Effects of organic and inorganic amendments on weed management in sweet maize

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Abstract

Field experiments were conducted to determine the effects of organic and inorganic amendments on weed suppression in sweet maize cultivation (*Zea mays* L.). A randomized complete block design was employed with four replicates per treatment with each organic amendment used at half (x/2), single (x=10 t ha^{-1}) and double (2x) rates (organic fertilization: cow manure, poultry manure and barley mulch; synthetic fertilizer (240 kg N ha^{-1}: 21-0-0); and control). The highest number and dry weight of weeds were recorded for double cow manure and chemical fertilizer treatments. The cow manure treatments promoted weed emergence and growth proportionally to the rate of application (x/2<x<2x). In the presence of barley residues, weed biomass or density was reduced for the species: redroot pigweed (*Amaranthus retroflexus* L.), common purslane (*Portulaca oleracea* L.) and prostrate knotweed (*Polygonum aviculare* L.). Weed suppressive effect of barley residues decreased with time following residue decomposition. The barley mulch plots presented the highest values of Shannon-Weiner and Simpson indices. These results indicate that green manure of barley are effective for the suppression of some weeds in sweet maize.

Keywords: Fertilization; Manure; Mulch; Synthetic fertilizer; Sweet maize; Weed.

Introduction

Weed control in organic farming is a major problem because herbicides, the most effective and easily used means, are not allowed for weed control, and so control is only based on mechanical and cultural means. An alternative method of weed management is weed suppression by green manures which are incorporated into the soil. Green manure of Brassicaceae plants (*Brassica juncea* L., *Sinapis alba* L.: Norsworthy et al. (2005)), sunflower (*Helianthus annus* L.), dhaincha (*Sesbania aculeata* Poiret: Om et al. (2002)), or red clover (*Trifolium pratense* L.: Ohno et al. (2000)) can be used for management of some weeds. The allelopathic properties of plants can be exploited successfully as a tool for weed reduction. Cereals have been reported to acquire allelopathic potential that affects the growth of other species (Dhima et al., 2006; Zotarelli et al., 2009). Bunna et al. (2011) reported that mulching of rice straw at 1.5 t/ha reduced weed biomass from 164 to 123 kg ha^{-1} and increased mungbean yield from 228 to 332 kg ha^{-1}. Moreover, Tabaglio et al. (2008) reported that rye mulches were not able to suppress velvetleaf and common lambsquarters seedlings, while redroot pigweed and common purslane were significantly affected. Weed suppression ranged from 40% to 52% for redroot pigweed and from 40% to 74% for common purslane. Cover crops such as hairy vetch, ryegrass and oat could be used to reduce weed infestation (Isik et al., 2009).

The management of crop fertilization may be an important component of integrated weed management systems (Blackshaw et al., 2005). Weed dynamics change according to different organic sources of nutrients. Manure is mainly used as a nutrient source and also in order to improve soil fertility (Baitilwake et al., 2011; Suthar, 2009; Piorr, 2003). However, its use can be a source of weed infestation. Among the manures used, poultry manure has high N content and good weed control efficacy due to its phytotoxic character (Baig et al., 2001). Haidar and Sidahmed (2006) have also reported that chicken manure was effective in reducing *Orobanche ramosa* growth and infestation early in the season in comparison with the control.

The main objective of this study was to determine the effect of three types of soil amendments with three levels of N on weed density, dry mass, and weed species diversity in sweet maize. Our study was also restricted to allelopathic effects of barley residues on weed density and biomass.

Material and Methods

Field experiments were carried out in southern Greece (Oropos, 60 km from Athens, Lat: 34°, Long: 23°) in 2005 and 2006. Sweet maize (*Zea mays* L.) F_1 hybrid 'Midas' was planted. The experimental site had previously been cropped with vegetables. The soil was a clay loam (30.2% clay, 36.8% silt and 33% sand) with pH 7.1 and organic matter 1.96%. The experiments were carried out under semi-arid Mediterranean climatic conditions, where soils typically have low organic matter content and weak structure, resulting in low infiltration rates and low moisture retention. Some meteorological data for the experimental site are presented in Figure 1. The precipitation during the growing season (April-August) in 2005 (151 mm) was higher than that in 2006 (76 mm).
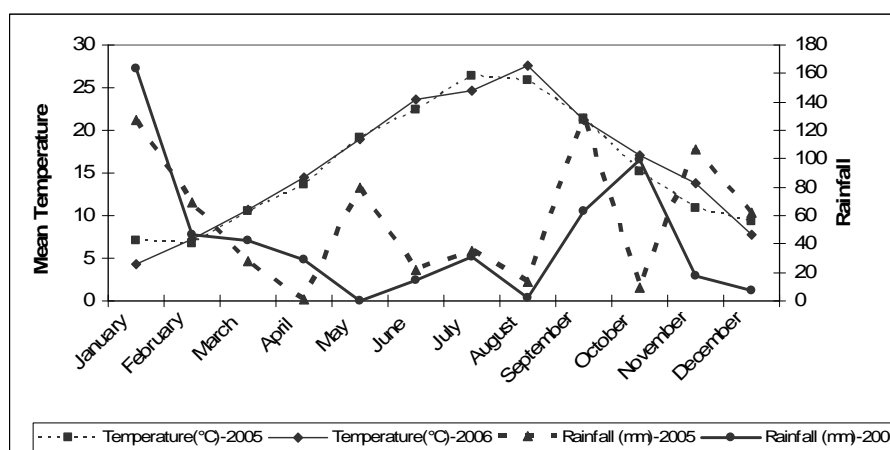

Figure 1. Meteorological data at the experimental sites (temperature: °C and rainfall: mm).

A randomized complete block design was employed with four replicates per treatment. Two experiments of approximately 1350 m^2 (71×19 m) were conducted. The plot size was 4.0×6.0 m. The three kinds of amendments used were: cow manure (CM), poultry manure (PM), barley residues (B) and fertilizer (F). All were subject to chemical analysis:

<u>Cow manure:</u> the cow manure used had undergone natural outdoor fermentation (composting) for 6-8 months and contained 1.21% of nitrogen, 0.4% P and 0.7% K.

<u>Poultry manure:</u> An industrially processed, standardized and dry product was used. It contained 0.74% of nitrogen, 0.9% P and 0.5% K.

<u>Barley:</u> Fresh barley was used, which was harvested immature prior to flowering, just before the establishment of the experiments, and contained 0.69% of nitrogen.

<u>Fertilizer:</u> Chemical fertilizer 21-0-0 (ammonium sulphide, $(NH_4)_2SO_4$).

The incorporation after the establishment of the treatments was carried out twice with a rotary hoe in each plot separately. The fertilizers were incorporated into the soil 5 days before sowing. According to the literature and the local practice, the optimum level of nitrogen for the cultivation of sweet maize is 240 kg N ha^{-1}. The treatments were:

Fertilization with 240 kg N ha^{-1} (fertilizer 21-0-0, 1143 kg ha^{-1}): F,

Poultry manure 5 t ha^{-1} (35 kg N): PM x/2,

Poultry manure 10 t ha^{-1} (70 kg N): PM x,

Poultry manure 20 t ha^{-1} (140 kg N): PM 2x,

Cow manure 5 t ha^{-1} (60 kg N): CM x/2,

Cow manure 10 t ha^{-1} (120 kg N): CM x,

Cow manure 20 t ha^{-1} (240 kg N): CM 2x,

Barley mulch 5 t ha^{-1} (35 kg N): B x/2,

Barley mulch 10 t ha^{-1} (70 kg N): B x,

Barley mulch 20 t ha^{-1} (140 kg N): B 2,

Control (no fertilization): C.

The maize was sown manually. In 2005 and 2006, the maize was sown on the same dates (25/4/2005 and 25/4/2006). Maize was planted at an 80 cm row spacing and 16 cm plant spacing, at an approximate density of 78125 plants ha^{-1}.

A sprinkler irrigation system (overhead irrigation) was used. Analysis showed that the pH of the water was 7.4 and its salinity 1000 (April)-1400 (August) µS cm^{-1}.

The number of weeds (redroot pigweed (*Amaranthus retroflexus* L.), prostrate pigweed (*Amaranthus blitoides* L.), common lambsquarters (*Chenopodium album* L.), officinel croton (*Chrozophora tinctoria* (L.) A. Juss.), bermudagrass (*Cynodon dactylon* (L.) Pers), squirting cucumber (*Ecballium elaterium* A. Rich), common purslane (*Portulaca oleracea* L.), prostrate knotweed (*Polygonum aviculare* L.) and greenfoxtail (*Setaria virdis* L. P. Beauv.) were assessed.

A wooden square quadrat (40×40 cm) was placed at random three times in each plot. Weeds in the 40×40 cm area were counted for each species present, and fresh and dry matter determined. Weed assessments were made at 37 and 67 days after sowing (DAS) as follows:

1. Density per unit area (no. m^{-2}).

2. Dry weight (g m^{-2}). Weeds were cut and roots discarded. The remaining material was placed in paper bags in an oven at 65 ^{o}C for 72 hours. Dry matter was then determined.

After the weed measurements were made, all remaining weeds were destroyed and weed seed return was prevented by two inter-row cultivations with a rotary hoe during the experimental period. The weeds on the row were destroyed manually.

For the computation of maize dry weight, 5 plants were randomly selected in each plot. The dry weight was determined after drying for 72 h at 65 ^{o}C. For the determination of yield, 10 plants were harvested per plot and all yield measurements were made at 14% seed moisture content.

The data were subjected to statistical analysis according to the randomized complete block design. Differences between treatment means were compared at P=0.05 with ANOVA to find significant differences and *LSD* were used to compare the plots. The statistical analysis of the data was performed using the STATGRAPHICS Plus 5.1 (Statistical Graphics Corp.) logistic package.

The species diversity of weed groups was characterized using Shannon-Weiner (H) and Simpson indices (D) (Krebs, 1978; Booth et al., 2003):

$$H = -\sum (Pi)(\ln Pi) \qquad \text{and} \qquad D = 1/\sum Pi^2$$

respectively, where P_i is the fraction of the weed density belonging to the ith species in a given group. For calculation of these indices, the software Species Diversity and Richness III (Pisces Conservation Ltd.) was used.

Results

Weed density

Nine species of weeds (redroot pigweed (*Amaranthus retroflexus* L.), prostrate pigweed (*Amaranthus blitoides* L.), common lambsquarters (*Chenopodium album* L.), officinel croton (*Chrozophora tinctoria* (L.) A.

Juss.), bermudagrass (*Cynodon dactylon* (L.) Pers), squirting cucumber (*Ecballium elaterium* A. Rich), common purslane (*Portulaca oleracea* L.), prostrate knotweed (*Polygonum aviculare* L.) and greenfoxtail (*Setaria virdis* L. P. Beauv.) were found in the experimental field.

The most frequently occurring weeds were: *A. retroflexus*, *P. oleracea*, *E. elaterium*, *S. viridis* and *P. aviculare*. In 2005, the plots treated with barley mulch gave lower total density (285-498 weeds m^{-2}) of weeds than the other treatments (Table 1). The cow manure treatments and fertilizer (240 kg N ha^{-1}) plots gave the highest density of weeds at both assessments. In 2006, at both assessments, synthetic fertilizer and all rates of manure (poultry and cow) resulted in higher values than the other treatments.

Table 1. The effect of organic amendments and fertilizer on total dry weight (g m^{-2}) and density (weeds m^{-2}) of weeds, 37 and 67 days after sowing (DAS). PM: Poultry manure, CM: cow manure, B: barley mulch, F: fertilizer 21-0-0, C: control, x: 10 t ha^{-1}.

| Treatment | Dry weight | | | | Number of weeds | | | |
| | 37DAS | | 67DAS | | 37DAS | | 67DAS | |
	2005	2006	2005	2006	2005	2006	2005	2006
PM x/2	35.09	24.78	110.64	59.94	1009	800	590	532
PM x	32.05	33.16	105.03	78.01	905	914	573	582
PM 2x	27.53	40.78	103.35	95.28	718	1037	569	612
CM x/2	43.8	32.86	120.64	81.13	1266	808	596	606
CM x	53.9	30	199.57	111.49	1468	856	849	647
CM 2x	78.45	37.94	276.09	165.4	1764	924	1022	713
B x/2	11.67	15.05	41.8	41.26	498	614	374	309
B x	7.41	18.3	39.99	40.14	356	516	340	325
B 2x	5.99	24.08	43.32	49.2	285	674	327	399
F	71.7	34.6	258.95	83.73	1551	933	971	482
C	26.17	16.03	79.42	36.2	854	673	632	357
LSD$_{5\%}$	3.32	2.17	20.91	15.62	303.45	76.65	121.87	89.23

Notes: The LSD (P=0.05) for fertilization treatments are shown.

The most frequently weed was *A. retroflexus* (Table 2). In 2005, at 37 DAS, the lowest densities of *A. retroflexus* were recorded for barley amendments and the double rate of poultry manure (P<0.05), whereas most weeds were found with the double rate cow manure (715 weeds m^{-2}) and the fertilizer treatment (Table 2), a situation that persisted at 67 DAS**.** In 2006, the suppressive effect of barley mulch and poultry manure (all rates) was much less evident. The density of *A. retroflexus* was reduced in all treatments because of the weed removal during the cropping period in 2005.

Table 2. The effect of organic amendments and fertilizer on *Amaranthus retroflexus* dry weight (g m^{-2}) and density (weeds m^{-2}), 37 and 67 days after sowing (DAS). PM: Poultry manure, CM: cow manure, B: barley mulch, F: fertilizer 21-0-0, C: control, x: 10 t ha^{-1}.

Treatment	Dry weight				Number of weeds			
	37 DAS		67 DAS		37 DAS		67 DAS	
	2005	2006	2005	2006	2005	2006	2005	2006
PM x/2	12.7	11.45	39.50	35.47	417	342	176	303
PM x	9.27	18.12	35.01	49.45	330	396	168	351
PM 2x	4.65	19.95	31.20	61.37	177	442	158	357
CM x/2	16.57	10.15	39.25	51.12	507	302	177	377
CM x	22.10	11.70	90.12	72.90	597	306	325	390
CM 2x	34.67	15.52	118.5	111.45	715	332	382	418
B x/2	5.05	6.85	9.22	23.40	208	278	83	99
B x	2.02	8.07	7.00	19.35	89	148	69	118
B 2x	1.20	10.56	3.95	22.25	59	332	49	178
F	32.67	13.60	97.35	39.95	690	334	300	317
C	10.50	6.50	33.5	18.31	300	228	260	147
LSD$_{5\%}$	1.56	1.10	5.48	3.08	29.14	24.5	24.93	13

Notes: The LSD (P=0.05) for fertilization treatments are shown.

For the weed *P. oleracea*, weed density was proportional to the application rate of amendments (P<0.05). In 2005, at the first assessment, the highest density (240 weeds m^{-2}) was recorded for the double rate cow manure treatment (Table 3) and the least for the half rate poultry manure plot (48 weeds m^{-2}). At the second assessment, the highest density was recorded in the fertilizer plots (165 weeds m^{-2}) and the lowest with the half rate barley mulch treatment (80 weeds m^{-2}). In 2006, 37 DAS, the double barley rate gave the highest weed density, while the half rate gave the lowest. Density was highest (P<0.05) 67 DAS for all barley mulch treatments. The double rate poultry and cow manure treatments had higher densities in comparison to the half rates.

However, in 2005, the plots treated with barley mulch gave a lower density (14-18 weeds m^{-2}) of *P. aviculare* than the other treatments (Table 4). The double rate cow manure and fertilizer plots gave the highest densities of *P. aviculare* at both assessments. In 2006, at both assessments, the lowest density of *P. aviculare* was associated with barley mulch (all rates) (P<0.05), and values were much lower than even the control plot. At both assessments, all rates of poultry manure and cow manure resulted in higher values than the other treatments.

Table 3. The effect of organic amendments and fertilizer on *Portulaca oleracea* dry weight (g m^{-2}) and density (weeds m^{-2}), 37 and 67 days after sowing (DAS). PM: Poultry manure, CM: cow manure, B: barley mulch, F: fertilizer 21-0-0, C: control, x: 10 t ha^{-1}.

Treatment	Dry weight				Number of weeds			
	37DAS		67DAS		37DAS		67DAS	
	2005	2006	2005	2006	2005	2006	2005	2006
PM x/2	2.10	2.65	20.40	3.65	48	60	93	20
PM x	6.07	3.41	25.77	4.77	104	70	99	22
PM 2x	10.52	4.4	31.45	6.33	140	80	110	27
CM x/2	5.33	9.21	25.8	2.72	170	56	87	12
CM x	7.25	2.34	31.62	3.10	188	54	95	14
CM 2x	10.42	2.78	46.00	3.78	240	44	125	16
B x/2	1.13	0.77	16.42	5.19	64	32	80	35
B x	2.32	3.92	22.25	7.29	84	120	100	40
B 2x	3.10	4.65	31.00	11.12	110	132	120	50
F	5.35	3.30	61.00	5.93	96	75	165	20
C	3.30	1.55	16.25	3.15	120	70	84	22
LSD$_{5\%}$	0.41	0.17	1.53	0.34	8.04	7.43	4.90	3.10

Notes: The LSD (P=0.05) for fertilization treatments are shown.

Table 4. The effect of organic amendments and fertilizer on *Polygonum aviculare* dry weight (g m^{-2}) and density (weeds m^{-2}), 37 and 67 days after sowing (DAS). PM: Poultry manure, CM: cow manure, B: barley mulch, F: fertilizer 21-0-0, C: control, x: 10 t ha^{-1}.

Treatment	Dry weight				Number of weeds			
	37DAS		67DAS		37DAS		67DAS	
	2005	2006	2005	2006	2005	2006	2005	2006
PM x/2	4.93	2.81	13.66	6.59	164	128	78	45
PM x	4.16	3.01	12.76	7.19	160	126	77	46
PM 2x	3.07	3.48	12.55	8.25	138	130	80	49
CM x/2	4.13	2.78	12.56	5.76	159	109	70	34
CM x	4.85	3.11	13.06	6.5	172	118	72	40
CM 2x	6.22	3.81	16.57	8.5	189	123	82	46
B x/2	0.19	0.43	0.92	1.62	14	24	18	18
B x	0.17	0.37	0.69	1.65	16	20	15	18
B 2x	0.15	0.39	0.53	1.85	18	19	12	16
F	5.14	3.84	16.81	7.9	169	133	89	44
C	4.47	3.04	10.56	6.21	154	125	75	46
LSD$_{5\%}$	0.27	0.17	1.16	0.34	8.16	6.93	3.69	1.64

Notes: The LSD (P=0.05) for fertilization treatments are shown.

For the weed *S. viridis*, at first assessment, in 2005, the control and the double cow manure treatment had the greatest density (P<0.05). The double rate barley plot had the lowest density (18 weeds m^{-2}) (Table 5). In 2006, 37

DAS, the fertilizer treatment gave the highest density (46 weeds m^{-2}), whereas the full poultry manure treatment gave the lowest (P<0.05).

Table 5. The effect of organic amendments and fertilizer on *Setaria viridis* dry weight (g m^{-2}) and density (weeds m^{-2}), 37 and 67 days after sowing (DAS). PM: Poultry manure, CM: cow manure, B: barley mulch, F: fertilizer 21-0-0, C: control, x: 10 t ha^{-1}.

Treatment	Dry weight				Number of weeds			
	37DAS		67DAS		37DAS		67DAS	
	2005	2006	2005	2006	2005	2006	2005	2006
PM x/2	0.32	0.23	1.37	0.82	23	19	30	26
PM x	0.31	0.27	1.31	0.83	23	23	29	19
PM 2x	0.30	0.33	1.67	0.99	25	26	31	21
CM x/2	0.26	0.31	1.63	1.43	21	31	23	23
CM x	0.41	0.42	2.37	1.50	25	31	30	23
CM 2x	0.65	0.56	3.27	2.01	31	34	39	26
B x/2	0.25	0.41	1.84	0.78	26	32	38	30
B x	0.23	0.36	1.65	1.02	22	26	40	33
B 2x	0.20	0.50	1.75	1.35	18	30	45	38
F	0.46	0.55	3.86	2.19	27	46	43	29
C	0.29	0.25	1.16	0.6	33	35	38	24
LSD$_{5\%}$	0.07	0.14	0.11	0.07	2.51	3.57	3.76	3.09

Notes: The LSD (P=0.05) for fertilization treatments are shown.

Final, for the weed *E. elaterium*, at the first measurement, in 2005, the highest density was recorded in the plots treated with double rate barley amendment and double rate cow manure (P<0.05), whereas the lowest was in the half rate poultry manure plots (Table 6). At 67 DAS, the greatest densities (P<0.05) were found in plots treated with all rates of barley mulch and the lowest in plots treated with all rates of poultry manure. In 2006, at 37 DAS, the density of *E. elaterium* was greater at all three rates of cow manure (26-30 weeds m^{-2}) and lower at all rates of poultry manure (9-11 weeds m^{-2}) and for the untreated control (11 weeds m^{-2} and 0.54 g m^{-2}). Densities of *E. elaterium* were intermediate for barley mulch treatments, comparable to the half rate cow manure plots (P<0.05). At 67 DAS, *E. elaterium* density remained high in the three barley mulch plots, but was lower at all rates of cow manure application.

Table 6. The effect of organic amendments and fertilizer on *Ecballium elaterium* dry weight (g m^{-2}) and density (weeds m^{-2}), 37 and 67 days after sowing (DAS). PM: Poultry manure, CM: cow manure, B: barley mulch, F: fertilizer 21-0-0, C: control, x: 10 t ha^{-1}.

Treatment	Dry weight				Number of weeds			
	37DAS		67DAS		37DAS		67DAS	
	2005	2006	2005	2006	2005	2006	2005	2006
PM x/2	1.20	0.56	9.22	2.10	22	9	10	13
PM x	1.28	0.64	6.67	2.19	26	10	9	13
PM 2x	1.32	0.69	9.82	2.52	31	11	13	14
CM x/2	1.83	1.62	31.20	3.67	30	26	34	18
CM x	2.02	2.04	35.00	3.90	34	28	33	17
CM 2x	5.00	2.31	42.50	4.80	46	30	35	16
B x/2	1.96	1.25	28.85	4.53	36	25	42	25
B x	1.93	1.35	30.60	5.31	38	24	42	27
B 2x	2.02	1.63	35.00	5.71	48	26	43	26
F	2.35	0.72	24.82	2.23	28	14	21	11
C	1.70	0.54	9.92	1.46	22	11	15	9
LSD$_{5\%}$	0.18	0.07	1.69	0.34	4.2	1.63	2.71	1.46

Notes: The LSD (P=0.05) for fertilization treatments are shown.

Weed biomass

The lowest total dry weight (5.99 g m^{-2}) of weeds was recorded with barley treatments (Table 1). In 2005, the highest biomass was recorded in the plots treated with double rate cow manure and inorganic fertilizer. In 2006, the biomass of weeds was highest ($P<0.05$) for fertilizer (240 kg N ha^{-1}) and cow manure treatments (60-240 kgN ha^{-1}). The double rate poultry (120 kg N ha^{-1}) and cow manure (240 Kg N ha^{-1}) treatments had higher biomass in comparison to the half rates (nitrogen content of poultry and cow manure was 40 and 60 kg N ha^{-1}, respectively).

For the weed *A. retroflexus,* at the first measurement, in 2005, the lowest dry weight was recorded for barley amendments, as well as the double rate of poultry manure ($P<0.05$). The highest dry weight (118.5 g m^{-2}) was recorded in the plots treated with double rate cow manure (240 kg N ha^{-1}) at 67 DAS. In 2006, the suppressive effect of barley mulch and poultry manure (all rates) was much less evident (Table 2).

In 2005, at both assessments (37 and 67 DAS), dry weight of *P. oleracea* was proportional to the application rate of amendments ($P<0.05$). The lowest dry weight (1.13-3.10 g m^{-2}) was recorded with barley treatments (Table 3). In 2006, 37 DAS, the double barley rate gave the highest biomass of *P. oleracea*, while the half rate gave the lowest. The biomass of *P. oleracea* was highest ($P<0.05$) 67 DAS for all barley mulch treatments.

The double rate poultry (120 kg N ha^{-1}) and cow manure (240 kg N ha^{-1}) treatments had higher biomass in comparison to the half rates.

For the weed *P. aviculare*, in the first year, the plots treated with barley mulch gave lower biomass (0.15-0.19 g m^{-2}) than the other treatments (Table 4). In 2006, at both assessments, the lowest biomass of *P. aviculare* was associated with barley mulch (all rates) (P<0.05), and values were much lower than even the control plot. At both assessments, all rates of poultry manure and cow manure resulted in higher values than the barley mulch treatments.

Also, for the weed *S. viridis,* at first assessment, in 2005, the control and the double cow manure (240 kg N ha^{-1}) treatment had the greatest biomass (P<0.05). The double rate barley plot had the lowest biomass (0.20 g m^{-2}) (Table 5). In 2006, barley mulch gave low biomass of *S. viridis* at 37 DAS, while at 67 DAS, the highest biomass was recorded in the plots treated with fertilizer.

Finally, for the weed *E. elaterium*, at 37 DAS, in 2005 the highest biomass was recorded in the plots treated with double rate barley amendment and double rate cow manure (P<0.05), whereas the lowest was in the half rate poultry manure plots (Table 6). In 2006, at 37 DAS, the biomass of *E. elaterium* was greater at all three rates of cow manure (1.62-2.31 g m^{-2}) and lower at all rates of poultry manure (0.56-0.69 g m^{-2}) and for the untreated control (0.54 g m^{-2}).

Weed community

At both measurements, the barley mulch plot presented the highest values of Shannon-Weiner (H) and Simpson indices (D) (Figure 2). At 37 DAS, the double rate barley mulch plot presented the highest values of both indices (H=4.83 and D=1.87). At the second measurement, the half rate barley mulch plot presented the highest (H=5.67 and D=1.88).

Sweet maize growth and yield

In 2005, the control plot had the lowest yield and dry weight (Table 7) and the double rate cow manure (240 kg N ha^{-1}) plot the greatest (P<0.05) followed by the fertilizer treatment. As the amount of cow manure (nitrogen availability) increased, yield also increased. In addition, as the amount of poultry manure and barley mulch increased, yield decreased. In 2006, yields were reduced in comparison to the previous year when organic and inorganic fertilizers were used. The control had the lowest yield (P<0.05).

Differences of the fertilizers (organic and inorganic) in nitrogen availability had a large effect on maize growth and yield; as the amount of poultry manure, cow manure and barley mulch increased, yield also increased.
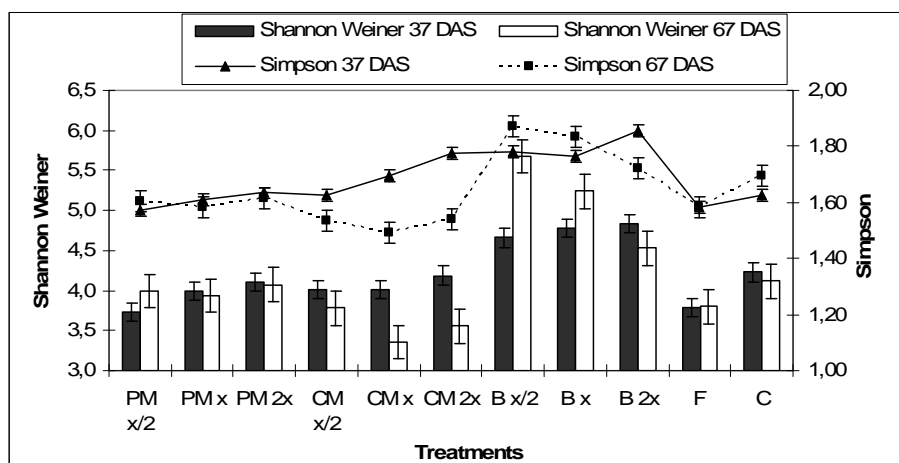

Figure 2. The effect of organic amendments and fertilizer on values of Shannon Weiner and Simpson indices, 37 and 67 days after sowing (DAS). PM: Poultry manure, CM: cow manure, B: barley mulch, F: fertilizer 21-0-0, C: control, x: 10 t ha^{-1} (error bars indicate the LSD$_{5\%}$, data are mean values of 2005 and 2006).

Table 7. The effect of organic amendments and fertilizer on sweet maize dry weight (g/plant) and yield (g/plant), 81 days after sowing (DAS). PM: manure, CM: cow manure, B: barley mulch, F: fertilizer 21-0-0, C: control, x: 10 t ha^{-1}.

Treatment	81 DAS			
	Dry weight		Yield	
	2005	2006	2005	2006
PM x/2	126.80	99.00	57.48	28.22
PM x	129.00	105.80	55.09	30.77
PM 2x	104.29	116.01	51.23	34.60
CM x/2	140.30	111.80	51.56	32.06
CM x	147.49	123.49	60.11	37.03
CM 2x	162.80	148.80	78.13	47.42
B x/2	102.50	107.00	39.22	29.40
B x	97.50	113.00	38.37	33.36
B 2x	87.50	135.50	30.78	40.99
F	147.49	110.30	70.18	30.75
C	81.00	83.25	26.96	20.39
LSD$_{5\%}$	5.47	5.45	1.71	0.95

Notes: The LSD (P=0.05) for fertilization treatments are shown.

Discussion

The highest number and dry weight of weeds were recorded for double cow manure and chemical fertilizer treatments. In a previous study (Efthimiadou et al., 2009), it was shown that sweet maize growth and yield in cow manure plots was significantly higher than those in conventional plots. The cow manure treatments promoted sweet maize and weed growth in direct proportion to the rate of application (x/2<x<2x). The highest weed densities were recorded in the synthetic fertilizer (240 kg ha^{-1}) and double cow manure (240 kg ha^{-1}) plots (Table 1). Therefore, weed seed immigration from manure was not important.

Weeds respond differentially to nitrogen. Differences of the fertilizers (organic and inorganic) in nitrogen availability had a large effect on weed density and biomass. Biomass of weeds was highest ($P<0.05$) for fertilizer (240 kg N ha^{-1}) and double cow manure treatment (240 kg N ha^{-1}). The double rate poultry (120 kg N ha^{-1}) and cow manure (240 kg N ha^{-1}) treatments produced higher biomass in comparison to the half rates (nitrogen content of poultry and cow manure was 40 and 60 kg N ha^{-1}, respectively).

Moreover, split application or controlled release of nitrogen may be a useful practice for managing weeds in sweet maize. Early-season soil N levels are kept intentionally low because sweet maize demand for N at this time is minimal. Several lines of research suggest that low early-season levels of nitrogen can result in selective weed suppression (Liebman and Davis, 2000). Farming systems that minimize nutrient availability early in the growing season should limit the growth of small-seeded weeds without compromising the growth or yield of larger-seeded, better-provisioned crops. Previous studies of the effect of delayed nutrient availability on weed crop competition have both corroborated (Angonin et al., 1996) and contradicted (Ball et al., 1996) this hypothesis.

Poultry manure amendments can also reduce the weed density, but not as effectively as barley mulch. It has been reported that use of chicken manure can be an effective weed management practice for weed control (Haidar and Sidahmed, 2000; Haidar and Sidahmed, 2006). Amanullah et al. (2006) have also reported that among organic manures, the least weed dry matter was recorded for poultry manure followed by composted poultry manure (poultry manure and chopped sorghum straw).

According to Davis and Liebman (2001), weed growth is suppressed by use of organic nitrogen sources compared to treatment with inorganic nitrogen. Dyck and Liebman (1994) addressed the issue of whether delayed N availability from organic N sources contributed to weed suppression. In addition, Blackshaw et al. (2005) observed that the gradual N release from manure and compost with time appeared to benefit weeds more than winter wheat.

The presence of barley residues clearly reduced weed number. The suppressive effect of barley mulch is evident at almost all rates, reducing weed density to less than that of the control. There is a probable allelopathetic effect of barley residues on weeds (Perez, 1989). Maine, Dyck and Liebman (1994) found that time to 50% emergence of common lambsquarters (*Chenopodium album* L.) was delayed 3.4 days in the presence of plant residue. Moreover, Ohno et al. (2000) by means of bioassays found that inhibition of weed seedling growth in soil amended with residues was due to phytotoxic effects of the residues. Delayed emergence of *Amaranthus* spp. due to residue presence has been reported elsewhere (Mohler and Callaway, 1995; Moore et al., 1994).

In the presence of barley residues, weed biomass or density was reduced for the following species: redroot pigweed (*A. retroflexus*), Common purslane (*P. oleracea*) and prostrate knotweed (*P. aviculare*). Cereal and barley plants have been reported to acquire allelopathic potential that affects the growth of other species (Brecke and Shilling, 1996; Purvis et al., 1998; Putman and DeFrank, 1983). Vasilakoglou et al. (2006) have also reported that cereal (barley, rye and triticale) mulches incorporated into the soil have the ability to suppress germination of weed seeds.

The weed-suppressive effect of barley residues decreased with time following residue decomposition. Xuan et al. (2005) reported that alfalfa (*Medicago sativa* L.) and kava (*Piper methysticum* L.) strongly inhibited barnyard grass growth for up to 10 days (80-100% weed control). After 20-25 days, the magnitude of inhibition was drastically reduced, but was still effective (50% weed control). Also, Karkanis et al. (2010) observed that red clover strongly inhibited germination and growth of barnyard grass but only at 35 days after transplanting of tobacco.

Finally, the diversity indices proposed by Shannon-Weiner and Simpson were found to be useful in assessing the shift in the weed population caused by changes in cultural practices. Both indices are increased either by having additional unique species, or by having greater species evenness (Booth

et al., 2003). The highest values were recorded in plots with barley treatment, hence weed flora in barley-treated plots had high species evenness because barley controlled the weeds (*A. retroflexus*, *P. oleracea*, *P. aviculare*) which had the highest density in other treatments.

Conclusions

Weed management is a major constraint in organic production. Our study indicated that the cow manure treatments promoted weed and sweet maize growth in proportion to the rate of application ($x/2 < x < 2x$). Regarding organic agriculture practice, green manure of barley mulch can affect weed emergence and growth. In the presence of barley residues, weed biomass or density was reduced for the following species: *Amaranthus retroflexus*, *Portulaca oleracea* and *Polygonum aviculare*. The barley mulch plot presented the highest values of Shannon-Weiner and Simpson indices. Moreover, the weed-suppressive effect of barley residues decreased with time following residue decomposition. Finally, our study indicated that green manure of barley can be used for the suppression of some weeds in sweet maize.

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