Nitrogen and Phosphorus Rate Determination for Sorghum Production in Wag-Lasta, North Eastern Ethiopia

Workat Sebnie* and Merse Mengesha

Sekota Dry-Land Agricultural Research Center, P.O Box 62 Sekota, Ethiopia

*Corresponding author email: workat71@yahoo.com

Abstract

Continuous cultivation of land became a common practice in major sorghum producing areas of Ethiopia, which eventually led to soil fertility decline and subsequent reduction of crop yields indicating importance of using inorganic fertilizers to enhance crop yield. A field experiment was conducted at Lasta and Sekota districts, Eastern Amhara, Ethiopia, to evaluate the effects of application of different rates of nitrogen and phosphorous fertilizers on yield and yield components of Sorghum (Sorghum bicolor L.*). Four rates of nitrogen (0, 23, 46, 69, kg N ha^{-1}) and three rates of phosphorous (0, 23, 46, kg P_2O_5 ha^{-1}) were arranged in Randomized Complete Block Design (RCBD) with three replications in a factorial arrangement. All phosphorus and half nitrogen were applied at planting while half nitrogen was applied at knee height. Composite soil samples were collected from 0-20 cm depth and major nutrient contents were determined following standard laboratory procedures. Agronomic data were collected and subjected to statistical analysis using statistical analysis software. Significant treatment means were separated using least significant difference LSD at 5%. Nitrogen and phosphorus showed significant effects on yield and yield components of sorghum. Application of 46 kg N and 23 kg P_2O_5 ha^{-1} increased sorghum yield by about 60.37% compared with the control. Therefore, application of 46 kg P_2O_5 and 23 kg N ha^{-1} was recommended for sorghum production at Sekota and similar agro-ecologies. While, application of 23 N kg N ha^{-1} and 23 kg P_2O_5 ha^{-1} was recommended for sorghum production at Lalibella and similar agro-ecologies.*

Keywords: *Fertilizer, nitrogen, phosphorus, sorghum, yield.*

Introduction

Globally, sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop after maize, rice, wheat and barley (Faostat, 2014). It is an important crop staple food crop in the semi-arid tropics of Africa, South Asia and Central America (Mbwika *et al.*, 2011). In Ethiopia, sorghum is a major staple food crop, ranking second after maize in total production. It ranks third after wheat and maize in productivity per hectare, and after Teff and maize in area cultivated. It is grown in almost all regions, covering a total land area of 1.8 million ha (CSA, 2015). Sorghum grain is as nutritious as other cereal grains; containing about 11% water, 340 k/cal of energy, 11.6% protein, 73% carbohydrate and 3% fat by weight (Thimmaiah, 2002; Taylor *et al.*, 2006; Yan *et al.*, 2012).

Despite the large-scale production and various merits, sorghum production and productivity have been by far below the potential. Currently, the average regional productivity is 2.65 t ha^{-1} but, the study area productivity is below 1.5 t ha^{-1} which is very low as compared to other small grain cereals grown in Ethiopia (CSA, 2019). Low productivity of crops has been attributed to abiotic stress (drought and low soil fertility) and biotic stress (disease, insect and weed) (Mbwika *et al.*, 2011). Wortmann *et al.* (2006) also reported that drought, low soil fertility (nutrient deficiencies), insect stem borers, insect shoot fly, quelea birds, Striga, and weeds were recognized as major production constraints affecting sorghum in eastern Africa.

To feed the ever-increasing population and generate income, continuous cultivation of land became a common practice in major sorghum producing areas, which eventually led to soil fertility decline and subsequent reduction of crop yields. Thus, as noted by Mwangi (1995) the use of inorganic fertilizer is critical to increase crop yield. Gruhn *et al.* (1998) also suggested that, the levels of the fertilizer being used are very low and this must be increased to meet the demand for food with population growth. In Waglasta, most farmers used to produce sorghum without any input though they are advised to use the blanket recommendation (100 kg urea and

half a year. Based on these facts the objective of this research was to determine the optimum rate of nitrogen and phosphorus fertilizer on yield and yield components of sorghum in Wag-Lasta areas.

Materials and methods

Study Area description

The study was conducted at Lalibella (Lasta district) and Aybra (Sekota district) Eastern Amhara, Ethiopia. The study site at Lasta was located at 11^{o} ^{o} E longitude at an altitude of 1966 masl (meters above sea level) while the study site at Aybra was located at 12^{o} 39^{o} longitude at an altitude of 1915 masl (Figure 1).

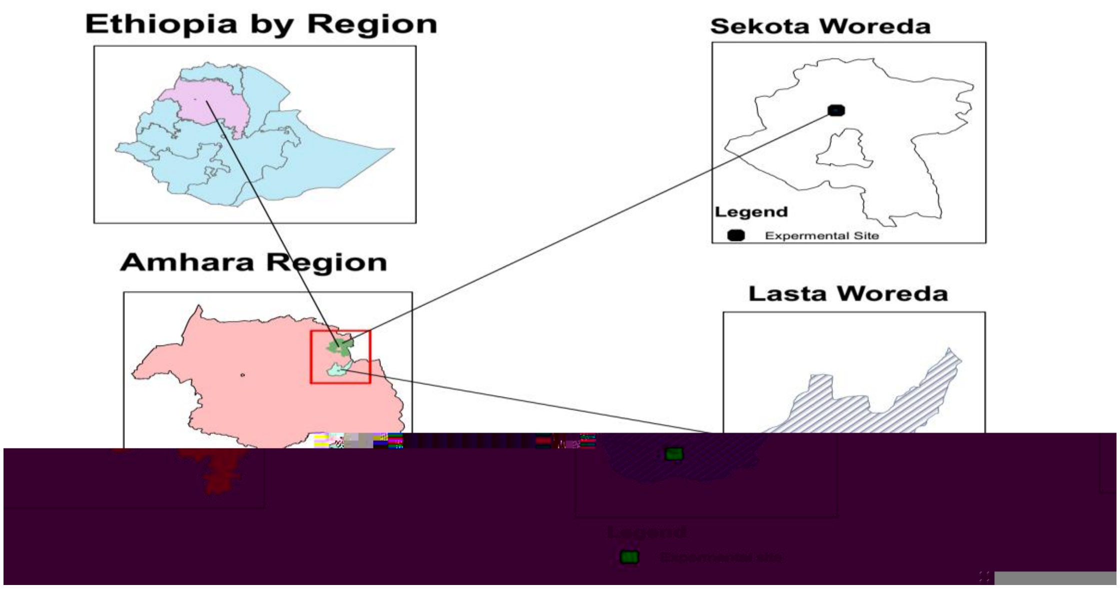

Figure 1. The experimental locations

Experimental design and treatments

The experiment was conducted during the main cropping season 2014 and 2016 at the aforementioned locations. The treatments were composed of four nitrogen levels (0, 23, 46 and 69 kg N ha^{-1}) and three phosphorous levels (0, 23 and 46 kg P_2O_5 ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications in a factorial arrangement. The plot size was 14.25m^2 (3.75 m X 4 m) and consisted of 5 rows and the net plot size was 9 m^2. A spacing of 0.5 m and 1 m were left between plots and blocks, respectively. The spacing of 75 cm x 15 cm was used between rows and plants, respectively and there were 26 plants per row with a total of 133 plants per plot. Urea and TSP were used as a source of nitrogen and phosphorus fertilizer, respectively. Nitrogen fertilizer was applied by split application method in the form of urea half at planting and the remaining half at 45 days after planting. Phosphorus was applied once in the form of TSP at the time of planting. Agronomic practices such as weeding, cultivation, and tie-ridging were done uniformly for all treatments whenever needed. The test sorghum variety was Miskir.

Data collection and analysis

The average plant height, length of sorghum head, the average weight of sorghum head, grain yield and above ground biomass were recorded from each plot. The data obtained were subjected to the analysis of variance using SAS statistical software version 9.0 and significant treatment effects were

significance.

Partial budget analysis

The partial budget analysis was done to see the economic feasibility based on the manual developed by CIMMYT (1988). The costs include fertilizer cost and price of sorghum was collected from the study areas.

Soil sampling and analysis

Composite soil samples were collected from 0-20 cm depth using augur sampler for the determination of major soil chemical parameters following standard procedures. The soil samples were air-dried and sieved through 2 mm sieve to determine pH, EC and soil texture and through 0.5 mm sieve to determine total nitrogen and organic carbon contents. Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter. Soil organic carbon was determined following the wet digestion method as described by Walkley and Black (1934) while percentage organic matter of the soils was determined by multiplying the percent organic carbon value by 1.724. Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method.

Table 1. Soil analysis of the study area

Site	pH	EC dec/m	OM %	TN%	Texture			
					Sand %	Silt%	Clay%	Textural class
Lalibella	6.23	1.3	1.06	0.07	39	27	34	Clay loam
Aybra	5.96	1.8	1.09	0.084	33	32	35	Clay loam

Results and discussion

Soil properties of the study sites (Aybra and Lalibela)

The pH of the surface soil at Lalibella was 6.3 and at Aybra was 5.96. Based on Tekalign's (1991) classification, the pH of the surface soil collected from Aybra was moderately acidic and from Lasta was slightly acidic. The organic carbon and total nitrogen contents were low for both sites (Tekalign *et al.*, 1991). The low organic carbon and total nitrogen might be attributed to the continuous cultivation and removal of crop residues from the farms. The result also indicates that a lot has to be done to improve the soil organic matter, total nitrogen and other nutrient contents through organic and inorganic amendments for both sites.

Effect of nitrogen and phosphorus on sorghum yield and yield parameters at Aybra

Plant height (cm)

Nitrogen and phosphorus highly sorghum plant height (Table 2). The tallest mean plant height was (140.01cm and 140.08 cm) was obtained from 23/46 kg N/P_2O_5 ha^{-1} which was significantly higher plant height compared to the control but at par with the other combined rates (Table 3). The result of the current study is inline with the finding of (Legesse and Gobeze, 2015) who reported nitrogen and phosphorus at the rate of 18 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} with tie-ridge had a significant effect on plant growth in southern Ethiopia. Similarly, Tesfahunegn (2012) observed that nitrogen and phosphorus at the rate of 18 kg nitrogen ha^{-1} and 46 kg phosphorus ha^{-1} with in situ moisture conservation had higher plant height.

Table 2: ANOVA of the effect of N and P on sorghum yield combined over years at Aybra.

Source of variation	DF	Mean square values				
		Plant height	Panicle Length of sorghum	Panicle weight of sorghum	Grain yield	Biomass yield
N	3	1879.41**	3.96ns	922.14**	3463406.69**	246540773**
P	2	1460.56**	3.61ns	667.37**	2959677.33**	223566291**
N*P	6	186.92*	7.34ns	310.57**	373721.83**	50981317**
Rep	2	72.02ns	580.26ns	14.92ns	34422.65ns	10681603ns
Error	40	60.65	66.26	41.11	72891.91	10725818

Table 3: Effects of nitrogen and phosphorus on sorghum growth parameter at Aybra combined over years

Treatment kg ha^{-1} P_2O_5	N	Plant height (cm)	Panicle Weight of sorghum (g)
0	0	109.74^{f}	14.30^{c}
0	23	126.11^{de}	24.00^{bc}
0	46	132.26^{dc}	31.12^{abc}
0	69	134.20^{bcd}	26.02^{bc}
23	0	128.52^{de}	21.90^{bc}
23	23	141.63^{abc}	37.43^{ab}
23	46	143.79^{abc}	28.70^{bc}
23	69	146.36^{ab}	47.90^{a}
46	0	119.26^{ef}	15.81^{c}
46	23	152.30^{a}	33.75^{ab}
46	46	141.43^{abc}	33.95^{ab}
46	69	138.30^{bcd}	21.90^{bc}
LSD (0.05)		12.42	17.59
CV (%)		8.1	25

Grain yield (kg ha^{-1})

The grain yield was significantly affected by nitrogen and phosphorus rates at ($P<0.05$) (Table 2). Increasing nitrogen and phosphorus rates from 0/0 to 23/46 kg ha^{-1} increased sorghum yield from 1172 to 2959.2 kg ha^{-1} (Table 4). The highest grain yield was obtained from 23/46 kg N/P_2O_5 ha^{-1} followed by 69/23 kg N/P_2O_5 ha^{-1} and 23/46 kg N/P_2O_5 ha^{-1} while the lowest was from the control (Table 4). Application of 23/46 kg N/P_2O_5 ha^{-1} gave 60.4% grain yield advantage over the control. All nitrogen and phosphorus rates gave significant yield difference over the control implying that production of sorghum without input is wastage for the yield the household. Our result is line with the finding of (Legesse and Gobeze, 2015 and Tesfahunegn, 2012) who reported that application of nitrogen fertilizer at the rate 18 kg ha^{-1} and application of phosphorus at rate 46 kg ha^{-1} increased the grain yield of sorghum significantly. Similarly, research done by Gebrekidan (2003) showed that application of 46 P_2O_5 and 18 N with tie-ridge increased sorghum grain yield by 15-38% in the moisture stress areas of Eastern Ethiopia.

Biomass yield (kg ha^{-1})

Sorghum biomass yield was significantly ($P< 0.05$) affected by different rates of Nitrogen and Phosphorus (Table 5). The highest biomass yield (13731.5 kg ha^{-1}) was recorded at the rate of 69/23 kg N/P_2O_5 ha^{-1} followed by 46/23 kg N/P_2O_5 ha^{-1}, 69/46 N/P_2O_5 ha^{-1} and 23/46 N/P_2O_5 ha^{-1} whereas the lowest biomass yield (5086.5 kg ha^{-1}) was recorded from the control (Table 5). The biomass yield is very important because the leaves and stalks are used for cattle feed during the long dry season (Birhane, 2012).

Partial budget analysis

The partial budget analysis showed that application of 23 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} had the highest net benefit (16,523.46 ETB ha^{-1}) with MRR of 2276 % followed by 46 kg N ha^{-1} and 23 kg P_2O_5 ha^{-1} with net benefit 13086.94 birr ha^{-1} and MMR of 509% (Table 6). The budget analysis showed that by incurring one Ethiopian birr, the producer can gain 22.76 and 5.09 additional Ethiopian Birr respectively.

Effect of nitrogen and phosphorus rates on sorghum yield and yield parameters at Lalibella

Plant height (cm)

Nitrogen and phosphorus rates highly sorghum plant height (Table 7). Application of 69/46 kg N/P_2O_5 ha^{-1} gave the highest plant height (Table 8). The increment in plant height due to nitrogen application could be attributed to the effect of nitrogen on cell division and elongation which lead to growth and increased height of the stems and leaves (Rabinowitch and Currah, 2002). The result of this study is in line with the findings of Gebremariam and Assefa, (2015) who reported significant effect of nitrogen at a rate of 69 kg ha^{-1} on plant growth in northern Ethiopia. Similarly Legesse and Gobeze (2015) also observed that 69 kg ha^{-1} N and 46 kg ha^{-1} P_2O_5 had significant effect on height of sorghum plant.

Table 4. Effect of nitrogen and phosphorus on grain yield (kg/ha) of sorghum at Sekota (Aybra) combined over year

	P_2O_5 level (kg ha^{-1})		
N level (kg ha^{-1})	0	23	46
0	1172.5^{e}	1507.1^{de}	1559.0^{d}
23	2104.0^{c}	2293.8^{bc}	2959.2^{a}
46	1480.2^{de}	2404.9^{bc}	2111.3^{c}
69	1656.5^{d}	2546.2^{b}	2301.2^{bc}
	LSD (5%)	348.99	
	CV (%)	15.04	

Table 5. Effect of nitrogen and phosphorus on biomass yield (kg/ha) of sorghum at Sekota (Aybra)

	P level (kg ha^{-1})		
N level (Kg ha^{-1})	0	23	46
0	5086.3^{g}	7126.6^{f}	7433.2^{f}
23	9048.0^{e}	10810.9^{cd}	12018.8^{bcd}
46	10679.4^{d}	13407.4^{ab}	11382.2^{cd}
69	9058.6^{e}	13731.5^{a}	12151.0^{ab}
	$LSD_{5\%}$	1410	
	CV %	12.01	

Gain yield

The grain yield was significantly affected by the application rates of Nitrogen and Phosphorus fertilizers at ($P<0.05$) at Laibella (Table 9). The highest grain yield (3888.3 kg ha^{-1}) was obtained from the plots receiving 69/23 kg N/P_2O_5 ha^{-1} while the lowest grain yield (1698.4 kg ha^{-1}) was obtained from the control (no NP). However, the highest grain yield obtained from the plots applied with 69/23 kg N/P_2O_5 ha^{-1} was at par with that obtained from the plots which received 46/23, 23/23 and 23/46 kg N/P_2O_5 ha^{-1}. The sorghum grain yield obtained from the application of 69/23 and 46/23 kg N/P_2O_5 was higher by 2189.9 kg (128.9%) and 2148 kg (126.6%) over the control. The result is in agreement with the findings of (Masebo and Menamo, 2016) who reported sorghum grain yield increment due to increased application of N and P. Similarly, Ashiona *et al.* (2005) also reported that increasing rate of nitrogen had increased sorghum grain yield.

Table 6. Partial budget analysis at Sekota (Aybra)

P2O5	N	Unadjusted yield	Adjusted	Gross benefit	Costs that varies	Net benefit	MRR%
0	0	1172.5	1055.25	7386.75	0	7386.75	
0	23	2104	1893.6	13255.2	608.5	9256.52	307.12
23	0	1507.1	1356.39	9494.73	755.5	8739.23	D
0	46	1480.2	1332.18	9325.26	1217	8108.26	D
23	23	2293.8	2064.42	14450.94	1364	13086.94	507
46	0	1559	1403.1	9821.7	1511	8310.7	D
0	69	1656.5	1490.85	10435.95	1825.5	8610.45	D
23	46	2404.9	2164.41	15150.87	1972.5	13178.37	15.03
46	23	2959.2	2663.28	18642.96	2119.5	16523.46	2275.57
23	69	2546.2	2291.58	16041.06	2581	13460.06	D
46	46	2111.3	1900.17	13301.19	2728	10573.19	D
46	69	2301.2	2071.08	14497.56	3336.5	11161.06	D

Table 7. ANOVA for N and P on the plant height, sorghum head length, head weight, grain yield and biomass at Lalibella Combined over years

Source of variation	DF	Mean square values		
		Plant Height	Grain Yield	Biomass Yield
N	3	1185.19**	10591267.03***	140261599.0**
P	2	152.80**	1267516.55**	1058796.5*
N*P	6	170.91**	1010479.64**	7253023.4**
Year	1	4402.58**	23109478.2**	483484.8*
Rep	2	25.98ns	81695.80ns	296755.9ns
Error	40	660.77	41557.58	458748.6

Biomass yield

Sorghum biomass yield was significantly (P< 0.05) affected by different rates of Nitrogen and Phosphorus fertilizers (Table 10). The highest biomass yield (24924 kg ha^{-1}) was recorded from the application of 69/23 kg N-P_2O_5 ha^{-1} followed by the biomass yield recorded from 46/46, 23/23 and 23/46 kg N-P_2O_5 ha^{-1}. While the lowest biomass yield (8993 kg ha^{-1}) was recorded from the control (no NP). Application of the combination of NP fertilizer increased sorghum biomass yield by 91% - 177% over the control.

Table 8. Effect of nitrogen and phosphorus on sorghum grain yield (kg/ha) at Lalibella

Treatment	Plant height (cm)			Length of sorghum head (cm)			Weight of sorghum head (g)		
N kg ha^{-1}	1st year	2nd year	Comb	1st year	2nd year	Comb	1st year	2nd year	Combined
0	140.80^{b}	156.69^{d}	149.17^{d}	19.11^{b}	18.63^{c}	18.87^{b}	40.12^{c}	44.60^{b}	42.96^{b}
23	146.78^{b}	161.73^{c}	156.50^{c}	19.51^{ab}	20.42^{b}	19.96^{a}	55.48^{a}	47.28^{b}	50.39^{a}
46	154.44^{a}	171.07^{b}	163.97^{b}	19.46^{ab}	21.11^{ab}	20.28^{a}	42.92^{bc}	54.60^{a}	48.74^{a}
69	154.46^{a}	179.26^{a}	167.38^{a}	19.95^{a}	21.44^{a}	20.70^{a}	44.13^{b}	56.37^{a}	49.11^{a}
LSD $_{0.05}$	6.48	3.43	2.73	0.83	0.93	0.73	2.94	4.04	4.96
P_2O_5 kg ha^{-1}									
0	146.86^{b}	165.88^{b}	157.84^{b}	19.35	20.18	19.76	45.74^{b}	47.49^{b}	46.28
23	147.93^{ab}	168.94^{a}	157.96^{b}	19.66	20.54	19.96	49.27^{a}	53.71^{a}	49.56
46	152.57^{a}	168.41^{a}	162.17^{a}	19.51	20.76	20.14	41.98^{c}	50.94^{ab}	45.39
LSD (0.05)	5.61	1.33	2.37	ns	ns	ns	2.54	3.5	ns
CV (%)	4.46	8.91	5.23	4.41	5.19	5.49	6.61	8.19	15.64

Partial budget analysis

The partial budget analysis showed that application of 23 kg N ha^{-1} and 23 kg P_2O_5 ha^{-1} had the highest net benefit (23,447.23 Birr ha^{-1}) with MRR of 1083% and followed by 23 kg N ha^{-1} with net benefit (16,269.97 Birr ha^{-1}) and MMR of 952%.

Table 9. Effect of nitrogen and phosphorus on grain yield (kg/ha) of sorghum at Lalibella

	P level (kg P_2O_5 ha^{-1})		
N level (kg ha^{-1})	0	23	46
0	1698.4^{d}	2160.2^{dc}	1718.9^{d}
23	2607.7^{bc}	3822.6^{a}	3319.6^{ab}
46	2790.0^{bc}	3846.4^{a}	2887.6^{bc}
69	2454.4^{dc}	3888.3^{a}	3293.4^{ab}
	LSD (0.05)	800.16	
	CV (%)	7.09	

Table 10. Effect of nitrogen and phosphorus on sorghum biomass yield (kg/ha) at Lalibella

N level (kg ha^{-1})	P level (kg ha^{-1})		
	0	23	46
0	8993^{d}	10387^{cd}	9786^{d}
23	12452^{bcd}	18253^{ab}	18156^{ab}
46	12493^{bcd}	17212^{bc}	18628^{ab}
69	12184^{bcd}	24924^{a}	17554^{b}
	LSD (0.05)	6983	
	CV (%)	18.55	

Table 11. Partial budget analysis at Lalibella

P	N	Unadjusted yield kg ha^{-1}	Adjusted kg ha^{-1}	Gross benefit	Cost that varies	Net benefit	MRR%
0	0	1698.4	1528.56	10959.77	0	10959.77	
0	23	2607.7	2346.93	16827.49	557.5	16269.99	952
0	46	2790	2511	18003.87	1115	16888.87	111
0	69	2454.4	2208.96	15838.24	1672.5	14165.74	D
23	0	2160.2	1944.18	13939.77	662.5	13277.27	D
23	23	3822.6	3440.34	24667.23	1220	23447.23	1083
23	46	3846.4	3461.76	24820.81	1777.5	23043.31	-72
23	69	3888.3	3499.47	25091.19	2335	22756.19	D
46	0	1718.9	1547.01	11092.06	1325	9767.06	D
46	23	3319.6	2987.64	21421.37	1882.5	19538.87	D
46	46	2887.6	2598.84	18633.68	2440	16193.68	D
46	69	3293.4	2964.06	21252.31	2997.5	18254.81	D

Conclusions and Recommendations

The result showed that Nitrogen and phosphorous fertilizers improve sorghum production and optimize farmers profit through in the study areas and similar agro-ecologies. The mean sorghum grain yield was significantly affected by NP fertilizer rates. The agronomic maximum grain yield was recorded from the application of 69/23 kg N/P_2O_5 ha^{-1} at Lalibella and from the application of 23/46 N/P_2O_5 ha^{-1} at Aybira while the economic optimum yield was obtained from the application of 23/23 N/P_2O_5 for Lasta (Lalibella) and 23/46 kg N/P_2O_5 ha^{-1} at Aybira. Hence, 23 kg P_2O_5 ha^{-1} and 23 kg N ha^{-1} was recommended for optimum sorghum yield at Lasta (Lalibella) similar agro-ecologies and 23 kg N and 46 kg P_2O_5 ha^{-1} was recommended for optimum sorghum yield at Sekota (Aybira) and similar agro-ecologies.

Reference

Ashiona, G., Akuja, T. & Gatiriku, J. (2005).Effects of nitrogen and phosphorus application on growth and yield of dual purpose sorghum in the dry highlands of Kenya. In *African Crop Science Conference Proceedings*, Vol. 7, 1149-1152.

Brhane, G. (2012). Effect of Tillage and Fertilizer Practices on Sorghum Production in Abergelle Area, Northern Ethiopia. *Momona Ethiopian Journal of Science (MEJS),* 4(2): 52-69.

Cimmyt, M. (1988). *From agronomic data to farmer recommendations: an economics training manual.* CIMMYT.

CSA 2015. Area and Production of Major Crops. Addis Ababa.

Faostat, F. (2014). Food and Agriculture Organization statistical database. *Retrieved Feb*.

Gebrekidan, H. (2003). Grain yield response of sorghum (Sorghum bicolor) to tied ridges and planting methods on entisols and vertisols of Alemaya Area, Eastern Ethiopian Highlands. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS)* 104(2): 113-128.

Gebremariam, G. & Assefa, D. (2015). Nitrogen fertilization effect on grain sorghum (Sorghum bicolor L. Moench) yield, yield components and witchweed (Striga hermonthica (Del.) Benth) infestation in Northern Ethiopia. *International Journal of Agricultural Research* 10(1): 14-23.

Gruhn, P., Goletti, F. & Roy, R. (1998). Proceedings of the IFPRI/FAO Workshop on Plant Nutrient Management, Food Security, and Sustainable Agriculture: The future through 2020.

Legesse, H. & Gobeze, L. (2015). Growth and grain yield response of sorghum (Sorghum bicolor L. Moench) varieties to moisture conservation practices and NP fertilizer at moisture stress area of Amaro, Southern Ethiopia. *AshEse Journal of Agricultural Science* Vol. 1(1): 001-005,.

Masebo, N. & Menamo, M. (2016). The effect of application of different rate of NP Fertilizers rate on yield and yield components of sorghum (Sorghum Bicolor): Case of Derashe Woreda, Snnpr, Ethiopia. *Journal of Natural Sciences Research* 6(5): 88-94.

Mbwika, J., Odame, H. & Ngugi, E. (2011).Feasibility Study on Striga Control in Sorghum, African Agricultural Technology Foundation AATF, Nairobi.

Mwangi, A. M. (1995). The role of urban agriculture for food security in low income areas in Nairobi.

Rabinowitch, H. D. & Currah, L. (2002). *Allium crop science: recent advances.* CABI.

Taylor, J. R., Schober, T. J. & Bean, S. R. (2006). Novel food and non-food uses for sorghum and millets. *Journal of cereal science* 44(3): 252-271.

Tekalign, T., Haque, I. & Aduayi, E. (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. *Working document* (13).

Tesfahunegn, G. B. (2012). Effect of tillage and fertilizer practices on sorghum production in Abergelle area, Northern Ethiopia. *Momona Ethiopian journal of science* 4(2): 52-69.

Thimmaiah, S. (2002). Effect of salinity on biochemical composition of Sorghum (Sorghum bicolor L.) seeds. *Indian Journal of Agricultural biochemistry* 15(1-2): 13-15.

Walkley, A. & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science* 37(1): 29-38.

Wortmann, C. S., Dobermann, A. R., Ferguson, R. B., Hergert, G. W., Shapiro, C. A. & Tarkalson, D. (2006). Fertilizer suggestions for grain sorghum. *NebGuide G1669, Univ. of Nebraska, Lincoln*.

Yan, K., Chen, P., Shao, H., Zhao, S., Zhang, L., Zhang, L., Xu, G. & Sun, J. (2012). Responses of photosynthesis and photosystem II to higher temperature and salt stress in Sorghum. *Journal of Agronomy and Crop Science* 198(3): 218-225.