



Determination of Optimum Rates of Nitrogen and Phosphorus Fertilization for Finger Millet (*Eleusine coracana* L. Gaertn) Production at Assosa Zone, in Benishangul – Gumuz Region of Ethiopia

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Abstract: Information on the response of finger millet to N and P fertilizers at the Assosa Zone is scanty. Field experiments were conducted at two locations, for two years at each location, to investigate the response of finger millet to N and P fertilization. Five levels of N (0, 23, 46, 69, 92 kg ha⁻¹) and four levels of P₂O₅ (0, 23, 46 and 69 kg ha⁻¹) were studied in factorial combinations in a randomized complete block design with triplicates. The results revealed substantial responses of finger millet to the main factors of N and P fertilization on plant height, grain and straw yield. Finger millet grain yield, straw and plant height increased significantly with increasing level of P₂O₅ (P<0.05). The effects of N by P interaction were non-significant (P ≤ 0.05) among the different yield and yield components studied. Grain yield significantly increased (P<0.01) from 1142 to 1769 kg ha⁻¹ with an increase of N level from 0 to 92 kg N ha⁻¹. No significant difference (p>0.05) were recorded among N levels of 23, 46, 69 and 92 kg N ha⁻¹ for grain yield. The grain yield significantly increased (p<0.01) with increasing level of phosphorous from 0 to 69 kg P₂O₅ ha⁻¹. However, the grain yield differences were not significant (p>0.05) among P₂O₅ level of 23, 46, and 69 kg ha⁻¹. The magnitude of increase in grain yield over the control due to application of 23 N and 46 kg P₂O₅ ha⁻¹ were 42.97% higher over the control. The partial budget analysis also indicated economic benefit for finger millet when it is fertilized with 23 N and 46 P₂O₅ kg ha⁻¹.

Keywords: Finger Millet (*Eleusine coracana* L. Gaertn), Fertilizers, Yield Increment

1. Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn.) is a staple cereal food crop for millions of people in the semi arid region of the world, particularly in Africa and India, especially those who live by subsistence farming Shinggu, et al (2009). Ethiopia is the center of diversity for finger millet. Zonary, D., (1870). It is mainly grown in northern, north-western and south-western part of the country. It is grown from sea level up to about 2400 m a.s.l and grown in a wide range of soil types and tolerate notable high rainfall and certain degree of alkalinity. It is used in many forms for human food.

Finger millet plays an important role in both the dietary

needs and income of many rural households where the crop is grown. Although the crop is not rich in total protein than other cereals, the main protein fraction (eleusinine) has high biological value with high amount of tryptophan, cystine, methionine and total aromatic amino acids (Phenylalanine and tyrosine). All these are crucial to human health and growth which are deficient in most cereals.

The two sulphur-containing amino acids, methionine (approximately 5%) and cystine are lacking in the diet of millions of the poor who live on starchy foods such as cassava (Zonary, D., 1870). Finger millet is therefore an

important prevention against malnutrition, especially kwashiorkor. Some samples contain 0.33% calcium which is 5–30 times more than in most cereals. Finger millet taste is better than most cereals. It has no major pest problem and so can be stored cheaply for a long time provided it is dried well to low moisture content. These attributes combine to make finger millet a suitable crop for ensuring food security in drought prone areas of the countries that grow it. The straw is used as animal feed and for roof thatching.

It is known as the poor man's food because of its long sustenance as it can be stored safely for many years without infestation by insects and pests. This property makes it a very necessary famine reserve food. The world production of finger millet is about 4.5 million tons per annum. Finger millet has excellent nutritional value. It contains 6–8% protein, 1–1.7% fat, starch 65–75%, minerals 2–2.25%, and dietary fiber 18–20%. Its proximate composition is superior to wheat, maize, sorghum, and rice with regard to dietary fiber, calcium, and few micronutrients. The seed coat of this millet is a rich source of phenolic compounds, minerals, and dietary fiber (Shobana, *et al* 2009).

Similarly, finger millet is the food crop in the Benishangul-Gumuz region in general and in Assosa zone in particular. Finger millet production in the zone is found both in shifting and permanent farming systems, which are practiced among natives and settlers farming communities, respectively. The productivity of finger millet crop was by far lower than the potential yields obtained on research stations and on farm verification trials (personal observation). Apparently, low soil fertility and inadequate nutrient management are among the major factors determining its yield level. Continuous cropping, high proportions of cereals in the cropping system, and the application of suboptimal levels of mineral fertilizers by farmers aggravates the situation in the area. Some other major challenges to farmers on finger millet production include figuring out of time of planting, plant spacing, and planting method.

Nitrogen, phosphorous and potassium are the essential elements required for plant growth in relatively large amounts (Dhhwayo, H.H. and E.E. Whhgwiri. 1984.). However, deficiencies of nitrogen and phosphorus are common. Soil nutrients become depleted due to leaching of nitrogen, fixation of phosphorous, soil erosion and removal by crops D. DURYODHANA, *et al* (2004). To maintain high crop production level, the nutrient status of the soil has to be maintained through crop rotation, addition of manures or application of inorganic fertilizers. Inorganic fertilizers are important inputs in any agricultural production system because they supply the required nutrients in a readily available form for immediate plant use.

Despite, the afore mentioned economic importance and coverage of large area, its productivity is very low as compared to other major crops grown in Ethiopia. Some of the factors contributing to low yield of finger millet are lack of high yielding cultivars, low moisture stress, pest and diseases and low fertility conditions and poor crop

management practices such as optimum fertilizer rate. So far efforts regarding to the determination of optimum fertilizer level and other agronomic requirement of finger millet in the study area are minimal. Among major yield limiting plant nutrients, N and P are the most determinant nutrients as they are required in large quantity by the crop. However, there are no scientific findings for nitrogen and phosphorus fertilizer application rates for the area. This implies that effort has to be made to improve the production and productivity of finger millet through application of appropriate level of N and P fertilizers. In view of this, this research activity was initiated with the objective of determining the optimum levels of N and P for optimum production of finger millet and to assess the interaction between N and P levels on yield and yield related parameters of finger millet crop on nitosols.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at the Assosa Agricultural Research center which is located at Assosa District in the Benishangul-Gumuz Regional State. The Benishangul-Gumuz Regional State is located in the western part of Ethiopia between 9° 30' to 11° 39' N and 34° 20' to 36° 30' E covering a total land area of 50,000 square kilometer (km²). The Assosa district is characterized by hot to warm moist lowland plain with uni-modal rainfall pattern. The rainy season starts at the end of April and lasts at the end of October with maximum rainfall in the months of June, July, August and September. The total annual average (2007-2014) rainfall is 1316 mm. The annual mean minimum and mean maximum temperatures of the District for the periods from 2007 to 2014 are 16.75 and 27.92°C, respectively.

2.2. Experimental Treatments, Design, and Procedures

The fertilizer treatments considered in this study consisted of five levels of N (0, 23, 46, 69 and 92kg N ha⁻¹) and four levels of P (0, 23, 46 and 69 P₂O₅kg h⁻¹) and their complete factorial combinations. The experiment was then conducted using a factorial experiment lay out in a randomized complete block design with three replications. A 3m × 4m plot size was used as an experimental unit. The blocks were separated by a 1.5 m wide open space where as the plots within a block were separated by a 0.75 m wide space. Soil bunds were constructed around each plot and around the entire experimental field to minimize nutrient and water movement from plot to plot. A local well-adapted improved finger millet variety, known as *Taddese*, was used as planting material. Planting was made on 25 June, 2014/15 by hand drilling the seeds at a rate of 15 kg ha⁻¹ in rows spaced 40 cm apart. Nitrogen was applied in two equal splits. First 50% of N was applied basal at planting and the remaining half was top dressed at the maximum tillering stage which occurred 40 days after germination, as urea (46%N). Urea was hand drilled to the side of plant rows at 5-10 cm depth of the soil.

Unlike N, the total dose of P was applied basal as triple super phosphate (46% P_2O_5) during sowing. Due to the frequent prevalence of vigorous growth and high infestation of weeds, the field was hand weeded five times at 15, 30, 45, 60 and 75 days after sowing.

2.3. Soil Sampling and Preparation

Prior to the field experimentation, ten random samples (0-20cm depth) were collected and a composite soil samples were prepared. These composite samples were used for soil physical and chemical analysis. Similarly, post crop harvest soil samples were collected plot-wise from each replication from the surface 0-20 cm depth for selected soil chemical analysis. The soil samples were air dried, sieved to pass through 2 mm sieve, and placed in labeled plastic bags.

2.4. Laboratory Analyses

The soil samples were air-dried and ground to pass 2 and 0.5 mm sieves (for total N). All samples were analyzed following standard laboratory procedures. Organic carbon and total N contents of the soil were determined following the wet combustion method of Walkley and Black, and wet digestion procedure of Kjeldahl method, respectively. The available P content of the soil was determined following Olsen method. Soil texture was analyzed by Bouyoucos hydrometer method. The pH (1:2.5 solid: liquid ratio) of the soils was measured in water using pH meter with glass-calomel combination electrode.

2.5. Plant Data Collection and Analysis

Central plants were used for data collection. Growth indicating parameters such as plant height, panicle length and grain yield was collected. The plant height was measured from the base of the plant to upper the top most leaves of the plant. The data was taken from five randomly selected plants and the average value was computed. The grain yield from the middle was recorded and then converted to hectare basis. Analysis of variance was carried out for the yield studied following statistical procedures appropriate for the experimental design using SAS computer software. Whenever treatment effects was significant, the means were separated using the least significant difference (LSD) procedures test at 5% level of significance.

2.6. Economic Data Collection and Analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. A partial budget, dominance and marginal analysis were used. The average yield was adjusted down wards to reflect the difference between the experimental plot yield and the yield farmers were expecting from the same treatment. The average open market price (Birr kg^{-1}) for finger millet and the official prices of N and P fertilizers were used for analysis.

3. Result and Discussion

3.1. Soil Physico-chemical Properties Before Sowing

The textural classes of the soils were clay, with varying proportions of sand, silt and clay According to the rating of (Landon, J. R. 19915), the soil used for this study ranges from very strongly acidic (pH 4.29) to the moderate acidic (pH 5.22) class indicating the possibility of Al toxicity and deficiency of certain plant nutrients. The exchangeable K of the soil before the application of the treatments ranges from 0.192 cmol (+) kg^{-1} to 0.42 cmol (+) kg^{-1} . All experimental soils had deficient to adequate K content. According to Landon, J. R. (19915), available (Bray II extractable) soil P level of less than 10 ppm is rated as low, 11-31 ppm as medium and greater than 18 mg kg^{-1} is rated as high. Thus, both trial location had very low (bray II extractable) P (Annex 1). Following the rating of total N of > 1% as very high, 0.5 to 1% high, 0.2 to 0.5% medium, 0.1 to 0.2% low and < 0.1% as very low N status as indicated by Landon, J. R. (19915), the experimental soils qualify for very low total N. Similarly, the organic carbon (OC) content of the soil was also very low to low in accordance with Landon (1991), who categorized OC content as very low (< 2%), low (2-4%), medium (4-10%), high (10-20%). The very low OC and low N content in the study area indicate low fertility status of the soil. This could be due to continuous cultivation and lack of incorporation of organic materials. (Table 1)

Table 1. Chemical analysis of some parameters of soil prior to cropping.

No.	Location/kebels	pH	CEC	OC (%)	N (%)	P	K
1	Amba 14	4.78	17.2	1.68	0.15	3.4	0.192
2	On station	5.22	29.02	2.49	0.17	3.4	0.42

3.2. Yield and Yield Components

Analysis of variance for two factors randomized complete block design (Table 2.and 3.) revealed significant difference ($P \leq 0.01$) due to the main effects of N and P application for both the means of grain yield and straw yield in case of nitrogen application and, grain yield and plant height in case of phosphorous application.

However the interaction effects of N and P was not significant ($P > 0.05$) for all means of grain yield and yield components. The effect of N and P fertilizer levels on yield and yield components of finger millet indicated in Table 2 and 3. Grain yield and straw yields were significantly affected ($p < 0.01$) by N fertilizer level and similarly plant height and grain yield were significantly affected ($p < 0.01$) by P fertilizer level. Application of N fertilizer significantly ($p < 0.01$) increased both grain and straw yields compared to 0 N fertilizer application. However the effect of N levels on grain and straw yield was not significant ($p > 0.01$). Grain yield steadily increased with increasing level of N fertilizer. In the same manner, the increase in N fertilizer level increased straw yield, but in non-consistent manner. Grain yield highly significantly increased ($P \leq 0.01$) from 1142 to 1769 $kg\ ha^{-1}$ with an increase in the level of N from the

control to 92 kg N ha⁻¹, however statically there were none significant different between 23,46,69 and 92 kg N ha⁻¹. The same as the straw yield of finger millet was highly significantly increased ($P \leq 0.01$) from 643 t/ha to 1186 t/ha with an increase in the level of N from the control to 46 kg N ha⁻¹, however statistically there were none significant difference between 23,46,69 and 92 kg N ha⁻¹. This yield increment could mainly be attributed to the increasing in panicle length and plant height of finger millet. This result is in agreement with Hegde, B.R.; Gowda, L.(1986), reported that finger millet grain yield was 23.1 kg per kg N at 20 kg N ha⁻¹, these results suggest that application of the correct dose of N fertilizer is important in order to maximize the profits of poor finger millet farmers.

Table 2. Effect of N fertilizer levels on yield (kg ha⁻¹) and yield components of finger millet at Assosa zone.

Nitrogen rate kg/ha	Plant Height (cm)	Panicle length(cm)	Grain Yield (Kg/ha)	straw Yield (t/ha)
0	66.45	9.87	1141.9 ^b	643 ^b
23	67.66	9.97	1632.4 ^a	956 ^{ab}
46	69.66	10.51	1737.1 ^a	1186 ^a
69	70.75	10.18	1770 ^a	947 ^{ab}
92	68.92	10.03	1769.1 ^a	1142 ^a
LSD	5.8	0.61	278.2	322
F test	NS	NS	**	**
CV	14.76	10.64	30.16	28.2

Notes: * = Significant at $P = 0.05$; ** = Significant at $P = 0.01$; ns = Non-significant; PH=plant height; PL= panicle length; GY=grain yield; SY; straw yield

Application of P fertilizer had also significantly ($P \leq 0.01$) increased the grain yield of finger millet up to the applied level of 69 kg P₂O₅ ha⁻¹ (Table 3). However, the response of grain yield obtained at 69 kg P₂O₅ did not show significant differences compared with application of 23 kg ha⁻¹ and 46 kg ha⁻¹ of P₂O₅. The magnitudes of increase in finger millet grain yield over the control due to application of 46 kg and 69 kg P₂O₅ ha⁻¹ were (445 kg ha⁻¹)and (485 kg ha⁻¹) respectively. Increase in the magnitude of yield attributes is associated with better root growth and increased uptake of nutrients favoring better growth of the crop Khalil, et al (1986). The plant height was significantly ($P \leq 0.05$) increased by all applied P rates. Application of P fertilizer had also significantly ($P \leq 0.01$) increased the plant height of finger millet up to the applied level of 69 kg P₂O₅ ha⁻¹. However, the response of plant height obtained at 69 kg P₂O₅ did not show significant differences compared with application of 23 kg ha⁻¹ and 46 kg ha⁻¹ of P₂O₅. Statically analysis indicates that panicle length and straw yield were not affected by phosphorous application. This result is in agreement with based on multi location field experiments conducted in Eastern Uganda Tenywa, J.S (1999), found that application of P fertilizer (20–40 kg P₂O₅ ha⁻¹) increased the growth and yield of finger millet compared to the no fertilizer control under row planting conditions. However, Hegde, B.R.;

Gowda, L. (1986), reported a reduction in finger millet grain yields from 16.3 to 14.7 kg per kg P₂O₅ when the P application rate was increased from 30 to 60 kg ha⁻¹ P₂O₅. Similar to inorganic N, this result suggests that application of excess P does not improve yield, but rather that application of balanced fertilizer is crucial.

Table 3. Effect of P fertilizer levels on yield and yield components of finger millet at Assosa zone.

Phosphorus rate (P ₂ O ₅ in kg ha ⁻¹)	Plant Height (cm)	Panicle Length (cm)	Grain Yield (kg ha ⁻¹)	Straw yield (t ha ⁻¹)
0	63.51 ^b	10.05	1314.9 ^b	857
23	70.22 ^a	10.43	1566 ^{ab}	925
46	70.24 ^a	9.93	1759.6 ^a	1055
69	70.55 ^a	10.08	1799.9 ^a	1063
LSD	5.19	0.55	248.8	270
F test	*	NS	**	NS
CV	14.76	10.64	30.16	28.2

Notes: * = Significant at $P = 0.05$; ** = Significant at $P = 0.01$; ns = Non-significant.

3.3. Nitrogen and Phosphorous Response Curve

The nitrogen and phosphorous response curve was derived from five and four different rates of fertilizer application rates of nitrogen and phosphorous respectively. To study finger millet yield response to N and P fertilizer, a suitable regression equation was fitted to the data of grain yield/ha for the tested variety of finger millet according to Murphy, H. F. (1968).). Response equation is $Y = a + bx - cx^2$ Where Y = is the grain yield (kg/ha), a = is the Y intercept, b = is the linear coefficient of regression, x = is the rates of nitrogen and phosphorous fertilizer applied (kg ha⁻¹) and c =is the quadratic coefficient of regression. Nitrogen and phosphorous rate for maximum grain yield was calculated with-b/2c from differentiation of the regression equation.

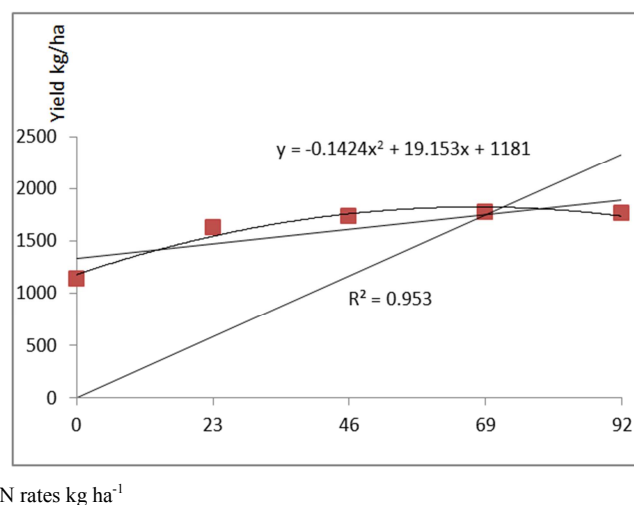
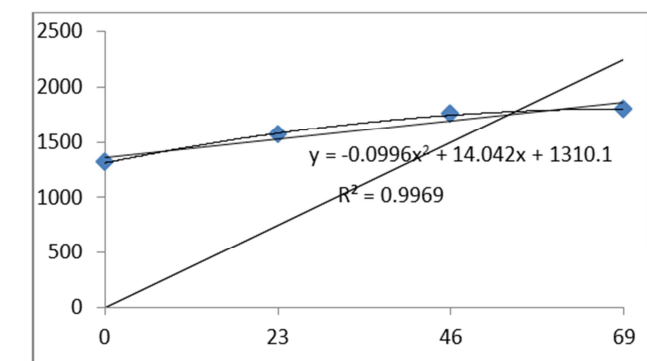


Figure 1. Response of finger millet to nitrogen fertilizers.



P₂O₅ rates kg/ha⁻¹

Figure 2. Response of finger millet to phosphorous fertilizers.

Table 4. Regression equation, maximum N and P rate and grain yield at maximum N and P dose for finger millet.

Fertilizers	Regression equation	Maximum N and P ₂ O ₅ rate(kg ha ⁻¹)	Yield at maximum N and P dose(kg ha ⁻¹)
Nitrogen	$Y = -0.142x^2 + 1915x + 1181$	67.42kg/ha	1826.64
Phosphorous	$Y = -0.099x^2 + 14.04x + 1310$	70.9kg/ha	1807.78

3.4. Economic Analysis

The result of this study revealed that except four treatments (0 N, 23 N, 0 P₂O₅ and 23 P₂O₅) all the other treatments were dominated. Because these treatments have net benefits less than treatments with lower variable costs. Such dominated treatments were dropped from economic analysis. As a result only marginal rate of return (MRR) of the four treatments was computed. (Table 5)

MRR of Nitrogen and Phosphorus (P₂O₅) at 23 and 46 kg

Table 5. Partial budget analysis of effect of N and P fertilizers on finger millet yield at Assosa Zone.

N in kg ha ⁻¹	P ₂ O ₅ in kg ha ⁻¹	Total cost	Finger millet yield in kg/ha	Price birr/kg	Income	Benefit	Dominance	Marginal rate of return (MRR %)
0	0	4200.00	1314.9	6.00	7889.40	3689.40		
0	23	5137.50	1566	6.00	9396.00	4258.50		61
0	46	6075.00	1759.6	6.00	10557.60	4482.60	D	
0	69	7012.50	1799.9	6.00	10799.40	3786.90	D	
0	0	4200.00	1141.9	6.00	6851.40	2651.40		
23	0	4892.50	1632.4	6.00	9794.40	4901.90		325
46	0	5585.00	1737.1	6.00	10422.60	4837.60	D	
69	0	6277.50	1770	6.00	10620.00	4342.50	D	
92	0	6970.00	1769.1	6.00	10614.60	3644.60	D	

4. Recommendations and Conclusions

The study was designed to determine the effects of Nitrogen and P fertilizer applications on grain yield and yield components of finger millet on Nitisols of Assosa District. The results obtained from this study showed that, grain yield and plant parameters were significantly ($P \leq 0.01$) influenced by the applied rates of nitrogen and/or phosphorous fertilizer.

From this result, it can be concluded that farmers of Assosa Zone need to apply a combination of 23 kg N and 46 kg P₂O₅ ha⁻¹ in order to improve the grain yield and yield components of finger millet on nitosols under rain fed conditions. Thus, in

The response of grain yield of finger millet to N and P fertilization in 2014/15 season is shown in Table (4), and Figures 1 and 2. Results in Table (4) showed that maximum N rates ranged to 67.42 kg N ha⁻¹ and to 70.9 P₂O₅ ha⁻¹ for finger millet. Grain yield at maximum N dose ranged from 1826.4 kg ha⁻¹ for nitrogen fertilizer and to 1807.78 kg ha⁻¹ for phosphorous fertilizers. Generally as we see from those trend curve (figure1. and figure2.), the maximum rate of nitrogen and phosphorous for finger millet production under Assosa zone were 67.42 kg N ha⁻¹ and 70.9 kg P₂O₅ ha⁻¹. However the statically analysis indicates that there was non-significant difference between 23 kg N ha⁻¹ and 46 kg P₂O₅ ha⁻¹, respectively (Table 2. and 3).

ha⁻¹ rate was above the 100% minimum and this in line with CIMMT, (1988). But investing on additional fertilizer rate gave less MRR. According to CIMMT, (1988) experience and empirical evidence, for the majority of situations indicated that the minimum rate of return acceptable to farmers would be between 50-100%. Therefore, the treatments that have highest Marginal rate of return (MRR%), is Nitrogen and Phosphorus (P₂O₅) at 23 and 46 kg ha⁻¹ rate for finger millet production are recommended.

the light of the significant response of finger millet to both N and P fertilizers, further studies aimed at promoting integrated soil fertility management and formulation of fertilizer recommendation on soil test basis over locations are desirable.

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