stress management practices.

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering to the wheat crop recorded significantly maximum total chlorophyll content (55.99 %), photosynthetic rate (34.90 μ mol CO₂ m⁻² s⁻¹), CO₂ concentration (380.25 μ mol CO₂ m⁻² s⁻¹), stomatal conductance (0.95 m mol m⁻² s⁻¹) and transpiration rate (8.81 m mol H₂O m⁻² s⁻¹) at 56 days after sowing. Whereas, scheduling of one irrigation to wheat crop at flowering stage along with control treatment recorded significantly maximum stomatal resistance (4.33 μ mol m⁻² s⁻¹) and leaf temperature (30.75°C) at 84 days after sowing than rest of the treatment combinations.

The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering recorded significantly maximum protein content (12.35 %) and minimum glutenin (25.15 %) and lysine content (2.15 %).

The consumptive use of water increased with increased in number of irrigations. Maximum consumptive use (40.11 cm) of water was registered with scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage coupled with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage.

The crop water use efficiency was increased with decrease in number of irrigations. Scheduling of one irrigation to wheat crop at crown root initiation coupled with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 % KNO₃ at flowering stage recorded maximum crop water use efficiency (208.24 kg ha⁻¹-cm) than rest of the treatment combinations.

The maximum field water use efficiency ($96.30 \text{ kg ha}^{-1}\text{-cm}$) was observed with scheduling of one irrigation to wheat crop at tillering stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage.

Among the treatment combinations scheduling of one irrigation to wheat crop at tillering stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 % KNO_3 at flowering stage registered maximum water productivity (0.96 kg m^{-3}) than rest of the treatment combinations.

Conclusions

1. The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage recorded significantly maximum growth attributes, yield attributes, grain yield (39.02 q ha^{-1}) and straw yield (51.37 q ha^{-1}).
2. Soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 per cent potassium nitrate (KNO_3) at flowering stage to wheat crop recorded maximum growth attributes, yield attributes, grain yield (26.92 q ha^{-1}) and straw yield (35.45 q ha^{-1}).
3. The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 per cent potassium nitrate (KNO_3) at flowering recorded maximum growth attributes, yield attributes, grain yield (41 q ha^{-1}) and straw yield (53.58 q ha^{-1}). However, under limited availability of irrigation water, scheduling of one irrigation at tillering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 per cent potassium nitrate (KNO_3) at flowering obtained more yield than scheduling of one irrigation at crown root initiation and flowering stage without any moisture stress management practices.
4. Scheduling of one irrigation to wheat crop at crown root initiation stage coupled with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha^{-1} at sowing + foliar spray of 1 per cent potassium nitrate (KNO_3) at flowering recorded maximum crop water use efficiency ($208.24 \text{ kg ha}^{-1}\text{-cm}$). Whereas scheduling of one irrigation to wheat crop at tillering stage along with soil

application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 per cent potassium nitrate (KNO₃) at flowering recorded maximum field water use efficiency (96.30 kg ha⁻¹-cm) and water productivity (0.96 kg m⁻³).

5. The scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage and foliar spray of 1 per cent potassium nitrate (KNO₃) at flowering stage obtained maximum net monetary returns and benefit cost ratio.

Based on one season experiment, it could be concluded that scheduling of four irrigations to wheat crop at crown root initiation + tillering + flowering + milk stage with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 per cent potassium nitrate (KNO₃) at flowering stage recorded higher grain yield. However, under limited availability of irrigation water, scheduling of one irrigation at tillering stage along with soil application of vascular arbuscular mycorrhizae culture @ 10 kg ha⁻¹ at sowing + foliar spray of 1 per cent potassium nitrate (KNO₃) at flowering stage found suitable for better yield and monetary benefits.

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7. APPENDICES

Appendix-I : Prevailing market price of inputs and outputs

Sr. No.	Particulars	Unit	Price
1.	Ploughing	` ha ⁻¹	2800
2.	Harrowing	` ha ⁻¹	1500
3.	Preparation of layout	` ha ⁻¹	1500
4.	Hired labour	` day ⁻¹	204
B.	Seed and fertilizer		
1.	Wheat seed	` kg ⁻¹	2600
3.	FYM	` t ⁻¹	1200
4.	Urea	` kg ⁻¹	5.68
5.	SSP	` kg ⁻¹	6.80
6.	MOP	` kg ⁻¹	16.80
C.	VAM application	` kg ⁻¹	800
D.	Biofertilizer		
1.	Azotobactor (250 g)	`	240
2.	PSB (250 g)	`	60
E.	KNO₃ spraying	` kg ⁻¹	480
F.	Out put		
1.	Wheat grain	` q ⁻¹	2520
2.	Straw	` q ⁻¹	450

8. VITAE

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