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Impact of integrated nutrient management and organic on yield and economics of Bt cotton under cotton based intercropping systems in rainfed Vertisol

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Abstract
Collective use of organic and inorganic sources is being considered the best way for increasing its accessibility to the cotton plants. The synergetic influence of organic with inorganic fertilizers improved the water holding capacity of soil, cation exchange capacity, soil aeration, phosphorus use efficiency (PUE) of applied fertilizer, soil nutrients availability, seed germination and plant growth rate which ultimately boosted up the final yield and net return. The present investigation was conducted at Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, during year 2017-18 and 2018-19. The experiment was laid out in split plot design with three replications. The main plot treatments comprised of nutrient management *viz*., INM (75% RDF + compensation through NPS compost) and Organic (100% NPK dose through NPS compost). Sub plot treatments consisted of cotton based intercropping systems *viz*., Cotton + dhaincha (1:1), Cotton + sunhemp (1:1), Cotton + greengram (1:1), Cotton + blackgram (1:1) and Sole cotton. Maximum cotton equivalent yield (1585 kg ha^{-1}) was obtained in cotton + greengram intercropping system, followed by cotton+ blackgram intercropping system (1531 kg ha^{-1}).
The experimental result showed that the significantly higher seed cotton yield and highest net return were recorded under treatment with application of 75% recommended dose of fertilizers with substitution of 25% dose through enriched compost (NPS). The 100% recommended dose of fertilizers through enriched NPS compost also showed improvement in cotton yield. However, maximum cotton equivalent yield was obtained in cotton + greengram intercropping system, followed by cotton+ blackgram intercropping system.
Thus the results revealed that, the chemical fertilizers of cotton can be reduced by 25% when compensated with enriched compost.

Keywords: INM, organic, intercropping, nitrophosposulpho compost (NPS), CEY and economics

Introduction
There is a huge gap between potential and the actual productivity of cotton. The high cost of fertilizers and unbalance crop production need for substituting part of the inorganic fertilizers by locally available low cost organic sources like Nitrophosposulpho (NPS) compost, green manuring and intercropping in an integrated manner for sustainable production and to maintain soil health. Organic sources and intercropping of leguminous crops adds plant nutrients to the soil during organic matter decomposition which act on the insoluble nutrients reserve in the soil and make them available biologically as it provides food for the beneficial soil microorganisms. Integrated nutrient management involving conjunctive use of organic, inorganic and crop residues may improve the soil productivity (Patra *et al*. 2000; Kumar *et al*. 2001) [20, 13] and system productivity become sustainable.
In India cotton is grown on 122.38 lakh ha with production of 361 lakh bales and productivity 501 kg ha^{-1}. In Maharashtra, cotton is grown on 41.19 lakh ha with production 81 lakh bales and productivity 334 kg lint ha^{-1} (Anonymous, 2018) [1]. In Vidarbha region, area under cultivation of cotton is 16.18 lakh ha with production of about 30.50 lakh bales and 320 kg lint ha^{-1}. *In-situ* incorporation of crop residues is one of the options to incorporate residues into fields to improve soil organic matter levels and return to the soils with the nutrients contained in straw. Long term incorporation of crop residues increase the availability of macro and micro nutrients and also build up the level of soil organic matter. Intercropping, which breaks down the monoculture structure, can provide pest control benefits, weed control advantages, reduced wind erosion and improved water infiltration (Turkhede *et al*., 2017) [28].

Nitrogen fixation by legumes helps to reduce the use of nitrogen fertilizers for next crop (Ladha *et al*. 2004) [14].
Vertisols, especially in a rainfed semi-arid tropical environment, encounter many problems on account of soil properties and consequently result in poor crop yields. Some reports revealed that the quality and productivity of black soils can be improved by adopting suitable practices such as inclusion of legumes or green mauring crops as intercrops with cotton and other main crops. Use of organic manures, plays a key role in sustaining soil fertility and crop productivity, these sources are often cheaper and more efficient than inorganic compounds.
The hypothesis of this study is use of integrated nutrient management and organics with cotton based intercropping systems would lead to higher cotton productivity and savings in fertilizer may lead to reduction in production cost.

Materials and Methods

It was two years study being conducted on the same site with same randomization. Field experiment was carried out during year 2017-18 and 2018-19 at Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra). The topography of the field was fairly uniform and leveled. The soil of the experimental area was Vertisol (black and clayey in texture) belonging to fine, smectitic, hyperthermic, Typic Haplusterts and slightly alkaline in reaction (pH 7.76), medium calcareous and moderate in soil organic carbon (4.96 g kg^{-1}). Soil fertility status indicated low in available nitrogen (195.17 kg ha^{-1}), medium in available phosphorous (12.90 kg ha^{-1}), high in available potassium (368.42 kg ha^{-1}) and deficient in available sulphur (8.27 mg kg^{-1}).
The experiment comprised of two main plots i.e. INM (75% RDF + Compensation through NPS compost) and Organic (100% NPK dose through NPS compost) and five subplot treatments with cotton based intercropping systems *viz*. T1: Control (Sole cotton), T2: Cotton + dhaincha (1:1), T3: Cotton + sunhump (1:1),T4: Cotton + greengram (1:1) and T5: Cotton + blackgram (1:1) which were executed in split plot design with three replications. Sowing of intercrops *viz*. dhaincha, sunhemp, green gram and black gram were done in between two rows of cotton crops. *In situ* incorporation of dhaincha and sunhemp was done forty days after sowing and covered it with the soil. The incorporation of greengram and blackgram residues was done after pod picking. The weight of biomass of intercrops on green basis and oven dry basis were recorded. The cotton variety Ajit-199 BG-II was sown with 120 x 30 cm spacing. Recommended dose of fertilizers in INM plots were 90 kg N ha^{-1}, 45 kg ha^{-1} P_2O_5 and 45 kg ha^{-1} K_2O applied from Urea, SSP and MOP. For organic plots RDF was compensated through Nitrophosposulpho compost which was applied before sowing of crops on the basis of actual NPK content present in compost and incorporated well in the soil.
The treatment wise initial surface soil samples (0-20 cm) before sowing from experimental site and after harvest of crop was collected. The air dried samples were carefully and gently ground with the wooden pestle to break soil lumps (clods) and passed through different sieves for analysis of soil parameters with standard analytical methods.

Results and Discussion

Seed cotton yield

The results (Table 1) revealed that the seed cotton yield was significantly influenced by both the treatments. Significantly highest seed cotton yield 991 kg ha^{-1} and 1310 kg ha^{-1} recorded with INM (75% RDF + compensation through NPS compost) during first and second year respectively. In Organic (100% NPK dose through NPS compost) seed cotton yield recorded were 856 kg ha^{-1} and 1202 kg ha^{-1} during both year respectively.
In pooled results of two years, highest seed cotton yield 1151 kg ha^{-1} was recorded in INM as compared with organic 1029 kg ha^{-1}. Application of INM i.e. 75% RDF + compensation through NPS compost registered maximum seed cotton yield may be due to the fact that NPS conjunction with mineral fertilizer not only provide additional nutrients other than N,P, K & S but also improved physical properties of soil. The results are in close agreement with the findings reported by Jayakumar *et al.* (2007) [10] and Venkataswarlu *et al*. (2007) [29]. Marimuthu *et al.* (2014) [17] observed that crop productivity sustained with integrated plant nutrient management practices.
Improvement in yield due to combined application of inorganic fertilizer and organic manure might be attributed to control release of nutrient in the soil through mineralization of organic manure which might have facilitated better crop growth.

Table 1: Seed cotton and stalk yield of cotton as influenced by different treatments

Tr. N	Treatments	Seed cotton (kg ha^{-1})			Stalk yield (kg ha^{-1})		
		2017	2018	Pooled	2017	2018	Pooled
A.	**Main Plot (Nutrient Management)**						
M1	INM (75% RDF + compensation through NPS compost)	991	1310	1151	2046	2763	2405
M2	Organic (100% NPK dose through NPS compost)	856	1202	1029	1678	2544	2111
	SE (m)±	42.60	34.58	38.48	109.36	70.63	90.35
	CD at 5%	128.18	104.36	116.27	329.64	212.87	271.24
B.	**Sub plot (Cotton based intercropping systems)**						
S1	Control (Sole cotton)	1049	1177	1113	2166	2538	2352
S2	Cotton + Dhaincha (1:1)	952	1349	1150	1971	2886	2428
S3	Cotton + Sunhemp (1:1)	930	1293	1111	1847	2674	2260
S4	Cotton + Greengram (1:1)	875	1238	1057	1752	2610	2181
S5	Cotton + Blackgram (1:1)	811	1222	1017	1574	2558	2066
	SE (m)±	33.69	23.77	21.05	88.59	78.30	58.37
	CD at 5%	101	71.26	63.10	265.56	234.70	174.97
	Interaction (M x S)	--	--	--	--	--	--

In respect of cotton based intercropping systems, results on seed cotton yield (Table 1) indicates that sole cotton cropping produced the maximum seed cotton yield (1049 kg ha^{-1}) as compared to other cropping in first year followed by cotton +

dhaincha (1:1) intercropping system (952 kg ha^{-1}) which was on par with each other during first year, which was followed by cotton + sunhump (1:1) (930 kg ha^{-1}). Among the grain legume intercropping, the higher seed cotton yield was noted under cotton + greengram (1:1) (875 kg ha^{-1}) followed by cotton + blackgram (1:1) (811 kg ha^{-1}) during first year. It may be due to the fact that the enhanced growth without intercrop competition resulted in better development of yield attributes such as number of bolls per plant and boll weight ultimately leading to increased seed-cotton yield.

In second year of experimentation, addition of easily mineralizable nutrients through intercropping and residual effect of first year the maximum seed cotton yield (1349 kg ha^{-1}) recorded with cotton + dhaincha (1:1) intercropping system which was found at par with cotton + sunhump (1:1) intercropping system (1293 kg ha^{-1}). In respect of grain legume, cotton + greengram (1:1) intercropping system recorded maximum yield as compared with cotton + blackgram (1:1) intercropping system i.e. 1238 kg ha^{-1} and 1222 kg ha^{-1} respectively.

Close scrutiny of the pooled data pertaining to seed cotton yield revealed that the maximum yield was recorded with cotton + dhaincha (1:1) intercropping system (1150 kg ha^{-1}) which was found at par with sole cotton (1113 kg ha^{-1}) and cotton + sunhump (1:1) intercropping system (1111 kg ha^{-1}). All other intercropping systems also added improvement in seed cotton yield. The lower yield of cotton in all the treatments during first year may be due to the overall lower rainfall, prolonged dry spells and pink bollworm infestation on cotton as compared to the second year of experimentation. Addition of organic matter and crop residue affects crop growth and yield, either directly by supplying nutrients or indirectly by modifying soil physical properties that may improve the root environment and stimulate plant growth (Hati *et al.*, 2007) [9].

Stalk yield of cotton

The stalk yield of cotton during first and second year showed considerable increase due to integrated nutrient management (75% RDF + compensation through NPS compost) and organic (100% NPK dose through NPS compost) (Table 1). Under crop residue and nutrient management, significantly highest stalk yield of cotton 2046 kg ha^{-1} and 2763 kg ha^{-1} was recorded in INM and 1678 kg ha^{-1} and 2544 kg ha^{-1} in organic in both the years respectively. In pooled results more stalk yield recorded with INM (2405 kg ha^{-1}) followed by organic (2111 kg ha^{-1}). It might be due to better nutrition of crop plants influenced NPS compost application which might have increased the photosynthesis rate. The highest stalk yield recorded in INM was attributed to the synergistic interaction primarily effect between compost and inorganic fertilizers. NPS compost might have acted as a source of additional nutrients and moisture retention. It may infer that increase in stalk yield of cotton may be due to more availability and efficient use of nutrients. The results are in accordance with the findings of Rajarajan *et al.* (2005) [21] and Rao *et al.* (2017) [23].

The data in respect of stalk yield of cotton (Table 1) as influenced by different intercropping systems was found significant. However, significantly higher stalk yield of cotton was obtained in sole cotton (2166 kg ha^{-1}) which was on par with cotton + dhaincha (1:1) intercropping system (1971 kg ha^{-1}) in first year followed by cotton + sunhemp (1:1) intercropping (1847 kg ha^{-1}). In grain legume intercropping cotton + greengram (1:1) and cotton + blackgram (1:1) recorded 1752 kg ha^{-1} and 1574 kg ha^{-1} stalk yield respectively.

During second year significantly maximum stalk yield of cotton was obtained with cotton + dhaincha (1:1) intercropping system (2886 kg ha^{-1}) which was found on par with cotton + sunhump (1:1) intercropping system (2674 kg ha^{-1}). In respect of pooled results maximum stalk yield of cotton was obtained with cotton + dhaincha (1:1) (2428 kg ha^{-1}) which was found on par with sole cotton (2352 kg ha^{-1}) and cotton + sunhump (1:1) intercropping system (2260 kg ha^{-1}).

Application of nitrophosphocompost with intercropping also helps in conversion of unavailable nutrients to available form through increased microbial activity and enabled the crop to absorb nutrients resulting in statistically identical dry matter accumulation. The improvement in stalk yield of cotton with intercropping of legume crops was also reported by Chandel *et al.*, 2017 [4].

Table 2: Cotton equivalent yield (CEY) as influenced by different treatments

Tr. No	Treatments	Cotton equivalent yield (kg ha^{-1})	
		2017	**2018**
A.	**Main Plot (Nutrient Management)**		
M1	INM (75% RDF + compensation through NPS compost	1116	1446
M2	Organic (100% NPK dose through NPS compost)	972	1328
	SE (m)±	43.70	33.96
	CD at 5%	131.48	102.29
B.	**Sub plot (Cotton based intercropping systems)**		
S1	Control (Sole cotton)	1049	1177
S2	Cotton + Dhaincha (1:1)	952	1349
S3	Cotton + Sunhemp (1:1)	930	1293
S4	Cotton + Greengram (1:1)	1162	1585
S5	Cotton + Blackgram (1:1)	1128	1531
	SE (m)±	36.56	24.32
	CD at 5%	109.6	72.90
	Interaction (M X S)	--	--

Maximum cotton equivalent yield was recorded with application of 75% RDF + compensation through NPS compost which was followed by 100% NPK dose through NPS compost during both the years (Table 2). During first year CEY in INM recorded 1116 kg ha^{-1} and in organic recorded 972 kg ha^{-1}. During second year CEY recorded in INM was 1446 kgha^{-1} and in organic 1328 kg ha^{-1}. During first year rain fall was very low as compared with normal rainfall and it was not well distributed throughout season, therefore recorded low seed cotton yield and yield of

intercrops.

Perusal of the results presented in Table 2 the maximum cotton equivalent yield (1162 kg ha^{-1}) was obtained with cotton + greengram intercropping system, followed by cotton + blackgram intercropping system (1128 kg ha^{-1}) during first year because of the yield of greengram was recorded 222.43 kgha^{-1} and blackgram recorded 253.33 kg ha^{-1} but the minimum support price (MSP) for greengram during first year was more as compared with blackgram.

During second year, maximum cotton equivalent yield (1585 kg ha^{-1}) was obtained in cotton + greengram intercropping system, followed by cotton+ blackgram intercropping system (1531 kg ha^{-1}). The yield of greengram was recorded 271.08 kg ha^{-1} and blackgram recorded 300.24 kg ha^{-1} during second year. Minimum cotton equivalent yield (1177 kg ha^{-1}) was recorded when cotton grown as sole crop as compared with other intercropping system. The maximum cotton equivalent yield was obtained in cotton + greengram intercropping system may be due to the higher additional seed yield of greengram and better prices fetched to greengram during both the years as compared with blackgram.

This result are in close agreement with the findings reported by Manoj *et al.* (2013) [16], Ramachandrappa *et al.* (2016) [22] and Pandagale *et al.* (2019) [18].

Economic evaluation

The data pertaining to the economics of cotton as recorded with INM (75% RDF + compensation through NPS compost) and organic (100% NPK dose through NPS compost) presented in Table 3. Significantly highest cost of cultivation was recorded with use of 100% NPK dose through NPS compost (Rs. 35185 ha^{-1}) as compared with 75% RDF + compensation through NPS compost (Rs. 34431 ha^{-1}) in first year. During second year, cost of cultivation required for application of only organic inputs was (Rs. 39177 ha^{-1}) and for INM it was somewhat less (Rs. 38636 ha^{-1}). It might be due to higher total cost of organic i.e. compost.

Significantly highest gross monetary returns (GMR) were recorded with INM (75% RDF + NPS compost) as compared with organic (100% NPK dose through NPS compost) during both the year of experimentation. Gross monetary returns obtained due to INM (75% RDF + compensation through NPS compost were (Rs. 60180 ha^{-1}) in first year and in second year (Rs. 78784 ha^{-1}). GMR obtained with application of organic (100% NPK dose through NPS compost) were (Rs. 52367 ha^{-1}) in first year and in second year (Rs. 72382 ha^{-1}) respectively. Higher gross monetary returns with application of INM during both the years might be due to the higher yield of cotton.

Similarly, significantly higher net monetary returns were recorded with INM (75% RDF + NPS compost) as compared with organic (100% NPK dose through NPS compost) during both the years. Net monetary returns obtained due to INM (75% RDF + NPS compost) were (Rs. 25749 ha^{-1}) in first year and in second year (Rs. 40148 ha^{-1}). NMR obtained with application of organic (100% NPK dose through NPS compost) were (Rs. 17181 ha^{-1}) in first year and in second year (Rs. 33206 ha^{-1}) respectively.

However, highest benefit to cost (B: C) ratio was recorded in INM (75% RDF + NPS compost) 1.75 and 2.04 as compared with organic (100% NPK dose through NPS compost) i.e. 1.49 and 1.84 during first and second year respectively.

The higher net monetary returns and B: C ratio was recorded in treatment with application of the conjoint use of chemical fertilizers with organics. Similar results were recorded by Bhalerao *et al.* (2007) [3]. The results are also supported by the findings of Gabhane *et al.* (2013) [8], Sankar *et al.* (2014) [25] and Channagouda and Babalad (2015) [5].

In respect of intercropping systems the cost of cultivation in first year recorded highest in cotton + greengram intercropping system which was followed by cotton + blackgram, cotton + dhaincha, cotton + sunhemp and sole cotton. Cost of cultivation required for cotton + greengram intercropping system was Rs. 35224 ha^{-1} and lowest cost of cultivation required for sole cotton was Rs. 33496 ha^{-1}. During second year, highest cost of cultivation required for cotton + dhaincha (Rs. 39567 ha^{-1}) which was followed by cotton + blackgram (Rs. 39509), cotton + greengram (Rs. 39438), cotton + sunhemp (Rs.39286) and sole cotton (Rs. 36732). The results of present study are in close agreement with the findings reported by Singh *et al.* (2015) [27].

Highest gross monetary returns (GMR) recorded with cotton when intercropped with greengram during both the year of experimentation. Gross monetary returns obtained due to cotton + greengram intercropping system were Rs. 63220 ha^{-1} and Rs. 86385 ha^{-1} which were followed by cotton + blackgram intercropping system Rs. 58406 ha^{-1} and Rs. 83423 ha^{-1} during both the years respectively. Asewar *et al.* (2008) [2] reported increase in GMR due to cotton + greengram and cotton + blackgram. Pulses intercropped with cotton found beneficial were also noticed to by Maitra *et al.* (2001) [15] to give higher returns. Similar results were recorded by Khargkharate *et al.* (2014) [15].

Table 3: Economic evaluation under cotton based intercropping systems

Tr. No	Treatments	Cost of cultivation (COC) (Rs. ha^{-1})		Gross monetary returns (GMR) (Rs. ha^{-1})		Net monetary returns (NMR) (Rs. ha^{-1})		B:C ratio	
		2017	2018	2017	2018	2017	2018	2017	2018
A.	**Main Plot (Nutrient Management)**								
M1	INM (75% RDF + compensation through NPS compost)	34431	38636	60180	78784	25749	40148	1.75	2.04
M2	Organic (100% NPK dose through NPS compost)	35185	39177	52367	72382	17181	33206	1.49	1.84
	SE (m)±	128	174	2392	1858	2264	1685	--	--
	CD at 5%	385	522	7179	5575	6795	5055	--	--
B.	**Sub plot (Cotton based intercropping systems)**								
S1	Control (Sole cotton)	33496	36732	57189	64140	23693	27408	1.71	1.75
S2	Cotton + Dhaincha (1:1)	35103	39567	51866	73514	16763	33947	1.48	1.86
S3	Cotton + Sunhemp (1:1)	35038	39286	50685	70452	15648	31166	1.45	1.79
S4	Cotton + Greengram (1:1)	35224	39438	63220	86385	27996	46947	1.80	2.19
S5	Cotton + Blackgram (1:1)	35182	39509	58406	83423	23224	43915	1.66	2.11

	SE (m)±	101	119	1978	1326	1878	1209	--	--
	CD at 5%	303	356	5928	3973	5630	3624	--	--
	Interaction (M X S)	--	--	--	--	--	--	--	--

During first year net monetary return obtained from cotton + greengram intercropping systems was Rs. 27996 ha-1 and in second year Rs. 46947 ha-1. In cotton + blackgram intercropping systems NMR recorded was Rs. 23224 ha-1 and Rs. 43915 ha-1 during both the years respectively.

The corresponding rise in net return was due to higher yield of intercrops, which resulted to bring out better use of natural resources *viz*., sunlight, land and moisture. The results are in conformity with the findings of Patel *et al.* (2007) [19]. Shah *et al.* (2002) [26] also reported cotton and greengram intercropping as the most compatible system which resulted in producing combined higher yield than monoculture cotton. Though there was a reduction in seed-cotton yield under intercrop situation, it was well compensated by additional yield from intercropping there by registered higher economic returns. The results of present investigation corroborate with the findings of Krishnasamy *et al.* (1995) [12]. Reddy and Mohammad (2009) [24] also reported that the intercropping of greengram and blackgram was significantly superior over sole cropping.

The maximum net production value i.e. benefit cost ratio (B: C ratio) was registered (1.80 and 2.19) when cotton intercropped with greengram which was followed by cotton intercropped with blackgram (1.66 and 2.11) during both the years respectively. The lower net production value (1.45) was obtained when cotton intercropped with sunhemp during first year. In second year it was recorded lowest (1.75) in sole cotton. Increased NMR in cotton + greengram intercropping system depicted to increased B: C ratio was also reported by Pandagale *et al.* (2019) [18]. The results are in accordance with the findings of Chellaiah and Gopalaswamy (2000) [6], Wankhede *et al.* (2000) [30] and Daisy *et al.* (2017) [7].

4. Conclusion

Conjoint use of integrated nutrient management and organics and inclusion of legumes in cotton based intercropping system was found effective in enhancing cotton yield, cotton equivalent yield, gross monetary return, net monetary return and also BC ratio as against sole cropping system under rainfed Vertisol. It also helps to reduce the use of inorganic fertilizers and promotes sustainable agriculture.

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References

1. Anonymous. ICAR-All India Coordinated Research Project on Cotton – PI Annual Report, 2018-19.
2. Asewar BV, Jadhav AS, Khan A. Effect of in situ water management and intercropping system on yield of rainfed cotton. Journal of Cotton Research and Development. 2008;(22):173-75.
3. Bhalerao PD, Patil BR, Katkar RN, Ghatol PU. Effect of integrated nutrient management on seed cotton yield and economics of hybrid cotton. PKV Research Journal. 2007;31(2):259-262.
4. Chandel Ashwini, Gabhane VV, Nagdeve MB, Turkhede AB, Patode RS. Effect of INM on soil fertility, productivity and economics of cotton + greengram intercropping system in Vertisols. Int. J Curr. Microbiol. App. Sci., 2017;6(11):3738-3743.
5. Channagouda RF, Babalad HB. Impact of organic farming practices on quality parameters of cotton. Research on Crops. 2015;16:752-756.
6. Chellaiah N, Gopalaswamy N. Effect of intercropping and foliar nutrition on the productivity of summer irrigated cotton. Madras Agricultural Journal. 2000;87(4-6):267-270.
7. Daisy M, Rajendran K, Mohamed Amanullah M. Effect of legume fodder intercrops and different fertilizer levels on growth, yield and economics of *Bt* cotton under irrigated condition. International Journal of Current Microbiology and Appied Sciences. 2017;6(7):2238-2243.
8. Gabhane VV, Nagdeve M, Ganvir M. Effect of long term integrated nutrient management on sustaining crop productivity and soil fertility under cotton and greengram intercropping in vertisols under semi arid agroecosystem of Maharashtra, India. Acta Boilogica Indica. 2013;2(1):284-291.
9. Hati KM, Swarup A, Dwivedi AK, Misra AK, Bandypopadhyay KK. Changes in soil physical properties and organic carbon status at the topsoil horizon of a Vertisol of central India after 28 years of continuous cropping, fertilization and manuring. Agriculture Ecosystems and Environment. 2007;119:127-134.
10. Jayakumar M, Ponnuswamy K, Mohamed A, Mohamad M, Yassin M. Effect of intercropping and sources of nitrogen on growth, yield and N use efficiency on cotton. Research Journal of Agriculture and Biological Science. 2007;3(5):398-402.
11. Khargkharate VK, Kadam GL, Pandagale AD, Awasarmal VB, Rathod SS. Studies on kharif legume intercropping with *Bt* cotton under rainfed Conditions. Journal of Cotton Research and Development. 2014;28(2)243-246.
12. Krishnasamy S, Ali AM, Manoharan S. Productivity and profitability of intercropping in summer cotton and integrated N management. Madras Agriculture Journal. 1995;82(7-9):460-461.
13. Kumar N, Verma LP, Sing R, Prasad K. Soil properties, nutrient uptake and productivity of rice under integrated nutrient management system. Annals of Plant and Soil Research. 2001;3(1):54-57.
14. Ladha J, Khind C, Gupta R, Meelu O, Pasuquin E. Long-Term Effects of Organic Inputs on Yield and Soil Fertility in the Rice-Wheat Rotation. Soil Science Society of America Journal. 2004;68:845-853.
15. Maitra SS, Samui K, Roy DK, Mondal AK. Effect of cotton based intercropping system under rainfed conditions in Sunderban region of West Bengal. Indian Agriculturist. 2001;45:157-62.
16. Manoj K, Shivran AC, Rekha C, Meena KS, Verma KC, Jat RD, *et al.* Production potential and economics of intercropping of castor with mungbean. Environment and

Ecology. 2013;31(2C):1065-1068.
17. Marimuthu S, Surendran U, Subbian P. Productivity, nutrient uptake and post-harvest soil fertility as influenced by cotton-based cropping system with integrated nutrient management practices in semi-arid tropics. Archives of Agronomy and Soil Science. 2014;60(1):87-101.
18. Pandagale AD, Khargkharate VK, Kadam GL. Studies on various intercropping system under different plant geometry in *Bt* cotton. International Journal of Research in Agronomy. 2019;2(1):07-09.
19. Patel DK, Patel PG, Patel MM. Intercropping studies on rainfed castor under North Gujarat conditions. Annals of Arid Zone. 2007;46(1):99-101.
20. Patra AK, Nayak BC, Mishra MM. Integrated nutrient management in rice (Oryza sativa) - wheat (*Triticum aestivum*) cropping system. Indian Journal of Agronomy. 2000;45(3):453-457.
21. Rajarajan A, Janaki P, Appavu A, Vadivel A. Effect of fertilizer NPK and FYM on yields of cotton and nutrient status in black soil. Madras Agricultural Journal. 2005;92:266-270.
22. Ramachandrappa BK, Thimmegowda MN, Sathish A, Dhanapal GN, Ravi Kumar HS. Effect of intercropping in nipped castor (*Ricinus communis* L.) under rainfed conditions. Indian Journal of Dryland Agriculture Research & Development. 2016;31(1):30-36.
23. Rao Joga P, Prasad PRK, Lalitha Kumari A, Prasuna Rani P, Pulla Rao CH. Long-term effect of manures and fertilizers on nutrient status under cotton mono-cropping in Vertisol. International Journal of Current Microbiology and Applied Sciences, 2017;6(7):2084-2094.
24. Reddy PR, Mohammad S. Evaluation of cotton based intercropping system through different approaches under rain fed condition. Indian Journal of Agricultural Sciences. 2009;79(3):210-214.
25. Sankar Maruthi GR, Sharma KL, Gabhane VV, Nagdeve MB, Osman M, Pushpanjali KA, *et al*. Effects of long-term fertilizer application and rainfall distribution on cotton productivity, profitability and soil fertility in a semi-arid Vertisol, Communications in Soil Science and Plant Analysis. 2014;45(3):362-380.
26. Shah KH, Siddiqui SH, Memon MY, Imtiaz M, Aslam M. Effect of different N management practices and planting geometries in cotton mungbean intercropping system. Asian Journal of Plant Sciences. 2002;1:358-60.
27. Singh Kulvir, Pankaj Rathore, Gumber RK. Studies on the nutrient management of Bt cotton based legume intercropping system. Journal of Cotton Research and Development. 2015;29(2):237-241.
28. Turkhede AB, Nagdeve MB, Karunakar AP, Gabhane VV, Mohod VD, Mali RS. Diversification in Cotton Based Cropping System under Mechanization in Rainfed Condition of Vidarbha of Maharashtra, India. Int. J Curr. Microbiol. App. Sci. 2017;6(9):2189-2206.
29. Venkateswarlu B, Ramesh SG, Venkataswarlu S, Katyal JC. Effect of long-term cover crop incorporation on soil organic carbon, microbial biomass, nutrient build-up and grain yields of sorghum/sunflower under rainfall conditions. Soil Use and Management. 2007;23:100-107.
30. Wankhede ST, Tukhede AB, Solanke VM, Malvi SD, Katkar RN. Effect of intercropping on yield of cotton. Crop Research. 2000;19(3):409-413.