Transition to Organic Crop Livestock Farming Systems

William B. Bryan

Market demand for organically produced food grew at more than 20% annually since 1992 (Moses, 2006) and, in the US, was valued at $6B in 2000 (USDA, 2000). Organic certification requires a transition period of several years from the last application of prohibited chemicals. Organic production systems also differ in agroecological characteristics from conventional systems. Conversion to organic requires much more than simply eliminating the use of prohibited chemicals (Lotter, 2003). Crop rotations and cover crops are the critical components of most organic farming systems. Biological, chemical and physical characteristics of soils are different. Weed management strategies are different. Changing from conventional to organic practices may result in a yield decline for the first 1 to 4 years, followed by a yield increase when soils have developed adequate biological activity (Liebhardt et al., 1989). Adding off-farm manure and including animals in the farming system could ameliorate this decline. Research in any aspect of organic agriculture at public institutions in the US has been minimal. In 2000, 245 ha or 0.07% of the land grant university agricultural research area was dedicated to such research (Tooby, 2001).

Changing from a management system which relies on synthetic pesticides and fertilizers to a management system based on organic components can result in a temporary reduction of income (Hanson et al., 1997). This transition period forms one of the most significant economic barriers to growers considering organic production methods. Two strategies to overcome problems in transition are to use off-farm nutrients and to use animals as part of the production system. The systems research reported here compared four methods of transition from conventional to organic farming procedures. The objective of the experiment was to determine the effects of off-farm dairy manure and animals (sheep) on farm production and economics and soil quality over the first 3 years of transition from conventional to organic methods of production.

Materials and Methods

The West Virginia University Horticulture Farm has been managed for conventional fruit and vegetable production for over 80 years. It was decided to convert the farm to organic methods and 1999 was the last year of conventional production. Seven acres of land were assigned to a small farm organic transition experiment in 1999. The experiment was designed to compare 4 farming systems:

1. No manure (low input), without animals
2. No manure (low input), with animals
3. Manure (high input), without animals
4. Manure (high input), with animals

The area was divided into three blocks based on previous use and soil series. Blocks I and III were on grassland, primarily composed of tall fescue (*Festuca arundinacea*), Kentucky bluegrass (*Poa pratensis*) and orchardgrass (*Dactylis glomerata*). Block II was an apple orchard with a tall fescue soil cover. Trees were bulldozed out and block II plowed in early 2000. Since the area in block II was limited, all fields were smaller than in blocks I and III. Farming systems (treatments) consisted of two sets of fields (all of equal size in a set and block). One set of fields was cropped; these are referred to as the cropped fields. The second set was permanent grassland and they are referred to as the grassland fields. Farming systems one and three (without animals) were made up of four cropped fields. Farming systems two and four were made up of seven cropped fields and three grassland fields. Of the total area assigned to each animal treatment 87.5% was in grassland fields. The cropped fields were laid out at random, within each block, along the contour. Cropped fields assigned to animal treatments were allowed to have up to 4% slope along the contour and 9% across the contour. Cropped fields assigned non animal treatments had maximum slopes of 2% along and 4% across the contour. The grassland fields were each divided in three equal parts and assigned a usage, hay, buffer and pasture. Hay and buffer usages were mowed for first cutting hay, while the pasture usage was grazed. Hay usage was then cut for aftermath hay and buffer and pasture usages were grazed. Hay was fed to animals on hay and buffer usages from November to March. Grazing was rotational at fixed stocking.

Fields were laid out in November 1999 and soil samples taken. Approximately 15 cores were taken along established transects in each field. These cores were air dried, mixed and analyzed for pH, organic matter, and available P, K, Ca and Mg by the WVU soil testing laboratory. Depth of soil sample was 5 inches for cropped fields and 2 inches for grassland fields. This soil sampling procedure was repeated in fall of succeeding years. Soil amendments and manure application are given in Table 1. All fields received applications of lime to bring soil pH above 6.2. In April 2002 most cropped fields received a second application of lime if pH was less than 6.3 or dolomite (if, in addition, available Mg was less than 200 lb per ha). Manure was disked in immediately after application on cropped fields awaiting seeding. Applications to grassland fields and cropped fields seeded to orchardgrass and red clover (*Trifolium pratense*) were not followed by any mechanical treatment. Manure for winter wheat (*Triticum aestivum*) was applied in Sept 2001 and 2002.

Table 1: Lime and manure applications.

	2000		2001		2002	
	---------------------------------- kg ha^{-1} --					
Lime	2,970[1]	2970 – 6,500	---	---	4,483[2]	---
Manure	29,150[3]	24,650 – 29,150	33,600	---	42,600	---
Total N[4]	126	118 – 126	146	---	230	---
P[4]	37	29 - 36	45	---	95	---
K[4]	97	78 - 113	134	---	260	---

[1]Applied March
[2]Applied in April, to almost all plots, some received dolomitic limestone
[3]Applied in April, except before wheat in September
[4] From analysis of manure

Crop Rotation

Potatoes were planted in May and harvested in August. A rye (*Secale cereale*)/hairy vetch (*Vicia villosa*) cover crop was sown in September. The following May this cover crop was cut with a rotary mower and soybeans (*Glycine max*) no-till seeded in June. Soybeans were harvested in early September and wheat no-till seeded into the stubble. The next year wheat was harvested in late July and the land disked. Brussels sprouts (*Brassica oleracea gemmifera*) were transplanted in September and harvested in June of the next year. Buckwheat (*Fagopyrum esculentum*) was then seeded as a green manure and chopped and disked in before seed set in early August. A rye/vetch cover crop was planted in September. In early May this cover crop was plowed in and the rotation sequence started again with potatoes. This 4-year rotation was extended to seven years for the with-animal farming system by seeding orchardgrass and red clover after the buckwheat. This temporary grassland remained in place for 3 years and was grazed or cut for hay according to need. In May of the year following the third year of this temporary grassland the land was plowed and potatoes planted to start the 7-year rotation again. In 2000 each farming system was assigned 4 or 7 cropped fields and crops were assigned at random within each system. Thus, each cropped field within a system had a different starting crop and each year crops were rotated in each cropped field following the same sequence of crop, cover crop and green manure. In the 3-year transition period no rotation was completed.

Data Collection

Potatoes were hilled one to three times. They were harvested in Aug/Sept after the tops had died or were brush hogged. Yield was estimated by collecting tubers from measured lengths of 2 rows. These tubers were then sorted and weighed. Wheat was combine-harvested in July or August. In 2000 the grain from the whole plot was collected and weighed. Weeds/trash was separated from sub samples and grain dried and yields calculated. In subsequent years nine or more 0.84 m lengths of row were clipped at soil level, number of stalks counted, weeds separated, and weighed. Stalks and weeds were sub sampled and dried. Ears were threshed and grain weighed. Soybean yield was measured by taking 3 sickle bar mower strips (0.76m x measured length) across the field, collecting and weighing material, subsampling, hand separating into crop and weeds, and drying. Hay was made on all soybean fields in 2000. Subsequently animal treatment fields were grazed and non-animal treatment fields were brush hogged. Brussels sprouts were transplanted to the fields in September. If crop plants were present three samples of three plants were harvested and dried. Length of row occupied by the three plants was measured and yield calculated. Vegetation was sampled the following spring using the clipping method described for grassland. Cropped fields assigned to the animal treatment were grazed occasionally depending on crop and conditions. The corresponding non-animal treated fields were brush hogged at the same time. Cropped fields assigned to orchardgrass and red clover were grazed or cut for hay. Herbage mass prior to harvest was estimated in either of three ways:

1. by meter, as described by Rayburn and Rayburn (1998). Herbage mass (DM) was then estimated using the formula:

   Herbage mass = (average sward plate meter height) x 231 - 81.9,
2. three quadrats (0.84 x 0.22 m) were hand clipped at soil level, vegetation separated into grass, legume, weeds and dead and dried at 65 ˚ C for 48 hours,
3. two strips were clipped with a sickle bar mower, length of strip measured, vegetation weighted and sub sampled for separation into grass, legume, weeds and dead and dried.

Between March 7 and 19, 2000 all grassland fields in blocks I and II were grazed heavily with yearling cattle (49 per ha per day) and overseeded with Cinnamon red clover (7 kg per ha). In early April manure at 24,650 kg per ha was applied to fields assigned to the manure systems. The corresponding nutrient applications were 118 kg total N, 29 kg total P and 78 kg total K per ha. The area assigned to grassland fields in Block II was plowed in March, manure (29,150 kg per ha, 126 kg total N, 35 kg total P and 113 kg total K per ha) spread on April 27 and disked in. Pennlate orchardgrass (17 kg per ha) and Cinnamon red clover (8 kg per ha) were seeded into this area April 28 with a Brillion.

Results

Crop Production

Potato: Total yield of potato dropped each year from 00 to 02. But the reduction from 00 to 01 (manure treatment only) was not significant (Table 2). Application of manure increased yield in 01 but had no effect in 02. No difference was found between animal and no animal treatments in 00 but this treatment could not have had any effect until 01. In 2001 the with-animal fields yielded approximately 16% less than the without-animal fields ($P < 0.05$). However, in 2002 no difference was found due to animals. When data for 01 and 02 were analyzed together the input by year interaction was highly significant. This confirms the result that manure had no effect on production in 2002, but increased production dramatically in 01. In 2000, 78% of total yield was classified as A's, 13% as B's and 9% as No 1. Only in yield of No1 was there a significant difference between the with- and without-animal treatments (2515 vs 1234 kg per ha). In 2001 65% of total yield was classified as A, 21% as B and 9% as No1. Neither manure nor animal treatment affected the percentage of total production classified as A, B or No1. In 2002, 42% of total yield was classified as A, 49% as B and only 0.5% as No1. There were no effects of treatments on percentages of total yield falling in different classes. In 2002 data collected on percent scab and injury showed no effect of treatments on either one. Average scab was 3% and injury 27%.

Soybeans: There was no effect of year on DM yield of soybeans or total yield (soybeans and weeds). Percentage weeds increased from 10 to 56 from 00 to 01 in manure treated fields ($P<0.05$). In 2002 percentage weeds was much higher where manure was applied (13% on control and 43% on manure treated fields). Application of manure had no effect on total yield in 2001 but resulted in a 46% increase ($P<0.01$) in 2002. In addition, the size of seedlings was rated higher (average 2 on a scale of 3) on manure-treated than on control fields (average 1.3). When yields were summed over 2001 and 2002 no significant treatment effects were found. There was a trend ($P = 0.29$) for with-animal fields to yield more than without-animal (8,122 kg per ha soybeans and 9,528 total yield compared to 6,905 and 7,856, respectively). In 2000 soybean samples from four fields were separated by plant part, dried and weighed, thus, stem was 44% (as a percent of DM), leaf 40%, petiole 14% and flower/pod 2%.

Table 2: Effect of manure and year on total potato, soybean, wheat grain and Brussels sprout production, 00/01/02.

	2000	2001	2002
		Potato[1]	
		---------- kg per ha ----------	
Without manure	---	8,712	3,974
With manure	21,914	16,567	2,571
Main effect of manure and year		***	
Main effect of animal		*	
Interaction manure by animal		ns	
Interaction manure by year		***	
Interaction animal by year		ns	
		Soybean[2]	
Without manure	---	5,055	3,610
Significance		ns	**
With manure	5,865	4,318	5,282
Interaction manure by year		*	
		Wheat[3]	
Without manure	---	1,776	5,727
Significance		***	ns
With manure	763	2,772	5,240
Interaction manure by year		**	
		Brussels sprouts[4]	
Without manure	---	985	---
With manure	---	1,840	---

ns = non significant: * =P<0.05; **=P<0.01; ***=P<0.001.Effects and interactions not listed were ns.
[1] All tubers, as harvested
[2] Total DM, including weeds;
[3] Grain DM
[4] Above ground total DM, crop failed in 2000 and 2002.

<u>Wheat:</u> Wheat grain yield increased each year (P<0.05). Yields were lower in 2000 because the crop was spring wheat and in subsequent years it was winter wheat. The proportion of weeds in wheat fields was not affected by year or treatment and was 11% in 2000 and 6% in 2002. Application of manure increased yield of grain by over 50% in 2001. However, there was a significant interaction between manure and animal treatments. The yield response to manure was much greater on with- than on without-animal fields. Yields in 2002 were double those of 2001 and there were no differences between treatments. The yield increase between 2001 and 2002 was over 3 fold for fields without manure and was less than 2 fold for fields to which manure was applied (interaction between manure

treatment and years was P=0.08). When yields for 2001 and 2002 were added no effect of treatments was found.

Brussels sprouts: The first Brussels sprouts crop was transplanted in fall 2000. It failed due to dry weather. Production was low in 2001, in this case, in addition to dry weather; the crop was heavily damaged by pests (presumably deer and ground hogs). In 2002 the crop failed again. Brussels sprouts fields transplanted in fall 2001 had been in orchardgrass and red clover. Production from these fields was measured in August 2001 before preparation for transplanting. Average herbage mass was 5,967 kg per ha with no effects of either manure or animal treatments.

Cropped Orchardgrass/Red Clover Grassland: In the animal systems 3 years of orchardgrass/red clover were included in the crop rotation. These cropped fields were designated O5, O6 and O7. Each year the Brussels sprouts fields assigned to the animal systems were seeded to orchardgrass/red clover and designated O5. . The following year they were designated O6 and a new set of cropped fields were seeded as O5. Similarly each year, in the animal systems the O7 cropped fields were plowed and planted to potatoes. All 3 cropped fields, O5, O6 and O7 were seeded in 2000. The fields designated O7 in 2000 were planted to potatoes in 2001, so it was not until 2002 that the O7 fields represented 3 years of sod. Manure increased grassland productivity (Table 3). This increase was not significant for 1st cut hay in 2001 possibly because of the high clover content (80%) in the without-manure fields. In some cases manured fields had more grass and less legumes compared to fields without manure.

Year had variable effects on productivity and botanical composition (Table 4). Fields seeded in 2000 had a high percent legume in 2001 and this dropped in 2002 with a corresponding increase in percent grass. But production of 1st cutting hay was similar for both years. Fields seeded in 2001 had lower legume and higher weeds in 2nd cutting hay compared to 1st cutting hay the following year. As expected, production of 2nd cutting hay was much less than 1st cutting. There was no effect of manure on production or botanical composition of grassland in August 2001. In July 2002 all cropped grassland fields were grazed. While pre grazing total herbage was somewhat higher on manured fields (3,506 compared to 3,063 kg per ha) and amount removed was numerically greater (2,120 compared to 1,608 kg per ha) these differences were not significant.

Table 3: Effect of manure on grassland production and botanical composition (cropped fields).

	Herbage Mass	Grass	Legume	Weeds	Dead
	----- kg ha^{-1} -----	-------------------------------	%	---------------------------	
		First cut hay 2001[1]			
Without manure	3,966	13	80	5	2
Significance	ns	**	**	ns	ns
Manure	4,724	46	49	3	2
		First cut hay 2002[2]			
Without manure	3,695	71	21	6	3
Significance	*	ns	ns	P<0.06	ns
Manure	5,782	83	12	2	3
		Average of first cut hay 2001 and 2002			
Without manure	3,845	42	50	6	3
Significance	**	**	**	**	ns
Manure	5,253	65	31	2	2
		Average of O5, 2nd cut 2001 and O6, 2002			
Without manure	2,798	76	8	12	4
Significance	**	**	ns	ns	ns
Manure	4,226	79	8	6	6
		Average of O6, 1st cut 2001 and O7, 1st cut 2002			
Without manure	3,977	42	50	5	2
Significance	*	P<0.10	ns	ns	ns
Manure	5,971	59	36	1	2

[1] Seeded 2000 (O6 and O7)
[2] O7 seeded 2000, O6 seeded 2001 (no differences between O6 and O7)

Table 4: Effect of year on grassland production and botanical composition (same cropped fields).

	Herbage Mass	Grass	Legume	Weeds	Dead
	----kg ha^{-1} -----	--------------------------------	%	----------------------------	
		Seeded 2001[1]			
2001	4.833	26	68	5	2
Significance	ns	**	**	ns	ns
2002	5,115	76	19	3	2
		Seeded 2002[2]			
2001	2,662	77	3	13	7
Significance	ns	ns	P<0.06	P<0.10	ns
2002	4,363	78	14	5	3

[1] 1st cutting hay, O6 in 2001 and O7 in 2002
[2] 2001 is 2nd cutting hay (O5) 2002, 1st cutting hay (O6)

Grassland Fields: Hay production on June 20, 2001 was 1,728 kg DM per ha for grassland without and 1,949 kg DM per ha for grassland with manure application (Table 5). This difference was not significant (P>0.05). Average percentages grass, legume, weeds and dead material were 66, 16, 5 and 13, respectively with no effect of manure. Hay and buffer usages yielded more than pasture (2,271 kg per ha compared to 973). Hay production on May 20, 2002 averaged 2,914 kg per ha with 82% grass, 6% legume, 5% weeds and 7% dead material. There was no effect of manure. Hay usage areas produced over twice as much (4,182 compared to 1,646 kg per ha) as buffers. Buffers had been grazed earlier in the season whereas hay usages had not. Buffers had 10% dead material and hay 3%, a reflection of recent grazing. Hay harvested in 2002 tended (P<0.07) to be more than in 2001. There was an interaction between years and usage. The hay usage produced almost 50% more hay in 2002 than 2001 (4,182 compared with 2,271 kg per ha). However, production of first cutting hay on the buffer usage was almost 30% less in 2002 than in 2001 (1,646 compared with 2,272 kg/ha) the buffer usage was grazed in late April 2002, prior to resting for hay production. Percentage grass was higher in hay than in buffer usages and was higher in both usages in 2002 compared to 2001. Percentage legume was greater (P<0.05) in 2001 compared to 2002 (17 vs. 6).

Table 5: Production and botanical composition of grassland fields.

	Herbage Mass	Grass	Legume	Weeds	Dead
	----- kg ha^{-1} -----	---------------------------- % --------------------------			
		1st cutting 2001			
Without manure	1,728	62	17	7	15
Significance	ns	ns	ns	ns	ns
Manure	1,949	70	14	4	12
Pasture	973a[1]	62a	13	3a	23a
Buffer	2,272b	62a	20	8a	10b
Hay	2,271b	74a	14	4a	8b
		1st cutting 2002			
Without manure	3,076	82	7	5	6
Significance	**	ns	ns	ns	ns
Manure	2,751	82	5	5	8
Pasture	1,646	77	6	7	10
Buffer	**	**	ns	ns	***
Hay	4,182	88	6	4	3
2001	2,271	68	17	6	9
Significance	P<0.10	**	*	ns	ns
2002	2,914	80	6	5	

[1] Data followed by same letter not significantly different within a column

Grazing 2001: A flock of 30 ewe lambs grazed the grassland fields from April 6 to May 29. They spent 2 to 4 days on each field according to available herbage. They received 600 g hay per head per day until April 20. Thereafter they received water and a salt mineral mixture ad libitum. Between Aug 2 and Oct 10 they grazed the cropped field grassland and the grassland fields a second time. At other times the ewes grazed non experimental grassland on the farm. A Suffolk ram was purchased Nov 5 and introduced to the ewes Nov 14. Hay usage grassland was harvested for hay in August. There was no effect of manure on production (Table 6). Pasture usage produced more in April/May because it was grazed last. In August/Oct pastures produced most because hay and buffer fields were harvested for hay.

Table 6: Grazing and aftermath hay production from grassland fields, 2001.

	April/May			Aug/Oct			August
	Available[1]	Harvested[2]	Grazing Days[3]	Available[1]	Harvested[2]	Grazing Days[3]	Aftermath Hay
	kg/ha		#	kg/ha		#	kg/ha
Without manure	2,548	1,026	2.8	3,152	1,979	4.6	3,779
Significance	ns	ns	ns	ns	ns	ns	ns
Manure	2,825	1,374	2.9	3,337	2,091	4.8	3,458
Pasture	2,690a[4]	1,571a	3.8c	3,683a	2,490a	6.3a	---
Buffer	2,431a	938a	2.0a	1,997b	924b	4.0?	3,730a
Hay	3,314a	1,201a	2.8b	1,858b	924b	2.9b	3,504a

[1] Before grazing
[2] Before grazing minus residual after grazing
[3] Number of days of grazing by 30 ewes
[4] Data followed by the same letter within a column are not significantly different ($P<0.05$)

Grazing 2002: Ewes lambed April 12 to 29. Prior to lambing animals grazed non experimental areas and were supplemented with 230 g first cutting and 230 g aftermath hay per head per day. One month prior to lambing and two weeks after lambing they also were supplemented with 85 g wheat per head per day. From April 16 to 25 they grazed Brussels sprouts (planted in 2001), soybeans, potato and O5 cropped fields. They grazed only the animal treatment fields and occupancy was 1 to 3 days depending on animal numbers and available herbage. There were three groups, pre and post lambing and dry. As ewes lambed they were moved from the pre to the post lambing group. On April 26 six experimental ewe/lamb groups were randomly chosen by ewe weight and single/twins. These groups were assigned to the grassland fields. Four ewes and 6 lambs were assigned to each field in blocks I and III, 3 ewes and 4 lambs were assigned in block II. On May 19, one ewe and one lamb were removed from each group. Usages were grazed in the order, buffer (18 days), pasture (36 days), and hay (18 days). Within each usage animals grazed rotationally in paddocks sized according to number of grazing days and to allow maximum 3 day occupancy. Usages were then grazed a second time in the order, pasture (18 days), buffer (18 days), and hay (18 days). Pasture and buffer usages were grazed a third time for 18 days each. In July and August cropped fields were grazed as needed. Only animal treatment cropped fields were grazed. On August 6 the six experimental groups were combined into two, one to graze manure treated fields and the other the without manure fields. Each group was made up of the 3 small groups previously assigned to the 3 blocks of manure and without manure treatments. There were then 8 ewes and 12 lambs in each group. Lambs were weaned Aug 29 and removed from the experimental grassland. Ten lambs were combined with each of the two ewe groups to graze soybeans from Sept 18 to 21. The combined ewes/lamb groups then continued grazing the pasture and buffer usages until Oct 23 when all animals were removed from the experiment. The breeding season began Nov 1 and animals grazed non-experimental areas.

Manure application increased herbage available on pasture and buffers by 19 % (12.6 cm, compared to 15 cm, sward height). This effect was not found on grazed hay and buffer usages. There was no difference in herbage removed (harvested) between treatments. This was expected since stocking rates were the same and animal performance did not differ between treatments (Table 7).

Table 7: Sheep performance (2002).

		Treatment	
		Manure	Without manure
Ewe weight, Aug 6	kg	52	52
Lamb weight, Aug 6	kg	26	24
Lamb birth weight	kg	5	4
Lamb ADG	kg $(ha\ day)^{-1}$	0.22	0.22
Stocking rate (total system)[1]	ewes ha^{-1}	6.4	6.4
	lambs ha^{-1}	9.4	9.4
Stocking rate (grassland only)	ewes ha^{-1}	7.4	7.4
	lambs ha^{-1}	11.1	11.1
Sale weight of lambs	kg	36	37
Lamb production (total system)	kg ha^{-1}	341	345
Lamb production (grassland only)	kg ha^{-1}	403	408

[1]Grassland and cropped fields

Internal Parasites: Sheep were not introduced to the farm until the second year of transition. They could have been introduced the first year and for purposes of the economic analysis we assume this would have been the case. Thus, for parasite control 3 years of experience are given. The first year we had no problems with parasites and took no special precautions. A graduate student in animal science took fecal samples off the pasture in the fall and found low numbers of internal parasite eggs; numbers were similar to those in fecal samples taken on sheep pastures on the adjacent conventional WVU Livestock Farm. Fecal samples were collected in the second and third years and a qualitative determination made of eggs. Presence of *Cocidia* and *Haemonchus contortus* is shown in Table 8. No eggs of *Nematodirus*, *Marshallagia*, *Strongyloides*, *Dictiocaulus* or *Thysanosoma* were found.

Table 8: Fecal egg counts, first two crops of lambs.

	Animal		*Coccidia*		*Haemonchus*	
Date	Type	Number	Animals with no eggs	Eggs	Animals with no eggs	Eggs
March 30, 02	ewes	30	28	3.5	0	0
May 30, 02	ewes	11	6	8.6	10	1
June 25, 02	lambs	39	3	14.1	38	1
Oct. 29, 02	lambs	31	1	28.5	6	8.8
Nov. 20, 02	ewes	25	18	2.0	9	3.1
March 25, 03	ewes	30	21	3.8	8	3.5
Nov. 03	ewes	27	26	1.0	6	4.1
Nov. 03	lambs	36	35	1.0	4	33.6

Soil Fertility: Addition of manure each year had no significant effect on soil organic matter percentage. The average soil organic matter was 2.8% for the cropped and 5.1% for the grassland fields (Table 9). Soil available P ($P<0.05$), K ($P<0.01$) and Mg ($P<0.05$) were increased by manure application on cropped fields. On grassland fields manure increased available soil P ($P<0.05$). In all these cases there were significant year by manure interactions. Fields assigned to the manure treatment were lower in P, K and Mg before the experiment began. After 3 years manure treated fields were all higher than those to which no manure was applied (Figures 1 to 4).

Soil test levels of almost all nutrients and pH was higher after 3 years than before the experiment started. Organic matter dropped after the first year in cropped fields because they were in grassland and were plowed and cultivated (Table 9). Soil pH increased after lime was applied. Soil P increased each year probably as a result of increasing pH from 5.6 to 6.6 (5.5 to 6.9 on grassland). Before the experiment started soil P was low and soil K high. After 3 years soil P levels were high to

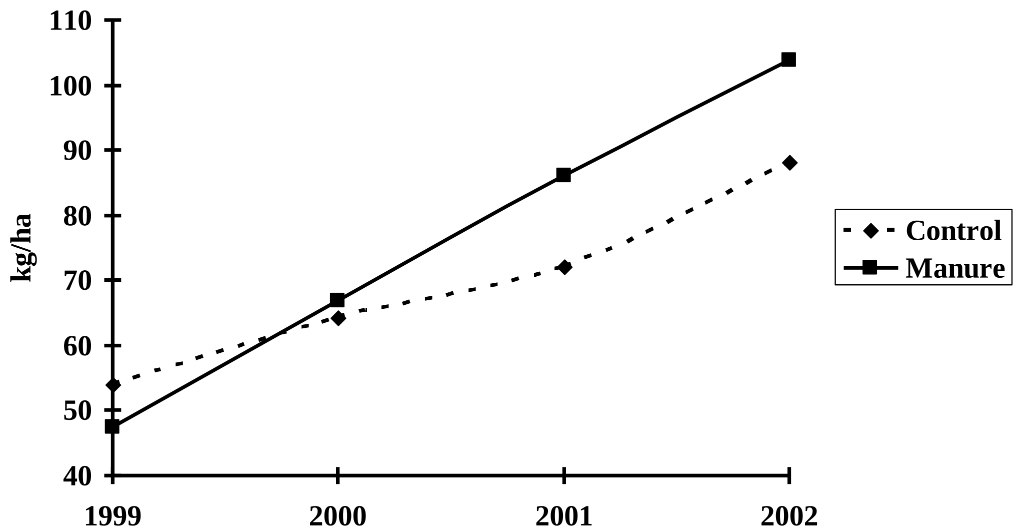


Figure 1. Effect of Manure and Year on Available Soil P in Cropped Fields (Interaction P<0.05).

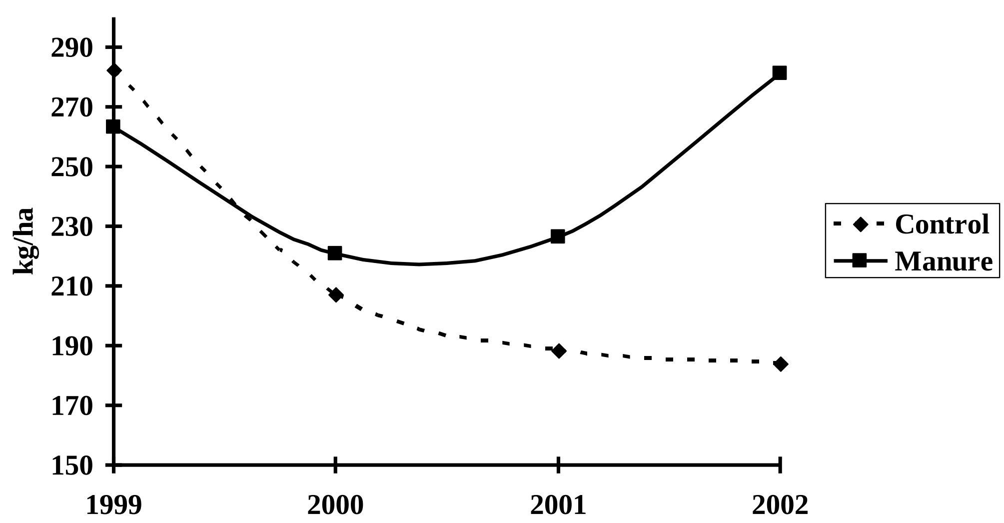


Figure 2. Effect of Manure and Year on Available Soil K in Cropped Fields (Interaction P<0.001).

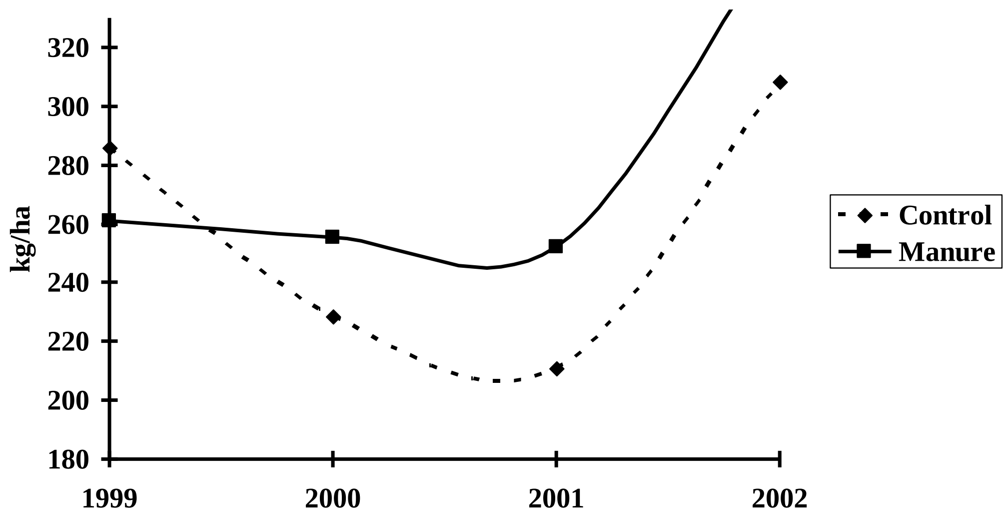


Figure 3. Effect of Manure and Year on Available Soil Mg in Cropped Fields (Interaction P<0.05).

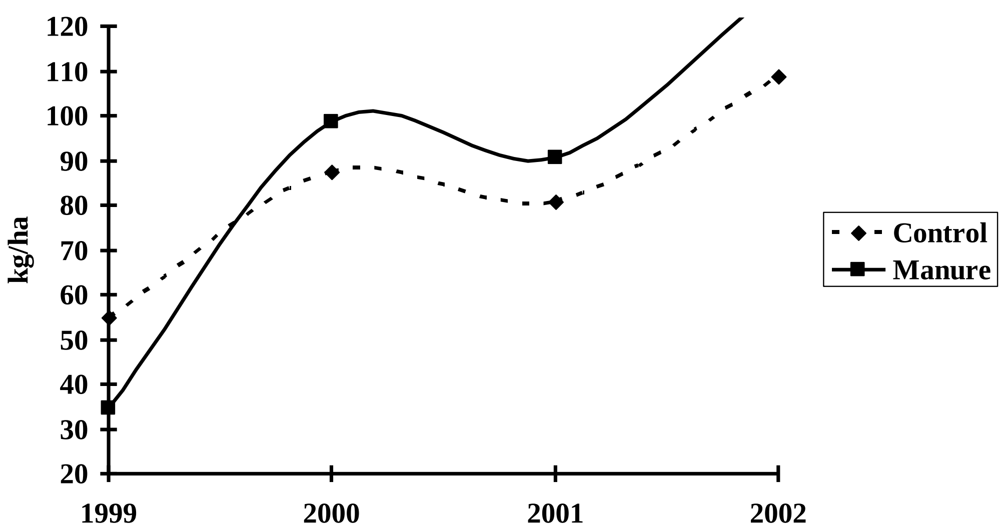


Figure 4. Effect of Manure and Year on Available Soil P in Grassland Fields (Interaction P<0.05).

very high in all fields. In cropped fields with no manure application soil K levels were much lower after 3 years than at the start. However, on the grassland fields soil K was high at all times and increased linearly with year ($P<0.05$).

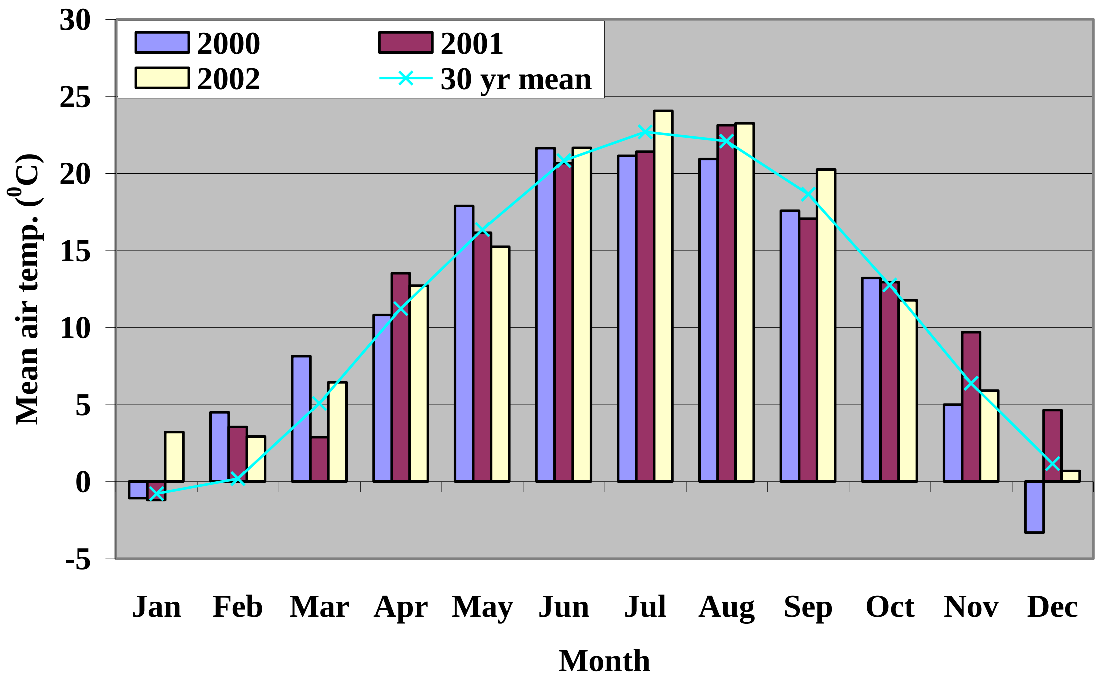
No effects of the animal treatment on soil fertility of the cropped field were seen. However, since hay was removed from the orchardgrass/red clover cropped fields each year and sheep were not wintered on these fields a reduction in available soil K could be expected. On the grassland fields hay was made and removed, however the hay was fed during the winter as the animals occupied the fields rotationally, ensuring return of nutrients. Grazing at a high stocking rate may have increased the rate of recycling of nutrients and contributed to the higher levels of available soil P at the end of the transition period. Animals could be managed to redistribute nutrients around the farm by feeding hay on areas with lower soil nutrient levels. This would remove nutrients from grassland harvested for hay. However, the results of this experiment show that soil available P and K are very high in permanent grassland and some of these nutrients could be readily transferred to cropped land.

Table 9: Effect of year on soil fertility in cropped and grassland fields

Year	Treatment	pH	P	K	Ca	Mg	OM
			----------------------- kg ha^{-1} -----------------------				----- % -----
1999	Cropped	5.6	50	272	2,718	273	3.5
	Grassland	5.5	45	346	2,159	332	5.4
2000	Cropped	6.0	65	215	3,828	242	2.4
	Grassland	6.4	93	391	5,693	321	4.8
2001	Cropped	6.0	80	207	3,177	231	2.6
	Grassland	6.5	86	434	5,582	343	5.2
2002	Cropped	6.6	96	232	3,987	333	2.6
	Grassland	6.9	119	455	7,886	363	5.2

Discussion

The first two years of transition were drier than average (Figures 5 and 6). However, precipitation was above average in April and May of 2000 and temperatures were above average providing good growing conditions. Dry weather in August and September affected growth of fall crops, particularly Brussels sprouts and it failed (Table 2). Rainfall in 2001 was close to normal during the growing season, but was below normal in October with the result that Brussels sprouts yields were low. This crop failed again in 2002 due to dry weather in September at the time of



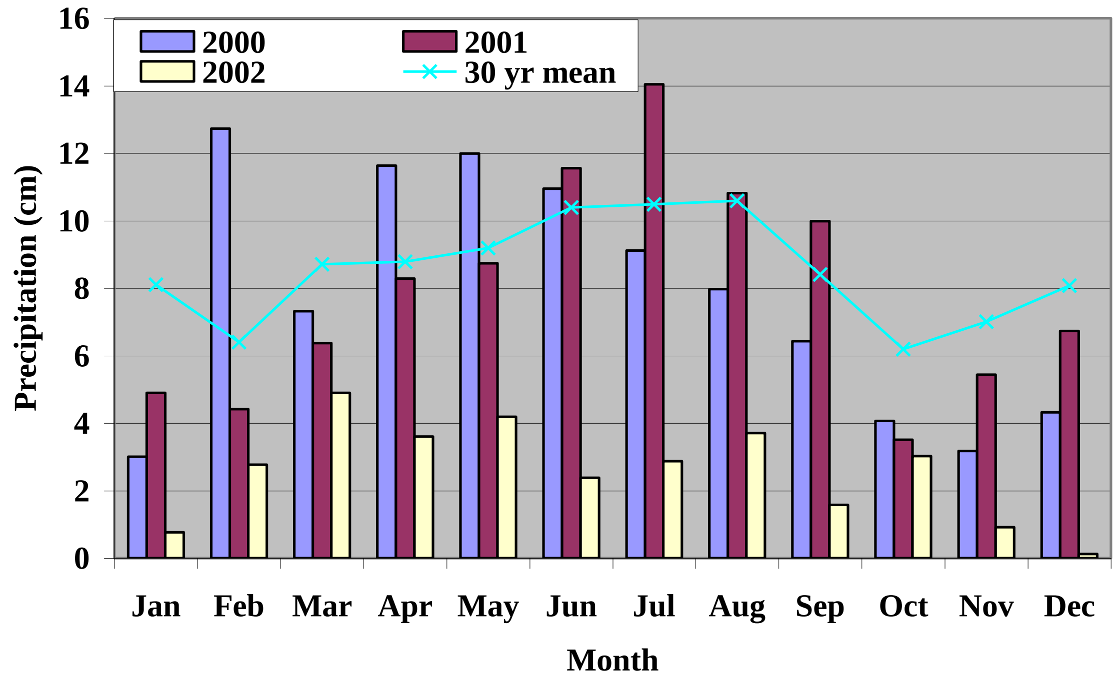


Figure 5. Monthly mean air temperature and precipitation and 30-year mean values for each parameter at Morgantown airport, WV.

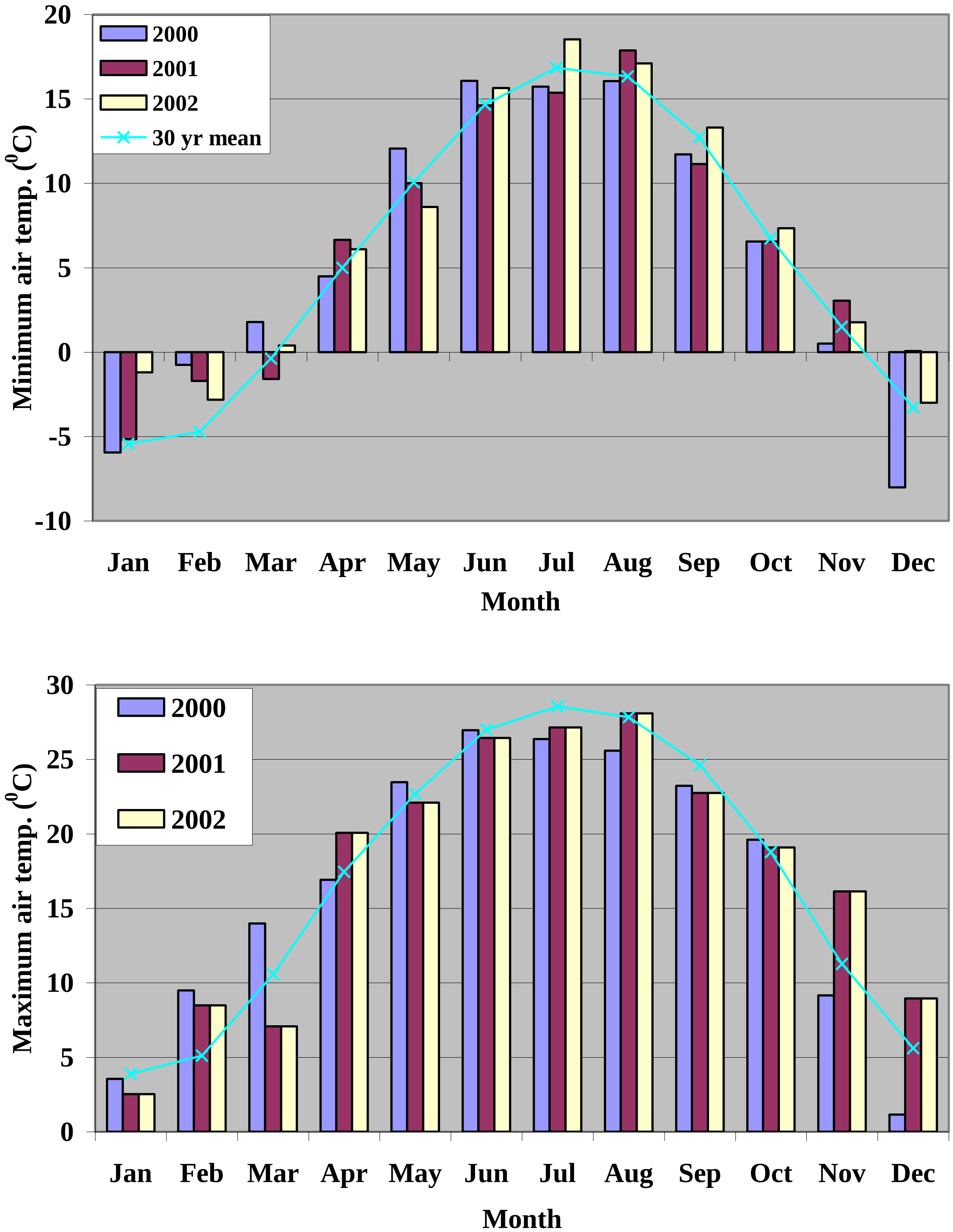


Figure 6. Monthly mean minimum and maximum air temperature and 30-year mean values for each parameter at Morgantown airport, WV.

transplanting. Brussels sprouts was chosen for this experiment because we wished to have a brassica in the rotation that would have sale value. However, after repeated failures we changed to rape in subsequent years. Wetter than normal weather in 2002 resulted in very late planting of potatoes. This combined with warmer temperatures in June and July, weeds and insects, resulted in very low yields. Wheat yield was very low in 2000 due to late planting and warmer temperatures in June. In addition the crop was spring wheat for first year. Subsequently, we planted winter wheat. Yields were again low in 2001 due to the dry fall in 2000 and dry spring in 2001. In 2002, however, yields were good as the wheat was able to take full advantage of the wet spring of that year. Yield of soybeans and grassland did not differ significantly by year (Tables 2, 4 and 5). (The year comparison for fields seeded in 2001, reported in Table 4 is confounded with harvest, since the 2001 data are from 2nd cut and the 2002 from first cut. The difference in yields is much more likely to be due to cut than to year).

To compare farming systems the field data were adjusted using various assumptions. Potato was assumed to produce 70% grade A. Yields in 2002 were low due to management and weather. We assume an average yield equal to 2001 and a 50% reduction in the difference between manure and no manure. In spite of a significant loss in potato yield on animal treatments in 2001 we are assuming no effect because there were no animals in 2000 and we could not measure any effect in 2002. We assume an average response to manure application of 36% in economic potato yield in the 2nd and 3rd year of transition with no effect of animals. In the case of soybeans we assume that total DM would be hay suitable for animal feed (total = soybeans + weeds). We assume that the effect of manure over both years (2001 and 2002) is the average, or about a 10% increase in yield of DM attributable to manure. Yield of wheat was increased 56% by manure in 2001 and not influenced by manure in 2002. We assume an average increase of 28% due to manure application. In spite of the finding that wheat yields were higher on animal treated fields in 2001 we assume no difference because animals were not present in 2000. Brussels sprouts are assumed to have produced forage at the same rate in all years as was found in 2001 with a 40% increase due to manure application. First cutting orchardgrass/red clover hay from cropped fields is assumed to have produced equally each year with a 35% increase due to manure application. This increase translates to a 5% increase in available hay each year on the with manure treatment. We assume manure and years did not affect production of hay from grassland. In 2002, the only one of the three years for which we have animal production data, manure application increased herbage mass on pasture usage by 20%. Since stocking rate was equal on both treatments and there were no differences in animal performance we did not measure this difference in animal production. We assume the with-manure treatment could have carried 5% more stock (based on the higher hay production from cropped grassland and higher pasture usage production).

Typical Farm

To make economic comparisons between the four organic systems described in this bulletin we assume an area of 2 ha for farms without and 13.5 ha for farms with sheep. All the area is in grassland at the start, and all cropped fields are plowed in year 1. Cropped fields are 0.5 ha in size. We assume that sheep are introduced in year 1 with 70% of the carrying capacity; full capacity would be reached in year 3. We had a stocking rate of 6.4 ewes/ha which corresponds to 74 ewes on 11.5 ha (the typical farm has 10 ha of grassland and 1.5 ha of cropped grassland). We assume that the with-manure treatment could carry 5% more animals than the without-manure treatment. Also we assume that, for the typical farm, the initial stocking rate would be 70% of the stocking rate in year 3. Thus, in year 1, 55 and 52 ewe lambs will be purchased for with- and without-manure treatments, respectively. These will produce 83 and 78 lambs (150% lambing rate expected) in year 2 from which 23 and 22 ewe lambs will be retained as replacements to increase the ewe numbers to 78 and 74 in year 3. Lambs sold in year 2 will be 58 and 54 (2.5% mortality expected) and in year 3, 81 and 76. Sale weight of lambs is 36 kg. Grassland will be divided in 3, 3 1/3 ha fields and assigned pasture, buffer and hay usages, 6 2/3 ha will be cut for first cut hay and 3 1/3 for aftermath. The cropped grassland will provide 1.5 ha of first cut hay but aftermath will be grazed by lambs. Total hay production will be 25,250 kg/ha first cut and 12,000 kg/ha from aftermath on the without-manure treatment and 27,350 and 12,000 kg/ha first cut and aftermath on with-manure.

Table 10: Production estimates for budget analysis.

		Without manure		With manure		
Crop		2001	2002	2000	2001	2002
Potato Grade A	kg ha^{-1}	6,100	7,250	15,350	11,600	10,450
Soybeans, hay	kg ha^{-1}	5,050	3,600	5,850	4,300	5,300
Wheat	kg ha^{-1}	1,800	5,750	750	2,750	5,250
Brassica, forage	kg DM ha^{-1}	1,000	1,000	1,850	1,850	1,850
Orchardgrass/ red clover hay	kg ha^{-1}	3,850	3,850	5,250	5,250	5,250
Grassland Hay	kg ha^{-1}	4,200	4,200	4,200	4,200	4,200
Buffer	kg ha^{-1}	1,650	1,650	1,650	1,650	1,650
Aftermath	kg ha^{-1}	3,600	3,600	3,600	3,600	3,600

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