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Effect of different nutrient sources on physiological parameters of desi cotton (*Gossypium arboreum* L.)

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Abstract
A field investigation on “Nutrient management for organic cotton (*Gossypium arboreum* L.) production” was carried out at All India Coordinated Research Project, Cotton Improvement Project, Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra (India) during *kharif* season of 2017 and 2018. The experiment was carried on the same site and same randomization of treatments during both the years. The result indicated that physiological parameters viz., chlorophyll content (%), photosynthetic rate (µ mol CO_2 m^{-2} s^{-1}), absorbed PAR (µ mol m^{-2} s^{-1}) significantly higher with application of recommended dose of fertilizer through inorganic (80:40:40 N, P and K kg ha^{-1}) to cotton. Whereas, among the organic nutrient sources application of nutrients through FYM based on P equivalent recorded maximum growth and yield attributes followed by seed treatment with *Azotobacter* + PSB + soil application of *Azotobacter* and PSB + foliar application of PPFM (1% Spray) + seed treatment with (*Azotobacter* + PSB) + soil application of *Azotobacter* + PSB) and foliar application of PPFM (1% spray at 45 and 65 DAS) + neemcake 250 kg ha^{-1} + raising of sunnhemp between two rows (1:1) and incorporation in soil at flowering stage during both the years. Significantly lower all the growth parameters were recorded in absolute control during both the years. Similarly the same treatment registered significantly higher plant height, leaf area, dry matter accumulation, number of bolls $plant^{-1}$ and seed cotton yield.

Keywords: Desi cotton, nutrient management, physiological characters

Introduction

Cotton (*Gossypium* spp.) popularly known as “the white gold” is an important commercial fiber crop grown under diverse agro-climatic conditions around the world. It provides fiber, a raw material for textile industry along with cotton seed and plays a vital role in economy of the country. It is one of the most important fibre and cash crop of global importance and being cultivated in tropical and subtropical regions of almost 77 countries of the world. The top five producers are China, India, USA, Pakistan and Uzbekistan. Cotton is said to be king of cash crop because of having vast importance in global economy. It is the basic raw material of the textile industries which are the backbone of industrial economy especially in India.

The indeterminate growth habit of cotton (*Gossypium arboreum* L.) dramatically affects its response to nitrogen fertilizer supply (Reddy *et al*., 1997) [7]. More than any other essential nutrients, the major nutrients nitrogen (N), phosphorous (P) and potassium (K) can increase or decrease yields of cotton. Yield can be drop sharply if apply inadequate nitrogen, phosphorous and potassium whereas apply nitrogen at improper time resulted slow growth of fruit, more attack of insects pests and delay in maturity whereas supply of phosphorous and potassium in maximum square formation and bolls development stages were also important. Insufficient nitrogen, phosphorous and potassium supply often affects the growth of cotton and developmental processes, resulting in a reduced leaf area index (LAI), low leaf chlorophyll concentration, photosynthetic rate, and biomass production (Zhao and Oosterhuis, 2000) [12], as well as reduced lint yield and poor fibre quality (Reddy *et al*., 2004) [8]. Estimation of the total chlorophyll and nitrogen contents is a potentially important aspect for both growers and researchers. Photosynthesis and absorbed photosynthetically active radiation (APAR) is an important chemical reaction in plants, and its measurement plays a critical role in agricultural production and scientific research (Wang *et al*., 2006) [10].

The major nutrients, nitrogen phosphorous and potassium requirements of cotton plants vary depending on the growth rate and growth stage. Cotton leaves contain 60-85% of the total nitrogen before flowering; after flowering, the nitrogen content declines because it is translocated from the leaves to the developing bolls, phosphorous and potassium required in succeeding growth phase of cotton crop. A greater amount of nitrogen is required in the later growth stages when nitrogen supplies typically diminish and there is less root activity (Gerik *et al*., 1998) [2]. The nutrient supplementation period can be increased with application of organic nutrient sources, which provides long time from square formation to boll development. Hence, nutrient requirement during critical stages can be better met with application of different organic nutrient sources. As such present investigation was planned to find out the response of with application of different organic nutrient sources of major nutrients, nitrogen (N), phosphorous (P) and potassium (K) in *desi* cotton.

Materials and Methods

A field investigation on "Nutrient management for organic cotton (*Gossypium arboreum* L.) production" was carried out at All India Coordinated Research Project, Cotton Improvement Project, Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra (India) during *kharif* season of 2017 and 2018. The experiment was in *kharif* season on variety Phule Dhanwantary.

The soil of the experimental field was clayey in texture with low in available nitrogen (180.49 kg ha^{-1}), medium in available phosphorous (20.12 kg ha^{-1}) and high in potassium (348.37 kg ha^{-1}). The soil slightly alkaline in reaction (pH 8.27) with electrical conductivity (0.33 dSm-1) and 0.43 organic carbon content.

The field experiment was laid out in Randomize Block Design and in three replications. The treatment consist of nine treatments for *desi* cotton *viz.*, T_1- Absolute control, T_2- Application of recommended dose of fertilizer through inorganic (80:40:40 NPK kg ha^{-1}), T_3- Application of nutrients through FYM based on P equivalent, T_4- Seed treatment with *Azotobacter* + PSB + soil application of *Azotobacter* and PSB + foliar application of PPFM (1% Spray at 45 and 65 DAS), T_5- Neem cake @250 kg ha^{-1}, T_6- Raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage (45 DAS), T_7- T_4 + neem cake @250 kg ha^{-1}, T_8- T_4 + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage (45 DAS), and T_9- T_4 + neem cake 250 kg ha^{-1} + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage (45 DAS). Observations on physiological parameters of *desi* cotton were recorded periodically for each season to investigate treatment effects during both the years.

Chlorophyll reading was measured with the help of chlorophyll meter SPAD- 502 Plus (Konika Minolta) from fully expanded leaf in between the leaf margin and the mid rib. The average of three SPAD values were taken as SPAD Index as the final value (Tewolde *et al*., 2008 and Hallikeri *et al*., 2011) [9, 4]. The readings were taken at 60, 90 and 120 DAS. The leaf level photosynthesis was measured by using portable photosynthesis system LI-COR 6400 (LICOR, Inc. Lincoln, NE) at 120 DAS. The observations were recorded on the five randomly selected plants (Arriaga *et al*., 2009) [1] from fully expanded leaf in between the leaf margin and the mid rib and then averaged for per plant. The total rainfall received during first and second year was 636.8 mm and 291.6 mm in 31 and 16 rainy days, respectively.

Results and Discussion

Chlorophyll content

The periodical chlorophyll content in cotton as influenced by different treatments are presented in Table 1. The mean chlorophyll content at 30, 60, 90, 120, and 150 days after sowing was 31.18, 35.07, 33.56, 32.23 and 24.55 per cent during first year, whereas it was 31.84, 36.22, 34.00, 39.96 and 25.52 per cent during second year, respectively. The chlorophyll content was increased progressively from 30 to 60 DAS and declines thereafter up to maturity.

Data presented in Table 4.10 revealed that the application of fertilizer through inorganic (80:40:40 N, P and K kg ha^{-1}) recorded significantly highest chlorophyll content than rest of the treatments at all crop growth stages during both the years. Whereas, absolute control (T_1) recorded significantly lowest chlorophyll content at all crop growth stages during both the years. The higher chlorophyll content might be due to more uptake of nitrogen which is a major component of chlorophyll as the nitrogen content increases. Whereas under absolute control lowest uptake of nitrogen resulted in reduction of chlorophyll content.

Among the organic nutrient sources treatment application of FYM based on P equivalent basis recorded higher chlorophyll content than rest of the organic treatments during both the years and it was at par with the treatment T_9-[(T_4- seed treatment with (*Azotobacter* + PSB) + soil application of *Azotobacter* + PSB) and foliar of PPFM (1 % spray at 45 and 65 DAS) + neem cake 250 kg ha^{-1} + raising of sunnhemp between two rows (1:1) and incorporation in soil at flowering stage)] at 90, 120, 150 DAS and harvest during first year and at 60, 90, 120, 150 DAS and at harvest during second year. It was also at par with treatment T_8-(T_4 + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage (45 DAS) at 90 and 120 DAS during first year and at 90 DAS during second year.

Increased chlorophyll content with combined use of organic nutrient sources could be attributed to effective absorption of N, P and K as well as micronutrient throughout the crop growth period favours in increasing the nitrogen uptake due to synergetic effect. Nitrogen being a major component of chlorophyll it directly increases the chlorophyll content. These results are in agreement with Zhao and Oosterhuis (2000) [12], Liu *et al.* (2008) [6] and Giri (2013) [3].

Photosynthetic rate

The periodical photosynthetic rates in cotton as influenced by different treatments are presented in Table 2. The mean photosynthetic rate at 30, 60, 90, 120, and 150 days after sowing was 5.57, 24.50, 21.74, 15.21 and 9.90 µ mol CO_2 m^{-2} s^{-1} during first year, whereas it was 6.32, 25.46, 22.54, 16.24 and 10.52 µ mol CO_2 m^{-2} s^{-1} during second year, respectively. The photosynthetic rate was increased progressively from 30 to 60 DAS and declines thereafter up to maturity.

Perusal of data present in Table 1 revealed that the application of fertilizer through inorganic (80:40:40 N, P and K kg ha^{-1}) recorded significantly higher photosynthetic rate than rest of treatments at all crop growth stages during both the years. However, it was at par with application of FYM based on P equivalent basis at 30 DAS during first year only. Whereas, the treatment of absolute control recorded significantly lowest photosynthetic rate at all stages of observations during both the years. The higher photosynthetic rate under inorganic sources of nutrients might be because of more uptake of nitrogen chlorophyll content and assimilating area resulted in more interception of light for photosynthesis.

Among the organic nutrient sources treatment application of

FYM based on P equivalent basis than the other organic treatments during both the years and it was at par with the treatment T_9-[(**T_4**- seed treatment with (*Azotobacter* + PSB) + soil application of *Azotobacter* + PSB) and foliar application of PPFM (1 % spray at 45 and 65 DAS) + neem cake 250 kg ha^{-1} + raising of sunnhemp between two rows (1:1) and incorporation in soil at flowering stage)] at 150 DAS during first year and 30 DAS during second year.

Among the organic nutrient sources application of nutrients through FYM on the basis of phosphorous equivqlent and combined application of Azotobacter and PSB, neem cake, foliar application of PPFM and incorporation of sunnhemp in soil supplied balanced nutrition throughtuot the crop growth period resulted in increased of number of functional leaves and leaf area $plant^{-1}$ which increase the interception of solar radiation and absorbed photosynthetic active radiation, which ultimately enhance the photosynthetic rate. Absolute control treatment found minimum rate of photosynthesis because of no any additional nutrients were supplied other than soil available nutrients which affect the vegetative growth and chlorophyll content resulted in reduction of interception of light and rate of photosynthesis. These findings are strongly supported by Zhao and Oosterhuis (2000) [12], Liu *et al.* (2008) [6] and Giri (2013) [3].

Absorbed Photosynthetically Active Radiation (APAR)

Absorbed PAR in cotton as influenced periodically by different treatments are presented in Table 3. The mean absorbed PAR at 30, 60, 90, 120, and 150 days after sowing was 210.89, 645.66, 566.25, 476.59 and 425.35 µ mol m^{-2} s^{-1} during first year, whereas it was 280.66, 730.76, 637.86, 534.96 and 533.98 µ mol m^{-2} s^{-1} during second year, respectively.

The absorbed PAR was increased upto 60 days after sowing and then decreased towards 150 days after sowing. The APAR in *desi* cotton was influenced significantly due to different treatments of nutrient sources during both the years. The application of fertilizer through inorganic (80:40:40 N, P and K kg ha^{-1}) recorded significantly highest absorbed PAR than other treatments at all crop growth stages during both the years. Whereas, the treatment of absolute control (T_1) recorded lowest absorbed PAR at all growth stages of during both the years. The higher APAR might because of less transmission and reflectance of photosynthetically active radiation.

Table 1: Periodical chlorophyll content in *desi* cotton as influenced by different treatment

Treatment		Chlorophyll content (%)									
		2017					2018				
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1	Absolute control	22.02	25.21	24.85	22.78	16.00	22.15	25.60	23.64	23.58	15.63
T_2	Application of fertilizer through inorganic (80:40:40 NPK kg ha^{-1})	41.92	45.77	44.38	43.01	32.65	44.26	47.47	45.53	45.35	34.48
T_3	Application of FYM based on P equivalent basis	37.54	41.40	39.71	38.63	29.86	38.21	42.73	40.60	39.30	31.06
T_4	ST with (*Azotobacter* + PSB) + SA of (*Azotobacter* + PSB) and FA of PPFM (1 % Spray at 45 and 65 DAS)	27.18	31.03	29.34	28.27	20.49	27.59	31.94	29.56	28.68	21.97
T_5	Neem cake @250 kg ha^{-1}	28.42	32.28	30.59	29.51	21.73	29.00	33.26	30.96	30.09	22.62
T_6	Raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	23.50	28.36	26.66	24.59	20.31	23.77	29.45	26.82	24.86	21.00
T_7	T_4 + neem cake @250 kg ha^{-1}	31.11	34.97	33.27	32.20	24.42	31.38	35.98	33.68	32.47	25.34
T_8	T_4 + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	33.61	37.47	35.77	34.70	26.92	33.97	38.66	36.24	35.06	27.69
T_9	T_4 + neem cake 250 kg ha^{-1} + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	35.28	39.13	37.44	36.37	28.59	36.20	40.89	38.93	37.29	29.89
S.Em.(±)		1.26	1.05	1.34	1.29	0.70	1.33	1.00	1.16	1.42	0.76
C.D at 5 %		3.76	3.16	4.01	3.86	2.08	3.98	3.00	3.49	4.26	2.29
General mean		31.18	35.07	33.56	32.23	24.55	31.84	36.22	34.00	39.96	25.52

SA - Soil application, ST - Seed treatment, FA - Foliar application, PPFM - Pink pigmented facultative methylotrophs

Table 2: Periodical photosynthetic rate in *desi* cotton as influenced by different treatment

Treatment		Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1})									
		2017					2018				
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1	Absolute control	4.30	18.78	16.07	8.87	6.95	4.53	17.98	16.31	7.86	7.01
T_2	Application of fertilizer through inorganic (80:40:40 NPK kg ha^{-1})	7.49	31.03	27.44	21.79	12.20	9.44	33.35	29.12	23.46	14.80
T_3	Application of FYM based on P equivalent basis	6.89	28.26	25.55	19.02	11.61	8.00	29.88	26.76	20.66	12.63
T_4	ST with (*Azotobacter* + PSB) + SA of (*Azotobacter* + PSB) and FA of PPFM (1 % Spray at 45 and 65 DAS)	4.59	20.52	18.47	11.27	8.97	4.95	20.90	18.20	12.00	9.19
T_5	Neem cake @250 kg ha^{-1}	4.98	22.93	20.21	13.68	9.70	5.66	23.12	20.24	14.91	9.94
T_6	Raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	4.28	23.69	20.97	14.77	7.89	4.65	24.61	21.22	15.73	7.93
T_7	T_4 + neem cake @250 kg ha^{-1}	5.52	24.04	21.17	14.79	10.23	5.56	25.43	22.87	15.88	10.41
T_8	T_4 + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	5.82	24.86	22.14	15.61	10.54	6.73	25.94	23.73	17.06	11.01

T_9	T_4 + neem cake 250 kg ha^{-1} + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	6.27	26.37	23.65	17.12	11.04	7.40	27.98	24.40	18.59	11.75
S.Em.(±)		0.26	0.48	0.58	0.32	0.31	0.38	0.42	0.42	0.19	0.27
C.D at 5 %		0.78	1.44	1.74	0.97	0.94	1.12	1.27	1.25	0.57	0.82
General mean		5.57	24.50	21.74	15.21	9.90	6.32	25.46	22.54	16.24	10.52

SA - Soil application, ST - Seed treatment, FA - Foliar application, PPFM - Pink pigmented facultative methylotrophs

Table 3: Periodical absorbed PAR of *desi* cotton as influenced by different treatment

Treatment		Absorbed PAR (μ mol m^{-2} s^{-1})									
		2017					2018				
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1	Absolute control	126.27	430.21	388.51	335.58	308.32	152.20	472.56	413.10	353.19	335.64
T_2	Application of fertilizer through inorganic (80:40:40 NPK kg ha^{-1})	283.79	756.95	667.24	581.56	502.31	358.73	868.04	766.54	665.84	626.91
T_3	Application of FYM based on P equivalent basis	261.29	711.78	621.11	535.56	479.81	336.23	822.21	720.39	619.84	598.87
T_4	ST with (*Azotobacter* + PSB) + SA of (*Azotobacter* + PSB) and FA of PPFM (1 % Spray at 45 and 65 DAS)	163.35	609.13	529.43	428.74	381.87	239.28	651.97	560.30	444.60	536.98
T_5	Neem cake @250 kg ha^{-1}	204.53	643.64	563.93	463.25	423.05	280.46	718.21	626.53	510.84	499.13
T_6	Raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	145.60	585.76	506.06	405.37	364.12	221.54	635.58	543.90	428.21	481.25
T_7	T_4 + neem cake @250 kg ha^{-1}	223.60	676.00	596.29	495.61	442.12	299.53	787.26	695.59	579.89	562.72
T_8	T_4 + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	236.59	688.52	607.91	515.13	455.11	312.53	800.79	699.29	599.42	575.71
T_9	T_4 + neem cake 250 kg ha^{-1} + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	252.94	708.95	615.81	528.56	471.46	325.45	820.22	715.11	612.85	588.63
S.Em.(±)		4.48	6.52	5.49	5.14	4.42	4.74	5.91	5.62	6.44	4.35
C.D at 5 %		13.42	19.53	16.47	15.40	13.24	14.20	17.73	16.85	19.30	13.06
General mean		210.89	645.66	566.25	476.59	425.35	280.66	730.76	637.86	534.96	533.98

SA - Soil application, ST - Seed treatment, FA - Foliar application, PPFM - Pink pigmented facultative methylotrophs

Table 4: Growth traits of *desi* cotton as influenced by different nutrient management

Treatments	Plant height (cm)		Leaf area (dm^2)		Dry matter accumulation plant^{-1} (g)		Number of bolls plant^{-1}		Seed cotton yield (kg ha^{-1})	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
T_1- Absolute control	66.81	67.50	281.71	267.59	37.98	36.99	12.44	12.13	694.08	715.85
T_2- Application of through inorganic (80:40:40 NPK kg ha^{-1})	102.78	104.34	509.36	540.70	78.00	80.21	24.60	27.46	1779.34	1924.58
T_3- Application of FYM based on P equivalent	92.32	94.00	489.77	505.93	72.17	73.88	22.29	24.33	1558.08	1664.82
T_4- ST with (*Azotobacter* + PSB) + SA of (*Azotobacter* + PSB) and FA of PPFM (1% Spray at 45 and 65 DAS)	75.84	77.43	382.23	385.24	55.44	56.53	17.88	18.63	908.24	988.74
T_5- Neem cake @250 kg ha^{-1}	80.10	81.24	414.87	421.40	61.45	62.35	18.61	20.66	1015.38	1102.31
T_6- Raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	71.42	72.46	360.15	362.94	49.80	50.93	15.47	16.93	868.03	938.20
T_7- T_4 + neem cake @250 kg ha^{-1}	85.23	86.42	433.97	439.18	65.37	66.69	19.87	21.08	1171.89	1260.48
T_8- T_4 + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	87.14	88.17	461.97	469.66	68.97	69.54	20.00	21.35	1287.58	1380.75
T_9- T_4 + neem cake 250 kg ha^{-1} + raising of sunnhemp between rows (1:1) incorporation in soil at flowering stage	89.74	91.07	475.91	485.80	70.28	71.94	21.18	24.23	1403.51	1525.77
SE (m)	1.36	1.79	6.47	8.79	1.35	1.22	0.61	0.55	54.45	65.19
CD at 5%	4.09	5.38	19.41	26.36	4.05	3.65	1.81	1.65	163.26	195.44
G.M.	83.49	84.74	423.33	430.94	62.16	63.23	19.15	20.76	1187.35	1279.06

SA - Soil application, ST - Seed treatment, FA - Foliar application, PPFM - Pink pigmented facultative methylotrophs

Among the organic nutrient sources, treatment application of FYM based on P equivalent basis recorded significantly maximum absorbed PAR at all the stages of the crop growth followed by treatment T_9-[(T_4- seed treatment with (*Azotobacter* + PSB) + soil application of *Azotobacter* + PSB) and foliar application of PPFM (1 % spray at 45 and 65 DAS) + neem cake 250 kg ha^{-1} + raising of sunnhemp between two rows (1:1) incorporation in soil at flowering stage)] during both the years.

Application of FYM based on P equivalent basis followed by treatment seed treatment with (*Azotobacter* + PSB) + soil application of *Azotobacter* + PSB) and foliar application of PPFM (1 % spray at 45 and 65 DAS) + neem cake 250 kg ha^{-1} + raising of sunnhemp between two rows (1:1) incorporation in soil at flowering stage registered significantly maximum absorbed photosynthetically active radiation (APAR) might be due to pronounced vegetative growth of crop in term of number of leaves plant^{-1}, leaf area palnt^{-1}, number of monopodial and sympodial branches plant^{-1} as well as increase the chlorophyll content resulted in increase absorbed photosynthetically active radiation at all the stages of observations during both the years. Absolute control registered minimum absorbed photosynthetically active radiation when compared with the mean absorbed photosynthetically active radiation obtained under different organic nutrient sources treatments. The similar findings are given by Li Song *et al.* (2005) [5], Zhang *et al.* (2008) [11] and Giri (2013) [3].

Conclusion

The physiological studies indicated that chlorophyll content, photosynthetic rate, absorbed photosynthetic active radiation (APAR), higher plant height, leaf area, dry matter accumulation, number of bolls plant^{-1} and seed cotton yield were found at maximum with application of fertilizer through inorganic sources (80:40:40 N, P and K kg ha^{-1}) in cotton. While among organic nutrient sources treatment application of FYM based on P equivalent basis recorded maximum values of all physiological parameters followed by seed treatment with (*Azotobacter* + PSB) + soil application of *Azotobacter* + PSB) and foliar application of PPFM (1 % spray at 45 and 65 DAS) + neem cake 250 kg ha^{-1} + raising of sunnhemp between two rows (1:1) and incorporation in soil at flowering stage during both the years.

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