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Weed seedbank dynamics under different tillage practices and planting density in organic basmati rice production system

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ABSTRACT

There is a growing demand for organically produced food, including basmati rice, worldwide and organic farming is continuously gaining importance. An experiment was conducted with an objective to study weed seedbank and its management with non-chemical weed management approaches including tillage, plant density and green manuring, in organically grown basmati rice. The two-year study was conducted at research farm of Department of Agronomy, Punjab Agricultural University, Ludhiana, India during (rainy) *Kharif* season of 2017 and 2018. Tillage has differential effect on vertical weed seed distribution as the maximum number of seeds of *Dactyloctenium aegyptium* (L.) Willd., *Echinochloa colona (L.) Link*, *Trianthema portulacastrum* L. and *Cyperus iria* L. in conventional tillage (CT) was observed in upper soil layer of 0-15 cm whereas in deep tillage (DT), most of weed seeds were displaced to deeper layer (15-30 cm). The lowest weed seedbank was observed with green manuring using sunhemp (*Crotalaria juncea* L.) crop raised by sowing seed of at 50 kg/ha before the transplanting of basmati rice and incorporating sunhemp plants into soil at 40 days after seeding it). Integration of differential tillage, green manuring and increased rice plant density resulted in low biomass of *Echinochloa colona* and *Eclipta alba* than weedy check. Rice growth, yield attributes and grain yield were found statistically similar in non-chemical weed management treatments and conventional agriculture treatment.

INTRODUCTION

Basmati rice is unique among other aromatic long grain rice varieties due to its delicious taste, superior aroma and distinct flavor (Prajapati and Patel 2013). Punjab is an important rice producing state and acreages under basmati rice in the state was estimated at 6.50 lakh hectares during 2021. The Green revolution led to many folds increase in rice and wheat production, but it resulted in deteriorating soil health and decreased organic matter content. The high level of chemical inputs is increasing pollution hazard and results in further degradation of soil health. There is need to shift some area under high value crops into organic agriculture system. Organic farming is defined as the production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. Total area under organic certification process (registered under national program for organic production, APEDA) was 4.33 million ha during 2020-21. It comprises 2.66 million ha of crop land and 1.68 million hectares of wild harvest.

Weeds have become an important production constraint in the transplanted rice, in general, and failure to control weeds results in lower crop yields, and the losses may go up to 40% (Maity and Mukherjee 2008; Pandey and Bhandari 2009). The weed competition during early growth period is more damaging for rice (Rao *et al.* 2007) and weed flora emerges in several flushes during the crop growth period and therefore higher rice yields can only be achieved if weeds are controlled earlier. Tillage helps in controlling weeds by burying weed seeds and emerged seedlings by leaving a rough surface to hinder weed seed germination and expose underground parts of perennial weeds leading to their desiccation (Subbulakshmi 2007). Preparatory tillage and interculture or hoeing can be employed to control weeds under organic agriculture system. Deep tillage is mechanical soil profile modifications, which could improve the nutrient availability and affect vertical distribution of weed seeds in soil profile (Schneider *et al.* 2017). Hand weeding is slow, labour intensive and high-drudgery involving weed management method. Moreover, it can only be adopted over small area by

organic growers (De Datta and Baltazar 1996). Hand pulling of weeds in standing water or from moist field may be more helpful in reducing drudgery.

The use of green manuring is primarily important in contributions to soil fertility which also play an important role in managing weeds. Green manuring has great potential and is feasible in rice-wheat system in northern India as there is 45-60 days fallow period between wheat harvest and transplanting of rice. Due to vigorous growth of sunhemp (*Crotalaria juncea* L.) plants in initial 30-40 days, it suppressed the emergence and growth of weed plants (Duke 1981). The weed suppression by sunhemp cover crops has been minimally investigated and only recently it has received more attention. As cropping density increased, the area occupied by weeds decreased which decreased the availability of growth resources to weeds, and thereafter crop yield losses decreased (Aminpanah 2014). Specific information on weeds and growth of basmati rice due to variable green manuring levels, tillage and plant density may provide valuable indications in developing integrated weed management approaches in organic agriculture systems. The objectives of this study were to study weed seedbank and its management with non-chemical weed management approaches including tillage, plant density and green manuring in organically grown basmati rice.

MATERIALS AND METHODS

The field experiment was conducted at the research farm, Punjab Agricultural University (PAU), Ludhiana (30°56'02 N latitude, 75°52'33 E longitude) during (rainy) *Kharif* season (July-October) of 2017 and 2018. The soil of the experimental field was sandy loam, medium in organic carbon (0.42%), low in nitrogen (257.7 kg/ha), medium in phosphorus (14.6 kg/ha) and potassium (163.1 kg/ha), with soil pH of 7.1 and electrical conductivity of 0.19 dS/m. This experiment was conducted in randomized complete block design in three replicates with a total of 30 experimental plots of 7.5 × 5.0 m size.

Weed control treatments tested in this study were: conventional tillage (CT) with (+) green manuring with sunhemp sown using seed rate of 50 kg/ha and incorporated in to soil at 45 days after sowing (DAS) *i.e.* one day before puddling operation (GM 50 kg/ha) + unweeded (weeds were allowed to grow for whole crop season); CT + GM 50 kg/ha + weed free (weeds were uprooted as and when these appeared in plot); CT + GM 50 kg kg/ha + 25 % higher rice plant density + one hand pulling; deep tillage (DT) + GM 50 kg/ha + 25% higher plant density + one hand pulling; CT + GM using sunhemp seed rate of 75 kg/ha (GM 75 kg/ha) + 25% higher rice plant density + one hand pulling; DT + GM 75 kg/ha + 25% higher rice plant density + one hand pulling; CT + using sunhemp seed rate of 100 kg/ha (GM 100 kg/ha) + 25% higher rice plant density + one hand pulling; DT + GM 100 kg/ha + 25% higher rice plant density + one hand pulling; DT + GM 100 kg/ha + normal plant density + one hand weeding. One treatment of conventional agriculture was kept which was compared with weed free treatment of organic agriculture system. In conventional agriculture treatment, pesticides (herbicides, insecticides, fungicides) were used for plant protection measures and inorganic fertilizer was added as per the recommendations of PAU.

Laser land leveller was used for field levelling and it was followed by pre-sowing irrigation. The tillage treatments were given before sowing of green manure crop at variable seed rate. In CT treatments, two ploughings with disc plough were followed by planking; while in deep tillage, one ploughing with mould board plough was followed by planking. Thereafter, green manure crop sunhemp was sown with different seed rates (50, 75 and 100 kg/ha) in respective treatments. At 45 days after sowing (DAS), the sunhemp plants were incorporated one day before puddling operation. The field was filled with water and puddling was done with the help of cultivator. Nursery of basmati rice cultivar *Pusa Basmati* 1121 (days to maturity: 145 days) was transplanted at 30 days of sowing in the puddled field. In normal planting density, 33 plants/m^2 were transplanted at spacing of 20 cm × 15 cm. The plant spacing of 20 × 12 cm was adopted for 25% higher plant density (41 plants/m^2). Hand pulling of weeds was done to uproot once at 35 days of transplanting (DAT) as per treatments. Weed free plots in the experiment were kept free from weeds for whole crop season by hand weeding as and when needed. In weedy plot, weeds were allowed to grow for whole crop season. Water was kept standing continuously for two weeks in the crop after transplantation. Afterwards, irrigation was applied two days after the ponded water has infiltrated into the soil. The irrigation was stopped 15 days before crop harvest. In conventional plot, N-P-K fertilizer was applied for meeting the nutrition and plot was kept weed free with use of pre-emergence herbicide (pretilachlor). For the protection of rice crop from stem borer attack, strips of tricho-cards of *Trichogramma japonicum* and *T. chilonis* per acre were stapled at a weekly interval, starting 30 days after transplantation. For protection from leaf folder, mechanical control by passing 30 cm long coir or jute rope forward and then backwards while touching the crop canopy,

starting from 30 days after transplanting was done 2-3 times up to flowering phase.

Weed seedbank study was done by taking soil samples from each plot at 0-7.5 cm, 7.5-15 cm and 15-30 cm soil depth with the help of core sampler before performing tillage (CT or DT) and after tillage. Weed seedbank study was also done by taking soil samples at 0-7.5 cm soil depth after incorporation of green manure crop at 45 DAS. To separate weed seeds from the soil, soil samples were washed with a 0.2 mm sieve cloth. In a laboratory under ambient temperature conditions, seed samples were transferred to petri plates lined with wet filter papers. Germination was recorded for weeds at a weekly interval, until no germination occurred in the dishes. Germination tests were performed at 25-30°C temperatures in the lab conditions and sufficient conditions of moisture were maintained in the plates. The data was converted into number of viable seeds/ m^2. Weed density and biomass was recorded at 30 days of transplanting (DAT) and at harvest from each plot.

Two representative quadrats were placed randomly in each plot each of 50 × 50 cm and observations were recorded. For weed biomass, weeds were separated out group-wise (grass and broad-leaved weeds). The above ground weed biomass sample was sun dried first and then placed in oven at 65°C for 72 hrs. Plant height was measured from ground level to the base of the panicle from each plot from five randomly selected plants at harvest. Tillers were counted from third row from two spots of 50 cm row length in each plot at maturity of crop and expressed as number of tillers/m^2. To record biomass data of basmati rice crop at harvest, above ground crop biomass was collected from 50 cm length of second row from two places in each plot. The samples were then oven dried at 65°C for 72 hrs for constant dry weight and the dry biomass data were expressed in g/m^2. The yield attributes and grain yield were recorded. The prevailing market prices of inputs and outputs were used for calculating benefit-cost ratio (B:C) under different weed control treatments.

Data were analyzed in SAS version 9.4 (SAS Institute, 2018) using PROC GLM. The data were pooled from 2017 and 2018. The data on weed density, biomass and data on control of weeds were subjected to square root transformation before statistical analysis. The differences between treatment means of weed free treatment of conventional agriculture and organic agriculture system for crop growth, yield attributes and quality were also analysed using CONTRAST procedures in SAS. Differences between means were compared using the least square means (LSMEANS) procedure and Fisher's protected LSD (Least significant difference) post-hoc. Treatment effects were declared significant at p=0.05.

RESULTS AND DISCUSSION

Effect of tillage on weed seedbank

Before tillage, number of seeds of *D. aegyptium*, *E. colona*, *T. portulacastrum* and *C. iria* in 0-7.5 cm soil profile were statistically at par in both conventional (CT) and deep tillage (DT) system (**Table 1**). Similarly, at 7.5-15 cm and 15-30 cm soil depth, non-significant differences in number of weed seeds in DT and CT were observed. Further, seedbank was lower in 15-30 cm soil profile as compared to 0-15 cm soil depth. After tillage treatments, significantly more number of seeds was observed in CT than DT in upper soil layer of 0-7.5 cm. Both CT and DT resulted in similar number of weed seeds at 7.5-15 cm soil depth. At 15-30 cm depth, the maximum number of weed seeds was observed in DT which was significantly more than CT.

Effect of green manuring of *Crotalaria juncea* on weed seedbank

Crotalaria juncea grown as green manure accumulated 4.54-4.63 t/ha of biomass at the time of incorporation. Weed seedbank after incorporation of green manure was strongly affected by green manuring treatment (**Table 2**). Number of weed seeds at 0-7.5 cm soil profile was significantly more in plots in which green manuring was not done as compared to green manured plots. With each successive increase in seed rate of green manure crop from 50 kg/ha to 100 kg/ha, there was significant increase in seedbank of *D. aegyptium*, *E. colona*, *T. portulacastrum* and *C. iria* in 0-7.5 cm soil profile. More number of weed seeds were observed in green manuring with 100 kg/ha seed rate than 75 kg/ha. This may be due to less weed seed emergence and density in green manure plots sown with 100 kg/ha of seed rate as compared to lower seed rate of green manuring.

Effect of treatments on weeds in basmati rice crop

Weed flora of the experimental field consisted only of *Echinochloa colona* and *Eclipta alba* at 30 DAT and at harvest (**Table 3**). It indicated that seeds of aerobic weeds (*D. aegyptium* and *T. portulacastrum*) could not germinate in puddled fields. Water is an excellent herbicide and inhibit emergence of aerobic weeds (Rao *et al.* 2007). Weed

Table 1. Effect of different weed management treatments on weed seedbank (0-30 cm) after tillage in organically grown basmati rice (mean of 2 years)

Treatment	Weed seed density at soil depths (cm)					
	0-7.5		7.5-15		15-30	
	Before tillage	After tillage	Before tillage	After tillage	Before tillage	After tillage
D. aegyptium (no./m^2)						
Conventional tillage	219.6a	249.6b	101.2a	76.2a	6.4a	6.4a
Deep tillage	226.5a	94.3a	93.8a	88.5a	5.7a	150.5b
E. colona (no./m^2)						
Conventional tillage	177.2a	215.2b	87.2a	76.0a	8.7a	8.3a
Deep tillage	169.8a	61.5a	62.7a	79.4a	7.2a	91.4b
T. portulacastrum (no./m^2)						
Conventional tillage	90.6a	132.6b	59.2a	76.2b	8.5a	8.7a
Deep tillage	85.2a	40.5a	44.0a	47.1a	8.0a	58.3b
C. iria (no./m^2)						
Conventional tillage	113.8a	151.8b	53.5a	70.5a	5.9a	5.7a
Deep tillage	119.0a	50.2a	45.2	59.6a	5.7a	70.2b

*Mean values in each column not connected by the same letter are significantly different according to Fisher's Protected LSD (p=0.05).

Table 2. Effect of planting density of green manuring using sunhemp (*Crotalaria juncea*) on weed seedbank (mean of two years)

Treatment	Weed seedbank before transplanting of basmati rice (no./m^2)			
	D. aegyptium	*E. colona*	*C. iria*	*T. portula-castrum*
Without GM[a]	266.0d	249.4d	246.90d	217.67d
GM using sunhemp seed rate of 50 kg/ha	101.5a	83.3a	74.42a	89.23a
GM using sunhemp seed rate of 75 kg/ha	159.9b	105.9b	129.79b	113.88b
GM using sunhemp seed rate of 100 kg/ha	205.5c	198.2c	189.35c	159.15c

[a]GM- Green manure with sunhemp *(Crotalaria juncea*); *Mean values in each column not connected by the same letter are significantly different according to Fisher's Protected LSD (p= 0.05).

Table 3. Effect of tillage, green manuring and planting density on weeds in basmati rice (mean of two years)

Treatment[a *]	*Echinochloa colona*				*Eclipta alba*			
	Weed density (no./m^2)		Weed biomass (g/m^2)		Weed density (no./m^2)		Weed biomass (g/m^2)	
	30 DAT	At harvest	30 DAT	At harvest	30 DAT	At harvest	30 DAT	At harvest
CT +GM50+UW	2.4 (5)b	3.0 (8)b	2.3 (5)c	3.7 (13)c	3.2 (9)c	2.6 (6)e	3.3 (10)c	3.9 (15)c
CT +GM50+WF	1.0 (0)a	1.0 (0)a	1.0 (0)a	1.0 (0)a	1.0 (0)a	1.0 (0)a	1.0 (0)a	1.0 (0)a
CT +GM50+25% hPD+1HP	2.2 (4)b	2.8 (7)b	2.1 (4)b	2.7 (7)b	2.0 (3)b	1.9 (3)d	2.2 (4)b	2.0 (3)b
DT +GM50+25% hPD+1HP	1.7 (2)b	2.9 (8)b	2.0 (3)b	2.5 (6)b	1.9 (3)b	1.7 (2)cd	2.0 (3)b	2.2 (4)b
CT +GM75+25% hPD+1HP	2.2 (4)b	2.6 (6)b	2.0 (3)b	2.5 (6)b	1.7 (2)b	1.7 (2)cd	2.0 (3)b	2.0 (3)b
DT +GM75+25% hPD+1HP	2.00(3)b	2.7 (7)b	2.0 (3)b	2.6 (6)b	1.8 (3)b	1.4 (1)b	2.0 (3)b	2.2 (4)b
CT +GM100+25% hPD+1HP	2.2 (4)b	2.8 (7)b	1.9 (3)b	2.2 (4)b	1.9 (3)b	1.7 (2)cd	2.0 (3)b	2.0 (3)b
DT+GM100+25% hPD+1HP	2.2 (4)b	2.6 (6)b	2.0 (3)b	2.6 (6)b	1.9 (3)b	1.6 (2)bc	2.0 (3)b	1.7 (2)b
DT+GM100+1HP	1.9 (3)b	2.8 (7)b	1.9 (3)b	2.7 (7)b	1.9 (3)b	1.7 (2)cd	2.0 (3)b	1.9 (3)b
Comparison between organic and chemical weed control treatments								
Conv.+WF	1.0 (0)ns	1.0 (0)ns	1.0 (0)ns	1.0 (0)ns	1.0 (0)ns	1.0 (0)ns	1.0 (0)ns	1.0 (0)ns

[a]Mean values in each column not connected by the same letter are significantly different according to Fisher's Protected LSD. Original data of weed density and biomass was square root transformed and figures within parentheses are means of original values; *CT = Conventional tillage; DP = Deep tillage; GM50 = Green manuring using sunhemp (Crotalaria juncea) seed rate of 50 kg/ha; GM75 = Green manuring using sunhemp (*Crotalaria juncea*) seed rate of 75 kg/ha; GM100 = Green manuring using sunhemp (*Crotalaria juncea*) seed rate of 100 kg/ha; UW = Un weeded; WF = Weed free; hPD = higher rice plant density; HP = Hand pulling of weeds in water inundated field

density was significantly affected by different weed control treatments of organically grown basmati rice. Weed density of *E. colona* was the minimum in weed free treatment and it was significantly lower than other weed control treatments including unweeded at 30 DAT and at harvest. This indicated that different tillage, green manuring and plant density treatments have non-significant effect on grass weed density. The density of *E. alba* was found significantly less under CT or DT with green manuring at 50-100 kg/ha plus 25% higher plant density along with one hand pulling as compared to unweeded check at 30 DAT and at harvest. These results are in agreement with those of Gnanavel and Kathiresan (2002) who reported that green manuring in the preceding season and ploughing in-situ before puddling resulted in reduced weed density in puddled transplanted rice.

Weed biomass at 30 DAT was very less due to less growth of weed. At 30 DAT, weed growth was very less as water was kept ponded in the experimental fields continuously for 15 days of transplanting rice seedlings in puddled fields. Different weed management techniques resulted in differential effect on weed biomass (**Table 3**). The maximum weed biomass of grass (*E. colona*) and broad-leaved (*E. alba*) weeds was reported in unweeded check due to greater weed density. The minimum weed biomass of both *E. colona* and *E. alba* was observed in weed free. All weed management methods including CT or DT with 50-100 kg/ha of green manuring with 25% higher rice plant density and hand pulling resulted in significantly lower biomass of grass and broad-leaved weeds than

Table 4. Effect of tillage, green manuring and planting density on crop growth, yield attributes and yield of basmati rice (mean of two years)

Treatment[a *]	Plant height at harvest (cm)	Tillers at harvest (no./m^2)	Crop biomass at harvest (g/m^2)	Panicle length (cm)	1000 grain weight (g)	Grain yield (t/ha)			B:C
						2017	2018	Pooled	
CT +GM50+UW	83.8a	357a	1491a	25.4a	25.8a	3.079a	3.096a	3.088a	1.534
CT +GM50+WF	87.5a	399a	1621a	26.4a	26.6a	3.181a	3.185a	3.183a	2.316
CT +GM50+25% hPD+1HP	87.0a	389a	1597a	26.2a	25.9a	3.134a	3.146a	3.140a	1.947
DT +GM50+25% hPD+1HP	87.1a	387a	1599a	26.4a	26.2a	3.149a	3.148a	3.149a	1.852
CT +GM75+25% hPD+1HP	87.8a	378a	1601a	26.2a	26.0a	3.145a	3.159a	3.152a	1.893
DT +GM75+25% hPD+1HP	86.6a	390a	1592a	26.2a	26.2a	3.150a	3.164a	3.157a	1.816
CT +GM100+25% hPD+1HP	86.6a	386a	1599a	26.2a	26.3a	3.157a	3.163a	3.160a	1.968
DT+GM100+25% hPD+1HP	86.8a	389a	1607a	26.5a	26.4a	3.149a	3.165a	3.157a	1.935
DT+GM100+1HP	86.6a	389a	1607a	26.5a	26.5a	3.128a	3.143a	3.136a	2.239
Comparison between organic and chemical weed control treatments									
Conv.+WF	89.3ns	437*	1888*	27.5ns	26.9ns	3.502ns	3.566ns	3.534 ns	2.542

[a]Mean values in each column not connected by the same letter are significantly different according to Fisher's Protected LSD ($\sqrt{x+0.5}$); *CT = Conventional tillage; DP = Deep tillage; GM50 = Green manuring using sunhemp (*Crotalaria juncea*) seed rate of 50 kg/ha; GM75 = Green manuring using sunhemp (*Crotalaria juncea*) seed rate of 75 kg/ha; GM100 = Green manuring using sunhemp (*Crotalaria juncea*) seed rate of 100 kg/ha; UW = Un weeded; WF = Weed free; hPD = higher rice plant density; HP = Hand pulling of weeds in water inundated field.

unweeded check. The incorporation of green manure crops by self-decomposition was reported to reduce the weed count and weed dry matter by 60 and 43% as compared to pure crop of rice (Anitha *et al.* 2009).

Effect of treatments on rice growth and yield

The effect of various weed control treatments on plant height was non-significant and resulted in statistically similar plant height at harvest (**Table 4**). Total number of tillers and crop biomass per unit area at harvest was numerically lower in unweeded check but it was statistically similar to rest of cultural weed management practices. This indicated that no improvement in crop parameters such as plant height, number of tillers and crop biomass was observed due to cultural weed control methods in transplanted basmati rice. All cultural weed management practices including differential tillage with higher planting densities and green manuring levels from 50-100 kg/ ha resulted in statistically similar yield attributes such as panicle length and thousand grain weight. Panicle length and thousand grain weight was numerically lower in unweeded check but it was statistically similar to rest of cultural weed management practices. The effect of different management methods on the grain yield was statistically non-significant. The weed free plots of CT along with GM 50 kg/ha, and DT along with GM 100 kg/ha along with hand hoeing in basmati rice resulted in greater benefits.

Conclusion

The weed problem in puddled transplanted basmati rice under organic agriculture system may be controlled with green manuring and increasing rice plant density.

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