International Journal of Bio-resource and Stress Management 2018, 9(6):733-739

Research Article

Doi: HTTPS://DOI.ORG/10.23910/IJBSM/2018.9.6.1921

Stress Management

Mulching Effects on Stress Management of Cotton in Relation to Irrigation and Nitrogen Levels

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Article History

Article ID: AR1921

Received in 25th October, 2018

Received in revised form 23rd December, 2018

Accepted in final form 24th December, 2018

Abstract

Severity of increasing temperature worldwide presents an alarming threat to crop production. Wider row-to-row and plant-to-plant spacing and high temperature lead to higher rate of evaporation and stress to cotton production. Effect of mulching on stress (water, nutrient and heat) and their associated effects on leaf water potential, canopy temperature, NDVI and SPAD value were evaluated during 2015 and 2016 cotton growing seasons in research farm of Punjab Agricultural University, Ludhiana, Punjab (India). A two-year field experiment was conducted and treatment included two mulch rates (0 and 6 t ha^{-1}), three irrigation regimes (Irrigation water to cumulative pan evaporation ratio 0.2, 0.3 and 0.4) and four nitrogen rates (0, 50, 100 and 150 Kg ha^{-1}) in factorial split plot design. Mulching has positive role in minimizing the effect of stress. Leaf water potential was higher under mulched crop over no mulched crop. Crop residue mulched canopy was 1.9-3.0, 1.7-2.3 and 1.8-3.0 °C cooler than the no mulched (stressed) canopy at $I_{0.4}$, $I_{0.3}$ and $I_{0.2}$ irrigation regimes. There was significantly increase in SPAD value with increasing irrigation input and in order of $I_{0.4} > I_{0.3} > I_{0.2}$ throughout the growing season. The SPAD value with mulch plot was significantly higher than the without mulch and the improvement was 2.3, 3.8, and 3.5 at 55, 82 and 110 DAS. Nitrogen rates significantly influenced the NDVI values at 55, 78 and 99 DAS. Nitrogen application also significantly increased SPAD value and with increased nitrogen rates SPAD value increased.

Keywords: Mulching, nitrogen levels, irrigation, cotton, leaf water potential

1. Introduction

When cotton grown during the summer (May-october), the crop experiences high water and heat stress, unless it is frequently irrigated. It has been reported for other crops that sub-optimal soil water status and/or a supra-optimal soil temperature reduce root growth, water and nutrient uptake and grain yield. In north-western India, cotton is sown immediately after wheat harvest and the summer season demands frequent irrigation and cotton crop is very sensitive to irrigation as excess irrigation in its starting period and uncontrolled water stress at later stages may adversely affect the cotton yield (Kashefipour et al., 2006). Mulching with straw offers a means of moderating supra-optimal soil temperatures, conserving moisture and increasing crop yield (Khera et al., 1976). Where cotton crops are grown during the summer, therefore, mulching treatments will improve soil moisture conditions and soil temperature conditions. Mulching and residue retention on soil surface is a crucial factor that can modify soil hydrothermal regimes, influence plant growth, and yield. It was reported that mulching conserved moisture content in soil, increased plant growth (Fang et al., 2011), moderate soil temperature, enhance water infiltration rate during intensive rain and controlled water erosion and runoff by reducing the rain drop impact and suppressed weed growth (Glab and Kulig, 2008). Plant growth has been reported to be greatly influenced by soil temperature as it has marked effect on their various physiological and metabolic processes viz., nutrient uptake, synthesis and translocation of metabolites, respiration, formation and activity of growth regulators, cell division and on various soil phenomena, viz., soil water retention and movement, gaseous exchange, evaporation, ion-movement, release and availability of plant nutrients and microbial activity. Soil temperature is more important for plant growth than air temperature. Numerous reports revealed that residue mulch affects hydrothermal regime by moderating soil temperature and reducing the soil water evaporation (E) component of evapo-transpiration (ET) that improves crop yields in tropical and subtropical regions (Lal, 1974; Kar and Kumar, 2007; Arora et al., 2011) and economized irrigation water use (Gajri et al., 1997). Surface soil moisture under the residue will evaporate slower, after the wetting event; cumulative evaporation from the residue-covered surface can exceed that of the bare surface. Bt cotton being highly exhaustive crop with regard to plant nutrients, fairly large quantities of nutrients are required (Rao and Setty, 2002). Nitrogen fertilization significantly affects plant growth, lint yields and fibre quality (Bondada et al., 1996, Boquet et al., 1993). Deficient N levels from emergence to early blooming could lead to inadequate vegetative growth, resulting in decreased fruiting (Gardner and Tucker, 1967, Clawson et al., 2008). In contrast, an over-dose of N will promote excessive vegetative development and delay maturity (Hodges, 2002).

2. Materials and Methods

The field experiment was conducted at the Punjab Agricultural University, Ludhiana situated at 38°56'N latitude and 75°52' E longitude at a height of 247 m above mean sea level during summer seasons of 2015 and 2016. Monthly maximum temperature of 39.9 °C was recorded in the month of May, minimum temperature of 19.0 °C was recorded in the month of October in 2015, monthly maximum temperature of 39.5 °C was recorded in the month of May, and minimum temperature of 19.1 °C was recorded in the month of October in 2016. Total rainfall received during the cropping season was 542.1 and 529.9 mm with maximum rain of 256.1 and 305.5 mm was recorded in the month of July in 2015 and 2016 cotton growing season. The soil of the experimental site was deep alluvial sandy loam in texture developed under hyperthermic regimes. The experiment was laid out in a factorial split plot design keeping combination of three irrigation regimes of 0.2, 0.3 and 0.4 (based on IW/ PAN-E ratios) and rice residue mulch two rates (0 and 6 t ha^{-1}) in main plots and four nitrogen rates in sub plots and replicated three times. All main plot treatments were randomized in each replication and all sub plot treatments were randomized in each main plot treatment and replication. The water applied in each irrigation was 70 mm for all the treatments. These irrigation schedules were maintained in the soil profile during crop growing period of Bt cotton. The $I_{0.4}$ received 2 irrigations; $I_{0.3}$ and $I_{0.2}$ received 1-1 irrigation in both the years. The rates of rice straw mulch included: no mulch (M_0) and 6 t (M_6) rice straw ha^{-1} Four nitrogen rates (0, 50, 100 and 150 kg ha^{-1}) were randomized as sub treatments.

3. Results and Discussion

3.1. Leaf water potential

Figure 1 (a) indicated leaf water potential at $I_{0.4}$ irrigation regimes at different days after sowing. Leaf water potential was higher under mulched crop (-11.1, -10.0 and -9.2 MPa) over no mulched crop (-13.5, -12.8 and -10.0 MPa) at 28, 45 and 55 DAS in 2015 and under mulched crop (-11.1, -10.5 and -9.0 MPa) over no mulched crop (-14.3, -13.9 and -11.7 MPa) at 23, 43 and 58 DAS, respectively in 2016. Nitrogen application enhanced leaf water potential over N_0 treatment in both the year and it was 0.6, 0.5 and 0.8 MPa higher in N_{150} over N_0 in 2015 at 28, 45 and 55 DAS and 0.6, 0.7 and 0.5 MPa at 23, 43 and 58 DAS, respectively in 2016. Fig 1 (b) indicated leaf water potential at $I_{0.2}$ irrigation regimes at different days after sowing. Same trend as in case of $I_{0.4}$ irrigation regimes was observed under $I_{0.2}$ irrigation regimes. Higher leaf water potential in $I_{0.4}$ irrigation regimes at 28 and 23 DAS was mainly due to better soil moisture status. With advancement of growing days differences in leaf water potential diminishes.

3.2. Canopy temperature

Figure 2 shows that crop residue mulched canopy was 1.9-3.0, 1.7-2.3 and 1.8-3.0 °C cooler than the no mulched (stressed) canopy at $I_{0.4}$, $I_{0.3}$ and $I_{0.2}$ irrigation regimes. Soil moisture changes as a result of different irrigation ratios appeared to have more pronounced effect on canopy temperature. At 35 DAS, mean canopy temperature was 35.7, 34.7 and 33.8 °C in $I_{0.2}$, $I_{0.4}$ and $I_{0.3}$ irrigation regimes and lowest temperature at $I_{0.3}$ irrigation regimes was mainly due to availability of water due to irrigation prior to canopy temperature measurement and at $I_{0.4}$ few days before measurement and no irrigation at $I_{0.2}$ irrigation regimes till the measurement. At 52 DAS, mean

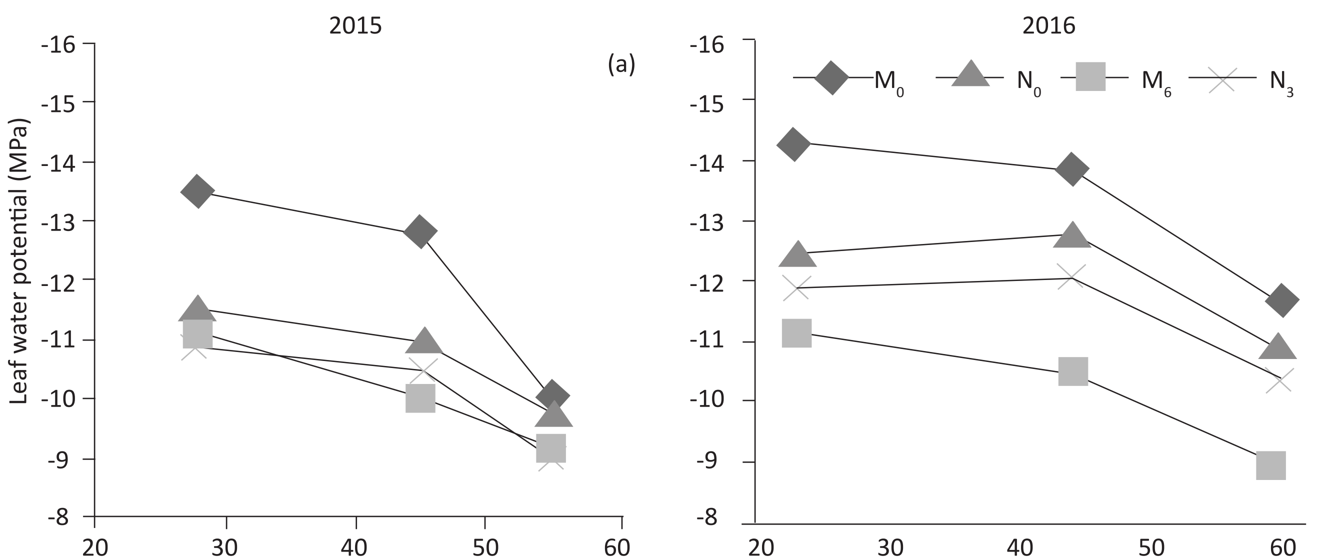

Figure 1: Continue...

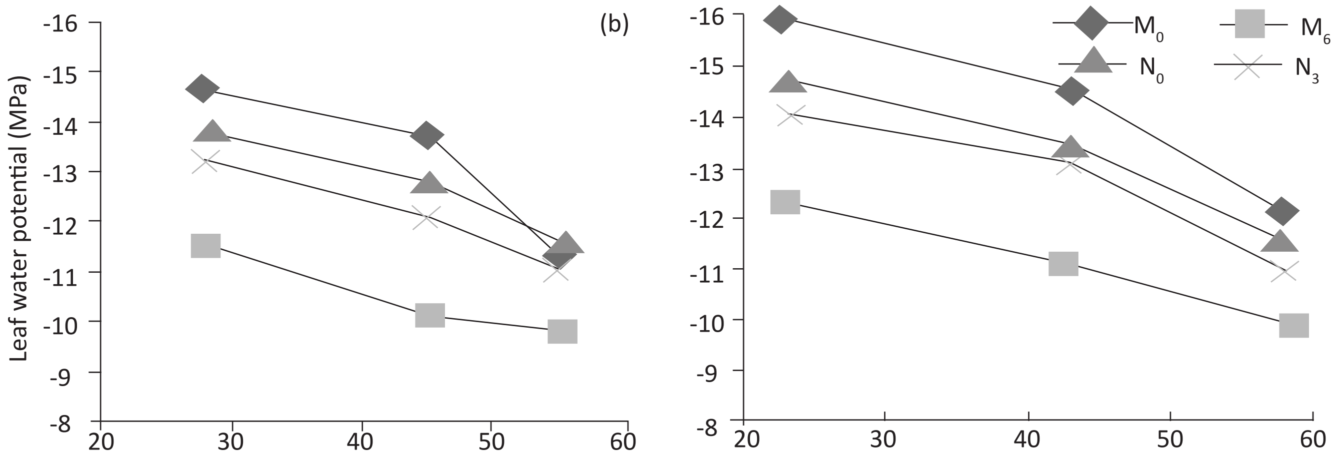

Figure 1: Effect of mulch and nitrogen on leaf water potential of Bt cotton crop at different irrigation regimes (a) IW/Pan-E=0.4 (b) IW/Pan-E=0.2 during 2015 and 2016

canopy temperature was equal in $I_{0.4}$ (27.9 °C) and $I_{0.2}$ (27.5 °C) irrigation regimes and highest at $I_{0.3}$ (28.2 °C) irrigation regimes because at $I_{0.4}$ and $I_{0.2}$ availability of water due to irrigation prior to measurement. At 79 DAS, mean canopy temperature was equal under $I_{0.4}$, $I_{0.3}$ and $I_{0.2}$ irrigation regimes.

Figure 2 revealed that crop residue mulched canopy was 2.0-2.8, 1.9-2.3 and 1.5-2.9 °C cooler than the no mulched canopy at $I_{0.4}$, $I_{0.3}$ and $I_{0.2}$ irrigation regimes. The difference in canopy

2015 crop growing season

2016 crop growing season

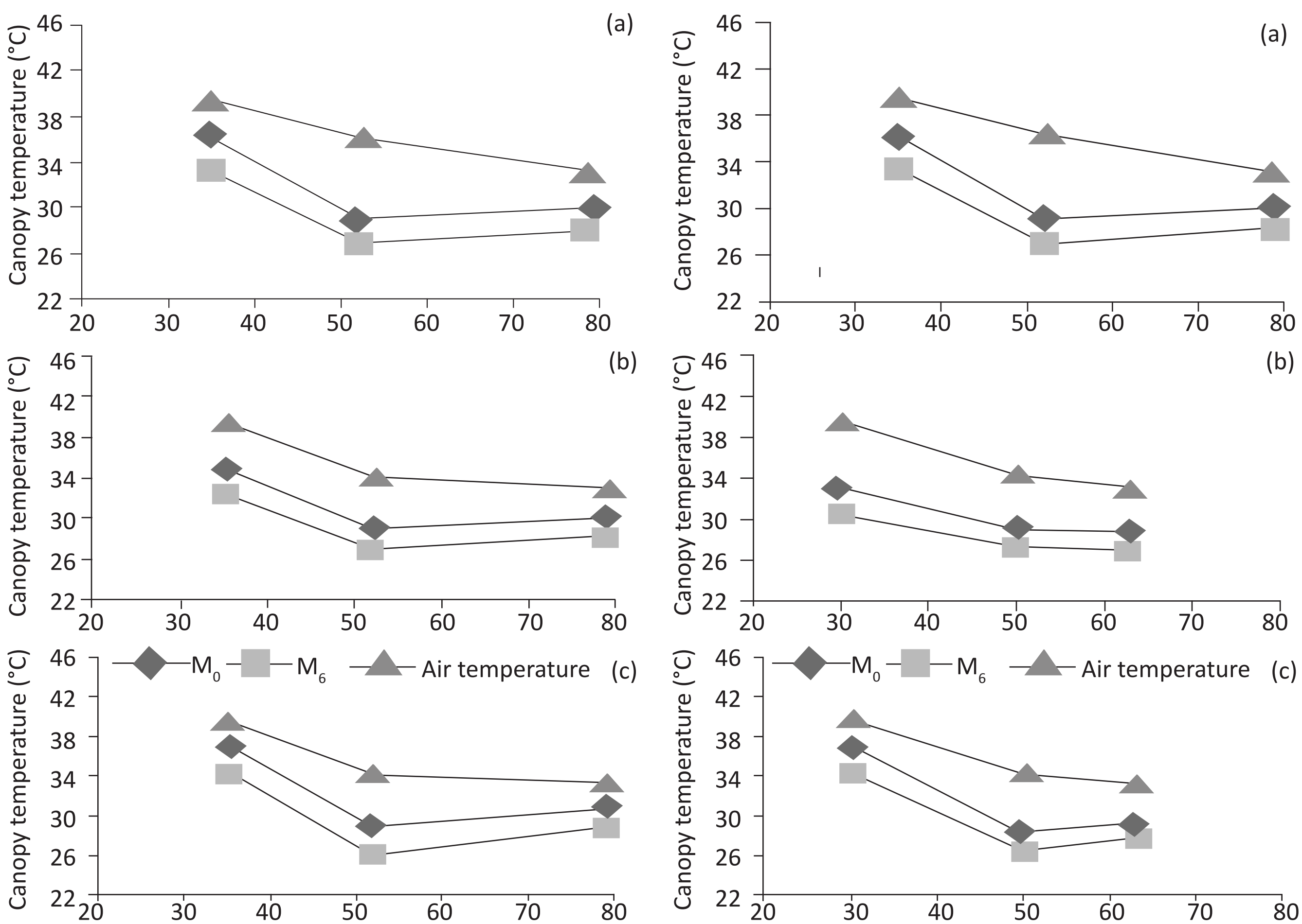

Figure 2: Canopy temperature as affected by mulch application during Bt Cotton growing season at different irrigation regimes (a) IW/Pan-E-0.4 (b) IW/Pan-E-0.3 and (c) IW/Pan-E-0.2

temperature in mulched and unmulched canopy was more at 30 DAS and decreased with the growing season at 50 and 63 DAS. It may be due to that sufficient amount of rainfall at later stages minimized the deficit conditions.

Nitrogen is one of the factors that directly influence canopy growth and dry matter production. Figure 3 depicted that the crop canopy with N_3 (150 kg N ha^{-1}) treatment was cooler than the N_0. Crop canopy N_0 treatment termed as stressed and N_3 treatment crop canopy termed as unstressed canopy. Same trend of nitrogen effect on canopy temperature was observed in all irrigation regimes. The unstressed crop canopy was 0.7-1.2, 0.8-1.6 and 1.3-1.5 °C cooler than the stressed crop canopy at $I_{0.4}$, $I_{0.3}$ and $I_{0.2}$ irrigation regimes. This might be due to the reason that availability of more nutrient in N_3 treatment and better growth of plant as compared to control treatment. Same trend was observed in 2016 crop growing season. Garden et al. (1981) reported a difference of 2 to 8 °C in the canopy temperature between the stresses and unstressed leaves of crop.

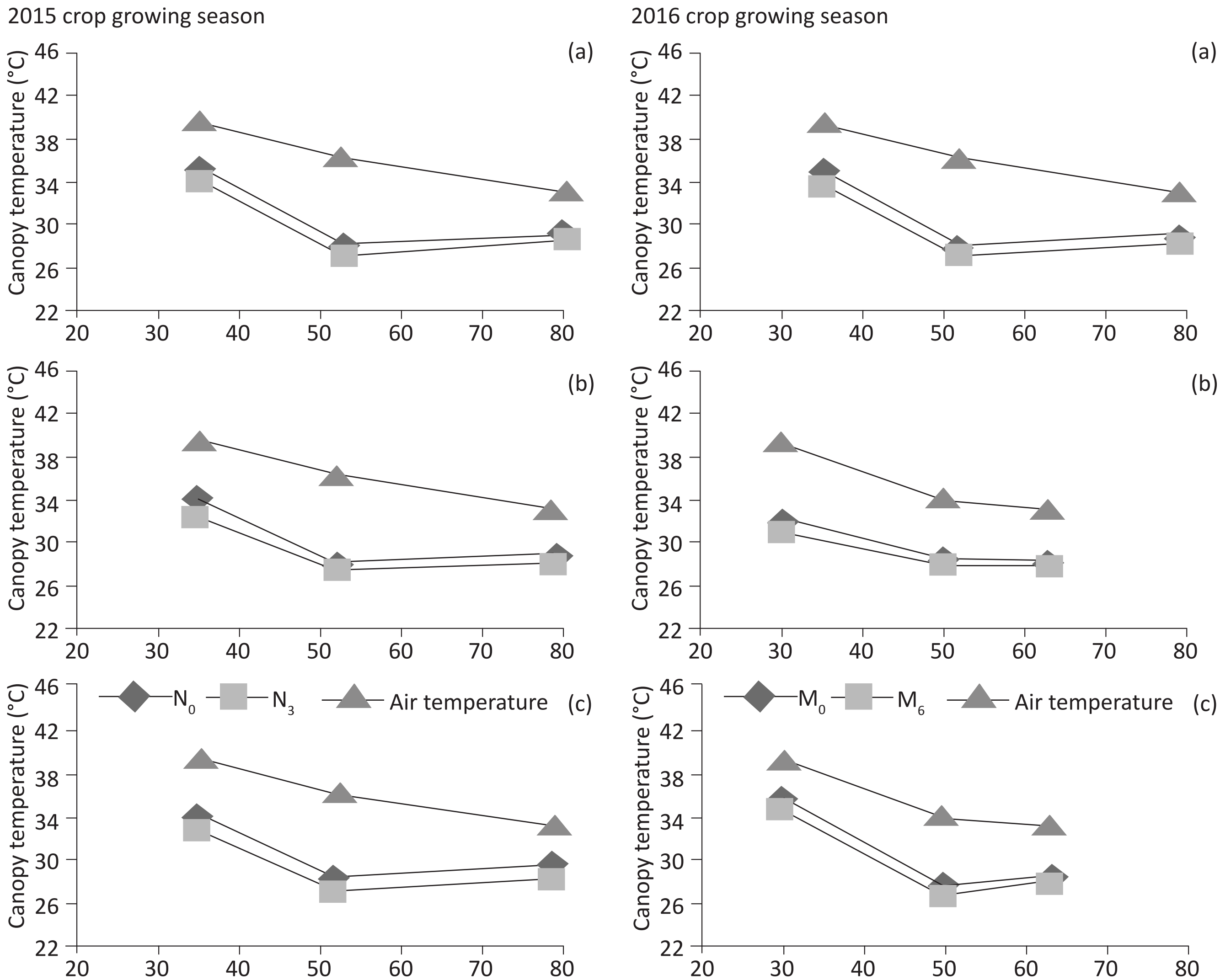

Figure 3: Canopy temperature as affected by nitrogen application during Bt Cotton growing season at different irrigation regimes (a) IW/Pan-E-0.4 (b) IW/Pan-E-0.3 and (c) IW/Pan-E-0.2

3.3. Leaf chlorophyll content (SPAD value)

Periodic chlorophyll content (SPAD) value of 3rd leaf from top of cotton affected by residue mulch, different level of irrigation and nitrogen rates is given in Table 1. There was significantly increase in SPAD value with increasing irrigation input and in order of $I_{0.4}$> $I_{0.3}$> $I_{0.2}$ throughout the growing season. Table 1 depicts that the increase in SPAD value in $I_{0.4}$ was 5.5, 4.5 and 4.3 at 55, 82 and 110 DAS, respectively over the restricted irrigation $I_{0.2}$. The corresponding increase in $I_{0.3}$ was 3.7, 1.9 and 2.5, respectively. The SPAD value with mulch plot was significantly higher than the without mulch and the improvement was 2.3, 3.8, and 3.5 at 55, 82 and 110 DAS. Nitrogen application also significantly increased SPAD value and with increased nitrogen rates SPAD value increased.

Table 1: Effect of mulching, irrigation and nitrogen on SPAD values

Nitrogen rate (kg ha^{-1})	55 DAS								80 DAS							
	M_0				M_6				M_0				M_6			
	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean
Pooled data of 2015 and 2016																
N_0	36.0	33.8	33.0	34.3	38.5	37.6	35.7	37.3	34.4	32.5	30.9	32.6	37.8	34.8	33.8	35.5
N_{50}	40.5	36.2	34.4	37.1	42.7	40.5	37.7	40.3	35.8	33.4	32.2	33.8	40.2	37.2	35.7	37.7
N_{100}	43.5	41.0	37.8	40.8	45.6	43.4	38.4	42.5	36.5	34.5	33.2	34.7	42.3	38.7	36.6	39.2
N_{150}	44.5	41.7	39.0	41.7	46.4	43.9	41.0	43.8	36.9	35.2	33.3	35.1	42.3	39.4	35.9	39.2
Mean	41.2	38.2	36.1	38.5	43.3	41.3	38.2	40.9	35.9	33.9	32.4	34.1	40.6	37.5	35.5	37.9
LSD (p=0.05)	I=1.6, M=1.3, N=1.5								I=1.4, M=1.1, N=1.3							

Table 1: Continue..

N rate (kg ha^{-1})	110 DAS							
	M_0				M_6			
	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean
Pooled data of 2015 and 2016								
N_0	32.2	30.4	27.7	30.1	35.8	34.8	33.3	34.7
N_{50}	35.2	32.2	29.4	32.2	37.7	35.5	34.4	35.9
N_{100}	36.6	35.6	29.9	34.0	38.3	36.1	35.2	36.5
N_{150}	36.3	35.4	31.9	34.5	38.5	36.9	35.9	37.1
Mean	35.1	33.4	29.7	32.7	37.6	35.9	34.7	36.0
LSD (p=0.05)	I = 1.2, M = 1.3, N = 1.2							

Higher SPAD value was observed in N_{150} at 55, 82 and 110 DAS and increase was 19.6, 8.2 and 9.8 per cent at 55, 82 and 110 DAS over N_0 treatment. As nitrogen availability to plant increase the chlorophyll content in plant leaves also increased that reflect in higher SPAD value in mulch plot, higher irrigation regimes and higher nitrogen rates. Application of straw mulching, frequent irrigation and optimum nitrogen to crop maintained optimum soil moisture status in the root zone that accelerated the nitrogen uptake by plant. Similar results were observed during 2016 (Table 1). SPAD value increased with increase in irrigation ratio and it was 4.5, 4.2 and 4.0 with $I_{0.4}$ at 62, 85 and 120 DAS, respectively over the restricted irrigation $I_{0.2}$. Due to mulch SPAD value was higher by 2.7, 3.9 and 3.2 at 62, 85 and 120 DAS, respectively over no mulch. With increase in nitrogen rates, SPAD value increased by 7.0, 3.4 and 3.5 in N_{150} at 62, 85 and 120 DAS over N_0 treatment.

3.4. Normalized differential vegetative index (NDVI)

Measurement of NDVI is a common approach to monitoring plant growth and biomass non-destructively. From the Table 2 it is clear that mean NDVI values recorded higher in frequent irrigation ($I_{0.4}$) as compared to $I_{0.3}$ and $I_{0.2}$ irrigation regimes and higher nitrogen rates recorded higher NDVI value. In 2015, mean comparison shows that there was a significant increase in NDVI values with increase in irrigation frequency, maximum values was observed in $I_{0.4}$ plots followed by $I_{0.3}$ and $I_{0.2}$ at 55 and 78 DAS but at later stages (99 DAS), the values did not differ significantly (Table 2). It may be due to that sufficient amount of rainfall at later stages minimized the effect of irrigation regime. The increase in NDVI of $I_{0.4}$ over $I_{0.2}$ was 0.13 (26.5%) and 0.04 (5.63%) at 55 and 78DAS and there is no increment of NDVI value of $I_{0.4}$ over $I_{0.2}$ was observed at 99 DAS. Application of straw mulch also significantly increased the NDVI values 0.06 (11.5%), 0.03 (4.2%) and 0.03 (3.6%) at 55, 78 and 99 DAS, respectively over no mulch. Nitrogen rates significantly influenced the NDVI values at 55, 78 and 99 DAS. Highest NDVI value was recorded at N_{100} treatment. The increment of NDVI value was 0.06, 0.09 and 0.07 in N_{100} over N_0 treatment at 55, 78 and 99 DAS irrespective of irrigation and mulch.

In 2016, there was a significant increase in NDVI values with increase in irrigation frequency, maximum values was observed in $I_{0.4}$ plots followed by $I_{0.3}$ and $I_{0.2}$ at 62 DAS but at later stages (92 DAS), the values did not differ significantly (Table 2). The increase in NDVI of $I_{0.4}$ over $I_{0.2}$ was 0.04 (6.0%) at 62 DAS and there is 0.01 (1.0%) decrement of NDVI value

Table 2: Effect of mulching, irrigation and nitrogen on NDVI values

N rate (kg ha^{-1})	55 DAS							
	M_0				M_6			
	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean
Pooled data of 2015 and 2016								
N_0	0.55	0.49	0.41	0.49	0.61	0.52	0.50	0.54
N_{50}	0.57	0.51	0.43	0.51	0.65	0.57	0.53	0.58
N_{100}	0.62	0.52	0.47	0.53	0.67	0.59	0.55	0.60
N_{150}	0.60	0.50	0.47	0.52	0.66	0.60	0.51	0.59
Mean	0.58	0.51	0.45	0.52	0.65	0.57	0.53	0.58
LSD (p=0.05)	I=0.03, M= 0.02, N=0.02							

Table 2: Continue

Nitrogen rate (kg ha^{-1})	80 DAS								110 DAS							
	M_0				M_6				M_0				M_6			
	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean	$I_{0.4}$	$I_{0.3}$	$I_{0.2}$	Mean
Pooled data of 2015 and 2016																
N_0	0.65	0.63	0.62	0.64	0.71	0.68	0.65	0.68	0.81	0.80	0.79	0.80	0.84	0.81	0.81	0.82
N_{50}	0.71	0.69	0.67	0.69	0.74	0.72	0.69	0.72	0.82	0.83	0.85	0.83	0.85	0.83	0.85	0.84
N_{100}	0.74	0.72	0.69	0.72	0.77	0.74	0.72	0.74	0.83	0.85	0.86	0.84	0.87	0.87	0.87	0.87
N_{150}	0.73	0.71	0.71	0.72	0.75	0.73	0.72	0.73	0.84	0.85	0.85	0.85	0.86	0.86	0.86	0.86
Mean	0.71	0.69	0.68	0.69	0.74	0.72	0.70	0.72	0.83	0.83	0.84	0.83	0.86	0.85	0.85	0.84
LSD (p=0.05)	I=0.03, M=0.02, N=0.03								I=NS, M=0.02, N=0.02							

of $I_{0.4}$ over $I_{0.2}$ was observed at 99 DAS. Application of straw mulch also significantly increased the NDVI values 0.02 (3.0 per cent) at 62 DAS over no mulch and there was no increment at 92 DAS. With increase in nitrogen rates, there was significantly increase in NDVI values at 62 and 92 DAS. Nitrogen rates significantly influenced the NDVI values at 62 and 92 DAS. The increment of NDVI value was 0.06 and 0.03 in N_{150} over N_0 treatment at 62 and 92 DAS irrespective of irrigation and mulch.

3.5. *NDVI and seed cotton yield relationship*

Regression equation was developed with NDVI to seed cotton yield of Bt. The mean NDVI Values in different irrigation, nitrogen and crop residue mulch was recorded at 55, 78 and 99 days after sowing and correlated with seed cotton yield (Table 3). The NDVI value recorded at different stages explain 65 to 80% of variation in seed cotton yield.

Table 3: Regression relating NDVI value with seed cotton yield

DAS	Dependent variable (Y)	Independent variable (X)	Regression equation	R^2
55	Seed cotton yield	NDVI	Y=45.3X-3.7	0.65
78	do	do	Y=54.4X-8.9	0.80
99	do	do	Y=250.7X-200.0	0.71

4. Conclusion

Mulching can minimize the stressed conditions in cotton, economize water by providing better hydrothermal regime and improved leaf water potential, SPAD value, canopy temperature, NDVI values, and ultimately seed cotton yield of crop. The interactive effects of irrigation, mulching and nitrogen were also meaningful.

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