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Chitosan fortified briquette implications in water stressed okra (*Abelmoschus esculentus*)

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Abstract
A field experiment was conducted during summer season, 2022 at Agronomy Farm, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra (India) to study Chitosan fortified briquette implications in water stressed Okra (*Abelmoschus esculentus* L.) in hot and humid climate of coastal region of Maharashtra where red lateritic soils are prominent. The field was laid out in strip plot design where 3 irrigation stress levels (vertical strip), 8 fertilizer treatments (horizontal strip) which formed 24 treatment combinations and replicated three times to get unbiased and correct data. Variety Konkan Bhendi was used for experimentation. In irrigation stress levels, I_2 (80% ETc irrigation) treatment was most superior for most of the growth and yield attributes. In fertilizer treatment levels, T_7 (100% RDF through 2% chitosan fortified briquettes) and T_5 (100% RDF through 1% chitosan fortified briquettes) were both treatments at par for most of the growth and yield attributes. In treatment interaction, I_3T_7 (60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) was most superior for growth and yield attributes with 224.27 q/ha fresh okra fruit yield. Nearly 108.7% yield increase in I_3T_7 treatment interaction over, i.e. I_1T_2 (conventional practice, 100% ETc irrigation with 100% RDF through straight fertilizer) was noted.

Keywords: Chitosan, lateritic soils, briquettes, stress

1. Introduction
In conventional agriculture, leaching of fertilizers is a major concern creating low fertilizer use efficiency (FUE) of crop, increased cost of cultivation, contaminating groundwater with chemical nutrients, etc. Climate change has propped up as a burning issue. Rise in abiotic and biotic stresses for crop is noticed. Water constraint in agriculture is present concern in agriculture and hence, water budgeting is required. To deal with these rising problems, some new products are in research and development that will lead to sustainable and precision agriculture.
To improve fertilizer use efficiency, briquette technology in fertilizers play a pivotal role. As a novel and innovative attempt, Chitosan fortified fertilizer briquettes are developed. Chitosan is a derivative of chitin and is considered the second most common polymer in the world after cellulose. The application of Chitosan in controlled release fertilizer is still in primary stage. However, it can be excellent fertilizer based on its biodegradable, environment friendly and other peculiar characteristics like biocompatibility and bioactivity. Chitosan also acts as plant growth enhancer, antitranspirant, etc and affects positively on plant growth even under various stress factors. Chitosan functions for hardiness of crop, improve water use efficiency, redefines opportunities for dryland agriculture, catalysis to per drop more crop initiative, etc. Briquettes can be used as spot application in vegetable crops like Okra with an object to improve production of crop, reduce leaching losses of fertilizers and as a slow nutrient release component in soil. Such technology can play a pivotal role in developing crop production technologies for precision agriculture.
Okra (*Abelmoschus esculentus* L.) of family Malvaceae is grown as summer vegetable in India. It grows best at temperature range of 24-27 °C. It grows best in loose, friable well drained sandy loam soils rich in organic matter having optimum soil pH range between 6.0-6.8. In World, the total area and production under okra is reported to be 2.5 million ha and 10.5 million tons respectively (Food and Agriculture Organization of the United Nations, 2020). India is the largest producer of okra contributing 73.25% share in world production (Indian Horticulture Database-2011).

2. Materials and Methods

The field experiment was conducted during the summer season of year 2022 at Agronomy Farm, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra (India) which is situated in the subtropical region at 17°45'55" N latitude and 73°10'26" E longitude having elevation of about 157.8 m above mean sea level. The climate is sub-tropical which is characterized by warm and humid atmosphere. The experimental field consisted sandy clay loam in texture, low in available nitrogen (242.5 kg ha^{-1}), low in available phosphorus (7.78 kg ha^{-1}) and medium in available potassium (234.6 kg ha^{-1}), low in organic carbon (0.41%) and acidic in reaction (pH 6.2) with 0.17 dSm^{-1} electrical conductivity of soil.

In this study, strip plot design was adopted for the investigation which comprises three irrigation stress levels (vertical strip), i.e. I_1 (100% ETc irrigation), I_2 (80% ETc irrigation), and I_3 (60% ETc irrigation). Irrigation treatments were given on the basis of evapotranspiration calculated from pan evaporation data. It also consists of eight fertilizer treatments (horizontal strip), i.e. T_1 (Absolute Control), T_2 (100% RDF through straight fertilizer), T_3 (100% RDF through briquettes), T_4 (75% RDF through briquettes), T_5 (100% RDF through 1% chitosan fortified briquettes), T_6 (75% RDF through 1% chitosan fortified briquettes), T_7 (100% RDF through 2% chitosan fortified briquettes) and T_8 (75% RDF through 2% chitosan fortified briquettes). Fertilizer treatments were allocated in 2 splits, i.e. 15 DAS and 45 DAS. The treatment combinations were done by superimposition of vertical and horizontal strip on each other and replicated three times to get unbiased and correct data. In all, there were 24 treatment combinations in the experimentation. Variety Konkan Bhendi with spacing 45 cm x 30 cm was used for experimentation. Gross plot size was 3.6 m x 3.0 m and net plot size was 2.7 m x 2.4 m accordingly.

From each plot, five representative plants were randomly selected from the net plot (6.48 m^2) for recording periodical biometric observations. The growth attributes *viz*. number of nodes per plant, diameter of stem (cm) and trichomes of stem were recorded on these selected five plants at 30, 60, 90 DAS and harvest. For recording trichomes of stem observation, the stem was touched to upper side of the hand and hairiness was measured by allotting score as 3, 2 and 1 for feelings as high, medium and low hairiness respectively. Days to first and last harvest was also recorded during the field trial. Fresh pod yield were recorded during trial and recorded on quintal per hectare basis.

3. Results and Discussion

3.1 Number of nodes per plant

The number of nodes per plant were increased with increase in the age of crop and it was maximum harvest (Table 1). At 30, 60, 90 DAS and harvest, I_2 (80% ETc irrigation) treatment was found superior with number of nodes as 5.40, 17.89, 22.12 and 22.39 respectively. I_2 treatment was found at par with I_3 (60% ETc irrigation) during 30, 90 DAS and harvest respectively. The probable reason for I_2 treatment being significant might be due to optimization of moisture in soil, i.e. 50% soil pores filled with water and 50% soil pores filled with air, as required for healthy crop growth and deep tap roots make it possible for water and nutrient uptake by plant. Jayapiratha *et al.* (2010) [8] also found that drip irrigation probably keeps root zone at field capacity. Hence, there is no shortage of water for physiological functions of plant.

Table 1: Number of nodes per plant of okra as influenced periodically by different treatments

Treatments	Number of nodes per plant			
	30DAS	60 DAS	90 DAS	At Harvest
Vertical strip (Irrigation stress levels) (I)				
I_1: 100% ETc Irrigation	4.83	16.19	20.48	20.73
I_2: 80% ETc Irrigation	5.40	17.89	22.12	22.39
I_3: 60% ETc Irrigation	5.17	16.33	21.23	21.51
S.Em. (±)	0.08	0.24	0.25	0.24
C.D. at 5%	0.29	0.94	0.99	0.93
Horizontal strip (Fertilizer treatments) (T)				
T_1: Absolute Control	3.78	9.69	14.40	14.67
T_2: 100% RDF through straight fertilizer	4.60	15.04	19.96	20.22
T_3: 100% RDF through briquettes	4.98	17.69	21.11	21.38
T_4: 75% RDF through briquettes	4.78	15.16	20.58	20.84
T_5: 100% RDF through 1% chitosan fortified briquettes	5.87	19.20	24.09	24.36
T_6: 75% RDF through 1% chitosan fortified briquettes	5.64	19.04	23.02	23.31
T_7: 100% RDF through 2% chitosan fortified briquettes	5.87	19.69	24.29	24.53
T_8: 75% RDF through 2% chitosan fortified briquettes	5.56	18.93	22.76	23.02
S.Em. (±)	0.09	0.20	0.28	0.28
C.D. at 5%	0.29	0.61	0.84	0.85
Interaction effect (I x T)				
S.Em. (±)	0.16	0.40	0.45	0.44
C.D. at 5%	0.49	1.23	1.37	1.35
General mean	5.13	16.81	21.28	21.54

At 30, 60, 90 DAS and harvest, T_7 (100% RDF through 2% chitosan fortified briquettes) was found to be most superior fertilizer treatment with 5.87, 19.69, 24.29 and 24.53 number of nodes respectively and T_7 was at par with T_5 (100% RDF through 1% chitosan fortified briquettes). The probable reason for T_7 and T_5 as superior treatments was the presence of chitosan in 2% and 1% respectively which acts as slow nutrient release component in soil and makes optimum nutrient availability to plants. Chitosan fortification induces partial closure of stomata and callose deposition in cells so there is less evapotranspiration. Thus, soil moisture gets saved. Along with it, chitosan also acts as growth promoter in okra. Treatment I_3T_7 (60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) recorded significantly highest number of nodes i.e., 6.40, 21.07, 27.07 and 27.33 at 30, 60, 90 DAS and harvest respectively (Table 2). At 30 DAS, treatments I_3T_5 (60% ETc irrigation with 100% RDF through 1% chitosan fortified briquettes), I_2T_5 (80% ETc irrigation with 100% RDF through 1% chitosan fortified briquettes), I_2T_6 (80% ETc irrigation with 75% RDF through 1% chitosan fortified briquettes), I_3T_8 (60% ETc irrigation with 75% RDF through 2% chitosan fortified briquettes) were statistically at par with I_3T_7.

Table 2: Interaction effect of irrigation stress levels (I) and fertilizer treatments (T) on number of nodes per plant of okra

	Number of nodes per plant											
	30 DAS			60 DAS			90 DAS			Harvest		
	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3
T_1	3.93	4.00	3.40	10.20	10.67	8.20	15.53	15.93	11.73	15.80	16.20	12.00
T_2	4.60	4.80	4.40	15.33	17.67	12.13	19.93	20.67	19.27	20.20	20.93	19.53
T_3	4.67	5.53	4.73	16.93	18.93	17.20	20.13	22.87	20.33	20.40	23.13	20.60
T_4	4.47	5.33	4.53	12.73	18.73	14.00	19.60	22.40	19.73	19.87	22.67	20.00
T_5	5.27	6.13	6.20	18.60	19.40	19.60	22.20	24.93	25.13	22.40	25.20	25.47
T_6	5.20	6.00	5.73	18.53	19.47	19.13	22.00	23.93	23.13	22.27	24.27	23.40
T_7	5.40	5.80	6.40	18.80	19.20	21.07	22.60	23.20	27.07	22.80	23.47	27.33
T_8	5.13	5.60	5.93	18.40	19.07	19.33	21.80	23.00	23.47	22.07	23.27	23.73
S.Em.±	0.16			0.40			0.45			0.44		
C.D. at 5%	0.49			1.23			1.37			1.35		
F Test	S			S			S			S		

3.2 Diameter of stem (cm)

At 30, 60, 90 DAS and harvest, I_2 (80% ETc irrigation) treatment was found superior with diameter of stem as 0.73 cm, 1.57 cm, 2.33 cm and 2.35 cm respectively (Table 3). I_2 treatment was found at par with I_3 (60% ETc irrigation) during 30, 60, 90 DAS and harvest respectively. Abubaker *et al*. (2014) [2] also found okra plants superior in plant height, stem diameter, better plant growth, high water use efficiency and enhancement in yield under drip irrigation as compared to surface irrigation system. The increased soil moisture in I_1 treatment create possibilities for crop falling susceptible to wilting disease and may lead to hurdles in healthy crop growth. At 30, 60, 90 DAS and harvest, T_7 (100% RDF through 2% chitosan fortified briquettes) was most superior fertilizer treatment with 0.84 cm, 1.72 cm, 2.60 cm and 2.62 cm respectively and treatment T_5 (100% RDF through 1% chitosan fortified briquettes) was found to be at par with T_7. Mondal *et al.* (2012) [12] also found that foliar application of chitosan at vegetative stage enhanced the plant growth and development, which resulted in increased fruit yield in okra. Treatment I_3T_7 (60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) recorded significantly highest diameter of stem i.e. 1.01 cm, 1.91 cm, 2.93 cm and 2.96 cm respectively at 30, 60, 90 DAS and harvest respectively (Table 4).

Table 3: Diameter of stem of okra plant (cm) as influenced periodically by different treatments

Treatments	Diameter of stem (cm)			
	30DAS	60 DAS	90 DAS	Harvest
Vertical strip (Irrigation stress levels) (I)				
I_1: 100% ETc Irrigation	0.66	1.44	1.98	2.00
I_2: 80% ETc Irrigation	0.73	1.57	2.33	2.35
I_3: 60% ETc Irrigation	0.73	1.50	2.26	2.28
S.Em. (±)	0.02	0.03	0.02	0.02
C.D. at 5%	0.06	0.12	0.08	0.08
Horizontal strip (Fertilizer treatments) (T)				
T_1: Absolute Control	0.52	0.98	1.49	1.51
T_2: 100% RDF through straight fertilizer	0.64	1.44	1.92	1.94
T_3: 100% RDF through briquettes	0.68	1.52	2.10	2.12
T_4: 75% RDF through briquettes	0.65	1.47	1.98	2.00
T_5: 100% RDF through 1% chitosan fortified briquettes	0.82	1.67	2.56	2.58
T_6: 75% RDF through 1% chitosan fortified briquettes	0.75	1.63	2.47	2.49
T_7: 100% RDF through 2% chitosan fortified briquettes	0.84	1.72	2.60	2.62
T_8: 75% RDF through 2% chitosan fortified briquettes	0.74	1.60	2.40	2.42
S.Em. (±)	0.02	0.03	0.03	0.03
C.D. at 5%	0.07	0.08	0.08	0.08
Interaction effect (I x T)				
S.Em. (±)	0.03	0.04	0.04	0.04
C.D. at 5%	0.10	0.13	0.13	0.13
General mean	0.71	1.5	2.19	2.21

Table 4: Interaction effect of irrigation stress levels (I) and fertilizer treatments (T) on diameter of stem (cm) of okra plant

	Diameter of stem of okra plant (cm)											
	30 DAS			60 DAS			90 DAS			Harvest		
	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3
T_1	0.55	0.55	0.45	1.00	1.17	0.78	1.57	1.59	1.31	1.59	1.61	1.33
T_2	0.64	0.67	0.61	1.44	1.49	1.38	1.92	2.01	1.81	1.94	2.03	1.83
T_3	0.65	0.73	0.66	1.46	1.61	1.47	1.94	2.35	2.01	1.96	2.37	2.03
T_4	0.62	0.71	0.63	1.40	1.58	1.42	1.86	2.19	1.90	1.88	2.21	1.92
T_5	0.70	0.86	0.89	1.56	1.71	1.73	2.17	2.73	2.79	2.19	2.75	2.81
T_6	0.69	0.81	0.77	1.54	1.70	1.64	2.11	2.72	2.59	2.13	2.74	2.61
T_7	0.72	0.78	1.01	1.59	1.66	1.91	2.23	2.63	2.93	2.25	2.65	2.96
T_8	0.68	0.74	0.79	1.51	1.62	1.68	2.05	2.44	2.70	2.07	2.46	2.72
S.Em.±	0.03			0.04			0.04			0.04		
C.D. at 5%	0.10			0.13			0.13			0.13		
F Test	S			S			S			S		

3.3. Trichomes (hairiness) of stem (score)

At 30, 60, 90 DAS and harvest, I_3 (60% ETc irrigation) treatment was found numerically superior with hairiness (trichomes) of stem score as 1.50, 2.50, 2.50 and 2.50 respectively (Table 5). It showed that irrigation stress results in stimulation of hairiness (trichomes) of stem in okra crop. Hairiness (trichomes) of stem is physical character of plant that is responsible for water stress adaptation. At 30, 60, 90 DAS and harvest, T_5 (100% RDF through 1% chitosan fortified briquettes), T_6 (75% RDF through 1% chitosan fortified briquettes) and T_7 (100% RDF through 2% chitosan fortified briquettes) treatments were equally most superior fertilizer treatments for hairiness (trichomes) of stem. These superior treatments showcase medium, high, high and high hairiness (trichomes) of stem at 30, 60, 90 DAS and harvest respectively. From Table 6, I_3T_7 (60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes), I_3T_5 (60% ETc irrigation with 100% RDF through 1% chitosan fortified briquettes), I_3T_6 (60% ETc irrigation with 75% RDF through 1% chitosan fortified briquettes), I_3T_8 (60% ETc irrigation with 75% RDF through 2% chitosan fortified briquettes), I_2T_5 (80% ETc irrigation with 100% RDF through 1% chitosan fortified briquettes), I_2T_6 (80% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) and I_2T_7 recorded numerically equal superior hairiness (trichomes) of stem score i.e. 2.0 (medium), 3.0 (high), 3.0 (high) and 3.0 (high) respectively at 30, 60, 90 DAS and harvest respectively.

Table 5: Trichomes (hairiness) of stem of okra plant (score) as influenced periodically by different treatments

Treatments	Trichomes of stem (score)			
	30DAS	60 DAS	90 DAS	Harvest
Vertical strip (Irrigation stress levels) (I)				
I_1: 100% ETc Irrigation	1.00	2.00	2.00	2.00
I_2: 80% ETc Irrigation	1.46	2.46	2.46	2.46
I_3: 60% ETc Irrigation	1.50	2.50	2.50	2.50
Horizontal strip (Fertilizer treatments) (T)				
T_1: Absolute Control	1.00	2.00	2.00	2.00
T_2: 100% RDF through straight fertilizer	1.00	2.00	2.00	2.00
T_3: 100% RDF through briquettes	1.00	2.00	2.00	2.00
T_4: 75% RDF through briquettes	1.00	2.00	2.00	2.00
T_5: 100% RDF through 1% chitosan fortified briquettes	1.67	2.67	2.67	2.67
T_6: 75% RDF through 1% chitosan fortified briquettes	1.67	2.67	2.67	2.67
T_7: 100% RDF through 2% chitosan fortified briquettes	1.67	2.67	2.67	2.67
T_8: 75% RDF through 2% chitosan fortified briquettes	1.56	2.56	2.56	2.56
General mean	1.32	2.32	2.32	2.32

Table 6: Interaction effect of irrigation stress levels (I) and fertilizer treatments (T) on trichomes of stem of okra plant (score)

	Hairiness (Trichomes) of stem (score)											
	30 DAS			60 DAS			90 DAS			Harvest		
	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3
T_1	1.00	1.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
T_2	1.00	1.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
T_3	1.00	1.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
T_4	1.00	1.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
T_5	1.00	2.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	2.00	3.00	3.00
T_6	1.00	2.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	2.00	3.00	3.00
T_7	1.00	2.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00	2.00	3.00	3.00
T_8	1.00	1.67	2.00	2.00	2.67	3.00	2.00	2.67	3.00	2.00	2.67	3.00

3.4 Days to first harvesting (DAS): Treatment I_2 (80% ETc irrigation) was found superior with minimum number of days for first harvesting which require 55.47 DAS. Treatment I_3 (60% ETc irrigation) was found at par with I_2 (Table 7). Treatment T_7 (100% RDF through 2% chitosan fortified briquettes) was most superior fertilizer treatment which required 53.78 DAS for first harvesting of okra fruit. Treatment T_5 (100% RDF through 1% chitosan fortified briquettes) was at par with T_7 accordingly. Amongst different interactions, the treatment I_3T_7 (60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) and I_3T_5 (60% ETc irrigation with 100% RDF through 1% chitosan fortified briquettes) recorded equally most superior treatment with 51.47 DAS for first harvesting (Table 8). It may be probably due to chitosan fortification in fertilizer briquettes which promoted early physiological growth and flowering in okra. Sharp (2013) [13] highlighted the precocious flowering and increased flower numbers when chitosan was applied to passion fruit (*Passiflora edulis*) as a soil drench and induction of flowering by chitosan was also observed in *Eustoma grandiflorum*.

Table 7: Days to first harvest (DAS), days to last harvest (DAS) and yield of fruit per ha (q/ha) as influenced by different treatments

Treatments	Days to first harvest (DAS)	Days to last harvest (DAS)	Yield of fruit per ha (q/ha)
Vertical strip (Irrigation stress levels) (I)			
I_1: 100% ETc Irrigation	57.13	96.25	117.19
I_2: 80% ETc Irrigation	55.47	98.63	151.53
I_3: 60% ETc Irrigation	56.12	97.63	141.96
S.Em. (±)	0.41	0.25	2.70
C.D. at 5%	1.62	0.98	10.62
Horizontal strip (Fertilizer treatments) (T)			
T_1: Absolute Control	61.02	94.33	43.36
T_2: 100% RDF through straight fertilizer	57.51	94.00	109.26
T_3: 100% RDF through briquettes	56.47	96.00	128.84
T_4: 75% RDF through briquettes	57.13	94.33	116.79
T_5: 100% RDF through 1% chitosan fortified briquettes	54.02	100.33	186.69
T_6: 75% RDF through 1% chitosan fortified briquettes	54.91	100.00	164.61
T_7: 100% RDF through 2% chitosan fortified briquettes	53.78	101.00	184.72
T_8: 75% RDF through 2% chitosan fortified briquettes	55.07	100.00	160.87
S.Em. (±)	0.27	0.24	2.68
C.D. at 5%	0.83	0.74	8.14
Interaction effect (IxT)			
S.Em. (±)	0.46	0.40	4.31
C.D. at 5%	1.39	1.22	13.09
General mean	56.24	97.5	136.89

Table 8: Interaction effect of irrigation stress levels (I) and fertilizer treatments (T) on days to first harvesting (DAS)

Days to first harvesting (DAS)			
	I_1	**I_2**	**I_3**
T_1	61.27	60.00	61.80
T_2	57.60	56.00	58.93
T_3	57.33	55.07	57.00
T_4	58.07	55.47	57.87
T_5	55.73	53.53	52.80
T_6	55.87	54.13	54.73
T_7	55.27	54.60	51.47
T_8	55.93	54.93	54.33
S.Em.±	0.46		
C.D. at 5%	1.39		
F Test	S		

3.5 Days to last harvest

Treatment I_2 (80% ETc irrigation) was found statistically significant with maximum 98.63 DAS (Table 7). Treatment T_7 (100% RDF through 2% chitosan fortified briquettes) was most superior fertilizer treatment with 101 DAS and T_5 (100% RDF through 1% chitosan fortified briquettes) was at par with T_7. Amongst different interactions, the treatment I_3T_7 (60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) recorded most superior treatment with 104 DAS (Table 9).

Table 9: Interaction effect of irrigation stress levels (I) and fertilizer treatments (T) on days to last harvest (DAS)

Days to last harvest (DAS)			
	I_1	**I_2**	**I_3**
T_1	95.00	94.00	94.00
T_2	95.00	95.00	92.00
T_3	95.00	98.00	95.00
T_4	93.00	98.00	92.00
T_5	98.00	101.00	102.00
T_6	98.00	101.00	101.00
T_7	98.00	101.00	104.00
T_8	98.00	101.00	101.00
S.Em.±	0.40		
C.D. at 5%	1.22		
F Test	S		

3.6 Yield of fruit per ha (q/ha): Treatment I_2 (80% ETc irrigation) was found statistically significant with maximum 151.53 q/ha and I_3 (60% ETc irrigation) was found at par with I_2 with 141.96 q/ha yield of fruit accordingly (Table 7). Abdulrahman *et al.* (2018) [1] found that the treatment with irrigation stress yielded highest harvest index and pod yield. Abubaker *et al.* (2014) [2] found that maximum yield of 249.71 kg ha^{-1} was obtained by using drip irrigation than furrow irrigation. Cemek *et al.* (2019) [4] also found that irrigations at around 0.5 water depletion factor appeared suitable to obtain higher yield in okra. Jayapiratha *et al.* (2010) [8] also found that that water saving with increased yield recorded under drip irrigation system than basin irrigation. Treatment T_5 (100% RDF through 1% chitosan fortified briquettes) was most superior fertilizer treatment with 186.69 q/ha yield of fruit and treatment T_7 (100% RDF through 2% chitosan fortified briquettes) was found to be at par with T_5 with 184.72 q/ha yield of fruit accordingly. Amongst different interactions, the treatment I_3T_7 (60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) recorded most superior treatment with 224.27 q/ha and I_3T_5 (60% ETc irrigation with 100% RDF through 1% chitosan fortified briquettes) was found at par with I_3T_7 with 212.27 q/ha yield of fruit (Table 10). There was 505.8% yield increase in I_3T_7 (most superior, 60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) treatment interaction over I_3T_1 (most inferior, 60% ETc irrigation with absolute control). There was 108.7% yield increase in I_3T_7 (most superior, 60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) treatment interaction over, i.e. I_1T_2 (conventional practice, 100% ETc irrigation with 100% RDF through straight fertilizer). The probable reason for I_3T_7 as superior treatment interaction is the improved nutrient availability to plant and reduced leaching of fertilizers due to reduced water supply via irrigation. The stress created due to irrigation in plant is mitigated by chitosan as it acts as anti transpirant, growth promoter, etc. Bittelli *et al.* (2001) [3] also found that chitosan foliar application induced stomata closure reducing transpiration losses and reduced water use to 26-43% by maintaining biomass production and yield in pepper plants. Lan *et al.* (2007) [9] found that CFCW (controlled release and water retention) was a good slow release fertilizer with excellent water retention capability and has potential in renewal of arid and desert environments. Somdutt *et al.* (2020) [14] found that chitosan is an effective organic molecule that improves productivity by supplying valuable nutrients to plant and it also enhance activity of protective enzymes that enables for biotic and abiotic stress resistance in plants. Mondal *et al.* (2012) [12] found that yield attributes (number of fruits $plant^{-1}$ and fruit size) and total dry mass $plant^{-1}$ were increased with increasing concentration of chitosan until 25 ppm, resulted the highest fruit yield in okra (27.9% yield increased over the control). Liberacki *et al.* (2021) [10] found that chitosan application contributes to increased yields, not only under normal conditions but also during drought stress. Chitosan application has tendency to alleviate the effects of stress and to improve growth parameters under unfavourable conditions.

Table 10: Interaction effect of irrigation stress levels (I) and fertilizer treatments (T) on yield of fruit per ha (q/ha)

Yield of fruit per ha (q/ha)			
	I_1	I_2	I_3
T_1	45.53	47.52	37.02
T_2	107.48	133.55	86.74
T_3	115.46	152.82	118.24
T_4	97.70	149.23	103.46
T_5	148.62	199.16	212.27
T_6	136.62	185.78	171.45
T_7	150.93	178.95	224.27
T_8	135.19	165.24	182.20
S.Em.±	4.31		
C.D. at 5%	13.09		
F Test	S		

Conclusion

For okra crop grown under irrigation stress levels, 20% of irrigation deficiency (80% ETc irrigation) than water requirement of okra crop was found to produce superior plant morphology and ultimately fruit yield. In sandy clay loam soils with hot and humid climate, chitosan fortified briquettes were found to yield more than current conventional agriculture practices. There was 108.7% yield increase in I_3T_7 (most superior, 60% ETc irrigation with 100% RDF through 2% chitosan fortified briquettes) treatment interaction over, i.e. I_1T_2 (conventional practice, 100% ETc irrigation with 100% RDF through straight fertilizer). In increasing irrigation stress, chitosan fortified briquettes were found as an effective solution to mitigate negative impacts on crop growth and yield.

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