Soil Fertility, Yield and Nodulation Status of Chickpea *(Cicer arietinum L.)* in Gondar Zuria District, North Western Ethiopia

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Abstract

Chickpea is the top most produced pulse crop in North Gondar Zone. However, it is marginally managed crop. Farm assessment was conducted in 2015/16 growing season in two peasant administrations areas of Gondar administrative district. Twenty chickpea farms were assessed to gather information on soil nutrient, nodulation and yield of chickpea. The result showed that the soil of all the assed chickpea farms had low organic matter (0.79 - 1.73%), very low nitrogen (0.04 - 0.09 %) and low to very low available phosphorus (3.24 - 12.55 ppm) contents. The number of nodules was moderately available in the soil (16 - 23.33 plant^{-1}). The average yield of chickpea was very low (1.96 t ha^{-1}) compared to its potential yield (4 t ha-1). The low yield in the assessed farms could be the result of low soil nutrient status. Since farmers are cultivating chickpea on soils which are poor in organic matter, nitrogen and phosphorus nutrient contents, measures should be taken to maintain the soil fertility status of the farms in the study area. Therefore, it is essential to undertake research on site specific nutrient management options to enhance sustainable productivity of chickpea.

Key Words: Chickpea, assessment, Soil fertility, nodulation, yield

Introduction

Chickpea is the third largest produced food legume in Ethiopia (CSA, 2015), which is the seventh largest producer in the world and the first most important producer in Africa (MoA, 2010). The crop covers 15.38 % area and 17.17 % total pulse production in 2014/15 growing season in the country. Amhara and Oromia are the two major chickpea producing regional states, which cover 95% area and 96% production. North Gondar is the top chickpea producer zone, which covers 31% farm area and 36.70% total chickpea production of Amhara region (CSA, 2015).

Chickpea is produced in such significant quantity because it is a multi-purpose crop. Nutritionally, it is a source of protein for millions of poor people. It has high protein content (20-22%). It is also rich in 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. It also increases livestock productivity as its residue is rich in digestible crude protein compared to cereals. Moreover, the growing demand in both domestic and export markets provides a source of cash for smallholder producers in the country (Menale Kassie *et al.,* 2009).

It also plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. It meets 80 % of its nitrogen requirement from biological fixation. It leaves substantial amount of residual nitrogen for subsequent crops and adds plenty of organic matter that improve soil fertility status (Gaur *et al.,* 2010). Hence it saves fertilizer costs in subsequent crops (Joshi *et al.,* 2001). Its production cost is low as it can withstand drought conditions by extracting water from deeper layers in the soil profile (Asnake Fikre, 2014). Moreover, it intensifies the use of scarce land resources through sequential cropping using residual moisture (Joshi *et al.,* 2001).

Generally, it is marginally managed crop by Ethiopian farmers. However, local specific information on production status of chickpea under farmers' management practices is limited around the study area. The objective of the field assessment was, therefore, to gather information on soil nutrient, nodulation and yield status of chickpea under farmers' management practices in two peasant administrative areas of north Gondar.

Materials and methods

Description of the Study Area

Farm assessment was conducted in 2015/16 growing season in two adjacent peasant administrations (PA's), locally known as Lay Teda Kebele and Tach Teda Kebele. The sites are among the rural areas of Gondar town administrative district, which is found in North Gondar Zone of the Amhara Region, North Western Ethiopia. The site is located at latitude of 12°36′N and longitude of 37°28′E. The altitude range of the area is 1800–2600 meters above sea level. The long term climate data (35 years) showed that the study area receives on average total annual rainfall of 1843 mm. On average the minimum and maximum daily temperature vary between 10.60-15.40°c and 20-31.83°c, respectively (national metrology agency, Bahirdar branch). According to the district annual production evaluation report of 2015/16 cropping season (unpublished), the major cereal crops in the rural areas of the district are maize, sorghum, teff, wheat, barley and finger millet. The most important pulse crops are faba bean and chickpea. Grass pea is also produced in small areas. The area is categorized under Woyna dega agro climatic zone with altitude of about 1800-2100 meters above sea level. The soils are mainly red and black. The mean daily temperature and mean annual rainfall ranges from 25-30 degree Celsius and 1800-2000 mm, respectively. The topography of the area is 15% hill, 50% plain and 35% mountainous (Haimanot Atinkut, 2016).

Assessment Methods of Chickpea Farms

Twenty chickpea farms were randomly selected in the study areas to take crop and soil samples. Samples were collected at two chickpea crop stages in 2015/16 growing season. Plant samples were collected from 20 selected farms (10 from each PA's) at days to 50% flowering and days to 90% physiological maturity. At 50% flowering stage, 10 plant samples were randomly taken across selected chickpea farms. The whole root systems of the plants were carefully uprooted using pickax and washed. The nodules were removed from the plant roots, counted, dried, weighed and recorded. At 90% physiological maturity, 10 plants were also taken on the same chickpea farms to collect data on yield of chickpea. Since the seeds of all the assessed farms were sown in broad cast method, the numbers of plant stands per unit area were estimated by randomly throwing 0.25 m^2 (0.5 x 0.5 m) wooden made square on five spots. In each chickpea farm, soil samples were taken within 0-30cm soil depth using augur.

Soil samples were collected within 0-30 cm soil depth using augur from the same spots of each farm where plant samples were collected during 50% flowering stage of chickpea. The collected soil samples at each spot were mixed together in a bucket and 1 kg homogenous composite sample was prepared. The samples were then labeled, bagged and sent to Gondar soil laboratory, where samples were air dried, milled and passed through 2 mm sieves.

Analysis of the result was performed for soil texture, pH, total nitrogen (TN), available P, exchangeable potassium and organic matter content. The soil analysis result of each parameter was qualitatively rated based on different methods of soil nutrient status categories.

Statistical Analysis

The data, which were collected from survey and field assessment, were analyzed using SPSS (statistical package for social scientist) version 20 software (SAS, 2004). Results were presented in descriptive statistics such as frequency distributions, percentages, mean, coefficient of variation and standard deviations.

Results and Discussion

Soil pH

Results of the soil analysis indicated that the soil texture of soil were either clay or clay loam. Globally, vertisols are mostly neutral to alkaline in reaction (Fassil Kebede and Charles Yamoah, 2009). Generally, pH is a major driver of soil fertility. The pH of the soil varied from 6.84 to7.41, with average value of 7.16, which is suitable for chickpea production.

According to the rating of EthioSIS (2016), 90% of the studied chickpea farms fall under neutral (pH= 6.6-7.3) and the remaining 10% were moderately alkaline (pH= 7.4-8.4) (Table 2). In line with the present result, the soil reaction varied from neutral (7.20) to slightly alkaline (7.90) in vertisols of Ethiopian highlands (Hillette Hailu *et al.,* 2015). Similarly, the pH values of vertisol profiles were within 7.25 in Shire to 8.66 in Adwa districts of Tigray region (Fassil Kebede and Charles Yamoah, 2009).

Soil Organic Matter Content

The soil organic matter content of the soil varied from 0.79 - 1.73% with average value of 1.40% (Table 1). The soil had low organic matter content in accordance with Metson (1961) who rated OC between 1-2%. This could be because of the repeated cultivation of the lands without replenishment of organic sources such as crop residue, green manure, compost and farm yard manures. Similar results were reported from Tigray region (Fassil Kebede and Charles Yamoah, 2009). The organic matter contents were very low (1.6%) to low (3.20%) on the surface soils (Hillette Hailu *et al.*, 2015).

Total Nitrogen Content

The total soil nitrogen content was within the range of 0.04 - 0.09% with average value of 0.07 (Table 1). All the assed chickpea farms had very low nitrogen content (Table 2) based on the soil nitrogen level rating method of Landon (1991), who categorized the total N content of the soils as very high (1.0 %), high (0.5-1.0%), medium (0.2-0.5%), low (0.1-0.2%) and very low (<0.1%). The result indicated that the soils of chickpea farms are deficient in nitrogen content, which is vital for photosynthesis and growth of the plant. The nitrogen content in the present result is more severe than the nitrogen status in vertisols of Wukuro (0.05%) and Adwa areas (1.00%) of Tigray region (Fassil Kebede and Charles Yamoah, 2009) and different sites of Ethiopian highlands (0.10 to 0.20%) (Hillette Hailu *et al.*, 2015).

Available Phosphorus

The available soil phosphorus contents of the assessed chickpea farms ranged within 3.24 - 12.55 ppm with average value of 5.85 ppm (Table 1). As shown in table 2, 50% of the farms had very low and the remaining half had low available soil phosphorus content according to rating of Olsen *et al.* (1954), who grouped as very low, low, medium and high when the value is < 5, 5-15, 15-25 and > 25 mg kg-1 of soil, respectively. This implies that soil phosphorus is deficient in chickpea farms of the study area.

Study by Fassil Kebede and Charles Yamoah (2009) revealed that the available P content is very low, ranging between 0.43 ppm in Shire to 1.95 ppm in Adwa districts of Tigray. It was found to be deficient (3.8mg kg−1) in 80% and medium (14.6 mg kg−1) in 20% of the samples in vertisols of Ethiopia highlands (Hillette Hailu *et al.*, 2015). Generally, phosphorus is the most limiting nutrient next to N (Fassil Kebede and Charles Yamoah, 2009).

Exchangeable Potassium

The exchangeable potassium content of assessed chickpea farms varied from 0.62 -0.95 cmol/kg with mean value of 0.80 cmol(+)/kg (Table 1). As indicated in table 2, 85% of the assessed chickpea farms had high exchangeable potassium content and the remaining 15% had medium value based on the rating method of Metson (1961), who considered as very high, high, medium, low and very low when soils have the value >2, 0.7-2.0, 0.3-0.7, 0.2-0.3 and 0-0.2 cmol /kg, respectively. This implies that potassium is not deficient in the assessed farms.

The potassium content in Shashamane district of South Ethiopia varied from 0.32 (low) to 3.30meq/100gof soil (high) (Tadesse Hunduma *et al.,* 2016). However, it was found 76% of sample soils in Tigray region were deficient in potassium (Fassil Kebede and Charles Yamoah, 2009).

Table1. Soil nutrient contents of the assessed chickpea farms

Soil Properties	Minimum	Maximum	Mean	CV (%)	SE
Exchangeable K^+ (cmol/kg)	0.62	0.95	0.80	14.00	0.04
pH	6.84	7.41	7.16	3.00	0.06
Electric conductivity (mS/cm)	0.05	0.11	0.08	26.00	0.01
Available P (ppm)	3.24	12.55	5.85	47.00	0.93
Organic Matter (%)	0.79	1.73	1.40	21.00	0.10
Total N (%)	0.04	0.09	0.07	22.00	0.01

By and large, the present result signifies that organic matter, total nitrogen and available phosphorus are deficient in the assessed chickpea farms that can contribute for low chickpea productivity. This could be attributed to repeated crop cultivation without adding fertilizers and organic manures such as crop residue, compost, farm yard manures and green manures as the plant materials, which could be used for compost and green manures, are used for animal feed and thatching huts.

Cow dung, which could be used as FYM, is also used as cooking fuel. Hence, it is crucial to recover the depleted soil nutrients through available fertilizer sources such as chemical, organic, bio- fertilizers and the possible combination of these sources according to their availability to improve the productivity of chickpea and other crops. Abrham Belete (2014) reported that all macro nutrient balance in cereal lands in each zone of the Tigray region (adjacent to north Gondar) was negative, which is mainly associated to huge export of NPK through nutrient leaching and soil erosion from the system and low application of mineral and organic fertilizers.

Table 2. Frequency table for soil nutrient status of assessed chickpea farms

		Frequency			
Nutrient Type	Rating	Number	%		Reference
Exchangeable K	Medium	3	15		Metson (1961)
	High	17	85		
Available P	Very low	10	50		Olsen *et al.*(1954)
	Low	10	50		
Organic Matter	Low	20	100		Metson (1961)
Total N content	Very low	20	100		Landon (1991)
pH	Neutral		18	90	ETHIOSIS (2016)
	Moderately alkaline		2	10	

Nodulation Status of Chickpea

The farm assessment result showed that the number of nodules per plant ranges between16 and 23.33, with average number of 20.79, which is moderately available according to the 0-5 scale of Bala *et al.* (2010), who grouped nodule number per plant as absent (0), rare (<5), few (5 -10), moderate (11-20), abundant (21-50) and super nodulation (>50). The fresh nodule weight varies between 177.50 and 543.33 mg plant^{-1}, with mean value of 293.83 mg plant-1 (Table 3). It was suggested that less than 500 mg nodule fresh weight plant-1 to be considered as sub-optimal, 500 to 1500 g plant-1 adequate and more than 1500 g plant-1 good nodulation (Elias, 2009). Based on this suggestion, the nodule availability in most of the assessed farms (90%) is sub-optimal.

The present study is in agreement with assessment study on nodulation status of twenty chickpea crop fields in Pakistan by Khattak *et al.* (2006), who found that native *Rhizobium* population of chickpea in most of the farmers' fields (70%) was less than what is required for optimum symbiotic association and hence it was suggested the need of artificial inoculation.

Table 3. Nodulation and seed yield of chickpea of the assessed chickpea farms

Variables	Minimum	Maximum	Mean	SE	CV (%)
Fresh nodule weight/plant (mg)	177.50	543.33	293.83	41.00	38.17
Nodule number/plant	16.00	23.33	20.79	0.77	3.70
Seed yield (quintal ha^{-1})	12.90	29.63	19.60	1.04	23.78

Seed Yield

Farm assessment result showed that the farmers in the study area produced on average 19.6 quintal ha-1 grain yield (Table 3). The assessment result indicated that the yield of chickpea obtained under farmers' management practice is by far lower than the potential productivity of the crop (4 t ha-1) (Asnake Fikre, 2014). The low yield could be attributed to production constraints of chickpea such as low nutrient status of the soil and poor management practices. The present average yield result is comparable with the national average yield of 1.91 t ha-1 (CSA, 2015)

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