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Performance of *Clitoria* grown in stressed environment as affected by compost of organic and inorganic nutrients

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Abstract: Arid lands characterized by harsh environments viz. high temperature, limited water, salinity and all adverse conditions for plant production. The excessive use of chemical fertilizers aggravated the problem. The study was conducted in an arid saline soil near City of Jeddah, western Saudi Arabia. The objective of this research was to look into composted manure as organic fertilizers as well as soil amendment and nutrients supplier in such stressed environment. The treatments consisted of farmyard manure and chicken manures applied separately and in combination with each other, in addition to NPK and a control for comparison purposes. Test crop was *Clitoria ternate* (leguminous forage). Treatments consisted of a composted chicken and cow manures applied separately and in combination plus NPK fertilizer and a control laid in a randomized complete block design. Composted organic fertilizers (poultry and cow manures) are more effective in increasing nodulation, productivity and improving forage quality of *C. ternate* L. than inorganic fertilizer (NPK) under adverse conditions of salinity in arid lands. Poultry manure increased forage fresh and dry productivity over the control by 145 and 137%, respectively and the differences were significant ($p \leq 0.05$). Composted organic fertilizers increased nodulation, yield and quality of *C. ternate* Compared to inorganic (NPK) fertilizers in an arid saline environment.

Subjects: Environment & Agriculture; Bioscience; Food Science & Technology

Keywords: bio fertilizers; *Clitoria ternate*; inorganic fertilizers; leguminous forages; salinity; seed pelleting

ABOUT THE AUTHOR

Awad Osman Abusuwar is a PhD holder from the University of Arizona in 1986. His Major is Agronomy and plant genetics and minor in range and forage production. He joined the University of Khartoum (Sudan) in late 1986 as staff member in the department of Agronomy, Faculty of Agriculture and continued there till 2009. In 2009 he joined King Abdulaziz University (KSA) till now as a professor in the arid land agriculture department. His research interest focuses on utilization of arid and desertified lands in range and forage production via use of wise cultural practices and selection of adapted species to such lands. His current paper touches this area of interest.

PUBLIC INTEREST STATEMENT

World population is increasing rapidly with many areas suffering food and feed shortages around the world. The wise use of different cultural practices and techniques aiming sustainability of plant production to face this problem necessitates looking into wise and effective ways to utilize to utilize vast arid areas and desertified lands to return them back into production. Excessive use of inorganic fertilizers to such soils created pollution of underground water , increased salinity and encourage desertification process. This research paper looked into using of organic manures (cow and poultry manures) as an alternative fertilizer and soil improvement in such areas.

1. Introduction

Arid lands characterized with fragile ecosystems, low land productivity, limited good quality irrigation water and non-sustainable farming systems. The soil is definitive in the earth system as it controls hydrological, erosional, biological and geochemical cycles (Keesstra et al., 2012; Mol & Keesstra, 2012) and also they are definitive for the supply of food, feed, fiber, services and resources to mankind (Brevik et al., 2015) especially in a world facing explosives in population and spreading hunger. This is why the United Nations goals for sustainability pay attention to soils (Keesstra et al., 2016).

The Kingdom of Saudi Arabia entirely lies within arid land with an annual rainfall below 100 mm/annum. This limited rainfall coupled with high evaporation so the cultivable pockets in valleys of the western region, which mostly depends on saline irrigation, become more saline. According to Ventorino et al. (2012), the saline and harsh climatic condition hinder survival of *Rhizobium spp*, therefore, leguminous crops like *Clitoria* cannot form effective nodules to assist in nitrogen provision to the crop.

Organic farming has become one of the fastest growing segments of agriculture throughout the world because in conventional agriculture system use of chemicals has worried people about food quality, sustainability and other environmental consequences while organic agriculture assures high-quality food, sustainability and protect the environment (Tredwel, Riddle, Barbercheck, & Grant, 2011). Shi, Zhao, Gao, Zhang, and Wu (2016) based on a 28-year experimentation in China, reported that organic manure application significantly improved soil hydraulic properties, field capacity, total porosity and water retention, while soil bulk density decreased in comparison to the control and mixture of organic and inorganic manures. Similar findings were reported by Dutta, Dell, and Stehouwer (2016) and Mamedov et al. (2016).

Saudi Arabia has low soil organic matter in spite that it is well known that enrichment of organic matter reduce salinity effect and increase moisture conservation and as result stimulates crop growth and quality (Daur, Hassan, & Khan, 2008; Zirbin, Faci, & Aragues, 2011). The use of composted organic fertilizers, particularly poultry and farmyard manures, are known to benefit soils under such adverse environment through improving soil physical and chemical properties, thereby enhancing crop productivity (Abusuwar & El Zilal, 2010). Several researchers pointed out that organic manure help in conserving cropping systems through recycling of nutrients (Domínguez, Bedano, Becker, & Arolfo, 2014; Zen-Ping, Sheng-Xain, Jun, Yu-Lin, & Jian, 2014). Moreover, Khan, Malik, and Saleem (2008) reported that addition of organic manures with crop residues led to an increase in available phosphorus in soil in comparison to the control. On the other hand, the use of inorganic fertilizers, particularly under saline condition, has not been helpful and is often associated with reduced crop yield, cause soil acidity and nutrient imbalances (Abusuwar & Bakhshawain, 2011; Ayoola & Adeniyan, 2008).

The aim of this research was to evaluate the effects of addition of composted farmyard manure and chicken manure alone and in combination with each other as seed pellets to serve as soil conditioner and nutrient suppliers in a saline arid site compared to inorganic (NPK) fertilizer at Hada Al-Sham Experimental Research Station of King Abdulaziz University.

2. Materials and methods

An experiment was conducted at Hada Al-Sham Research Station over two successive seasons during 2015/2016. The experiment included a forage legume (*Clitoria ternate* L.) as a test crop. The treatments consisted of:

(1) Composted cow manure applied at a rate of five tons ha^{-1}—denoted as CM.

(2) Composted Poultry manure applied at a rate of five tons ha^{-1}—denoted as PM.

(3) Composted poultry and cow manure combined at a rate of two and half tons ha^{-1} of each—this is denoted as 1/2PMCM.

(4) PK applied at a rate of 50 kg ha^{-1}—denoted as NPK.

(5) Control-no fertilizers added—denoted as C.

Table 1. Chemical analysis of composted cow and poultry manures for six weeks

Element	N (gkg^{-1})	P (gkg^{-1})	K (gkg^{-1})	C (gkg^{-1})	C:N ratio
Poultry manure	16.50	4.20	24.25	265	16.50
Cow manure	6.45	1.25	13.20	86.50	13.20

The poultry and cow manures were composted for six weeks by digging a pit of 4 × 4 × 4 meters into the soil. Two such pits were made; one for the cow manure and the other for the poultry manure. Each pit was sprayed with water till it got moisted and then covered with a thin layer of soil and left for six weeks before use to illuminate all weed seeds and pathogens present in the manure. Thereafter, it was incorporated into soil before planting. In addition, seeds were pelleted with the composted manure according to treatments.

Chemical analysis was performed on the cow and poultry manures at the end of the composting period (6 weeks) and it revealed that composted poultry manure contained about three folds nutrients than cow manure (Table 1).

Rhizobium strain specific to *Clitoria* was inoculated to seeds before planting during the seed pelleting process. This was done by mixing gum Arabic powder with the strain of bacteria, composted manure and seeds immediately before planting.

The following growth and yield parameters were taken during the course of the study:

2.1. Leaf area
Leaf area was determined three times (at 2nd, 4th and 6th cut) during the study period using plant canopy analyzer, Model LAI-2270 manufactured by Li-cor Biosciences, USA.

2.2. Forage fresh and dry yields
The entire plot (3 Sq.m) was harvested and weighed to get forage fresh yield, whereas a sample was taken from each plot, oven dried to obtain dry yields. Both fresh and dry yields were transformed from kg ha^{-1} into tons ha^{-1}.

2.3. Forage nutritive value
Proximate analysis for plant tissues to determine the nutritive value of the forages was performed according to AOAC. NDF, ADF and cellulose were determined by the method of Goering and Van (1970). Total carotenoids were extracted and quantified as described by Qauckenbush, Dyer, and Smallidge (1970).

2.4. Nodulation
Two month after planting, random samples were taken from each treatment by carefully uprooting plants to examine total number and effective number of nodules per plant produced. Effective nodules were determined by microscopic examination to look for the red pigment (leg hemoglobin) if present or not as its presence indicates its effectiveness in nitrogen fixation.

2.5. Experimental design and data analysis
A randomized complete block design (RCBD) with three replications was used and analysis of variance (ANOVA) was performed on data according to Steel, Torrie, and Dicky (1997). Means of treatments were separated according to the LSD method.

Table 2. Effect of treatments on leaf area of *Clitoria* (cm^2)

Sampling date	2nd cut	4th cut	6th cut
Treatment			
Control	3.40^{c}	4.42^{b}	4.43^{b}
CM	7.22^{a}	6.17^{a}	6.17^{a}
Pm	7.27^{a}	6.80^{a}	6.79^{a}
PM+CM	6.20^{ab}	5.20^{b}	5.18^{b}
NPK	5.15^{b}	4.62^{b}	4.61^{b}
LSD 0.05	1.19	0.95	0.93
CV	13.21	11.40	11.20

Notes: CM: cow manure, Pm: Poultry manure, PM + CM: mixture of both Cow & Poultry Manures.

Figures followed by same superscript letters within each column are not significantly different at $p \leq 0.05$ according to LSD test.

3. Results and discussion

3.1. Leaf area

Leaf area, which was measured three times (2nd, 4th and 6th cut) during the course of the study, showed significant ($p \leq 0.05$) differences between treatments (Table 2). Organic manures (poultry and Cow manures) were always superior over the inorganic NPK fertilizer and the control throughout the three sampling dates. The ranking order for the treatments was PM > CM > PM + CM > NPK > Control. Analysis of composted poultry and cow manures showed that poultry manure contained three folds nutrients more than cow manures although cow manure was more effective in improving soil physical characteristics compared to poultry manure (Abusuwar & Daur, 2014). Moreover, addition of inorganic fertilizers to saline soils will add more to soil solutes, which depresses plant uptake of water and causes nutrients imbalances (Abusuwar & Bakhshawain, 2011; Ayoola & Adeniyan, 2008).

3.2. Fresh and dry forage yields

Fresh and dry forage yields are presented in Tables 3 and 4, respectively. Significant differences ($p \leq 0.05$) were detected between treatments for both parameters. Poultry manure led to an increase in forage productivity both in fresh and dry matter. It increased fresh yield by 145% over the control for the seven cuts. Corresponding increment for dry matter for the same treatments was 137%. As was noticed for results of leaf area, the same trend was repeated in forage productivity rankings. The ranking order for productivity both for fresh and dry matter yields were PM > CM > PM + CM > NPK > Control. Poultry and cow manures applied separately or in combinations improved forage productivity in comparison to inorganic (NPK) manure. Since leaf area was improved by organic manures, it was expected to have this reflected in forage productivity as leaf area is one of the components contributing to productivity and the quality of the forage.

Table 3. Effect of treatments on fresh weight (ton ha^{-1})

Treatments	1st cut	2nd cut	3rdcut	4th cut	5th cut	6th cut	7th cut
Control	2.95^{d}	4.75^{c}	2.00^{c}	11.00^{d}	13.00^{c}	12.85^{c}	17.10^{d}
CM	9.95^{ab}	8,85^{b}	4.75^{b}	23.80^{b}	22.65^{ab}	25.10^{b}	27.25^{ab}
PM	13.25^{a}	12.50^{a}	8.10^{a}	32.00^{a}	24.35^{a}	34.10^{a}	29.60^{a}
CM+PM	7.75^{bc}	7.25^{bc}	4.50^{b}	18.60^{bc}	19.10^{b}	20.10^{bc}	24.85b
NPK	5.30^{cd}	5.35c	2.60^{bc}	14.65^{cd}	15.15^{c}	17.85^{bc}	19.85c
LSD	4.05	3.20	2.25	6.35	3.90	8.95	2.45
CV	33.66	27.20	33.85	20.72	13.42	26.43	6.74

Notes: CM: cow manure, Pm: Poultry manure, PM + CM: mixture of both Cow & Poultry Manures.

Figures followed by same superscript letters within each column are not significantly different at $p \leq 0.05$ according to LSD test.

Table 4. Effect of treatments on dry weight (ton ha^{-1})

Treatments	1st cut	2nd cut	3rdcut	4th cut	5th cut	6th cut	7th cut
Control	1.45^{b}	1.90^{c}	1.10^{c}	6.75^{d}	4.80^{d}	2.15^{d}	7.35^{c}
CM	3.05^{b}	3.30^{b}	2.80^{b}	16.95^{b}	8.55^{b}	5.65^{b}	11.20^{ab}
PM	6.80^{a}	5.20^{a}	5.00^{a}	23.30^{a}	10.00^{a}	7.60^{a}	11.80^{a}
CM+PM	2.10^{b}	3.15^{b}	2.15^{bc}	13.85^{bc}	7.10^{c}	4.80^{b}	10.55^{b}
NPK	1.70^{b}	2.55^{bc}	1.50^{bc}	10.10^{cd}	5.55^{d}	3.55^{c}	8.05^{c}
LSD	3.50	0.75	1.65	4.55	1.15	1.10	0.80
CV	17.01	15.72	14.36	20.81	10.48	15.18	5.58

Notes: CM: cow manure, Pm: Poultry manure, PM + CM: mixture of both Cow & Poultry Manures.

Figures followed by same superscript letters within each column are not significantly different at $p \leq 0.05$ according to LSD test.

The chemical analysis of the experimental site soil indicates its salinity and irrigation water analysis showed that it contained 3,500 TDS (ppm) which were enough to depress plant growth. The application of composted organic manures (poultry and cow manures) might have mitigated the negative effects of salinity on growth through improvement of soil physical properties to allow salts go below rooting zone of the crop (Abusuwar & Bakhshawain, 2011; Ayoola & Adeniyan, 2008).

In addition, the nutrients supplied by the manures might have positively affected plant growth (Abusuwar & Bakhshawain, 2011; Daur, Abusuwar, & Alghabari, 2015; Zirbin et al., 2011).

It is to be mentioned that composted poultry manure contained three folds nutrients compared to composted cow manures (Abusuwar & Daur, 2014). It is well documented that organic manures have great beneficial effects on soil physical and chemical properties plus supplying nutrients to plants (Abusuwar & El Zilal, 2010; Ayoola & Adeniyan, 2008; Daur et al., 2015). This was especially true in case of the studied site where the soil is poor and known for low productivity. Reports showed that farmyard manure increased forage sorghum yield four times compared to the control in a saline-sodic soil in the Sudan (Abusuwar & El Zilal, 2010).

3.3. Proximate analysis

Forage nutritive value (quality) expressed in CP, CF, NDF, ADF, cellulose and carotenoids percent is presented in Table 5. Significant ($p \leq 0.05$) differences were detected between treatments. Higher CP and carotenoids and lower CF, NDF, ADF, ether extract and cellulose were reported for the poultry manure treatments in comparison to other treatments indicating the improvement in forage

Table 5. Effect of treatments on proximate analysis

Treatments	CP (%)	CF (%)	NDF (%)	ADF (%)	Ether extract (%)	Cellulose (%)	Total carotenoids (mg/kg)
Control	17.0^{e}	31.0^{a}	54.21^{a}	45.50^{a}	4.80^{a}	29.30^{a}	310.23^{e}
CM	20.0^{b}	28.5^{b}	44.60^{d}	42.40^{c}	4.35^{b}	26.18^{a}	430.61^{b}
PM	21.3^{a}	28.0^{b}	42.65^{e}	34.80^{d}	4.26^{b}	21.22^{b}	580.16^{a}
CM+PM	19.2^{c}	28.5^{b}	48.30^{c}	43.80^{ab}	4.38^{b}	28.10^{a}	399.21^{c}
NPK	18.2^{d}	29.0^{b}	50.20^{b}	44.10^{a}	4.46^{b}	28.50^{a}	330.50^{d}
LSD	0.70	0.9	1.80	1.50	0.33	3.50	30.17
CV	12.05	14.70	14.28	9.15	8.13	12.87	16.85

Notes: CM: cow manure, Pm: Poultry manure, PM + CM: mixture of both Cow & Poultry Manures.

Figures followed by same superscript letters within each column are not significantly different at $p \leq 0.05$ according to LSD test.

Table 6. Effect of treatments on nodulation of *Clitoria ternate*

Treatments	Total number of nodules	Effective nodules
Control	3.0[cd]	0.0[cd]
CM	15.0[b]	13.0[b]
PM	20.0[a]	19.0[a]
CM+PM	18.0[a]	17.0[a]
NPK	5.0[c]	1.0[c]
LSD	2.1	2.5
CV	13	14

Notes: CM: cow manure, Pm: Poultry manure, PM + CM: mixture of both Cow & Poultry Manures.

Figures followed by same superscript letters within each column are not significantly different at $p \le 0.05$ according to LSD test.

quality. Total carotenoids concentration is known to decrease rapidly with plant age (Barro & González, 1981) and stress environment, like salinity, may have a negative effect too. Berthelsen (1982) concluded that carotene assists in increasing conception rates.

The composted organic fertilizer (poultry and cow manures) treatments significantly improved forage quality in terms of nutrients. Organic materials, besides improving soil physical properties, supply plants with nutrients especially under saline conditions. This is in line with the results reported by Abusuwar and El Zilal (2010) and Ayoola and Adeniyan (2008).

3.4. Nodulation

Total and effective number of nodules per plant is presented in Table 6. Significant differences ($p \le 0.05$) were reported for total and effective number of nodules per plant among all treatments. Composted poultry manure applied alone (PM) or in combination with composted Cow manure (PM + CM) significantly outscored other treatments both in total and effective number of nodules per plant. The least number of nodules per plant (total and effective) was reported for the control followed by the NPK treatment. The poultry manure treatment produced 566% more nodules compared to the control and 300% more than the NPK treatment.

It is worth mentioning that the control treatment, unlike other treatments, produced no effective nodules. It is known that salinity and soil pH in general affects *Rhizobium* growth and consequently forage productivity as seen in forage fresh and dry yields presented in Tables 2 and 3, respectively. Both composted organic manures improved soil physical and chemical properties especially in saline soils to mitigate their harmful effects on growth (Faust, Hanisch, Burkert, & Joergensen, 2014; Mahmoud, El-Gizawy, & Geries, 2015).

It can be concluded from the results of this study that composted organic fertilizers (poultry and cow manures) are more effective in increasing nodulation, productivity and improving forage quality of *C. ternate* L. than inorganic fertilizer (NPK) under adverse conditions of salinity in arid lands. Composted poultry manure increased forage fresh and dry productivity over the control by 145 and 137%, respectively and the differences were significant ($p \le 0.05$).

Composted organic manures increased nodulation, yield and quality of *C. ternate* Compared to inorganic (NPK) fertilizers in an arid saline environment of western Saudi Arabia.

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Competing Interest
The author declares no competing interests.

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