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Contents

EDITORIAL

THE ROOTS OF ORGANIC AGRICULTURE

This issue of the Journal of Organic Systems (JOS) draws us back to the roots of organic agriculture. Four studies explore a diversity of organic fertilizers and one study examines consumer concerns.

Before the current era of unease about manufactured nanomaterials in food and farming, genetically modified organisms (GMOs), antibiotic-fattened farm animals, and synthetic pesticides, there was the issue of synthetic fertilizers. It was concerns about the replacement of traditional organic fertilizers by the then new chemical fertilizers that precipitated the early stirrings of disquiet about the prevailing direction of agriculture and which has grown into today's organic agriculture movement.

When Dr Rudolf Steiner was urged to give a series of lectures on agriculture at Koberwitz (now Kobierzyce, Poland) in 1924, those farmers were concerned about the encroachment of chemical fertilizers into their domain, and their worries were that this was compromising the fertility of their farms and the nutritiousness of their food (Wachsmuth, 1989). In his eight lectures Steiner called for a differentiated agriculture that eschewed chemical fertilizers and championed organic fertilizers. He gave his indications about how such an agriculture might develop, he established an experimental group of agriculturists to develop it, and he urged that this differentiated (and at that point un-named) agriculture was for all farmers of the world (Steiner, 1924). His death shortly after the course meant that Steiner witnessed almost none of the diffusion or development of his ideas.

Earlier, Professor F H King had written his *Farmers of Forty Centuries* (1911). He was railing against the agricultural theories and practices advocated at the time by the United States Department of Agriculture (USDA) and he was carefully documenting, with an approving eye, the traditional practices of Asian famers (Paull, 2011). He documented the cycle of farm produce travelling to the cities of China, Japan and Korea and the fastidious collection of the organic wastes of the cities and their transfer back to fertilize farms and fields.

King's championing of the merits of recycling all organic 'wastes' back as fertilizer to farms was prescient given that Haber and Bosch had only just demonstrated their process (the Haber-Bosch process) for capturing atmospheric nitrogen and converting it to ammonia (Haber, 1920). That process ushered in an era of cheap and abundant fertilizers - as well as cheap and abundant explosives. World War I facilitated the financing of massive industrial scale production of explosives using the Haber-Bosch process. The cessation of hostilities released this productive artefact of the war machine to service an untapped new market, farmers.

Albert Howard and Yeshwant Wad (1931) took up aspects of King's ideas in their book *The Waste Products of Agriculture: Their Utilization as Humus*. In quick succession, Ehrenfried Pfeiffer (1938) introduced Biodynamic agriculture to a worldwide audience, and Lord Northbourne (1940) coined the term 'organic farming' and released his manifesto of organic agriculture. All of these authors advocated for organic fertilizers. They wrote before farmers were introduced to DDT, the tasteless, indiscriminate and persistent insecticide, that subsequently expanded the focus of the organic movement to synthetic pesticides (Pfeiffer, 1958).

This issue of JOS presents research from around the world - Africa, Asia, the Middle East and Australia. Four papers in this issue reveal empirical results with actionable outcomes for using various organic fertilizer regimes on nominated crops.

Maize is the world's number one cereal grain, a staple cereal for Africa and other parts of the world. In a study from Nigeria, Fabuni & Agbonlahor (2012) present the results of the green-manuring of maize and their analysis of farming practices that can be used "by small farmers to sustainably raise income and promote soil health" without the use of synthetic fertilizers.

Tomatoes are a favourite and versatile food relished around the globe, and Iran produces around five million tonnes annually. The paper by Kochakinezhad, Peyvast, Kashi & Olfati (2012) compares production parameters for four cultivars of tomatoes subjected to various regimes of chemical and organic fertilizers. The paper presents practical fertilization regimes tailored for each cultivars to produce yields from organic fertilizers comparable to yields from chemical fertilizer, with differences in yield of 0.5% to 4.3% between the tailored organic fertilizer regime and the chemical regime.

Wheat is the world's number three cereal grain and an important ingredient of the diet within many cultures. In India it is the second most important cereal crop - after rice. Davari, Sharma & Mirzakhani (2012) present the results of the application of various combinations of organic materials and biofertilizers on aspects of wheat production including the yield and the economics of these organic fertilization regimes. As the author's state, these results "hold promise for organic wheat farming".

Lemon grass is a herb, native to India, which is popular in various Asian cuisines and is used as a tea, in cosmetics and in Ayurvedic medicine The study by Punam, Kumar, Sharma & Atul (2012) reports the positive effects of biodynamic agricultural practices and Homa farming (using agnihotra ash) accounting for increased yields (+144%, +155% compared to the control) and higher oil content (+99%, +124%).

From the very beginning, consumers have been an important element of the organic movement, expressing their concerns about the quality of their food and its relationship to their health, and voting with their wallets. Pearson (2012) presents the responses of a sample of Australian consumers to a list of nine "priority actions for improving sustainability in the food system" produced by the UK's Sustainable Development Commission (SDC) in 2009. Of these nine "priority actions" eating more organic food was rated as a mid-level priority by the SDC but as the lowest priority by the Australian respondents. Eighty seven percent of the respondents purchased organic food ('rarely' to 'always') while 54% of respondents "indicated a readiness to increase their organic consumption". If consumers are to drive the growth of organics, then harnessing that reported 'readiness' is the challenge and the opportunity for the sector.

Finally, in this issue of JOS, the book *Rudolf Steiner - Alchemy of the Everyday* (Kries, Vegesack & Althaus, 2010) is reviewed (Paull, 2012). Agriculture was the last of the 'impulses' that Steiner unleashed on the world and this book presents the myriad of his interests and presents his agriculture (which evolved to become biodynamic agriculture) in the context of the rich tapestry of his life and work.

JOS is a free, open access, peer reviewed journal. There is an ongoing call for papers on the multiplicity of aspects of the organics sector in all its diversity worldwide. For upcoming issues, JOS is keen to receive papers exploring the economics of organic food and agriculture, the achievements and challenges of manufacturing and marketing organic produce, analyses of the size of the fringe organics sector (i.e. non-certified organic), the breeding of varieties specifically suited to organic production, as well as a variety of perspectives on organic food, farming, floristry and forestry and kindred subjects.

John Paull, Editor

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THE ECONOMICS OF MAIZE PRODUCTION UNDER DIFFERENT COWPEA-BASED GREEN MANURE PRACTICES IN THE DERIVED SAVANNA ZONE OF NIGERIA

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Abstract

There is a challenge in Nigeria of how to sustainably increase land productivity in the face of land pressures, un-availability and/or high cost of fertilizers, and reduced fallow periods. The present study analyzed the economic potential of producing maize under different regimes of cowpea green manure cropping. Two different field experiments were carried out in the derived savannah zone (part of the grain belt) in Nigeria in the 2009 and 2010 planting season. The first trial evaluated the performance of succeeding maize crops grown after the application of two varieties of cowpea green manure (Drum and Oloyin), grown at different population rates. The second trial involved the agronomic and economic evaluation of succeeding maize yield using three populations of the green manure from the Oloyin under in situ mulch or tilled-in. The field experiments were simultaneously conducted under standardized growth conditions. Production data (input used and output), yield characteristics, and implicit and explicit cost data were collected. The data were analyzed using descriptive statistics and budgetary analysis. The results show that maize grain yield was significantly enhanced ($p \leq 0.05$) by using cowpea green manure. Compared to the controlled plot (no green manure) yields, the net yield was 49% and 75% higher in Experiment I, and by 65% and 69% higher in Experiment 2, in the years 2009 and 2010 respectively. A dense green manure population in the preceding year (>80,000 plants/ha) raised both yield (3,630kg) and profit (N.145,620)[1] of maize per hectare in Experiment I. The study concludes that the use of cowpea as green manure raises the economic profits from maize production. The net profit realized was found to be significantly greater ($P \leq 0.05$) than the reported mean profit (N.113,660) from the use of chemical fertilizer in the location. The study recommends that manuring maize plots with Drum variety at a minimum population of 80,000 plants/ha is the most economically profitable in maize production system that can be used by small farmers to sustainably raise income and promote soil health as an alternative to chemical fertilizers.

Keywords: Green manure, cowpea, derived savannah, gross margin.

[1] Nigerian currency: naira (NGN); NGN1000 = €5.00 = US$6.35, www.coinmill.com, October 2012.

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Introduction

Agricultural production is the mainstay of the Nigerian economy. Agriculture is the single largest contributor to the well-being of the rural poor in Nigeria, sustaining about 86 percent of rural households in the country. The sector provides employment for over 70% of the economically active population (NBS 2006), it is the major source of domestic food consumed, and it contributes about 46% to the Gross Domestic Product (Idachab 1998; NBS 2006; Agbonlahor 2010; Sanyal & Babu 2010). Because agriculture is the largest employer of all sectors (accounting for 70 percent of the work force) and labor is the main (and sometimes only) asset for the poor (Agenor et al., 2003), the agricultural sector has the greatest potential for reducing poverty in Nigeria. Improved agricultural development and growth can offer a pathway out of poverty. In the light of this view, the government (Federal, State and Local) now promotes the agricultural sector as an essential driver of economic growth and ingredient for the country's development strategy. This trust is built on the country's rich, favorable agro-ecological conditions, and the fact that most of the population live in rural areas.

A series of strategies has recently been designed that aim to accelerate agricultural growth, strengthen food security, and reduce poverty. The agricultural production landscape is dominated by resource poor farmers who cultivate food crops (intercrop) in small (< 1ha) land holdings with little or no use of purchased inputs. The dismal performance of the agricultural sector in terms of its contribution to Nigeria's yearly total revenue in the last three decades prompted the government to initiate several agricultural schemes and programs to enhance agricultural productivity in Nigeria, which include the following: the River Basin Development Authorities, the National Accelerated Food Production Project, the Agricultural Development Project, Operation Feed the Nation, the Green Revolution, the National Directorate of Food, Roads and Rural Infrastructure, the Agricultural Credit Guarantee Scheme Fund, the National Special Programme for Food Security, Root and Tuber Expansion Project, and the National Fadama program. With a burgeoning population, estimated at about 150 million, and an annual growth rate of 4.1% which increasingly limit access to natural resources, the need to shift toward an environmentally responsible and 'greener' economy has become increasingly apparent.

Maize is a dominant component of the crop production system in the derived savanna zone2. The bulk of cereal production in Nigeria is located in the derived savanna zone hence the name 'the grain belt' of the country (Ismaila et al., 2010; Kudi et al., 2011). The importance of maize is tied to its use both as a basic staple food and its use as major source of energy feedstuff in livestock feed.

Cowpea is the most popular edible legume cultivated in Nigeria. It is used as the base ingredient in the preparation of a wide range of food recipes. The agronomic potential as soil nitrogen fixer has not been fully exploited in the savanna zone.

A major limitation to maize production in Nigeria is the declining soil fertility which is exacerbated by the high cost and/or unavailability of chemical fertilizer (Ismaila et al., 2010). Achieving sustainable food security for the burgeoning population can only be achieved through the intensification of food production on existing crop land using

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[2] The derived savanna zone is a transition zone between the southern forest and northern savanna zones. It is characterized by a vegetation type composed of tall shrubby grasses and sparse hard woods.

enhanced soil nutrient, input and recycling methods (Hossner & Juo, 1999). Efforts directed towards ameliorating soil fertility problems include use of fallow land, however where fallow periods have been shortened below a critical level, the system can no longer sustain crop yield. Chemical fertilizer has also been used but it is often scarce and expensive especially at the peak demand periods (Hossner & Juo, 1999).

Green manuring is the practice of enriching the soil fertility by turning under, un-decomposed plant materials (other than crop residues), either at the location (in situ) or brought in from a different location (Pieters, 1927). Green manure is an age long practice in African, especially among farmers in Egypt and South Africa (Pieters, 1927). Research has shown that green manure can substitute for up to 60-100 kg fertilizer N/ha in the production of cereals (Ozowa, 1995). Green manure has also been found to enhance the availability of native phosphorous and other micronutrients to crops as well as improving soil aeration and organic matter (Abrol and Palaniappan, 1988; Maobe et at., 2011).

Despite these well reported benefits, green manuring is not a common soil improvement practice use by peasant farmers in Nigeria. Both economic and technical factors are responsible for this low rate of adoption. The economic factors are the more limiting. The costs of labour for establishment, maintenance and incorporation, the, seemingly zero output value, the time and land value to cultivate the manure crops are all disincentives to adoption. As opined by Agbonlahor et al., (2007), no farmer will adopt a soil amendment scheme, no matter how novel or innovative, if the economic benefits cannot be ascertained.

The present study seeks to explore the economics of producing maize under different cowpea green manure trials in derived savanna zone of Nigeria, specifically, the study objectives were to:

1. Determine the optimal cowpea variety and population density that when used as green manure will give the highest yield of maize
2. Determine the relative yield level and profitability of cultivated maize crops under green manuring.
3. Determine the significant differences in maize yield from different cowpea-based green manure schemes.

Materials and Methods

Two field trials were carried out at the Teaching Research Farm of the Federal University of Agriculture, Abeokuta, Nigeria; Latitude 7º10'N and longitude 3º26'E, between May and September 2009 and repeated March to August 2010. In experiment I, two brown cowpea varieties that are popular in the zone (Oloyin and Drum[3]) were planted at three different planting densities, each in two consecutive years, in a 2 x 3 factorial combinations arranged in a Randomized Complete Block Design (RCBD). The control plot was left uncultivated (without green manure crop). The population densities for the Drum variety in 2009 were 26,666, 40,000 and 80,000 this was doubled in 2010 by reducing the intra-row spacing. Thus the planting densities for 2010 for Drum were 53,333 (75cm x 25cm), 80,000 (50cm x 25cm), and 160,000 (25cm x 25cm)plants per hectare. Population

3 Drum is the brown big bean creeping variety while Oloyin is erect and the bean size is smaller than Drum.

densities for Oloyin were kept constant for both years at 55,555 (60cm x 30cm), 111,111 (30cm x 30cm) and 222,222 (30cm x 15cm) plants per hectare. In the second experiment, three different population densities of Oloyin variety 55,555 (60cm x 30cm), 111,111 (30cm x 30cm) and 222,222 (30cm x 15cm) plants per hectare were used in the trial. The green manure was either left as mulch materials or uprooted and incorporated in situ as green manure after six weeks of planting to take advantage of the optimum vegetative growth.

A week after application of the cowpea green manure, open pollinated maize Suwan-1-Y was planted in each of the six green manure plots per block and the control plot which serve as the seventh treatment in each of the two experiments. Both yield and economic data (prices and labour use) were collected. The yield data was analyzed using analysis of variance (ANOVA) using GenStat Discovery (edition 3). The economic data were analyzed using gross margin analysis and inferential statistics.

Results and Discussion

The results show that maize grain yield was significantly enhanced ($p < 0.05$) by using cowpea green manure. Compared to the controlled plot (no green manure) yields, the net yield was increased 49% and 75% in Experiment I and by 65% and 69% in Experiment 2, in years 2009 and 2010 respectively. The economic benefit from using different populations of two cowpea varieties as green manure in maize production is shown in Tables 1 and 2. The partial budgetary technique reveals that the Drum variety of cowpea is economically more profitable as green manure material in maize production compared to the Oloyin variety.

The second experiment analyzed the economics of the incorporation method of the manure. The cost of green manure incorporation has been reported as a major constraint to adoption as it represents a major cost item (about 13%) of the variable cost in maize production. It was therefore necessary to analyze the economic benefits under different incorporation methods. The tilled-in method and the open mulch methods were assessed (Table 3 & 4). The tilled-in method is *in situ* manual turning-in of the entire above ground parts of the green manure materials. The evaluation of the performance of the succeeding maize plant, based on method of green manure incorporation shows that tilled-in green manure plots had higher yields compared to the mulched plots. As shown in Table 5, the in situ tilled-in green manure plots resulted in a 26% increase in the gross profits from maize compared to the mulch plots. Although tilled-in and mulch incorporation of green manure yielded a positive rate of return on investment, the tilled-in incorporation gave about 2.6 times more economic return compared to the mulch incorporated plots for every naira invested.

It was observed that maize grain yield in 2009 was generally lower compared to the succeeding year (2010) in Experiment I, and across all treatments, except in the control plots. This may be due to the yield enhancing effects of the accumulated organic matter and nitrogen in the soil after the initial treatment in 2009 as well as the increase in the planting density of the Drum variety in 2010. In 2009, the Drum variety had not achieved complete ground cover at the time of incorporation. Sullivan (2003) identified late planting, poor stand establishment, and water stress as factors that limit the growth of legumes.

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Table 1: Cost and Returns Analysis for maize production using two varieties of cowpea green manure and three planting densities (Nigerian naira) (Year 2009).

Item	*Drum plots*			*Oloyin plots*			*Control*
Plot	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P0**
Cowpea population	26,666	40,000	80,000	55,555	111,111	222,222	
Maize yield (kg/ha)	1,031	1,240	1,075	1,487	1,370	1,357	752
Gross returns (N/ha)	72,170	86,800	75,250	104,090	95,900	94,990	52,640
Cost (N/ha)							
Land preparation (N/ha)	18,000	18,000	18,000	18,000	18,000	18,000	18000
Cowpea seeds(N/ha)	1,120	1,680	3,360	3,733	7,466	14,932	
Planting cowpea	9,000	9,000	9,000	9,000	9,000	9,000	
Incorporation	18,000	18,000	18,000	18,000	18,000	18,000	
Maize seed	2,760	2,760	2,760	2,760	2,760	2,760	2,760
Planting of maize	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Weeding	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Harvesting of maize	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Total variable cost	102,880	103,440	105,120	105,493	109,226	116,692	74,760
Gross Margin	-30,710	-16,640	-29,870	-1,403	-13,326	-21,702	-22,120

Table 2: Cost and Returns Analysis for maize production using two varieties of cowpea green manure and three planting densities (Nigerian naira) (Year 2010).

Item	*Drum plots*			*Oloyin plots*			*Control*
Plot	**P1**	**P2**	**P3**	**P1**	**P2**	**P3**	**P0**
Cowpea population	53,333	80,000	160,000	55,555	111,111	222,222	
Maize yield (kg/ha)	2,780	3,590	3,630	1,541	1,402	1,332	721
Gross returns (N/ha)	194,600	251,300	254,100	107,870	98,140	93,240	50,470
Cost (N/ha)							
Land preparation (N/ha)	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Cowpea seeds(N/ha)	2,240	3,360	6,720	3,733	7,466	14,932	
Planting cowpea	9,000	9,000	9,000	9,000	9,000	9,000	
Incorporation	18,000	18,000	18,000	18,000	18,000	18,000	
Maize seed	2,760	2,760	2,760	2,760	2,760	2,760	2,760
Planting of maize	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Weeding	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Harvesting of maize	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Total variable cost	104,000	105,120	108,480	105,493	109,226	116,692	74,760
Gross Margin	90,600	146,180	145,620	2,377	-11,086	-23,452	-24,290

Table 3: Cost and Returns Analysis for maize production using cowpea green manure (Oloyin), three planting densities and two different incorporation methods (Nigerian naira) (Year 2009).

Plot & treatment	P1 Tilled-in	P2 Tilled-in	P3 Tilled-in	P1 Mulch	P2 Mulch	P3 Mulch	Control
Maize grain yield(Kg/ha)	2,140	2,490	2,260	1,730	1,680	1,760	1,710
Gross returns at N. 70/Kg of grain	149,800	174,300	158,200	121,100	117,600	123,200	119,700
Variable costs							
Land preparation 20 WD/ha	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Cowpea seed 20 Kg at N.100 or N. 160 per Kg	3,733	7,466	14,932	3,733	7,466	14,932	
Planting of cowpea 10 WD	9,000	9,000	9,000	9,000	9,000	9,000	
Incorporation of green manure 20 WD	18,000	18,000	18,000	9,000	9,000	9,000	
Maize seed 23 Kg at N.120/Kg	2,760	2,760	2,760	2,760	2,760	2,760	2,760
Planting of maize 10 WD	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Weeding 1st and 2nd 40 WD	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Harvesting of maize 10 WD	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Total variable cost	105,493	109,226	116,692	96,493	100,226	107,692	74,760
Gross margin/ha	44,307	65,704	41,508	24,607	17,374	15,508	44,940

(WD = work day (N.900); P1=55,555, P2=111,111, P3=222,222 plants/ha)

The early planting of green manure in March 2010 before the rain stabilized, compared to the May planting in 2009, may account for the difference in the vegetative yield of the cowpea variety between the period. There is the need to balance the trade-off between the peak vegetative growth period and the yield of the succeeding maize plant from tilled-in manure. The buildup of organic matter was higher in the tilled-in plots than in the mulched plots. It is not unlikely that mineralization of the mulched cowpea manure would have been negatively affected by the harsh weather elements prevalent in the derived savanna (Babalola 1988; Kudi et al., 2011).

The significant difference obtained in the results of the test of differences in the succeeding maize yield between the treatments suggest that the use of the creeping and highly vegetative (high biomass yield) Drum variety can be recommended for green manure. Also, in situ tilled-in incorporation of the green manure gave a higher gross profit (N.73,287/ha) from maize than in the mulched plots (N.25,662/ha) (Table 6).

Grain yield of maize from the control plots in the experiments were generally low (mean 134.7 kg/ha) (Tables 3 & 4). Low grain yield of maize is typical on farmers' field in tropical soils due to the limiting soil nitrogen and phosphorous (Ismaila et al., 2010). This contributes to the poor and unsustainable yields associated with maize production in the derived savanna in the absence of soil amendments. The assessment of the succeeding maize performance, with different cowpea green manure variety, suggests that the use of the Drum variety (mean 2,780 kg/ha) was found to be the better legume manure material,

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due to agronomic and economic considerations, to adopt in the derived savanna rather than the Oloyin variety (mean yield 1540 kg/ha) (Tables 1 & 2).

Table 4: Cost and Returns Analysis for maize production using cowpea green manure (Oloyin), three planting densities and two different incorporation methods (Nigerian naira) (Year 2010).

Plot & treatment	P1 Tilled-in	P2 Tilled-in	P3 Tilled-in	P1 Mulch	P2 Mulch	P3 Mulch	Control
Maize grain yield(Kg/ha)	1,780	1,690	1,970	1,790	1,700	2,080	1,340
Gross returns at N.70/Kg of grain	124,600	118,300	137,900	125,300	119,000	145,600	93,800
Variable costs							
Land preparation 20 WD/ha	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Cowpea seed 20 Kg at N.100 or N. 160 per Kg	3,733	7,466	14,932	3,733	7,466	14,932	
Planting of cowpea 10 WD	9,000	9,000	9,000	9,000	9,000	9,000	
Incorporation of green manure 20 WD	18,000	18,000	18,000	9,000	9,000	9,000	
Maize seed 23 Kg at N.120/Kg	2,760	2,760	2,760	2,760	2,760	2,760	2,760
Planting of maize 10 WD	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Weeding 1st and 2nd 40 WD	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Harvesting of maize 10 WD	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Total variable cost	105,493	109,226	116,692	96,493	100,226	107,692	74,760
Gross margin/ha	19,107	9,074	21,208	28,807	18,774	37,908	19,040

(WD = work day (N.900); P1=55,555, P2=111,111, P3=222,222 plants/ha)

Table 5: Cost and Returns Analysis for different methods of green manure incorporation (Nigerian naira) (Drum variety).

Year	2009		2010	
Treatment	Tilled-in	Mulch	Tilled-in	Mulch
Cowpea density, Plants/ha	80000	80000	80000	80000
Maize grain yield	2580	1760	2855	2001
Revenue (Naira/ha)	180600	123200	199850	140070
Total variable cost (N/ha)	116210	98601	122042	113022
Gross margin (N/ha)	64390	24599	77808	32048
Returns on investment (%)	55.4	24.9	63.8	32.0

The Drum variety yielded more biomass of applied green manure than the Oloyin variety (Tables 1 & 2). A constraint to the adoption of green manure technology by resource-poor farmers, is the associated sacrifice (loss) of farm resources use in the cultivation and incorporation of the manure. With the Drum variety of cowpea, the economically recommended plant population is a minimum of 80,000 plants/ha. Cowpea population less than 80,000 plants/ha can be expected be suboptimal for the derived savanna zone, as the associated variable costs will far exceed the extra revenue from the succeeding (i.e. second year) maize cultivation. The test of difference of means (Table 6) shows that there was a significant ($p < 0.05$) difference in the gross margin of the succeeding maize plant based on cowpea variety ($t = 4.03$) and the method of incorporation of manure ($t = 3.22$).

Table 6: Test of mean difference in maize yield by treatment

Treatment	Mean Gross margin (N/ha)	t-value	Decision
Variety			
Oloyin	13,421	4.03	Reject H_o
Drum	64,922		
Method of incorporation			
Tilled-in	73,288	3.22	Reject H_o
mulch	25,662		

Summary and Conclusions

Maize grain yield was found to be enhanced by using cowpea green manure. The results of this study show that the economic benefits associated with cowpea green manuring, evident in the yield of the succeeding maize crop, far outweighs the cost of cultivating and incorporating the manure. Against the backdrop of high cost and or unavailability of inorganic fertilizer, this holds huge promise for sustaining the cropping system in the derived savannah and for promoting rural growth and development. The associated economic benefits suggest that cowpea green manure can be adopted by maize farmers to enhance yield and incomes. Planting Drum cowpea variety, at a minimum population of 80,000 plants/ha was superior in terms of financial returns to maize production. The superiority of Drum variety as a green manure crop for the cultivation of maize is greatly enhanced when established either very early before the rains stabilize or a little further into the rainy season. Given an adequate growing environment for the green manure, tilled-in incorporation of the generated biomass will result in better yield of maize crops.

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A COMPARISON OF ORGANIC AND CHEMICAL FERTILIZERS FOR TOMATO PRODUCTION

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Abstract

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and versatile vegetables in the world, and organic production with a high yield and desirable quality is a target of many producers. The effect of four different fertilizers (chemical, municipal solid waste compost, cattle manure, and spent mushroom compost) on four commercial tomato cultivars (Redstone, Flat, Peto Pride and Chief) was assessed in this research. The highest yield was obtained with the Chief cultivar when fertilized with chemical fertilizer and the lowest value was obtained with Peto Pride fertilized with 20 tonnes per hectare (t/ha) of cow manure. The difference between the two classes of fertilizers (organic and chemical) was not very high so that organic fertilizers are competitive and may be a suitable replacement for chemical fertilizer. According to our results, to achieve maximum yields with organic fertilizers, 20 t/ha of spent mushroom compost can be recommended for the Redstone cultivar, 30 t/ha of cow manure for Flat, 300 t/ha of municipal solid waste compost for Peto Pride, and 300 t/ha of municipal solid waste compost or 20 t/ha of spent mushroom compost can be recommended for the Chief cultivar. These recommended organic fertilizing regimes achieved cultivar yields comparable to the chemical fertilizer treatments, achieving a yield of 98.4% for Redstone, 99.5% for Flat, 97.6% for Peto Pride, and 95.7% for Chief.

Keywords: Tomato, municipal solid waste compost, cattle manure, cow manure, spent mushroom compost, organic agriculture.

Introduction

Iran has a total annual production of 4,826,396 tonnes of tomatoes and ranks seventh in the world for tomato production. Conventional production uses chemical fertilizers mainly urea, superphosphate and potash. However, the continuous use of chemical fertilization leads to deterioration of soil characteristics and fertility, and may lead to the accumulation of heavy metals in plant tissues which compromises fruit nutrition value and edible quality (Shimbo et al., 2001). Chemical fertilizer also reduces the protein content of crops, and the carbohydrate quality of such crops also gets degraded (Marzouk & Kassem, 2011). Excess potassium content on chemically overfertilized soil decreases Vitamin C, carotene content and antioxidant compounds in vegetables (Toor et al., 2006). Vegetables and fruits grown on chemically overfertilized soils are also more prone to attacks by insects and disease (Karungi et al., 2006).

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Although chemical fertilizers have been claimed as the most important contributor to the increase in world agricultural productivity over the past decades (Smil, 2001), the negative effects of chemical fertilizer on soil and environment limit its usage in sustainable agricultural systems (Peyvast et al., 2008). Weakening soil quality requires increasing inputs to maintain high yields. This, in turn, threatens future food security and raises production costs for often already poor farmers.

Research comparing soils of organically and chemically managed farming systems have recognized the higher soil organic matter and total nitrogen (N) with the use of organic agriculture (Alvarez et al., 1988; Drinkwater et al., 1995; Reganold, 1988). Soil pH becomes higher, plant-available nutrient concentrations may be higher, and the total microbial population increases under organic management (Clark et al., 1998; Dinesh et al., 2000; Reganold, 1988; Lee, 2010).

Organic fertilizers, which mainly come from agricultural waste residues such as cow manure and spent mushroom compost or municipal solid waste compost (MSWC), are often identified as suitable local organic fertilizers. These contain high levels of nutrients, e.g. N and P and high amounts of organic matter (Peyvast et al., 2007, Peyvast et al., 2008; Olfati et al., 2008; Shabani et al., 2011). According to these studies, the usage of MSWC can be an effective alternative to chemical fertilizers. However, the apparent deficiency of an adequate supply of plant-available N from organic fertilizer, resulting from a slow rate of mineralization, makes crop yields in fields treated with organic fertilizer lower than in those treated with chemical fertilizers (Blatt, 1991; Lee, 2010). Organic fertilizers should be used in appropriate amounts to achieve suitable yield and quality.

The aim of this study was to determine appropriate amounts of different organic fertilizers in tomato fields to achieve maximum yield and quality.

Materials and methods

The tomato plants (*Lycopersicon esculentum* Mill. Cvs. Chief, Redstone, Peto Pride and Flat) were grown in a research field at the University of Guilan (altitude 7 meters below mean sea level, 37°16′N, 51°3′E). The experiment was arranged in a randomized block design and comprised three different fertilizers, namely cow manure (20, 30 and 40 t/ha), spent mushroom compost (10, 20 and 30 t/ha), and municipal solid waste compost (100, 200 and 300 t/ha), as well as chemical fertilizer (150N-100P-300K kg/ha) and unfertilized plots as control. Each treatment had three replications with 10 plants in each replicate. After sowing, seedlings were transferred to a potting medium containing peat and cattle manure (1:1 v/v) and irrigated when it was necessary by tap water. Seedlings were transplanted with a distance of 0.5 m × 0.5 m between rows and plants, respectively.

The soil was a clay loam, pH 7.2, containing total N (1.2%), total C (0.6%), a C/N ratio of 0.5, with 12, 68, 167 mg/kg of Ca, P, and K, respectively, and with an EC of 0.09 dS/cm. Compost was purchased from Bazyafte Zobaleh Company in Rasht, Iran, and analyzed before using in the field (Table 1). The soil was prepared by ploughing and disking. Fruits were harvested manually when they had reached maturity stage 5 (Californian Tomato Commission, 2002) and total yield was calculated on a hectare basis. Chopped fruit tissues were placed in a forced air drying oven at 75°C for 48 h for dry matter determination.

Table 1. Chemical and physical characteristics of cow manure, municipal solid waste compost and spent mushroom compost.

Type of organic fertilizer	Cow manure	Municipal solid waste compost	Spent mushroom compost
Total-N (g/kg)	28.6	25.6	21
Organic-C (g/kg)	411.7	500	645
C:N ratio	14.4	19.5	30.7
Total-P (g/kg)	9.5	15.8	18
EC (dS/m)	8.8	4.9	10
pH	8.8	7.1	6.8
Ca (g/kg)	29.6	5.32	28
Mg (g/kg)	4	3.3	18
K (g/kg)	5	6.8	20

Phosphorus, calcium and magnesium (P, Ca & Mg) in fruits and leaves were measured by spectrometry (JENWAY 6105 U.V/V) (Elliot & Dempsey, 1991). Potassium (K) was determined by flame photometer (Latiff et al., 1996). One gram of dry matter was ashed at 550°C for 6 h (Gbolagade et al., 2006).

Data were subjected to analysis of variance in SAS (SAS Inc., Cary, N.C.). If interactions were significant they were used to explain the data. If interactions were not significant, means were separated with Tukey test.

Results

ANOVA determined that cultivar, type of fertilizer and their two way interactions had a significant effect on all measured characteristics of tomato (Tables 2-4). Due to the significant interactions between type of fertilizer and cultivar we were unable to propose an overall preferred type of fertilizer for all cultivars, but instead we have nominated one or several preferred fertilizer types for each cultivar.

Table 2. ANOVA table of cultivars and fertilizers on tomato total yield and yield characteristics.

		Mean square				
S.O.V.	d.f.	Number of fruit per plant	Fruit length (mm)	Fruit width (mm)	Mean of fruit weight (g)	Total yield (t/ha)
Block	2	23.92**	1.1 ns	5.55 ns	1.62 ns	0.7 ns
Cultivar (C)	3	271.74**	245.4**	1,504.35**	15,054.43**	358.8**
Fertilizers (F)	10	48.15**	155.6**	87.74**	1,374.84**	25.4**
C*F	30	11.54**	26.67**	27.22**	429.19**	7.2**
Error	86	1.91	0.98	2.06	1.18	1.49
C.V. (%)		14	1.77	2.89	1.33	0.24

(S.O.V. = Sources of variation; d.f. = degrees of freedom; C.V. = coefficient of variation; ns, **, *: non significant, and significant at $P \leq 0.01$ and $P \leq 0.05$ respectively)

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Table 3. ANOVA table of cultivars and fertilizers on tomato fruit and leaves dry matter and ash.

		Mean square			
S.O.V.	d.f.	Fruit dry matter (%)	Leaf dry matter (%)	Fruit ash (%)	Leaf ash (%)
Block	2	1.64 ns	0.03 ns	0.76 ns	0.03**
Cultivar (C)	3	5.01**	9.07**	6.83**	248.41**
Fertilizers (F)	10	1.77**	4.23**	2.43**	47.6**
C*F	30	1.36**	5.43**	1.29**	24.53**
Error	86	0.61	0.12	0.17	0.003
C.V. (%)		11.08	2.02	9.27	0.46

(S.O.V. = Sources of variation; d.f. = degrees of freedom; C.V. = coefficient of variation; ns, **, *: non significant and significant at P≤0.01 and P≤0.05 respectively)

Table 4. ANOVA table of cultivars and fertilizers on tomato fruits and leaves P, K, Ca and Mg.

		Mean square							
S.O.V.	d.f.	P (mg·100 g FW)		K (mg·100 g FW)		Ca (mg·100 g FW)		Mg (mg·100 g FW)	
		Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf
Block	2	177.02**	25.12 ns	37.42**	1009.8**	348.2**	11.72 ns	0.14 ns	1.01 ns
Cultivar (C)	3	352.92**	11,503.36**	62,985.86**	19,599**	184.4**	734.33**	50.83**	272.4**
Fertilizers (F)	10	257.75**	10,358.88**	15,075.3**	19,122**	385.7**	2,477.17**	233.64**	434.78**
C*F	30	112.95**	3,600.61**	17,387**	6,797**	134.8**	763.77**	72.87**	139.4**
Error	86	12.68	15.54	7.49	50.06	18	4.11	3.62	0.69
C.V. (%)		10.69	2.75	0.73	3.47	10.2	3.24	5.4	4.48

(S.O.V. = Sources of variation; d.f. = degrees of freedom; C.V. = coefficient of variation; ns, **, *: non significant and significant at P≤0.01 and P≤0.05 respectively)

The interaction between cultivar and type of fertilizer on number of fruit per plant showed that the highest number of fruit per plant was obtained in Flat cultivar fertilized with chemical fertilizer and the lowest value was obtained with Peto Pride fertilized with 30 t/ha of spent mushroom compost. ‘Red stone’ showed the highest number of fruit per plant when fertilized with 100 t/ha of municipal solid waste compost, while Flat brought on the highest number of fruit per plant when it was fertilized with chemical fertilizer. The highest number of fruit per plant by other cultivars was obtained when they were fertilized with 200 t/ha of municipal solid waste compost (Table 5).

Table 5. Influence of different cultivars and fertilizers interaction on tomato total yield and yield characteristics.

Cultivars	Fertilizers	Number of fruit per plant	Fruit length (mm)	Fruit width (mm)	Mean of fruit weight (g)	Total yield (t/ha)
Redstone	Control	15±0.7	54±0.01	42±0.1	59±0.5	41±0.6
Redstone	Chemical fertilizer	11.87±0.5	56±0.3	43±0.6	65.5±0.2	44±0.01
Redstone	10 t/ha SMC	15.66±0.4	59±0.3	42±0.2	66.5±0.5	42.5±0.2
Redstone	20 t/ha SMC	18.27±0.6	55±0.3	43±0.6	63.5±0.4	43.3±0.2
Redstone	30 t/ha SMC	13.25±0.5	60±0.6	43±0.4	69.7±0.5	41.3±0.04
Redstone	20 t/ha CM	13±0.7	56±0.5	43±0.9	62.5±0.6	41.3±0.03
Redstone	30 t/ha CM	11.41±0.5	56±0.6	45±0.5	63.5±0.6	41.4±0.2
Redstone	40 t/ha CM	14.19±0.4	59±0.4	46±0.2	75.3±0.5	41.5±0.1
Redstone	100 t/ha MSWC	19.58±0.3	57±1.2	40±0.5	58.2±0.5	42.4±0.3
Redstone	200 t/ha MSWC	14.5±0.3	50±0.5	41±0.2	55±0.2	42.5±0.2
Redstone	300 t/ha MSWC	19.52±0.3	44±0.2	39±0.6	38±0.5	41.3±0.2
Flat	Control	11.58±0.5	55±0.4	51±0.3	81.4±0.3	39.6±0.5
Flat	Chemical fertilizer	23.25±0.3	56±0.7	51±0.4	86±0.5	43.7±0.4
Flat	10 t/ha SMC	12.83±0.1	51±0.5	49±1	74.3±0.5	41.7±0.01
Flat	20 t/ha SMC	15±1.7	56±0.7	52±0.9	85.6±0.5	42.2±0.3
Flat	30 t/ha SMC	11.35±1.1	60±0.5	51±0.6	90.7±0.2	42.5±0.1
Flat	20 t/ha CM	11.5±0.3	53±0.6	53±0.4	86.7±0.3	41.4±0.4
Flat	30 t/ha CM	11.91±0.7	54±0.1	51±0.6	79.6±0.2	43.5±0.2
Flat	40 t/ha CM	13.52±0.3	52±0.3	52±0.9	78.5±0.6	42.8±0.4
Flat	100 t/ha MSWC	17.38±1.2	56±0.4	48±0.7	82.9±0.9	43±0.01
Flat	200 t/ha MSWC	19.5±1.1	51±0.5	47±0.5	89.5±0.5	43±0.01
Flat	300 t/ha MSWC	17.4±1.1	46±0.7	44±0.5	65.7±0.7	43±0.2
Peto Pride	Control	8±0.1	66±0.5	68±0.6	154.3±0.4	39.4±0.1
Peto Pride	Chemical fertilizer	9±0.6	62±0.3	63±1.2	127.9±0.3	46.6±0.2
Peto Pride	10 t/ha SMC	8.5±0.6	60±0.6	58±0.2	95.8±0.6	43.3±0.4
Peto Pride	20 t/ha SMC	10.5±0.6	60±0.5	57±2.8	108.5±0.7	39.6±0.1
Peto Pride	30 t/ha SMC	7.75±0.1	65±0.6	54±1.1	112.3±0.6	39±0.005
Peto Pride	20 t/ha CM	8.5±0.3	66±0.4	62±1	127.2±0.6	37.5±0.2
Peto Pride	30 t/ha CM	10±0.5	60±0.2	57±0.9	106.9±0.8	42±0.04
Peto Pride	40 t/ha CM	8.41±0.4	63±0.4	58±1.4	117.6±0.4	42.4±0.2
Peto Pride	100 t/ha MSWC	10.16±0.6	58±0.5	62±0.4	137±0.2	39±0.3
Peto Pride	200 t/ha MSWC	12.16±0.6	48±0.5	46±0.2	85±0.4	40.5±0.2
Peto Pride	300 t/ha MSWC	8.41±0.8	52±0.3	58±0.2	76.5±0.7	45.5±0.3
Chief	Control	14.83±1	56±0.5	52±0.5	77.3±0.3	48.3±0.1
Chief	Chemical fertilizer	15.83±0.6	56±0.5	47±0.4	81±0.2	53±0.5
Chief	10 t/ha SMC	16.27±0.4	54±0.6	46±0.3	67.7±0.6	48±0.5
Chief	20 t/ha SMC	14.75±0.8	56±0.2	50±0.3	78.3±0.3	50.5±0.1
Chief	30 t/ha SMC	15.66±0.8	55±0.6	48±0.6	76.3±0.6	47.9±0.2
Chief	20 t/ha CM	13.66±0.2	61±0.2	50±0.6	84±0.6	46.8±0.2
Chief	30 t/ha CM	13.41±1.7	53±0.4	49±0.2	72.5±1.1	48.8±0.04
Chief	40 t/ha CM	13.16±0.2	60±0.6	50±0.6	86.4±0.6	45±0.4
Chief	100 t/ha MSWC	15.5±1.1	51±0.2	45±0.2	62.3±0.9	46.4±0.2
Chief	200 t/ha MSWC	16.66±1.5	51±0.4	45±0.8	62.6±0.2	47.5±0.3
Chief	300 t/ha MSWC	16.58±2	51±0.6	45±0.4	67.8±0.3	50.7±0.4

(SMC = Spent mushroom compost, CM = cow manure, MSWC = municipal solid waste compost)

The interaction between cultivar and type of fertilizer on fruit length showed that the longer fruit was obtained in Peto Pride fertilized with 20 t/ha of cow manure and control, and the lowest value was obtained in Redstone fertilized with 300 t/ha municipal solid waste compost. ‘Red stone’ and Flat cultivars showed the highest fruit length when fertilized with 30 t/ha spent mushroom compost. Chemical fertilizer didn’t have any positive effect on Chief cultivar (compared to the control), and decreased Peto Pride fruit length (compared to the control). Chief cultivar showed the highest fruit length when fertilized with 20 t/ha cow manure (Table 5).

The highest fruit width was obtained in Peto Pride cultivar without any type of fertilizer (control), and the lowest value was obtained in Redstone fertilized with 300 t/ha of municipal solid waste compost. Redstone and Flat have showed the highest fruit length when fertilized with 40 and 20 t/ha of cow manure respectively. For the cultivar Chief all of the fertilizers decreased the fruit width, compared to the control (Table 5).

The highest mean of individual fruit weight was obtained in Chief without any type of fertilizer (control), and the lowest value was obtained with Redstone fertilized with 300 t/ ha of municipal solid waste compost. ‘Red stone’ and Chief showed the highest fruit length when fertilized with 40 t/ha of cow manure. For Peto Pride fertilizers reduced fruit weights, compared to the control (Table 5).

The highest yield was obtained in Chief when fertilized with chemical fertilizer and the lowest value was obtained in Peto Pride fertilized with 20 t/ha of cow manure. Between different organic fertilizers the higher yield was obtained in Redstone and Chief when fertilized with 20 t/ha spent mushroom compost. The yield of Flat cultivar peaked when fertilized with 30 t/ha cow manure or chemical fertilizer. Similarly, the yield of Peto Pride peaked when fertilized with 300 t/ha municipal solid waste compost or chemical fertilizer (Table 5).

Interaction between cultivar and type of fertilizer on dry matter percent in tomato fruit showed that the highest dry matter was obtained in Peto Pride fertilized with 200 t/ha of municipal solid waste compost, and the lowest value was obtained in Chief fertilized with 40 t/ha of cow manure. ‘Red stone’ showed the highest dry matter of fruit when fertilized with 10 t/ha of spent mushroom compost, while chemical fertilizer decreased the dry matter in fruit. Flat showed the highest dry matter percent in fruit when fertilized with municipal solid waste compost. The highest dry matter percent in fruit was obtained by Peto Pride and Chief when fertilized with 200 and 100 t/ha of municipal solid waste compost respectively (Table 6).

The interaction between cultivar and type of fertilizer on dry matter percent in tomato leaves showed that the highest dry matter was obtained in Peto Pride fertilized with chemical fertilizer, and the lowest value was obtained in Chief when fertilized with 40 t/ha of cow manure. All types of fertilization decreased Redstone leaves dry matter. Flat cultivar showed the highest dry matter percent in leaves when fertilized with 20 t/ha of cow manure. Chemical fertilizer increased Peto Pride leaves dry matter while organic fertilizers didn’t show any significant effect. In contrast to the Peto Pride response to different types of fertilizer, Chief leaves dry matter decreased with chemical fertilizer and 200 t/ha of municipal solid waste compost achieved the highest dry matter percent in tomato leaves (Table 6).

Table 6. Influence of different cultivars and fertilizers on tomato fruit and leaves dry matter and ash.

Cultivars	Fertilizers	Fruit dry matter (%)	Leaf dry matter (%)	Fruit ash (%)	Leaf ash (%)
Redstone	Control	6.9±0.2	18.2±0.03	3.7±0.1	11.9±0.05
Redstone	Chemical fertilizer	6.2±0.1	17.4±0.04	4.3±0.1	9.8±0.1
Redstone	10 t/ha SMC	8.6±0.6	17±0.05	3±0.5	9.7±0.005
Redstone	20 t/ha SMC	6.8±0.5	17.4±0.005	2.6±0.2	7.8±0.005
Redstone	30 t/ha SMC	7.5±0.3	16.9±0.05	4.5±0.03	4±0.002
Redstone	20 t/ha CM	7.6±0.5	17±0.005	3.8±0.1	15.8±0.05
Redstone	30 t/ha CM	7.2±0.3	17.9±0.05	4.5±0.2	8.1±0.005
Redstone	40 t/ha CM	6.6±0.2	17.3±0.05	4.3±0.1	11.9±0.005
Redstone	100 t/ha MSWC	7.4±0.5	16.7±0.04	4.5±0.1	5.9±0.005
Redstone	200 t/ha MSWC	6.6±0.2	17.7±0.05	4.4±0.1	17.5±0.05
Redstone	300 t/ha MSWC	7.6±0.6	16.6±1	4.5±0.1	11.3±0.005
Flat	Control	6.54±0.2	18.56±0.03	4.7±0.05	17.2±0.005
Flat	Chemical fertilizer	6.7±0.5	17.29±0.05	3.2±0.03	13.7±0.005
Flat	10 t/ha SMC	6.8±0.3	16.69±0.04	5.2±0.05	17.9±0.01
Flat	20 t/ha SMC	6.26±0.5	17.45±0.03	4.2±0.1	15.6±0.005
Flat	30 t/ha SMC	6.62±0.4	17±0.05	4.3±0.02	11.6±0.005
Flat	20 t/ha CM	6.19±0.4	21.87±0.05	3.8±0.1	19.6±0.01
Flat	30 t/ha CM	6.2±0.05	17.96±0.03	4.3±0.2	20.7±0.02
Flat	40 t/ha CM	6.64±0.6	17.26±0.1	2.8±0.3	17.9±0.01
Flat	100 t/ha MSWC	7.29±0.1	17.14±0.1	5.5±0.05	17.5±0.05
Flat	200 t/ha MSWC	7.15±0.5	17.85±0.005	4.6±0.05	17.9±0.01
Flat	300 t/ha MSWC	7±0.3	16.4±0.005	4.3±0.1	13.7±0.005
Peto Pride	Control	6.92±0.04	17.42±0.02	5.6±0.2	10.5±0.005
Peto Pride	Chemical fertilizer	7.69±0.4	23.9±0.01	4.5±0.1	8.6±0.005
Peto Pride	10 t/ha SMC	7±0.4	17.1±0.01	3.8±0.1	15±0.005
Peto Pride	20 t/ha SMC	6.43±0.5	18.61±0.02	4.6±0.04	7.9±0.005
Peto Pride	30 t/ha SMC	6.98±0.1	17.36±0.4	5.5±0.2	10±0.005
Peto Pride	20 t/ha CM	7.61±0.05	17.99±0.1	3.5±0.2	10±0.01
Peto Pride	30 t/ha CM	6.83±0.6	18.31±0.004	4.9±0.4	11.7±0.01
Peto Pride	40 t/ha CM	8.52±0.7	17.92±0.1	4.3±0.2	10±0.005
Peto Pride	100 t/ha MSWC	7.89±0.5	18.04±0.01	6±0.2	8±0.005
Peto Pride	200 t/ha MSWC	9.31±0.2	17.28±0.005	5.1±0.05	15.3±0.005
Peto Pride	300 t/ha MSWC	7.67±0.05	17.37±0.004	4.2±0.05	10±0.005
Chief	Control	6.37±0.3	17.34±0.02	5.5±0.2	16.3±0.005
Chief	Chemical fertilizer	7.68±0.4	16.54±0.03	5.3±0.05	12±0.005
Chief	10 t/ha SMC	6.65±0.2	17.63±0.005	5.4±0.1	17±0.005
Chief	20 t/ha SMC	5.84±0.4	17.13±0.05	4.4±0.1	16±0.005
Chief	30 t/ha SMC	6.85±0.2	16.17±0.03	5.2±0.3	13±0.005
Chief	20 t/ha CM	7.78±0.5	16.96±0.005	4.7±0.5	14±0.01
Chief	30 t/ha CM	6.79±0.2	16.79±0.01	3.8±0.03	11±0.005
Chief	40 t/ha CM	5.62±0.2	15.6±0.02	4.7±0.1	14±0.005
Chief	100 t/ha MSWC	8.29±0.6	17.58±0.03	4.8±0.5	15.7±0.01
Chief	200 t/ha MSWC	6.57±0.4	18.11±0.004	5.6±0.05	13.7±0.005
Chief	300 t/ha MSWC	6.42±0.5	17.4±0.03	5.5±0.4	13±0.02

(SMC = Spent mushroom compost, CM = cow manure, MSWC = municipal solid waste compost)

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The interaction between cultivar and type of fertilizer on percent of ash in tomato fruits showed that the highest ash was obtained in Peto Pride and Redstone cultivars when fertilized with 100 t/ha of municipal solid waste compost (while Peto Pride also responded equally well on this measure with 20 t/ha of SMC, 30 t/ha of CM, and 300 t/ha of MSWC). The lowest value was obtained in Redstone fertilized with 20 t/ha of spent mushroom compost. For the Flat fruits, 100 t/ha of MSWC or 10 t/ha spent mushroom compost achieved the greatest increases in the ash percent, compared to the control and chemical fertilizer. For `Peto Pride` and Chief fruits, the highest ash percent was obtained with 100 and 200 t/ha of municipal solid wastes compost respectively (Table 6).

The highest ash percent of leaves was obtained in Flat fertilized with 30 t/ha of cow manure, and the lowest value was obtained in Redstone fertilized with 30 t/ha of spent mushroom compost. The highest ash percent in the Redstone cultivar leaves was obtained when fertilized with 20 t/ha of cow manure or 200 t/ha of MSWC. The highest ash percent in Flat and Chief cultivar leaves were obtained when fertilized with 30 t/ha of cow manure and 10 t/ha of spent mushroom compost, respectively. The highest ash percent in Peto Pride cultivar leaves was obtained when fertilized with 10 t/ha of spent mushroom compost and 200 t/ha of MSWC. Chemical fertilizer decreased the leaf ash percent in all varieties, compared to the controls (Table 6).

Interaction between cultivar and type of fertilizer on P content in tomato fruits and leaves showed that the highest P content were obtained in the Peto Pride cultivar fertilized with 200 t/ha of MSWC, and the Chief cultivar when fertilized with chemical fertilizer. The lowest values were obtained in Flat cultivar fertilized with 20 t/ha of spent mushroom compost, and Chief cultivar fertilized with 20 t/ha of cow manure. In the Redstone cultivar, the highest P content in fruits and leaves were obtained when fertilized with 20 and 40 t/ha of cow manure respectively, while in the Flat cultivar the highest P content in fruits and leaves were obtained when fertilized with 20 and 30 t/ha of cow manure respectively. In the Peto Pride and Chief cultivars, the highest P content in leaves were obtained when fertilized with chemical fertilizer, while the highest amount in fruit were obtained when fertilized with 200 and 100 t/ha of MSWC respectively (Table 7).

The interaction between cultivar and type of fertilizer on K content in tomato fruits and leaves showed that the highest K content were obtained in the Redstone cultivar fertilized with 200 t/ha of municipal solid waste compost, and Chief cultivar when fertilized with chemical fertilizer, and the lowest values were obtained in the Flat cultivar fertilized with chemical fertilizer, and the control. The reaction of cultivar to different type of fertilizer was quite varied (Table 7).

The highest Ca and Mg in tomato fruit was obtained from Chief cultivar with no fertilizer, and Peto Pride cultivar fertilized with 200 t/ha of MSWC. There was not any significant correlation between element content in tomato leaves and tomato fruits (Table 8).

Table 7. Influence of different cultivars and fertilizers on tomato fruits and leaves P and K.

Cultivars	Fertilizers	P (mg·100 g FW)		K (mg·100 g FW)	
		Fruit	Leaf	Fruit	Leaf
Redstone	Control	27.2±1.7	113±0.2	317±0.4	159±1.7
Redstone	Chemical fertilizer	28.2±1	151±0.2	371±0.1	201±0.9
Redstone	10 t/ha SMC	38±2.3	160±3	422±0.2	221±0.5
Redstone	20 t/ha SMC	37±1.8	156±0.01	393±0.3	224±2
Redstone	30 t/ha SMC	35±3	154±0.5	449±0.2	206±3
Redstone	20 t/ha CM	46±0.5	170±0.01	452±0.3	194±1.7
Redstone	30 t/ha CM	36.7±2.7	122±0.3	406±0.01	193±3
Redstone	40 t/ha CM	37.5±0.6	211±0.9	359±0.3	248±3
Redstone	100 t/ha MSWC	30±1.5	146±0.6	309±0.9	182±2.8
Redstone	200 t/ha MSWC	34±0.3	140±0.4	598±0.3	185±3
Redstone	300 t/ha MSWC	27±1.7	148±3	328±0.4	200±3
Flat	Control	27.5±1.8	108±0.2	329±0.2	97±1.5
Flat	Chemical fertilizer	26±2.1	185±0.7	225±0.1	275±1.2
Flat	10 t/ha SMC	32.5±0.8	94±0.2	369±0.7	174±1.5
Flat	20 t/ha SMC	18±3	101±0.2	355±0.4	184±2
Flat	30 t/ha SMC	26±1.3	169±0.6	303±0.7	224±3
Flat	20 t/ha CM	44.5±2.8	119±0.3	383±0.2	249±2
Flat	30 t/ha CM	30.5±0.2	129±0.1	313±0.9	277±2
Flat	40 t/ha CM	41±3	116±0.01	474±0.3	347±3
Flat	100 t/ha MSWC	23.8±1.7	147±3	320±0.7	225±3
Flat	200 t/ha MSWC	32.4±3	124±0.03	292±0.2	258±2
Flat	300 t/ha MSWC	26.9±2.8	106±0.03	294±0.4	258±2.3
Peto Pride	Control	25.4±1.1	103±0.1	440±3	121±1.7
Peto Pride	Chemical fertilizer	32.3±0.2	169±0.1	400±0.3	196±2.8
Peto Pride	10 t/ha SMC	36±2.3	97±0.01	353±2	123±1
Peto Pride	20 t/ha SMC	31±2.3	144±0.1	381±0.4	222±1.7
Peto Pride	30 t/ha SMC	43±0.9	139±0.5	458±2	217±3
Peto Pride	20 t/ha CM	29±0.2	94±3	246±0.2	178±3
Peto Pride	30 t/ha CM	31.3±2.3	126±0.02	386±0.8	162±1.3
Peto Pride	40 t/ha CM	52.6±1.7	152±1.5	563±0.2	192±0.3
Peto Pride	100 t/ha MSWC	37.7±2.8	140±0.1	382±3	121±2.3
Peto Pride	200 t/ha MSWC	53.3±0.5	126±0.01	504±0.1	177±1.7
Peto Pride	300 t/ha MSWC	39.3±1	106±0.02	475±0.7	205±1.5
Chief	Control	22.9±1.7	102±0.1	293±0.3	143±1
Chief	Chemical fertilizer	34.7±3	238±0.5	323±1	405±1.7
Chief	10 t/ha SMC	29.6±1.7	134±0.01	233±0.3	128±2.3
Chief	20 t/ha SMC	29.5±3	147±1.7	282±3	160±1.7
Chief	30 t/ha SMC	30.5±2.3	209±0.4	276±0.5	309±1
Chief	20 t/ha CM	39.6±0.6	76±0.03	464±0.4	156±1
Chief	30 t/ha CM	27±2.8	183±0.1	348±0.3	187±1.7
Chief	40 t/ha CM	32.3±1.7	229±0.4	318±0.3	189±2.8
Chief	100 t/ha MSWC	39.7±0.5	96±0.5	413±0.3	156±3
Chief	200 t/ha MSWC	31.2±2.8	96±0.01	379±0.3	176±1
Chief	300 t/ha MSWC	30.2±1	95±0.1	359±0.3	227±1

(SMC = Spent mushroom compost, CM = cow manure, MSWC = municipal solid waste compost)

Table 8. Influence of cultivars and fertilizers on tomato fruits and leaves Ca and Mg.

Cultivars	Fertilizers	Ca (mg·100 g FW)		Mg (mg·100 g FW)	
		Fruit	Leaf	Fruit	Leaf
Redstone	Control	33.3±1.7	44±0.3	27±0.4	12±0.1
Redstone	Chemical fertilizer	36±1.3	55±0.1	32±0.6	11±0.1
Redstone	10 t/ha SMC	47±2.7	62±0.6	43±0.6	14±0.4
Redstone	20 t/ha SMC	46±0.3	41±0.3	38±0.2	14±0.2
Redstone	30 t/ha SMC	43±1.5	35±0.5	41±0.5	17±0.2
Redstone	20 t/ha CM	48±3	52±0.2	42±1	24±0.3
Redstone	30 t/ha CM	43±2.4	57±0.2	35±0.9	22±0.2
Redstone	40 t/ha CM	46±3	60±0.8	37±0.5	34±0.4
Redstone	100 t/ha MSWC	42±1.2	45±0.4	36±0.4	19±0.3
Redstone	200 t/ha MSWC	39±0.3	62±0.7	36±0.4	16±0.1
Redstone	300 t/ha MSWC	30±0.6	35±1.5	27±0.4	15±0.6
Flat	Control	33±1.9	45±0.1	30±0.3	17±0.2
Flat	Chemical fertilizer	31±1.7	66±0.4	28±0.7	20±0.1
Flat	10 t/ha SMC	41±3	44±0.1	37±0.1	11±0.4
Flat	20 t/ha SMC	31±1	46±0.3	28±0.8	11±0.3
Flat	30 t/ha SMC	33±1.7	53±0.2	34±3	17±0.4
Flat	20 t/ha CM	51±2.8	76±0.2	42±1.8	19±0.2
Flat	30 t/ha CM	33±0.3	46±0.1	32±0.1	20±0.2
Flat	40 t/ha CM	51±2.8	77±0.6	42±1.2	21±0.8
Flat	100 t/ha MSWC	33±3	72±0.8	25±0.6	11±1.5
Flat	200 t/ha MSWC	45±2.4	64±0.3	39±0.3	12±0.3
Flat	300 t/ha MSWC	38±3	42±0.2	29±0.01	12±0.1
Peto Pride	Control	30±1.7	57±0.1	25±0.2	12±0.1
Peto Pride	Chemical fertilizer	38±0.5	75±0.4	31±0.1	15±0.1
Peto Pride	10 t/ha SMC	42±3	56±0.2	36±0.9	12±0.4
Peto Pride	20 t/ha SMC	41±3	63±0.2	31±0.1	15±0.1
Peto Pride	30 t/ha SMC	52±0.9	63±3	45±0.6	13±0.6
Peto Pride	20 t/ha CM	32±3	62±2	29±1.9	17±1.4
Peto Pride	30 t/ha CM	38±0.4	70±0.1	31±0.02	11±0.4
Peto Pride	40 t/ha CM	61±3	74±1	44±1.8	15±0.1
Peto Pride	100 t/ha MSWC	48±2.8	46±0.4	38±1.2	21±0.1
Peto Pride	200 t/ha MSWC	57±0.1	65±0.4	49±0.7	13±0.1
Peto Pride	300 t/ha MSWC	43±3	60±0.4	38±0.1	17±0.1
Chief	Control	27±0.7	56±0.1	24±0.01	12±0.1
Chief	Chemical fertilizer	44±3	69±0.4	35±0.3	21±0.2
Chief	10 t/ha SMC	44±1.4	56±0.3	35±0.6	14±0.3
Chief	20 t/ha SMC	39±1.7	42±0.8	32±0.9	11±0.2
Chief	30 t/ha SMC	43±3	60±0.4	34±0.2	17±0.4
Chief	20 t/ha CM	60±3	53±0.2	42±0.1	11±0.1
Chief	30 t/ha CM	35±0.1	57±0.4	30±0.5	31±0.3
Chief	40 t/ha CM	44±1	58±0.9	35±0.2	30±0.4
Chief	100 t/ha MSWC	51±1.5	59±0.2	43±0.5	18±0.3
Chief	200 t/ha MSWC	43±1.9	58±0.2	38±0.3	18±0.2
Chief	300 t/ha MSWC	38±0.4	79±0.3	35±0.3	20±0.3

(SMC = Spent mushroom compost, CM = cow manure, MSWC = municipal solid waste compost)

Discussion and Conclusions

The present study found that different tomato cultivars respond differently to different fertilizers. For each of the four cultivars tested, the highest yields were achieved with chemical fertilizer, however, for each cultivar the difference between the yield under a chemical fertilizer regime and the best performing organic fertilizer for each cultivar was small. The yields achieved under the optimized organic fertilization were 99.5% of the chemical fertilized crop for Flat, 98.4% for Redstone, 97.6% for Peto Pride, and 95.7% for Chief.

The use of organic fertilizers can avoid or reduce the deleterious effects attributed to the use of chemical fertilizer. Applying chemical fertilizer leads to the deterioration of soil characteristics and fertility, and as well it leads to a reduction in fruit nutrition values and edible qualities (Shimbo et al., 2001). It also reduces the dry matter content of tomatoes (Marzouk and Kassem, 2011; Alvarez et al., 1988; Drinkwater et al., 1995; Reganold, 1988). The continuous use of chemical fertilizers may also lead to the accumulation of heavy metals in plant tissues which compromises the nutrition value and fruit quality (Shimbo et al., 2001). Although it is reported that the supply of plant-available N from organic fertilizer, resulting from a slow rate of mineralization, makes crop yields in fields treated with organic fertilizer lower than in those treated with chemical fertilizer (Blatt, 1991; Lee, 2010), the present study shows that the selection of a cultivar-appropriate organic fertilizer can narrow that yield decrement to between 0.5% to 4.7% in the case of the four cultivars that were the subject of the study.

Given the different response of cultivars to different types of fertilizer, we can recommend a particular amount of a specific type of fertilizer for each cultivar to replace chemical fertilizer. According to the results, where the criterion for fertiliser selection and its application rate is based on the total yield, then the following organic fertilizer regimes can be recommended: 20 t/ha of spent mushroom compost for Redstone, 30 t/ha of cow manure for Flat, 300 t/ha of municipal solid waste compost for Peto Pride and Chief.

For commercial cropping, aspects other than environmental outcome and crop yield come into play, and in the present study various other fruit attributes, besides gross yield, were reported (Tables 1 to 8). Other considerations such as the availability of various organic fertilizers, the security of supply, and the different supply costs of fertilizers, as well as the different costs of the management and application of the various fertilizers, will be further important considerations for commercial cropping and are worthy of further research.

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THE EFFECT OF COMBINATIONS OF ORGANIC MATERIALS AND BIOFERTILISERS ON PRODUCTIVITY, GRAIN QUALITY, NUTRIENT UPTAKE AND ECONOMICS IN ORGANIC FARMING OF WHEAT

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Abstract

Organic farming often has to deal with a scarcity of readily available nutrients, and this is in contrast to chemical farming which relies on soluble fertilisers. The present study was conducted to ascertain the effect of different combinations of organic manures, rice residues and biofertilisers in organic farming of wheat. The field experiments were carried out on the research farm of Indian Agricultural Research Institute (IARI), New Delhi in 2006-07 and 2007-08. Treatments consisted of a control (no fertiliser) and six fertiliser treatments, namely, farmyard manure (FYM), vermicompost (VC), FYM + rice residue (RR), VC + RR, FYM + RR + biofertilisers (B), and VC + RR + B. FYM and VC were applied on nitrogen basis (60 kg ha^{-1}), whereas RR was applied at 6 t ha^{-1}. For biofertilisers, *Azotobacter*, cellulolytic culture (CC) and phosphate solubilising bacteria (PSB) were used. The combinations of FYM + RR + B and VC + RR + B resulted in the highest increased growth and yield attributing characters of wheat and increased grain yield of wheat over the control by 81% and 89% (Year 1 & Year 2), and net return by 82% and 73% . These combinations were significantly superior to all other combinations for all the growth and yield parameters, yield, net profit and grain quality of wheat. The results of this study show that VC + RR + B was the most productive treatment, while FYM + RR + B was the most economical treatment with respect to increasing net profit. This was because of the higher price of vermicompost compared with FYM. Both of these combinations resulted in improved grain quality and nutrient uptake by grain. The present study thus indicates that a combination of FYM + RR + biofertilisers or VC + RR + biofertilisers hold promise for organic wheat farming.

Key words: Grain quality, nutrient uptake, organic farming, wheat, economics.

Introduction

Wheat is the second most important cereal crop in India, after rice, both in terms of area and production. The country has witnessed spectacular progress in wheat production and is the second largest producer of wheat next to China (Kumar and Yadav, 2006). Organic farming often has to deal with a scarcity of readily available nutrients in contrast to inorganic farming which relies widely available on soluble fertilisers. The aim of nutrient

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management in organic systems is to optimise the use of on-farm resources and minimise losses (Kopke, 1995). Incorporation of straw results in the recycling of a sizable amount of plant nutrients. For example rice straw accounts for about 35-40% N, 12-17% of P and 80-90% of K removal by a rice crop (Sharma & Sharma, 2002). The sole recycling/incorporation of cereal straw, which is available *in situ* is not possible due to two main reasons, (i) in many parts of the Indo Gangetic plains, in the Terai of Nepal and in China, straw is used as bedding for animals, fuel and other uses (Prasad & Power, 1991), and (ii) because of the wide C:N ratio (70 or above), it can result in a temporary immobilisation of native soil and applied mineral N (Aulakh et al., 2000). A number of researchers (Pandey et al., 1985; Rajput & Warsi, 1995; Prasad et al., 2004) have reported increased yield of rice and /or wheat by the incorporation of wheat/rice residue, while others (Sharma, 2005; Singh & Sharma, 2000) have failed to do so. Hence there is an urgent need to develop a suitable technology to use crop residues in the organic farming of wheat. Mixing the crop residues of cereals with well decomposed farmyard manure/compost/vermicompost or crop residue of legumes reduces the C:N ratio so as to overcome the adverse effect of N immobilisation. Hence, the present study was conducted to study the effect of different combinations of organic manures, rice residues and biofertilisers in the organic farming of wheat.

Materials and methods

A field experiment was conducted at the research farm of the Indian Agricultural Research Institute, New Delhi in 2006-2007 and 2007-2008. The farm is situated at 28.4° N and 77.1° E at an elevation of 228.6 metres. The soil had a moderate level of organic C (5.1 mg kg^{-1} soil), available phosphorus (8.42 mg kg^{-1} soil) and available potassium (108.87 mg kg^{-1} soil), and was low in available nitrogen (73.1 mg kg^{-1} soil), and pH was 8.16. In 2006-07, the minimum and maximum temperature ranged from 3.4-7º C and 28.9- 31.4 °C, respectively, with a total rainfall of 145.6 mm received during the cropping season. During 2007-08, it was 3.2-6.9 °C and 29.8- 33.9 °C respectively, and a total of 46.9 mm rainfall was received.

The treatments consisted of a control (no fertiliser applied) and six combinations of organic manures, crop residues and biofertilisers: (1) farmyard manure equivalent to 60 kg N ha^{-1} (FYM); (2) FYM + rice residue of preceding crop @ 6 t ha^{-1} (RR); (3) FYM + RR + biofertilisers (B); (4) vermicompost equivalent to 60 kg N ha^{-1} (VC); (5) VC + RR and (6) VC + RR + B. The experiment was laid out in a randomised block design with six replications.

For biofertilisers, *Azotobacter,* cellulolytic culture and phosphate solubilising bacteria (PSB) were used in wheat. Farmyard manure used in the experiment was well decomposed for 6-8 weeks. It contained 6100-6200 mg kg^{-1} N, 2500-2700 mg kg^{-1} P, 3000-3100 mg kg^{-1} K, 11-12mg kg^{-1} Mn, 39-40 mg kg^{-1} Zn, 2.6-2.7 mg kg^{-1} Cu, 21-22 mg kg^{-1} Fe and had a C:N ratio of 23-24. VC contained 11900-12000 mg kg^{-1} N, 6265-6300 mg kg^{-1} P, 6900-7000 mg kg^{-1} K, 37-38 mg kg^{-1} Mn, 86-88 mg kg^{-1} Zn, 8-9 mg kg^{-1} Cu, 57-58 mg kg^{-1} Fe and had a C:N ratio of 71-72. The nutrients added through various organic materials are given in Table 1.

Rice residue, FYM and VC were incorporated before sowing wheat. Cellulotic culture containing four fungi, *Aspergillus awamori, Trichoderma viride, Phanerochcete chrysosporium* and *Aspergillus wolulens* was inoculated at the time of residue incorporation, whereas *Azotobacter* and *Pseudomonas striata* (a PSB) were used to inoculate the seeds as per the treatments. After the harvest of rice, the field was irrigated and at the optimum soil moisture level (15-20% of field capacity), the required quantity of FYM, VC and crop residue was uniformly spread on the relevant plots and incorporated with tractor drawn heavy disc. Wheat was irrigated four times in the first year and five times in the second year at critical stages of crop growth. In both years, wheat was harvested in the fourth week of April, 19 weeks after sowing.

Table 1. Quantity (kg/ha/year) of N, P, K, Fe, Zn, Mn and Cu added through organic materials and biofertilisers under various treatments.

Treatments	N	P	K	Fe	Zn	Mn	Cu
Farmyard manure (FYM)	60	25-27	30-31	0.21-0.22	0.40-0.41	0.12	0.03
Vermicompost (VC)	60	31-32	35-36	0.29-0.30	0.43-0.44	0.19	0.04
FYM + Rice residue (RR)	83	28-29	124-125	2.31-2.32	0.58-0.61	0.56-0.59	0.13
VC + RR	83	36-37	128-129	2.39-2.51	0.61-0.65	0.46-0.63	0.14
FYM+RR+Biofertilisers (B)	108	41-42	124-125	2.31-2.32	0.58-0.61	0.56-0.59	0.13
VC + RR + B	108	48-89	128-129	2.39-2.52	0.61-0.65	0.46-0.63	0.14

Grain and straw samples of wheat were collected at harvest and analysed for total N using a micro-Kjeldahl method, while total P and potassium (K) were determined using sulphuric-nitric-perchloric acid digest (Prasad 1997). Nutrient removal was estimated by multiplying the N, P and K concentration (%) of grain and straw with their respective yield (kg ha^{-1}) and total nutrient uptake was calculated from the sum of grain and straw nutrient uptake.

Kernel hardness index was determined using the Single Kernel Characterization system 4100 from Perten Instruments, Australia. All dockage was removed from the sample using a seed cleaner and 200 g of seed was used for the analysis. The values of kernel hardness, moisture and grain weight were recorded for 100 seeds of each sample. The Sodium Dodecyl Sulphate (SDS)-sedimentation test (Dick & Quick, 1983, cited in Misra et al., 1998) was used to determine gluten strength.

The cost of cultivation of wheat was calculated on the basis of prevailing rates (Directorate of Economics and Statistics, 2008) of inputs and gross income was calculated on the basis of procurement price of organic wheat grain (Export-import Bank of India, 2007; Export-import Bank of India, 2008) and prevailing market price (Directorate of Economics and Statistics, 2008) of wheat straw. The income was obtained by subtracting cost of cultivation from gross income, i.e. net income = gross income – cost of cultivation.

The data relating to each variable were analysed using Analysis of Variance (Cochran & Cox, 1957). Critical difference (CD) at 5% level of significance was calculated for comparing the mean of difference presented in the summary table.

Results and discussion

Growth, yield attributes and yields

Farmyard manure contains primary, secondary and micronutrients. Thus, application of FYM significantly increased total biomass, number of spikes, spike length and grains per spike in both the years of study (Table 2) which led to a significant increase in grain and straw yield of wheat with FYM application over the control (Table 3). The grain yield increased due to FYM application by 22% compared to the control in the first year and 64% in the second year. FYM applied to wheat during the first year is expected to leave a sizeable amount of nutrients in the soil, and potentially improve the physical and biological properties of soil during the second year as compared to during the first year. Behera et al. (2007) reported that the application of available organic sources, particularly FYM and poultry mature along with the full recommended dose of mineral fertilisers to wheat was essential for improving productivity of wheat-soybean system. Thakur & Patel (1998), Tripathi & Gehlot (1999), Singh & Agarwal (2004) also reported a beneficial effect of FYM on wheat.

Vermicompost (VC) in wheat resulted in a significant increase in all of the growth parameters and yield attributes except test weight in the first year, which led to a 28.9-76.1% increase in grain yield and a 25-70% increase in straw yield over control. Ranva & Singh (2006) reported the application of vermicompost at 7.5 or 10 t ha^{-1} gave higher yields than 10 t ha^{-1} FYM.

The combination of FYM + RR was better than FYM alone for improvement in growth and yield attributes of wheat which resulted in 0.50-0.54 and 0.7-3.2 t ha^{-1} increase in grain yield and straw yield, respectively over FYM application. Kler et al. (2007) reported that grain yield, grains per ear and thousand grain weight were significantly higher where 10 t FYM ha^{-1} with 80% of the recommended mineral fertiliser dose, and with crop residue incorporation/mulching and the recommended fertiliser dose. The combination of VC + RR was significantly better than VC alone for the improvement in growth and yield attributes of wheat which resulted in an 18 and 12% (Year 1 & Year 2), and an 18 and 10% increase in grain and straw yield, respectively, over VC alone (Table 3).

Inoculation of *Azotobacter* + PSB with FYM + RR significantly increased number of grains per spike and test weight in both the years over FYM + RR which resulted in an 11-13% higher increase in grain yield and an 8-10% higher increase in straw yield over FYM + RR. Maity (2006) reported that the grain yield of wheat at 75% recommended dose of NP along with the application of FYM @ 10 t ha^{-1} and inoculation of PSB resulted in significantly higher yield even over the 100% recommended dose of NP. Inoculation of *Azotobacter* + PSB with VC + RR resulted in significant and non-significant increase in all the growth parameters and yield attributes of wheat over VC + RR alone which resulted in 10.6 and 6.9%% (Year 1 & Year 2) increase in grain yield, 6.9 and 4.2% increase in straw yield (Table 3). The increase in grain yield was related to the amount of nutrients added through various organic materials and biofertilisers under the different treatments (Table 1). FYM and vermicompost only, and no crop residue and biofertilisers had lower wheat grain yield that could be attributed to deficiency of required plant nutrients in those treatments.

Grain quality

Since the N, P, K, Zn, Fe, Mn and Cu concentration in wheat grain did not differ significantly in two years the mean data over two years are presented in Table 4. Application of FYM or VC significantly increased N, P, Cu and Mn concentration in wheat grain over control but did not affect the K, Zn and Fe Concentration of wheat grain significantly. The effects of FYM + RR and VC + RR were similar and significantly increased N, P, K, Cu and Mn concentration over control. The combinations of FYM + RR + B and VC + RR + B were at par and significantly increased N, P, K, Zn, Cu, Fe and Mn concentration in wheat grain over control. The increase in the nutrient concentration with FYM + RR + B or VC + RR + B was higher as compared to those obtained with other nutrient combination. The concentration of a particular nutrient in wheat grain was, thus, linked with the supply of that particular nutrient through organic materials applied in different treatments (Table 1). In other words, the combined use of materials and biofertilisers can produce the highest nutrient parameters of wheat grain. Ngoc Son et al. (2001) reported significant positive effects on the quantity of nutrient content due to organic and bio-fertilisers applied to soybean.

Table 2. Effect of different organic materials and biofertilisers on yield attributes of wheat.

Treatments	Spike (no. m^{-2})		Spike length (cm)		Grains $spike^{-1}$		Test weight (g)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Control	317	339	9.4	9.1	31.3	31.0	38.0	37.9
Farmyard manure (FYM)	345	370	10.1	10.8	36.2	37.6	38.2	38.8
Vermicompost (VC)	350	378	10.3	11.1	38.3	39.2	38.2	39.1
FYM + Rice residue (RR)	352	383	10.2	11.1	38.7	39.7	38.3	38.9
VC + RR	359	395	10.5	11.6	40.3	41.3	38.6	39.5
FYM+RR+Biofertilisers (B)	366	395	10.5	11.6	40.5	41.7	38.7	39.6
VC + RR + B	371	404	11.0	11.9	42.2	42.9	38.9	39.8
SE	9.15	11.60	0.16	0.26	0.50	0.59	0.10	0.20
LSD (P = 0.05)	28.18	36.67	0.50	0.79	1.54	1.83	0.31	0.62

Table 3. Effect of different organic materials and biofertilisers on yields and harvest index of wheat.

Treatments	Grain (t ha^{-1})		Straw (t ha^{-1})		Harvest Index (%)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Control	2.66	2.64	4.24	4.20	38.5	38.6
Farmyard manure (FYM)	3.25	4.32	5.04	6.71	39.2	39.3
Vermicompost (VC)	3.43	4.65	5.30	7.15	39.3	39.4
FYM + Rice residue (RR)	3.75	4.86	5.75	7.44	39.5	39.5
VC + RR	4.06	5.19	6.25	7.89	39.5	39.7
FYM+RR+Biofertilisers (B)	4.24	5.37	6.35	8.04	40.0	40.0
VC + RR + B	4.49	5.55	6.68	8.22	40.2	40.3
SE	0.09	0.11	0.16	0.17	0.17	0.22
LSD (P = 0.05)	0.29	0.36	0.49	0.54	0.52	0.67

The physical and cooking quality of wheat was also affected by different nutrient combinations. The data of two years indicated that hardness and sedimentation value of wheat grain were not significantly affected by FYM and VC application in both the years of study (Table 5). Kharub & Chander (2008) reported that protein content in wheat increased with increase in the rate of FYM, but the highest protein content (11-24%) was recorded for inorganic fertiliser. The sedimentation value of wheat grain was unaffected by FYM + RR and VC + RR application, but hardness of wheat grain was significantly increased over the control. The combinations of VC + RR + B in both of years and FYM + RR + B in the second year only significantly increased the sedimentation value of wheat grain over the control. Konvalina et al. (2009) reported that a low-input (organic) farming system was associated with a reduction in the yield and technological quality, expressed by a reduction in the crude protein content in grain and a reduction in protein swelling (sedimentation values). With an increase in applied N, there was an increase in the protein percent, sedimentation value and grain hardness (Zecevic et al., 2004). A similar effect of N on wheat grain was reported by Mattas et al. (2011).

Table 4. Effect of organic materials and biofertilisers on nutrient concentration of wheat grain.

Treatments	N (%)	P (%)	K (%)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
Control	1.40	0.27	0.34	43.3	6.2	30.1	32.2
Farmyard manure (FYM)	1.56	0.29	0.37	45.3	7.3	32.3	35.7
Vermicompost (VC)	1.59	0.30	0.38	46.1	7.8	33.4	36.3
FYM + Rice residue (RR)	1.58	0.30	0.40	45.7	7.6	33.7	36.7
VC + RR	1.63	0.31	0.42	47.1	7.8	35.6	37.6
FYM+RR+Biofertilisers (B)	1.64	0.32	0.43	47.4	8.2	36.3	38.6
VC + RR + B	1.66	0.33	0.44	48.3	8.5	37.5	39.8
SE	0.05	0.005	0.01	1.29	0.28	1.94	1.14
LSD (P = 0.05)	0.16	0.015	0.05	3.97	0.86	5.99	3.51

Table 5. Effect of treatments on physical and cooking quality parameters of wheat grain.

Treatments	Hardness (HI)		Sedimentation value (ml)	
	2006-07	2007-08	2006-07	2007-08
Control	78.7	79.1	39.8	38.8
Farmyard manure (FYM)	81.5	82.1	39.5	40.0
Vermicompost (VC)	83.2	83.7	40.5	41.0
FYM + Rice residue (RR)	85.9	86.5	40.3	41.0
VC + RR	87.5	88.2	41.2	42.0
FYM+RR+Biofertilisers (B)	87.9	88.5	42.5	43.3
VC + RR + B	89.4	90.7	44.0	44.7
SE	2.24	2.34	0.96	1.07
LSD (P = 0.05)	6.91	7.22	2.96	3.32

Nutrient uptake

The application of FYM significantly increased the quantity of N, P, K, Fe, Mn and Cu removed by wheat grain over the control (Table 6). Singh & Agarwal (2004) reported that the application of 10 t ha^{-1} FYM in rice-wheat cropping system resulted in significantly higher N, P and K uptake as compared with the control. Vermicompost was superior to FYM with respect to P, K, Zn, Fe, Mn, and Cu removal by rice grain. The application of wheat residue with FYM or VC also resulted in a significant increase in nutrient uptake by wheat grain. Kachroo et al. (2006) reported that the incorporation of rice residues in wheat not only increased nutrient uptake compared to no residue incorporation, but it also increased the productivity and yield components of wheat. Similarly inoculation of biofertilisers along with FYM + RR or VC + RR significantly increased the quantity of nutrient removal by wheat grain. The increase in nutrient uptake may be due to an increase in available N, P and K contents in the soil, and improved soil structure for higher uptake of nutrients (Manna et al. 2001).

Table 6. Effect of organic materials and biofertilisers on nutrient uptake (g ha^{-1}) by wheat grain.

Treatments	N	P	K	Zn	Cu	Fe	Mn
Control	37.1	7.2	9.0	114.7	16.4	79.8	85.3
Farmyard manure (FYM)	58.9	11.0	14.0	171.2	27.6	122.1	134.9
Vermicompost (VC)	64.2	12.1	15.4	186.2	31.5	135.0	146.7
FYM + Rice residue (RR)	67.9	12.9	17.2	196.5	32.7	145.0	157.8
VC + RR	75.5	14.4	19.5	218.1	36.1	164.8	174.1
FYM+RR+Biofertilisers (B)	78.9	15.4	20.7	228.0	39.4	174.6	185.7
VC + RR + B	83.3	16.6	22.1	242.5	42.7	188.2	200.0
SE	2.3	0.4	0.8	0.3	0.2	0.2	0.1
LSD (P = 0.05)	7.2	1.1	2.3	0.9	0.5	0.6	0.4

Economics

The cost of cultivation of wheat in the first year varied from Rs. 20,610 ha^{-1} for the control to Rs. 37,770 ha^{-1} for VC + RR + B, and from Rs. 13,400 ha^{-1} for the control to Rs. 31,600 ha^{-1} for VC + RR + B in the second year. The application of FYM increased the cultivation cost by 64-63%, VC by 50-47%, FYM + RR by 60-55%, VC + RR by 45-43%, FYM + RR + B by 56-54% and VC + RR + B by 45-42%. The application of FYM significantly increased the net income of rice over control by Rs 2600-22,300 ha^{-1} (Table 7). Hargilas (2006) also reported an increase in the net income of wheat with FYM application. FYM and VC did not differ significantly in terms of net income of wheat. The application of FYM + RR gave significantly higher net profit for rice than FYM alone in both the years of the study. Similarly, VC + RR was significantly superior to VC alone. Inoculation of biofertilisers with FYM + RR and VC + RR also significantly increased net profit of wheat over FYM + RR and VC + RR, respectively. The application of vermicompost + rice residue + biofertilisers (*Azotobacter* + cellulolytic culture + PSB) was most productive and FYM + rice residue + biofertilisers was economical for nutrient need of wheat. Both these combinations resulted in higher improvement in grain quality and physical, chemical and biological properties of soil. The net return and benefit:cost ratio were highest in the case of FYM + RR + B (Table 7), which might be due to the lower cost of FYM in comparison with vermicompost in India.

Table 7. Effect of treatments on economics of cultivation of wheat.

Treatments	Cultivation cost (×1,000 Rs* ha^{-1})		Net return (×1,000 Rs ha^{-1})		Benefit:cost ratio	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Control	12.7	13.4	31.5	34.3	2.48	2.55
Farmyard manure (FYM)	19.7	21.4	34.1	56.6	1.73	2.64
Vermicompost (VC)	25.2	28.4	31.6	55.5	1.25	1.95
FYM + Rice residue (RR)	22.7	24.4	39.4	63.2	1.73	2.59
VC + RR	28.2	31.4	39.0	62.1	1.38	1.97
FYM+RR+Biofertilisers (B)	22.8	24.6	47.1	72.1	2.06	2.93
VC + RR + B	28.3	31.6	45.7	68.2	1.61	2.15
SE	-	-	0.68	0.87	0.21	0.23
LSD (P = 0.05)	-	-	2.09	2.67	0.62	0.68

* Indian Rupees (Rs) Re.1 = US$ 0.018

Conclusions

The results of this study show that application of vermicompost + crop residue + biofertilisers (*Azotobacter* + cellulolytic culture + PSB) was the most productive treatment but FYM + crop residue + biofertilisers was the most economical treatment with respect to increasing net profit. This was because of the higher price of vermicompost compared with FYM. Both of these combinations resulted in improved grain quality and nutrient uptake by grain. The present study thus indicates that a combination of FYM + RR + biofertilisers or VC + RR + biofertilisers holds promise for the organic farming of wheat.

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THE EFFECT OF ORGANIC MANAGEMENT TREATMENTS ON THE PRODUCTIVITY AND QUALITY OF LEMON GRASS *(CYMBOPOGON CITRATUS)*

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Abstract

An experiment was conducted at the Model Organic Farm of CSK Himachal Pradesh Agricultural University, Palampur (31º54' N and 76º17' E), Himachal Pradesh, India, to evaluate the effect of various organic management treatments on the productivity and quality of lemon grass (*Cymbopogon citratus*). Organic inputs (viz. farm yard manure (FYM); vermicompost; agnihotra ash; and neem powder) were added at the time of planting, while Bt + Himbio and the biodynamic preparation BD 500 were sprayed regularly at one month intervals. Crops were sown on dates matching moon and non moon position according to the Biodynamic Planting Calendar. Addition of agnihotra ash along with sowing as per moon position resulted in a higher yield of lemon grass (+124%, +99%) and a higher oil per cent (+155%, +144%) over the control, in both the years of study. Sowing as per moon position may have improved germination rate, water absorption and metabolism of the plants, whereas addition of agnihotra ash may have stabilized the nutrients present in soil.

Key Words: lemongrass, integrated organic management, yield, oil percent, moon position, agnihotra ash, biodynamic agriculture.

Introduction

Lemon grass is a perennial herb widely cultivated in the tropics and subtropics. The reported adaptation zone for lemon grass is: temperature 18 to 29ºC with an annual precipitation of 0.7 to 4.1 meters and a soil pH of 5.0 to 5.8. Since the plants rarely flower or set seed, propagation is by root or plant division. The plants are harvested mechanically or manually about four times each year with the productive life span between four and eight years.

Lemon grass is used in herbal teas, other non-alcoholic beverages, and in confections. Oil from lemon grass is widely used for fragrance in perfumes and cosmetics, such as soaps and creams. Essential oil isolated from C. flexuosus (citral-type), is reported to contain citral-b from 14% to 35% and citral-a from 23% to 56%, while geraniol type is reported to contain geraniol from 17% to 88 % (Verma et al. 1987). Citral, extracted from the oil, is used in flavoring soft drinks, in scenting soaps and detergents, as a fragrance in perfumes and cosmetics and as a mask for disagreeable odors in several industrial products. Citral is also used in the synthesis of ionones used in perfumes and cosmetics. As a medicinal plant, lemon grass has been considered a carminative and insect repellent. Lemon grass is generally recognized as safe for human consumption as plant extract/essential oil.

In the case of medicinal plants such as lemon grass, the type and amount of compound and hence the quality along with the quantity is an important aspect considered in its production. Quality and safety are of concern to all. The understanding of food quality has been expanded beyond the mere definition by chemical content, to technical characteristics for processing and storage, appearance and taste. Organic farming is gaining momentum especially in the cultivation of medicinal plants owing to reputed improvements in the quality of the produce under organic systems of farming as well as the price premiums for certified produce. Organic production systems are based on specific and precise standards of production which aim at achieving agro-ecosystems which are socially and ecologically sustainable. Organic agriculture is based on minimizing the use of external inputs and avoiding the use of synthetic fertilizers and pesticides. Particularly in organic agriculture, but not exclusively so, other considerations like ethical values and production principles (environmental impact such as energy efficiency, non-pollution, animal welfare, aim for sustainability and social impact) are gaining weight as integral product values. There is a growing demand for organic foods driven primarily by consumers' perceptions of the quality and safety of these foods and to the favourable environmental impact of organic agriculture practices.

Biodynamic farming and Homa farming are two important practices within the family of organic production systems. Biodynamic agriculture is an organic farming system that arose out of a philosophical movement Anthroposophy (Steiner, 1924; Paull, 2011). Rudolf Steiner indicated that the Moon, especially in its synodic cycle, was of great importance for the growth of crops. Lili Kolisko (1936) reported the positive results of her experiments following Steiner’s indications. In 1956, Thun developed a procedure of sowing according to the position of the Moon relative to the twelve zodiacal constellations. These constellations were classified into four groups according to the element (Earth, Water, Air and Fire) astrologically associated with them. Root, leaf, flower and fruit crops were found to show increased yields if sown when the Moon stood before Earth, Water, Air and Fire constellations, respectively. Thun’s philosophy of sowing by this sidereal rhythm has become a major component of biodynamic planting calendars. In 1962, the Thun theory became embodied into a biodynamic gardening calendar which has appeared annually ever since (e.g. Thun 2001) and is presently translated into 21 languages. This calendar incorporates various lunar cycles and events. Crop yield experiments were conducted by Thun in collaboration with the statistician Heinze over the eight years 1964–71, mainly with potatoes, but also with carrots and radishes, and beans as a seed-crop (Thun & Heinze 1979). In these experiments, twelve rows of a crop were sown over one sidereal month, one row per 2–3 days, while the Moon traversed a particular constellation. Final crop yield weights were compared, measuring the total yield per row of potatoes or of beans. The weight ratio of the crop/total plant was also evaluated. There is evidence that parameters such as germination rate (Maw 1967), water absorption (Brown & Chow 1973) and metabolism (Brown 1960) respond to this cycle.

Biodynamic methods of farming are distinct in that they make use of several unique fermented substances, called preparations, as field sprays and compost inoculants (Koepf et al. 1976). Biodynamic preparations numbered 502 to 507 are used as compost additives, Biodynamic 500 (BD 500) is called cow horn manure, and is made from fresh lactating cow dung packed into cow horns, buried over the winter for fermentation in the earth (Perumal & Vatsala 2002; Pfeiffer 2006)

Homa farming is an Indian holistic concept of growing plants in a healthy atmosphere and maintaining an ecological balance by performing agnihotra (*Yajna*) in the middle of the farm and using the Yajna-ash as a fertilizer. Homa or *Yajna* ia a pyramid fire technique passed down from the ancient Atharva Vedas. The technical term *Yajna* denotes a process of removing the toxic conditions of the atmosphere through the agency of fire. The thereby healed and purified atmosphere is said to have beneficial effects on man, animals and plants (Paranjpe 1989). The basic Homa called Agnihotra (Sanskrit: agni=fire, hotra=healing), is performed at sunrise and sunset. A small fire is prepared from dried cow dung and clarified butter (ghee) in a copper pyramid. Some grains of unbroken whole brown rice, mingled with clarified butter (ghee) are put into the fire accompanied by the chanting of a mantra. The ash produced by the fire is credited with having healing properties and it is said to have fertilizing as well as plant protecting quality. Reports from India, Peru, Venezuela, the United States of America, and Austria, give accounts of the beneficial effects of Homa farming on plant germination, development, health and pest resistance, as well as on yield and product quality, and with regard to soil quality, an improved water holding capacity, an increase in amount and solubility (plant availability) of macro nutrients and trace elements (Bhujbal 1981; Paranjpe 1989; Perales et al. 2000; Mutalikdesai 2000; Schinagl 2004; Atul et al. 2006 and Kratz and Schung 2007).

Biodynamic and Homa Farming practices were incorporated with other components of organic farming in the present study to investigate the best combination of different organic practices for increasing the productivity and quality of lemon grass.

Materials and Methods

The experiment was conducted in the experimental fields of Model Organic farm, CSK HP Agricultural University, Palampur (31º54’ N and 76º17’ E), Himachal Pradesh, India. Before laying the experiment, the initial status of soil fertility was examined. Composite soil samples collected from 0-15 cm depth before start of the experiment were run for chemical analysis. On the basis of chemical analysis, the soil was categorized as acidic (pH 5.3), medium in organic carbon (1.35%), available nitrogen (330 kg ha^{-1}), low in phosphorus (6 kg ha^{-1}) and high in available potassium (395 kg ha^{-1}).

The experiment was laid out in a randomized block design replicated thrice with twelve treatments consisting of all the combinations of organics and time of sowing as per moon position and non moon position (Table 1). Lemon grass was transplanted as per the Biodynamic Planting Calendar of the year during which the study was conducted. The calendar was obtained from the Bio-Dynamic Association of India <www.biodynamics.in>. The calendar describes various lunar cycles and events. In this calendar, separate dates are prescribed for the planting of different crops (seeds/fruits, tubers/roots, flowers or leaves end product crops). In the present study planting as per moon position refers to the day prescribed by the calendar for leaf end product. The non moon position adopted in the study was the day prior to the moon position day as prescribed by the calendar for planting. The calendar also specifies dates for other biodynamic agricultural practices such as the use of the preparations, and where applicable the recommendations of the calendar were followed.

The organic inputs (viz. FYM, vermicompost, agnihotra ash and neem powder) were added at the time of planting while Bt + Himbio and BD 500 were sprayed regularly at one month interval s starting from a month after planting. Neem powder was prepared by crushing the neem kernels purchased from the local market. Himbio was prepared from local strains of trichoderma and had a viable cell count of 10^8 cfu. The crop was planted in July, 2006 with a plot size of 12 m^2 and plant spacing of 60 X 45 cm. Growth parameters *i.e.,* plant height and plant spread (x and y axis) and number of off shoots, were determined from 10 sampled plants per plot at regular intervals of 30 days. The first cut of the crop was taken after 90 days of planting and the second cut was taken 150 days after planting. The crop was cut using sickles at about 15 cm above the ground. Oil from the leaves was extracted using steam distillation following the method given by the Persian physicist Avicenna (c.980-1037) for extraction of essential oils. Statistical analysis was done by the standard procedures suggested by Gomez & Gomez (1984) with correlations and critical differences (CDs) between means reported. CDs are reported at 95% significance throughout.

Table1. Details of Treatments

Treatments	Details of treatments
T_1	Organic manure (FYM @ 20 t/ha + vermicompost @ 15 t/ha) & sowing as per moon position (MP)
T_2	T_1 + Neem (0.05 %)
T_3	T_1 + Agnihotra ash (@ 33 kg ha^{-1})
T_4	T_1 + *Bacillus thuringiensis* (Bt) (0.3%) & Himbio (0.5 %)
T_5	T_1 + Biodynamic 500 (BD 500 – Cow horn manure)
T_6	Control + Sowing as per moon position (MP)
T_7	Organic manure (FYM @ 20 t/ha + vermicompost @ 15 t/ha) & Sowing as per non moon position (NMP)
T_8	T_7 + Neem (0.05 %)
T_9	T_7 + Agnihotra ash (@ 33 kg ha^{-1})
T_{10}	T_7 + *Bacillus thuringiensis* (Bt) (0.3%) & Himbio (0.5 %)
T_{11}	T_7 + Biodynamic 500 (BD 500 – Cow horn manure)
T_{12}	Control + sowing as per non moon position (NMP)

Results

Plant Growth

Growth parameters recorded after 30 days of planting of lemon grass (Table 2) reveal that there was no effect of date of sowing on plant height and plant spread. However, sowing according to moon position significantly increased the number of off shoots over the sowing as per non moon position. Addition of agnihotra ash significantly increased plant height, number of off shoots and plant spread. However, interaction between date of sowing and addition of organics was non significant. There was no attack of insect pest on the crop and the crop was disease free.

Table 2: Effect of organics on yield attributes of lemon grass at 30 days after planting.

Sr. No	Parameters	Organic manure* (OM)	OM + Neem	OM + agnihotra ash	OM + Himbio + Bt	OM + BD 500	Control	Mean
1	**Plant height (cm)**							
	MP	41.55	42.83	44.68	42.79	42.84	38.85	42.26
	NMP	41.65	41.37	43.50	43.33	42.76	35.12	41.29
	Mean	41.6	42.10	44.09	43.06	42.80	36.99	
	CD							
	Date of sowing	NS						
	Treatments	2.39						
	Interaction	NS						
2	**Number of off shoots (No.)**							
	MP	9.67	9.00	11.00	7.67	7.00	7.00	8.56
	NMP	8.00	6.67	11.00	7.00	6.33	6.00	7.50
	Mean	8.83	7.83	11.00	7.33	6.67	6.50	
	CD							
	Date of sowing	0.78						
	Treatments	1.35						
	Interaction	NS						
3	**Plant spread (cm^2)**							
	MP	418.43	350.19	594.61	553.69	540.45	344.68	467.01
	NMP	490.72	451.18	561.62	543.94	499.22	305.93	475.44
	Mean	454.57	400.69	578.12	548.81	519.84	325.31	
	CD							
	Date of sowing	NS						
	Treatments	80.79						
	Interaction	NS						

(CD: Critical Difference, NS: not significant, MP: Moon Position Sowing, NMP: Non Moon Position sowing. OM* (Organic manure): FYM @ 20 t/ha + Vermicompost @ 15 t/ha; Himbio: Mixture of Trichoderma (JMA-4, SMA-5, DMA-8 and JMA-11); Bt; *Bacillus thuringiensis* ; BD 500: Biodynamic 500.)

At 60 days of planting (Table 3), the treatments where organic manure alone was added and where organic manure was added in conjunction with biopesticide were at par with each other. Sowing as per moon position significantly increased plant height, number of off shoots and plant spread over the non moon position sowing. There was a significant improvement in these parameters in the treatments where organics were added over the control. Highest plant height and plant spread was observed in treatment T_3 followed by

T_9 treatment. There was no attack of insect pest on the crop and the crop was disease free.

Table 3: Effect of organics on yield attributes of lemon grass at 60 days after planting.

Sr. No	Parameters	Organic manure* (OM)	OM + Neem	OM + agnihotra ash	OM + Himbio + Bt	OM + BD 500	Control	Mean
1	**Plant height (cm)**							
	MP	54.93	55.18	84.33	75.22	62.36	52.48	64.09
	NMP	53.24	53.00	75.35	65.41	58.27	48.97	59.04
	Mean	54.08	54.09	79.84	70.32	60.32	50.72	
	CD							
	Date of sowing	1.58						
	Treatments	2.73						
	Interaction	3.87						
2	**Number of off shoots (No.)**							
	MP	32.00	33.00	71.00	60.00	48.00	16.00	43.33
	NMP	25.00	23.00	65.00	53.00	43.00	11.33	36.72
	Mean	28.50	28.00	68.00	56.50	45.50	13.67	
	CD							
	Date of sowing	1.56						
	Treatments	2.70						
	Interaction	NS						
3	**Plant spread (cm^2)**							
	MP	1,290.84	1,194.20	6,413.67	5,302.89	3,824.91	1,506.93	3,255.57
	NMP	1,349.16	1,273.04	6,069.47	4,470.77	3,204.90	401.56	2,794.82
	Mean	1,320.00	1,233.62	6,241.57	4,886.83	3,514.91	954.24	
	CD							
	Date of sowing	181.08						
	Treatments	313.63						
	Interaction	443.54						

(CD: Critical Difference, NS: not significant, MP: Moon Position Sowing, NMP: Non Moon Position sowing. OM* (Organic manure): FYM @ 20 t/ha + Vermicompost @ 15 t/ha; Himbio: Mixture of Trichoderma (JMA-4, SMA-5, DMA-8 and JMA-11); Bt; *Bacillus thuringiensis* ; BD 500: Biodynamic 500.)

Plant height and number of off shoots at harvest

Perusal of data reveals that there was a significant effect of date of sowing and addition of different organics on plant height and number of off shoots in the first and second year (Tables 4 & 5). Sowing as per moon position resulted in a significant increase in plant height and number of off shoots over the sowing as per non moon position. Treatments where organic manure was added alone and where organic manure was added in conjunction with bio-pesticide, were at par with each other. However, in both the years the interaction between date of sowing and addition of different organic manures was non significant for both the parameters.

Table 4: Effect of date of sowing and addition of organics on plant height of lemon grass at harvest.

Organics	Plant height (cm)					
	First year			Second year		
	MP	NMP	Mean	MP	NMP	Mean
Organic manure* (OM)	68.85	67.54	68.20	63.0	58.6	60.80
OM + Neem	69.65	67.26	68.45	65.04	61.24	63.14
OM + Agnihotra ash	98.59	92.41	95.50	80.97	72.86	76.92
OM + Himbio + Bt	87.58	79.67	83.63	75.55	65.91	70.73
OM + BD 500	76.62	72.53	74.58	74.61	64.5	69.56
Control	64.74	61.01	62.88	57.78	53.07	55.43
Mean	77.67	73.40		69.49	62.70	
CD						
Date of sowing	1.27			2.56		
Organics	2.02			4.43		
Interaction	NS			NS		

(CD: Critical Difference, NS: not significant, MP: Moon Position Sowing, NMP: Non Moon Position sowing. OM* (Organic manure): FYM @ 20 t/ha + Vermicompost @ 15 t/ha; Himbio: Mixture of Trichoderma (JMA-4, SMA-5, DMA-8 and JMA-11); Bt; *Bacillus thuringiensis* ; BD 500: Biodynamic 500.)

Table 5: Effect of date of sowing and addition of organics on number of off shoots of lemon grass at harvest.

Organics	No. of off shoots					
	First year			Second year		
	MP	NMP	Mean	MP	NMP	Mean
Organic manure* (OM)	47.00	40.00	43.5.0	43.33	32.33	37.83
OM + Neem	48.00	38.00	43.00	44.67	35.33	40.00
OM + Agnihotra ash	86.00	80.00	83.00	56.67	52.33	54.50
OM + Himbio + Bt	75.00	68.00	71.50	49.00	40.33	44.67
OM + BD 500	63.00	58.00	60.50	47.33	37.00	42.17
Control	26.00	21.00	23.50	26.33	20.00	23.17
Mean	57.50	50.83		44.56	36.22	
CD						
Date of sowing	1.51			2.98		
Organics	2.62			5.16		
Interaction	NS			NS		

(CD: Critical Difference, NS: not significant, MP: Moon Position Sowing, NMP: Non Moon Position sowing, OM* (Organic manure): FYM @ 20 t/ha + Vermicompost @ 15 t/ha; Himbio: Mixture of Trichoderma (JMA-4, SMA-5, DMA-8 and JMA-11); Bt; *Bacillus thuringiensis* ; BD 500: Biodynamic 500.)

Effect on plant spread and yield at harvest

The highest yield was recorded (7853 kg ha^{-1} in first year and 7278 kg ha^{-1} in second year) in the treatment where lemon grass was sown as per moon position with organic manure and agnihotra ash (Table 6 & 7) while lowest yield (2833 kg ha^{-1} in first year and

3193 kg ha^{-1} in second year) was obtained in control with sowing as per non moon position.

Table 6: Effect of date of sowing and addition of organics on plant spread of lemon grass at harvest.

Organics	Plant spread (cm^2)					
	First year			Second year		
	MP	NMP	Mean	MP	NMP	Mean
Organic manure* (OM)	2,520.79	2,442.83	2,481.81	4,592.13	3,613.79	4,102.96
OM + Neem	2,244.94	2,349.95	2,297.45	4,758.34	4,448.69	4,603.52
OM + Agnihotra ash	9,191.72	8,226.35	8,709.03	6,863.55	6,174.35	6,518.95
OM + Himbio + Bt	7,425.67	6,409.59	6,917.63	5,189.57	4,578.92	4,884.25
OM + BD 500	5,572.97	4,817.07	5,195.02	4,820.03	4,558.34	4,689.19
Control	1,475.87	1,064.52	1,270.20	3,355.24	3,025.61	3,190.43
Mean	4,738.66	4,218.39		4,929.81	4,399.95	
CD						
Date of sowing	226.05			455.33		
Organics	391.54			788.65		
Interaction	553.72			NS		

(CD: Critical Difference, NS: not significant, MP: Moon Position Sowing, NMP: Non Moon Position sowing, OM* (Organic manure): FYM @ 20 t/ha + Vermicompost @ 15 t/ha; Himbio: Mixture of Trichoderma (JMA-4, SMA-5, DMA-8 and JMA-11); Bt; *Bacillus thuringiensis* ; BD 500: Biodynamic 500.)

Table 7: Effect of date of sowing and addition of organics on yield of lemon grass.

Organics	Fresh Yield (kg/ha)					
	First year			Second year		
	MP	NMP	Mean	MP	NMP	Mean
Organic manure* (OM)	4,667.00	4,083.00	4,375.00	5,137.00	3,603.00	4,370.00
OM + Neem	4,583.00	4,417.00	4,500.00	5,253.00	3,998.00	4,626.00
OM + Agnihotra ash	7,853.00	7,467.00	7,660.00	7,278.00	5,883.00	6,581.00
OM + Himbio + Bt	7,292.00	7,000.00	7,146.00	6,025.00	5,200.00	5,613.00
OM + BD 500	6,754.00	6,500.00	6,627.00	5,581.00	5,069.00	5,325.00
Control	4,000.00	2,833.00	3,417.00	3,389.00	3,193.00	3,291.00
Mean	5,858.00	5,383.00		5,444.00	4,491.00	
CD						
Date of sowing	125			407		
Organics	216			704		
Interaction	306			NS		

(CD: Critical Difference, NS: not significant, MP: Moon Position Sowing, NMP: Non Moon Position sowing. OM* (Organic manure): FYM @ 20 t/ha + Vermicompost @ 15 t/ha; Himbio: Mixture of Trichoderma (JMA-4, SMA-5, DMA-8 and JMA-11); Bt; *Bacillus thuringiensis*; BD 500: Biodynamic 500.)

Effect on oil per cent

Oil percent was significantly higher where sowing was done according to moon position as compared to that in the crop sown as per non moon position Table (8). Interaction of date of sowing and addition of organics was significant for oil percent with highest oil (0.46 %) in treatment where lemon grass was sown as per moon position with organic manure + Agnihotra ash while lowest oil (0.18 %) was obtained in control with sowing as per non moon position. There was no attack of insect pest on the crop and the crop was disease free.

Table 8: Effect of date of sowing and addition of organics on oil percent in lemon grass.

Organics	Oil percent		
	Date of sowing		
	As per moon position (MP)	As per Non moon position (NMP)	Mean
Organic manure* (OM)	0.31	0.21	0.26
OM + Neem	0.31	0.19	0.25
OM + Agnihotra ash	0.46	0.41	0.44
OM + Himbio + Bt	0.34	0.35	0.35
OM + BD 500	0.38	0.35	0.37
Control	0.18	0.18	0.18
Mean	0.33	0.28	
CD			
Date of sowing	0.014		
Organics	0.024		
Interaction	0.033		

(CD: Critical Difference, NS: not significant, OM* (Organic manure): FYM @ 20 t/ha + Vermicompost @ 15 t/ha; Himbio: Mixture of Trichoderma (JMA-4, SMA-5, DMA-8 and JMA-11); Bt; *Bacillus thuringiensis*; BD 500: Biodynamic 500.)

Correlation analysis

Correlation analysis between growth parameters, yield and oil percent showed that all the growth parameters were highly and significantly correlated to yield and oil percent with coefficient ranging from 0.904 to 0.998 in first year and 0.767 to 0.885 in the second year (Table 9). Highest correlation of yield was established with number of new slips, showing that yield increased with the increase in number of new slips.

Table 9: Correlation between different parameters, yield and oil content of lemon grass.

Parameter	**Plant height**		**Plant spread**		**Fresh yield**	
	1st year	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
No. of off shoots	0.943*	0.885*	0.961*	0.827*	0.964*	0.850*
Plant height			0.960*	0.767*	0.904*	0.826*
Plant spread					0.959*	0.818*

(*Significant at 95% confidence.)

Discussion

In both the years of study, sowing as per moon position significantly increased plant height and number of off shoots (Plates 1 & 2) which may be due to better germination rate (Maw, 1967), water absorption (Brown & Chow, 1973) and metabolism in these plants (Brown, 1960). These growth parameters improved all the more with the addition of organics, contributing towards healthier chemical, physical and biological conditions of the soil. Steiner (1924) stated that the Moon especially in its synodic cycle was of great importance for the growth of crops. Brown & Chow (1973) have reported the effect of lunar cycle on the water absorption process in the plants. It may have an indirect effect on the nutrient uptake by the plants, resulting in increased growth in case of crop sown on moon position day. Brown (1960) has also confirmed the effect of this lunar phase ('synodic') cycle on metabolism of the plants. Within the Anthroposophical movement, botanical studies of plant morphology by Bockemühl have supported the view that stages of plant growth may be seen in terms of such 'formative forces' that are linked with the traditional four elements. He has related the stages of leaf, flower, and seed formation with water, air and warmth (Bockemühl, 1980). Significantly higher plant height and number of off shoots were obtained with addition of agnihotra ash, followed by addition of Himbio + Bt and BD 500.

Plate 1 **Plate 2**

Plate 1: Lemon sown as per moon position (MP).
Plate 2: Lemon grass sown as per non moon position (NMP).

Sowing according to moon position with organic manure and agnihotra ash recorded the highest yield. Results from the trial of Thun and Heinze (1979) on potato, beans and radish have also indicated that the yield maxima appeared in the, predicted 'trigon' or Moon-constellation-element of the sowing dates. Abele (1975) in his experiment on grain crops (barley and oats) and root crops (carrots and radish) showed that there was a mean yield excess of 7% in the 'fruitday' trigons and an averaged excess of 21% in the 'rootday' trigons as compared to sowings at other times. In a two year study conducted at the Model Organic Farm of CSK Himachal Pradesh Agriculture University, significantly higher maize yield has been reported (ICAR, 2007) in crop sown as per moon position (18.2%) than the crop sown as per non moon position. Kollerstron & Staudenmaier (1998) have reported the results from their trial on potatoes and showed that mean yields on 'rootday' sowings were 30 per cent in excess of sowings on other days. Bishop (1977) has also obtained yield excesses in leaf-day sowings. The increase in yield can be attributed to the significant effect of date of sowing as per moon position on growth and development of these crops.

In association with soil microorganisms, organic manures are known to help in synthesis of certain phytohormones and vitamins which promote the growth and development of crops (Kumar, 2007). Similar results have been obtained by Sharma (1983). Organic manures are also known to increase the cation exchange capacity of soil, form chelates with micronutrient elements and consequently leaching losses are reduced considerably. Besides this, organic manures help to improve the soil structure which in turn increases the infiltration and retention of water, improves soil aeration and moderates the soil temperature (Allison, 1973).

Agnihotra ash, when put on the soil, helps stabilize the amount of nitrogen and potassium present. Trace elements in the soil change drastically (Paranjpe, 1989). Kratz & Schnug (2007) found that the addition of agnihotra ash improves the short-term solubility of soil phosphorus compounds, which then may be more readily available to plants and soil microorganisms.

Oil percent was significantly higher where sowing was done according to moon position as compared to that in the crop sown as per non moon position (Table 8). There was no attack of insect pest on the crop and the crop was disease free. Better metabolism of plants due to sowing as per moon position might have increased oil content and at the same time agnihotra ash might have stabilized the nutrient present in soil contributing in synthesis of better oil recovery in lemon grass. The present study clearly indicates that Homa farming and Biodynamic farming (Biodynamic Planting Calendar) have potential for improving the plant yield and oil content of *Cymbopogon citratus*.

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CONSUMER CONCERNS: IS ORGANIC FOOD IMPORTANT IN AN ENVIRONMENTALLY RESPONSIBLE DIET?

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Abstract

How humans manage environmental sustainability will impact the wellbeing of future generations. Research has been considering the environmental impact of consumers' dietary preferences. This paper reports on the specific role of organic food in such choices. Results based on a survey of consumers (N=163) in Australia show that many want to have an environmentally responsible diet and believe that their purchases of organic food contribute to such a diet. When respondents were presented with 12 food attributes, 17% rated 'organic' as very or extremely important while 73% rated 'quality' as very or extremely important, and with the ten other attributes rating in between. Thirteen percent of respondents reported 'never' purchasing organic, while 2% responded 'always', 15% 'frequently', 36% 'sometimes', and 34% 'rarely'. Of nine strategies presented to respondents for achieving a sustainable diet 3% reported maximizing their purchases of organic food, 17% of respondents reported avoiding bottled water, and the other seven strategies rated in between. Fifty four percent of respondents indicated a readiness to increase their organic consumption. One strategy for growing sales of organic food is to encourage existing consumers of organics to purchase more of these products. This may require focusing on promoting its superior health credentials whilst offering it at comparatively convenient locations and competitive price/quality relationships. In addition this research suggests that there is scope to jointly promote the co-benefits of other environmentally friendly dietary behaviours, such as encouraging reductions in eating meat and junk food, as well as minimising the amount of food waste.

Key words: organic food, sustainable consumption, consumer behaviour, market growth.

Introduction

This paper contributes to addressing emerging concerns about the long term environmental impacts of high levels of consumption by focussing on the environmental impact of consumers' dietary preferences. The specific example reported in the present study is the role that organic food purchases have in contributing to a healthy and sustainable diet. By using a marketing framework, the general but somewhat problematic concept of sustainable consumption is discussed prior to reviewing relevant food marketing literature. The focus is on household level actions that contribute to creating environmentally sustainable diets. This is followed by the presentation of empirical research that identify what consumers are currently report doing and areas in which they are susceptible to change. The conclusions provide recommendations for strategies that may assist the organic food sector to continue growing its market whilst simultaneously contributing to the challenge of environmental sustainability.

Background literature

Sustainable consumption has emerged as a relative new area of research. It originally addressed the negative impact that high levels of individual purchases, also referred to as consumerism, tend to have on the natural environment. This rapid increase in consumption, particularly in developed countries, is being driven by an expanding and increasingly affluent global population. Sustainable consumption focuses on the equitable use of resources across the planet (intragenerational equity) and for future generations (intergenerational equity) as well as encompassing the consideration of the full product-life-cycles, minimisation of wastes and pollution as well as the use of renewable resources within their capacity for renewal (NME 1994).

Whilst the notion of sustainable consumption has intuitive appeal, achieving meaningful sustainability from any form of consumption is problematic. Recent publications have emphasised this, including those that use the term ‘affluenza’ to describe consumerism as a socially transmitted disease which erodes human wellbeing (e.g. Hamilton & Denniss, 2005). Others are more pragmatic and optimistic.

It has been suggested that it is necessary to make sustainable choices easier by:

- “ensuring that incentive structures and institutional rules favour sustainable behaviour”,
- “enabling access to pro-environmental choice”,
- “engaging people in initiatives to help themselves”, and
- “exemplifying the desired changes within Government policies and practices” (Jackson, 2005, p.iii).

More recently it has even been suggested that individual wellbeing and environmental sustainability is possible without curtailing economic growth with the concept of ‘prosperity without growth (Jackson, 2009).

Not surprisingly, food is a major focus for sustainable consumption (WWF 2011), as it is a daily choice for most citizens and the food system is a large contributor to global warming, at around 20% of greenhouse gas emissions (Friel et al. 2009). There are many areas in which the sustainability of the global food system may be improved, ranging from production, through the supply chain, to consumption. The United Nations has identified improving the environmental sustainability of diets through consumer education as a priority area within the more general area of the ‘green’ economy initiative – being one that “achieves increasing wealth, provides decent employment, successfully tackles inequities and persistent poverty, and reduces ecological scarcities and climate risks” (UNEP 2010, p. 2).

The ability to understand and influence food related consumer behaviour is what the UK Government has recently referred to as demand-led change towards low environmental impact diets (Defra 2010). More recently it has been stated that vital work is needed to establish what is sustainable food (GOS 2011).

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Organic food is recognised as contributing to sustainable consumption by many influential organisations (DAFF 2011; FAO 2011; UNEP 2011). It offers an exemplar of a more sustainable food system due to its superior environmental credentials, many of which may be incorporated into other food systems. However, it is important to note that these alleged superior environmental credentials are not necessarily fully supported by the available scientific evidence and continue to be the focus of research. A recent meta-analysis of the literature concluded that, on average, organic soils on farms have a higher content of 'organic' matter and higher biodiversity, both in terms of the natural biodiversity in the wildlife present and in the agro-biodiversity of the breeds used by farmers (Mondelaers et al. 2009). In relation to leaching of nitrates and phosphates, when measured on a per hectare basis organic farms are better, however, on a per unit of production the benefit is not as pronounced, or non-existent, due to the lower yields. This reduction in this aspect of the environmental benefits of organic farming when measured on a per unit of production and in instances where there is a lower yield is supported by other research (de Backer et al. 2009, de Ponti et al. 2012). In relation to energy use, most organic farms demonstrate a lower environmental impact, both in terms of per hectare and per unit of production, except for some specific products, such as poultry (due to the longer time taken to reach maturity) and fruits.

The superior environmental credentials of organic food, or at least the perception of these, is important to some, but not all, consumers. Many consumers, particularly those in affluent countries, have the option to choose between organic and conventional food products. Recent research (Mondelaers et al. 2009; Aertsens et al. 2011) supports the claim that the most important feature of organic food products are their superior health claims (due to the fact artificial biocides are not allowed during their production) whilst being better for the environment is a lower order priority for consumers. The reasons why consumers select organic products are remarkably consistent across products, cultures and time (Hughner et al. 2007; Pearson et al. 2008; Pearson et al. 2011). As with the environmental credentials it is important to note that the scientific evidence to support the superior health claims is contested (Dangour et al. 2009; Hoefkens et al. 2009; Dangour et al. 2010).

It is recognised that diets and their associated food systems are hugely complex, with numerous interconnected but often independently managed stages along the supply chain from production, processing and retailing before final consumption. Consequently there are many points of intervention where efforts could change its environmental impact (see for example, Lynch et al. 2011, GECAFS 2012). However, eating healthily has been identified as the primary link for how consumers engage in sustainable food consumption in the UK (Defra 2007). The Sustainable Development Commission in the UK has developed a list of priority actions for improving sustainability in the food system that could be initiated by individual consumers (SDC 2009).

The SDC study used a very broad definition of sustainability, which included more than just ecological outcomes. It is based around the UK Government's principles of sustainable development by "ensuring a strong, healthy and just society and living within environmental limits" (SDC 2009, p.8). Thus it embraces requirements of a healthy diet as a prerequisite for pursuing a more sustainable diet. Further they explicitly aimed at integration (rather than trade-offs) between environmental, social and economic outcomes. Its hierarchy of recommendations is based on the relative ease, or difficulty, of implementation. It placed highest priority on actions they considered were “likely to have the most significant and immediate impact on making our diets more sustainable, in which health, environmental, economic and social impacts are more likely to complement each other” (p.4).

The high priority proposed actions are:

- “lowering consumption of meat”,
- “lowering consumption of dairy products”,
- “consuming less low nutritional value products”, and
- “reducing food waste” (SDC 2009).

Actions which were likely to result in trade-offs between different aspects of sustainability were given a lower priority. These were:

- “increasing consumption of seasonal and field grown fresh fruits and vegetables (and reducing consumption of foods grown in heated greenhouses)”,
- “only eating fish from sustainable sources”, and
- “increasing consumption of organic food” (SDC 2009).

Actions expected to make a smaller contribution towards sustainability were given the lowest priority. These were:

- “reducing energy use in food purchases and cooking”, and finally,
- “drinking tap water rather than from bottles” (SDC 2009).

Although these recommendations are for the UK, they are argably relevant to Australia due to the major similarities in both consumer diets (relatively high levels of protein sourced mainly from beef whilst wheat and potatoes are the main sources of carbohydrates, and an abundance of fruits and vegetables) and food systems that supply them (dominated by intensely competitive chains of supermarkets, and a food service sector that is increasing its market share, both of which use global sourcing of products). In addition, it is relevant to note that shortening the supply chain, which often manifests itself as a reduction in food miles is not on this list of priorities. Whilst this more local sourcing of food has a strong resonance with many consumers (Pearson et al. 2011) an environmental benefit only occurs in specific circumstances (ABARE 2009).

In a similar manner to the global average, the food system in Australia has a major impact on the natural environment where it accounts for around 20% of greenhouse gas emissions. Whilst agriculture also produces natural fibres, and some fuel and pharmaceuticals, it is dominated by production of food for human consumption. Rather than subsistence farming or wild harvesting, it is industrial-scale agriculture that is the source of most raw materials for food products in Australia. The environmental impact of agriculture is substantial. For example, it is responsible for the management of 60% of the landscape and uses almost 70% of the available fresh water (ABS 2010).

In summary, increasing consumption of organic food is seen to be one of the top nine behavioural changes that consumers could make to improve the sustainability of their diets - although it is recognised that the details of its environmental contribution is beyond the scope of this paper. However, this research contributes to the literature by exploring consumer purchases of organic food in terms of their existing behaviour and the potential to change this behaviour within the context of the nine areas identified that lead towards a more sustainable diet.

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Materials and methods

The collection of empirical data was undertaken in two phases. All of the empirical information was obtained in the city of Canberra which is in the Australian Capital Territory (ACT), is the capital of Australia, and has a population of almost 400,000 people. The questionnaire responses were collected and collated using an online survey tool (SurveyMonkey) prior to analysis with descriptive statistics.

The first phase aimed to gain a qualitative understanding of the context in which dietary choices were made and the relevance, if any, of environmental sustainability in relation to these preferences. This was completed in two focus group discussions with a convenience sample of 8-10 young adults in each. Key aspects of the discussion were recorded and used to inform development of the questionnaire that was used in the following phase.

The second phase of data collection aimed to quantify the extent of key behaviours within a population of innovators or 'early adopters' of an environmentally sustainable diet. Previous research has identified that affluence and education are positively correlated with pro-environmental behaviours (e.g. Defra 2007, Lea & Worsley 2007). An online questionnaire was developed containing both open and closed-ended questions. It was pilot tested with a convenience sample of 10 young adults who were known to the author, and, with minor modifications, was made available to a sample of adult food shoppers in the target population – government employees associated with the University of Canberra. Subjects were recruited by sending a single bulk-email invitation to participate through an informal intranet communication network (N = approximately 600) of staff and higher degree research (HDR) students of the University of Canberra comprising individuals who had opted-in for the intranet chat forum.

A total of 163 responses to the questionnaire were received. As anticipated with food shoppers the majority of the respondents (75%) were female. Respondents represented all age groups (ranging from 15 to 55+ year olds) and living arrangements (ranging from unrelated single adults through the various stages of having children to empty nesters). Most households (73%) had no children living at home. As planned, respondents had higher than average levels of income and education. For example their average level of education (78% with Bachelor Degree) is higher than the average in the ACT (30%) and Australia (19%). With this higher level of knowledge and purchasing power these respondents, on average, were expected to be leaders – as opposed to followers or laggards - in terms of their behaviour with respect to reducing the environmental impact of their diets (Defra 2007). In addition, these respondents would be expected to be more aware and engaged in proactive measures to improve their health. Evidence to support this is found in the fact that a relatively high proportion of respondents were in a healthy weight range, with only 32% reportedly being overweight or obese, half that of the Australian population at 62% (ABS 2008).

In addition, in terms of the methodology used, it is important to note that the collection of information was based on self-reported behaviour. Hence the results may be, for example, overstated if respondents reported on how they would like to behave, rather than how they actually behave. Further, whilst previous research has confirmed that most consumers have a correct knowledge about what certified organic food is (Pearson et al.

2011) this research method includes the implicit assumption that they are able to identify it at the point of purchase, which is not always the case (Henryks et al. 2010).

Results and discussion

The results indicate that these food purchasers are concerned about the environment, with nearly all (96%) wanting to lead a more environmentally friendly lifestyle. Further, just over half (56%) report that they consider the environment when making food related choices.

Food is often seen as a relatively frequent low value purchase where consumers tend to rely on habits that enable them to simplify the choice task. Hence it is important to understand the relative importance of organic within the context of other product features which are used by consumers to make their purchase decisions. It is generally recognised that health, quality, price and convenience dominate food buyer's decision making (Pearson et al. 2011). This was supported by results from this research as shown in Figure 1 with health and product quality being by far the most important product features.

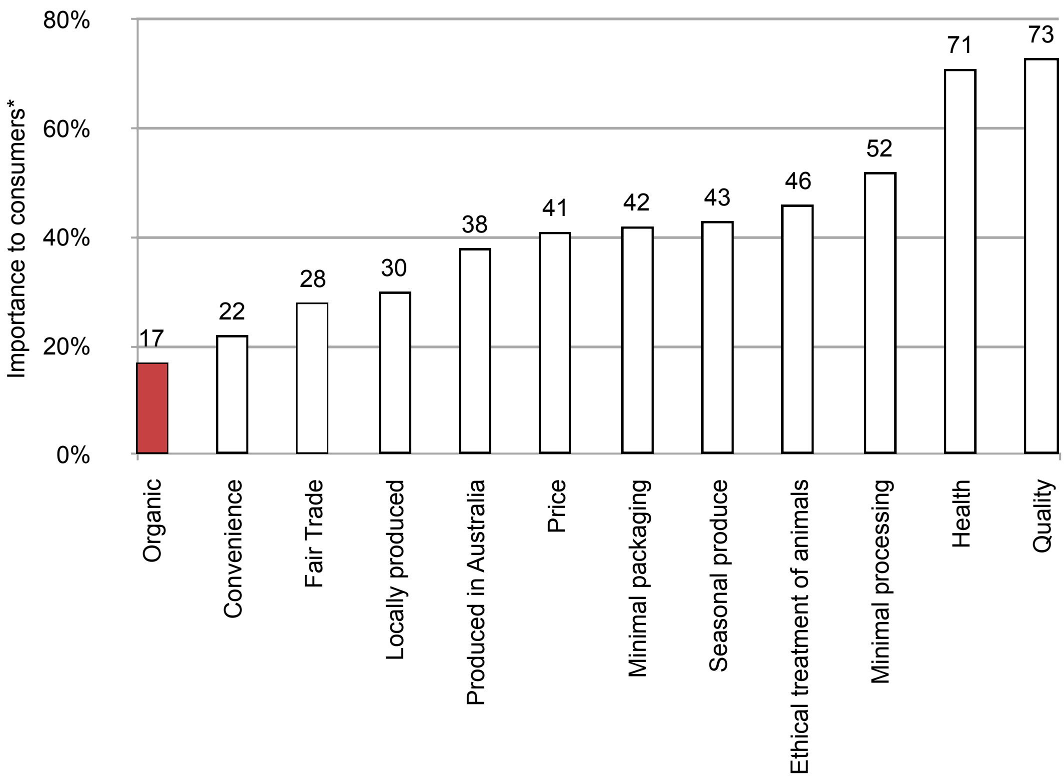

Figure 1. Importance of organic in relation to other product features. (* % of customers who rated it 'very' or 'extremely important' on five point scale. N=163. All differences relative to 'organic' are significant at a 90% confidence level except 'convenience').

As shown in Figure 1, price (at 41%) was around twice as important as organic (at 17%) and convenience (at 22%). Throughout the discussion of these results it is important to remember that the respondents represent a sample of consumers who are expected to be leaders in terms of adopting sustainable dietary behaviours. Evidence of these potential leaders in terms of health and sustainability is found with Figure 1 where health and quality are extremely important in contrast to the lesser reported importance of price and convenience.

However, in spite of the relatively low importance that respondents place on organic food (Figure 1), the vast majority (87%) claim that they buy it, albeit most only do this rarely (33%) or sometimes (36%) with a small proportion purchasing frequently (15%) and only a few (3%) always purchasing it (Figure 2).

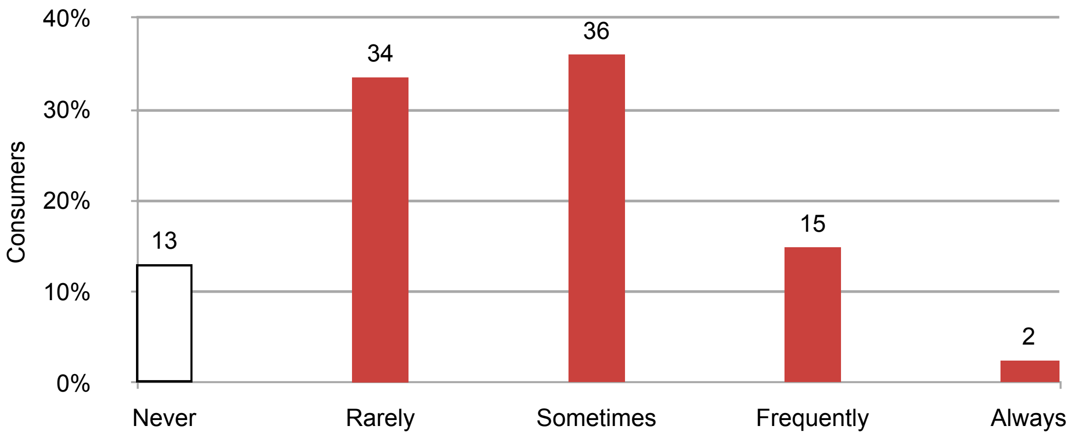

Figure 2. Frequency of organic food purchases. (N=163. All differences relative to 'never' are significant at a 90% confidence level except 'frequently').

This is consistent with the results from other research which has shown that most food consumers are 'switchers' as they purchase organic products some of the time and conventional products at other times (Henryks & Pearson, 2012); there are only a few dedicated organic food consumers.

As shown in Figure 3, only a small percentage of respondents (3%) purchase as much organic food as they can. However a larger number are engaged in contributing to reducing the environmental impact of their diet through other behaviours.

In relation to the nine food-related behaviours nominated (SDC 2009), around 1 in every 10 food respondents have stopped eating junk food and meat. The motivation for this is not determined in the present study and may not be to contribute to the environment and may alternatively be related, for example, to health and/or animal welfare concerns. With only a small percentage of respondents (4%) actively reducing their food waste the vast majority of the respondents apparently continue to waste food by throwing it out. However, there is the additional issue of 'wasting' food by eating more than is required. This latter issue is important as a significant portion of the survey respondents, at around

1 in 3, were self-classified as being overweight or obese. The range of motivations for those who have already given up eating dairy products may be similar to those for meat. However, they represent a much smaller portion of respondents (4%).

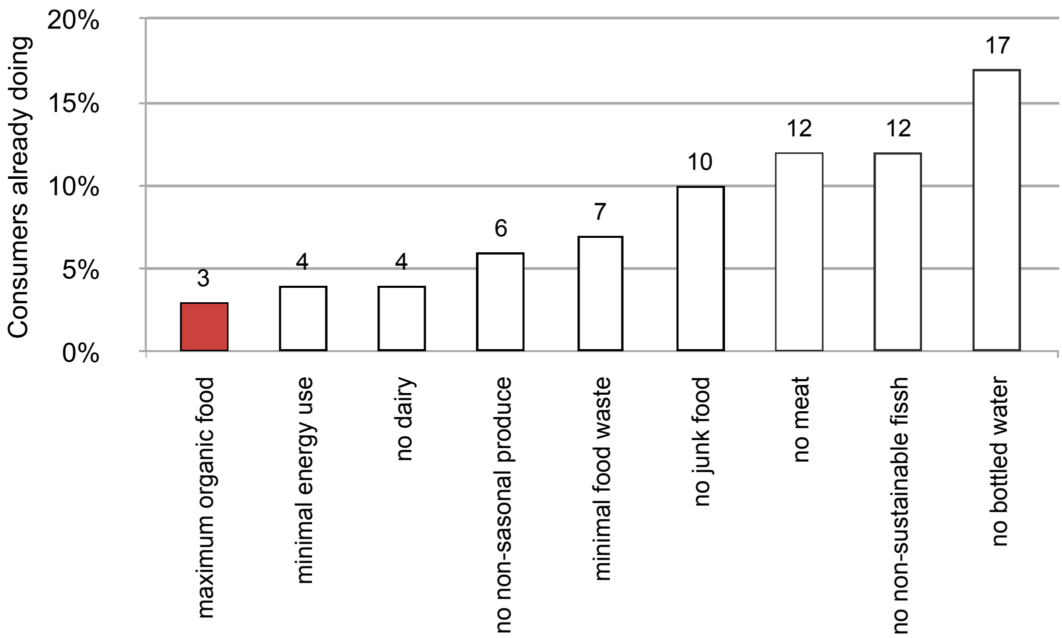

Figure 3. Relative popularity of organic food purchases in sustainable dietary behaviours. (N=163. All differences relative to ‘organic’ are significant at a 90% confidence level except ‘minimal energy use’ and ‘minimal food waste’).

In relation to the less important behaviours, almost 1 in 5 do not purchase bottled water (Figure 3). In addition, over 1 in 10 food respondents either do not purchase fish, or only purchase fish that has been sourced from sustainable sources. Just over 1 in 20 report that they only eat seasonal fruits and vegetables. And finally, only a small portion, around 1 in 25, have reduced the energy used to purchase, store and cook their food (Figure 3).

This leads to two questions, would respondents change their behaviour if they were told that purchasing organic food would improve the environmental sustainability of their diet, and related to this, are there other behaviours that the organic food movement could associate with to achieve a benefit in terms of its own market growth?

The results for likely changes in behaviour, when prompted with the statement that there are nine areas in which they could improve the environmental sustainability of their diet (SDC 2009), are shown in Figure 4. In relation to improving the sustainability of their diet in the nine areas identified, there is a big range from only a few (15%) being willing to reduce their purchases of dairy products through to most (80%) being willing to stop purchasing water in bottles. Increasing purchases of organic food sits in the middle of this range with many respondents (54%) being willing to do it.

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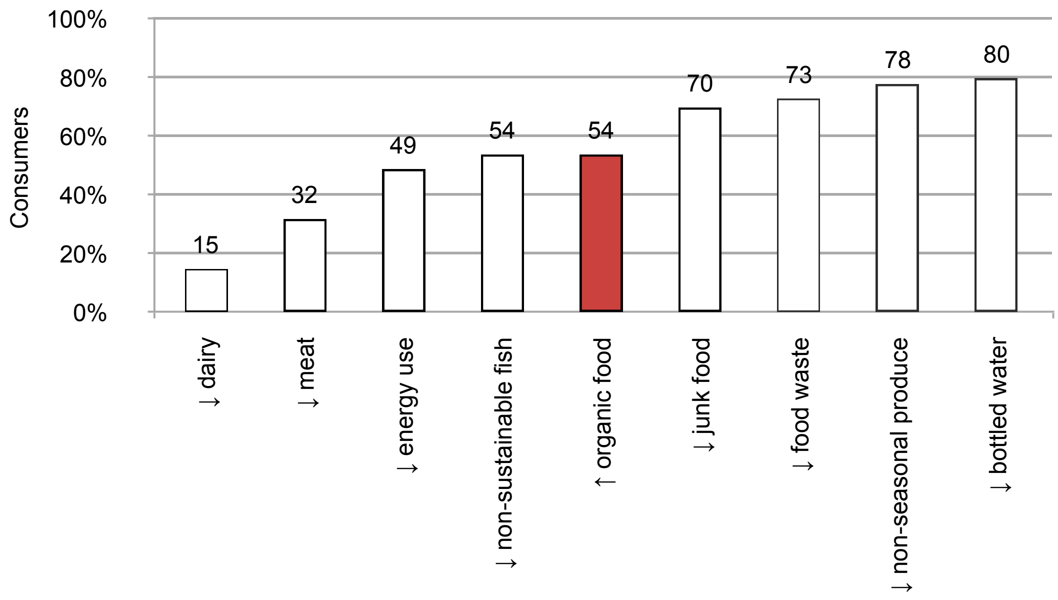

Figure 4. Relative popularity of increasing organic food purchases to improve sustainability of diet. (N=163. All differences relative to 'organic' are significant at a 90% confidence level except 'energy use' and 'non-sustainable fish').

In relation to the four high priority areas (SDC 2009), most respondents (over 70%) would reduce food waste and their consumption of junk food, a much small number (32%) would reduce their purchases of meat and even less (15%) would consider reducing their consumption of dairy products. These results provide support for recent government led activities in Australia that focus on reducing waste (e.g. 'Love food – Hate Waste' http://www.lovefoodhatewaste.nsw.gov.au/) and perhaps for improving health through reducing obesity (e.g. 'Swap it – Don't stop it' http://swapit.gov.au/).

Conclusions

The results from this research show that many respondents (around half) were aware that their food choices have a direct impact on the environment, and a majority responded favorably to the proposal to increase their organic food consumption (Figure 4). It is important to note that diets and the food system that supports them are complex. Their multiple stages and independent actors offer many potential points of intervention. Further, sustainability is a multi-layered and multifaceted concept that may be approached and measured in many different ways. Conclusions from this paper make a specific contribution at the level of individual consumer choice and the role that organic food purchases play in the more encompassing challenge of environmental sustainability.

Historically the dominant choice criteria for organic food has been its personal health benefits. Environmental concerns, such as those associated with climate change, are moving up the political agenda in countries like Australia. This suggests that there is scope to align the superior environmental credentials of organic food with these emerging concerns from both individuals and governments. A strategic priority for the organic food movement could be promoting the contribution that it makes to improving the natural environment, with perhaps appropriate cautions due to the contested nature of the scientific evidence. If successful this might influence the large portion of consumers who 'switch' between organic and conventional food. By migrating them along the continuum from 'rarely' to 'frequent' they will increase their purchases of organic food. Such a promotion of organic food could be combined with other sustainable diet behaviours to provide co-benefits for the environment, such as encouraging reductions in eating meat and junk food, and minimising the amount of food that is wasted. However, as with any competitive market place where consumers have a range of choices, to achieve sustained sales growth, individual organic food products will need to meet or exceed consumer's experiences in relation to conventional alternatives.

Thus, in summary, this research indicates that participants in the organic food movement who wish to increase sales should continue to promote its superior health credentials whilst ensuring that products are offered in comparatively convenient retail outlets at competitive price/quality relationships. This research has added to the literature by identifying the relative importance consumers place on organic food in relation to an environmentally sustainable diet. Whilst its specific contribution is modest, there is the opportunity to align with other behavioural changes that support a more sustainable diet. Hence continued recognition and enhanced support for organic food producers, processors, retailers and consumers from Government is justified as it provides a meaningful contribution to their environmental policy agenda as well as supporting their health policy aims.

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BOOK REVIEW:
RUDOLF STEINER - ALCHEMY OF THE EVERYDAY

Mateo Kries, Alexander von Vegesack & Julia Althaus (editors), Vitra Design Museum, Weil am Rhein, 2010. ISBN 978-3931936860, 336 pp., hardcover, English version, €79.90

In the nineteenth century a future of chemical farming was imagined by chemistry advocates (e.g. Liebig, 1840; & Riddle, 1868). It was Fritz Haber and Carl Bosch with their 1909 process for capturing atmospheric nitrogen that ushered in the era of synthetic fertilizer and chemical agriculture. In 1924 Rudolf Steiner raised a contrarian voice to the chemicalization of agriculture and he proposed a differentiated agriculture (Paull, 2011a; Steiner, 1924). But who was Rudolf Steiner?

Rudolf Steiner - Alchemy of the Everyday aims to present an overview of Steiner's life work. This is a timely retrospective tome whose appearance coincides with the one hundred and fiftieth anniversary of Steiner's birth. *Alchemy* accompanies a travelling exhibition, of the same name, curated by Germany's Vitra Design Museum.

Rudolf Steiner was a pioneer of New Age thinking. He displayed a prodigious appetite for work, and his output was prolific as well as diverse. He presented over 5105 lectures (Stewart, 2012) and he is the author of 354 books (SteinerBooks, 2012), so that any overview of Steiner is destined to be challenging.

Alchemy is first and foremost a visual feast showcasing the life and mind of Steiner. It illustrates the diversity and novelty of Steiner's personal work as it touched the 'everyday' and as it manifested across a multitude of fields. Those fields include architecture, furniture, art, painting, sculpture, dance, jewellery, typography, medicine, education, and agriculture. *Alchemy* encapsulates Steiner's oeuvre within the space of 336 pages.

Alchemy, the book, is a comprehensive record of *Alchemy*, the exhibition. The book is a 'coffee table size' (215 x 290 mm) hardcover which is lavishly illustrated in colour throughout. There are over 500 illustrations, 16 essays, and a biographical timeline of Steiner's life (1861-1925). The book provides exhibition visitors with an enduring record of the experience and of the exhibits (Paull, 2011c). For those unable to attend the exhibition, *Alchemy* offers the rare opportunity, and a rich experience, within the span of a single volume, to grasp the breadth and depth of Steiner's life work.

The Foreword states that: "Rudolf Steiner was one of the most influential - yet most controversial - reformers of the 20th century" (Vegesack & Kries, in Kries et al., 2010, p. 18). In the nearly nine decades since his departure, the influence of Steiner has not subsided and nor has the contestation of his ideas. As Frath states: "Rudolf Steiner wanted a new spirituality to counter the prevailing zeitgeist, a spirituality which would find expression in art and design and again influence the life and inner essence of human beings" (in Kries et al., 2010, p.135).

Alchemy opens with a full page reproduction of Huschke's finely crafted oil painting of Steiner, 1906. The book moves on to the apogee of Steiner's architecture, the two Goetheanum buildings. The first Goetheanum was destroyed by fire on New Year's eve, 1923. The present Goetheanum is a masterpiece of design executed in reinforced concrete. These and other of Steiner's buildings appear in *Alchemy* as plans, models, construction photos, and completed projects. As Frath points out: "Rudolf Steiner issued this challenge to his colleagues: 'Let us work on making our building … so that those who come to look at it are unconsciously transported into the sphere of love with which it was constructed'" (in Kries et al., 2010, p.136).

A strength of *Alchemy* reflects the strength of Vitra's own collection of anthroposophic furniture. For a design museum located within fifteen kilometres of Anthroposophy's headquarters at Dornach, Switzerland, anthroposophic furniture offers attractive opportunities for collection and exhibition of 'the everyday'. *Alchemy* presents Steiner's own, and anthroposophically-inspired, furniture including chairs, desks, cabinets, wardrobes, a bed, and a dressing table.

Alchemy states that: "Steiner is regarded as one of the pioneers of organic farming" (Gogos, in Kries et al., 2010, p.274). Agriculture appears towards the end of *Alchemy,* and is less well represented than one might wish, but that is perhaps under-standable given the book's design museum provenance, and the context of agriculture within Steiner's life work. The subject of agriculture comprised just eight Steiner lectures delivered over a ten day period, and this was out out of an oeuvre of more than 5000 lectures over four decades. The terms 'biodynamic agriculture' and 'organic farming' both derive from Steiner's characterization of the farm as an organism, although he himself neither coined, used nor heard either term (Paull, 2011b). Shortly after presenting his Agriculture Course in the summer of 1924, Steiner retired from public life in the September of the same year, and he died in March 1925. Alchemy includes images of one of Steiner's colourful Agriculture Course blackboard drawings, of the first German edition of his *Landwirtschaftlicher Kursus* (Agriculture Course), and of Demeter farmers stirring biodynamic preparations. In an unfortunate turn of phrase, Gogos refers to "the organic fad" (p.272). He observes that "Steiner's originality … lay in the cross-disciplinary synthesis of disconnected fields" (p.273). When referring to "Steiner's direct successors" (p. 275) and the crystallization process, it is an oversight not to acknowledge the preeminent successor and developer, Ehrenfried Pfeiffer (Paull, 2011d; Pfeiffer, 1936, 1938).

Alchemy is an unparalleled opportunity to consider Rudolf Steiner in the context of a life lived intensely and with purpose. The organic sector is but a single strand of his diverse and enduring legacy. Released simultaneously, and complementing *Alchemy*, are two new books, *Rudolf Steiner in Stuttgart* (Neider & Schukraft, 2011) and *Rudolf Steiner and Contemporary Art* (Brüderlin & Groos, 2010).

Previous generations have been, variously, baffled and bewildered, enthralled and intrigued, endeared and enraged by Rudolf Steiner. As *Alchemy bears* witness, Steiner was a remarkable man and this major retrospective is a celebration of his difference. *Rudolf Steiner - Alchemy of the Everyday* is a delightful book that belongs in every serious Steiner collection and library.

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