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JOS has been founded on the spirit of participation. We have identified a need, worked with stakeholders to ensure that it meets all needs and pursued it till a point of completion. Our work has been voluntary and collaborative. We have much more to do and require your support.

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EDITORIAL: ASIAN SPRING FOR ORGANIC AGRICULTURE: KOREA TAKES A LEAD

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May, 2012

A vote in the bowels of a medieval castle in Vignola, Italy, witnessed Korea win the right to host the Organic World Congress (OWC). This was a quarry that the Koreans had unsuccessfully pursued in Adelaide, Australia, three years earlier. The 15th OWC in Adelaide was the first for the southern hemisphere, and now Korea's victory for the 17th OWC would be the first for Asia.

The OWC is the triennial event where organics people come together - researchers, advocates, producers activists and administrators. Korea as a host for the OWC signals the aspirations of the organic sector in that country, rather than their achievements to date. Korea most recently reported a modest 15,518 hectares of organically managed land, that being 0.84% of its agricultural land (Willer, 2012). Korea only accounts for about half of one per cent of Asia's total of 2,778,290 hectares of organic land. The OWC is however an indicator that Korea is in pursuit of a leadership position in the world of organic agriculture.

The OWC was held at the pleasant Namyangju Sports and Culture Centre which is several hours west, by land transport, of Seoul's international Incheon airport, and on the outskirts of the sprawling conurbation of high density urban ugliness that is modern Seoul.

As with previous OWCs, Korea offered thematic organic pre-conferences. These were held "at various sites in Korea" (KOC, 2011, p.19) and may have attracted greater attendances if there had been better pre-event specific information on dates, venue addresses and locations, along with travel and accommodation details and options. There were eight thematic pre-conferences: Aquaculture, Cosmetics, Ginseng, Seeds, Tea, Textiles, Urban Agriculture, and Wine.

Korea was identified long ago as offering agricultural practices worthy of emulation. A century ago a visiting US Professor of agriculture commented that: "China, Korea and Japan long ago struck the keynote of permanent agriculture, but the time has now come when they can and will make great improvements, and it remains for us and other nations to profit by their experience, to adopt and adapt what is good in their practice and help in a world movement for the introduction of new and improved methods" (King, 2011a, p.274). King's book was published as *Farmers of Forty Centuries: Permanent Agriculture in China, Korea and Japan*. In a nod to King's prescience, the title was recently redacted by a US publisher to read: *Farmers of Forty Centuries: Organic Farming in China, Korea and Japan* (King, 1911b). It has taken a century but King's book has been finally appeared in Chinese, translated by Cheng Cunwang and Shi Yan, and published by Oriental Press, Beijing, in 2011 (ISBN: 9787506042284).

Korea's organic food offerings were on display in the OWC demountable pavilions. Korean organic labels are somewhat impenetrable (for foreigners) being in Korean script. What is not intuitive and was probably not obvious to most visitors was that Korea has taken its own idiosyncratic path with organic labelling. There are four label versions, each of which shares the common logo of a stylized blue and green apple with a white core and a green leaf; however below the logo comes a band of colour with Korean text in white. It was translated to the present author as: a dark green band means certified organic; a light green band means organic-in-conversion; a blue band means no pesticides and reduced synthetic fertilizers; and an orange band means reduced pesticides and reduced synthetic fertilizers. Most of the produce and products on display in the OWC pavilions set up to showcase Korea's organic production bore labels other than the fully fledged dark green 'certified organic' mark. Korea's novel four-way labelling regime is a more 'relaxed' organic labelling scheme than we meet elsewhere in the world. Neighboring China, for example, now has a commendably straight-forward single organic label which appears in two versions, certified organic and in-conversion organic, each with bilingual text, Chinese and English.

The Congress had its lighter and darker moments including: a plenary delegate landing noisily but apparently safely on the floor from a disintegrating chair; the then Vice-president of IFOAM, Andre Leu, bravely keeping a plenary session on the move through a venue power failure; and an IT technician falling soundly asleep onto a keyboard and thereby sending a delegate's statistical presentation into a techno-spasm. It was surprising that taxi drivers struggled with Korean addresses even in Korean script, as well as with maps in the local script, and, despite impressive looking GPS navigation units, they resorted to ringing destinations on their mobile phones for directions. Buses were provided to ferry delegates between their respective accommodations and the Congress venue. The accommodation, none of which was close to the Congress venue, varied from the high-rise Hotel Riviera in downtown Seoul, to the Hanwha Resort which offered share units with ‘floor bedding’, to the quiet and comfortable suites of the Korea International Cooperation Agency (KOICA) situated in a parkland setting - although the soft drink, on offer at the KOICA kiosk, bearing the name ‘Pocari Sweat’ would have benefitted from being workshopped through an Anglophone focus group.

There are some very tangible and enduring outcomes of Korea’s first Organic World Congress. There are two volumes of proceedings, a total of 1090 printed pages of peer reviewed research on organic food and agriculture of the Third Scientific Conference of ISOFAR, which are hardcopy documents of the event (Neuhoff *et al*., 2011a, 2011b). They are useful records for those who attended, and a good resource for those who did not. Some of these papers are available at www.orgprints.org. It is an unfortunate lost opportunity not to have them all posted beyond the ISOFAR members-only website and into the Orgprints mega-archive of organics research.

When the delegates have all departed and those PVC-tents have been packed away, what remains? For Korea, one remarkable enduring legacy of the OWC is the Namyangju Organic Museum. It is the world’s first museum dedicated to organic agriculture and was launched to coincide with the OWC. It is housed in a bold and strikingly modern new building overlooking the Bukhan River (Bukhangang; North Han River). The museum presents a timeline of the history of organic farming beginning with Rudolf Steiner’s Agriculture Course of 1924. The museum showcases Korean traditional farming which we learn is synchronised to twenty four seasonal divisions of the year. The museum has been designed to appeal to a broad audience. It includes interactive experiences successfully targeted at children and families. With its captions in both Korean and English, the Namyangju Organic Museum deserves to attract a broad audience and it rewards a visit (Paull, 2011b).

Each OWC presents an opportunity to refresh the World Board of the International Federation of Organic Agriculture Movements (IFOAM) at the General Assembly. The Korean event was notable in ushering in the first Australian, Andre Leu, as President of IFOAM. Andre is an organic lychee farmer from North Queensland and Chair of the Organic Federation of Australia. We share the hope that his ascendancy to the presidency will reap tangible benefits for organics globally, and especially in Asia, the Pacific, and Australasia.

Figures cited at the closing ceremony were that there were: 800 attendees for the main conference (of whom 268 were from Korea); 1163 attendees for the eight pre-conferences (of whom 949 were from Korea); and that perhaps a total of 250,000 people attended the aggregate of main and ancillary events which included the Slow Food pavilion, the Food Court, the ‘Organic Sports’, the ‘Market Festival’, the ‘Organic Exhibition’, the ‘G Food Show’, the ‘Ssamzie Organic Sound Festival’, and the ‘Bio Tours’.

There were a few lost opportunities for the OWC. There appeared to be no presence of delegates from North Korea, or acknowledgment otherwise that the Korean peninsula was, and remains, split in two by foreign powers as spoils of World War 2. There was also a lost opportunity to showcase Korean food - apparently a fine cuisine, but surely not at its best at the Congress dining hall?

The success of Korea’s Organic World Congress was an affirmation of the resolve, the vision, the vibrancy and the persistence, that remain wedded to the odd idea that we really don’t want out food pesticided, irradiated, and genetically modified and otherwise corporatised, industrialised and patented.

The OWC is about science, about the administration of the movement, about networking, and about showcasing the host country. But more than anything, it is about value and values - what we value, and the values we embrace. There is no consumer clamour, anywhere in the world, for pesticided food, for irradiated food, for GMO food, nor for nano-food. The diverse spiritual traditions of the world recognise the sacredness of food. Every parent wants for their child, clean, safe, nutritious, sustaining food. In a world that is not always open, and is sometimes openly hostile, to the organic solution, it is timely to remember that it was primarily values, rather than science or economics, that ridded agriculture of its previous pernicious dependence on slavery, and that the affirmation of values will be a crucial component of the organic movement’s continuing quest to rid food production of synthetic pesticides, insecticides and herbicides. Each OWC is an affirmation anew of the values that drive, and that unite, the global organic movement.

The twenty-first century is Asia’s century, and Korea’s OWC can serve to reinvigorate the momentum of organics in the region. Asia’s organic statistics are dominated by the ‘organic giants’ of China and India. These two countries occupy global leadership positions in the world of organic agriculture. Worldwide, they are the only states that rank in the top ten countries for those two important indices of organics growth: the increase in organic hectares over the past decade; and the rate of increase of organic agricultural land over the decade (Paull, 2011c).

Korea's Organic World Congress was a milestone for Korea, for Asia, and for the world. It perhaps signals an Asian Spring for organics where Korea, in particular, and Asia, in general, are set to make rapid progress in meeting their aspirations and goals for reclaiming food and agriculture as organic.

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DRY SEASON CROP RESIDUE MANAGEMENT USING ORGANIC LIVESTOCK REPELLENTS UNDER CONSERVATION AGRICULTURE IN ZIMBABWE

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Abstract

The maintenance of a permanent organic soil cover using crop residues under conservation agriculture in Zimbabwe is limited by the competing use of residues as livestock feed. To help address this challenge, this study evaluated the effectiveness of repellents as a management option for protecting crop residues from grazing cattle during dry seasons. Initial on-station trials at Domboshawa, Zimbabwe, in 2009 demonstrated the potential of cow dung, goat droppings, chilli, dry tobacco dust and soaked tobacco as possible cattle repellents and optimum application rates of 3000, 500, 400, 1200 and 300 kg/ha, respectively, were established. These were then tested on farmers' fields at Hereford, an area with high biomass production and Madziwa with low biomass production. It became apparent that at Hereford, after 5 weeks, cow dung, soaked tobacco and tobacco scrap treatments, retained significantly ($P < 0.05$) higher residue amounts of 66.4, 64.5 and 60.7% respectively, compared to the untreated control with 49.7%. On the other hand, at Madziwa, all residues were consumed within three days, irrespective of treatment. The study thus demonstrated that these repellents can be used to protect crop residues from livestock grazing in areas with high biomass production offering alternative feed but ineffective in areas with acute shortage of alternative feed. The study opens a new avenue for crop residue control in crop-livestock systems.

Key words: maize residues, moisture conservation, non-consumption period.

Introduction

The conservation agriculture (CA) principle of maintaining a permanent soil cover has been found to increase soil water retention (Nyagumbo, 2002; Reicosky, 2008) and increase soil fertility (Chivenge *et al.* 2007). Soil water retention can be increased by mulching as a result of reduced run-off, hence increasing infiltration and reducing the soil water evaporation (Nyagumbo 2002, Thanachit *et al.* 2011). Despite the benefits of mulching, adoption of this principle has largely remained low (Chiputwa *et al.* 2010, Twomlow *et al.* 2008). The low adoption of this principle has been attributed to high labour demands arising from the need to carry maize residues from fields at harvest and returning them at the beginning of the next season and the competing uses of residues as soil cover and as livestock feed.

When animals graze crop residues, more nutrients are removed than returned via cow dung (Powell and Williams 1993) since manure and urine voidings are distributed unevenly in fields during grazing. In contrast, fields regularly receiving manure applications from cattle kraals benefit from increase in soil pH, infiltration rate, water holding capacity and decreased bulk densities (Murwira 1993). Vulnerable groups of farmers without livestock thus find themselves struggling to maintain or improve the fertility status of their soils, resulting in reduced crop productivity. In Zimbabwe, crop yield for cattle owners was 3-5 t grain yr^{-1} $farm^{-1}$ whilst the non-cattle owners had less than 1 t grain yr^{-1} $farm^{-1}$ due to poor soil quality and low manure use by non-cattle owners (Rufino *et al.* 2010). A reduction in field surface mulch by 30-46% as a result of dry winter season grazing by livestock, leaving less than 0.2 t/ha of biomass, has been recorded in Zimbabwe (Mtambanengwe and Mapfumo 2005). This is mainly due to communal livestock grazing in arable areas during the winter season in most smallholder farming areas. Farmers practising CA thus face a critical problem to ensure enough residues remain in the field to meet the threshold of mulching at the start of the rain season (Mazvimavi and Twomlow 2008). Innovative ways of managing crop residues during non-cropping seasons are thus required to ensure that farmers embarking on CA can do so without being disadvantaged by cattle.

Generally, fencing was identified as the most common option of residue protection practiced by farmers (Nyagumbo *et al.* 2009). However, adoption has been poor amongst smallholder farmers due to prohibitive costs of fencing materials (Wall 2009). Alternatively, farmers may use live fencing to protect residues but the length of time required for establishment of the live fences remains a challenge. One approach to address this problem could be through the use of organic livestock repellents applied to the crop residues. Repellents are substances designed to irritate a specific animal or type of animal such that the targeted animal will avoid the protected objects or area (Osko 1993). Some repellents (such as mixture of *Allium sativum* (garlic), *Allium cepa* (onions) and *Capsicum oleoresin* (chilli*))* successfully deterred animals like deers from grazing gardens (Deer-Departed LLC 2007) while elephants were repelled from fields by chilli spray (Osborn 2002). Several specific chemicals in cattle faeces were also found to be involved in inhibiting cattle from ingesting grass near cattle faeces (Dohi *et al.* 1999). Such an approach could thus provide an option for protecting crop residues and hence the need to test whether substances such as chilli, cow dung and goat droppings can also exhibit the same repelling characteristics to cattle when they are sprayed on crop residues during the dry season.

This study thus sought to investigate and establish the feasibility of such repellents to control the dry season grazing of crop residues by livestock in CA systems. The research hypothesised that effective locally available organic substances exist that can be used as repellents to grazing of crop residues by cattle under CA, during dry winter season. The objectives of this study were to identify, screen and test locally available organic resources that can be used as repellents to grazing of maize residues by cattle during dry seasons.

Materials and Methods

Site description

Initial work to screen organic repellents to be used as residue management options to grazing of crop residues by livestock was carried out at Domboshawa Training Centre (DTC) (17° 35' S; 31° 10' E) located about 33 km North of Harare, Zimbabwe. DTC is in agro ecological zone IIa (Vincent and Thomas 1960) and experiences a subtropical climate with an annual rainfall range of 750 – 1000 mm and a mean annual temperature of 15-20 ℃. Intensive crop farming is the recommended farming activity (Vincent and Thomas 1960). The soils are shallow to moderately deep, gleyic granite derived sands generally classified as Paraferralitic soils (Nyamapfene 1991). DTC is a centre for agricultural training and research.

Subsequent on-farm studies on screened repellents were carried out in Bindura from August –September 2010 at Hereford Farm (17° 25' S; 31° 26' E) and Madziwa communal area (16° 55' S; 31° 32' E). Hereford farm is in agro ecological zone IIa, thus receives same climatic conditions as for DTC but has red clays soils. Madziwa in agro ecological zone IIb, (receiving less than 750 mm annual rainfall) is a communal area with depleted sandy soils. Maize is the major cereal crop grown in both Domboshawa and Bindura, hence maize stover was used for the experiment. The livestock used for both on station and on farm was cattle. On station, the cattle were driven into the field and removed at sunset, whilst on farm, the cattle grazed communally and in some instances spent the night in the field.

Experimental design and treatments

Potential repellents were identified through consultations with farmers, livestock experts and other key informants by asking for names of local plants or materials that were shunned by livestock, but were known to be non poisonous to the livestock. Farmers consulted were in areas where CA was already being implemented but with challenges of cattle grazing the crop residues in the dry season. Informal discussions were made with CA practitioners, livestock experts and key informants for the possible repellents. The names of possible repellents were suggested by 1) farmers in Kadoma, Chikombedzi, Domboshawa and Bindura; 2) livestock experts at the University of Zimbabwe (Animal Science and Veterinary Science departments) and 3) key informants, mainly extension workers in the same areas as farmers. The eight potential resources/substances suggested to function as repellents were: garlic (*Allium sativum*); onions (*Allium cepa*); mixture of garlic and onion; cow dung; goat droppings; cow dung mixed with goat droppings; chilli (*Capsicum* spp.); tobacco (*Nicotiana* spp.); crotalaria (*Crotalaria grahamiana*) and *mutovoti* plant (*Spirostachys africana*). These resources or substances were then screened using a completely randomised block design (CRBD) with 3 replicates at DTC.

Each plot measuring 5 m x 5 m received 10 kg of maize residues (equivalent to a residue application rate of 4 t/ha) at the beginning of the experiment. The dry residues were initially weighed using a digital hanging scale and then evenly applied and spread by hands on the surface of marked plots, lying across the field slope. For the repellents that were soaked, the pure form of repellents was put in a bucket and the desired amount of water was added. The mixture was then stirred thoroughly until a perfect mixture was made and was left to soak overnight. To apply the repellents to the maize stover, a sweeping broom was used to spray and spread wet chilli on the residues while hands were used for the other soaked ones. Dry repellents were manually broadcasted onto the residues uniformly until the desired amount was finished on each plot. The residues remaining in the field after grazing were weighed. The effectiveness of these substances suggested as potential repellents was determined by measuring the period taken to consume 50% of sprayed residues after releasing cattle. A substance was considered as a potentially effective repellent if it (a) repelled livestock from grazing maize stover for a period of at least three weeks and (b) prevented more than 50% of the maize stover being removed. Estimation was used to determine that 50% was used during the screening stage. This initial screening was carried out using a medium application rate of each repellent (Table 1). We assumed that the drying rates of residues was similar since all plots started with the same residue application rate.

Further tests were carried out at DTC on four screened repellents in September - November 2009, to determine their optimum application rate. For the best four screened resources (cow dung, goat droppings, chilli and tobacco), a split plot design was laid out in three randomized blocks to determine their optimum application rate. The four repellents were assigned at random to the main plots within each block at three application rates (Table 1) as subplots.

A control where nothing was sprayed was also assigned at random to the main plot in each block. The efficacy of repellents (compared to the control) was indicated by the non-consumption period of residues by livestock and the amount of residues left after a given period. The repellent's application rate (out of the three in Table 1) with the least consumed residues was considered as the optimum application rate. The optimum application rates obtained from the DTC trials were then tested on communally grazed areas in Bindura district.

Table 1. The three application rates tested at the Domboshawa Training Centre for each repellent to obtain the optimum level.

Repellent	Concentration	Weight of dry repellent (kg)	Concentration (kg/l)	Application rate (kg/ha)
Chilli powder	Low	0.25		100
	Medium	0.5		200
	High	1		400
Soaked cow dung	Low	7.5	1.5	3000
	Medium	10	2	4000
	High	12.5	2.5	5000
Tobacco scrap	Low	0.75		300
	Medium	1.5		600
	High	3		1200
Soaked goat droppings	Low	1.25	0.17	500
	Medium	2.5	0.33	1000
	High	3.75	0.5	1500
Soaked chilli	Low	0.25	0.03	100
	Medium	0.5	0.05	200
	High	1	0.1	400
Soaked tobacco	Low	0.75	0.05	300
	Medium	1.5	0.1	600
	High	3	0.2	1200
Control		0	0	0

On-farm trials were set up in Madziwa and Hereford to determine the efficiency of the optimum application rates obtained at DTC on communally grazed areas. At Hereford farm and Madziwa, efficiency was based on non-consumption days and reduction in residue amount over time using CRBD layouts (Figure 1).

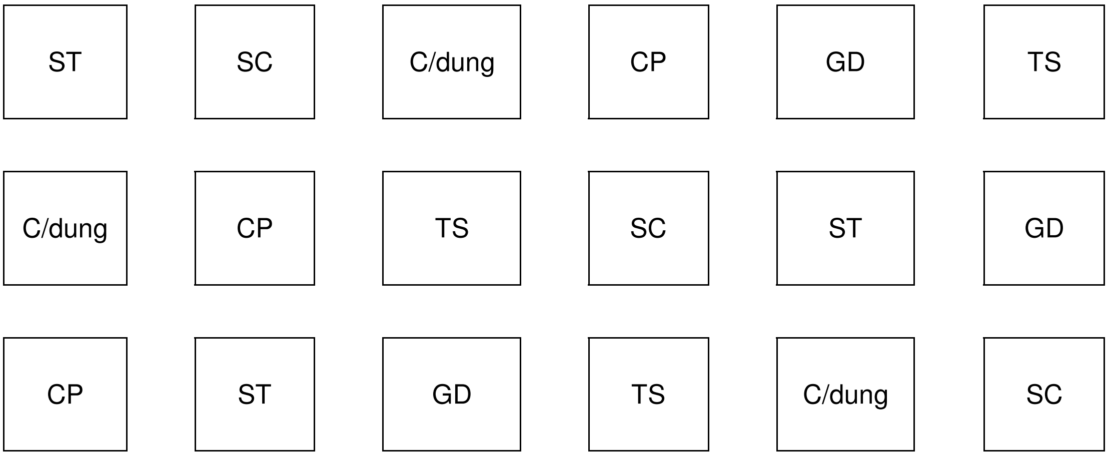

Figure 1. Field layout used at on farm experiments in Bindura (Madziwa and Hereford). Notes: The plots are 5m × 5m and the paths are 2m × 2m. ST =soaked tobacco, SC = soaked chilli, C/dung = cow dung, CP = chilli powder, GD = goat droppings, TS = tobacco scrap.

Results

From observations and informal discussions with local people, it became apparent that in Bindura, cattle were left to graze freely on pastures and arable areas during the dry season compared to DTC where fencing controlled which areas were grazed. Hereford farm by virtue of being in a high potential region, tended to produce more crop residues and the conditions there provided for alternative animal feed in the form of grasses and shrubs persisting during the dry season and thus retained a considerable amount of crop residues in the field up to the beginning of the next cropping season after cattle grazing. In contrast, Madziwa had much lower annual biomass yield and all the crop residues in the fields are consumed by July with little alternative grass and shrubs available for livestock grazing. Farmers usually collect and stock/pile crop residues from their fields and store them as dry season animal feed.

Identification and screening of potential repellents

Cow dung, goat droppings, chilli and tobacco were found to be effective repellents to grazing of crop residues by livestock at DTC (Table 2) as greater than 50% of initial residues were left after cattle consumption for up to 21 days.

Table 2. Number of days when more than 50% of initial maize stover was consumed after organic repellents were used to control cattle at Domboshawa in 2009. The medium application rates of each repellent in Table 1 were tested

Repellent	Days
Soaked garlic	5
Soaked onions	5
mixture of soaked garlic and onion	4
Soaked cow dung	up to 21
Soaked goat droppings	up to 21
Mutovoti plant	6
Chilli (both powder and soaked)	up to 21
Tobacco (both soaked and scrap)	up to 21
Control	4
Soaked crotalaria	4

Results of the best four resources at different concentrations proved that soaked cow dung, tobacco and goat droppings were more efficient at low concentrations (Figure 2). Generally, the low concentration (equivalent to 3 t/ha) of cow dung was more effective compared to others. The optimum application rates (Table 3) obtained at DTC were then used on on-farm trials in Bindura district.

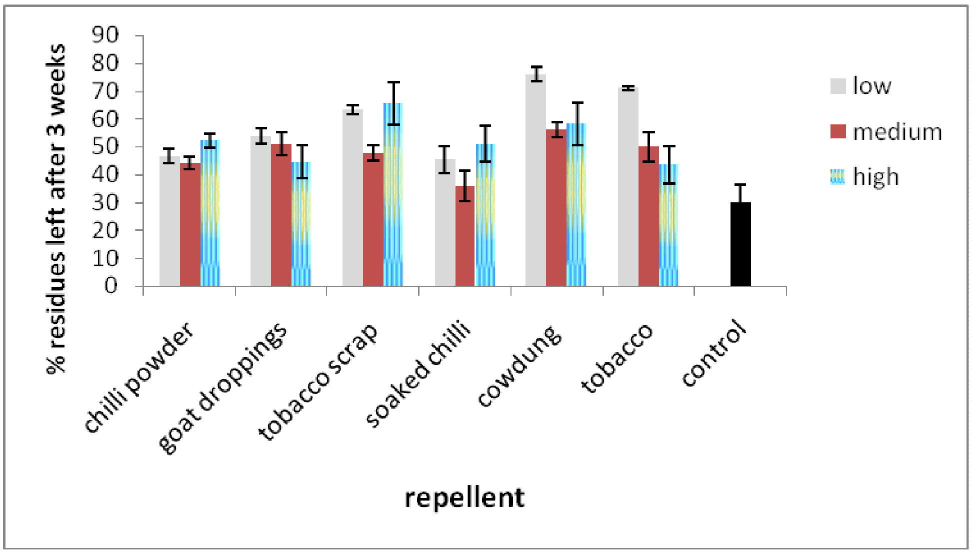

Figure 2: Efficacy of different application rates of each repellent at the Domboshawa Training Centre in 2009. Note: Low, medium and high, represents the three application rates for each repellent. Error bars (standard error of means) were used to compare means of each repellent at the three concentrations levels and not across repellents.

Table 3. The optimum application rates of repellents from Domboshawa that were tested in Bindura (Hereford and Madziwa communities).

Repellent	Application rates (kg/ha)
Soaked cow dung	3,000
Soaked goat droppings	500
Chilli (soaked and powder)	400
Tobacco scrap	1,200
Soaked tobacco	300

Efficacy of repellents

Results collected from Hereford farm showed that cow dung and tobacco (both soaked and scrap) were effective to repel the livestock for a longer time of up to 5 weeks. There were no significant repelling effects arising from chilli (both soaked and powder) and goat droppings compared to the control (Figure 3).

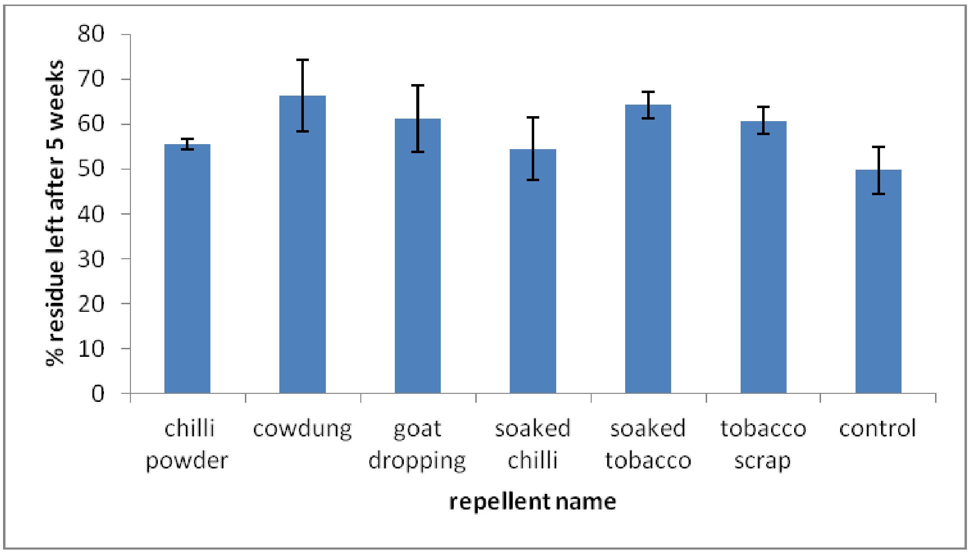

Figure 3: Efficacy of repellents at Hereford farm in 2010 in terms of percent residues remaining after 5 weeks. Error bars = standard error of means.

In terms of the non-consumption period, the control was eaten the very day the experiment was set up (day 0) whilst cow dung and soaked tobacco were the last to be eaten (Table 4). Despite the choking effect, tobacco and chilli powder were easily blown away by wind to underneath the residues or away from residues, hence residues treated with them were eaten earlier than soaked repellents (Table 4).

Table 4. Efficacy of repellents in terms of non-consumption period at Hereford farm in 2010.

Name of repellent	Non-consumption period (days after application)
Chilli powder	4
Soaked chilli	7
Soaked tobacco	10
Tobacco scraps	6
Cow dung	10
Goat droppings	7
Control	0

In Madziwa, all the residues were eaten up within three days of setting up the trial. Thus, no data on weights of remaining residues was collected after that period. From observations in Madziwa, livestock consumed the residues preferentially in the order: control > goat droppings > dry tobacco > wet chilli > chilli powder > wet tobacco > cow dung.

Discussion

Effectiveness of repellents to deter grazing livestock

The screened repellents (tobacco, chilli, cow dung and goat droppings) used in this study reduced grazing intensity in Hereford but did not eliminate grazing entirely, although repellents should be designed to be so irritating to a specific animal or type of animal that the targeted animal will avoid the protected objects or area (Osko 1993). A study in Zimbabwe by Mtambanengwe *et al.* (2010) showed that fields that are unprotected from livestock grazing during dry season periods had residue amounts declining by up to 93% over the 5-6 months dry season compared to less than 25% in protected/fenced fields. However, in this study, use of repellents resulted in a decline of initial crop residues by 36-45% compared to the control with a 50% decline at Hereford. Hence, repellents provided a better retention of crop residues during winter than unfenced fields but were less effective than exclusion of grazing by fencing crop residues. The repellents with a disagreeable odour and choking effect (chilli, cow dung and tobacco) tended to be more effective in controlling grazing than the ones that repelled by taste (onions, garlic, mutovoti plant, and *Grahamiana* spp). This finding is supported by Hill (2002) who also found out that substances that repel by taste are less effective compared to those that repel by a disagreeable odour when deterring elephants from crop fields.

From the three application rates tested at DTC for each repellent (Table 1), soaked cow dung, tobacco and goat droppings proved to be more efficient when the solution is more dilute (3000, 300 and 500 kg/ha respectively) compared to a highly viscous slurry (5000, 1200 and 1500 kg/ha respectively), whilst wet chilli was more efficient at high concentration 400 kg/ha compared to 100 kg/ha. The higher efficacy of lower concentrations could be due to the fact that the residues would absorb more of the solution thus adding a bad taste on the residues for a longer time. The repellents could then be deterring livestock through both the smell and taste effect. With respect to chilli, Osborn (2002) reported that a naturally occurring chemical in chilli peppers, called capsaicin causes a heat sensation when it reaches nerve receptors. This heat deters mammals from grazing on chilli peppers or on crops that have been sprayed with chilli pepper extract. This could then support the efficacy of chilli to deter cattle from treated crop residues at DTC and Hereford.

Although the repellents proved to be more efficient via the smelling and choking effect as opposed to taste, chilli and tobacco scrap which had the choking effect were easily blown way from the residues by wind and could drop off the residues as the cattle trampled on the residues during grazing. For soaked chilli, cow dung and goat droppings, their stains tend to disappear from residues after sometime, where after, their efficacy was now due to taste and livestock would bite and spit. This supports findings by Dohi *et al.*, (1999) that taste repellents only work after the animal has taken a bite out of the plant.

The difference in results obtained at Hereford and Madziwa confirms that what an animal eats largely depends on available food resources (Osko 1993, Hill 2002). The repellents proved to be effective at Hereford where there is alternative feed, whilst in Madziwa where there is nothing except the treated residues, they were not effective. Cow dung was more effective in Hereford than other repellents thus supporting Marten (1978) who reported refusal of dairy cattle to graze on brome (*Bromus* spp) growing over areas dressed with cow, sheep and turkey manure and accepted the same vegetation when it was harvested and offered as fresh fodder. We think that as long as farmers in areas like Hereford have realised the benefits of CA and its principles, they are prepared to conserve the maize stover provided the repellents are accessible and available since those who afford fencing are already doing so.

Challenges in using repellents

In smallholder farming areas of Zimbabwe where grazing is communal in croplands during the dry season (Rufino 2010), the use of repellents might raise social conflicts on ownership of repellents and where individual farmers do not have exclusive rights to the residues on their land, any attempts to conserve the residues can lead to confrontation (Wall 2009). Information sharing and knowledge development in such rural areas could then help to resolve these issues since if farmers carry, store and then return residues to their fields, no conflicts are raised. In Zimbabwe, Wall (2009) reported success with CA farmers through support from a local government councillor who facilitated a by-law barring communal grazing of fields in winter following CA demonstrations implemented in Shamva. The practice of communal grazing has been found to result in net nutrient transfer from fields owned by non-cattle owners to those of cattle owners through regular manure applications in the fields of the latter (Mtambanengwe 2006). Local studies in the past have also shown the benefit of cattle manure and goat droppings (Masikati 2006) to replenish soil fertility. Thus, communal grazing occurs at the expense of the poorer farmers who lose their residues to cattle owners. The use of livestock repellents (in conditions where feasible) could thus prove to be a useful measure to protect residues in CA fields of non-livestock owners, thereby helping to curb this unperceived theft of nutrients by livestock owners. The findings of this study could thus open a new avenue for livestock management in CA systems.

Most repellents lasted for at most three to five weeks and thus need re-application after a certain period to deter grazing livestock throughout the long 5-6 month dry season. The need for reapplication may be influenced by factors such as rainfall, atmospheric temperature and appetite of the livestock, which affect the efficacy of the repellent. The timing of the application is also important since there is need for dry weather for about 48 hours when one applies the repellent. Apart from these challenges, livestock can become adapted to the repellents and end up grazing protected/sprayed residues. It is admitted that the rates used here are too high, hence the study provides a benchmark to effective control rates and so further studies should be conducted to refine or extract the active repelling ingredients that can be applied at much lower rates. More factors could be explored, which might reduce the required repellent amounts such as by increasing or reducing the period of soaking repellents. However, since most farmers have already seen the importance of mulching and thus were carrying stover, stacking it and bringing it back at the beginning of the next season, while others were fencing, we believe that the task of applying such repellents should be borne by the individual owners managing their fields and cannot be a communal effort since traditionally field activities are managed individually.

While unlikely, side effects might arise if animals are forced to eat excessive amounts of the repellents. Unfortunately this aspect could not be substantiated in this study. For example, excessive capsaicin (from chilli) has been known to temporarily irritate mucus membranes in the gastrointestinal tract of an animal (Mozsik *et al.* 2009), whilst nicotine in tobacco is known to causes relaxation of muscles in the gastrointestinal tract (Irie *et al.* 1991). Literature also suggests the consumption of animal excreta such as cowdung and goat droppings might cause the spread of internal parasites such as *Ooperia* and *Trichostronglus* species in the animal (Fontenot and Webb 1975). This probably warrants further studying to determine the amounts of these active ingredients in each repellent to prevent animal poisoning, particularly in situations where the animals are forced to eat the repellent because of acute shortages of alternative feed. Unfortunately this study did not establish the extent of these potentially harmful effects on livestock.

Limitations of the study

The study results were obtained from small sized plots, and they might differ if a bigger area was used, since untreated feed would be far away. Furthermore, some of the required repellents' effective application rates were rather high and thus may be difficult to acquire if resources are to be borrowed or bought, e.g. chilli in contrast to cow dung which can be readily available.

Conclusion

Cow dung and tobacco dust proved to be the promising repellent options that could be used to keep livestock away from residues during the winter, but their efficiency largely depends on the availability of alternative feed. The study demonstrates that these repellents can be used to protect crop residues from livestock grazing in areas with high biomass production offering alternative feed but may be ineffective in areas with acute shortage of alternative feed. Repellents' effectiveness was generally found to be temporary and short lived as the residues were eaten in time, suggesting the need for repeated applications at least every 3 weeks. The study opens a new avenue and approach for residue management in CA systems that could potentially address the livestock competition challenges experienced in crop-livestock systems, particularly if the repellents' active ingredients are extracted and repackaged in more user-friendly formats such as sachets, enabling easy application through knapsack spraying.

Besides the need for repackaging the identified effective repellents, there is need for further studies to quantify the potential side effects of these repellents on animal health.

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INFLUENCE OF FRESH, COMPOSTED AND VERMICOMPOSTED *PARTHENIUM* AND POULTRY MANURE ON THE GROWTH CHARACTERS OF SESAME (*SESAMUM INDICUM*)

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Abstract

A goal of sustainable agriculture is to maintain a non-negative trend in productivity while maintaining soil quality. The objective of the present study was to determine the sustainability of organic cropping systems and utilisation of the weed *Parthenium hysterophorus* and an organic product poultry manure. The influence of fresh, composted and vermicomposted *Parthenium* and poultry manure on the growth characters of sesame (*Sesamum indicum*) were observed. Manures were mixed with pot soil at the rate of 35.0g/pot of fresh manures, 26.25, 35.0 and 43.75g/pot composted and vermicomposted *Parthenium* and poultry manure individually. The recommended dose of NPK/hectare was calculated and added to pots. The impact of fresh, composted and vermicomposted *Parthenium* and poultry manure were assessed on 30, 60 and 90 days after sowing (DAS) in terms of growth attributes and compared with control soil without manures and NPK. The germination percent of sesame was more in composted and vermicomposted manures applied pots compared to the control and NPK. The longest roots of sesame were in composted poultry manure (T11 and T9) on 30 and 60 DAS and in composted *Parthenium* (T3) on 90 DAS. Shoot length was more in T12 (vermicomposted poultry manure) on 30 DAS, T9 composted poultry manure on 60 DAS, T5 (vermicomposted *Parthenium*) on 90 DAS. Maximum fresh and dry weights were in T7 (vermicomposted *Parthenium*) on 30 and 90 DAS and in T9 (composted poultry manure) on 60 DAS. Maximum vigour index was observed to be more in composted poultry manure T10 on 30 and 90 DAS and in T11 on 60 DAS. The growth attributes of sesame were improved by manure application compared to the control. The significant differences in biometric parameters might be due to different treatments. The difference in the release of nutrients from different manures might have influenced the plant biometric characters. The observed parameters were improved by the treatments which could be attributed to the positive effects of composts and vermicomposts on physical, chemical and biological properties of soil which in turn influence the crop. Organic matter resources need to be evaluated to meet plant nutrient requirements. Recycling of wastes can transform them to useful composts for plant growth and soil health. In the present study, the use of weed biomass and poultry manure in compost was beneficial for the growth of sesame.

Keywords: sesame, growth attributes, *Parthenium*, poultry manure, compost, vermicompost.

Introduction

In the face of global ecological concern on the use of chemicals in agricultural production, alternative sources of plant nutrients such as poultry manure and plant residues can be tested as a source of nutrients for crop plants. The term organic farming is not directly related to the type of inputs used, but refers to the concept of farm as an organism, in which all the component parts - the soil minerals, organic matter, micro organisms, insects, plants, animals and humans interact to create a coherent role. Organic farming represents the restructuring of a whole farm system, rather than the adoption of current practices to reduce environmental impact (Chaudhary 2002).

Parthenium (*Parthenium hysterophorus*) continues to spread in undisturbed public, waste, abandoned, fallow lands in residential and industrial premises and lawns (Sharma and Gautam 2004). *Parthenium* and its harmful effects can be effectively reduced by converting it as compost. The species was ranked as the most important weed by 90% of the farmers in the lowlands. According to a partial canonical correspondence analysis (pCCA), altitude, rainfall, month of planting, number of weedings and soil type were the major environmental/crop management factors influencing the species distribution. *Parthenium* has, in a very short time period, emerged as one of the most troublesome weed species in eastern Ethiopia (Tamado and Milberg 2008). The high concentration of elements (N, P, K, Fe, Mn, Cu and Zn) in composted *Parthenium* may increase crop yields (Kishor *et al*. 2010). *Parthenium* compost contains two times more nitrogen, phosphorus and potassium than farm yard manure (Angiras 2008).

To sustain the fertility status of soil for efficient crop production, poultry waste can be used as a source of fertilizer particularly for nitrogen and phosphorus (Khan and Ali 2000). Poultry wastes contain higher concentrations of N, Ca and P than wastes from other farm animals (Stephenson *et al*. 1990). Composting may provide a beneficial alternative method for handling poultry litter due to the immobilization of nutrients and a reduction in litter volume (Millner *et al*. 1998). The slow release of nutrients from composted poultry litter may lessen adverse environmental effects from leaching of N in run-off from farm lands (Chang and Janzen 1996). Poultry manure increased soil organic matter, N and P. Soil bulk density were reduced and moisture content increased with levels of manure. Manure applications increased leaf N, P, K, Ca and Mg concentrations of tomato, plant height, number of branches, root length, number and weight of fruits. The 25 t ha^{-1} poultry manure gave highest leaf P, K, Ca and Mg and yield relative to control. The 10, 25, 40 and 50 t ha^{-1} manure levels increased average fruit weight by 58, 102, 37 and 31% respectively (Ewulo *et al.* 2008). Spain is one of the major producers of broilers and laying hens in the European Union, with an overall market share of around 12%. The poultry manure that is produced is usually employed as fertilizer on cropland, either directly or after a composting process (Quiroga *et al*. 2010).

Vermicompost, a potential organic input for sustainable agriculture, it contains beneficial microorganisms, both major (N, P, K) and micronutrients, enzymes and hormones (Probodhini 1994). The results of Avnish Chauhan and Joshi (2010) showed a high increase in nitrogen, potassium, phosphorus and a substantial decrease in organic carbon, C/N, C/P ratio in the experiment set up using earthworms. Adding of vermicompost to soil improves the chemical and biological properties of soil and thereby improves its fertility (Purakeyastha and Bhatnagar 1997). Earthworms constitute more than 80% of soil invertebrate populations in many ecosystems, especially in the tropical ecosystems (Sinha *et al.* 2002). Micro-organisms in composting require C, N, phosphorus (P) and potassium (K) as the primary nutrients. Of particular importance is the C:N ratio of raw materials. The optimal C:N ratio of raw materials is between 25:1 and 30:1 although ratios between 20:1 and 40:1 are also acceptable. Where the ratio is higher than 40:1, the growth of micro-organisms is limited, resulting in a longer composting time. A C:N ratio of less than 20:1 leads to underutilization of N and the excess may be lost to the atmosphere as ammonia or nitrous oxide, and odour can be a problem. The C:N ratio of the final product should be between about 10:1 and 15:1 (Misra *et al*. 2003).

The objective of this investigation was to evaluate the efficacy of fresh, composted and vermicomposted *Parthenium* and poultry manure on the growth parameters of sesame (*Sesamum indicum*).

Materials and methods

An experiment was conducted to determine the effect of fresh, composted and vermicomposted *Parthenium* and poultry manure on the growth attributes of sesame. The treatments are listed in Table 1. The experiment was completely randomized design with three replications. The dosages were designed for the present study as per the recommendations of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India for red soil and also based on the nutrient contents of the manures. The NPK levels applied were the recommended dosage for the sesame plant variety used in this experiment.

Table 1. List of fresh and composted *Parthenium*, poultry manure and vermicompost treatments and their application rates.

Number	Treatment	Rate (g/pot)
T0	Control, 7 kg red loamy soil	
T1	Fresh *Parthenium*	35.0
T2	Composted *Parthenium*	26.25
T3	Composted *Parthenium*	35.0
T4	Composted *Parthenium*	43.75
T5	Vermicomposted *Parthenium*	26.25
T6	Vermicomposted *Parthenium*	35.0
T7	Vermicomposted *Parthenium*	43.75
T8	Fresh poultry manure	35.0
T9	Composted poultry manure	26.25
T10	Composted poultry manure	35.0
T11	Composted poultry manure	43.75
T12	Vermicomposted poultry manure	26.25
T13	Vermicomposted poultry manure	35.0
T14	Vermicomposted poultry manure	43.75
T15	NPK mineral fertiliser	35:2:23 kg/ha

Nutrient contents of the organic inputs

The fresh, composted and vermicomposted *Parthenium* and poultry manure were assessed for its nutritional value in terms of micro- and macro-nutrients, physico chemical parameters and microbial population. The decomposition exhibited significant variation from the fresh forms and the improved nutrient value was assessed in this experiment.

The content of organic carbon (C) varied among the fresh and decomposed samples. It was 2.02% in fresh *Parthenium* and reduced to 0.87% in composted *Parthenium* and 1.03% in vermicomposted *Parthenium*. The organic matter was found to be 3.49%, 1.50% and 1.78% for fresh, composted and vermicomposted *Parthenium*. The fresh *Parthenium* recorded the lowest per cent of total Nitrogen (N) (0.62%), the composted *Parthenium* (2.10%) and vermicomposted *Parthenium* (2.30%) exhibited higher values. While the fresh sample recorded the least value of 0.10% for Phosphorus (P), it was found to be 0.30% in composted *Parthenium* and 0.42% in vermicomposted *Parthenium*. The Potassium (K) content was recorded to be 0.32% in fresh and 1.20% and 1.36% in composted and vermicomposted *Parthenium* samples. Zinc (Zn) and Copper (Cu) contents were lower in fresh *Parthenium* (178 and 76 ppm) compared to the composted (210 and 82 ppm) and vermicomposted *Parthenium* (235 and 80 ppm). The Iron (Fe) content was lower (76 ppm) in composted *Parthenium* compared to both fresh (84 ppm) and vermicomposted samples (94 ppm). Manganese (Mn) content was observed to be 125 ppm, 140 ppm and 156 ppm respectively in fresh, composted and vermicomposted *Parthenium*. The C:N ratio of the decomposed samples showed a steady reduction from 3.26 (fresh *Parthenium*) to 0.41 in composted and 0.45 in vermicomposted *Parthenium* . There was a drastic reduction in C:P ratio of the samples from 20.20 in fresh sample to 2.90 and 2.45 in composted and vermicomposted samples.

It was observed that there was a gradual reduction in organic C content from fresh poultry droppings (2.00%) to composted (0.61%) and vermicomposted (0.93%) samples. The organic matter was also less in composted poultry droppings (1.05%) compared to fresh poultry droppings (3.44%) and vermicomposted poultry droppings (1.59%). The vermicomposted sample registered the least content of N (1.20%) and the highest value was recorded in fresh form (2.87%) and composted poultry droppings had a content of 2.07%. The P contents of fresh, composted and vermicomposted samples were 2.90, 2.38 and 1.11%, respectively. The fresh poultry droppings had a higher content of K (2.35%) which was reduced to 1.50% in composted and 0.80% in vermicomposted samples. The highest contents of Zn and Cu (85 and 46 ppm) were found in fresh form which were reduced to 36 and 4.4 ppm in vermicomposted poultry droppings and 50 and 6.9 ppm in composted sample. The Fe and Mn contents were 107 and 190 ppm in compost, 101 and 187 ppm in vermicompost samples and least in fresh poultry droppings (38 and 44 ppm). The C:N ratio of fresh and vermicomposted samples were 0.70 and 0.78. The composted sample recorded a C:N ratio of 0.29 .The C:P ratio of fresh poultry droppings was 0.69 and 0.41 in compost. The vermicomposted sample showed a C:P ratio of 0.84

Growth attributes

One plant per replication was selected from each treatment and washed to remove adhering soil particles. Root length was measured from root collar to root tip and shoot length was recorded from root collar to shoot apex. The fresh weight of the whole plant was measured then the plant was placed in an oven at 70°C for 12 hours and the dry weight recorded. The vigour index was calculated using the formula, vigour index = germination percentage x (root length + shoot length) (Abdul-Baki and Anderson 1973).

Statistical analysis

The data collected from the different treatments were subjected to statistical analysis using one way analysis of variance and group means were compared using Duncan's Multiple Range Test. *P* values at 5% were considered significant (Panse and Sukhatme 1978). The Standard Error and Critical Difference among the treatments were reported.

Results

Germination percentage

The germination percentage of sesame was calculated on 7, 14, 21 and 28 days after sowing (DAS) and depicted in Table 2. On 7 DAS, the highest germination percentage of 60% was observed in T1 and T15 and least in T14 (17%). On 14 DAS 80% germination was observed in T3 and T7 among *Parthenium* applied plants and in T10 (83%) amongst poultry manure applied plants. The lowest value of 53% was observed in

T9 and T14. On 21 and 28 DAS, T3, T7, T10 and T11 recorded the highest value of 83% and the lowest value of 57% in T14. The growth attributes of sesame namely root length, shoot length, fresh weight, dry weight and vigour index were observed on 30, 60 and 90 DAS (Table 2).

Root length

On 30 DAS, the longest root was observed in T6 as 7.40 cm among *Parthenium* and in T11 as 10 cm among poultry manure treatments. The shortest root was recorded in T13 (4.3 cm). On 60 DAS, T7 among *Parthenium* (11.5 cm) and T9 among poultry manure treatments (14.8 cm) registered the longest root against control (6.1 cm), which showed the minimum root length. On 90 DAS, maximum root lengths of 22.4 and 18.2 cm were observed in T3 and T8 among *Parthenium* and poultry manure applied plants; the minimum value was seen in T14 (7.1 cm) (Table 2).

Shoot length

The shoot length was positively affected by T7 (15.8 cm) among *Parthenium* and T12 (17.6 cm) among poultry manure treatments at 30 DAS. The T8 plants exhibited the shortest shoot length at 8.0 cm on 30 DAS. The greatest shoot length was seen in T7 (58.2 cm) among *Parthenium* and T9 (70.2 cm) among poultry manure treatments on 60 DAS with the shortest in the control (25.0 cm). On 90 DAS, the shoot length was highest in T5 (87.5 cm) and in T10 (85.1 cm) among *Parthenium* and poultry manure applications and the control (42.0 cm) showed the lowest length of shoot (Table 2).

Table 2. Impact of fresh, composted and vermicomposted *Parthenium* and poultry manure on growth of sesame (SE = Standard Error; CD = Critical Difference; DAS = Days After Sowing).

Treatments	Germination (%)				Root length (cm)			Shoot length (cm)		
	7 DAS	14 DAS	21 DAS	28 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T0	40.00	66.67	66.67	66.67	4.73	6.13	9.73	8.60	25.00	42.03
T1	60.00	76.67	76.67	76.67	4.87	7.43	12.67	11.40	50.90	77.50
T2	23.33	63.33	66.67	66.67	4.97	6.43	15.90	8.13	33.07	87.30
T3	40.00	80.00	83.33	83.33	6.90	7.27	22.37	11.87	34.13	66.93
T4	30.00	76.67	80.00	80.00	6.23	6.50	9.23	10.97	27.40	81.17
T5	56.67	73.33	76.67	76.67	6.90	7.70	7.27	13.50	43.80	87.53
T6	46.67	76.67	80.00	80.00	7.40	9.30	7.23	14.33	53.00	55.57
T7	53.33	80.00	83.33	83.33	7.20	11.53	13.53	15.77	58.17	77.70
T8	30.00	63.33	76.67	76.67	9.57	9.43	18.17	8.03	47.40	84.70
T9	40.00	53.33	60.00	60.00	4.90	14.83	14.07	13.50	70.23	83.80
T10	33.33	83.33	83.33	83.33	7.53	9.73	17.83	17.07	57.57	85.10
T11	43.33	70.00	83.33	83.33	10.20	10.13	14.50	11.20	65.13	84.60
T12	30.00	63.33	70.00	70.00	6.17	7.70	8.33	17.60	48.53	58.60
T13	20.00	60.00	63.33	63.33	4.30	7.20	7.90	16.13	52.70	59.67
T14	16.66	53.33	56.67	56.67	4.80	7.27	7.13	16.83	43.80	43.43
T15	60.00	63.33	70.00	70.00	5.00	6.97	9.30	11.83	42.20	64.03
SE	11.22	8.69	6.38	6.38	0.45	0.42	1.34	0.53	1.30	1.06
CD (5%)	22.91**	17.74*	13.02**	13.02**	0.93**	0.85**	2.73**	1.08**	2.65**	2.17**

Fresh weight and dry weight

The fresh weight of the plants in T7 and T10 exhibited the greatest values of 1.5 and 1.2 g on 30 DAS among *Parthenium* and poultry manure compared to the control (0.3 g). On 60 DAS, the greatest fresh weight was recorded in T6 (7.7 g) within the *Parthenium* treatments and T9 (18.6 g) within the poultry manure treatments against control (2.0 g). The greatest fresh weights, 27.9 and 15.7 g, were noticed in T7 and T10 among *Parthenium* and poultry manure applications on 90 DAS and the lowest fresh weight was 4.7 g in the control (Table 3).

On 30 DAS, the dry weight was found to be greatest in T7 (0.76 g) and T10 (0.60 g) among *Parthenium* and poultry manure applications and the lowest in the control (0.13 g). On 60 DAS, the highest dry weight was noticed in T6 (1.8 g) within the *Parthenium* treatments and in T9 (4.7 g) within the poultry manure applications compared to T0 (0.47 g) which was the lowest. The dry weight was found to be greatest in T7 (6.4 g) within the *Parthenium* treatments and T10 (5.4 g) within the poultry manure treatments on 90 DAS and lowest in the control T0 (1.1 g) (Table 3).

Vigour index

The maximum vigour index of sesame plants was observed in T7 (1915) within the *Parthenium* treatments and T10 (2044) within the poultry manure treatments and minimum in T0 (904) on 30 DAS. On 60 DAS the value of vigour index was greatest in T7 (5807) within the *Parthenium* treatments and T11 (6282) within the poultry manure treatments and lowest in the control (2522). The maximum value of vigour index was 7911 (T2) within the *Parthenium* treatments and 8585 (T10) within the poultry manure treatments on 90 DAS against a minimum value of 3459 in T0 (Table 3).

Table 3. Impact of fresh, composted and vermicomposted *Parthenium* and poultry manure on yield of sesame (SE =Standard Error; CD = Critical Difference; DAS = Days After Sowing).

Treatments	Fresh weight (g)			Dry weight (g)			Vigour index		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T0	0.27	2.00	4.71	0.13	0.47	1.08	904.33	2522.00	3459.33
T1	0.85	5.32	9.82	0.35	1.14	3.53	1200.67	4478.00	6914.67
T2	0.39	2.71	9.76	0.19	0.47	3.78	856.00	2635.00	7911.00
T3	0.72	3.98	9.53	0.27	0.73	3.66	1562.33	3448.67	7438.67
T4	0.99	3.30	14.64	0.46	0.69	4.36	1380.33	2719.33	7501.00
T5	0.74	5.61	14.85	0.26	0.94	4.76	1566.33	3948.33	7268.67
T6	0.84	7.68	9.57	0.37	1.80	3.49	1731.33	4977.67	5023.67
T7	1.53	6.43	27.85	0.76	1.46	6.37	1914.67	5807.00	7602.67
T8	0.34	10.07	12.97	0.16	2.24	4.23	1329.67	4361.00	7898.00
T9	0.60	18.56	11.59	0.28	4.69	3.85	1104.67	5114.33	5868.33
T10	1.21	8.02	15.70	0.60	1.87	5.40	2044.00	5608.67	8584.67
T11	0.55	11.44	10.52	0.28	3.65	3.36	1782.00	6282.00	8258.33
T12	1.02	3.93	5.59	0.54	0.82	1.28	1661.67	3932.33	4679.67
T13	0.70	4.28	5.70	0.34	0.79	1.52	1294.00	3798.00	4286.67
T14	0.64	4.52	6.37	0.31	0.77	1.44	1223.67	2882.67	2528.33
T15	0.35	2.55	8.30	0.16	0.67	1.83	1143.33	3441.67	5133.33
SE	0.07	0.24	0.60	0.03	0.11	0.25	125.20	419.83	594.74
CD (5%)	1.14**	0.49**	1.22**	0.06**	0.23**	0.50**	255.69**	857.43**	1214.64**

Discussion and conclusion

The sesame root length was more in composted poultry droppings and *Parthenium* treatments compared to the vermicomposted and fresh forms and NPK. Application of organic manures might have supplied N, P and K nutrients through out the crop growth period as slow released nutrients. The length of shoots was increased in composted and vermicomposted poultry droppings and vermicomposted *Parthenium* treatments than in fresh *Parthenium*, poultry droppings and NPK. Nethra *et al*. (1999) observed that the maximum plant height and number of leaves of China aster (*Callistephus chinensis*) were after application of 10 t/ha vermicompost. This is attributed to better growth of plants and higher yield by slow release of nutrients for absorption with additional nutrients like gibberellin, cytokinin and auxins, by the application of organic inputs like vermicompost. The fresh and dry weights of sesame was higher in vermicomposted *Parthenium* and in composted poultry droppings applications. The plants showed higher vigour index in composted poultry droppings applied plants than other treatments. Composted poultry manure increased plant height, dry matter, production, leaf area index and number of branches per plant in cowpea (Rajavel 2002). This might be due to better N release from organic manures and better crop growth was the result of adequate nutrition. Vermicomposted market waste resulted in significant increase in morphological parameters of *Vigna mungo* (Balamurugan and Vijayalakshmi 2004). The presence of vermicompost enhances the macro and micro nutrients uptake by plants, and it harbours rich amounts of microbes that degrade and mobilize the nutrients to available form. Exudates of earthworms support the micro organisms which secrete plant growth hormones. Benefits have been attributed to the additional availability of N, P and K nutrients in the soil due to the application of organic manures and also conversion of unavailable form of nutrients into available forms. Singh *et al*. (1997) found that an application of 7.5 – 10 t ha^{-1} vermicompost to wheat (*Triticum aestivum*) was able to save about 50 kg N, 60 kg P_2O_5 and 25 kg $ZnSo_4$ per ha and this may well facilitate a step towards complete organic farming. The yield of potato and the average weight of potato tubers were significantly higher in plots treated with vermicompost. This may be attributed to increased bioavailability of P by the application of organic amendment in the form of vermicompost (Ansari 2008).

From the results of the present investigation, it could be concluded that composted *Parthenium* and poultry manure can be used for preparing organic manures and be used in successfully increasing crop productivity as an alternative source to inorganic fertilizers. The introduction of organics is beneficial in the successful production of sesame. This research showed that significant relationships exist between the utilisation of the various manures and plant growth. Further studies may be designed investigating other crops and soil types.

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CONVERSION FROM CONVENTIONAL TO ORGANIC PRODUCTION: A CASE STUDY OF CHINA'S PADDY RICE FARMERS IN WUCHANG CITY

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Abstract

Based on China's organic paddy rice farmers' data collected from field surveys in Wuchang City, this paper utilises a data envelopment analysis method to estimate the technical efficiency scores of organic paddy rice farmers converting from conventional to organic production. Local organic rice-processing firms provide support to farmers to convert to organic production and, thereby, expand their growing scale. This paper finds that there was no change in crop yields experienced by farmers (N=95) converting to organic. Firstly, there was no statistically significant difference comparing the yields for farmers (N=76) under 'conventional' management and their first year of conversion to organic management. Secondly, there was no statistical difference comparing the yields for farmers (N=19) in their first year of conversion to organic management with their yields in their second year of organic conversion.

Keywords: paddy rice, farmer, data envelopment analysis, technical efficiency.

Introduction

The demand of China's consumers for agricultural products that will relieve the burden on the environment, such as organic agricultural products, has been motivated in part by continuing problems with food safety (Shuo *et al.* 2009; The Lancet Editorial, 2009) and environmental pollution (Wong *et al.* 2002). Meanwhile, the exporting of China's organic agricultural products continues to increase, a result of the increasing growth in recent years of the market for organic products worldwide (Paull, 2007). By 2007, the planting area of organic agricultural products in China had extended from 2.3 million hectares in 2005 to 4.1 million hectares (Sheng *et al.* 2009).

China's paddy rice production plays a key role in ensuring its grain supply, as rice is a staple food feeding more than 60 percent of its population. Paddy rice planting areas lead all other crop planting areas in accounting for 20 percent of the gross crop planting area. Furthermore, China's rice production indicates that the number of organic paddy rice planting areas is increasing. To date, certifications for organic paddy rice plantations have been granted in the Heilongjiang, Jiangxi, Jiangsu and Shandong provinces. Planting areas for organic paddy rice total more than 30,000 hectares of which 60 to 70 percent are located in the provinces of Heilongjiang, Jilin and Liaoning (Jin, 2007). In the Heilongjiang province, one of the main provinces for organic paddy rice cultivation, organic paddy rice growing areas increased from 8,000 hectares in 2004 to 16,000 hectares in 2006. This accounted for an 18 percent share of China's total organic paddy rice growing areas and it also accounted for 1.12 % of the total paddy rice planting area in the Heilongjiang province.

Currently, the land used for paddy rice production in China is divided among the main operators/farmers of relatively small-scale farms. Because farmers engaging in paddy rice production not only face certain market risks but must also pay organic certification costs, an individual farmer is often unable to afford the costs associated with converting to organic production. During the conversion process, the operation modes of "organic firm + growing base + farmer" or "organic firm + growing co-operative + farmer" are available options (Zhang *et al.* 2009). This means that an organic firm selects the organic paddy rice growing base, and farmers convert with the guidance of the organic firm. The organic firm also organises the farmers who belong to the organic paddy rice growing base, allowing them to apply for their organic certifications uniformly.

Wuchang City is located in the Heilongjiang Province of north eastern China and has a long history of growing paddy rice and of possessing rich labour resources. Farmers in the Heilongjiang Province have extensive experience in growing paddy rice which provides a foundation for this type of labour-intensive work. Additionally, several organic rice-processing firms have been built and are promoting the operation mode of firm + growing base + co-operative + farmer. Therefore, Wuchang City is considered a pioneer in the field of organic paddy rice production. By 2008, Wuchang's organic paddy rice planting area had reached

2,000 hectares. Thus, paddy rice farmers in this region serve as representative samples for the analysis of the evolution of technical efficiency scores from conventional to organic production.

In the process of converting, farmers' production technical efficiency impacts not only the enthusiasm level of participating farmers, but also the interest levels of the firms' operations and management teams. There are many studies on farming system conversion (Kerselaers *et al.* 2007). However, few studies focus on technical efficiency analysis during the conversion process at the farmers' level. Therefore, it is increasingly important to perform studies in this field.

In terms of research methods, when researching production technical efficiency, the literature suggests that parametric estimation methods and non-parametric estimation methods are frequently used (Cooper *et al.* 2004; Bravo-Ureta *et al.* 2007). The parametric estimation method, also known as the stochastic frontier production function model, has already been used in organic agriculture production technical efficiency studies (Tzouvelekas *et al.* 2001; Mayen *et al.* 2010). Among the studies on the technical efficiency of paddy rice production in China, the Data Envelopment Analysis (DEA), a non-parametric method, is now widely used (Zhou and Chu, 2003; Wang and Lu, 2006; Zhang *et al.* 2007; Chen and Li, 2008). It mainly utilises average data from the province or country level and focuses on the conventional paddy rice mode. The DEA method had been used in measuring efficiency and productivity of conventional and organic farms in Finland 1994-1997 (Lansink *et al.* 2002). But the DEA has not been used in organic paddy rice production technical efficiency studies. Thus, the DEA method may be an effective method to measure production technical efficiency during the conversion process from conventional to organic production at the farmers' level.

The first section of this paper is the introduction; the second section focuses on clarification of research methods and identification of data sources. The third section contains the analysis and discussion of the findings based on estimated results; and the final section summarises our conclusions.

Methods

DEA method

The data envelopment analysis (DEA) method is a non-parametric estimation method used in the stochastic frontier model. An example of this is the linear programming method which has been used and broadly extended after being introduced by Charnes *et al.* (1978). It has been especially widely used in agricultural production technical efficiency estimation (Coelli 1996a).

This method measures technical efficiency mainly by calculating a constant returns to scale model (CRS) and a variable returns to scale model (VRS) respectively. It then computes for scale efficiency.

The constant returns to scale model (CRS) is as follows:

$$\begin{aligned} \min_{\theta,\lambda} \quad & \theta_c \\ st \quad & -y_i + Y\lambda \ge 0 \\ & \theta_c x_i - X\lambda \ge 0 \\ & \lambda \ge 0 \end{aligned} \qquad (1)$$

where θ_c is a constant measure of efficiency of the *i*-th decision-making unit, that is the ith farmer, where if $\theta_c<1$ it denotes that there is a loss of technical efficiency; λ is a constant of N×1 vector; y_i is the paddy rice yield of the *i*-th farmer; x_i is the paddy rice production input of the *i*-th farmer (i = 1,…,M); *X* is an input matrix M×N vector; and *Y* is the paddy rice yield per farmer of 1×N vector.

Some slackness may arise in the solutions with the CRS model. A two-stage estimation method is used to deal with this potential problem (Coelli 1996b).

$$\begin{aligned} \min_{\lambda,OS,IS} \quad & -(M1'OS + K1'IS) \\ st \quad & -y_i + Y\lambda - OS = 0 \\ & \theta_c x_i - X\lambda - IS = 0 \\ & \lambda \ge 0, OS \ge 0, IS \ge 0 \end{aligned} \qquad (2)$$

where *OS* is a 1×1 vector of paddy rice yield error per farmer; *IS* is a M×1 vector of input errors, *M*1 and *K*1 are 1×1 and M×1 unity vectors, respectively.

The variable returns to scale model (VRS) is as follows:

$$\begin{aligned} \min_{\theta,\lambda} \quad & \theta_v \\ st \quad & -y_i + Y\lambda \geq 0 \\ & \theta_v x_i - X\lambda \geq 0 \\ & N1'\lambda = 1 \\ & \lambda \geq 0 \end{aligned} \quad (3)$$

where θ_v is a constant measure of efficiency of the i-th farmer; $N1$ is N×1 vector of 1; and the other variables have the same meanings as in equation (1).

Technical efficiency (θ_c) obtained from the CRS model can be regarded as a combination of technical efficiency (θ_v) and scale efficiency (θ_s) derived from the VRS model (where $\theta_c = \theta_v \times \theta_s$). Scale efficiency can be derived from θ_c and θ_v (where $\theta_s = \theta_c / \theta_v$). When scale efficiency equals 1, the production is at optimal scale. When scale efficiency is less than 1, technical efficiency (θ_n) of the non-increase returns to scale model (NIRS), as in equation (4), can be calculated and compared with θ_v, in order to determine in which stage of returns to scale the production lies. When θ_n is equal to θ_v this production is at the stage of decreasing returns to scale. When θ_n is less than θ_v, the production is at the stage of increasing returns to scale.

The concrete form of NIRS is as follows:

$$\begin{aligned} \min_{\theta,\lambda} \quad & \theta_n \\ st \quad & -y_i + Y\lambda \geq 0 \\ & \theta_n x_i - X\lambda \geq 0 \\ & N1'\lambda \leq 1 \\ & \lambda \geq 0 \end{aligned} \quad (4).$$

Data

The data in this paper are the results of field surveys administered to 95 organic paddy rice farmer households living in Taiping Town, Fanshen Town, Hengdaozi Town or Minle Town of Wuchang City. Organic certification is authenticated by the Heilongjiang Lvhuan Organic Food Certification Co., Ltd. The survey covers the years 2006 to 2007. The panel data include 95 cross-section identifiers over two distinct time periods, for a total of 190 gross sample observations. In addition, farmers surveyed all signed purchasing agreements with local organic rice-processing firms.

In order to observe the evolution of paddy rice production technical efficiency during conversion, we classified farmers into two groups based on whether they were using organic fertiliser in 2006 according to paddy rice production data from farmers surveyed in 2006 and 2007. Farmers of one group started the conversion in 2006, meaning that they began using organic fertiliser and reduced their use of inorganic fertiliser and completely abandoned the use of inorganic fertiliser in 2007. This group of farmers is called the 2006TF farmers and includes 19 households. Farmers of the second group did not begin using organic fertiliser until 2007. This group of farmers is called the 2007TF farmers and includes 76 households. Technical efficiency estimated by data from the 2006TF farmers reflects production level changes during the conversion period from a conventional growing mode to an organic growing mode, while technical efficiency estimated by data from the 2007TF farmers reveals production level changes during the turning point from a conventional growing mode to an organic growing mode.

Results

The summary data (Table 1) reveal that while there were variations for such key variables as yield per hectare, planting area and total output, there were no statistically significant differences, across the two years under investigation, either between the two farmer cohorts or within the cohorts. Farmers possibly chose to convert to the organic mode and expand the growing area a result of the support provided by local organic rice-processing firms. In the contracts, firms promised that a payment of CNY 30,000 per hectare (about US$ 4,700 per hectare) would be paid to farmers who had signed agreements, regardless of their paddy rice output.

Table 1. Statistical summary of input and output indicators in paddy rice production

Statistical indicators	Total output	Production inputs: Organic fertiliser	Farmyard manure	Fertiliser	Labour	Organic pesticide extract and biological natural	Seed	Production facilities and irrigation	Average household planting area	Yield per unit area
	kilogram	kilogram	cubic metre	kilogram	day	kilogram	kilogram	yuan	hectare	kg /hectare
2007TF farmers										
2006										
mean	16411.8	0.0	25.2	1125.5	115.7	249.4	151.5	1967.8	2.2	7450.5
standard error	12553.3	0.0	46.9	876.5	92.7	221.2	113.1	1688.8	1.7	603.0
minimum	2099.3	0.0	0.0	154.5	27.5	19.2	27.2	171.0	0.3	6000.0
maximum	64020.0	0.0	335.8	3780.0	570.0	1150.1	540.0	9840.0	8.0	9000.0
samples	76									
2007										
mean	17546.7	1430.2	28.1	0.0	138.8	268.6	188.7	2215.1	2.4	7493.0
standard error	13960.6	1173.5	51.5	0.0	144.8	295.2	160.8	2288.1	2.0	495.5
minimum	2400.8	180.0	0.0	0.0	30.0	17.6	29.3	306.0	0.3	6150.0
maximum	62977.5	5400.0	335.8	0.0	924.2	1667.3	840.0	13320.0	9.0	8640.0
samples	76									
2006TF farmers										
2006										
mean	15719.8	1121.8	20.2	293.3	146.7	400.3	150.7	2197.3	2.1	7775.1
standard error	16017.6	1421.7	31.0	562.9	169.7	708.0	182.7	2280.8	2.3	1131.4
minimum	2774.2	174.2	0.0	0.0	12.0	29.4	24.0	435.0	0.3	6502.5
maximum	69975.0	6000.0	126.0	2475.0	769.5	3075.0	750.0	10005.0	10.0	12000.0
samples	19									
2007										
mean	17308.1	1386.3	31.2	0.0	227.9	427.0	174.7	2489.4	2.3	7601.1
standard error	21686.0	1848.9	39.0	0.0	419.9	993.7	239.7	3113.2	3.1	993.8
minimum	2425.8	208.0	0.0	0.0	12.0	10.4	24.0	435.0	0.3	6600.0
maximum	97965.0	8400.0	132.0	0.0	1917.3	4305.0	1050.0	14007.0	14.0	11475.0
samples	19									

Note: 2007TF farmers denote farmers who began to use organic fertiliser and abandon fertiliser input in 2007 instead of in 2006. 2006TF farmers denote farmers who began to use organic fertiliser in 2006, and abandoned fertiliser input in 2007.

Secondly, during 2006 and 2007, the minimum average household total output of the 2007TF farmers ranged between 2099.3 kilograms and 2400.8 kilograms while the maximum value was between 64,020 kilograms and 62,977 kilograms. The extreme difference of average household total output for the 2007TF farmers was far greater than that of the 2006TF farmers. The minimum for the 2006TF farmers ranged between 2425.8 kilograms and 2774.2 kilograms, and the maximum value ranged between 69,975 kilograms and 97,965 kilograms. The variations are primarily due to the differences in size of the average household planting area. While the minimum average household planting area was 0.3 hectares, the maximum average ranged between 9 hectares and 14 hectares, and the maximum planting area of the 2006 TF farmers exceeded that of the 2007TF farmers. Because of the promises contained within the contracts, the farmers were anxious to expand the scale of their organic paddy rice growing.

Third, the data from Table 1 suggests an increase in average household labour when compared with that in 2006. There was also a slight increase in plant disease and insect prevention, seed, production facilities and irrigation improvements when compared with 2006. An increase in average household production was correlated with the corporate culture of local organic rice-processing firms. In addition to signing purchasing agreements with farmers, firms also provided funds and subsidies for education tuition for the farmers' children and housing reimbursements for the farmers which resulted in an increase in labour and, consequently, in paddy rice production. The data suggest that greater input of labour, organic biological pesticide and natural extract, seed, production facilities and irrigation and household planting area, lead to greater output (Figure 1 and Figure 2).

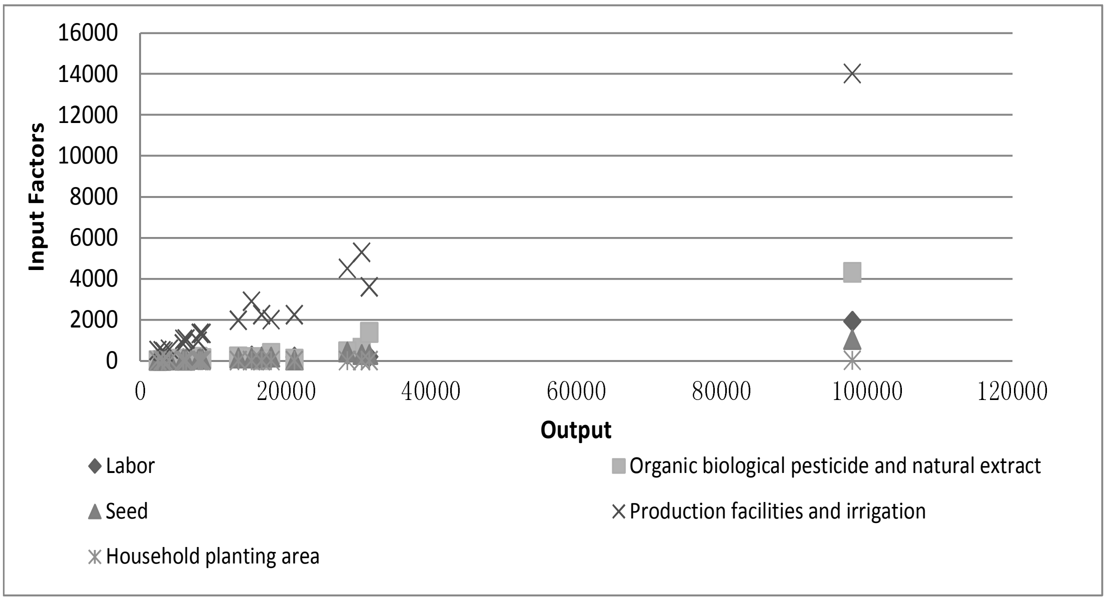

Figure 4. The fluctuation of output and input factors of 2006TF farmers in 2007. The units of output and input factors are the same as that in Table 1.

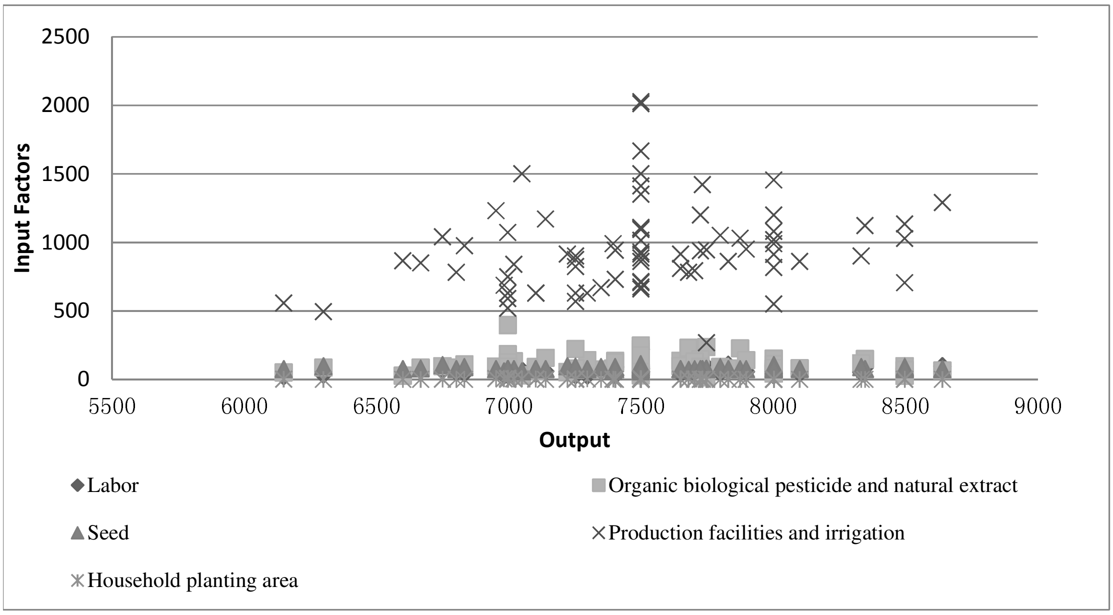

Figure 5. The fluctuation of output and input factors of 2007TF farmers in 2007. The units of output and input factors are the same as that in Table 1.

The results of average technical efficiency scores and scale efficiency scores of paddy rice farmers estimated by the above data and models can be seen in Table 2. According to the results, average technical efficiency scores and scale efficiency scores of the 2006TF farmers showed a downward trend. The average technical efficiency scores of the CRS model declined from 0.982 to 0.892 while the scores of the VRS model dropped from 0.999 to 0.953. Meanwhile, scale efficiency scores fell from 0.983 to 0.936. This reveals that for those farmers who began to convert to organic production in 2006, the average technical efficiency scores of the CRS model decreased over time, and the scale efficiency also decreased.

Table 2. Results of the average technical efficiency and scale efficiency scores

	Technical efficiency scores of CRS	Technical efficiency scores of VRS	Scale efficiency scores	Farmers' percentage in different phases of returns to scale		
year	θc	θv	θs	decreasing	increasing	optimum
2006TF farmers						
2006	0.982	0.999	0.983	0.211	0.000	0.789
2007	0.892	0.953	0.936	0.421	0.368	0.211
2007TF farmers						
2006	0.886	0.922	0.961	0.289	0.329	0.382
2007	0.941	0.966	0.974	0.342	0.382	0.276

Note: Authors' estimated results.

Figure 3 indicates that not only no technical efficiency 2006TF farmers whose scores are less than 1 increase but also 2006TF farmers whose scale of efficiency scores less than 1 increase sharply. The results of 2007TF farmers show similar fluctuations except the technical efficiency scores of VRS which are not changed (Figure 4).

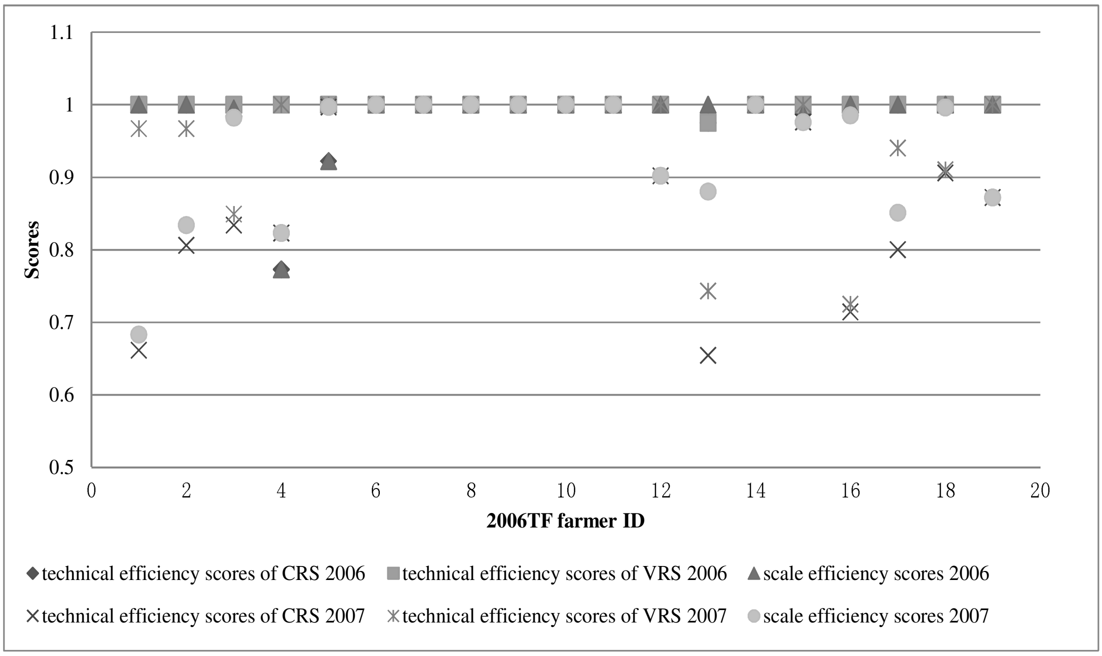

Figure 6. Figure 3. The average technical efficiency and scale efficiency scores of 2006TF famers

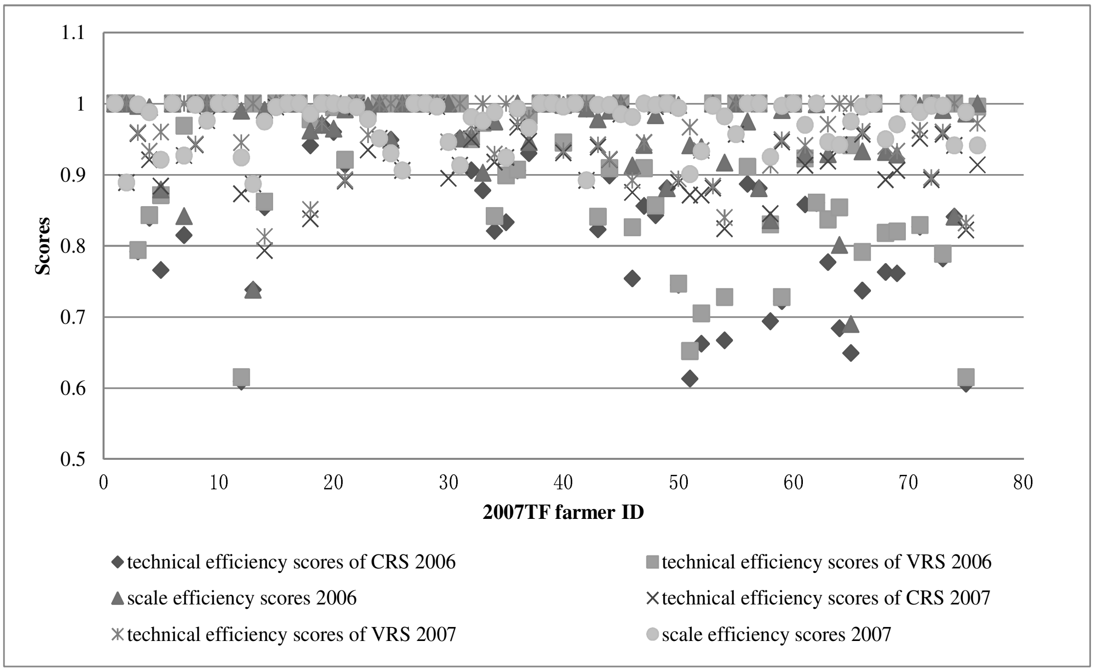

Figure 7. The average technical efficiency and scale efficiency scores of 2007TF famers

On the other hand, average technical efficiency scores and scale efficiency scores for the 2007TF farmers revealed an upward trend. Average technical efficiency scores of the CRS model increased from 0.886 to 0.941 and that of the VRS model rose from 0.922 to 0.966. Similarly, scale efficiency scores rose from 0.961 to 0.974. This indicates that the average technical efficiency of the CRS model of the 2007TF farmers increased, and that the scale efficiency is higher than that for the 2006TF farmers. The technical efficiency of paddy rice production can therefore increase over the short term during the conversion process. However, the influence may lessen over time as the ecological and marketing system for organic paddy rice evolves (Acs *et al*. 2007).

From real input and aimed input of average household paddy rice production (Table 3), as well as aimed input of per hectare paddy rice production (Table 4), the average aimed labour input, organic fertiliser input, organic biological pesticide and natural extract input, production facilities and irrigation input of the 2006TF farmers were higher than those of the 2007TF farmers. Only the average seed input of the 2006TF farmers in 2007 was lower than that of the 2007TF farmers. In the conversion process, real and aimed farmyard manure input and labour input of both the 2006TF and 2007TF farmers increased, whereas the organic biological pesticide and natural extract input decreased. From input percentage for saving in the average household paddy rice production (Table 3) and input percentage for saving in per hectare paddy rice production (Table 4), input percentages for saving of the 2006TF farmers were all lower than those of the 2007TF farmers, except in seed input. Therefore, the longer the conversion period, the greater the dependence on labour input in the organic system. However, as the organic systems develops over time and farmer experience increases, it is likely that labour requirements will decrease (Kristiansen *et al.* 2003), though labour can be expected to remain higher than under conventional systems (Morison *et al.* 2005).

Table 3. Aimed input and input percentage of enabling saving in average household paddy rice production inputs

		Average household production inputs						
		Organic fertiliser	Farmyard manure	Fertiliser	Labour	Organic biological pesticide and natural extract	Seed	Production facilities and irrigation
		kilogram	cubic metre	kilogram	day	kilogram	kilogram	yuan
2006TF farmers	aimed input							
	2006	1117	18	293	144	400	148	2190
	2007	1313	24		214	418	159	2319
	input percentage of enabling saving（%）							
	2006	-0.45	-10.83	-0.04	-1.94	-0.02	-1.66	-0.32
	2007	-5.29	-24.01		-6.20	-2.11	-9.23	-6.83
2007TF farmers	aimed input							
	2006		13	1020	95	195	138	1735
	2007	1391	16		114	217	178	1925
	input percentage of enabling saving（%）							
	2006		-48.57	-9.39	-18.06	-21.80	-8.79	-11.83
	2007	-2.73	-42.52		-17.77	-19.24	-5.65	-13.10

Note: Input percentage of enabling saving = (aimed input - real input)/real input×100%.

Table 4. Paddy rice production inputs per hectare and input percentage of enabling saving

		Production inputs per unit area						
		Organic fertiliser	Farmyard manure	Fertiliser	Labour	Organic biological pesticide & natural extract	Seed	Production facilities and irrigation
		kilogram	cubic meter	kilogram	day	kilogram	kilogram	yuan
2006TF farmers	input							
	2006	503	11	109	74	141	68	1100
	2007	600	15		90	107	73	1122
	2006 *	498	9	109	72	141	66	1094
	2007 *	557	11		78	98	61	1027
	input percentage of enabling saving（%）							
	2006	-0.01	-0.18	0.00	-0.03	0.00	-0.03	-0.01
	2007	-0.07	-0.26		-0.14	-0.08	-0.16	-0.08
2007TF farmers	input							
	2006		12	515	58	119	71	931
	2007	600	13		63	109	79	949
	2006 *		8	455	48	88	64	820
	2007 *	579	9		54	79	74	849
	input percentage of enabling saving（%）							
	2006		-0.36	-0.12	-0.17	-0.26	-0.10	-0.12
	2007	-0.04	-0.28		-0.14	-0.27	-0.06	-0.11

Note: * = aimed input.

Conclusions

The findings from results are summarised below.

First, there was no significant change in consecutive year crop yields experienced by paddy rice farmers (N=95) converting to organic. In particular, there was no statistically significant difference comparing the yields for farmers (N=76) under conventional management and their first year of conversion to organic management. And in addition, there was no statistical difference comparing the yields for farmers (N=19) in their first year of conversion to organic management with their yields in their second year of organic conversion. It is thought that farmers choose to convert to organics and thereby expand the total organic growing area as a result of the support provided by local organic rice-processing firms, especially when that support includes products purchasing, income guarantee and standard of living assurance.

Second, average technical efficiency scores and scale efficiency scores of the 2006TF farmers showed a downward trend while those of the 2007TF farmers increased, thus indicating that technical efficiency of organic paddy rice production might increase in the short run, yet decrease over time. The evolution of the organic ecological and marketing system may require more time to become stable and effective.

Third, labour input, organic fertiliser input, organic biological pesticide and natural extract input, production facilities and irrigation input levels of the 2006TF farmers who had a long conversion period were relatively higher when compared with those of the 2007TF farmers. The dependence on labour was also found to be greater while the labour input percentage for saving in aimed input declined. Therefore, in the conversion process from conventional mode to organic mode, the longer the conversion period, the greater the dependence of the organic system on labour. While, the costs associated with this are not easily reduced, system evolution and farmer experience are likely to reduce labour requirements.

In addition, there are some limits in this paper due to the limited number of participants in the survey, the relatively short survey periods and the absence of details on rainfall, temperature and other climate factors. We recognise that it requires several years to achieve the organic paddy rice producing goal for famers as they transition from conventional to organic production.

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