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Effect of different organic sources and PGR on growth and chlorophyll content in organic cotton under *rainfed* condition

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Abstract
Field experiment was carried out during 2016 and 2017 to study the effect of organic sources on growth parameter of organic cotton under *rainfed* condition at Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* season. The treatments consist of Absolute control (no organic/ Inorganics), recommended dose of nutrient through organics on P equivalent basis (FYM @12.5t ha^{-1}), seed treatment (ST) of biofertilizer + foliar application of pink pigmented facultative metylobacterium (PPFM) @1 % at flowering (FL) & boll development (BD), Neem cake (NC) @ 250 kgha^{-1}, green manuring of sunhemp (GMS) in between cotton rows (1:1), intercrop with blackgram (1:1), ST + PPFM @1 % at FL & BD+ NC, ST + PPFM @1 % at FL & BD + cotton+ sunhemp (GMS) (1:1), ST+ PPFM @1 % at FL & BD+ NC + cotton+ sunhemp (GMS) (1:1) and ST + PPFM @1 % at FL & BD+ NC + Intercrop with blackgram (1:1). The experimental soil was vertisol with clay loam in texture, low in available nitrogen (175.6 kg ha^{-1}), medium in available phosphorus (15.10 kg ha^{-1}) and very high in potassium content (375.4 kg ha^{-1}). The soil pH, EC and organic carbon were 8.08, 0.34 dSm^{-1} and 3.80 g kg^{-1}, respectively.
The results revealed that among the different nutrient management through organic sources, the growth attributing characters *viz.* plant height, number of functional leaves and drymatter accumulation plant^{-1} at different growth stages were observed significantly highest with application of recommended dose of nutrient through organics on P equivalent basis (FYM @ 12.5 t ha^{-1}). However, the chlorophyll content was more in ST+ PPFM @1 % at FL & BD+ NC + cotton + sunhemp (GMS) being statistically at par with application of RD of nutrient through organics on P equivalent basis (FYM @ 12.5 t ha^{-1}).

Keywords: Biofertilizers, Pink Pigmented Facultative Methylobacterium, Chlorophyll, Organic cotton

Introduction
Cotton (*Gossypium hirsutum* L.) has a pride of place among the cultivated plants that satisfy the material need of man because next to food, clothing is the prime need of life. It is important for the local textile industry in the manufacture of garments and fabrics. Inorganic fertilizers are costly and cause environmental problems. The increased use of pesticides also resulted in buildup of pesticide resistance in insects, toxicity of pesticides to natural predator and parasites of pests affecting the natural balance (Singh *et al.*, 2013) [14]. Organic agriculture is believed to be the sustainable remedy in reversing the negative trends into a more sustainable system.
About 97 % *Bt* cotton cultivated nationally and globally only 3 % area under non *Bt* cotton. Desi cotton varieties are likely to open up a huge export market of surgical cotton, giving a remunerative alternative to cotton farmers from *rain-fed* areas like Vidarbha. There is demand of surgical cotton having medium staple length hence it is need to grow organic cotton and having less traces it also fetches more price than conventional cotton. Non *Bt* cotton having potential to grow organically. The demand for absorbent cotton in India is estimated to be about 2 million bales (of 170 kg each) per year (Organic cotton Market Report, 2018) [15]. Besides this, Indian market, there is enormous export potential for surgical cotton in countries such as the US, EU and Japan. India is the only country that grows desi cotton varieties which are highly suitable for surgical cotton. China, India, Pakistan, and Bangladesh are the largest cotton consumers in the world, accounting for more than 65% of global consumption

(Organic cotton Market Report, 2018) [15]. for many years, China and India have been the major markets for cotton consumption.

Organic cotton production is not related to farming by merely replacing synthetic fertilizer and pesticide with organic ones. Organic cotton by definition refers to any cotton that is cultivated and certified according to the organic agriculture standards. It includes cotton that is grown, harvested and processed without the use of chemical fertilizer, pesticide or herbicide, growth regulator or defoliant. Organic agriculture is developing rapidly and is practiced in 178 countries across the globe with 57.8 million hectares including conversion areas accounting for 1.2% of the world's agricultural lands. In 2016, India ranked 9th in area with 1.49 million hectares under organic cultivation (Anonymous, 2018) [1]. Organic cotton is already successfully being in 18 countries around world. However, the vast majority (84%) takes place in just in four countries, India (51%), China (19.0%), Turkey (7.0%) and Kyrgyzstan (7.0%). The total land area of all organic cotton growing internal Control system (ICS) was 359 ha of which it is estimated that 43-45 % (168,654ha) was actually planted with organic cotton. Organic cotton production is estimated at 60,000 MT, sharing 51% of global organic production which is the highest in the world. Based on current projections, it is estimated that organic cotton production will grow 35-40% by 2020. (Organic Cotton Market Report, 2018) [15].

Organic cotton is the production system, which can bring back the cotton cultivation on sustainable basis without affecting environment. Maintain ecological balance through adoption of organic inputs. Farmyard manure provides essential plant nutrients including micronutrients and it also improves soil physical, chemical and biological environment of soil for favourable crop growth and yield. The exact cultivation practices vary across region or even from farmer to farmer but the use of genetically modified seed, toxic and persistent agrochemical synthetic pesticide, fertilizers and growth regulator is non-negotiable. (FiBL-2018) [2].

Pink Pigmented Facultative Methylotrophs (PPFMs) are ubiquitous in nature found in variety of habitats including soil, dust, fresh water lake sediments, leaf surface and nodules. These organisms are capable of growing on compounds containing one carbon. Pink-pigmented facultative methylotrophs (PPFMs) are Gram-negative bacteria with the ability to use C-1 compounds such as formate, formaldehyde and methanol as sole source of carbon and energy (Green and Bousifield 1982**).** Applications of methanol or PPFMs increased the total cytokinins in cotton. The main role of PPFM cytokinin production in plants, and might play a role in plant growth promotion result increasing in yield of cotton. The PPFMs offer the associative symbiotic life with crop plants by utilizing the methanol emitted through the leaves and in turn provide cytokinins to the plants. They are able to produce plant growth regulators such as cytokinins and auxins which affect plant growth and different physiological processes.

Organic sources of manures *viz.*, FYM, neem cakes are readily available with many farmers and intercropping of *in-situ* green manuring crop like sunhemp can easily possible. Methods of their preparation and application are very easy, if hypothesis is proved then this technique can be profitably used by farmers for optimization of crop yield and maintaining soil health without harmful to environment Therefore, present investigation was undertaken to study the effect of organic sources of manures and PGR (PPFM) spray on soil health in organic cotton under *rainfed* condition .

Material and Methods

A field experiment on "effect of organic sources of manures and PGR on growth parameters and chlorophyll content in organic cotton under *rainfed* condition" was conducted at Cotton Research Unit which was located at Central Research Station of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola in Vidatbha region of Maharashtra during the growing seasons 2016 and 2017. Akola is situated in the subtropical region at 22^0 42' North latitude and 77^0 02' East longitudes and at an altitude of 307.42 m (Agromet observatory) above mean sea level.

The soil is very deep and fairly moisture retentive and loamy. The soil of experimental site had low organic carbon (3.80g kg^{-1}) low available N (175.6 $kgha^{-1}$), medium available P_2O_5 (15.10 $kgha^{-1}$) and high available K_2O (375.4 $kgha^{-1}$). The experiment was laid out in randomized block design with three replication and ten treatments. The treatments consist of T_1: Absolute control (no organic/ Inorganics), T_2: Recommended dose of nutrient through organics on P equivalent basis (FYM @12.5t ha^{-1}), T_3: Seed treatment (ST) of biofertilizer + foliar application of pink pigmented facultative metylobacterium (PPFM) @1 % at flowering (FL) & boll development (BD), T_4: Neem cake (NC) @ 250 $kgha^{-1}$, T_5: green manuring of sunhemp (GMS) in between cotton rows (1:1), T_6: Intercrop with blackgram (1:1), T_7: ST + PPFM @1 % at FL & BD+ NC, T_8: ST + PPFM @1 % at FL & BD + cotton+ sunhemp (GMS) (1:1), T_9: ST+ PPFM @1 % at FL & BD+ NC + cotton + sunhemp (GMS) (1:1) and T_{10}: ST + PPFM @1 % at FL & BD+ NC + intercrop with blackgram (1:1).

The PPFM is developed at NAU, Coimbatore and biofertilizer from Plant pathology Department, Dr. PDKV, Akola. All agronomical practices, *in-situ* green manuring of sunhemp, blackgram stalk incorporation after harvest of blackgram was done. The appropriate biopesticides were used for plant protection measures were adopted to grow a good crop of cotton. The biometric observation and growth parameters of cotton were recorded and chlorophyll content index reading was recorded by SPAD meter. The data of growth parameters were statistically analyzed using analysis of variance (ANOVA) technique and the treatments were compared at 5% levels of significance by Panse and Sukatme (1967) [12].

Results and Discussion

Plant growth parameters: Growth attributing parameters of cotton as influenced by different treatments of organic sources of manures and PGR (PPFM) was recorded at 60, 90 and 120 DAS for plant height, number of functional leaves and Chlrophyll content are given in Table no.1 and 2.

1. Plant height (cm)

Data given in Table no. 1 revealed that during the first year study showed significant results in plant height at different growth stages of cotton. The maximum plant heights was recorded with application RD of nutrient through organics on P equivalent basis (FYM @12.5 t ha^{-1}) which was statistically at par with combined application of different organic sources .i.e. ST+ PPFM @1 % at FL & BD+ NC + cotton+ sunhemp (GMS) (1:1) + neem cake @ 250kg ha^{-1} with their respective values of 48.2 , 47.9 cm and 92.0, 88.1 cm and 52.1, 46.9 and 97.1 cm at 60 and 90 DAS however, at 120DAS plant height was attained more in combined application of different organic sources .i.e. ST+ PPFM @1 % at FL & BD+ NC + cotton+ sunhemp (GMS) (1:1) 129.5 and 128.7 cm.

However, second year study the, statistically highest plant height was observed with application of RD of nutrient through (FYM @12.5 t ha^{-1}) followed by ST+ PPFM @1 % at FL & BD+ cotton + sunhemp (GMS) both the treatment was at par with each other. However, both the years of study, statistically lowest plant height was observed in control (no manure or no inorganic). This increase in plant height might be due to increased availability of major as well as micro elements and increased in nodulation bacteria in first year of study. Foliar application of PPFMs increased plant height because exogenous methanol of plant stimulated the growth of *methylobacterium* spp. which provided plants with cytokinins and auxin which in turn enhanced plant development. Neem cake plays an important role to reduce pest infestations. Similar findings were also reported by Ramprakash and Mangal Prasad, (2000) [13], Khawale *et al.* (2001) [8], Wankhade (2001) [16], Madhaiyan, *et al*. (2006) [9, 10], Navalkahe *et al.* (2009) [11] Dhale *et al*. (2010) [4] and H.G. Abd El-Gawad, *et al*. (2015) [5].

Table 1: Growth attributing parameters as influenced by different organic sources of manures and PGR (PPFM)

Treatments	Plant height (cm)						Number of functional leaves						Dry matteraccumulation plant $^{-1}$ (g)					
	2016			2017			2016			2017			2016			2017		
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
T_1	29.7	54.6	79.7	34.2	67.6	96.4	19.4	30.7	77.6	18.2	29	69.3	5.8	20.4	60.6	7.5	19.1	56.8
T_2	48.2	92.0	128.7	52.1	97.1	120.7	38.5	66.7	125.1	27.4	56.3	100.7	13.3	83.8	141.9	18.0	82.2	98.5
T_3	36.2	67.5	98.0	44.0	87.1	104.1	27.8	55.7	98.9	21.4	50..0	90.0	7.8	35.8	79.3	11.7	41.8	71.7
T_4	38.3	84.3	121.4	41.9	86.4	115.0	25.9	55.7	98.3	23.7	42.0	87.0	9.0	60.3	104.1	15.1	58.6	89.2
T_5	34.9	68.2	104.3	40.5	85.5	110.7	25.8	40.3	98.1	21.1	32.0	65.0	8.5	37.5	96.4	8.8	38.5	83.6
T_6	47.1	87.5	102.9	41.7	86.8	106.9	29.9	60.0	109.7	25.7	52.2	85.7	7.8	25.2	96.5	10.4	41.4	78.0
T_7	32.5	77.4	104.6	44.5	88.8	99.5	30.2	52.0	89.3	24.2	44.7	58.0	9.9	64.5	122.3	15.6	61.1	95.5
T_8	38.2	84.4	117.3	38.9	89.2	118.2	24.8	62.0	122.3	21.1	64.0	94.0	8.3	42.5	132.4	12.2	52.6	83.3
T_9	47.9	88.1	129.5	46.9	91.7	118.3	46.4	71.7	128.5	34.2	55.3	92.0	10.9	76.3	137.1	16.1	76.0	95.0
T_{10}	34.1	69.8	105.3	33.1	76.9	112.7	25.3	36.3	79.8	19.4	41.5	69.7	7.4	32.0	104.1	9.2	33.3	83.2
SE (m) ±	1.40	2.10	2.99	1.80	1.90	2.17	1.90	1.76	2.91	1.25	2.38	2.28	0.74	1.08	2.61	0.80	2.52	2.20
CD P= 0.05	4.20	6.20	8.90	5.30	5.50	6.44	5.62	5.24	8.66	3.71	7.08	6.78	2.21	3.00	7.62	2.26	7.50	6.70
GM	38.7	77.4	109.2	41.8	85.7	110.3	29.4	53.1	102.8	23.6	46.7	81.1	8.83	47.8	107.5	12.5	50.5	83.5

2. Number of Functional leaves plant^{-1}

Data from the Table no.1 indicated that, during both the years of experimentation, the application RD of Nutrient through organics on P equivalent basis (FYM @ 12.5 t ha^{-1}) was recorded the maximum number of functional leaves at different growth stages and remained statistically at par with the treatment of ST+ PPFM @1 % at FL & BD+ NC + cotton + sunhemp (GMS) (1:1).

This increased in number of leaves due to application of different organic sources of manures, green manuring and intercropping, might be due to increase in availability of major as well as micro elements, improved microbial population, suppressed the weeds through smothering effects and conserve soil moisture by reducing evaporation from the soil. Supply of cytokinin by PPFMs helped in promotion of cell division, delaying of senescence, counteracting apical bud dominance, translocation of assimilates, which is ultimately increases number of functional leaves. Similar findings were also reported by H.G. Abd El-Gawad, *et al*. (2015) [5].

3. Dry matter accumulation plant^{-1}

The total dry matter accumulation per plant estimation regarding leaves, stem and fruiting bodies was done at 60, 90 and 120 DAS and the data was presented in Table no.1 and it was plant was found to be significant due to various organic sources of manures and PGR (PPFM) during the years 2016 and 2017 except at 60 DAS in 2016.

During both the years, the application of recommended dose of nutrient through organics on P equivalent basis of (FYM @12.5 t ha^{-1}) was recorded significantly highest total dry matter statistically being at par with the treatment of ST+ PPFM @1 % at FL & BD + NC + cotton+ sunhemp (GMS) (1:1). However, the next best treatment was ST+ PPFM @ 1% at FL & BD + NC. The significantly lowest dry matter was recorded in without organic/ no organic. similar trend was noticed in total dry matter accumulation. While lowest total dry matter was attained in control.

Significantly higher accumulation of carbohydrates in fruiting bodies with recommended dose of (FYM @12.5tha^{-1}) might have resulted greater production of photosynthesis, wherein fruiting bodies was the major sink for the total accumulated photosynthate due to adequate supply of plant nutrients through metabolic system induced rate of mobility towards fruiting and stem. FYM are considered to be good source of all plant nutrients and also the mineralization of organic nitrogen in FYM, which is a slow process, might have provided nitrogen during the crop requirement.

The distribution of dry matter in different plant parts indicated that increase in dry matter accumulation with higher nitrogen availability and physical soil parameters with various organic sources of manures which are helpful to providing macro and micro nutrients and protect crop from pest and disease with sustainable manner. The significant improvement in leaf area, number of monopodial and sympodial branches and fruiting bodies may be related to the gain in dry matter of leaf, stem and fruiting bodies with application organic sources. Similar results were reported by Ramprakash and Mangal Prasad, (2000) [13], Khawale *et al.* (2001) [8] and Basavannappa and Biradar (2002) [3].

4. Chlorophyll content

Data from table no. 2, during the years 2016 and 2017, the application of treatment of ST+PPFM @ 1% at FL & BD + sunhemp (1:1) GMS + NC was found most effective in increasing the chlorophyll content at 60, 90 and 120DAS. The ST + PPFM @ 1% at FL & BD +cotton + sunhemp GMS+NC was found significantly superior over FYM @ 12.5 t ha^{-1} but was found statistically at par with ST+PPFM @ 1% at FL & BD + sunhemp (1:1) GMS during first year of study. But in second year of study, the treatment ST+PPFM @ 1% at FL & BD + sunhemp GMS was recorded highest chlorophyll content and it was statistically being at par with the treatment

ST+PPFM @ 1% at FL & BD +cotton + sunhemp GMS+ NC. Significantly lowest chlorophyll content index was noticed in no manure or inorganic plot during both the years.

During both the years, chlorophyll content was highest at 90 DAS and then it declined towards maturity in both the years that may be due to decrease in photosynthetic activity with the advancement in crop age.

Table 2: Chlorophyll content as influenced by different organic sources of Manures and PGR (PPFM)

Treatments		Chlorophyll content					
		2016			2017		
		60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
T_1	Absolute control (no organic/ Inorganics)	28.8	31.7	34.1	26.5	33.7	32.3
T_2	RD of Nutrient through organics on P equivalent basis (FYM @12.5t ha^{-1})	36.1	44.0	37.1	32.6	45.0	36.1
T_3	Seed treatment of bio- fertilizer + foliar application of PPFM @1 % at FL & BD	33.2	32.6	36.9	34.3	40.9	33.2
T_4	Neem cake (NC) @ 250 $kgha^{-1}$	33.1	37.3	34.2	34.2	39.0	33.1
T_5	GM of sunhemp (GMS) in between cotton rows (1:1)	33.6	37.5	36.1	31.8	39.7	35.0
T_6	Intercrop with blackgram BGS (1:1)	30.3	33.5	36.3	34.3	39.1	35.9
T_7	ST + PPFM @1 % at FL & BD+ NC	32.2	37.8	35.9	34.3	41.1	35.0
T_8	ST + PPFM @1 % at FL & BD + cotton+ sunhemp (GMS) (1:1)	34.8	45.6	37.2	35.3	43.0	35.2
T_9	ST+ PPFM @1 % at FL & BD+ NC + cotton+ sunhemp (GMS) (1:1)	36.8	47.4	39.0	34.7	47.8	37.7
T_{10}	ST + PPFM @1 % at FL & BD+ NC + Intercrop with blackgram BGS (1:1)	33.9	40.9	40.3	37.1	46.7	36.6
SE (m) ±		1.22	4.00	1.20	0.60	1.58	0.53
CD P= 0.05		3.60	11.8	3.50	1.78	4.70	1.57
GM		33.3	38.8	36.7	33.5	41.5	34.9

The significant improvement was resulted in chlorophyll content with the increased in combined application of seed treatment of biofertilizer + PPFM PGR spray @1% at FL &BD + NC @ 250 kg ha^{-1} is the indicative of the fact that nutrients play a vital role and exogenous methanol of plant stimulated the growth of *methylobacterium* spp. in the chlorophyll formation and consequently the photosynthesis of plants. These results imply that the foliar spray of PPFM at flowering and boll development stage which to retain the greenness of leaves through increasing the chlorophyll content of leaves. They are able to produce plant growth regulators such as cytokinins and auxins which affect plant growth and different physiological processes. The induction of methylotrophic community on leaf surfaces was observed methanol application which stimulated the production of plant growth substances such as cytokinin and auxins it additionally enhanced leaf chlorophyll (Ivanova *et al*, 2001) [7].

Conclusion

It is concluded that, the growth parameters and chlorophyll content of organic cotton was improved by combined application of organic manures, biofertilizer and plant growth regulator (PPFM) under *rainfed* condition

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