Organic amendment effect on soil properties and yield of potato (*Solanum tuberosum*) under irrigated condition: a case study from Kombolcha, Eastern Harergie, Ethiopia

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Abstract: Field experiment was conducted in 2005/06 cropping season in Kombolcha to understand the comparative effect of organic and inorganic sources of soil ameliorant for managing surface soil crust under basin and furrow irrigation practices to boost potato production. A factorial experiment was conducted on plots of 12 m^2 (4 m x 3 m) and arranged in RCBD with three replicates, which combine irrigation methods and soil amendments. The treatments were the control (no amendment), FYM, *chat* residue (decayed leaves of *Chata edulis*) and sediment (sub surface inorganic material locally known as '*decay dimma'*). Results have, therefore, revealed that FYM and *chat* made compost significantly ($p \leq 0.05$) improved moisture content, bulk density, porosity and infiltration rate over the sediment amended plot and the control. However, yield harvested from plots, which were amended with *chat*-made compost was significantly ($p \leq 0.05$) lower than FYM under furrow irrigation practice. [Journal of American Science 2010;6(11):420-425]. (ISSN: 1545-1003).

Keywords: Chata edulis, decay dimma, organic amendment, potatoes, soil properties, irrigation

Introduction

The total area of land under *chat* cultivation in Ethiopia, in the year 1997/98 was estimated at 78,570 hectare (Central Statistics Authority, 1997/98). In Oromiya region, mainly East and West Hararghe zones are the most important centres of *chat* production (East Hararghe zone alone contributes 53.4% of the total production area) in Ethiopia (Dechassa, 2001). It can be grown rain fed and/or irrigated and the crop could be planted both in home garden and in the field. Tremendous quantity of the *chat* residue is left after consumption as solid waste material, which is readily available in various states of decomposition at dumping site near farmlands, around homestead and along the roadside on the way from Aweday town to Harer.

Continuous harvesting of *chat* exhausts and debilitates the mother plant unless fertilizer is used to maintain soil fertility. Manure is applied on *chat* every year based on the availability of manure or compost. Farmers prefer organic fertilizers (manure and compost) as compared to inorganic (chemical) fertilizers. The volume of manure available is limited and too scarce to satisfy the needs of farmers. Thus, farmers in Hararghe prepare their own compost and use this to improve soil fertility. Farmers usually use both organic and inorganic fertilizers to improve the soil fertility status whenever they grow cash crops. In addition, subsurface sediment, which is unintentionally added into irrigated land, is regarded by farmers as soil ameliorant. This ameliorant is formed from as alluvial deposition at the sub- surface soil layer. It is mainly drawn from hand dug wells in the form of water suspension while pumping is taking place. Based on the farmers' experience the sediment has improved fertility of the soil as well as the structure of the soil (Pers. Comm.).

Materials and Methods

The study was conducted in 2005/6 in Kombolcha, which is located 542 km east of Addis Ababa with an altitude between 1200 and 2460 masl, Latitude 42° 07' 0'' E and Longitude of 9° 25' 60'' N.

3.1 Bulk density, porosity and moisture content determination

Determination of dry bulk density and porosity was made for the profile pit, which was opened on the irrigated at the depths (0-15, 15-30, 30-45 and 45-60 cm) by using core samplers (diameter = 3.75 cm; height = 5 cm). Similarly, samples were taken in treatment-wise from depth plowing depth (0-30 cm) using the same core samplers to check the treatment effect on bulk density and total porosity. And the soil moisture content was determined using gravimetric method.

3.2 Experimental design and layout

The field experiment was conducted in 2005/6 during the normal growing season (Jan – mid April) for potato under irrigation practice and treatments were arranged in RCBD, with three replicate and eight treatments (4 x 2 factorial experiments). Each form of treatment was applied on plot size of 12 m^2 [3 m x 4 m] and the inter block and between plot spacing was 1 m and 0.5 m, respectively (Fig 1). All plots were also designed for methods of basin and furrow irrigation practices. The experimental site was chosen as the land has been irrigated for more than a decade (Pers. comm.). It also represents the major soil type of the study area where vegetables are mainly grown.

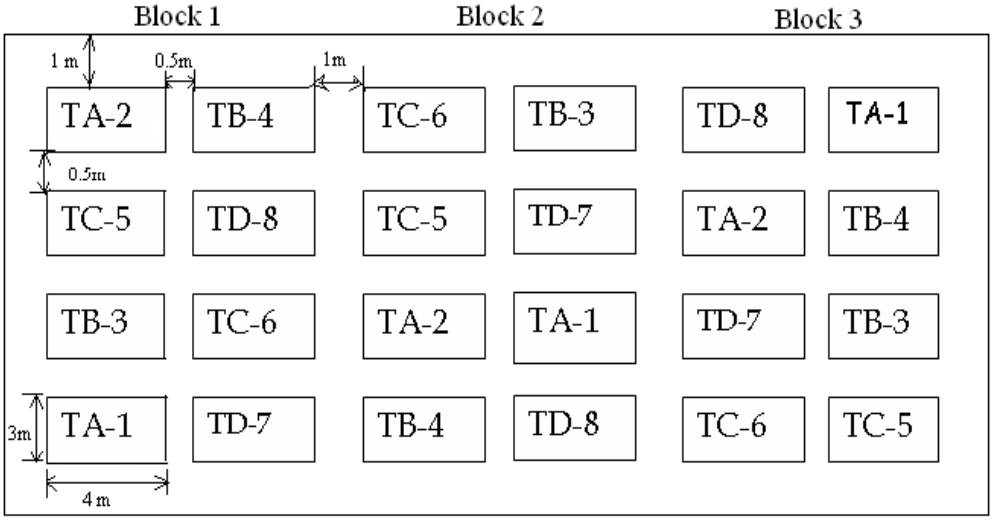

Fig 1. Layout of the field experiment

Under this experiment, two forms of organic compost were used as soil ameliorant (Farm Yard Manure (FYM) and *Chat* residue or decomposed leaves of *Chata edulis F.)* and sediment (inorganic material from subsurface soil, locally called '*dicay dimma'* to *mean 'qey afer').* The latter was manually collected from hand dug-well, which is located at a distance of 75 m from the experimental site and is different from the source of irrigation water for the experiment. They were incorporated into the surface soil with rate (dry mass) of 1.5 ton/ha, 2.5 ton/ha and 1.3 ton/ha, respectively. The method of soil amendment was partly adopted from the existing farmers' knowledge and experience. Description of the treatments is summarized in Table 1.

Table 1. Descriptions of treatment combinations

Treatment ID	Treatment combination	
	Surface soil crust management practices	Irrigation practices
TA-1	Control	Furrow
TA-2	Control	Basin
TB-3	FYM [chopped wheat straw and cattle dung]	Furrow
TB-4	FYM [chopped wheat straw and cattle dung]	Basin
TC-5	Residue of *chat (Catha edulis F.)*	Furrow
TC-6	Residue of *chat (Catha edulis F.)*	Basin
TD-7	Sediment [decay dimma]	Furrow
TD-8	Sediment [decay dimma]	Basin

All plots have also received equal amount of mineral fertilizer: DAP and urea with rate of 100 and 150 kg/ha, respectively; and half of the urea and full dose of DAP was applied at the time of sowing while the remaining amount of urea was top dressed just before the 3rd irrigation cycle.

On the field experimental plots, tuber seed of same variety *(Solanum tuberosum L.)* was sown with rate of 2 and 1.67 ton/ha under the basin and furrow irrigation practices, respectively. Each furrow plots had four ridges and sowing was done along the shoulders of two rows of the middle ridges in staggered arrangements while the remained were planted up on the inward side of the two border ridges. In both cases the planting was made at 0.4 m spacing. On the other hand, the basin plots were sub-divided into two equal sections for ease of water management. The main water channel, which is 0.5 m wide, was designed in a row along with the replication where as inlet channels between the experimental plots. The mode of water application and the amount of water was based on the existing irrigation practices by using engine pump as water lifting device from the hand dug well. At each irrigation cycle, roughly flow rate of 2.25 lit/sec that usually preferred by farmers, was allowed to irrigate both the furrow and basin plots for equal time (105 sec per plot). In the case of furrow irrigation practice, the furrow-flow was diked at the end to check the outflow.

Results and Discussions

4.1 Growth response

Both the soil amendment and irrigation practices have a significant effect on the average plant height when measured at the flowering stage. Based on mean comparison, plants grown over plots, which were amended with FYM and *chat* residues, were significantly taller than those from the control plots under basin irrigation practices. The shortest average plant height was recorded from the control plot under furrow irrigation practice (Fig. 2). However, no significant difference was obtained from plots, which were amended with sediment and *chat* residues under the same irrigation practice. Similarly, those which have been raised over FYM amended plots were significantly taller than those from the other treatments under furrow irrigation practices.

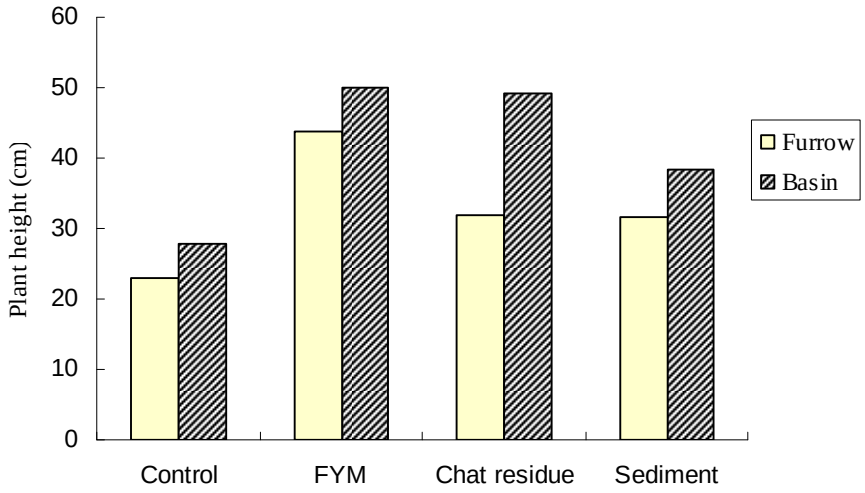

Fig 2. Treatment effect on growth of plant height

In general, those plants which have been grown under basin irrigation practices were more vigorous than plants from furrow irrigation. This may be due to the fact that plants over the furrow ridges relatively bears more roots than shoots in search of soil moisture as more proportion of the applied water is deep percolated (FAO, 1985) .

The number of tubers per plant was not affected by the irrigation practices as well as the soil ameliorants. Based on mean comparison, all the treatment combinations had no any significant effect on the number of tubers per plant. Similarly, the mean comparison revealed that soil amendment practice has no significant effect on individual tuber weight with in each irrigation practice while more tuber weight was obtained from FYM amended plots. On the other hand, the irrigation practice had significant effect on individual tuber weight from which more weight was recorded from plots, which were managed under basin irrigation practices. The crops which have been grown under basin irrigation practices produce larger tubers than those from furrow irrigation practices while considering all the management practices.

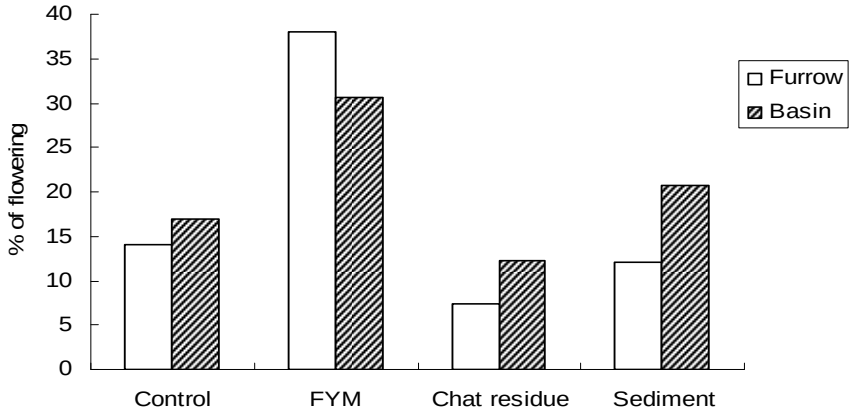

Fig 3. Effect of soil amendment on percent of flowering

Unlike the type of irrigation practice, the crust management practices have a significant effect on the rate of flowering. Based on mean comparison, plants raised over FYM amended plots were significantly effective to bear flower under both irrigation practices (Fig 3). They bear 80 to 60 % more flowering than those which have grown over plots amended with *chat* residue under the furrow and basin irrigation practices, respectively. However, there was no significant difference among the control, sediment and *chat* residue under both irrigation practices. In spite of the fast growth in height of plants which were grown under *chat* amended plots, rate of flowering was relatively late as compared to the FYM. This may be due to the oversized height growth on cost of tuber formation through excess irrigation water application (Khurana et. al. 2003).

4.2 Yield response

Both soil amendments and irrigation practices have significant effect on tuber yield. Based on mean comparison (Table 2), yield obtained from plots amended with FYM was significantly different from the treatment of *chat* residue under basin irrigation while maximum records on yield harvested over the other treatments. The yield from FYM amended plots was significantly higher than the remaining amendments under furrow irrigation practices.

Table 2. Growth and yield response of potato *(Solanum tuberosum)* to different soil amendments under furrow and basin irrigation practices

Treatment combination	Plant height (cm)	Flower (%)	No. of tuber per plant	Tuber wt.* (gram)	Tuber wt. per plant (kg)	Total yield (tones/ha)
Control +Furrow	23.1^{d}	14^{bc}	12.7^{a}	46.7^{c}	0.59^{d}	7.5^{b}
Control +Basin	27.9^{cd}	17^{bc}	14.3^{a}	74.1^{abc}	1.07^{ab}	11.8^{ab}
FYM + Furrow	43.8^{ab}	38^{a}	14.7^{a}	81.9^{abc}	1.17^{ab}	13.8^{a}
FYM +Basin	50.1^{a}	30.7^{ab}	12.7^{a}	107.1^{a}	1.38^{a}	14.7^{a}
Chat residue + Furrow	31.8^{cd}	7.3^{c}	10.7^{a}	47.7^{bc}	0.53^{d}	7.6^{b}
Chat residue + Basin	49.3^{ab}	12.3^{c}	13^{a}	74.7^{abc}	0.95^{bc}	10.8^{ab}
Sediment + Furrow	31.5^{cd}	12^{c}	12^{a}	57.2^{bc}	0.65^{cd}	7.6^{b}
Sediment + Basin	38.5^{bc}	20.7^{abc}	12.3^{a}	91.7^{ab}	1.11^{ab}	12.2^{a}
R^2	0.75	0.79	0.47	0.72	0.75	0.63
$P \leq 0.05$	0.0094	0.025	0.168	0.015	0.019	0.034

Levels not connected by same letter are significantly different at 5 % level
* Average of individual tuber weight

Based on mean comparison, significantly higher yield was harvested from FYM amended plots under the furrow irrigation practice (Table 2). Moreover, there was no significant difference on yield due to amendment under the basin irrigation practice while the highest yield was harvested from FYM amended plots. Similarly, there was no significant difference on yields from the control, sediment and *chat* residue amended plots under both irrigation practices, while more yield was obtained from the last two soil ameliorants.

Unlike comparison of the maximum yield, mean comparison has shown that relatively low yields were harvested from *chat* amended plot, while it is significantly lower as compared to the FYM amended plot under furrow irrigation practices. This may be due to the effect of excess soil moisture condition together with the sealing effect of the crust, which further deteriorates the hydrologic condition of the soil with in the rooting zone, where tuber is normally formed. This in turn could affect the crop to be more vulnerable with blight and cut worm attack (Khurana et al. 2003). In contrast, maximum yield was gained from plots, which were amended with *chat* made compost have received less suspension load than the other.

Being acquainted with the already existing irrigation practice, farmers are mainly preferring basin irrigation practice to cultivate the crop, which is locally known as '*Ketare'*. Results have also shown that higher yield was harvested from plots, which were managed under basin irrigation practices than furrow irrigation practices in each soil amendment.

In addition, highest yield was harvested from FYM amended plots under both irrigation practices over the others. The yield reduction can be explained by the effect of pronounced moisture stress under the furrow irrigation practice. This may be explained by the lower bulk density of the furrow ridges, which allows the soil water to escape from the ridges. In general, it has been indicated that optimum supply of water is the key factor in production of the potato; both over supply and deficiency of water are harmful as the crop requires readily available water throughout the growing season (Khurana et. al. 2003).

4.3 Effects of compost and sediment on some physical and chemical properties of the amended soil

As is shown in Table 3, soils treated with *chat* residue and FYM have significant effect on infiltration rate. Based on mean comparison there was no significant difference between soil amendment with *chat* residue and FYM while higher rate of infiltration was recorded from plots treated with *chat* residue. Treatments of FYM and *chat* residue have a significant effect on infiltration rate over the control and sediment treated soil. However, there was no significant difference between the two forms of compost. The results agreed with several studies that soil particle aggregation, water holding capacity, drainage, nutrient retention, and plant root growth were all increased when organic compost was incorporated (Keith, 1997; Wayne et. al., 1999). Soil amended with *chat* residue has significantly lower bulk density than the remaining treatment under basin irrigation practices, and similarly soils amended with *chat* residues and FYM have shown lower bulk density than the control and sediment under furrow irrigation practices. Records of initial moisture content (v/v) within the depth of 0-30 cm were found as 38.1 %, 38.4 %, 35 % and 38.2 % that measured under the control, FYM, *chat* residue and sediment amended plots, respectively. The total time required to attain the basic infiltration rate for each measurement was ranged from 140 up to 200 minutes.

Table 3. Effect of soil amendment on soil physical properties under furrow and basin irrigation

Treatment combination	Bulk density (g/cm3)	Porosity (%)	% moisture content (v/v)		In. rate (cm/hr)	Basic In. rate (mm/hr)
			0-15 cm	15-30 cm		
Control +Furrow	1.27bc	51.9bc	13.1c	22.4b	-	-
Control +Basin	1.42a	46.5d	25.8b	24.5bc	10.8b	2.2a
FYM + Furrow	1.07d	59.5a	21.7bc	25.7bc	-	-
FYM +Basin	1.3ab	50.7cd	28.1ab	32.1ab	16.2a	2.8a
Chat residue + Furrow	1.05d	60.3a	26.8ab	29.4b	-	-
Chat residue + Basin	1.15cd	56.6ab	30.5a	35.6a	14.5a	3.2a
Sediment + Furrow	1.31ab	50.7cd	14.6c	25.5bc	-	-
Sediment + Basin	1.33ab	49.8cd	17.6c	26.4bc	9.7b	2.4a
R2	0.82	0.81	0.75	0.81	0.97	0.93
P< 0.05	0.0123	0.0123	0.039	0.0032	0.0002	0.058

Levels not connected by same letter are significantly different at 0.05 levels

Conclusions

This experiment has tried to demonstrate that *chat* residue can benefit potato production by virtue of its soil moisture conservation and improvement in soil organic matters thereby reduce the risk of soil encrustation as frequent abstraction of suspension laden irrigation water from the hand dug well is minimized. It also indicated that production of potato under basin irrigation practice is better than the furrow irrigation practice, in terms of tuber yields. Although, the yield obtained from *chat* amended plot has shown to be less, addition of *chat* residue on crusted surface soil has shown improvement up on similar soil physical properties, which play a key role to suppress soil encrustation. The yield obtained from would rather imply the need to conduct further research by integrating the surface crust management options with improved irrigation water management. Although, the yield obtained from *chat* amended plot has shown to be less, addition of *chat* residue on crusted surface soil has shown improvement up on similar soil physical properties, which play a key role to suppress soil encrustation.

9/9/2010

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