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Stesi S
Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Dr. M Raju
Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Dr. S Pazhanivelan
Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Dr. KP Ragunath
Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Dr. S Selvakumar
Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding Author:
Stesi S
Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Impact of fertigation scheduling on growth, yield and yield attributes of cotton under high density planting system

Stesi S, Dr. M Raju, Dr. S Pazhanivelan, Dr. KP Ragunath and Dr. S Selvakumar

Abstract
Field experiments were carried out at Eastern Block Farm, Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore during the *winter* and *summer* seasons (2022-2023) to evolve the optimum fertigation scheduling in high density cotton through Crop Growth Curve Nutrition Approach (CGCNA). The experiments were laid out in RBD and replicated thrice. The treatments comprises of different NPK fertilizers levels that are being supplied through fertigation in a definite ratio at different growth stages *viz*., seedling stage (10% NPK), vegetative stage (20% NPK), square formation (30% NPK), 50% flowering (20% NPK), boll formation and boll development stages ((10% NPK) and its comparative study with drip and conventional irrigation practice with STCR based recommendations of fertilizer NPK and 100% RDF NPK as soil application in the same split ratios (i.e., seedling stage (10% NPK), vegetative stage (20% NPK), square formation (30% NPK), 50% flowering (20% NPK), boll formation and boll development stages (10% NPK) to cotton planted under HDPS. The growth yield and yield attributes were significantly influenced by various levels of fertigation schedules and their combination. The maximum yield of 3568 and 3475 $kgha^{-1}$ were recorded under 25% enhanced dose of K along with 100% of N&P through fertigation during *winter* and *summer* seasons respectively.

Keywords: Drip fertigation, STCR, HDPS, conventional irrigation, RDF, NPK

Introduction
Cotton (*Gossypium* sp.) is the major fiber and cash crop, grown worldwide plays a significant role in the agricultural and industrial economy. It is cultivated in the tropical as well as sub-tropical regions of more than seventy countries of the World. Around 60% of fiber to Indian textiles is from cotton. Its production provide income for more than 250 million people around the world and employs almost 7% of labour in developing countries (CCI, 2022) [5]. Around 67% of India's cotton is grown on rain-fed areas and 33% on irrigated areas (Ministry of textiles, 2022) [5]. The recent statistics revealed that the India (13.40 million ha) has more than one third of the World's area (32.94 million ha) under cotton cultivation with a productivity of 487 kg ha^{-1}, which is far below than the World's productivity of 775 kg ha^{-1} (USDA- FAS, 2020). This clearly signifies the productivity gap prevailing in India for cotton. In India, despite having a larger area dedicated to cotton farming than many other countries in the globe, the seed cotton yield per unit area is very low. The longer duration cultivars requires more number of pickings, which necessitate increased labour requirement as a result, cost of cotton cultivation upsurge especially owing to manual picking and fluctuating prices resulting in lesser realistic income. Under these circumstances, high density planting system (HDPS) have a remarkable relevance under the present scenario of cotton cultivation in India, researchers are developing new compact cotton genotypes which are ideally suited to HDPS.

Global cotton production requires over 250 billion tons of water annually. It takes nearly 10,000 litres of water to produce one kilogram of cotton (CWC, 2017) [4]. Improving irrigation facilities and water harnessing techniques is considered to be imperative for enhancing the production and lowering the dependence on monsoon. Around the major share of the area under cotton is rainfed with poor irrigation facilities, exposing production to monsoon fluctuations (as projected by the ministry of textiles, 2022) [7]. Hence there is a need to promote the use of hi-tech irrigation practices like drip irrigation, which is more ecologically viable and ethically sound. Application of water combined with fertilizers can induce drought tolerance and sustain the cotton lint yield under water-saving technology, which is of great importance for the sustainable development of cotton. This research study has been carried out to optimize drip fertigation technique in HDPS for increasing productivity of cotton.

Materials and Methods

a. Location of the experimental field

The field experiments were conducted at Eastern Block Farm, CWGS, TNAU, Coimbatore during winter and summer seasons (2022-2023) to study the impact of fertigation scheduling in high density cotton through crop growth curve nutrition approach. The area is geographically located in Western Agro- Climatic Zone of Tamil Nadu with the coordinates of 11^{o} N latitude, 77^{o} E longitude and an altitude of 426.7 m above mean sea level.

b. Soil Characteristics of the experimental field

The soil characteristics of the experimental site is clay loam in texture, slightly alkaline pH (8.34& 8.12) with low soluble salts (EC = 0.63 & 0.76) and with low in available nitrogen (212 & 207 kg/ha), medium in available phosphorus (15 &17kg/ha) and high in available potassium (395 & 386 kg/ha) during 2022-2023.A total rainfall of 348.0 mm and 287.5mm and mean solar radiation 324.5 cal/cm^2/day and 347.7 cal/cm^2/day were received during the *winter* and *summer* cropping periods (Sept 2022 – July 2023). The mean maximum and minimum temperature recorded during *winter* season were 30.5 °C and 21.0 °C and *summe*r season were 33.7 °C and 23.3 °C, respectively.

c. Design of experiment and treatment details

The experimental trial was laid out in Randomized Block Design with three replications. The variety chosen for the study is CO17 zero monopodial variety of cotton. The recommended cultural practices were carried out. The treatments comprises of different levels of RDF NPK (75%, 100% and 125%) that are being supplied through fertigation in a definite ratio at the peak growing stages *viz*., seedling stage (10% of RDF NPK), vegetative stage (20% of RDF NPK), square formation (30% of RDF NPK), 50% flowering (20% of RDF NPK), boll formation and boll development stages ((10% of RDF NPK) (T_1: DF with 75% RDF NPK, T_2: DF with 100% RDF NPK, T_3: DF with 125% RDF NPK, $T_{4:}$ DF with 75% N + 100% P & K of RDF, $T_{5:}$ DF with 125% N + 100% P & K of RDF, $T_{6:}$ DF with 75% P + 100% N & K of RDF, $T_{7:}$DF with 125% P + 100% N & K of RDF, $T_{8:}$ DF with 75% K + 100% N & P of RDF, $T_{9:}$ DF with 125% K + 100% N & P) and these combinations were compared with the drip and conventional furrow irrigation practice with STCR based recommendations of fertilizer NPK and 100% RDF NPK as soil application in the same split ratios (i.e., seedling stage (10% NPK), vegetative stage (20% NPK), square formation (30% NPK), 50% flowering (20% NPK), boll formation and boll development stages ((10% NPK) to cotton planted under HDPS. (T_{10}: DI with soil application of STCR based NPK, T_{11}: DI with soil application of 100% RDF NPK, $T_{12:}$ CI with soil application of STCR based NPK, T_{13}: CI with soil application of 100% RDF NPK).

Results and Discussion

The drip fertigation system highly influenced the growth and yield attributes of cotton under HDPS. The biometric observations such as plant height and dry matter production has been recorded in all crop growth stages and results were discussed here under

a. Plant height

Plant height is a direct index to assess the growth and vigour of the plant. Maximum plant height (46.24 cm, 80.55 cm, 116.51 cm, 128.65 cm and 151.54 cm) during *winter* season and *summer* seasons (43.56 cm, 79.26 cm, 108.57 cm, 126.33 cm and 148.36 cm) were recorded at30 DAS, 60 DAS, 90 DAS and 120 DAS respectively with the application of 25% enhanced dose of K along with 100% of recommended dose of N and P (T_9) when compared to other treatments (Table1.). Plant height was increased by 24% during *winter* season and 22% subsequently during *summer* season of the harvest stages when compared to the control, where conventional irrigation was practiced with soil application of 100% RDF (T_{13}). Arun *et al*., (2020) [2] reported that the highest plant height was achieved due to 50% enhancement in the dose of NPK than the normal RDF, which increased the nutrient supply to plants, that might have accelerated the plant height. They also found out that the closer spacing pattern with compact and erect type of variety have attributed more towards attainment of vertical growth, where no sympodial growth was possible. This is in concordance with the findings of Udikeri and Shashidhara (2017) [14] and Bharathi *et al*. (2018) [3].

Table 1: Impact of fertigation scheduling on plant height (cm) of cotton under high density planting system

Treatments	Winter cotton (2022)					Summer cotton (2023)				
	30DAS	60 DAS	90 DAS	120 DAS	At harvest	30DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	32.72	49.28	82.87	102.45	131.19	30.99	49.37	80.72	100.28	130.33
T_2	38.46	69.66	93.18	115.99	140.80	36.41	65.70	90.26	110.64	138.14
T_3	44.57	80.03	106.49	126.21	149.32	42.73	75.49	102.33	123.43	147.46
T_4	35.62	55.35	86.40	105.20	133.75	33.54	50.23	83.61	103.35	132.16
T_5	40.83	70.64	96.35	118.63	143.72	39.20	69.76	93.29	113.26	140.58
T_6	36.30	63.40	90.64	110.42	138.48	34.37	60.29	89.75	108.38	135.14
T_7	42.44	76.28	98.52	121.32	146.31	40.82	73.44	96.48	120.67	144.32
T_8	33.85	58.23	88.38	107.31	135.53	31.34	56.82	85.84	106.52	133.27
T_9	46.24	80.55	116.51	128.65	151.54	43.56	79.26	108.57	126.33	148.36
T_{10}	30.13	48.25	80.66	100.75	129.36	27.25	46.84	79.56	98.71	127.54
T_{11}	29.82	45.32	78.39	97.32	126.34	25.29	43.45	75.94	95.54	125.89
T_{12}	26.79	43.67	74.71	95.24	123.87	23.68	41.88	72.66	93.29	122.31
T_{13}	25.95	41.39	72.55	92.68	121.65	22.94	40.77	70.24	90.85	120.89
S.Ed	1.23	2.77	2.94	4.05	5.67	1.46	2.45	4.10	4.79	4.97
CD	2.56	5.74	6.11	8.40	11.77	3.02	5.09	8.51	9.94	10.32

Table 2: Impact of fertigation scheduling on total dry matter production (kg ha^{-1}) of cotton under high density planting system

Treatments	Winter cotton (2022)					Summer cotton (2023)				
	30DAS	60 DAS	90 DAS	120 DAS	At harvest	30DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	366	1614	3025	6897	7034	317	1498	2845	6323	6526
T_2	432	1659	3955	8082	8394	400	1621	3647	7965	8253
T_3	513	1942	4645	9013	9421	457	1879	4136	8871	8517
T_4	394	1623	3260	7216	7432	321	1535	3066	7015	7325
T_5	456	1758	4268	8432	8564	427	1643	3895	8250	8338
T_6	425	1672	3967	7856	8016	387	1593	3423	7456	7543
T_7	497	1794	4426	8865	9027	445	1685	4054	8531	8756
T_8	405	1658	3573	7549	7764	353	1572	3125	7342	7451
T_9	525	2123	4873	9324	9568	505	2056	4546	9064	9356
T_{10}	344	1581	2765	6546	6343	287	1477	2543	6457	6632
T_{11}	325	1566	2472	6365	6578	255	1469	2165	6169	6457
T_{12}	305	1509	2108	5764	6213	235	1418	2097	5675	5876
T_{13}	286	1464	1989	5652	6001	224	1365	1843	5438	5649
S.Ed	15	65	119	288	380	10	70	138	239	279
CD	31	134	245	596	784	20	145	285	493	596

b. Dry Matter Production

Cotton is an exhaustive crop and manifest vigorous growth and dry matter production to the enhanced dose of fertilizers. The results of the experiment revealed that the DMP of cotton showing a linear increasing pattern at successive growth stages with increased fertilizers levels supplied through drip fertigation than the direct soil application of 100% of recommended dose of fertilizers, where followed the conventional irrigation practice (Table 2.). Significantly higher DMP were recorded at all the growth stages and at harvests stage (525, 2123, 4873, 9324, 9568 kg ha^{-1} and505, 2056, 4546, 9064, 9356kg ha^{-1}) under T_9 treatment (DF with 125% K + 100% N & P) followed by T_3 (DF with 125% RDF NPK) during both winter and summer seasons, respectively. The lower DMP was noticed where direct application of 100% RDF under conventional irrigation was practiced (T_{13}) during both the seasons of successive years. (286, 464, 1989,5652, 6001kg ha^{-1} and 224,1365, 1843, 5438 and 5649 kg ha^{-1}). The enhanced dose of NPK fertilizers results in a steady fast supply of nutrients which in turn resulted in better accumulation of more photosynthates to cotton plants, may be the probable reason for the higher performance in terms of DMP. The results are in line with the findings of Sisodia and Khamparia (2007) [12] and Parihar *et al*. (2018) [10]. It was also noticed that the leaf area index is maximum in plants which were grown under HDPS system when compared to plants grown under wider spacing, this because of the better light interception and better leaf area development, which in turn resulted in better accumulation of phyotosynthates, which might also resulted in increased DMP. These results were in agreement with the findings of Kumar *et al.* (2020) [9].

c. Yield and yield attributes

Seed cotton yield is the reflection of many of the yield attributing parameters. The yield attributes like no. of fruiting points per plants, no. of bolls per plants and boll setting percentage were significantly influenced by the fertigation levels. Among the treatments application of 25% enhanced dose of K along with the application of 100% N and P (T_9) recorded the higher number of fruiting points, number of bolls per plants and boll setting percentage during both *winter* and *summer* seasons respectively (104.29, 53.55, 51.38) and which was followed by the treatment T_3 (DF with 125% RDF NPK) but without any significant disparity between them (101.60, 50.21, 49.48) as per the Table 3. The lowest yield attributes were recorded under the conventional irrigation practiced with soil application of 100% RDF NPK (T_{13}). This might be due to the fact that the optimum spacing with enhanced fertilizer levels could probably allow entry of more sunlight and air which could lead to increased auxin synthesis and hence, resulting in more boll retention than the other treatments. These results are in accordance with the findings of Parlawar *et al.,* (2017) [11].

Table 3: Impact of drip fertigation on number of no. of fruiting points per plant, no. of bolls per plant, boll setting percentage of cotton under high density planting system

Treatments	Winter cotton (2022)			Summer cotton (2023)		
	No. of fruiting points per plant	No. of bolls per plant	Boll setting percentage	No. of fruiting points per plant	No. of bolls per plant	Boll setting percentage
T_1	87.16	37.66	43.24	81.71	35.74	43.86
T_2	95.61	45.08	47.33	86.67	39.26	45.34
T_3	102.38	50.36	49.20	95.45	45.41	47.56
T_4	90.23	38.97	43.18	82.69	35.53	43.11
T_5	97.56	46.32	47.55	89.99	40.83	45.37
T_6	93.87	43.28	46.30	86.23	38.56	44.72
T_7	100.92	48.65	48.22	93.35	42.33	45.51
T_8	90.54	40.18	44.55	84.38	36.88	43.76
T_9	104.29	53.55	51.38	101.60	50.21	49.48
T_{10}	82.63	35.68	43.18	81.00	34.23	42.67
T_{11}	82.44	34.65	42.11	82.16	34.05	41.47
T_{12}	81.78	34.23	42.01	80.57	33.21	41.50
T_{13}	80.65	33.21	41.35	79.83	32.56	41.01
S.Ed	4.23	2.09	2.96	4.48	1.61	2.94
CD	8.74	4.32	6.10	9.24	3.32	6.06

Table 4: Impact of fertigation scheduling onseed cotton yield (kg ha-1), stalk yield (kgha-1) and harvest Index of cotton under high density planting system

Treatments	Winter cotton (2022)			Summer cotton (2023)		
	Seed cotton yield	Stalk yield	Harvest Index	Seed cotton yield	Stalk yield	Harvest Index
T_1	2667	4989	0.35	2442	4457	0.35
T_2	3252	5463	0.38	2784	4954	0.36
T_3	3354	5711	0.37	3354	5465	0.38
T_4	2708	5078	0.35	2456	4554	0.35
T_5	3296	5580	0.37	2888	4988	0.37
T_6	3041	5437	0.36	2657	4850	0.36
T_7	3392	5624	0.38	3225	5379	0.37
T_8	2896	5324	0.35	2614	4572	0.36
T_9	3568	5766	0.39	3475	5486	0.39
T_{10}	2581	4877	0.35	2283	4324	0.35
T_{11}	2432	4754	0.34	2234	4266	0.34
T_{12}	2267	4456	0.34	2123	4210	0.34
T_{13}	2134	4325	0.33	2045	4185	0.33
S.Ed	91	390	0.02	90	367	0.02
CD (p=0.05)	188	806	0.04	186	758	0.04

The data on the table 4. clearly depicts that the drip fertigation of 25% enhanced dose of K along with 100% N and P (T_9) recorded significantly higher seed cotton yield for both *winter* and *summer* seasons. (3568 kg ha^{-1} and 3475 kg ha^{-1}) and it was found to be on par with the treatment where 25% enhanced dose of NPK applied through drip fertigation (T_3). The lowest values were recorded for the 100% RDF NPK applied through conventional irrigation practice (2134 kg ha^{-1} and 2045 kg ha^{-1}). Among the NPK nutrients, the requirement of K_2O was 1.09 times higher than N and 2.20 times higher than P_2O_5 to produce one quintal of seed cotton for rainfed transgenic cotton on black calcareous soil. (AICRP report, 2011) [1]. Similar findings of affinity of cotton more towards potassium were reported by Katherine *et al*., (2013) [8], SubbaRao and Rathore (2003) [13] and Jagvir Singh and Blaise (2000) [6].

Conclusion
The results of the experiment revealed that the application of enhanced dose of fertilizers and fertigation scheduling at the peak growth stages in split ratios had a significant influence over the growth, yield and yield attributes of cotton under HDPS during both *winter* and *summer* seasons of 2022-2023.The optimized fertigation scheduling practiced on cotton planted under HDPS system had increase the yield to the tune of 67% and 69% during the *winter* and *summer* seasons of 2022-2023. Based on the research outcome, it is concluded that drip fertigation of 25% enhanced dose of K along with 100% N and P (T_9) is the optimum drip fertigation system for higher cotton yield under HDPS.

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