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Soil Weed Seed Bank under different Cotton (*Gossypium hirsutum*) Management Systems

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ABSTRACT: Cotton is a long duration, widely spaced, and relatively slow-growing crop that faces a serious weed threat in its early growth stages. The weeds growing in a crop can be considered as merely the vehicle by which seeds in the soil produce further seeds for incorporation into the soil seed bank. Due to the complexity of characterizing the soil seed bank, it is difficult to predict the abundance of weed species and communities. One way of describing weed soil seed bank is that they are primarily an assemblage of seeds that will occasionally germinate, emerge, and grow into adult plants. A pot culture experiment was conducted in the greenhouse located at Agronomy farm, Centre of Organic Agricultural Research and Training (COART), Department of Agronomy, Dr. PDKV, Akola during *kharif* season of the year 2020-21, to compare the weed seed bank and weed flora in the soil under organic, bio-dynamic, conventional management systems of Bt and non-Bt cotton (*Gossypium hirsutum*). The present investigation was carried out in completely randomized design with the soil collected from five different crop management practices done in the field, each replicated four times. The treatments were allotted randomly to various pots. The five treatments consist of Organic management soil of cotton, Bio-dynamic management soil of cotton, Conventional management soil of non-Bt cotton, Conventional management soil of Bt cotton, Absolute Control soil (without fertilizers). *Panicum dichotomiflorum*, *Cyperus rotundus*, *Paspalum dilatatum*, *Euphorbia hirta*, *Acalypha indica* and *Digeria ravensis* were the dominant weed species observed. *Poaceae* was the dominant family in terms of composition. Weed flora between the treatments was found to be having very minor differences. The weed seed bank, weed species, weed count and weed dry matter were found to be statistically non-significant, but numerically highest in the Organic and Biodynamic than in the Conventional treatments.

Keywords: Bio-dynamic, Bt, Conventional, Cotton, Organic, Weed.

INTRODUCTION

The most significant cash crop, nicknamed as "white gold" due to its ability to generate foreign income, is cotton. A notable fibre in the globe, cotton is used as a raw material for the textile industry, which has an annual major economic impact of at least \$600 billion (Khan *et al*., 2020). Weeds are increasingly causing severe challenge to the global cotton industry. Early growth stages of the cotton crop are extremely sensitive; weed presence within the first two months of growth may result in production losses of 10% to 90% (Tariq *et al*., 2020).

The main source of weeds in cultivated soils is weed seed banks. Selecting the most integrated weed control strategies may be aided by understanding about the weed seed bank. Additionally, it would be very helpful in determining herbicide dosages, lowering the overall herbicide use, and assisting farmers in selecting the best weed control strategies (Rahman *et al*., 2001). The soil seed bank may contain hundreds or even thousands of seeds per m^2. There have been reports of up to 50,000 seeds per square metre (Barralis and Chadoeuf 1980). Although it is assumed that the median seed density per square metre is between 500 and 5,000, this range is still rather varied when taken as a whole for all species that might be present in a field (Albrecht and Forster 1996; Leck *et al*., 1989; Roberts, 1981). Weed soil seed banks can be considered of as basically being an assortment of seeds, some of which will occasionally germinate, emerge, and grow into adult plants.

Due to their buried seed banks in the field, annual plants are difficult to predict in terms of population dynamics. However, particularly in agricultural environments, such projections are quite helpful in deciding management options. Since the establishment of weed seed banks can occur over a number of growing seasons, it can be challenging to link weed populations to weed management techniques. Most weed seeds in agro-ecosystems endure unfavourable seasons and last for several years in the seed bank. This causes difficulties in making accurate predictions of weed population dynamics and life history traits (LHT). As a result, it is extremely challenging to find management strategies that reduce both weed numbers and species diversity (Borgy *et al.*, 2015).

Generally, in field conditions as there will be addition of new seeds by the dispersal through several factors, it is difficult to study the weed seed bank in the soil. To study the weed seed bank in the soil, we need to culture the soil in the protected environment such as greenhouses, net houses, etc. where there will be zero addition.

Grundy and Jones (2002) reported that the soil weed seed bank consists of many different species and dominant species can account for up to 70–90% of the seed number in soil. The amount of weed seeds considerably varies depending on soil type, crops grown, crop rotation, cultivation methods and the use of herbicides. Uludag *et al.* (2004) reported that the soil seed bank density is an approach to understand weed biology and to develop suitable integrated weed management tactics. Seed bank at cotton-wheat cropping system in the Cukurova region of Turkey was studied. In total 30 fields were examined for the composition and density of the soil seed bank during three years. In this paper relation between weed flora and weed seed bank was compared for 5, 10 and 25 cm soil depths. There was a correlation of the seed number from different depths at all three years. The number of weed species was closer among species. But the number of seeds and species in the seed bank were greatly varied among fields. Almost in all fields more weed species were detected above-ground than in the soil seed bank for all sampling depths. *Portulaca oleracea* or *Amaranthus* spp. were the most abundant species in the soil seedbank in all depths except in a few fields. The mean recruitment ratio from the seedbank varied. Sampling depth of 10 cm can be used for seed bank studies. Shiratsuchi *et al.* (2005) evaluated weed seed bank method to generate spatial distribution maps. Soil cores were collected at 0.20 m depth, air-dried, and then submitted to seedling growth in greenhouse. Weed seed bank maps were obtained at different stages of seedling growth. It was concluded that for site-specific in management, the evaluation of seedling growth in greenhouse until the first emergence peak is enough to generate weed seed bank maps.

MATERIALS AND METHODS

The present investigation on “Soil Weed Seed Bank under different Cotton (*Gossypium hirsutum*) management systems” was conducted in the greenhouse at Agronomy farm, Centre of Organic Agricultural Research and Training (COART), Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra State, India during *kharif* season of 2020-21. Akola is situated in subtropical zone, at 307.42 m (Agromet observatory) above the mean sea level at 22°42′ North latitude and 77°02′ East longitude and lies in subtropical continental climate. Average annual precipitation is approximately 740 mm (average of 30 years). During monsoon season, July is the wet month with 253.1 mm average monthly rainfall. The mean maximum temperature varies from 29.0 ^{o}C to about 44.3 ^{o}C in May, whereas, the mean minimum temperature varies from 9.40 ^{o}C during winter to 27.6 ^{o}C in summer. The relative humidity ranges from 30.75% and 61.62% in summer and rainy season respectively.

The soil was collected from the experimental field under the FiBL Sys-Com project, which has established a long-term experiment (LTE) in which different farming systems were compared over a period of 10 – 20 years, since 2007. Cotton, soybean and wheat production were compared in a two-year crop rotation. The experiment was laid out in completely randomized design in pots with soil from five different crop management practices for field experiment, each replicated four times. The soil from the treatments was allocated randomly to various pots. Treatments were (i) organic management soil, (ii) biodynamic management soil, (iii) conventional management soil, (iv) conventional management soil with genetically modified Bt cotton and (v) control soil. In each experimental plot, four quadrants of 1m × 1m (1m^2) area were established randomly on the four sides permanently throughout the experiment and the various biometric observations were recorded from each quadrant treatment wise. From each experimental plot, soil samples from 0-30 cm depth were taken from randomly selected spots, spread over the experimental area. A composite sample was then prepared by thoroughly mixing the soil. From this composite sample, 2 kg of soil was taken into each pot and cultured under controlled conditions of greenhouse. The various biometric observations were recorded from the pot culture. The soils are low in available nitrogen (159.3 kg ha^{-1}); medium in phosphorus (15.5 kg ha^{-1}), organic carbon (0.71 %); highly rich in available potassium (672.4 kg ha^{-1}) and slightly alkaline in reaction (7.75). The emergence of weed seeds i.e., the germination of new weed seeds from the soil, number of each weed present in each pot and types of weeds in the each pot were recorded. The weeds removed were first air dried and kept in an oven at 65^{o}C till the constant dry weight was obtained. Thus, the dry weight of the weeds was recorded. All observations were statistically analyzed by ‘Analysis of Variance’ method (Panse and Sukhatne 1967) and ‘F-test of significance’ was used for testing the ‘null hypothesis’.

RESULTS AND DISCUSSION

The summary of the findings and the discussion related to the present investigation as influenced by different treatments was as follows.

Weed flora and details. Total weed species found in the pot culture were 16 (Table 1). Even though 16different species were observed in the soil weed seed bank, only 6 weed species had a major share in terms of composition which included *Panicum dichotomiflorum, Cyperus rotundus, Paspalum dilatatum, Euphorbia hirta, Acalypha indica and Digeria arvensis* with (80-90) % of the total composition. Soil weed seed bank consists of many different species and dominant species can account for up to 70–90% of the seed number in soil (Grundy and Jones 2002). Among the total weed species observed in the pot culture experiment, 12 were dicotyledonous weeds and 3 were monocotyledonous weeds. Monocot weeds observed in the experiment were highest in the treatment Control and dicot weeds in the treatment Conventional non-Bt. In the Organic, Biodynamic and Conventional non-Bt treatments, the dominant weed observed was *Paspalum dilatatum* and the least was *Sphaeranthus indicus. Panicum dichotomiflorum* was found dominant and *Sphaeranthus indicus was* the least in the treatments Control and Conventional Bt.

Poaceae, *Cyperaceae*, *Euphorbiaceae*, *Fabaceae* and *Asteraceae* were the major weed families observed in the experiment. The dominant family in terms of composition was *Poaceae*.70-80 % of the total weeds infested in pots belong to the family *Poaceae*. The dominance of the weeds belonging to the family *Poaceae* was may be due to perennial nature and the vegetative propagation. Family *Poaceae* dominates the fields under cotton cultivation (Nazar *et al.,* 2008; Memon *et al.,* 2014). The weed flora observed in the soil weed seed bank was not exactly similar with the weed flora observed in other places of cotton cultivation. Weed flora differs widely in their diversity depending upon environmental and soil conditions of the area of cultivation (Nalini *et al.*, 2015).

Other than control, highest weed species diversity was observed with the organic treatment. This may be due to the higher weed diversity observed in the field. Organic field shows greater weed species richness and higher species diversity (Ngouajio and McGiffen 2002; Albrecht, 2005; Adam and Beata 2018). The soil was found to be having weed seed bank containing all the three categories of weeds, which included grasses, sedges and broad leaved weeds. However, the grasses dominated the seed bank followed by sedges and broad leaved weeds.

Monocot weed count. At 30 DAS, 120 DAS and 150 DAS, all the treatments Organic, Biodynamic, Conventional non-Bt, Conventional Bt and Control were found to be non significant with respect to the monocot weed population. Significantly higher number of monocot weeds at 60 DAS were observed in the treatment Control followed by the Organic. The treatment Control differed significantly with the Organic and Biodynamic treatments, whereas the Organic was found statistically similar with the Biodynamic. The lowest monocot weed population was observed in the treatment Conventional Bt followed by Conventional non-Bt and the difference between them could not reach to the level of significance.

At 90 DAS, the maximum monocot weed population was observed in the treatment Control which was found statistically similar with the Organic and Biodynamic treatments. The treatment Conventional Bt was recorded with the lowest monocot weed population but was on par with the treatment Conventional non-Bt (Table 2). Adam and Beata (2018) also reported that significantly higher species diversity and abundance of above-ground and soil seed bank weeds in organic than in conventional farms.

Dicot weed count. Between all the treatments, there was no significant difference found at all the intervals except 90DAS with respect to the dicot weed population. Significantly highest number of dicot weeds at 90 DAS was observed in the treatment Control which was found statistically similar with Organic and Biodynamic treatments. The treatment Conventional Bt was recorded with the lowest dicot weed population and was found statistically at par with the treatment Conventional non-Bt. The conventional management shows less weed count compared to organic (Graziani *et al.*, 2012) (Table 2).

Total weed count. All the treatments were found to be non-significant with respect to the total weed population at 30 DAS, 120 DAS and 150 DAS. At remaining intervals, the treatment Control was found highest and was found statistically similar with the Organic and Biodynamic treatments. The lowest number of monocot weeds was recorded with the treatment Conventional Bt but was found non-significant with Conventional non-Bt (Table 3). This might be due to the higher soil weed seed bank and the non-chemical management of weeds done in the field previously. Significantly higher species diversity and abundance of above-ground and soil seed bank weeds in organic than in conventional farms (Adam and Beata 2018). There were no statistically significant differences observed in weed population due to biodynamic sprays. Weed population was similar with organic and biodynamic management (Lynne *et al.,* 2000).

Dry matter of weeds (g). At all the intervals, treatments were found to be non significant with respect to the dry matter of weeds (g). This might be due to the less growth of biomass in the pots and the lesser weights obtained from the weeds. The results showed that other than control, the weed dry matter was highest in the organic and biodynamic treatments numerically (Table 3). This might be due to the more weed population and the non-chemical management strategies adapted in the previous crop. In tomatoes and maize crops, highest weed biomass at harvest was observed in the organic treatment (Poudel *et al.*, 2002). Numerically lowest weed dry weight was observed in the both of the conventional treatments. This might be due to the low weed population and the integrated weed management stratagies adapted earlier. Leek (*Allium porrum* L.) was reported with lowest weed biomass in the conventional treatments (Karkanis *et al.*, 2012).

Table 1: Percentage of each weed of soil in the pot as influenced by different treatments.

Sr. No.	Weeds	POT				
		T1-ORG	T2-BD	T3-Cnv-NBt	T4-Cnv-Bt	T5-CTRL
	Monocot weeds	(%)	(%)	(%)	(%)	(%)
1.	*Panicum dichotomiflorum*	31.75	34.66	32.50	35.20	33.45
2.	*Cyperus rotundus*	19.75	13.01	10.50	9.40	18.16
3.	*Commelinaforskaoliivahl*	-	-	-	-	0.25
4.	*Paspalum dilatatum*	38.50	40.33	45.00	43.40	35.14
	Dicot weeds					
1.	*Euphorbia hirta*	0.50	0.35	0.65	0.55	0.30
2.	*Convolvulus arvensis*	0.25	-	-	-	0.40
3.	*Cassia tora L.*	0.45	0.55	-	-	0.90
4.	*Physalis minima*	-	2.15	2.30	1.85	2.00
5.	*Portulaca oleracea*	1.05	1.23	0.75	1.00	1.33
6.	*Phyllanthus niruri*	0.75	0.85	0.72	0.50	1.00
7.	*Acalypha indica*	2.20	2.15	3.00	3.15	2.30
8.	*Digeria arvensis*	3.05	3.15	3.15	4.25	3.15
9.	*Anagalis arvensis*	0.60	0.75	0.55	0.65	0.70
10.	*Sphaeranthus indicus*	0.05	0.07	0.08	0.05	0.07
11.	*Tridax procumbens*	0.10	-	-	-	0.20
12.	*Corchorus fascicularis*	1.00	0.75	0.80	-	0.65

(ORG= Organic, BD= Bio-dynamic, Cnv-NBt= Conventional non-Bt, Cnv-Bt= Conventional Bt, CTRL= Control)

Table 2: Monocot and dicot weed count per pot as influenced by different treatments.

Treatment Details	Monocot Weed Count per pot					Dicot Weed Count per pot				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1- Organic farming cotton	3.52 (11.92)	3.54 (12.06)	3.44 (11.37)	3.63 (12.7)	3.66 (12.94)	1.35 (1.32)	1.6 (2.17)	1.58 (2.01)	1.38 (1.41)	1.39 (1.44)
T_2- Bio-dynamic farming cotton	3.46 (11.49)	3.41 (11.19)	3.48 (11.61)	3.6 (12.5)	3.62 (12.62)	1.33 (1.28)	1.63 (2.22)	1.59 (2.05)	1.37 (1.39)	1.38 (1.40)
T_3- Conventional farming non-Bt cotton	3.43 (11.29)	2.7 (6.81)	2.75 (7.09)	3.43 (11.29)	3.65 (12.81)	1.32 (1.25)	1.44 (1.56)	1.32 (1.25)	1.32 (1.25)	1.39 (1.42)
T_4- Conventional farming Bt cotton	3.45 (11.53)	2.69 (6.74)	2.72 (6.94)	3.51 (11.81)	3.62 (12.62)	1.33 (1.28)	1.29 (1.19)	1.31 (1.22)	1.35 (1.31)	1.38 (1.40)
T_5- Absolute Control (without fertilizers)	3.75 (13.61)	3.79 (13.93)	3.58 (12.34)	3.77 (13.75)	3.83 (14.17)	1.42 (1.51)	1.72 (2.45)	1.64 (3.48)	1.42 (1.53)	1.44 (1.57)
SE(m)±	0.09	0.07	0.08	0.09	0.09	0.03	0.13	0.03	0.03	0.03
CD at 5 %	NS	0.22	0.25	NS	NS	NS	NS	0.09	NS	NS
GM	3.52 (11.97)	3.23 (10.15)	3.19 (9.87)	3.59 (12.41)	3.67 (13.03)	1.35 (1.33)	1.54 (1.89)	1.49 (1.74)	1.37 (1.38)	1.39 (1.45)

(Data are subjected to square root transformation $\sqrt{(x+0.5)}$ and original data are presented in parenthesis.)*DAS= Days after sowing

Table 3: Total weed count and dry matter of weeds per pot(g)as influenced by different treatments.

Treatment Details	Total Weed Count per pot					Dry matter of weeds per pot(g)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1- Organic farming cotton	3.71 (13.25)	3.84 (14.24)	3.72 (13.37)	3.82 (14.11)	3.85 (14.37)	0.99 (0.49)	1.07 (0.64)	0.74 (0.04)	0.72 (0.02)	0.75 (0.06)
T_2- Bio-dynamic farming cotton	3.64 (12.77)	3.72 (13.42)	3.76 (13.66)	3.79 (13.89)	3.81 (14.02)	0.98 (0.47)	1.07 (0.64)	0.74 (0.04)	0.73 (0.03)	0.75 (0.06)
T_3- Conventional farming non-Bt cotton	3.61 (12.55)	2.98 (8.38)	2.97 (8.35)	3.61 (12.54)	3.84 (14.24)	0.97 (0.45)	0.98 (0.47)	0.73 (0.04)	0.72 (0.02)	0.74 (0.05)
T_4- Conventional farming Bt cotton	3.63 (12.81)	2.89 (7.93)	2.94 (8.16)	3.69 (13.12)	3.81 (14.02)	0.97 (0.45)	1.00 (0.51)	0.73 (0.04)	0.72 (0.02)	0.74 (0.05)
T_5- Absolute Control (without fertilizers)	3.95 (15.12)	4.11 (16.39)	3.87 (14.52)	3.97 (15.27)	4.03 (15.74)	1.03 (0.56)	1.09 (0.70)	0.74 (0.05)	0.72 (0.02)	0.76 (0.08)
SE(m)±	0.09	0.08	0.09	0.1	0.09	0.02	0.03	0.004	0.003	0.01
CD at 5 %	NS	0.26	0.27	NS	NS	NS	NS	NS	NS	NS
GM	3.71 (13.29)	3.51 (12.07)	3.45 (11.61)	3.77 (13.79)	3.87 (14.48)	0.99 (0.49)	1.04 (0.59)	0.74 (0.03)	0.72 (0.02)	0.75 (0.06)

(Data are subjected to square root transformation $\sqrt{(x+0.5)}$ and original data are presented in parenthesis.)*DAS= Days after sowing

CONCLUSION

From the above findings, it can be concluded that weed flora was reported with very less difference between the treatments. Organic and Biodynamic soil was reported with higher weed seed bank, weed species diversity, weed count and weed dry matter than in the Conventional soil. The conventional management soil was found to be best as reported with very less seed bank. The Organic management soil weed seed bank was observed with high number of overall plant species and best in conserving the soil plant species biodiversity.

FUTURE SCOPE

This experiment can be used as reference for the weed seed bank that occur in the cotton fields in India. It gives an idea of weeds that occur in the *kharif* season of the vertisols of Madhya Pradesh, India.

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Conflict of Interest. None.

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