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Effect of organic farming on productivity and quality of basmati rice

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ABSTRACT

A study was carried out in farmers' fields in Kaithal district of Haryana during wet season 2009-10 to evaluate the impact of organic and conventional farming systems on productivity and quality of basmati rice. Yield and harvest index of Taraori basmati rice cultivated under both the practices were similar. Organic management enhanced grain elongation, kernel length, kernel breadth and their ratio compared to conventional practice. Organic management increased amylose content and slickness of grains but reduced crude protein content. Micronutrient (Fe, Mn and Zn) concentration in rice grain also increased with organic practices. No difference in aroma of basmati rice was observed under both the management practices. The yield data indicated that farmers adopting organic farming were able to get sustainable and comparable yield during nine years of organic farming. The study concluded that basmati rice can be grown organically with optimum productivity and improved grain quality.

Key words: *basmati rice, organic agriculture, productivity, cost analysis, grain quality, micronutrient*

Basmati rice is the leading aromatic fine quality rice of the world trade and fetches good export price in the international market. Priced for characteristic long-grain, subtle aroma and delicious taste. It is one of the major agricultural commodities the country exports every year to earn foreign exchange. India is the largest producer and exporter of basmati rice in the world. Taraori Basmati (CSR-30) is grown mostly for export purpose and grown exclusively in northern India. Taraori Basmati is widely cultivated for decades and salinity resistant compared to traditional cultivars, with very similar grain quality.

Organic farming has caught up during the last few years because of increased consumer awareness regarding food safety, health issues and environmental safety. Organic farming encourages the reduction of agrochemicals and promotes soil conservation principles. Extensive scientific research is being carried out worldwide to determine differences in the quality of organic food products compared to conventional in addition to other tests. Hansen (1996) showed that the type of fertilization does not affect plant quality but yield may be comparable after transition from conventional to organic farming. Although yield and crop quality depends on several factors, among which the nutrient source plays a great role, there is little information available on how basmati rice quality is affected by different organic cultivation practices. Adoption of standardized plant protection techniques like controlling pest populations through cultural practices, enhanced pest-predator balances and the use of biodegradable pesticides that have no toxicity to beneficial insects, fish, birds and mammals may attract small and marginal farmers and improve their livelihood with clean environment and financial benefits as envisioned by Eyhorn *et al.,* (2003) for Indian farmers. With this background, the present investigation was undertaken to compare the effect of organic and conventional management practices on productivity and quality of basmati rice.

MATERIALS AND METHODS

The study was conducted during wet seasons of 2009 and 2010 in randomly selected farmers' fields situated in Kaithal (Haryana), India containing 7 organic and 7 conventionally managed fields situated in six villages viz. Kahlword, Pattichoudary, Pai, Pattiafgan, Jakhouli and Keorak. A private company (Agrocel Pvt. Ltd.,) had started contract organic farming in 2000 with these farmers in Kaithal. The company had 5750 ha land during wet season of 2009 for certified organic farming. Organic and conventional fields growing 'Taraori Basmati' rice were chosen for comparative analysis in 7 farmers' fields of each system in farmers' participatory mode.

For organic cultivation farmers were trained in the beginning about different crop management practices. They were following the guidelines formulated by Agricultural and Processed Food Products Export Development Authority and International Federation of Organic Agriculture Movements. For crop nutrition farmers applied FYM enriched with *Trichoderma* (Trichocel) @ 2 kg ha^{-1}. For plant protection need based spraying of Sudocel (*Pseudomonas* formulation) and Trichoel (*Trichoderma* formulation) both at 2 % along with Neem oil (3000 ppm) was done @ 2%. Application of Biotercel (consortium of entomopathogenic fungi) and soil augmentation with neem cake at 125 kg ha^{-1} was also undertaken. Egg parasitoid *Trichogramma chilonis* @ 1, 20,000 ha^{-1} were released.

Under conventional method, farmers managed their fields through traditional system of management of rice. For crop nutrition they depended on chemical fertilizers and for insect pest control they used chemical pesticides. For control of bacterial leaf blight (BLB) farmers applied hexaconazole @ 300 ml ha^{-1} and tricyclazole @ 120 gm ha^{-1}. Application of carbendazim (50 WP) was done for control of sheath blight @ 1.35 kg a.i ha^{-1}. For control of stem borer and leaf folder, Chlorpyriphos (@1.0 L a.i ha^{-1}), Cartap hydrochloride (@ 5-7.5 kg a.i ha^{-1}), Imidachlorprid (@100 ml a.i ha^{-1}) and Fipronil (5 kg a.i ha^{-1}) were applied as and when required and in most of the cases rate of application of pesticides was higher than recommended doses.

For observations on productivity, grain and straw yield data were taken from a net plot area of 1.0 acre (0.405 ha). Harvest index was determined by dividing the economic yield by the biological yield of rice and expressed as percentage. Based on the input used in farming practices and their cost of cultivation under both the practices were taken for cost analysis and for its calculation decision support system (DSS), namely InfoRCT (Information on Use of Resource Conservation Technologies in Agriculture), a simulation model developed to quantify the input-output budget along with detailed cost:benefit analysis of the prominent options in the rice-wheat system (Pathak *et al*., 2009) was utilized.

Cooking quality or aroma was evaluated by the technique developed at IRRI (Dela Cruz, 1991). Grain elongation test was performed as per the method of Azeez and Shafi (1966). Length : breadth ratio was estimated by dividing the length of grains by the breadth before and after cooking. Amylose content of the ground sample was derived by the principle of absorption of iodine within helical coils of amylose to produce a blue-coloured complex which is measured colorimetrically. Total nitrogen in grain sample was estimated by Micro-Kjeldahl method (Yoshida *et al.,* 1976). Crude protein in grain was calculated by the multiplying nitrogen percent by the factor 6.25 (AOAC, 1960). Heavy metal (Cd, Cr and Pb) and micronutrient content (Fe, Zn, Mn, Cu) in grain samples were determined by the atomic absorption spectrophotometer (ECIL AAS4141 model) directly from the di-acid mixture of HNO_3: $HClO_4$ (3:1) digest aliquot using a nitrous oxide acetylene flame.

For disease incidence, quadrate method was followed involving of a square frame of the size 1 m^2. Ten quadrates were set at random sites both in organic and conventional basmati rice fields and the number of plants infected with disease in each quadrate were counted and results were shown in percent infection. Insect infestation was counted by visual measuring of damage caused by insects in the fields.

RESULTS AND DISCUSSION

Mean grain yield of rice was slightly lower (2%) in organic fields (2.88 t ha^{-1}) as compared to conventional fields (2.93 t ha^{-1}). However, the harvest index (HI) was comparable in both the practices (Table 1). Grain yield was found to be stabilized under organic fields. This stabilization in yield may be due to the cultivation of organic rice in the same fields over the last 9 years after transition period. Magdoff and Harold (2000) found 12% increase in crop yield with each 1% increase in soil organic matters at Michigan, USA. However, Saha *et al*. (2007) and Mader *et al.* (2002) found crop yields to be 20 % lower in the organic fields.

Organic system proved to be beneficial for farmers as it gave higher net return than the conventional system (Table 2). Organic rice growers in Kaithal, Haryana got higher revenue of their produce in terms of premium from Agrocel Pvt. Ltd. @ Rs 4500 t^{-1} of basmati rice. The net return under organic system varied between Rs 104520 to 134475 ha^{-1} while in conventional farming it ranged between Rs 52483 to 80642 ha^{-1}. Same trend was observed in cost benefit ratio. Kharub and Chander (2008) also found higher net returns (Rs 74,170) and benefit: cost ratio (2.1) under organic farming and these were significantly higher than inorganic fertilization. Ramesh *et al*. (2010) revealed that under organic farming, in spite of the reduction in crop productivity by 9.2%, net profit to farmers was higher by 22.0% compared to conventional farming. This was mainly due to the availability of premium price (20–40%) for the certified organic produce and reduction in the cost of cultivation by 11.7%.

Table 1. Effect of organic and conventional systems of rice cultivation on productivity and harvest index

Field No.	Organic farming			Conventional farming		
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index
1	2.50	3.58	0.41	3.00	4.26	0.41
2	2.75	4.11	0.40	2.50	3.82	0.40
3	2.50	3.92	0.39	3.38	4.36	0.44
4	3.13	4.24	0.29	2.55	3.16	0.45
5	3.38	4.21	0.45	2.25	3.26	0.41
6	3.25	4.26	0.43	3.00	4.57	0.41
7	3.00	4.45	0.40	3.25	4.12	0.44
Mean	2.88	4.11	0.40	2.93	3.94	0.42
SD	0.40	0.28	0.05	0.35	0.54	0.02
CV (%)	13.98	6.89	12.87	12.04	13.89	4.67

Organic cultivation exhibited higher amylose content (25.3 %) as compared to 21.7 % in conventional fields (Table 3). Tripathi and Verma (2008) also found similar type of results in their study. However, Elaine *et al.* (2007) found no apparent difference in amylose and mineral contents due to organic cultivation. Total nitrogen and crude protein content was considerably higher under inorganic (1.57 % total N, 9.87 % crude protein) compared to organic cultivation (1.38 % total N and 8.6 % crude protein) (Table 3). Higher crude protein content in inorganic basmati rice grains might be attributed to increased non-protein nitrogen content in inorganic grains due to application of more inorganic nitrogenous fertilizers under inorganic cultivation practice. Organic management resulted in reduced protein content and a change in texture that may positively affect consumer acceptance of organically grown rice in markets that prefer slicker rice. Roughness and hardness of grain, which have a weak positive correlation with protein content, also differed significantly with crop nutritiont. Observed differences in pasting and cooked textural properties of cultivars grown with different cultivation practices and were the result of differences in protein content and not due to organic management *per se*. Saha *et al.* (2007) also reported higher protein content in rice grains (8.98%)

Table 2. Cost analysis (Rs. ha^{-1}) in organic and conventional systems of rice cultivation

Field No.	Organic farming				Conventional farming			
	Total cost	Total return	Net return	Output/Input	Total cost	Total return	Net return	Output/Input
1	20730	125250	104520	6.04	21208.5	88800	67596	4.19
2	21834	138978	117144	6.36	19017.3	71500	52483	3.76
3	20730	125250	104519	6.04	22786.0	103428	80642	4.54
4	23235	120505	97269.6	5.19	19792.6	88230	68437	4.46
5	24289	135538	111248.3	5.58	18528.6	75600	57071	4.08
6	23100	157575	134475.3	6.82	21331.9	91800	70480	4.31
7	18842	129300	110457.9	6.86	22330.3	102700.0	80373.4	4.60
Mean	21823	133199	111377	6.13	20714	88866	68155.0	4.27

Table 3. Impact of organic and conventional systems of cultivation on amylose (%), total nitrogen (%) and crude protein content (%) of rice

Field No.	Organic farming			Conventional farming		
	Amylose	Total N	Crude protein	Amylose	Total N	Crude protein
1	25.14	1.18	7.35	21.20	1.54	9.65
2	24.97	1.43	8.93	20.94	1.52	9.52
3	24.73	1.51	9.45	22.80	1.51	9.43
4	24.11	1.54	9.63	21.56	1.66	10.38
5	29.40	1.15	7.20	22.01	1.58	9.88
6	24.53	1.49	9.28	20.63	1.68	10.50
7	24.28	1.34	8.40	22.90	1.56	9.75
Mean	25.31	1.38	8.60	21.72	1.57	9.87
SD	1.84	0.16	0.99	0.89	0.07	0.41
CV (%)	7.28	11.50	11.52	4.09	4.45	4.20

{Crude protein (%) -Total N (%)* 6.25}

under inorganic treatment (100:60:40 kg N, P, K ha^{-1}) as compared to organic treatments (7.78%).

There was no effect of cultivation practices on aroma of rice grain. All grain samples of Taraori basmati, from organic as well as conventional fields have been rated as having very strong aroma because the presence of volatile chemical responsible for aroma 2-Acetyl, 1-Pyrroline depend on temperature condition of the surroundings only. Elaine *et al*., (2007) also demonstrated that rice grown on land that is being transitioned into organic production was not having significant differences in cooking or processing quality.

Organic cultivation practices affected grain elongation and length: breadth ratio. Inorganic nutrients had no effect on grain elongation, kernel length (KL), breadth (KB) and KL: KB ratio. Mean values of KL: KB increased from 3.98 (before cooking) to 6.23 (after cooking) in organic fields whereas this increment was from 3.75 to 5.82 under conventional farming. Grain elongation was higher in organic fields (194.3%) over the conventional fields (190.4%) (Table 4). Increased length: breadth ratio and elongation in organic fields might be due to increased amylose content in organically grown basmati rice. Similar observations have also been reported by Quyen *et al.,* (2003). Singh and Singh (1987) reported that length-wise expansion upon cooking without increase in girth is considered a desirable trait in high quality rice.

In analysis for heavy metals in rice grains, Chromium (Cr) was detected only in one out of seven organic samples whereas cadmium (Cd) and lead (Pb) were not detected in any of the organic grain samples. Cd and Cr were detected in two out of seven inorganic grain samples and Pb was not detected in any of the grain samples (Table 5). However, concentrations of heavy metals in the samples detected were low enough to cause any hazardous health effects.

Higher concentration of iron (Fe), manganese (Mn) and zinc (Zn) was found in grains managed by organic system as compared to inorganic management, however, copper (Cu) content was same in both type of management (Table 6). Increased micronutrient

Table 4. Impact of organic and conventional systems of cultivation on length: breadth and grain elongation of basmati rice.

Field No.	Organic farming							Conventional farming						
	Before cooking			After cooking			Grain elongation	Before cooking			After cooking			Grain elongation
	KL	KB	L:B	KL	KB	L:B	(%)	KL	KB	L:B	KL	KB	L:B	(%)
1	6.6	1.7	3.9	12.7	2.0	6.3	193.2	6.5	1.7	3.8	12.4	2.1	5.9	190.9
2	6.6	1.7	3.9	12.8	2.0	6.3	194.5	6.5	1.8	3.7	12.4	2.1	5.9	910.5
3	6.5	1.6	3.9	12.7	2.0	6.3	194.0	6.5	1.7	3.8	12.4	2.2	5.8	190.2
4	6.6	1.6	4.0	12.8	2.0	6.3	194.5	6.4	1.7	3.8	12.4	2.1	5.8	191.5
5	6.6	1.6	4.1	12.7	2.1	6.2	194.2	6.5	1.8	3.7	12.4	2.1	5.9	190.8
6	6.5	1.7	3.9	12.8	2.1	6.2	195.1	6.5	1.7	3.8	12.5	2.1	5.9	191.7
7	6.6	1.7	3.9	12.7	2.1	6.1	194.4	6.5	1.7	3.8	12.4	2.2	5.7	190.4
Mean	6.6	1.6	3.9	12.7	2.0	6.2	194.3	6.5	1.7	3.8	12.4	2.1	5.8	190.9
SD	0.02	0.02	0.05	0.02	0.02	0.07	0.59	0.02	0.01	0.03	0.0	0.03	0.07	0.58
CV(%)	0.25	1.31	1.35	0.19	1.12	1.11	0.30	0.24	0.77	0.79	0.3	1.32	1.27	0.30

Table 5. Effect of organic and conventional systems of cultivation on heavy metal content (ppm) in rice grain sample

Field No.	Organic farming			Conventional farming		
	Cd	Cr	Pb	Cd	Cr	Pb
1	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	0.0003	ND	ND
3	ND	ND	ND	ND	0.003	ND
4	ND	ND	ND	0.0001	ND	ND
5	ND	ND	ND	ND	ND	ND
6	ND	0.0002	ND	ND	0.006	ND
7	ND	ND	ND	ND	ND	ND

(ND -Not Detected)

concentrations in organic grain samples over conventional system might be attributed to the application of FYM and other organic manures applied under organic cultivation practice. These results are in line with the report of Singh *et al.* (2007).

Brown spot, bacterial leaf blight (BLB), stem rot, sheath blight and blast were the major diseases infecting crop at various growth stages. Pest management strategies comprising green manuring (*Sesbania* sp.) and use of *Trichoderma* enriched farmyard manure helped in reducing sheath blight and other soil borne disease incidence considerably in comparison to chemical insecticide treatments (Fig. 1). Disease management strategies comprising green manuring and use of *Trichoderma* enriched farmyard manure helped in reducing sheath blight and other soil borne disease incidence considerably in comparison to chemical insecticide treatments due to better control of microbial pathogens. Management strategies comprising field sanitation, removal of weed hosts and spray of *Pseudomonas fluorescence* (2%) at the initial stage reduced the level of disease incidence considerably in comparison to conventional fields. There was no consistent difference in the incidence level of blast in organic fields and inorganic fields.

Table 6. Effect of organic and conventional systems of cultivation on micronutrient content (ppm) in rice grain

Field No .	Organic farming				Conventional farming			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
1	58.7	23.2	7.2	2.2	19.5	19.4	4.4	1.6
2	47	26.6	7.5	2.0	29.8	16.3	5.1	1.8
3	69.5	21.4	5.7	1.9	22.5	16.3	3.9	2.0
4	39.8	17.3	3.9	1.7	15.3	19.4	7.5	1.8
5	43.4	18.4	6.9	2.1	26.1	24.5	5.7	1.7
6	47.8	27.3	6.3	1.9	26.1	16.3	7.1	1.6
7	47.0	19.3	5.1	1.6	18.9	15.3	5.5	1.7
Mean	50.46	21.9	6.0	1.9	22.6	18.2	5.6	1.7
SD	10.21	3.94	1.28	0.21	5.08	3.20	1.32	0.14
CV (%)	20.23	17.99	21.05	11.05	22.34	17.62	23.57	8.02

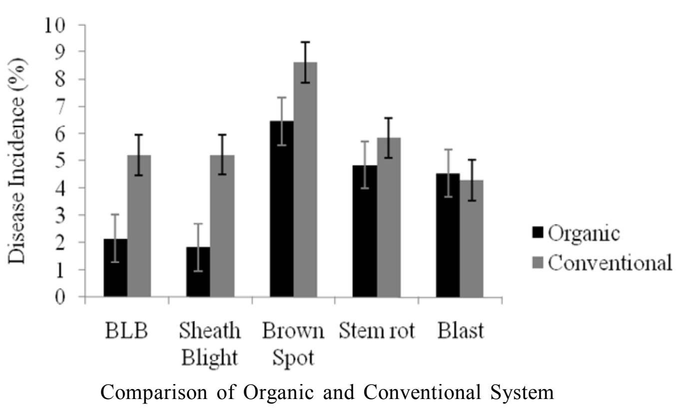

Fig 1. Effect of organic and conventional cultivation on disease incidence in basmati rice.

Among insect pests, yellow stem borer and leaf folder were key pests in organically grown rice in this region. In organic fields, management of leaf folder through dislodging by rope running, installation of pheromone traps for monitoring of yellow stem borer, sprays of neem oil and release of *T. japonicum* were able to suppress pest incidence below economic threshold level in comparison to conventional practices. Efficacy of bio-agents in rice pest management has successfully been demonstrated in several studies (Ignacimuthu, 2005). While comparing the plant protection practices it was found that conventional farmers group by and large were not risk evasive and go for spray of chemical pesticides for managing weeds, insects and plant diseases as per recommended schedule. However, in organic fields the same crop was managed by alternative eco-friendly pest management method, which mainly relied on cultural, microbial and bio-rational approaches. The findings of the present study are in line with the description of Reganold (2006) and supported our findings. The study concluded that basmati rice can be grown organically with optimum productivity and improved grain quality

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