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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON SOIL NUTRIENT STATUS, NUTRIENT UPTAKE, PROTEIN CONTENT AND YIELD OF CHICKPEA (*Cicer arietinum* L.) IN NORTH WESTERN ETHIOPIA

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ABSTRACT

Field experiment was conducted for two consecutive years (2015 and 2016) in north western Ethiopia to test the effect of Integrated Nutrient Management (INM) on soil nutrient status, nutrient uptake, protein content and yield of chickpea. The experiment comprised of 6 levels of INM treatments (unfertilized, 100% recommended dose of chemical fertilizer (RDF), 6 t compost ha^{-1} alone or combined with: 75, 50 and 25% RDF). The treatments were arranged in randomized complete block design with three replications. The result showed that application of full recommended dose of chemical fertilizer (RDF) or integrated application of compost along with 25, 50 or 75% RDF appreciably enhanced soil N and P status, seed and biomass yield, protein content and nutrient uptake of chickpea. Compared to the unfertilized treatment, application of 100% RDF alone; combined application of 6 t compost ha^{-1} along with 75, 50 and 25% RDF improved seed yield by 44, 38, 37.5, and 38% and seed protein content by 63, 61, 69 and 60%, respectively. All INM treatments produced statistically the same yield to that of RDF. Therefore, INM can be recommended as sustainable nutrient management option for production of chickpea by poor small holder farmers who cannot afford direct monetary expenditure in cash for chemical fertilizers and to maintain the soil health.

Key words: Chickpea, Compost, Fertilizer, Integrated nutrient management, Sustainability, Yield

INTRODUCTION

Chickpea is the third largest produced food legume globally after common bean and field pea (Gaur *et al*., 2010). It is also the third most cultivated pulse crop next to faba bean and haricot bean in Ethiopia, which is the seventh largest producer in the world and the first most important producer in Africa (MoA, 2010; CSA, 2015). Chickpea covers about 15% area and 17% total production of pulse crops in the country (CSA, 2015). Amhara and Oromia regional states covered 90% area and 92% production (Menale *et al*., 2009). In Amhara region, North Gondar zone is the top chickpea producer, which has 31% area and 37% production of pulse crops (CSA, 2015).

Chickpea is produced in such significant quantity because it is a multi-purpose crop. It has high protein content (20-22%). It is also rich in fiber, carbohydrates, vitamins, minerals (phosphorus, calcium, magnesium, iron and zinc) and β-carotene (Gaur *et al*., 2010). Hence, it reduces malnutrition and improves human health for the poor people who cannot afford livestock products. Moreover, the growing demand in both domestic and export markets provides a source of cash for smallholder producers in the country (Joshi *et al*., 2001). It grows mainly on vertisols of Ethiopia with residual moisture just immediately after the main rainy season (Getachew and Woldeyesus, 2012). Thus it plays a significant role in intensifying the use of scarce land resources through sequential cropping (Joshi *et al*., 2001). However, its national average yield of 1.91 t ha^{-1} (CSA, 2015) is very low compared to its potential yield of 4 t ha^{-1} (Asnake, 2014). Low soil fertility is one of the major factors responsible for low yield of crops including chickpea. Inadequate supply of nutrients aggravates nutrient depletion of soils (Gruhn *et al*., 2000). High cost of chemical fertilizers coupled with the low affordability by small holder farmers is the biggest obstacle for fertilizer use in Ethiopia (Tolessa *et al*., 2002). Specifically, the use of fertilizer for chickpea by farmers is negligible. According to CSA (2015), fertilizer was applied only to 6.75% of cultivated land area of chickpea in Ethiopia. Our previous chickpea farm assessment result (unpublished) further indicated that all respondent farmers around the study location asserted that they did not apply any fertilizer to chickpea. This scenario drives the use of organic manures (Tolessa *et al*., 2002), which are environmentally friendly and at the same time improves and maintains soil fertility. However, sole application of organic manure is constrained by access to sufficient organic inputs, low nutrient content of manures, high labor demand for preparation and transportation. These constraints can be solved by integration of organic and inorganic sources, which can improve and sustain crop yields while improving soil fertility status (Getachew *et al.*, 2014). Though chickpea meets 80% of its nitrogen requirement from symbiotic nitrogen fixation, application of fertilizer is important as starter until the N-fixation system operates well (Roy *et al.*, 2006; Gaur *et al.*, 2010). The crop also requires balanced and optimum amounts of other nutrient elements such as phosphorus, potassium, sulfur and micro nutrients. Research results in other places indicated the improvement of chickpea yield due to integrated nutrient management (Nandania, 2005; Sarawad *et al.*, 2005; Arya *et al.*, 2007; Das *et al.*, 2008; Gudadhe *et al.*, 2015; Sohu *et al.,* 2015; Dhakal *et al.*, 2016). So, it is necessary to apply balanced nutrients from easily available sources of organic and inorganic fertilizers to sustainably improve the productivity of chickpea (Singh and Diwakar, 1995). Integrated nutrient management is the way towards sustainable development for developing countries like Ethiopia (Devi *et al.*, 2007). However, information on integrated nutrient management of chickpea is scanty in the country and exclusively absent in the study area. Therefore, the experiment was initiated with the objective to test the effect of integrated nutrient management on soil nutrient status, nutrient uptake, protein content and yield of chickpea.

MATERIALS AND METHODS

Description of the Experimental Site

Field experiment was conducted at College of Agriculture and Rural Transformation of University of Gondar, northwestern Ethiopia. It is located at longitude of 12°36'N 37°28'E and has an altitude of 1977 meters above sea level (GPS reading). Long term climate data (37 years) of the study area indicated that the minimum and maximum temperatures are 12.70 °C and 27.30 °C, respectively. The mean annual average rainfall is 1843 mm. As indicated in table 1, the soil of the experimental area is clayish in texture with particle size distribution of 27.28% sand, 31.28% silt and 41.44% clay. Soil analysis before land preparation for chickpea sowing in both 2015 and 2016 growing season showed that the soil of the experimental site had very low nitrogen, low organic matter and low available phosphorus and high exchangeable potassium according to the soil nutrient status rating methods of Olsen *et al.* (1954), Metson (1961), Berhanu (1980) and Havlin *et al.* (1999), respectively. The exchangeable potassium of the soil was high according to the rating of Metson (1961) and very high cation exchange capacity (CEC) according to the suggestion of Landon (1991). The result showed that the soil in the study area has no potassium deficiency problem and has very high CEC to retain cations. The very high CEC may be attributed to the high percentage of clay (Table 1).

Table 1: Selected properties of compost and soil in the experimental field before seed sowing

Parameters	Soil		Compost	
	2015	2016	2015	2016
pH	7.95	7.91	7.14	6.16
Available Phosphorus (ppm)	5.97	5.20	234	219
Organic carbon (%)	0.67	0.75	7.7	10.00
Organic matter (%)	1.15	1.20	13.24	17.24
Total nitrogen (%)	0.058	0.062	0.67	0.87
Carbon: nitrogen	11.17	10.71	11.5	11.53
Electric conductivity (mS/cm)	0.21	0.22	-	-
Exchangeable K (cmol/kg)	1.07	1.06	-	-
Cation exchange capacity (cmol/kg)	57.3	56.5	-	-
Soil particle	Sand	Silt	Clay	Textural Class
Proportion (%)	27.28	31.28	41.44	Clay

Treatments and Design

The experiment was conducted for two consecutive years (2015 and 2016). The treatments consisted of 6 levels of integrated nutrient management proportions (unfertilized, 100% RDF, 6 t ha^{-1} compost alone, 6 t compost ha^{-1} combined with: 75, 50 and 25% RDF), which were arranged in randomized complete block design (RCBD) with three replications. The blanket recommended dose of chemical fertilizer for chickpea (RDF) is 100 kg Di-ammonium phosphate (DAP) (18% N and 46% P_2O_5) (MOA, 2010). The equivalent of 100, 75, 50 and 25% RDF is 18/46, 11.5/34.5, 9/23, and 4.5/11.5 kg N/P_2O_5 ha^{-1}, respectively. The size of each plot was 8.4 m^2 (2.8 m wide x 3 m long). The spacing between blocks and plots was 1.5 and 1 m, respectively. Each plot had 7 rows, of which 2 periphery rows at both ends of the plots were considered as border rows. Two rows next to the border rows at both sides were used for destructive sampling. The size of the net plot area was 2.4 m^2 (1.2 m x 2.2 m).

Soil and Compost Sampling and Analysis

Before land preparation and division into plots, soil samples were collected randomly from 3 spots of the experimental site within 0-30 cm depth using augur. Soil texture, organic carbon content, total N, available P, exchangeable K, pH, electrical conductivity (EC) and cation exchange capacity (CEC) were determined following standard laboratory procedures. Soil samples were also collected from each plot after chickpea harvest at 0-30 cm depth to determine pH, organic carbon, total N and available P contents.

Particle size distribution analysis was done by hydrometer method (FAO, 2008). The pH was determined using 1:2.5 soil to water ratio using a glass electrode attached to a digital pH meter (FAO, 2008). Soil organic carbon (OC) was determined by volumetric method (Walkley and Black, 1934). Organic matter content was calculated as OM (%) = OC x 1.72. Total nitrogen was analyzed by Micro-Kjeldhal digestion method using sulphuric acid (Jackson, 1962).

Available phosphorus was determined using spectrophotometric method of Olsen *et al.*, (1954). Compost sample was also analyzed for organic carbon, pH, available P and total N as indicated in table1.

Field Management

The land was plowed three times. The first tillage was done at the beginning of the main rainy season. The second and third plowing were done a week before and at sowing time using oxen plow. *Habru* chickpea variety was used as a test crop. It is among the improved varieties that are resistant to diseases in addition to giving high yield (ICARDA, 2010). Two seeds were sown in a hole at a spacing of 10 cm between seeds and 40 cm between rows for each plot. Recommended agronomic practices, except the treatments, were uniformly followed throughout the growing season of the crop as per the recommendation of extension package for the crop. The sources of fertilizers were compost and DAP (Di-ammonium phosphate). Compost was applied on dry weight basis and incorporated into the soil a week before planting. All doses of DAP were applied at planting. Weeding was done twice in the growing season. The first weeding was done one month after seed emergence and the second was followed two weeks later.

Data Collection and Statistical Analysis

At physiological maturity, five plant samples were taken and partitioned into grain and straw, which were separately oven-dried at 70 ºC to a constant weight, ground to pass a 1 mm sieve and taken to laboratory for analysis of nitrogen and phosphorus content. The plant tissues analysis for total nitrogen and phosphorus content were done by Micro-Kjeldahl and wet digestions method, respectively as described in FAO (2008). The total N and P content were multiplied with respective dry straw and grain yield (kg ha^{-1}) to determine total N and P uptake in straw and grain. The seed protein content was estimated by multiplying seed nitrogen content with 6.25 (Nelson and Sommers, 1973; Yagmur and Kaydan, 2011). Grain and biomass yields were recorded by harvesting the chickpea in the net plot area of each plot. After harvesting, the total biomass was air dried and yield was measured using weighing balance. It was then trashed on a mat to record seed yield of each plot. The seed moisture content was measured using seed moisture tester and adjusted to 13%.

All the relevant data collected from the experimental plots were subjected to single factor analysis of variance (ANOVA) using the SAS statistical computer software program. When the treatment effects were significant, mean differences were separated following least significant difference (LSD) tested at 5% probability level.

RESULT AND DISCUSSION

Biomass Yield

The effect of treatments on biomass yield was significant in both years (Table 2). During both seasons the recommended chemical fertilizer (18 kg N and 46 kg P_2O_5 ha^{-1}) produced significantly maximum biomass yield and it was at par with combined application of 6 t ha^{-1} compost along with 25 and 50% RDF, while the lowest value was recorded from the unfertilized plots. The result showed that chemical fertilizer alone or in combination with compost can produce massive above ground biomass. The improvement due to INM and chemical fertilizer application might be due to supply of nutrients that helped for vigorous plant growth. This result is in agreement with the results of other researchers (Nandania, 2005; Kumar *et al*., 2014; Dhakal *et al*., 2016). Significant improvement in biological yield was observed from RDF + 5 t ha^{-1} vermi-compost + *Rhizobium* + phosphorus solubilizing bacteria (PSB) (Kumar *et al*., 2014) and RDF + 20 t farm yard manure (FYM) ha^{-1} + *Rhizobium* + phosphorus solubilizing bacteria (PSB) (Nandania, 2005) on chickpea. Similar result was observed by Dhakal *et al.* (2016) with application of 75% RDF + 2.5 t ha^{-1} vermi-compost + *Rhizobium* + PSB on green gram (*Vigna radiata* L.).

Table 2. Effect of INM on biomass and seed yield of chickpea

Treatments	Biomass yield (q ha^{-1})			Seed yield (q ha^{-1})		
	2015	2016	Mean	2015	2016	Mean
Unfertilized/Control	46.92^{c}	49.65^{b}	48.29^{c}	23.71^{c}	23.20^{b}	23.46^{b}
100 % RDF	72.552^{a}	66.20^{a}	69.36^{a}	35.16^{a}	32.54^{a}	33.86^{a}
6 t C ha^{-1} + 75 % RDF	58.87^{bc}	58.43^{ab}	58.65^{b}	31.24^{b}	33.62^{a}	32.43^{a}
6 t C ha^{-1} + 50 % RDF	63.29^{ab}	70.95^{a}	67.12^{a}	31.00^{b}	33.50^{a}	32.25^{a}
6 t C ha^{-1} + 25 % RDF	69.42^{ab}	69.12^{a}	68.77^{a}	31.74^{b}	32.97^{a}	32.36^{a}
6 t compost (C) ha^{-1}	49.79^{c}	50.79^{ab}	50.29^{c}	24.84^{c}	24.69^{b}	24.76^{b}
F-test	**	*	**	**	*	**
LSD ($p < 0.05$)	12.24	13.77	8.19	2.90	6.93	3.42
CV (%)	11.13	12.43	11.44	5.29	12.66	9.73

RDF= Recommended Dose of Chemical Fertilizer, C = compost, q = quintal, LSD = Least Significant Difference, CV= Coefficient of Variation. Means followed by the same letter in a column are not significant.

Seed Yield

The two years result showed that the effect of fertilizer treatments on seed yield was highly significant ($p < 0.01$). The result revealed that application of RDF alone or integrated application of 6 t compost ha^{-1} along with 25, 50 or 75% RDF appreciably improved the yield of chickpea. In the first year, application of 100% RDF (18 kg N and 46 kg P_2O_5 ha^{-1}) produced significantly maximum seed yield (35.16 q ha^{-1}), followed by INM treatments. During second season, application of 100% RDF and INM treatments were statistically at par and significantly improved seed yield of chickpea compared to the unfertilized treatment. In both years, the lowest yields were recorded from the unfertilized treatment (23.71 q ha^{-1} in 2015 and 23.20 q ha^{-1} in 2016), which were at par with application of compost alone. The two years combined mean result showed that application of 100% RDF produced maximum yield (33.86 q ha^{-1}), which was statistically similar with INM treatments (Table 2). Application of 100% RDF; 6 t compost ha^{-1} along with 75, 50 or 25% RDF increased seed yield by 44, 38, 37.5, and 38%, respectively compared to the unfertilized plots. In terms of sustainability, INM has long-term positive impacts on soil health and crop productivity compared to sole application of chemical fertilizer (Getachew *et al.*, 2014). The present result agrees with the findings of others (Nandania, 2005; Sarawad *et al.*, 2005; Arya *et al.*, 2007; Das *et al.*, 2008; Gudadhe *et al.*, 2015; Sohu *et al.,* 2015; Dhakal *et al.*, 2016), who reported significant improvement of chickpea yield with application of integrated use of organic and inorganic fertilizers. Das *et al.* (2008) found significantly higher yield of chickpea with application of 60 kg P_2O_5 ha^{-1}. Other researchers recorded maximum seed yield of chickpea with application of INM at different proportions such as RDF + 5 t ha^{-1} vermi-compost + *Rhizobium* + PSB (Kumar *et al.*, 2014); 50% RDF(18-36-20 kg NPK ha^{-1}) + 20 t ha^{-1} poultry manure (Sohu *et al.,* 2015); RDF + 20 t farm yard manure (FYM) ha^{-1} + *Rhizobium* + PSB (Nandania, 2005); 75 kg P_2O_5 ha^{-1} (Memon *et al.*, 2016); RDF+ vermi-compost 2.5 t ha^{-1} compost (Kumar and Pandita, 2016); or application of 15 kg N through compost + 20 kg N through chemical fertilizer (Sarawad *et al.*, 2005). Hailu (2010) also observed significantly higher grain yield of faba bean with application of 6.4 t ha^{-1} compost in Tigray region, western Ethiopia.

Nitrogen Uptake

The effect of INM on nitrogen uptake by grain and straw was highly significant ($p < 0.01$) in the two years (Table 3). In the first season, the maximum amount of nitrogen taken up by the grain (127.96 Kg ha^{-1}) were recorded with application of 100% RDF (18 Kg N ha^{-1} and 46 P_2O_5 Kg ha^{-1}) followed by application of INM treatments, which were at par to each other, while the lowest value (50.22 Kg ha^{-1}) was recorded from the unfertilized plot. The second season result indicated that application of chemical fertilizer and INM treatments were statistically at par and significantly improved grain N uptake compared to the unfertilized treatment. The two years mean result also indicated that application of chemical fertilizer and INM treatments significantly improved straw N uptake.

Table 3.Effects of integrated nutrient management on nitrogen uptake

	Grain N uptake (Kg ha^{-1})			Straw N uptake (Kg ha^{-1})		
Treatments	2015	2016	Mean	2015	2016	Mean
Unfertilized/Control	50.22^{d}	51.02^{b}	50.62^{c}	9.52^{c}	8.56^{c}	9.04^{c}
100% RDF	127.96^{a}	110.46^{a}	119.21^{a}	21.70^{a}	15.80^{ab}	18.75^{a}
6 t C ha^{-1} + 75% RDF	112.33^{b}	112.70^{a}	112.51^{a}	14.84^{b}	13.23^{bc}	14.03^{b}
6 t C ha^{-1} + 50% RDF	115.65^{b}	118.77^{a}	117.21^{a}	18.05^{ab}	19.20^{a}	18.62^{a}
6 t C ha^{-1} + 25% RDF	114.09^{b}	108.95^{a}	111.53^{a}	19.87^{ab}	19.05^{a}	19.46^{a}
6 t compost (C) ha^{-1}	67.56^{c}	63.66^{b}	65.61^{b}	10.45^{c}	10.90^{c}	10.67^{c}
F-test	**	**	**	**	*	**
LSD ($p < 0.05$)	8.88	22.45	11.04	5.83	4.72	3.44
CV (%)	5.00	13.10	11.30	20.36	17.96	19.25

RDF= Recommended Dose of Chemical Fertilizer, C = compost, LSD = Least Significant Difference, CV= Coefficient of Variation. Means followed by the same letter in a column are not significant, C = compost

The result implies that application of recommended chemical fertilizer (18 Kg N ha^{-1} and 46 P_2O_5 Kg ha^{-1}) or integrated application of 6 t compost with 25, 50 or 75% of the recommended chemical fertilizer is helpful in chickpea plant to uptake more nitrogen that helps for the improvement of its productivity. The present result agrees with observation of others (Arya *et al.*, 2007; Singh *et al.*, 2015; Balai *et al.,* 2017). In other works, significantly maximum N uptake was observed in the application of 50% recommended dose of chemical fertilizer (20 kg N and 40 kg P ha^{-1}) + farm yard manure (FYM) at 5 t ha^{-1} + biofertilizers (*Rhizobium* + PSB) (Arya *et al.*, 2007); chemical fertilizer alone (60+40+5 kg/ha P_2O_5 +S + Zn) (Singh *et al.*, 2015), or 60 kg P_2O_5 ha^{-1} (Balai *et al.,* 2017).

Phosphorus Uptake

The effect of INM on phosphorus uptake by grain and straw was highly significant ($p < 0.01$) (Table 4). In the first season, the highest grain phosphorus uptake by grain (14.26 Kg ha^{-1}) and straw (9.59 Kg ha^{-1}) were obtained with application of 100% RDF (18 Kg N ha^{-1} and 46 P_2O_5 Kg ha^{-1}), while the lowest values (7.87 Kg ha^{-1} by grain and 3.52 Kg ha^{-1} by straw) were recorded from the unfertilized plots. During the second season, in comparison with the unfertilized treatment, 100% RDF or integrated nutrient management treatments resulted in significantly high phosphorus uptake by the grain and they were at par to each other. The two years mean result indicated that application of 100% RDF or INM treatments significantly improved phosphorus uptake by both plant parts. The present result is in agreement with previous works (Arya *et al.*, 2007; Singh *et al.*, 2015). In other works, significantly maximum P uptake was observed with application of 50% recommended dose of chemical fertilizer (20 kg N and 40 kg P ha^{-1}) + FYM at 5 t ha^{-1} + biofertilizers (*Rhizobium* + PSB) (Arya *et al.*, 2007) and with chemical fertilizer alone (60+40+5 kg/ha P_2O_5 +S + Zn) (Singh *et al.*, 2015).

Table 4. Effects of INM on phosphorus uptake of chickpea

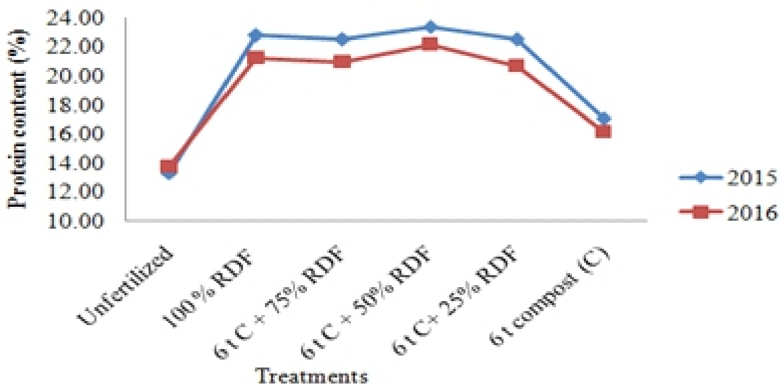
	Grain P uptake (Kg ha^{-1})			Straw P uptake (Kg ha^{-1})		
Treatments	2015	2016	Mean	2015	2016	Mean
Unfertilized/Control	7.87^{c}	7.89^{b}	7.88^{c}	3.52^{c}	4.48^{c}	4.00^{d}
100% RDF	14.26^{a}	12.90^{a}	13.58^{a}	9.59^{a}	8.24^{a}	8.91^{a}
6 t C ha^{-1} + 75% RDF	13.32^{a}	13.44^{a}	13.38^{a}	6.67^{b}	5.36^{bc}	6.02^{bc}
6 t C ha^{-1} + 50% RDF	11.39^{b}	12.30^{a}	11.85^{b}	6.47^{b}	7.91^{a}	7.19^{b}
6 t C ha^{-1} + 25% RDF	11.49^{b}	12.59^{a}	12.04^{b}	7.46^{ab}	7.23^{ab}	7.35^{b}
6 t compost (C) ha^{-1}	8.87^{c}	9.13^{b}	9.00^{c}	5.27^{bc}	4.99^{c}	5.12^{cd}
F-test	**	**	**	**	*	**
LSD ($p < 0.05$)	*1.04*	*2.64*	1.33	*2.52*	2.12	1.52
CV (%)	5.08	12.78	9.93	21..32	18.30	19.90

RDF= Recommended Dose of Chemical Fertilizer, C = compost,LSD = Least Significant Difference, CV= Coefficient of Variation. Means followed by the same letter in a column are not significant.

Seed Protein Content

Single or combined application of compost and chemical fertilizer treatments improved the seed protein content of chickpea compared to the control (Figure 1).The protein content is slightly higher in 2015 compared to 2016 due to higher nitrogen concentration in seeds in the first season than the second one. Compared to the unfertilized treatment, application of 100% RDF, 6 t compost, combined application of 6 t compost along with 75, 50 and 25% RDF increased seed protein content by 63, 23, 61, 69 and 60%, respectively.

The protein improvement could be due to enhancement of nitrogen concentration in seeds with combined and sole application of compost and chemical fertilizer. The result is in agreement with other findings such as in the works of Nandania (2005), Namvar *et al.,* (2011) and Dhakal *et al.*, (2016), who reported high protein content of chickpea with application of chemical fertilizer or INM treatments.



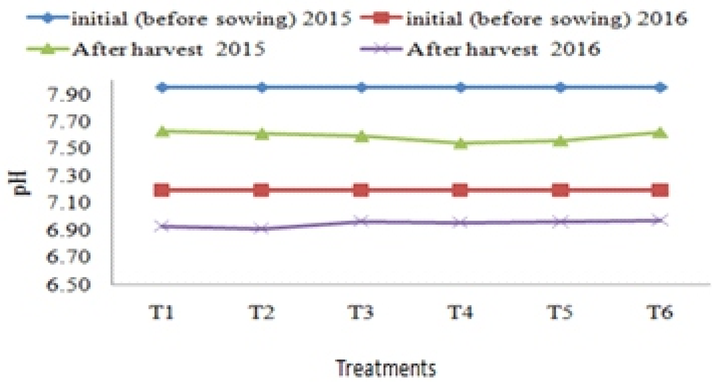
RDF= Recommended Dose of Chemical Fertilizer, C = compost

Figure1. Effects of INM seed protein content of chickpea in two seasons

Soil Reaction (pH) and Nutrient Status of Soil after Chickpea Harvest

Soil pH

Analysis showed that the pH was decreased from the initial value of 7.95 to a range of 7.68 -7.55 in 2015 and to a range of pH 7.64 -7.55 in 2016 after chickpea harvest (Figure 2). The decrease in pH could be because of the intermediate acids produced during organic decomposition of chickpea leaf fall and application of compost and/or chemical fertilizer.

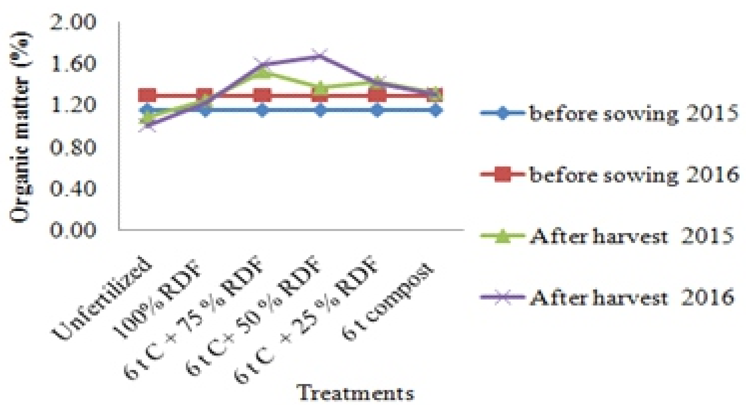


RDF= Recommended Dose of Chemical Fertilizer, C = compost

Figure 2. Soil pH before sowing and after harvest of chickpea in two seasons

Soil organic matter

Compared to the unfertilized treatments, fertilizer treatments slightly enhanced the effect of organic matter content (Figure 3). Combined application of compost along with 25, 50 or 75% RDF improved the soil organic matter content. The present result agrees with other research results (Sarawad *et al.* 2005; Gudadhe *et al*, 2015; Dhakal *et al.*, 2016), who found improvement of organic matter with sole or combined application of organic fertilizer and chemical fertilizer in chickpea field.

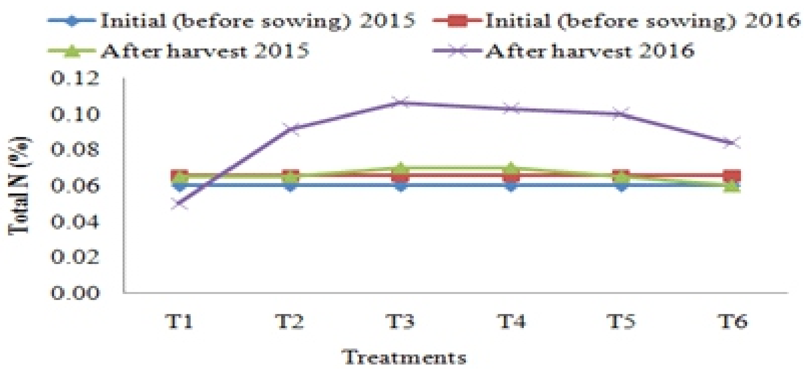


RDF= Recommended Dose of Chemical Fertilizer, C = compost

Figure 3. Soil organic matter before sowing and after harvest of chickpea at two years

Total Nitrogen

After harvesting of chickpea, the total nitrogen content of fertilized plots were slightly improved due to single or combined application of chemical fertilizer and compost but the value of unfertilized plots tended to decrease compared to the value initially before planting (Figure 4). The slight increment in the nitrogen content by combined application of compost along with 25, 50 or 75% RDF might be due to the addition of nitrogen through application of organic and inorganic fertilizers (Sarawad *et al.* 2005). The present result is in agreement with other research results (Sarawad et al. 2005; Arya *et al.*, 2007; Gudadhe *et al*, 2015; Dhakal *et al.*, 2016), who observed enhanced soil nitrogen content with sole or combined application of organic and inorganic fertilizers after chickpea harvest.

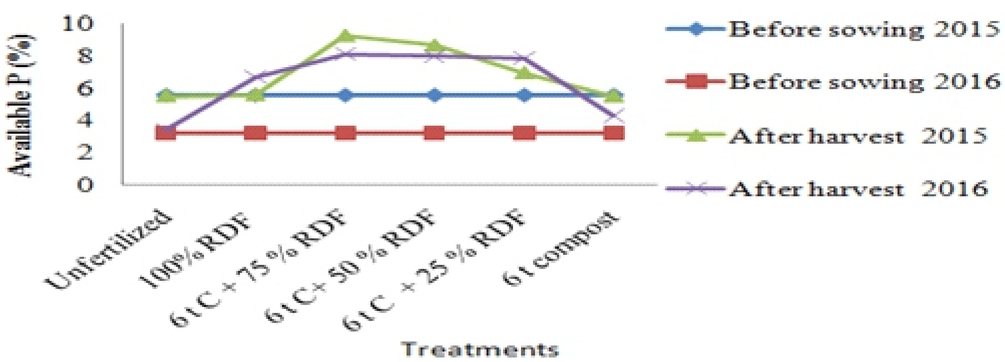


T_1= unfertilized/Control, T_2 = 100% RDF (Recommended chemical fertilizer), T_3= 6 t compost ha^{-1} + 75% RDF, T_4= 6 t compost ha^{-1} + 50% RDF, T_5= 6 t compost ha^{-1} + 25% RDF and T_6 = 6 t compost ha^{-1}

Figure 4. Effect of INM on soil N content after chickpea harvest at both years.

Soil Phosphorus Content

Laboratory analysis of the soil after chickpea harvest showed that combined application of compost along with 25, 50 or 75% RDF enhanced improved available phosphorus content compared to the initial soil test before sowing of chickpea (Figure 5). The improvement of soil phosphorus with application of INM could be because of the intermediate acids, produced during organic manure decomposition, might have solubilized the fixed forms of phosphorus in the soil to be available (Dhakal *et al.*, 2016). The improvement due to application of chemical fertilizer could be attributed to the residual effect of the phosphorus. The present result is in agreement with other research results (Sarawad *et al.* 2005; Arya *et al.*, 2007 ; Gudadhe *et al.*, 2015; Dhakal *et al.*, 2016), who observed higher available P in the soil with sole or combined application of organic and inorganic fertilizers after chickpea harvest.



RDF= Recommended Dose of Chemical Fertilizer, C = compost

Figure 5. Effect of INM on soil available P content after chickpea harvest at both seasons.

CONCLUSION AND RECOMMENDATION

Mean result of the two years' study revealed that application of full dose of recommended chemical fertilizer (RDF) or integrated application of compost along with 25, 50 or 75% RDF appreciably enhanced soil N and P status, seed and biomass yield, protein content and nutrient uptake of chickpea. Compared to the unfertilized treatment, application of 100% RDF alone; combined application of 6 t compost ha^{-1} along with 75, 50 and 25% RDF improved seed yield by 44, 38, 37.5, and 38% and seed protein content by 63, 61, 69 and 60%, respectively. Integrated nutrient management (INM) produced statistically the same yield to that of RDF. Moreover, INM sustainably improves chickpea productivity through improving soil fertility and ultimately human health. Therefore, INM can be recommended as sustainable nutrient management option for production of chickpea by poor small holder farmers who cannot afford direct monetary expenditure in cash for chemical fertilizers, while maintaining the soil in good state. The result gives baseline information on integrated nutrient management of chickpea in the study area.

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