International Journal of Plant & Soil Science
3(9): 1044-1054, 2014; Article no. IJPSS.2014.9.002

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Effect of Organic Manure on Soil Bio-physical Properties and Dry Matter Partitioning in Cauliflower

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Authors' contributions

This work was carried out in collaboration between all authors. Author AAB contributed in designing and conducting the experiment. Authors PEN and ARC contributed in designing, statistical analysis and report writing. Authors JCS and EAL contributed in designing, monitoring the experiment. All authors read and approved the final manuscript.

Original Research Article

Received 18th April 2014
Accepted 23rd May 2014
Published 12th June 2014

ABSTRACT

Aims: The main aim of the study was to assess the influence of organic fertilizers on selected soil bio-physical properties and dry matter partitioning in cauliflower.
Methodology: A field experiment was conducted at Wageningen University Experimental Site, Netherlands during 2012 cropping season. The experiment was laid in a Randomized Complete Block Design (RCBD) with four replications. The treatments included N-source (dried grass clover (DGC) and lucerne pellets (LUP)) and N application rate (0, 75, 150 and 225 kg $N.ha^{-1}$). Data analysis included soil structure (% granular), soil pores, earthworm population, weight and activities and crop residues. Growth (plant height and diameter) and dry matter partitioning in leaves, stems and heads were also assessed.
Results: Cauliflower amended with 150kg $N.ha^{-1}$ LUP and 225kg $N.ha^{-1}$ DGC had highest numbers of large (≥500mg) earthworms, while the non-amended plot (control) exhibited the lowest earthworm population. Percentage granular, organic residue and earthworm activities increased with increasing organic application. The LUP manure supported

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earlier and higher earthworm activities, which promoted good soil structure formation, plant growth and development. Generally, LUP-amended plants produced taller plants, larger stem diameter and higher dry matter partitioning in leaf and head organs than DGC- amended plants.

Conclusion: The results implied that organic fertilizers with low C/N ratio promote early micro-organism activities with consequent early good vegetative growth and yield. Earthworm activities influence soil fertility in ways that may be of great importance to sustainable land use in naturally degraded ecosystems as well as agro-ecosystems. Findings suggest use of proper land use management practices that promote earthworm activities and sustain crop yields. Future studies will consider comprehensive cost benefit analysis to compare the economic advantages of LUP over DGC.

Keywords: Organic fertilizers; bio-physical properties; earthworms; cauliflower; dry matter.

1. INTRODUCTION

Soil is the store house of plant nutrients and the natural organic medium for micro-organisms [1,2]. The decomposition of organic manure improves soil physical properties and provides food to support microbial activities in the soil [3].

Organic manures are soil amendments derived from natural sources used to supply minimum percentages of nitrogen, phosphate and potash to support plant growth [4]. Legume-based organic manures are incorporated into soil to provide nitrogen and substantial amounts of other nutrients including carbon (C) [5]. Several studies have shown that using organic fertilizers with high nutrient concentration and low C/N ratio as supplementary fertilizer considerably increased yield in vegetable production systems [6-9]. At neutral pH, nitrogen released from green manure was observed within 3 or 6 weeks after incorporation [10].

Besides soils that are inherently fertile, low population of earthworms in soils is often indicative of little organic residues, low soil moisture and high soil temperature [11]. Several authors have reported the many significant roles played by earthworms in boosting soil fertility that enhances increased crop productivity [11,12]. Some of these roles include decomposition of plant residue, nutrient cycling and redistribution in the soil profile; production of binding agents responsible for the formation of water-stable macro-aggregates; modification of soil physical structure by producing new aggregates and pores that improves soil tilth, aeration, infiltration, drainage and root development. Earthworm casts contribute to building soil physical structure and replenishing it with major plant nutrients such as nitrogen, phosphorus, potassium and calcium [11,12].

Dry matter partitioning is an outcome of the flow of assimilates from source organs through a transport pathway to the sink organs [13]. Dry matter partitioning in various plant organs is influenced by the growing environment, growth and development of plants [14]. Precise information on dry matter partitioning in relation to growth and development is imperative in modeling crop growth and yield. The total dry matter accumulated during photosynthesis is partitioned into different plant organs based on the needs of the various developmental stages of the plant species [14]. Such knowledge has not been thoroughly investigated in cauliflower. The aim of this study was therefore to investigate the effect of organic fertilizers on soil bio-physical properties and dry matter partitioning in cauliflower. The specific objective of the study was to compare the effects of the type and rate of two organic manures on soil physical and biological properties and dry matter partitioning in cauliflower.

2. MATERIALS AND METHODS

2.1 Experimental Site

A field experiment was conducted at the Droevendaal Certified Organic Research and Demonstration Site of Wageningen University, Netherlands, to evaluate the effect of organic manure on soil bio-physical properties and dry matter partitioning in Cauliflower during 2012. The mean annual temperature and precipitation of the study area were 11°C and 829 mm, respectively.

2.2 Treatments, Design and Cultural Practices

A total of eight treatments consisting of dried grass clover (DGC) applied at four rates (0, 75, 150 and 225 kg $N.ha^{-1}$) were compared with the same rates of Lucerne pellets (LUP). The grass clover was dried for two days before application. Cauliflower variety, *botrytis*, was used. The experiment was laid in a Randomized Complete Block Design (RCBD) with four replications. A plot size of 3 x 3 m was used. The soil amendments were applied one day before transplanting at 50 x 60 cm apart giving a density of 30 plants per plot (33,333 plants ha^{-1}). Cauliflower seedlings were transplanted in last week of June 2012. Weeding was done manually by hoeing when necessary.

2.3 Data Collection

Soil biological properties were investigated by determining the number and size of earthworms. At harvest, soil was demarcated using plastic markers, followed by excavation of profile pit for the assessment of soil structure using hand trowel as described by ISRIC/FAO, 2005 [15] (Fig. 1). The profile pit measuring 20 x 20 x 30 cm was dug from the experimental units of each plot. The biological data collected and procedure used were based on those described by Houšková with slight modifications as below [16]: Earthworms collected were first rinsed, blotted and grouped into two categories including small-medium sized (< 500 mg) and large sized ($\geq$500mg) using a sensitive scale before counting. The number of each earthworm category was counted and their activities at the different soil layers (i.e. 0-5 cm and 5-30 cm) recorded. Two profile pits per plot were also dug to visually assess the soil structure and amount of N source residues. Earthworm activity, manure residue and soil pores were assessed using a 0-5 scale (Table 1).

In each experimental unit, six plants were randomly selected and tagged for agronomic data collection. Data collected included plant height, Head diameter and yield of various organs (leaf, stem and head). Dry matter was determined by oven-drying plant parts at 75-80ºC for 72h. Total N in plants was measured after wet digestion by concentrated H_2SO_4 and addition of mixed catalyst at 420ºC in a KJELTEC 1030 auto-analyzer using standard procedures [17]. Nutrient uptake by cauliflower grown in the two organic fertilizers has been published in previous work [18].

Table 1. Soil bio-physical traits measured using the 0-5 scale

Trait	Score code
Earthworm activity	0=no holes, 1=very few (1-3), 2=few (3-6), 3=some (6-10), 4=many (10-20), 5=very many (>20)
Manure residue	0=none, 1=very little (<1%), 2=little (1-5%), 3=some (5-10%), 4=a lot (10-20%), 5=abundant (>20%)
Soil pores	0=none, 1=few and small (<5%), 2=few small and medium (5-10%), 3=some small and medium (10-25%), 4=many small and medium (25-50%), 5=many medium and large (>50%)

Fig. 1. Photos showing (a) demarcating soil excavated space (b) assessing soil structure (c) counting of earthworms (d) weighing of earthworms

2.4 Data Analysis

Data were subjected to analysis of variance (ANOVA) using the GENSTAT statistical programme (GENSTAT, 15th release, Rothampstead, UK). Mean separation was done using the Duncan's Multiple Range Test (DMRT). The residuals of data for the parameters used were first checked for normality and homogeneity using the Shapiro-Wilk test and Bartlett's test to ensure that data were normally distributed.

3 RESULTS AND DISCUSSION

3.1 Soil Analysis

The initial composition of the soil is shown in Table 2.

Table 2. Soil characteristics before planting

Characters	0-30 cm soil depth	30-60 cm soil depth
N tot (%)	0.10	*
N-min (kg ha^{-1})	48.0	32.0
pH (1 M KCl)	5.40	5.60
Bulk density (kg dm^{-1})	1.45	1.50
SOM (%)	1.80	*

**=not determined, N tot=total nitrogen, N-min=nitrogen mineralization, SOM=soil organic matter*

3.2 Plant Analysis

The LUP manure had higher dry matter and total N than DGC (Table 3). Dried grass clover exhibited longer decomposition time and higher C/N ratio compared to LUP). The P_2O_5 and K_2O contents were higher in DGC than in LUP.

Table 3. Mean dry matter (DM) content and chemical composition of plant-based fertilizers

Plant-based manures	DM (%)	C/N[1]	N_{tot} (%)	P_2O_5 (%)	K_2O (%)
Dried grass-clover	55.6	23.2	1.9	0.4	2.4
Lucerne pellet	90.9	18.3	2.4	0.3	2.1

[1]C/N ratio are based on a carbon content of 44%

3.3 Earth Worm Assessment

Earthworm number and activity increased with increasing organic manure application rate (Figs. 2A and B; Table 4). Cauliflower amended with 150 kg $N.ha^{-1}$ LUP and 225 kg $N.ha^{-1}$ DGC had highest numbers of large ($\geq$500 mg) earthworms, whereas the non-amended plot (control) had the lowest number of earthworms. Large earthworm population in LUP plots decreased at 225 kg $N.ha^{-1}$, whereas population of small (<500 mg) earthworms in LUP plots was similar at 150 and 225 kg $N.ha^{-1}$ rates. For DGC plots, the highest small earthworm population was obtained at 225 kg $N.ha^{-1}$ rate. The lower numbers of earthworms in DGC plots compared to LUP may be related to the dryness and slow decomposition of DGC. The low C/N ratio of LUP accelerated its decomposition rate which resulted in an increase in earthworm number. The lowest numbers and activities of earthworms in the control plots were indicative of poor finely decomposed organic matter content in the soil that promotes soil microbial activities.

Earthworm activity was assessed at harvest. Generally, earth worm activity decreased with soil depth. The control plot exhibited the lowest activity at both soil depths (i.e. 0-5 and 5-30 cm) compared to the organic amended plots. For LUP amended plots, earthworm activity ranged between very few and few compared to DGC amended plots. The results indicate that the early decomposition of LUP by earthworms and other soil microbes led to reduced activity at harvest. The percent soil pores created by earthworm activities followed similar trends with no significant difference between LUP and DGC amended plots. These findings were consistent with those obtained by other researchers, who observed that the presence and activity of earth worms are good indicators of soil quality [19,20]. Similarly, an increasing number and activities of earthworms were noted in soils with low C/N ratio [21]. Soils with earthworms have higher percent soil macro pores, creating balance between water- and air-filled pores, consequently favoring increased root growth, microbial activity and soil aggregate stability [22]. The activity of earthworms accelerated initial soil organic matter decomposition through indirect effects on soil carbon as determinants of microbial activity. The lower activities of earthworm in LUP plots at harvest implied that most of the organic matter had been decomposed at the early stages of growth, compared to the slow decomposing DGC.

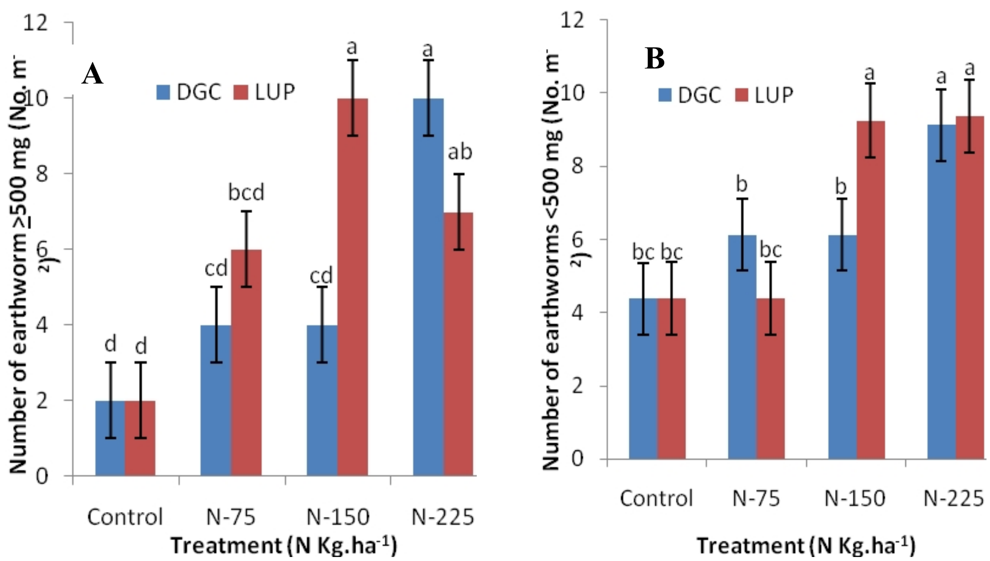

Fig. 2. Effects of plant amendments and rates on population of earthworms. Means with similar letters are not significantly different according to DMRT (α=0.05)

Table 4. Effects of plant amendments and rates on earthworm activities and soil pores

N rate (kg.ha^{-1})	Earthworm activity***				Soil pores**			
	0-5 cm		5-30 cm		0-5 cm		5-30 cm	
	DGC	LUP	DGC	LUP	DGC	LUP	DGC	LUP
0	0.8^{c}	0.8^{c}	0.0^{c}	0.0^{c}	1.00^{b}	1.00^{b}	0.25^{b}	0.25^{b}
75	2.3^{ab}	1.3^{bc}	0.8^{b}	0.0^{c}	2.25^{a}	2.00^{a}	1.25^{a}	1.00^{a}
150	2.5^{ab}	1.3^{bc}	1.0^{ab}	0.8^{b}	2.25^{a}	2.00^{a}	1.25^{a}	1.00^{a}
225	3.5^{a}	2.8^{a}	2.0^{a}	1.0^{ab}	2.25^{a}	2.00^{a}	1.25^{a}	1.00^{a}
Mean	1.9		0.7		1.84		0.91	
CV(%)	10.9		10.5		16.0		13.2	

*Means with the same letters are not significantly different (P<0.05 DMRT); ***=significant at 0.001; **=significant at 0.01*

3.4 Soil Structure Assessment

Soil structure and manure residue were significantly (*P*<.05) influenced by N source, N rates and soil depth (Table 5). At 0-5cm soil depth, LUP amended plots produced highest % granular at all application rates compared to DGC and control. However, DGC amended plots exhibited higher % granular than LUP at the 5-30 cm soil depth. For both LUP and DGC, the % granular increased as application rate increased. The findings implied that the higher % granular of LUP at the 0-5cm soil depth was possibly due to its faster decomposition compared to DGC. Thus, the apparent increasing % granular of LUP amended plots was indicative of the increased soil organic matter. It also implied that earthworm activities enhanced mineralization by fragmenting soil organic matter, and mixing it with mineral particles and microorganisms, thereby creating new surfaces of contact between soil organic matter and microorganisms. Dried grass clover plots exhibited significantly higher manure residues compared to LUP probably due to its higher C/N ratio and larger particle size.

Table 5. Effects of plant amendments and rates on soil structure and manure residue

N rate ($kg.ha^{-1}$)	Soil structure (% granular)***				Manure residue***	
	0-5cm		5-30cm		0-5cm	
	DGC	LUP	DGC	LUP	DGC	LUP
0	5.8^f	5.8^f	0.0^c	0.0^c	0.0^c	0.0^c
75	10.5^e	15.0^d	9.5^a	8.8^a	1.3^b	0.0^c
150	16.3^{cd}	20.0^b	10.0^a	8.8^a	2.0^a	0.0^c
225	17.3^c	25.0^a	10.0^a	5.0^b	2.8^a	1.0^b
Mean	14.3		6.5		0.9	
CV (%)	7.9		6.8		16.5	

*Means with the same letters are not significantly different (P<0.05 DMRT); ***=significant at 0.001*

Lucerne pellet application at 75 and $150kg.ha^{-1}$ had no residue left at harvest similar with the control plot at the 0-5cm soil debt; whilst application at $225kg.ha^{-1}$ exhibited very little residue as DGC application at $75kg.ha^{-1}$. However, DGC application at 150 and $225kg.ha^{-1}$ had little and some residues left, respectively. Earthworms were also reported to significantly contribute to good soil-structure formation [23]. The type of agricultural practices may negatively or positively influence soil organic matter content, soil biota and soil structure [24]. In this study, earthworm activities played crucial role in improving and maintaining soil fertility, soil structure and aggregate stability, which to a greater extent depends on their population in the soil.

3.5 Plant Height and Diameter

Generally, plant height and diameter increased as sampling regime progressed from 3-10 WAT (Figs. 3A and 3B). Lucerne pellets significantly exhibited tallest and biggest plant height and diameter during all sampling regimes followed by DGC and control plots. The increased growth in LUP amended plants could be explained by its early decomposition by higher population of earthworms, which contributed to higher initial N-mobilization and lower C/N ratio compared to DGC-amended plots. Results are consistent with findings by other colleagues that nitrogen is the most critical plant nutrient that limits crop growth [25]. Additionally, they noted that optimum nitrogen rate is not constant for a specific crop or field, but can vary from one cultivar to another, site to site and from year to year. In this study, it appeared that DGC could not supply enough initial nitrogen required for early growth.

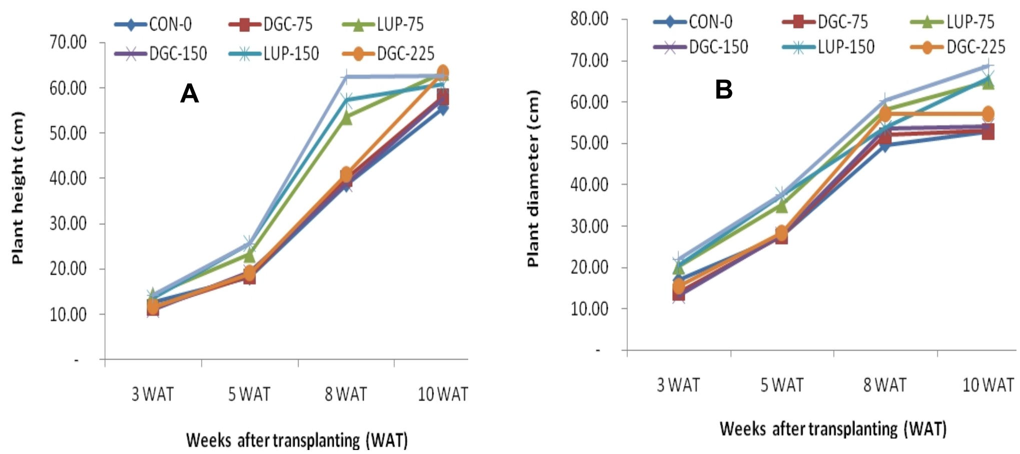

Fig. 3. Effect of N source and rate on (a) plant height and (b) plant diameter of botrytis at various sampling regimes

Generally, plants with organic amendments had higher dry matter partitioning in plant organs compared with the non-amended plots (Table 6). Plants amended with LUP had higher dry matter partitioned in leaf and head organs than DGC plants. However, DGC plants exhibited higher dry matter partitioning in stem organ than LUP amended plants. The dry head yields of LUP mended plants significantly out-yielded DGC at 150 and 225kg $N.ha^{-1}$ rates, while the control had the lowest. For LUP and DGC, highest dry head yields of 8.305 $t.ha^{-1}$ and 7.285 $t.ha^{-1}$, respectively, were obtained at 225 $kgN.ha^{-1}$.

Table 6. Effects of plant amendments and rates on dry matter yield ($t.ha^{-1}$) of leaves, stems and heads of cauliflower

N rate ($kg.ha^{-1}$)	Leaf dry yield ($t.ha^{-1}$)***		Stem dry yield ($t.ha^{-1}$)***		Head dry yield ($t.ha^{-1}$)***	
	DGC	LUP	DGC	LUP	DGC	LUP
0	2.817^{e}	2.817^{e}	0.317^{c}	0.317^{c}	4.405^{d}	4.405^{d}
75	3.720^{d}	3.879^{cd}	0.580^{ab}	0.507^{b}	6.773^{c}	6.878^{c}
150	4.299^{abc}	4.605^{ab}	0.650^{a}	0.496^{b}	7.257^{bc}	7.865^{ab}
225	4.240^{bc}	4.697^{a}	0.660^{a}	0.505^{b}	7.285^{bc}	8.305^{a}
Mean	3.884		0.504		6.966	
CV (%)	7.1		14.0		7.0	

*Means with the same letters are not significantly different (P<0.05 DMRT); ***=significant at 0.001*

The high dry matter accumulation observed in leaf and head organs of LUP amended cauliflower could be related to the early higher N mobilization and plant growth parameters, which may have increased both light interception and overall assimilates production. Results agree with other researchers, who noted that dry matter yield increased as N rate increased [26,27]. It appeared, therefore, that soils with higher number and activities of earthworms, contribute immensely in boosting soil fertility, and consequently, enhancing increased dry matter production and partitioning in cauliflower.

4. CONCLUSION

The influence of organic matter on soil bio-physical properties depends on the type and rates of organic manure used. Plant organic manure with low C/N ratio promotes early soil micro-organism activities with consequent early good vegetative growth and yield. Findings could serve as guide to farmers in the selection of organic manure with lower C/N ratio. It is also useful for future investigation of the biology and ecology of earthworms and in devising good management strategies that may impact soil biota and crop performance.

ACKNOWLEDGEMENTS

The authors appreciate Paul Speijer and the Anne van den Band Foundations for their financial support, and the Farming Systems Ecology of the Wageningen University, Netherlands for their technical support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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