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ENVIRONMENTAL IMPACT OF TRANSGENIC COTTON ON PHYSICOCHEMICAL QUALITIES OF SOIL ECOSYSTEMS IN NORTHERN KARNATAKA, INDIA

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Abstract

One of the very least understandings of ecological risk assessment is the impact of genetically modified crops on biotic and abiotic factors. Even though, farmers have adopted transgenic crops in large scale because of high yield and immediate financial gain. Key factor to be considered in the development of a genetically modified plant is the assessment of its safety. Transgenic crops may have the potential to influence the soil in which they are growing through the release of the Bt proteins in root exudates or from sloughed or decaying plant material. The present study aims to determine the impact of Bt cotton on soil physical and chemical properties of agricultural lands of three districts of Karnataka, India. About 21 parameters have been studied and determined that were significant differences in the soil nutrients such as nitrogen, potassium and other essential salts such as calcium and magnesium between transgenic and Non-transgenic cotton growing field. All results obtained in the present work suggested that there is no notable significant impact to specify any negative effects of transgenic cotton on the soil properties.

Key words*: Bt proteins, physicochemical properties, root exudates, soil ecosystem, transgenic cotton.*

INTRODUCTION

In India, cotton crop is an important agricultural crop which is playing a vital role in economy of the country through supporting millions of lives by cultivation, processing and trading of this industrial crop. India ranks second in cotton production with 6423 metric tons after China. In recent years, cotton cultivation area is fluctuating between 8-9 million hectares. Insects and pests are the most important pathogens to reduce the cotton production by infecting during various stages of growth. Loses up to 60% is caused by defoliators, tissue borers or bollworms and sap suckers. Considerable benefits such as increase in crop yield through the control of plant diseases and reduction in the use of chemical fertilizers and pesticides have been noticed by the use of transgenic crops. In recent times, several concerns remain on the impact of transgenic organisms for their adverse effect on soil ecosystem (Icoz and Stotzky, 2008). Soil biota is diverse in terms of their physiology, size and environmental requirements and that the composition and metabolic capabilities of soil biota communities underpin many soil processes. Plant-microbe interactions also play a critical role in variety of biological functions in the rhizosphere soil (Nihorimbere et al., 2011). Plant residues as well play an important role in these interactions which includes leaf litter and root exudates from Bt cotton that could potentially influence soil ecosystem functions. It is well known that Bt Cotton plants produce Bt-toxin in above-ground parts. Many researchers have suggested that Bt-toxin is also released from roots, and could bind to clay minerals in soil, raising concerns about the persistence of the toxin (Saxena and Stotzky, 2000; Knox et al., 2008; Audiseshamma et al., 2014).

Alteration in the soil ecosystem ultimately affects the microbial dynamics, availability of soil microbial diversity, soil functions such as nutrient mineralization, carbon turnover, plant growth promotions and biodegradation processes (Dunfield and Germida, 2004; Stotzky, 2004; Beura and Rakshit, 2011). Among researchers, there is a concern about the transgenic crop release of Bt toxins in to the soil environment which may reduce soil fertility as changes in chemical and biological activities. Changes in the soil ecosystems may include changes in microbial dynamics, soil biodiversity, nutrient mineralization, plant growth and biodegradation of agrochemicals because they usually produce insecticidal Cry proteins (Bt toxin) through all parts of the plant (Icoz and Stotzky, 2008). Over the last decade, many researchers carried out research on the assessment of the usage of genetically modified crops and microorganisms in agriculture promotion (Sharma and Ortiz, 2000). Biosafety assessment of genetically modified crops is very important aspect to study their impact on soil ecosystem (Bruinsma et al., 2003; Kowalchuk et al., 2003).

Impact of genetically modified (GM) crops on soil microorganism especially rhizosphere are still least understood areas in the application of GM crops. Nutrient and essential element cycling is mainly takes place due to rhizosphere microorganisms. Any changes in the rhizosphere microbial community due to Bt toxin have either positive or negative impact on plant growth and environmental health (Dunfield and Germida, 2004). Plants are releasing 20% of their assimilates to the rhizospheric soil as root exudates and at the end of plant life, the residues of crops are released to the soil, any changes in the plant exudates or plants content have direct impact on rhizosphere microbes which ultimately affect the biogeochemical cycle and soil fertility (Whipps, 1990). Hence, the present work aims at studying the impact of transgenic cotton on soil physicochemical properties in Northern Karnataka, India.

MATERIALS AND METHODS

Study area

The study was carried out in three districts of Northern Karnataka, India where cotton is intensively grown for several years. Haveri is located in the middle of the State, with 14°80' N and 75°40' E of Latitude and Longitude respectively. Dharwad is located in the northwest of Karnataka with 15°27' N Latitude and 75°05' E Longitude. Belgaum is located in northwestern part of the state at 15°87′ N and 74°50′ E of Latitude and Longitude respectively. These three districts of Karnataka are known for cultivation of transgenic cotton crops regularly.

Soil collection and physicochemical analysis

Soil samples were collected from three districts such as Belgaum, Haveri and Dharwad of North Karnataka from Bt and Non-Bt cotton crop fields. Bt cotton fields were selected where Bt crops had been planted for more than ten years which was compared with the Non-Bt fields. Before sowing and after harvest, soil samples were collected in the depth of 25, 50 and 75 cm.

Composite samples were taken from random pits on profile basis using augur, totally 108 composite soil samples were analyzed. Physicochemical properties such as pH, Ca, Mg, Cl, available potassium, nitrate nitrogen, ammonical nitrogen, available phosphate, % oxidizable organic carbon, sulfur, sodium, zinc, iron, manganous and copper were analyzed using standard protocols for Bt and Non-Bt soil samples (Jackson, 1967; Trivedy and Goel, 1986).

Statistical analysis

The statistical differences among the data were determined by independent samples test in ANOVA at the 95% confidence interval of the mean with SPSS 16.0 version. Differences were considered $p \leq 0.05$ as significant.

RESULTS AND DISCUSSIONS

Duration of Bt-cotton planting at different sampling sites in the districts of Belgaum, Haveri and Dharwad of Northern Karnataka in India is given in Table 1.

Physicochemical properties of before sowing and after harvesting of BT and Non-Bt cotton soil samples of three districts have been analyzed and the results are given in Tables 2, 3 and 4. Data from this study suggests that, among 108 soil samples collected from three districts, the pH of all the collected soil samples were alkaline in nature.

The pH of the soil is not constant, which will change over time, based on the parent material, weathering and current agricultural practices (Icoz and Stotzky, 2008).

Table 1. Details of Bt-cotton planting at different sampling sites in Northern Karnataka, India

District	Sampling site	Soil type	Years of Bt-cotton grown prior to sampling
Belgaum	Gokak	Clay loam	14
	Athani	Clay loam	
	Belgaum	Clay to clay loam	
Haveri	Hangal	Clay loam	15
	Tavarmallihalli	Clay loam	
	Haveri	Clay loam	
Dharwad	Annigeri	Clay loam	13
	Dharwad	Black soil	
	Aminbhavi	Clay loam	

Table 2. Soil properties of Bt and Non-Bt cotton growing fields before sowing and after harvest in Belgaum District of Karnataka, India

Parameters	Before sowing		After harvest	
	NBT	BT	NBT	BT
pH	$8.01^a±0.31$	$9.10^b±0.21$	$8.50^a±0.27$	$8.41^a±0.15$
Ca meq/100g	$25.21^a±1.89$	$13.41^b±0.10$	$33.54^a±0.99$	$21.99^a±1.24$
Mg meq/100g	$6.91^a±0.41$	$10.62^b±0.01$	$13.32^a±0.30$	$9.08^b±0.59$
Cl meq/100g	$7.82^a±0.55$	$8.07^a±0.51$	$6.16^a±0.67$	$7.63^a±0.70$
Available Potassium Kg/ha	$123.28^a±1.63$	$145.53^b±0.94$	$141.84^a±0.70$	$137.11^b±1.37$
Nitrate Nitrogen Kg/ha	$7.32^a±0.71$	$4.78^b±0.50$	$7.00^a±0.90$	$4.77^a±0.73$
Ammonical Nitrogen Kg/ha	$46.07^a±0.73$	$12.62^b±0.83$	$32.49^a±0.04$	$22.87^b±0.65$
Available Phosphate Kg/ha	$17.16^a±0.56$	$13.17^b±0.16$	$9.58^a±0.64$	$9.90^a±0.75$
% Oxidizable Organic Carbon	$0.34^a±0.03$	$0.52^b±0.02$	$0.53^a±0.02$	$0.49^a±0.02$
Sulfur Kg/ha	$4.09^a±0.42$	$8.02^b±0.83$	$6.32^a±0.66$	$6.37^b±0.87$
Sodium meq/100g	$0.48^a±0.04$	$0.65^b±0.04$	$0.31^a±0.02$	$0.27^a±0.02$
Zinc ppm	$1.09^a±0.19$	$0.62^b±0.02$	$1.05^a±0.17$	$0.62^b±0.11$
Iron ppm	$1.30^a±0.16$	$2.56^b±0.25$	$1.88^a±0.19$	$1.91^a±0.12$
Manganous ppm	$18.57^a±0.61$	$24.45^a±0.71$	$21.73^a±0.92$	$22.72^a±0.76$
Copper ppm	$2.78^a±0.27$	$5.12^b±0.58$	$5.70^a±0.75$	$5.61^a±0.61$

NBT: Non-Bt cotton field soil sample; BT: Bt cotton field soil sample; Same superscript in the same row under each head is not significantly different; different superscript in the same row under each head is significantly different.

Table 3. Soil properties of Bt and Non-Bt cotton growing fields before sowing and after harvest in Haveri District of Karnataka, India

Parameters	Before sowing		After harvest	
	NBT	BT	NBT	BT
pH	$9.10^a±0.13$	$8.78^a±0.25$	$8.57^a±0.12$	$8.23^a±0.10$
Ca meq/100g	$13.60^a±0.59$	$19.10^b±0.68$	$26.35^a±1.21$	$17.68^b±0.02$
Mg meq/100g	$10.28^a±0.97$	$12.29^b±0.36$	$12.47^a±0.12$	$11.56^a±0.72$
Cl meq/100g	$8.17^a±0.35$	$6.99^a±0.42$	$7.18^a±0.58$	$9.20^b±0.66$
Available Potassium Kg/ha	$235.90^a±1.40$	$203.54^b±0.10$	$172.73^a±1.39$	$198.85^b±1.09$
Nitrate Nitrogen Kg/ha	$5.64^a±0.63$	$6.35^a±0.62$	$8.61^a±0.15$	$7.17^b±0.67$
Ammonical Nitrogen Kg/ha	$15.30^a±0.85$	$12.94^b±0.86$	$33.68^a±1.31$	$37.11^a±0.70$
Available Phosphate Kg/ha	$11.58^a±0.82$	$12.27^a±0.91$	$11.28^a±0.79$	$8.70^a±0.49$
% Oxidizable Organic Carbon	$0.59^a±0.01$	$0.52^a±0.06$	$0.36^a±0.01$	$0.28^a±0.12$
Sulfur Kg/ha	$8.13^a±0.77$	$8.57^a±0.22$	$21.78^a±0.71$	$12.13^b±0.23$
Sodium meq/100g	$2.90^a±0.51$	$0.47^b±0.02$	$0.39^a±0.01$	$0.20^b±0.07$
Zinc ppm	$0.38^a±0.02$	$0.47^a±0.06$	$0.68^a±0.15$	$0.64^a±0.11$
Iron ppm	$1.76^a±0.18$	$1.86^a±0.21$	$2.18^a±0.26$	$2.11^a±0.17$
Manganous ppm	$18.57^a±0.61$	$53.65^b±1.05$	$29.47^a±0.80$	$32.27^a±1.04$
Copper ppm	$2.79^a±0.28$	$4.12^b±0.59$	$2.43^a±0.23$	$2.26^a±0.39$

NBT: Non-Bt cotton field soil sample; BT: Bt cotton field soil sample; Same superscript in the same row under each head is not significantly different; different superscript in the same row under each head is significantly different.

Table 4. Soil properties of Bt and Non-Bt cotton growing fields before sowing and after harvest in Dharwad District of Karnataka, India

Parameters	Before sowing		After harvest	
	NBT	BT	NBT	BT
pH	7.97[a]±0.35	8.32[a]±0.18	8.42[a]±0.19	8.71[a]±0.19
Ca meq/100g	20.57[a]±1.04	14.92[b]±0.84	28.77[a]±1.72	25.97[a]±1.48
Mg meq/100g	10.71[a]±0.10	14.42[b]±0.31	17.60[a]±1.16	13.67[b]±0.72
Cl meq/100g	6.86[a]±0.57	9.08[b]±0.41	6.38[a]±0.54	6.74[a]±0.59
Available Potassium Kg/ha	163.77[a]±1.16	217.93[b]±1.39	206.30[a]±1.90	254.02[b]±1.21
Nitrate Nitrogen Kg/ha	7.26[a]±0.80	6.99[a]±0.55	6.92[a]±0.60	6.85[a]±0.49
Ammonical Nitrogen Kg/ha	17.22[a]±0.71	12.41[b]±0.31	44.55[a]±1.62	22.56[a]±1.24
Available Phosphate Kg/ha	12.12[a]±0.04	13.63[a]±0.12	11.63[a]±0.13	8.88[a]±0.20
% Oxidizable Organic Carbon	0.43[a]±0.01	0.61[b]±0.06	0.45[a]±0.02	0.42[a]±0.02
Sulfur Kg/ha	7.95[a]±0.44	10.82[b]±0.84	13.42[a]±1.05	9.03[b]±0.85
Sodium meq/100g	0.53[a]±0.04	0.54[a]±0.03	0.35[a]±0.02	0.29[a]±0.03
Zinc ppm	0.52[a]±0.06	0.50[a]±0.84	0.61[a]±0.01	0.49[b]±0.10
Iron ppm	1.56[a]±0.25	2.51[b]±0.19	4.61[a]±0.80	1.98[a]±0.16
Manganous ppm	29.67[a]±1.13	28.63[a]±1.02	32.42[a]±1.09	38.48[a]±1.87
Copper ppm	4.50[a]±0.59	5.20[a]±0.59	2.51[a]±0.26	2.76[a]±0.48

NBT: Non-Bt cotton field soil sample; BT: Bt cotton field soil sample; Same superscript in the same row under each head is not significantly different; different superscript in the same row under each head is significantly different.

There is no much difference in the soil samples of three districts with respect to soil chemical properties. Results also confirmed that samples collected from three districts showed poor soil fertility. This may be due to poor cultivation practices among farmers. Results compared with Bt and Non-Bt soil samples suggests that there is no measurable impact of cultivation of Bt cotton on soil chemical parameters observed. Significant differences in many of the soil properties particularly before sowing was observed between the Bt and Non-Bt soil samples of three districts. Significance of differences was tested by using independent samples test in ANOVA.

Based on the analysis of soil samples of before sowing from Bt and Non-Bt cotton from Belgaum district shows significant difference in all the chemical properties other than chloride and manganous. After harvest of the Bt and Non-Bt cotton the soil analysis showed significant differences in magnesium, available potassium, ammonical nitrogen, sulfur and zinc. Bt and Non-Bt (before sowing) soil samples of Haveri district shows significant differences in calcium, magnesium, available potassium, ammonical nitrogen, sodium, manganous and copper. After harvest of Bt and Non-Bt cotton field soil samples of Haveri district shows significant difference in calcium, chloride, available potassium, nitrate nitrogen, sulfur, sodium and sulfur. Bt and Non-Bt (before sowing) soil samples of Dharwad district shows significant differences in calcium, magnesium, chloride, available potassium, ammonical nitrogen, % oxidizable organic carbon, sulfur and iron. Bt and Non-Bt (after harvest) soil samples of Dharwad district shows significant differences in magnesium, available potassium, sulfur and zinc.

The present work was designed to study the impact of continuous cultivation of Bt cotton for decades on soil properties. Based on the analytical and statistical results of the soil properties from Bt and Non-Bt cotton cultivated soil before sowing and after harvesting suggests that there are no much differences in chemical properties of the soil. Significant differences of some chemical compounds can be expected as a result of plant nutrient uptake and after harvesting releases of plant residues on the field. Results of this study suggested that there is negligible difference in nutrient mineralization in reference to nitrogen, potassium and phosphorous before sowing and after harvest in Bt and Non-Bt cotton fields. Moreover, overall results suggest that there is no significant adverse effect of Bt cotton on soil ecosystems.

CONCLUSIONS

The present study conclude that there were very less significant differences in essential ecosystem functions such as nutrient mineralization with reference to analyzed physicochemical parameters between Bt and Non-Bt cotton fields during before sowing and after harvesting period in three districts of Northern Karnataka, India. In conclusion, there was no alarming significant evidence to indicate any adverse effects of Bt cotton on the physicochemical properties of soil ecosystem in Northern Karnataka, India.

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