14. Dry Bio-Slurry with Nitrogen Fertilizer Application and Its Residual Effect on Soil Physico-Chemical Properties and Crop Yield under Potato-Wheat Cropping System in North West Amhara Region, Ethiopia

Zelalem Addis*[1],Tadele Amare[1], Bitewlgn Kerebih[1], Antenh Abewa[1], Tesfaye Feysa[2] ,Abrham Awoke[1] and Abere Tenagne[1]

1 Adet Agricultural Research Center P.O.Box 08, Bahir Dar Ethiopia

2 Amhara Agricultural Research Institute, P.O.Box 527, Bahir Dar, Ethiopia

*Correspondence: zelalemaddis660@gmail.com

Abstract

The experiment aimed to determine the effect of dry bio-slurry with equivalent nitrogen (N) rates on soil physico-chemical properties and the yield of potato and wheat in a potato-wheat cropping system at Yelmana Denesa District. The study included ten treatments (Control, recommended NP, 50% dry bio-slurry, 100% dry bio-slurry, 75% dry bio-slurry, 75% dry bio-slurry + 25% recommended NP, 50% dry bio-slurry + 50% recommended NP, 25% dry bio-slurry + 75% recommended NP, 100% dry bio-slurry + 25% recommended NP, and 100% dry bio-slurry + 50% recommended NP) in a randomized complete block design (RCBD) with three replications over three years. Data on soil physico-chemical properties, yield, and yield components of potato and wheat were collected and subjected to ANOVA using SAS software. The results revealed that the application of different rates of dry bio-slurry with N fertilizer significantly affected the yield and yield components of both potato and wheat. Soil properties, except pH, were not significantly affected by dry bio-slurry. Application of 25% dry bio-slurry with 75% recommended NP resulted in the highest tuber yield (27.6 t/ha) compared to the control. Similarly, sole application of 100% and 75% dry bio-slurry yielded the highest grain yield (3.85 t/ha) and above-ground biomass (9.59 t/ha) of wheat, respectively, due to the residual effect. The 25% dry bio-slurry with 75% recommended NP treatment achieved the highest net benefit with an acceptable marginal return (above 100%), next to 50% dry bio-slurry with 50% recommended NP. Overall, the application of dry bio-slurry with nitrogen rates improved the yield and yield components of potato and wheat in the study area. For the highest net benefit within a short period, a rate of 50% dry bio-slurry with 50% recommended NP is preferable for yield improvement in the study area and similar agro-ecologies. Given the study's three-year duration, further research should be conducted extensively and repeatedly in permanent plots.

Keywords: dry bio-slurry, Nitrogen, soil properties, potato, wheat

Introduction

Potato (*Solanum tuberosum L.*) is the world's third most important food crop after wheat and rice (Birch et al., 2012). In Ethiopia, the area coverage for potato cultivation reached about 73,677.64 ha and *its* production was 1,044,436.359 *tons (CSA, 2020).* The productivity of potato in Ethiopia is 13.9tha^{-1} (CSA, 2018), which is relatively low compared to other African countries (FAOSTAT, 2017). Bread wheat (*Triticum aestivum* L.) is also one of the major cereal crops grown in the highlands of Ethiopia, and regarded as the largest wheat producer in Sub-Saharan Africa (Efrem *et al*, .2000). Out of the total area allocated for cereals, wheat ranked 4th after tef (Eragrostis tef), maize (Zea mays) and sorghum (Sorghum bicolor), while third in total production after maize and tef (CSA, 2016). Despite the long history of wheat cultivation and its importance to Ethiopian agriculture, its average yield is still very low, not exceeding 2.4tha^{-1} (CSA,2014) which is below the world's average of 3.4tha^{-1} (FAOSTAT,2015) which is the same phenomenon in Amhara region.

Low level of potato and wheat productivity is mainly due to soil fertility degradation, improper fertilization, poor pest management practices, use of the low-quality seed, and soil nutrient depletion (Chanie *et al*., 2017). Enhancing soil fertility is a precondition for improving crop production and productivity through organic manure like bio-slurry that can achieve sustainability soil fertility and crop production (Shankarappa *et al*., 2012; *Khan et al*., 2015). The bio-slurry obtained after extraction of the energy content of animal manure is an excellent fertilizer, rich in major nutrients (Nitrogen, Phosphorous and Potassium) and organic matter that determine the soil fertility and yield of different crops and vegetables (Yalemtsehay and Fisseha, 2016). It also improves the physical and biological quality of soil besides providing both macro and micro-nutrients to crops and vegetables. The application of bio-slurry also helps in the reduction of dependence on mineral fertilizers (Karki, 1997). *Both Potato and wheat are* highly responsive to N fertilization; it is usually the most limiting essential nutrient for growth and development (Errebhi *et al*., 1998). In addition, Nitrogen plays an important role in the balance between vegetative and reproductive growth for both crops (Alva, 2004; White *et al*., 2007). The studies have shown that N fertilizer applications can increase the dry matter-protein content of wheat and potato tubers (Zelalem *et al*., 2009). Furthermore, most of the time the available Nitrogen in most organic source fertilizers including bio-slurry is high as compared to other nutrients in concentration (Gupta, 2000). Due to this, dry bio-slurry and Nitrogen fertilizers were applied through Nitrogen equivalence. Neither organic manure nor chemical fertilizer alone is not enough to meet the demand for crops in the different cropping systems via soil-plant interaction (Rahman, 2016). Because of this, the study was done with flowing objectives to determine the optimum rate of dried bio-slurry and Nitrogen fertilizer on potato and wheat yield and Physico-chemical properties improvement in northwestern Amhara region Ethiopia

Materials and Methods

Description of Study Area: The experiment was conducted at Yilemana Densa district on farmer's field for three consecutive years 2019/20-2021/22 cropping seasons at Debremewi Keble, West Gojam zone, northwestern Ethiopia, Amhara region. The site is located at 33km east direction from Bahirdar. Geographically the area lies at 11^0 21' 22" N and 37^0 25' 43" E (Figure 1) with a mean altitude of 2304 meters above sea level. It receives a mean annual rainfall of 1421 mm with mean minimum and maximum temperatures of 12.29 and 27.56°C, respectively (Bureau of Agriculture (BOA unpublished). The landforms of the area are characterized by undulating to rolling plateaus, scattered moderate hills, dissected side slopes, and river gorges (Eyasu, 2016). Based on the district office of agriculture, the major land use comprises cultivated land (57%), forest and bushes (2%), grazing land (33%), and others (8%). Major crops, grown in the study area are Maize, Tef, wheat, barley, potato, and field pea which take the lion's share. Soil types in the area are Nitisols (45%), Vertisols (30%) and Luvisols (25%). This on-farm experiment was conducted on Luvic Nitisols which is the most dominant soil in the study area.

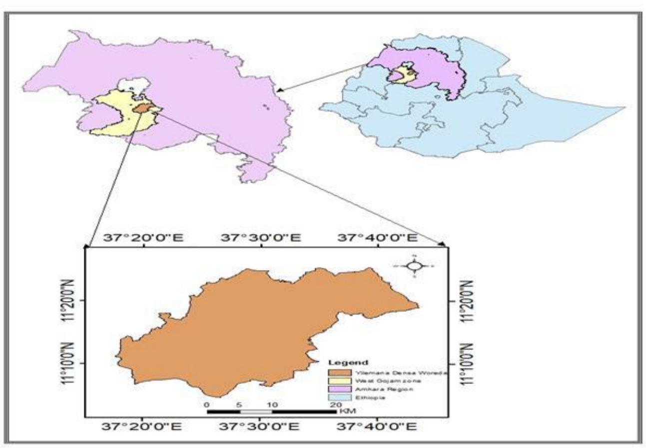

Figure 1. The geographical location of the site

Experimental Design and Experimentation: The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications in permanent plots for three years. Treatments include control (without N), recommended N (138N),dry-bio slurry 50% equivalence (5.3tha^{-1}),dry-bio slurry 100% equivalence (10.6 tha^{-1}), dry-bio slurry 75% equivalence (7.95 tha^{-1}), dry-bio slurry 75% equivalence (7.95tha^{-1})+25% recommended N (34.5N), dry-bio slurry 50% equivalence (5.3tha^{-1})+50% recommended N (69N), dry-bio slurry 25% equivalence (2.65tha^{-1}) +75% recommended N (103.5N), dry-bio slurry100% equivalence (10.6tha^{-1})+25% recommended N (34.5N) and dry-bio slurry 100% equivalence (10.6 tha^{-1}) +50% recommended N (69 N). The rates of dry-bio slurry were adjusted based on recommended rate of N equivalency corresponding to its N content. Urea was used as a source of synthetic N whereas TSP was applied as sources of P to all plots. The experiment was carried out under rain-fed conditions. *Gudenie* and Tay varieties were used as test crops for Potato and wheat respectively. Total area of each plot was 13.5 m^2 having 1m space between plots and 1.5m between blocks. Potato was spaced 0.3m between plants and each plot consisted of six rows at 0.75m intervals and the data were collected from the middle four rows. Wheat was planted as a rotated crop in 0.2m row spacing and harvested from middle rows by avoiding four rows as a border. Dry bio-slurry and P_2O_5 were applied during the planting period of time as basal whereas inorganic N for potato was applied in three splits; one-third at planting, one-third about 30 days after planting, and the remaining one-third at the beginning of the flowering. While for wheat recommended NP was applied in all plots except control which only received P_2O_5 to see the residual effect of dry bio-slurry in the next crop. Nitrogen was supplied, in two splits for wheat crop.

Data Collection, Preparation, and Analysis

Dry- Bio Slurry Analysis: Representative composite sample dry-bioslurry was taken from the whole collected dried pit of slurry that was collected from different biogas plants across individual and make them composite for analysis of (pH), organic carbon (OC%), cation exchange capacity (CEC), total Nitrogen (TN%) and available Phosphorus (P) by following laboratory procedures (Sahlemedhin and Taye, 2000).

Table 1. Physico-chemical analysis of dry-bio slurry before incorporation in to the soil in year1and 2 and its average

Dry bio-slurry	Concentration
Year 1	
Dry matter%	11.2
*OC%	27.8
TN%	1.2
Av P (mgKg^{-1})	112.1
pH (H_2O;1:2.5)	7.9
C:N ratio	22.9
CEC (cmolKg^{-1})	59.8
Year 2	
Dry matter%	11.8
OC%	16.3
TN%	1.4
Av P (mgKg^{-1})	91.6
pH (H_2O;1:2.5)	7.7
C:N ratio	11.6
CEC (cmolKg^{-1})	67.4
Average result of Year1 and Year 2	
Dry matter%	11.5
OC%	22.1
TN%	1.3
Av P (mgKg^{-1})	101.9
pH (H_2O;1:2.5)	7.8
C: N ratio	17.3
CEC (cmolKg^{-1})	63.6

**OC%=organic carbon percent, TN%=total Nitrogen percent, C: N=carbon to Nitrogen ratio, CEC = cation exchange capacity, AvP=available Phosphorus, and pH= Power of hydrogen concentration.*

Soil Sampling and Analysis: Before planting, representative soil samples were collected from 0-20 cm depth in a diagonaly zigzag sampling method from 10 spots in the field by using an auger. All samples were mixed together and one composite sample was formed for each site. The composite samples were grounded using a mortar and pistel and passed through a 2 mm sieve for analysis of soil texture, CEC, pH, and available P; whereas a 0.5 mm sieve was used for determining the organic carbon (OC) and total N. Bulk density was determined by the core sampling method.

Determination of the particle size distribution was done by using the hydrometer method (procedures) compiled by Sahlemedhin and Taye (2000) from each site and the sand, silt, and clay percent's were calculated and identified using FAO textural triangle. The major chemical properties of soil such as OC, pH, CEC, total N and available P were analyzed following the compiled laboratory manual of Sahlemedhin and Taye (2000). Soil pH was measured in water at the ratio of 1:2.5 using glass electrode pH meter. The soil OC content was determined following the wet digestion method as outlined by Walkley and Black which involves the digestion of OC in the soil samples with Potassium dichromate ($K_2Cr_2O_7$) in a sulphuric acid solution. AvP was determined by Olsen extracting method. The total N content in the soil samples was determined following the Kjeldahl method. CEC was determined by extracting the soil samples with ammonium acetate ($1NNH_4OAc$) followed by repeated washing with ethanol (96%) to remove the excess ammonium ions in the soil solution. Percolating the NH_4^+ saturated soil with sodium chloride would displace the ammonium ions adsorbed in the soil and the ammonium liberated from the distillation was titrated using 0.1N NaOH.

Crop Data Collection: Plant height, number of plants per hill, and spike length were measured for both potato and wheat at the maturity stage by taking five randomly selected plants from ground level to the top apex and averaging for a single reading.

The number of tubers per plant was taken by counting tubers from five randomly taken plants at the maturity stage from the middle rows of experimental plots and averaged for a single estimation of the mean value. While thousand seed weight for wheat was taken from each treatment plot by counting of 1000 seeds. Total tuber yield, grain yield, and above-ground biomass were measured atharvesting from the middle plot area by avoid border effects.

Economic Analysis: Because potato is the main crop in this experimenting system the economic analysis was done based on its. Economic analysis was performed to make rational choice among the applied variables in the production of potato. The partial budget and marginal rate of return (MRR) were used for evaluating the change in farming methods that affect partially rather than the whole farm practice and also concerned with planning tool to estimate the profit change within a farm (CIMMYT, 1988). This was computed by adjusting yield downward by a 10% and multiplying it with the local field price (6 Ethiopian ETB per Kg of potato). Dominance analysis was done by listing of treatments in an increasing order of cost and thathas net benefit less than or equal to treatments with the lower costs that vary is dominated (CIMMYT, 1988).

Statistical Analysis: All data were subjected to analysis of variance through GLM procedure by using SAS software program version 9.4 (SAS Institute, 2002). List significant test (LSD) at 0.05

probability level was employed to separate treatments means where significant differences exist (Gomez and Gomez, 1984).

Results and Discussion

Soil Chemical Properties before Planting and after Harvesting of Potato: The analysis result of soil chemical properties before planting in each site and after harvest from each main and residual experimental site were indicated in Table 2, 3 & 4. Soil analysis results before-planting showed that the soil was acidic in reaction with a pH (H_2O 1:2.5) value of 5.1 for Y1S1 and 5.2 for Y2S1, which is within the range of soil pH for potato production Tekalign (1991) (Table 2). The total N, available P, OC, C: N ratio and CEC of the soil for Y1S1 and Y2S1 before planting were 0.16%, 6.9 mgKg^{-1}, 1.8%, 11.1^{-} and 33.9 cmol (+) Kg^{-1} and 0.16%, 6.3 mgKg^{-1}, 1.5%,9.3 and & 30.3 cmol (+) Kg^{-1}, respectively (Table 2). The total N content of the soil was within the range of medium category according to Tekalign (1991) who classified the range of total N < 0.1, 0.1- 0.15, 0.15-0.25 and > 0.25% as very low, low, medium and high, respectively. Olsen *et al*., (1954) classified available P content of the soil with < 5 mgKg^{-1} as very low, 5 -15 mgKg^{-1} as low, 15 -25 mgKg^{-1} as medium and > 25 mgKg^{-1} as high. Hence the available P of the soil before planting lies under the low range. According to Landon (1991) the soil OC content ranged 1-2, 2-4, and 4-6% are rated as low, medium and high, respectively. Based on these ratings the OC (1.4 & 1.5%), of the experimental fields were in the low. while cation exchange capacity (CEC) ranges of 5-15, 15-25 and 25-40 cmolKg^{-1} are rated as low, medium and high, Hence, the CEC of (33.9 & 30.3 cmolKg^{-1}) the experimental site before planting was ranged in high category.

Generally, the nutrient contents of the study site Y2S1 is not good in terms of availability of major plant nutrients beside its nice CEC. On the other hand, on Y2S2 pH, TN, avP, OC, C: N and CEC before planting were 5.5, 0.17%, 6.8ppm, 2.4%, 14.1 and 33.9, respectively. Based on Tekalign (1991) rating the pH value was under moderate while total Nitrogen was medium. Similarly, according to olsen *et al*. (1954) available P was under low while OC and CEC were medium and high respectively landon (1991). The soil fertility status of Y2S2 was better than Y1S1and Y2S1 based on its soil chemical properties. However, the acidity of the soil Y1S1 and Y2S2 may cause sorption of available P. Thus, application of OM like bio-slurry is very essential in order to neutralize soil solution for the availability of nutrients. On the other hands, after harvest all soil chemical properties except soil pH (on Y2S2) were not affected by the application of dry bio-slurry with N equivalence rates (Table3).

The non-significant effects of the applied treatments on these parameters might be due to the slow release of nutrients from dry bio-slurry that was applied during the experimentation period. This might be due to short cropping season of potato cultivation which might not get enough time to decompose the dry bio-slurry to release these nutrients to the soil solution. However, applied dry bio-slurry and N rates had a significant (P < 0.05) effect on pH at site Y2S2 after harvest as compared to the control (Table 2). Numerically the highest soil pH content was obtained by the application of 100% and 100%+25%N dry bio-slurry as compared to the control (Table 3). The increment of soil pH in treated plots may be related due to the releasing of basic cations from dry bio-slurry into soil solution that makes substitute of acid cations. These results were in agreement with the investigation of Workineh *et al.,* (2021) who reported that the combined application of compost with inorganic NPSB in maize increased the soil pH content after harvest as compared to control.

Residual Effect of Dry Bio-Slurry on Soil Chemical Properties after Harvesting Of Wheat

The residual effect of dry bio-slurry on selected soil chemical properties was significantly explained at (p<0.05) across sites and years in Table 4. Related to this, addition of 100% (10.6tha^{-1}) dry bio-slurry gives the highest TN% (0.207 and 0.223) on Y1S1 and Y2S2 respectively than the control. This might be due to the gradual releasing of Nitrogen by dry bios-slurry into soil solution beyond its chelating capacity. The finding was in lined with Geremew *et al*., 2019 who found that an application of dry bio-slurry with inorganic fertilizers gives the maximum value of total Nitrogen than control. Similarly, the study conducted by Tsegaye *et al*., 2018 also indicated that an application of 70cm^3 scored the highest (1.36%) TN as compared to the control which gives 0.07%.

On the other hand, OC, C: N and CEC are significantly affected at Y2S1 (Table 4) in addition Y2S2 only CEC is significant at (p<0.05) Table 4. Based on this, numerically the highest value of CEC (34.6), C: N (12.82) & OC% (2.20) was observed by application 50% DBS and 100% DBS with 25%N as compared to control on Y2S1. On Y2S2 the maximum value of CEC (cmolKg^{-1}) 36.06 was obtained in plots that receive 100% DBS with 25%N than control plots. This might be due to the positive effect of applied DBS that enables increasing organic matter and holding capacity of positive cation in the soil exchangeable site. The finding agreed with Zelalem *et al*., 2020 who revealed that an application of 41.3m^{-3} liquid bio-slurry with 20.5$Kgha^{-1}$ N significantly increased soil organic carbon than untreated plots. The study conducted by Sandeep and Salwinder (2019) also indicated that an application of 10tha^{-1} with 50% N $Kgha^{-1}$ significantly increased OC% by scoring the maximum value of 0.67 than the control. Organic amendments significantly enhanced SOC which had a considerable effect on soil microbes and nutrient availability and uptake that may alter the C: N ratio. This makes Nitrogen trapped by organic matter; a phenomenon known as the priming effect (Shahzad *et al*., 2015). The application of the 50% DBS and 100% DBS with 25% N gives the highest CEC at Y2S1 and Y2S2 respectively as compared to the control (Table 1). Such increment in CEC might be due to the application of DBS on soil that makes a negatively charged colloidal site and storehouse of basic cations. The finding agreed with Tamado and Mitiku (2017) who reported that the use of organic FYM and inorganic fertilizers significantly increased CEC over the control.

2019-20 site1 (Y1S1)							
Texture	BD	pH	TN%	Av P (ppm)	CEC (cmol Kg^{-1})	C:N	OC%
SCL	1.22	5.1	0.16	6.9	33.9	8.8	1.4
2020-21 site1 (Y2S1)							
Texture	BD	pH	TN%	Av P (ppm)	CEC (cmol Kg-1)	C:N	OC%
SCL	1.33	5.2	0.16	6.3	30.3	9.3	1.5
2020-21 site2 (Y2S2)							
Texture	BD	pH	TN%	Av P (ppm)	CEC (cmol Kg-1)	C:N	OC%
SCL	1.26	5.5	0.17	6.8	33.9	11.8	2.0

***NB:** *SCL= sandy clay loam; BD= bulk density*

Table 3. Main effect of dry bio slurry with Nitrogen on soil chemical properties after harvest of potato

Treatment	pH	TN%	Av P (ppm)	CEC (cmol Kg^{-1})	C:N	OC%
2019-20 site1 (Y1S1)						
Treatment	pH	TN%	Av P (ppm)	CEC (cmol Kg^{-1})	C:N	OC%
Control (0,0)	5.13	0.12	9.3	29.1	11.6	1.4
RN (138NKgha^{-1})	5.11	0.12	7.8	29.9	11.61	1.3
50% DBS (5.3tha^{-1})	5.19	0.13	8.8	29.6	11.59	1.4
100% DBS (10.6tha^{-1})	5.18	0.13	9.6	29.7	11.58	1.5
75%DBS(7.95tha^{-1})	5.19	0.13	10.2	29.1	11.62	1.5
75%DBS+25%N (7.95tha^{-1}+34.5NKgha^{-1})	5.22	0.16	10.1	28.3	11.57	1.9
50%DBS+50%N (5.3tha^{-1}+69NKgha^{-1})	5.10	0.15	9.1	28.7	11.59	1.7
25%DBS+75%N (2.65tha^{-1}+103.5NKgha^{-1})	5.18	0.15	7.5	29.2	11.61	1.7
100%DBS+25%N (10.6tha^{-1}+34.5NKgha^{-1})	5.12	0.13	12.3	28.3	11.62	1.5
100%DBS+50%N (10.6tha^{-1}+69NKgha^{-1})	5.15	0.13	11.2	27.6	11.60	1.5
LSD	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV%	**1.2**	**14.3**	**22.43**	**3.3**	**0.21**	**14.19**
2020-21 site1 (Y2S1)						
Treatment	pH	TN%	Av P (ppm)	CEC (cmol Kg^{-1})	C:N	OC%
Control (0,0)	5.2	0.15	4.4	27.3	11.59	1.7
RN (138NKgha^{-1})	5.3	0.16	4.3	27.7	11.59	1.8
50% DBS (5.3tha^{-1})	5.3	0.14	6.5	30.8	11.61	1.7
100% DBS (10.6tha^{-1})	5.4	0.15	6.2	27.4	11.60	1.8
75%DBS(7.95tha^{-1})	5.4	0.15	5.8	28.6	11.58	1.7
75%DBS+25%N (7.95tha^{-1}+34.5NKgha^{-1})	5.3	0.14	5.4	24.4	11.63	1.7
50%DBS+50%N (5.3tha^{-1}+69NKgha^{-1})	5.3	0.14	4.5	26.7	11.61	1.6
25%DBS+75%N (2.65tha^{-1}+103.5NKgha^{-1})	5.2	0.14	4.6	27.5	11.59	1.7
100%DBS+25%N (10.6tha^{-1}+34.5NKgha^{-1})	5.4	0.17	4.4	28.4	11.59	1.9
100%DBS+50%N (10.6tha^{-1}+69NKgha^{-1})	5.4	0.16	4.4	28.5	11.61	1.9
LSD	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV%	**2.12**	**13.5**	**21.6**	**9.0**	**0.17**	**13.5**
2020-21 site2 (Y2S2)						
Treatment	pH	TN%	Av P (ppm)	CEC (cmol Kg^{-1})	C:N	OC%
Control (0,0)	5.3^{cd}	0.17	12.2	30.6	12.10	2.1
RN (138NKgha^{-1})	5.4b^{cd}	0.17	7.1	31.9	11.60	1.9
50% DBS (5.3tha^{-1})	5.5^{abc}	0.18	11.5	30.4	11.60	2.0

100% DBS (10.6tha^{-1})	5.6^{ab}	0.18	9.5	32.1	12.62	2.3
75%DBS(7.95tha^{-1})	5.6^{ab}	0.17	13.2	32.1	12.00	2.0
75%DBS+25%N (7.95tha^{-1}+34.5NKgha^{-1})	5.5^{abc}	0.18	13.3	33.5	11.60	2.1
50%DBS+50%N (5.3tha^{-1}+69NKgha^{-1})	5.5^{abcd}	0.17	13.1	32.6	12.01	2.1
25%DBS+75%N (2.65tha^{-1}+103.5NKgha^{-1})	5.3^{d}	0.16	9.5	30.9	11.60	1.9
100%DBS+25%N (10.6tha^{-1}+34.5NKgha^{-1})	5.6^{a}	0.18	11.6	31.8	11.80	2.1
100%DBS+50%N (10.6tha^{-1}+69NKgha^{-1})	5.4^{bcd}	0.17	15.3	33.4	11.60	2.1
LSD	**2.3**	**NS**	**NS**	**NS**	**NS**	**NS**
CV%	**0.22**	**9.9**	**29.1**	**6.1**	**5.9**	**13.8**

** nded Nitrogen and Phosphorus, DBS =dry bio-slurry, pH= power of hydrogen concentration, TN% = total Nitrogen percent, AvP = available Phosphorus, OC% = organic carbon percent, C: N *ratio = carbon to Nitrogen ratio, CEC = cation exchange capacity, OM% = organic matter percent, Y1S1= year one site one, Y2S1= year two site one and Y2S2 = year two site two.*

Table 4. The residual effect of dry bio-slurry on soil chemical properties after wheatharvesting in the potato-wheat cropping system

Treatment	pH	TN%	Av P (ppm)	CEC (cmolKg^{-1})	C:N	OC%
Control (0,0)	5.40	0.174bcd	8.97	21.39	9.68	1.69
RN (138NKgha^{-1})	5.40	0.196a	10.12	21.69	10.01	1.95
50% DBS (5.3tha^{-1})	5.40	0.197a	9.25	26.13	9.64	1.88
100% DBS (10.6tha^{-1})	5.38	0.168d	11.04	23.51	11.81	1.98
75%DBS(7.95tha^{-1})	5.40	0.192ab	9.34	25.60	9.42	1.82
75%DBS+25%N (7.95tha^{-1}+34.5NKgha^{-1})	5.42	0.172cd	9.07	24.51	11.98	2.06
50%DBS+50%N (5.3tha^{-1}+69NKgha^{-1})	5.36	0.188abc	10.06	22.09	9.61	1.80
25%DBS+75%N (2.65tha^{-1}+103.5NKgha^{-1})	5.35	0.202a	10.08	25.11	10.14	2.04
100%DBS+25%N (10.6tha^{-1}+34.5NKgha^{-1})	5.31	0.194ab	10.46	21.81	11.01	2.13
100%DBS+50%N (10.6tha^{-1}+69NKgha^{-1})	5.37	0.205a	10/76	23.78	9.35	1.89
	NS	0,020	NS	NS	NS	NS
	1.3	6.2	12.7	11.9	14.8	13.3

Treatment	pH	TN%	Av P (ppm)	CEC (cmolKg^{-1})	C:N	OC%
Control (0,0)	5.61	0.178	10.15	27.70d	7.61d	1.36b

RN (138NKgha^{-1})	5.53	0.179	10.22	30.52bc	10.31abc	1.85a
50% DBS (5.3tha^{-1})	5.69	0.180	11.56	34.67a	12.25abc	2.20a
100% DBS (10.6tha^{-1})	5.67	0.160	9.85	31.77bc	12.42ab	1.98a
75%DBS(7.95tha^{-1})	5.64	0.194	9.85	31.09bc	9.74cd	1.88a
75%DBS+25%N (7.95tha^{-1}+34.5NKgha^{-1})	5.70	0.178	11.76	29.56cd	10.79abc	1.90a
50%DBS+50%N (5.3tha^{-1}+69NKgha^{-1})	5.62	0.167	10.69	30.63bc	11.38abc	1.90a
25%DBS+75%N (2.65tha^{-1}+103.5NKgha^{-1})	5.54	0.186	9.59	30.37bc	10.00bcd	1.86a
100%DBS+25%N (10.6tha^{-1}+34.5NKgha^{-1})	5.58	0.172	9.88	31.99bc	12.82a	2.20a
100%DBS+50%N (10.6tha^{-1}+69NKgha^{-1})	5.44	0.185	10.19	32.91ab	11.78abc	2.17a
	NS	NS	NS	2.60	2.61	0.41
	2.0	6.7	14.4	4.8	14.1	12.6

Treatment	pH	TN%	Av P (ppm)	CEC (cmolKg^{-1})	C:N	OC%
Control (0,0)	5.51	0.176de	10.03	29.43c	12.03	2.12
RN (138NKgha^{-1})	5.65	0.190bcd	8.76	30.69bc	12.19	2.29
50% DBS (5.3tha^{-1})	5.62	0.186bcde	13.49	35.92 a	12.78	2.38
100% DBS (10.6tha^{-1})	5.62	0.209ab	14.08	33.68ab	11.63	2.43
75%DBS(7.95tha^{-1})	5.76	0.178cde	11.74	34.47a	13.41	2.39
75%DBS+25%N (7.95tha^{-1}+34.5NKgha^{-1})	5.68	0.207ab	12.93	34.81a	12.29	2.54
50%DBS+50%N (5.3tha^{-1}+69NKgha^{-1})	5.57	0.202abc	13.08	35.88a	11.47	2.30
25%DBS+75%N (2.65tha^{-1}+103.5NKgha^{-1})	5.59	0.164e	11.07	33.27ab	13.52	2.19

100%DBS+25%N (10.6tha^{-1}+34.5NKgha^{-1})	5.66	0.223a	11.51	36.06a	10.09	2.24
100%DBS+50%N (10.6tha^{-1}+69NKgha^{-1})	5.66	0.207ab	11.21	35.95a	11.75	2.42
	NS	0.025	NS	3.78	NS	NS
	2.3	7.6	17.8	6.5	10.5	7.3

*Means followed by the same letter (s) within the column are not significantly different at ($P \leq 0.05$). RNP=percent of recommended Nitrogen and Phosphorus, DBS =dry bio-slurry, pH= power of hydrogen concentration, TN% = total Nitrogen percent, AvP = available Phosphorus, OC% = organic carbon percent, C: N ratio = carbon to Nitrogen ratio, CEC = cation exchange capacity, OM% = organic matter percent, Y1S1= year one site one, Y2S1= year two site one and Y2S2 = year two site two.

Main and Residual Effects of Bio-Slurry on Potato and Wheat Yield and Yield Components in the Potato-Wheat Cropping System

Plant Height and Number of Stem per Hill of Potato: Combined analysis of dry bio slurry with N rates significantly ($P < 0.05$) affected plant height (Table5).,The highest values of plant height (52.1 and 48.8cm) was achieved with addition of RNP and 25% DBS with 75% N recpectively as compare control and 50%DBS that gives minimum values (Table 5). Increasing of plant height in response to application of DBS with N fertilizer may be due to the improvement of physico- chemical properties of the soil that resulted increased water absorption and nutrient utilization of the plant.Moreover, application of DBS may deliver balanced micro and macronutrients as well as enhanced availability of plant nutrients,which would help to enhance the metabolic activity of microorganisms and improvement of plant growth.The result was in agreement with the findings of Melkamu *et al*., (2020) who observed longer potato plants when farm yared manure (13.5tha^{-1}) and NPS (245.1Kgha^{-1}) were applied. lt is also in confirmity with the findings of moniruzzaman *et al.,* (2009) who recorded maximum plant height of french bean from the application of 120 Kgha^{-1} N while, the minimum value was recorded from the control treatment. Another study conducted by Muhammad *et al.,* (2017) reflected that the highest value of mung bean plant height (78.08 cm) was recorded from the treatment which received 20:50 NP Kgha^{-1} with inoculation Rhizobium as compared to the lowest value 68 cm on control treatment. On the other hand, a combined analysis of variance revealed that DBS with N fertilizers had not significant effects on the stem numbers of potato per hill (Table 5). This may be due to the parameter more favors genetic makeup, physiological age and tuber seed size rather than a nutrient supplement. This finding was in line with finding of De La, Guillen, & Del Moral (1994) who reported shoot number of potato is mostly determined by the genetic makeup, the physiological age, and the size of potato seed tubers rather than mineral nutrients added in the form of fertilize

Plant height and spike length of wheat: After a year of DBS application, the residual dry bio-slurry significantly affected at ($P < 0.05$) both plant height and spike length of bread wheat (Table 5). The highest values of plant height and spike length of wheat (93.2 and 9.3 cm) were achieved by application of 100% DBS as compared to control, RN and 25% DBS

+75% N plots (Table 5). This might be from the positive effect of DBS for delivering balanced micro and macronutrients as well as enhanced availability of plant nutrients via improving of soil properties. The result agreed with the findings of Balasubramanian, *et al.*, 2016 who observed that the longer plants were in plots which received 75% cow dung with 25 % vermicompost than non-treated plots. the result was also in harmony with Bilkis *et al*., 2017 who recorded maximum plant height (101.5cm) of Boro rice from the application of 5tha^{-1} tricho compost while the minimum value (78.6) was recorded from control treatment .The result related to spike length also much with Pandey *et al*., 2020 who said that an application of 15tha^{-1} bio-gas slurry gives the highest spike length of wheat than checked treatment or control

Table 5. Main and residual effects of dry bio-slurry with equivalence N on growth parameters of potato and wheat over years

Treatments	Potato		Wheat	
	PH (cm)	NSPH	PH (cm)	SL (cm)
Control (0,0)	29.4^{de}	3.3	68.2d	6.7d
RN (138NKgha^{-1})	52.1^{a}	4.8	89.1c	8.5c
50% DBS (5.3tha^{-1})	28.2^{e}	4.4	92.3ab	8.7bc
100% DBS (10.6tha^{-1})	30.4^{de}	4.4	93.2a	9.3a
75%DBS(7.95tha^{-1})	36.6^{cd}	4.5	93.0ab	9.0abc
75%DBS+25%N (7.95tha^{-1} + 34.5 N Kgha^{-1})	41.9^{bc}	4.6	92.1abc	9.0abc
50%DBS+50%N (5.3tha^{-1}+69NKgha^{-1})	42.7^{bc}	3.7	90.2bc	8.9abc
25%DBS+75%N (2.65tha^{-1} + 103.5 N Kgha^{-1})	48.8^{ab}	4.0	90.2bc	8.7bc
100%DBS+25%N (10.6tha^{-1} + 34.5NKgha^{-1})	44.0^{bc}	4.3	92.1ab	9.0abc
100%DBS+50%N (10.6tha^{-1}+69NKgha^{-1})	47.1^{ab}	4.2	90.6abc	9.1ab
LSD	7.9	NS	3.0	0.5
CV%	20.9	30.1	3.6	6.6

*

dry bio slurry, N= Nitrogen, PH= plant height, NSPH = number of stems per hill, SL=spike length.

Number of Tubers per Plant and Total Tuber Yield of Potato: The combined analysis result in both years across sites indicates that yield and yield component of potato was significantly differ at ($P<0.05$) due to the effects of DBS with equivalence N (Table 6). The application of 75% N with 25% DBS gives the highest fresh total tuber yield (27.6tha^{-1}) while the lowest fresh tuber yield (8.6tha^{-1}) was observed at control. This might be due to the release of N from dry bio-slurry (DBS) and urea to soil solution. This condition created favorable environment for plant growth and development. Moreover, the application of

DBS could provide both macro and micro nutrients to plants. This study is in line with the findings of Yalemtsehay and Fisseha (2016) who revealed that, the supplying of recommended inorganic fertilizer (100Kg DAP, 50Kg Urea and 50Kg Murate potash per hectare) with 8tha^{-1}bio-slurry gives maximum (266.7 tha^{-1}) yield of cabbage as compare to the lowest (160 tha^{-1}) from the control treatment which gave about 66.7% yield increment due to the combination of both bio-slurry and recommended fertilizers over control. On the other hand the study done by Tsegaye *et al*., (2020) revealed that the lowest value of fresh shoot biomass and marketable yield of potato tuber were achieved from control while the highest values were obtained in plots that recieved both farm yard manure and recommended Nitrogen and Phosphorus.

Similarly, number of tubers per plant (NTPP) was significantly affected at (P<0.05) by the application of DBS with equivalence Nitrogen. Maximum value of NTPP was observed through the application of recommended NP followed by 100% DBS+50%N as compare to control treatment (Table 6). Even if the maximum value occurs at Recommended NP, the other dry bio slurry-Nitrogen combination treatments also give better yield advantage than control. This might be due to; the harmonization of organic and inorganic fertilizers for uptake and assimilation of nutrients to potato tubers by increasing the availability of native soil nutrients through higher biological activities. The result coincides with Suh *et al*., (2015) who observed that an application of combined organic and inorganic fertilizers increasing number of tubers per plant in treated plots than control or untreated plots. Another study done by Geremew *et al*., (2019) showed that an addition of dry bio-slurry with recommended Nitrogen Phosphorus increase 40 to 73% number of fruits per plant on tomato.

Grain Yield and Above Ground Biomass of Wheat: Yield and above ground biomass of wheat was significantly differed at (P<0.05) (Table 6) by residual effect of dry bio slurry. The application of 100% DBS gives the highest grain yield (3.85tha-1) while the lowest was recorded on control plots. Similarly, addition of 75%DBS gives the highest above ground biomass yield of wheat (9.59tha-1) as compare to control (Table 6). Releasing N from dry bio-slurry (DBS) to soil solution may make favorable for better plant growth and development. Moreover, it could be due to the release of both macro and micro nutrients from the dry bio-slurry in to soil solution that can be used by wheat; Beyond its positive effect on soil improvement by increasing the availability of native (inherit) soil nutrients. The result coincides with Pandey et al., 2020 who reported the supplement of 10 and15 tha-1 of significantly increased grain yield of wheat. Similarly study done by Shahid et al., 2016 revealed that he application of combined use of biogas slurry and chemical fertilizer @ 50% has a good strategy for sustainable crop yield by improving soil health. Beside to this, Mercy et al. (2022) also showed an addition of 100% dry bio-slurry increase stover and stalk yield of maize by 45.5 and 42.2% than control treatments through biological activities.

Table 6. Response of potato and wheat yield parameters for dry bio slurry and equivalence Nitrogen main and residual effect

Treatments	DBS on Potato		Wheat		
	NTPP	TYD tha^{-1}	GY (tha^{-1})	BY (tha^{-1})	1000 SW(g)
Control (0,0)	4.2^{e}	8.6^{d}	1.23d	3.11d	30.1
RN (138NKgha^{-1})	10.9^{a}	26.2^{ab}	3.17c	7.9c	32.4
50% DBS (5.3tha^{-1})	5.0^{de}	12.0^{cd}	3.33bc	8.37bc	32.8
100% DBS (10.6tha^{-1})	6.4^{cd}	13.4^{c}	3.85a	9.52ab	33.6
75%DBS(7.95tha^{-1})	7.3^{bc}	14.9^{c}	3.83a	9.59a	33.9
75%DBS+25%N (7.95tha^{-1} + 34.5 N Kgha^{-1})	6.5^{bcd}	23.0^{b}	3.47abc	9.08ab	33.2
50%DBS+50%N (5.3tha^{-1}+69NKgha^{-1})	6.4^{cd}	24.6^{ab}	3.47abc	8.53abc	32.1
25%DBS+75%N (2.65tha^{-1}+103.5NKgha^{-1})	6.8^{bc}	27.6^{a}	3.28bc	8.43abc	32.6
100%DBS+25%N (10.6tha^{-1}+34.5NKgha^{-1})	7.0^{bc}	25.2^{ab}	3.70ab	9.56a	33.0
100%DBS+50%N (10.6tha^{-1}+69NKgha^{-1})	8.1^{b}	26.8^{a}	3.59abc	9.06abc	32.4
LSD	1.7	3.7	0.5	1.2	NS
CV%	25.6	19.4	15.6	14.8	10.1

dry bio-slurry, N= Nitrogen, PH= plant height, NTPP = number of tubers per plant, TYD, = total tuber yield, GY= grain yield, BY= above-ground biomass and SW = seed weight.

Partial Budget Analysis: Net benefits were calculated by current fertilizer (urea) cost of 13.643 ETB Kg^{-1}, cost of DBS Kg^{-1} 0.2ETB, field price of potato was 6 ET Kg^{-1}, and cost of labor per man day in the area is 70 ETB. The marginal rate of returns was used to determine the acceptability of treatments with 100% as acceptable. This economic analysis indicated that most of treatments give high net benefit than control (Table 7). Addition of 50%DBS with 50%RN and 25%DBS with 75%RN gives (128613.6 ETB) and (144460.3 ETB) net benefit with marginal rate of return of 8461.1% and 4486.3% respectively. This indicate that for every 1ETB invested for 50%DBS with 50%RN and 25%DBS with 75%RN in field, farmers can be obtain an additional 84.611 and 44.863 ETB respectively (CIMMYT, 1988). All un-dominated treatment rates could be acceptable for potato producers in the study area. Even if enough un-dominated alternatives treatments have been available as choice for potato cultivation farmers in the study area. Application of 25%DBS with75%RN and 50%DBS and 50%N scored the most promising result 144460.3 and 128613.6 ETB net benefit respectively as compare to other treatments (Table 7). Therefore, the most economical rate for producers with low cost and higher benefit was 25%DBS with 75%RN. As second option farmers can be used 50%DBS with 50%RN for potato production because it also has promising net benefit with marginal rate of return

Table 7. Partial budget and marginal analysis of potato as affected by the application of dry bio-slurry with Nitrogen at Yilemana Densa District.

Treatments (RN +DBS Kgha^{-1})	10% Adjusted tuber Yield tha^{-1}	Total variable Cost ETBha^{-1}	Net Benefits ETBha^{-1}	MRR%
Control	7.74	0	46440	0
50% DBS	10.8	1760	63040	943.2
75%DBS	13.41	2640	77820	1679.6
100% DBS	12.06	3520	68840	D
50%DBS+50%N	22.14	4226.45	128613.6	8461.1
25%DBS+75%N	24.84	4579.675	144460.3	4486.3
100%DBS+25%N	22.68	4753.225	131326.8	D
RNP*	23.58	4932.9	136547.1	D
100%DBS+50%N	24.12	5986.45	138733.6	D
75%DBS+25%N	20.7	10873.23	113326.8	D

**RNP=percent of recommended Nitrogen and Phosphorus in Kg per hectare, DBS=dry bio-slurry in kilogram per hectare, MRR= marginal rate of return; D= is dominated treatments*

Conclusion and Recommendation

Yield and yield components of potato and wheat were significantly affected by main and residual effect of dry bio slurry with Nitrogen fertilizer. Both Potato and wheat was improved in yield and yield components as compared to control. Applied dry bio-slurry with N (Nitrogen) had a positive impact on plant height, number of tubers per plant, total tuber yield, grain yield and above ground biomass of potato and wheat. Addition of Dry bio-slurry with N rate in most treatments gives higher net benefit when compared to control. Among treatments used for this experiment undominated once gave better net benefit response with over 100% marginal rate of return than control in the main crop (potato). Therefore, resource poor producers or small scale farmers can benefited, if they apply these soil improvement rates depending on their convenience. Related to this application 50%DBS with 50% N gives a higher net benefit with 8461.1% marginal return. As a result, small-scale farmers could use it for potato-wheat production system in the area. In a mixed farming system like the Yilemana Densa district livestock production is a component of their livelihood; cattle manure and bio digester plantation is available. Hence, farmers should be encouraged to practice these fertilizers in order to produce vegetables and cereal crops in their back yards and nearest farms. Finally, similar studies should be done in different locations, crops, years and forms of bio-slurry in order to provide more evidence on the current findings and to give a concrete recommendation for crop production and soil health amendment in the study area.

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