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Weed dynamics, grain yield and quality of basmati rice (*Oryza sativa*) under organic agriculture system

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ABSTRACT

There is a growing demand for organically produced food including basmati rice (*Oryza sativa* L.) worldwide and organic farming is continuously gaining importance. The objectives of study were to manage weeds in organically grown basmati rice with non-chemical weed management approaches including tillage, plant density and green manuring. The two year experiment was conducted at Punjab Agricultural University, Ludhiana during summer (*kharif*) of 2017 and 2018. The combinations of conventional tillage (CT) or deep tillage (DT) with green manure levels at 50, 75 and 100 kg/ha plus 25% higher plant density and one hand pulling including one weedy check and weed-free treatment were studied for weed control in basmati rice. The lowest weed density and biomass was observed in plots with green manuring at 100 kg/ha. Weed density was statistically similar in weed control treatments including CT or DT with green manuring at 50-100 kg/ha plus 25% higher plant density along with one hand pulling and it was significantly lower than weedy check. Crop growth, yield attributes and grain yield was found statistically similar in non-chemical weed management treatments and conventional agriculture treatment. Different quality parameters such as physical and milling properties of paddy and eating and cooking parameters of milled rice grains were statistically similar in differential tillage, green manuring and plant density treatments. Thus, weeds in organically grown-basmati rice may be controlled by using green manuring and higher plant density.

Keywords: Deep tillage, Green manure, Puddled transplanted, Quality, Seed rate, Weed control

Basmati rice (*Oryza sativa* L.) has a unique position in the rice world due to its price, fragrance, grain morphology, quality and other desirable traits (Prajapati and Patel 2013). The increased use of agrochemicals in conventional agriculture resulted in water and air pollution, which adversely affected crop production and also have a negative impact on health of humans and animals. Organic farming is one of the important approaches for achieving the sustainable agriculture goals which will reduce the use of various chemicals used in crop production.

Cultural practices and establishment methods determine composition of weed flora and weed management strategies (De Datta and Baltazar 1996). Tillage helped 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). 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). The vigorous growth of sunhemp (*Crotalaria juncea* L.) plants in initial 30-40 days suppressed the emergence and growth of weed plants (Duke 1981). There is direct negative correlation between increase in sunhemp plant density and reduction in weed biomass (Mosjidis and Wehtje 2011). As cropping density increased, the area occupied by weeds decreased which resulted in lower availability of growth resources to weeds, and thereafter crop yield losses decreased (Aminpanah 2014). At higher seeding rates than optimum for any crop, the crop had a competitive advantage over weeds due to earlier closed canopy, thus it helped in reducing weed growth (Ahmed *et al.* 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. This study was undertaken to investigate interactive effect of different tillage systems and green manuring levels on weed dynamics in puddled transplanted basmati rice. The effects of rice planting densities and hand pulling on weed dynamics, grain yield and quality of basmati rice grown under organic agriculture system was also studied.

MATERIALS AND METHODS

The field experiment was conducted at Research Farm,

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Department of Agronomy, Punjab Agricultural University, Ludhiana during summer (July-October) of 2017 and 2018. The experimental site is situated at 30°56'02 N latitude, 75°52'33 E longitude and soil 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 under organic cultivation. Weed control treatments for organic agriculture were conventional tillage (CT) with (+) Green manure (GM) 50 kg/ha + unweeded, CT + GM 50 kg/ha + weed free (weeds were uprooted as and when these appeared in plot), CT + GM 50 kg/ha + 25 % higher plant density (HPD) + one hand pulling (HP), deep tillage (DT) + GM 50 kg/ha + 25% HPD + HP, CT + GM 75 kg/ha + 25% HPD + HP, DT + GM 75 kg/ha + 25% HPD + HP, CT + GM 100 kg/ha + 25% HPD + HP, DT + GM 100 kg/ha + 25% HPD + HP, DT + GM 100 kg/ha + normal plant density + HP. One treatment of CT + GM 50 kg/ha + weed free under conventional agriculture was kept for the comparison purpose. In conventional agriculture treatment, pesticides were used as plant protection measures and inorganic fertilizer was added to fulfill the plant nutrition demand.

Laser land leveller was used for field levelling and it was followed by pre-sowing irrigation. Tillage for field preparation was done as per treatments. In CT treatments, two ploughings with disc plough was followed by planking; while in deep tillage, one ploughing with mould board plough was followed by planking. The tillage treatments were given before sowing of green-manure crop at variable seed rate. Sunhemp was sown with different seed rates (50, 75 and 100 kg/ha) in respective treatments. At 45 days after sowing, green-manure crop was 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 sown by broadcasting 20 kg/ha of seeds in moist soil. Nursery was ready for transplanting at 30 days of sowing and inoculated with biofertilizer before transplanting in the puddled field. Thereafter, in normal planting density treatments, 33 plants/m^2 were transplanted at spacing of 20 cm × 15 cm. The plant spacing of 15 cm × 15 cm was adopted for 25% higher plant density (44 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.

To fulfill the nutrition demand as per soil-test report, 15 t/ha (on dry weight basis) of well-decomposed farmyard manure was mixed in the soil before pre-sowing irrigation. The 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 the use of pre-emergence herbicide. For the protection of rice crop from stem-borer attack, tricho-cards were stapled at a weekly interval, starting from 30 DAT. During the evening hours, these strips were stapled evenly on the underside of the leaves at 40 spots per acre. Mechanical control of leaf folder was done by passing forward 30 cm long coir or jute rope and then backwards while touching the crop canopy, starting from 30 days after transplanting and it was done 2-3 times up to the flowering phase.

The biomass data of green-manure crop was recorded before incorporation. Weed density and biomass was recorded at 60 DAT. Two representative quadrats were placed randomly in each plot of 50 cm × 50 cm and observations were recorded. The above ground weed biomass sample was sun dried first and then placed in oven at 65°C for 72 h and dry biomass was expressed in g/m^2. Plant height was recorded from each plot from five randomly selected plants at 60 DAT. Tillers and crop biomass data were recorded from third row from two spots of 50 cm-row length in each plot at 60 DAT. Effective tillers (panicles bearing tillers) were counted from third row from two spots of 1-m row length in each plot at maturity. The number of grains/panicle was counted manually from randomly selected five panicles at harvest.

Different quality parameters of basmati rice-grain were analysed. Different physical and milling parameters of paddy such as paddy length and breadth was measured (Yadav *et al.* 2007), recovery of brown rice according to method (Khush *et al.* 1979). Cooking properties of rice grains such as cooked kernel length and breadth with millimetre scale, elongation ratio (Azeez and Shafi 1966) and water uptake ratio (Bhattacharya and Sowbhagya 1971) were measured.

Data were analyzed in SAS version 9.4 (SAS Institute 2018) using PROC GLM after pooling data of two years. The data on weed density and biomass were subjected to square-root transformation ($\sqrt{x+1}$) before statistical analysis. Differences between means were compared using the least square means (LSMEANS) procedure and Tukey HSD (honest significant difference at $\alpha = 0.05$) post-hoc test.

RESULTS AND DISCUSSION

Effect of C. juncea *on weeds*: Green-manure crop sown using seed rate of 50, 75 and 100 kg/ha accumulated statistically similar crop biomass at the time of incorporation (Table 1). With each successive increase in seed rate of green-manure crop from 50–100 kg/ha, there was significant reduction in weed density. Weed density and biomass at 40 DAS were 56–88% and 56–93%, respectively less in green manured plots (green manuring with 50–100 kg/ha) as compared to without green manured plots. Weed biomass was the minimum in green-manured plot with 100 kg/ha seed rate which was statistically similar to green manuring with seed rate of 75 kg/ha. It indicated that green manuring with 75 kg/ha have sufficient smothering effect on weeds which was more than lower seed rate of 50 kg/ha. The

Table 1 Effect of planting density of green manuring before incorporation at 40 DAS on weeds

Treatment	*Crotalaria juncea* biomass (t/ha)	Weed density (No./m^2)	Weed biomass (g/m^2)
Without green manuring (GM)		196^d	151^d
GM with 50 kg/ha	4.54^a	87^c	66^c
GM with 75 kg/ha	4.58^a	53^b	23^b
GM with 100 kg/ha	4.63^a	22^a	10^a

*Mean values in each column not connected by the same letter are significantly different according to Tukey's HSD (α= 0.05).

lower weed density and biomass under green manuring may partly be attributed to smothering effects of green manure which suppressed the weed growth. These findings are in corroboration with research findings of earlier researchers (Adler and Chase 2007, Collins *et al.* 2007, Mosjidis and Wehtje 2011).

Effect of treatments on weeds in basmati rice: Weed flora of the experimental field consisted of *Echinochloa colona* (L.) Link. amongst grass weeds and *Eclipta alba* (L.) Hassk. amongst broadleaf weeds. Ponding of water for initial 15 days of transplanting inhibited emergence of aerobic weeds and it acted as an excellent herbicide (Rao *et al.* 2007). Weed density and biomass was significantly affected by different weed control treatments of organically-grown basmati rice (Table 2). 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. All weed management methods including CT or DT with 50-100 kg/ha of green manuring with 25% higher plant density and hand pulling resulted in significantly lower biomass of grass and broadleaf weeds than unweeded check. The minimum weed biomass of grass and broadleaf weeds was reported in weedfree check and maximum weed biomass was observed in weedy check. Weed biomass of *E. colona* was statistically similar in weed control treatments including CT or DT with green manuring at 50–100 kg/ha plus 25% higher plant density along with one hand pulling and it resulted in 62-87% reduction in weed biomass as compared to weedy check. Different weed control treatments involving CT or DT with green manuring at 50–100 kg/ha plus 25% higher plant density along with one hand pulling resulted in significantly lower weed biomass (72–90% less weed biomass) than weedy treatment. These results are in line with the findings of Anitha *et al.* (2009) who reported that incorporation of green manure crops by self-decomposition reduced the weed count and weed dry matter by 60 and 43%, respectively as compared to pure crop of rice.

Effect of treatments on growth and yield of basmati rice: Different crop growth attributes of basmati rice crop such as plant height, number of tillers and crop biomass per unit area was numerically lower in unweeded check but it was statistically similar to rest of cultural weed management practices (Table 2). This indicated that different cultural weed control methods in transplanted basmati rice crop resulted in non-significant effect on crop growth attributes such as plant height, number of tillers and crop biomass. Similarly, different yield attributes such as number of effective tillers and grains per panicle was statistically similar in all cultural weed management practices. The effect of different management methods on the grain yield was statistically non-significant. The grain yield of any crop depends upon yield components like number of effective tillers, panicle production, grain weight and percentage

Table 2 Effect of tillage, green manuring and planting density on weeds, growth and yield attributes of basmati rice

Treatment	Weed data at 60 DAT#				Growth attributes at 60 DAT#			Yield attributes at harvest#		
	Echinochloa colona		*Eclipta alba*		Plant height (cm)	Tillers (No./m^2)	Crop biomass (g/m^2)	Effective tillers (No./m^2)	Grains/ panicle	Grain yield (t/ha)
	Density (No./m^2)	Biomass (g/m^2)	Density (No./m^2)	Biomass (g/m^2)						
CT +GM50+UW	2.83(7)^b	2.90(8)^c	2.83(7)^c	3.50(11)^c	71.65^a	208.5^a	880.0^a	340.5^a	58.6^a	3.088^a
CT +GM50+WF	1.00(1)^a	1.00(1)^a	1.00(1)^a	1.00(1)^a	76.40^a	301.5^a	995.5^a	373.5^a	60.7^a	3.183^a
CT +GM50+25% HPD+1HP	2.43(5)^b	1.60(2)^b	1.87(3)^b	1.90(3)^b	73.85^a	293.5^a	969.0^a	368.5^a	60.1^a	3.140^a
DT +GM50+25% HPD+1HP	2.43(5)^b	2.00(3)^b	1.87(3)^b	1.21(1)^b	74.60a	286.5^a	982.5^a	362.5^a	60.5^a	3.149^a
CT +GM75+25% HPD+1HP	2.39(5)^b	1.60(2)^b	1.87(3)^b	1.41(1)^b	74.40a	291.5^a	982.0^a	365.0^a	60.3^a	3.152^a
DT +GM75+25% HPD+1HP	2.44(5)^b	1.40(1)^b	2.00(3)^b	1.21(1)^b	75.10a	289.5^a	978.5^a	364.5^a	60.2^a	3.157^a
CT +GM100+25% HPD+1HP	2.43(5)^b	1.40(1)^b	1.73(2)^b	1.41(1)^b	76.90a	291.0^a	950.0^a	367.5^a	60.1^a	3.160^a
DT+GM100+25% HPD+1HP	2.60(6)^b	1.60(2)^b	1.73(2)^b	1.22(1)^b	77.05a	290.0^a	964.5^a	366.0^a	60.0^a	3.157^a
DT+GM100+1HP	2.60(6)^b	1.90(3)^b	1.73(2)^b	1.22(1)^b	77.60a	293.0^a	966.5^a	368.5^a	60.3^a	3.136^a
Conv.+GM50+WF	1.00(1)*	1.00(1)*	1.00(1)*	1.00(1)*	80.60*	401.5^{ns}	1070.5 ^{ns}	427.0 ^{ns}	64.4 ^{ns}	3.534 ^{ns}

#Mean values in each column not connected by the same letter are significantly different according to Tukey's HSD (α= 0.05).

Table 3 Effect of tillage, green manuring and planting density on quality parameters of basmati rice

Treatment	Physical and milling parameters of paddy[#]				Eating and cooking parameters of milled rice[#]			
	Paddy length (mm)	Paddy breadth (mm)	Brown rice (%)	Head rice (%)	Cooked kernel length (mm)	Cooked kernel breadth (mm)	Elongation ratio (mm)	Water uptake (g/g)
CT +GM50+UW	8.35[a]	1.55[a]	75.75[a]	55.05[a]	18.10[a]	2.75[a]	2.15[a]	4.70[a]
CT +GM50+WF	8.45[a]	1.60[a]	76.25[a]	55.40[a]	18.25[a]	2.75[a]	2.25[a]	4.80[a]
CT +GM50+25% HPD+1HP	8.40[a]	1.60[a]	76.25[a]	55.60[a]	18.30[a]	2.70[a]	2.20[a]	4.75[a]
DT +GM50+25% HPD+1HP	8.40[a]	1.60[a]	76.30[a]	55.50[a]	18.40[a]	2.75[a]	2.20[a]	4.75[a]
CT +GM75+25% HPD+1HP	8.45[a]	1.60[a]	76.10[a]	55.70[a]	18.25[a]	2.80[a]	2.15[a]	4.75[a]
DT +GM75+25% HPD+1HP	8.40[a]	1.60[a]	75.75[a]	55.60[a]	18.50[a]	2.80[a]	2.25[a]	4.70[a]
CT +GM100+25% HPD+1HP	8.40[a]	1.60[a]	76.10[a]	55.40[a]	18.35[a]	2.75[a]	2.15[a]	4.80[a]
DT+GM100+25% HPD+1HP	8.45[a]	1.55[a]	76.15[a]	55.75[a]	18.25[a]	2.75[a]	2.20[a]	4.70[a]
DT+GM100+1HP	8.50[a]	1.60[a]	76.00[a]	55.50[a]	18.45[a]	2.80[a]	2.20[a]	4.80[a]
Conv.+GM50+WF	8.60 [ns]	1.65 [ns]	71.65 [ns]	54.15 [ns]	18.80[*]	3.00[*]	2.40[*]	4.15[*]

[#]Mean values in each column not connected by the same letter are significantly different according to Tukey's HSD (α= 0.05).

filled grain (Ismaila *et al.* 2015). In our study, only 3% higher grain yield was observed with adoption of different weed management practices as compared to weedy check in organically-grown transplanted basmati rice.

Effect of treatments on quality of basmati rice: Paddy length and breadth was statistically similar in all organic weed control treatments (Table 2). After milling, brown and head rice recovery of basmati rice was found statistically similar amongst nine organic weed control treatments. These quality parameters are statistically similar in organically- and conventionally-grown basmati rice crop. The brown rice, milled rice and head-rice recovery was also not affected by different treatments of tillage, green manuring and plant density (Table 3). The data on cooking properties of rice grains such as cooked kernel length and breadth was statistically similar among different weed control treatments. The conversion from conventional to organic phase takes around 3-4 years, and it is estimated that quality parameters of basmati rice will improve after continuous adoption of organic agriculture practices (Zinati 2002). However, conventional agriculture treatment exhibited more cooked kernel length-breadth and elongation ratio which may be due to more availability of nutrients in conventional agriculture which lead to more lengthy grains upon cooking.

It is concluded that green manuring with *C. juncea* using 50 kg/ha and transplanting 25% higher plant density (15 cm × 15 cm) can be employed to control weeds in organically-grown basmati rice crop.

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