International Journal of Research in Agricultural Sciences
Volume 1, Issue 6, ISSN (Online): 2348 – 3997)

Effect of Triple Superphosphate and Minjingu Phosphate Rock Fertilizer application on Nutrient Content and Grain Yields of Sorghum in Various Cropping Systems

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Abstract – **Field experiments were conducted at the Egerton University agricultural field, Kenya to determine effect of phosphorus fertilizer application and integration of legumes on nitrogen (N) and phosphorus (N) content and grain yield of sorghum. The experiments, conducted in the short (SRS) and long rain seasons (LRS) of 2012 and LRS of 2013 comprised either lupin or chickpea as test crops. The set up was a split plot arranged in a randomized complete block design. The main plots were cropping systems; sorghum monocrop, legume- sorghum rotation and legume/ sorghum intercrop. The subplots comprised P sources (60 kg P ha^{-1}); triple super phosphate (TSP) and minjingu phosphate rock (MPR). P and N concentrations in the plant tissues were significantly higher with addition of TSP than MPR in the first season (LRS 2012). However, in the SRS 2012, nutrient concentrations in plant tissues with MPR application approached that of TSP and exceeded it the LRS 2013. Comparison of the two legumes with MPR application showed that both were competitive in enhancing plant N and P and sorghum yields. Furthermore, in the subsequent seasons, decomposition of incorporated legume residue led to release of nutrients, P and N for uptake by sorghum. Since MPR is cheaper than TSP, growing lupin or chickpea in intercropping system with sorghum with application of MPR is recommended. Intercropping offers farmers the opportunity to exploit nature's principle of diversity on their farms and greatly contributes to crop production by its effective utilization of resources.**

Keywords – **Chickpea, Minjingu Phosphate Rock, Nitrogen, Phosphorus, White Lupin.**

I. Introduction

Sorghum (*Sorghum bicolor* L. Moench) is a crop native to sub-Saharan Africa and has been cultivated for centuries in Africa and Asia. It is the fifth most important world cereal after wheat (*Triticum* spp.), rice (*Oryza sativa*), maize (*Zea mays* L.) and barley (*Hordeum vulgare* L.) [1]. It is an important grain crop and food source in many developing countries [2]. In Eastern Africa, it is grown on approximately seven million hectares annually and is the second most important cereal crop after maize [3]. It is one of the most versatile crops in terms of its importance as a food grain in the dry regions of the semi-arid tropics [4, 5].

Adequate supply of nitrogen (N) and phosphorus (P), the two most critical plant nutrient elements, is required for optimum sorghum growth and reproduction [6, 7]. Use of inputs of N and P in water soluble chemical fertilizers for continuous agricultural production on regular basis has, however, become a costly affair for small holder farmers and is also environmentally undesirable [8]. Continuous cereal mono cropping coupled with application of sub-optimal rates of inorganic fertilizers has resulted in soil fertility depletion and is the fundamental biophysical root cause of declining per capita food production in sub Saharan Africa [9].

Integration of legumes white lupin (*Lupinus albus*) and chickpea (*Cicer arietinum*) in sorghum based cropping system with application of minjingu phosphate rock (MPR) is novel approach to increase soil N and P for enhanced sorghum nutrition and yield in smallholder farming systems. Leguminous crops have nodules and can accumulate N as NH_3 through symbiosis with Rhizobium micro-organisms [10]. MPR has a high phosphate content lasts long in the soil and thus can increase the P level in soils. Direct application of phosphate rock is an environmentally-friendly and foreign-currency saving way of alleviating P deficiency [11]. Chickpea and white lupin, exude carboxylates from their roots [12] and can enhance the solubility of phosphate rock and thereby avail P for uptake by sorghum grown in intercropping or rotation systems with the legumes [13].

The objective of the study was to determine effect of phosphorus fertilizer application and integration of legumes on nitrogen (N) and P contents and grain yield of sorghum.

II. Materials and Methods

2.1 Study Area

The study was conducted at the Agricultural Field Experimental site, Egerton University, Kenya during the short (SRS) and the long rain seasons (LRS) of 2012 and

LRS of 2013. The farm (2,238 als) lies at a latitude of 0° 23’ South, longitudes 35°35’ East in the Lower Highland III Agro Ecological Zone (LH3) [14]. The average maximum and minimum temperature of the area, ranges from 19 to 22° C and 5 to 8°C, respectively with a total annual rainfall ranging from 1200 to 1400 mm. The rainfall distribution is bimodal. The long rains are experienced in April to August while short rains from September to November.

Table 1: Initial physical and chemical properties of soil

Soil Property	Soil Depth (cm)			Soil Property	Soil Depth (cm)		
	0-15	15-30	30-60		0-15	15-30	30-60
pH	6.34	6.43	6.5	Exchangeable bases			
CEC (C mol kg $^{-1}$)	62.9	42.5	20.4	K (cmol$_c$kg^{-1})	6.0	6.55	5.44
Total N (%)	1.67	0.63	0.63	Mg (cmol$_c$kg^{-1})	0.25	0.25	0.24
Org. C (%)	1.57	1.59	1.5	Ca (cmol$_c$kg^{-1})	0.23	0.4	0.24
Available P (mg kg^{-1})	27.3	27	24.1	% clay	20	20	20
Mineral N (%)	0.79	0.73	0.59	% sand	50	40	36
Bulk density (g cm^{-3})	1.31	1.31	1.24	% silt	30	40	44
Exchangeable Al (%)	0.2	0.3	0.4	Textural class	Sandy loam	Loam	Loam

The soils are predominantly vitric mollic Andosols [14]. The soils were neutral in pH, sandy loam in texture and had low amounts of soil available P and N (Table 1).

2.2 Experimental design and treatments

Two field experiments, comprising either lupin or chickpea, were laid side by side. Sorghum variety *Know Kanty* was the test crop in both of the experiments. The experiments are hereafter referred to as lupin sorghum (LS) and chickpea sorghum (CS). The experimental set up in both experiments was a split plot in a randomized complete block design with three replicates. The main plots were three cropping systems; sorghum monocrop, legume- sorghum rotation and legume/ sorghum intercrop. The subplots, of size 4.8 m × 3.75 m, comprised two P sources; TSP and MPR, both applied at the rate of 60 Kg P ha^{-1}. There was a 0.5 m wide path between the split plots and a 1 m wide foot path between the main plots and blocks.

2.3 Agronomic practices

Land preparation was done prior to the start of rains, using a mould board plough. Harrowing was performed twice, to a depth of 30 cm, using a tractor so as to obtain a fine, firm and weed-free surface for planting. In all cropping systems, sorghum seeds were drilled to a depth of 1 cm in rows spaced at 75 cm by 20 cm. In the rotation system, chickpea and lupin seeds were planted at spacing of 30 by 10 cm and 50 by 30 cm, respectively. In the intercropping system, two lupin or chickpea seeds were planted per hole in the inter-row spaces of sorghum. Spacing of 30 cm between lupin seeds or 10 cm between chick pea seeds was used. MPR and TSP were applied in all seasons, by banding method, and mixed well with soil before placement of the seeds. Treatments and cropping sequences in the LRS and SRS are shown in Table 2. Top dressing (60 kg N ha^{-1}) was done a month after planting in all treatments using calcium ammonium nitrate (CAN). After grain harvest, legume residues were chopped into 5-20 cm small pieces, spread across the plots and incorporated to a soil depth of 15 cm.

2.4 Plant Sampling and Analysis

Six sorghum plants (above ground) were sampled per plot at seedling, flowering and harvest stages. The plants were cut close to the soil surface and chopped into small pieces. Sub-samples were taken and oven dried at 70°C, ground and wet digested for N and P analyses. Nitrogen concentration was determined by semi micro-Kjeldahl digestion and distillation and P concentration determined by the vanadomolybdate yellow method [15].

2.5 Sorghum grain yield determination

At maturity, sorghum grain yield was determined from three plants from the middle rows. The grains were harvested and threshed manually, dried and weighed. Grain yield was recorded and converted to t ha^{-1}.

2.6 Data Analysis

All data collected were subjected to analysis of variance (ANOVA) to detect statistical variations in treatment effects. Means that were significantly different according to the F-test were separated by LSD test at P≤0.05. The SPSS Statistical package was used in the analysis [16]. The results in the tables are presented as mean values ± SD (standard deviations).

III. Results

3.1. Main effect of P source, cropping system and stage of growth on plant N

The mean plant N ranged from 0.85- 8.41% and 0.6-6.38% for LS and CS experiments, respectively (Table 4). Main effect of fertilizer type and stage of growth had no significant effect on plant N in both experiments (Table 3). Cropping systems had a significant effect on plant N in both experiments (Table 3). In the LS experiment, monocropping showed highest plant N in the LRS and SRS 2012 whereas intercropping system had the highest plant N in the LRS of 2013 (Table 4). CS experiment showed similar results except for the 2013 LRS where rotation had the highest plant N (Table 4).

3.2 *Main effect of P source, cropping system and stage of growth on plant P*

The mean range plant P was 0.11- 0.38% in TSP plots and 0.09- 0.42% in MPR plots for LS experiment and 0.17- 0.38% in TSP plots and 0.17- 0.42% in MPR plots for CS experiment (Table 5). There were no significant differences in plant P in both experiments with use of either fertilizer (Table 3). Cropping systems had a significant effect on plant P (Table 3) in both experiments.

Table 2: Treatments and cropping sequences in the long and short rains of 2012 and 2013

Cropping system	Description	P source	Cropping sequence 2012 LRS	2012 SRS	2012 LRS
		Lupin sorghum experiment			
Monocrop	Sorghum	MPR	sorghum	sorghum	sorghum
	Sorghum	TSP	sorghum	sorghum	sorghum
Rotation	Lupin-sorghum	MPR	lupin	sorghum	lupin
	Lupin-sorghum	TSP	lupin	sorghum	lupin
Intercrop	Lupin/sorghum	MPR	Lupin/sorghum	Lupin/sorghum	Lupin/sorghum
	Lupin/sorghum	TSP	Lupin/sorghum	Lupin/sorghum	Lupin/sorghum
		Chickpea sorghum experiment			
Monocrop	Sorghum	MPR	sorghum	sorghum	sorghum
	Sorghum	TSP	sorghum	sorghum	sorghum
Rotation	Chickp-sorghum	MPR	chickpea	sorghum	chickpea
	Chickp-sorghum	TSP	chickpea	sorghum	chickpea
Intercrop	Chickp/sorghum	MPR	Chickp/sorghum	Chickp/sorghum	Chickp/sorghum
	Chickp/sorghum	TSP	Chickp/sorghum	Chickp/sorghum	Chickp/sorghum

Key: Chickp= chickpea, MPR = minjingu phosphate rock, P= phosphorus, TSP= triple super phosphate; - = rotation; / = intercrop

There were higher contents in rotation and monocropping systems in LS and CS experiments, respectively (Table 5). Stage of growth had a significant effect on plant P within LS experiment only (Table 3) with higher levels at sorghum seedling and flowering (Table 5).

3.3 Effect of interaction between stage of growth, fertilizer type and cropping system on plant N and P.

Fertilizer type, cropping systems and stage of sorghum growth interacted significantly (Table 3) to affect plant N and P in lupin sorghum and in the chick pea sorghum experiment (Table 4 and 5). Effect of cropping system (CR) × fertilizer source (F); CR × stage of growth (S); and CR × S × F interactions were significant for plant N and P in both experiments (Table 3)

3.4 Main effect of fertilizer type and cropping system on sorghum grain yield

There were no significant differences in sorghum grain yield with use of either fertilizer in LS experiment. A significant difference was however observed In the CS experiment (Table 3) with greater grain yield in MPR than TSP plots (Table 6). The mean range for sorghum grain yield was 10.53- 18 t ha^{-1} for TSP plots and 14.7- 18.3 t ha^{-1} for MPR plots in LS experiment and 14.3- 21.7 t ha^{-1} for TSP plots and 17.7- 24 t ha^{-1} for MPR plots in CS experiment (Table 6).

Main effect of cropping system on sorghum yield was not significant in both experiments (Table 3).

3.5 Effect of interactions between cropping system and fertilizer type on sorghum grain yield

Cropping system and fertilizer type interacted significantly to affect the grain yield content (Table 3) in LS experiment (Table 6).

IV. Discussion

4.1 Treatment effects on Plant N

Sorghum had adequate N content, in both experiments. The average range of N in sorghum is usually 2.4- 4% [17]. A higher N content in sorghum was observed in the intercropping and rotation systems in the 2013 LRS. This could have resulted from supply of N due to biological nitrogen fixation by legume component and mineralization of incorporated residues [18].

N content in sorghum did not differ significantly with P fertilizer type used, in both experiments. Adequate P supply is necessary proper root development, nodule formation and N fixation process of legumes [19].

Absence of legumes partly led to the lower plant N in the monocropping system in the 2013 LRS. Growing cereals continuously in low input conditions is likely to be an unsustainable system in the long run due to depletion in soil fertility.

There is thus a strong need to introduce crop rotation practices as well as intercropping so as to increase N supply for cereals [20]. Legumes, when integrated into cereal cropping systems either as rotational fallows or relay intercrops, have been shown to provide considerable amounts of organic matter and nitrogen to the soil [21].

Table 3: Summary of analysis of variance for measured parameters as influenced by P fertilizer source, growth stage and cropping system

Source of Variation	df	Plant N	Plant P	Grain yield
Lupin sorghum experiment				
Fertilizer (F)	1	ns	ns	ns
Stage (S)	2	ns	*	-
S × F	2	ns	ns	-
Cropping System (CR)	8	*	*	ns
CR × F	8	*	*	*
CR× S	16	*	*	-
CR × S × F	16	*	*	-
Chickpea sorghum experiment				
Fertilizer (F)	1	ns	ns	*
Stage (S)	2	ns	ns	-
S × F	2	ns	ns	-
Cropping System (CR)	8	*	*	ns
CR × F	8	*	*	ns
CR × S	16	*	*	-
CR × S × F	16	*	*	-

Table 4: Plant N (%) as affected by P source, growth stage and cropping systems interaction (mean ± SD)

		2012LRS				2012SRS				2013LRS			
C	P	S1	S2	S3	Aver.	S1	S2	S3	Aver.	S1	S2	S3	Aver.
Lupin sorghum experiment													
S	T	4.3	1.2±0	0.93	2.14	2.58	1.98	2.58	2.38	1.73	5.06	7.94	4.91
		±0.01	.01	±0.07	±0.03	±0.33	±0.23	±0.52	±0.36	±0.26	±0.3	±0.52	±0.36
	M	4.2	1.4±0	0.98	2.19	2.58	2.18	2.58	2.45	2.6	4.62	4.69	3.97
		±0.06	.2	±0.97	±0.41	±0.09	±0.33	±0.52	±0.28	±0.1	±0.69	±0.42	±0.4
S/L	T	4.6	0.94	0.97	2.17	2.38	1.79	1.77	1.98	1.62	6.83	8.41	5.62
		±0.52	±0.46	±0.08	±0.35	±0.43	±0.85	±0.21	±0.5	±0.4	±0.41	±0.54	±0.45
	M	4.28	1.01	1.1	2.13	2.58	2.58	2.00	2.39	2.52	6.28	4.74	4.51
		±0.06	±0.1	±0.1	±0.09	±0.51	±0.52	±0.01	±0.34	±0.01	±0.01	±0.04	±0.02
S-L	T	4.74	0.85±	0.89	2.16	2.38	1.79	2.78	2.32	2.69	2.07	7.47	4.08
		±0.25	0.08	±0.02	±0.12	±0.43	±0.85	±0.23	±0.5	±0.01	±0.13	±0.83	±0.32
	M	4.68	0.85	1.12	2.23	1.19	1.79	1.19	1.39	3.45	5.68	12.2	7.11
		±0.22	±0.02	±0.34	±0.19	±0.28	±0.85	±0.13	±0.42	±0.01	±0.49	±2.98	±1.16
Chickpea sorghum experiment													
S	T	4.6	0.98±	0.89	2.16	1.1	1.59	1.45	1.38	1.1	4.69	5.87	3.89
		±0.65	0.98	±0.23	±0.62	±0.9	±0.12	±0.49	±0.5	±0.9	±0.42	±1.1	±0.81
	M	4.8	1.06±	0.96	2.27	1.31	1.98	1.0	1.43	1.31	3.16	5.21	3.23
		±0.3	0.11	±0.06	±0.16	±0.01	±0.47	±0.6	±0.36	±0.01	±0.24	±0.21	±0.15
S/C	T	3.18	0.79	0.95	1.64	2.73	0.6	0.91	1.41	2.73	4.09	6.38	4.4
		±0.01	±0.96	±0.57	±0.51	±0.15	±0.36	±0.01	±0.17	±0.15	±0.24	±0.15	±0.18
	M	3.58	0.76	1.13	1.82	2.52	2.18	1.47	2.06	2.52	4.17	6.28	4.32
		±0.3	±0.05	±0.5	±0.28	±0.8	±0.33	±0.01	±0.38	±0.02	±0.29	±0.01	±0.1
S-C	T	4.52	0.83	0.92	2.09	3.55	2.18	1.9	2.54	3.55	1.57	7.0	4.04
		±0.58	±0.01	±0.07	±0.22	±0.28	±0.33	±0.53	±0.38	±0.28	±0.01	±2.65	±0.98
	M	4.52	1.24	1.31	2.36	2.13	1.98	2.06	2.06	2.13	3.53	10.0	5.22
		±0.1	±0.03	±0.03	±0.05	±0.23	±0.23	±0.11	±0.19	±0.22	±0.55	±2.7	±1.16

Key; Aver. = average, C= cropping system; SRS= short rain season; LRS = Long rain season; S= Sorghum monocroping system; / intercropping; -= rotation; L= Lupin; C= chickpea; M= Minjingu phosphate rock; P= phosphorus source; T= triple superphosphate; S1= seedling; S2= 50% flowering; S3= maturity; LS= lupin sorghum experiment; CS= chick pea sorghum experiment; - =rotation; /= intercropping

Table 5: Plant P (%) as affected by P source, growth stage and cropping systems interaction (mean ± SD)

Lupin sorghum experiment													
		2012LRS				2012SRS				2013LRS			
C	P	S1	S2	S3	Aver.	S1	S2	S3	Aver.	S1	S2	S3	Aver.
S	T	0.56	0.67	0.23	0.38	0.24	0.29	0.18	0.24	0.49	0.32	0.26	0.36
		±1.05	±0.1	±0.4	±0.75	±0.4	±0.05	±0.05	±0.17	±0.4	±1.3	±0.15	±0.3
	M	0.54	0.51	0.20	0.42	0.13	0.18	0.18	0.16	0.33	0.41	0.24	0.33
		±0.15	±0.36	±0.05	±0.17	±0.65	±0.35	±0.1	±0.37	±0.35	±0.1	±0.15	±0.2
S/L	T	0.43	0.39	0.34	39.05	0.07	0.12	0.15	0.11	0.29	0.15±	0.06	0.17
		±0.4	±0.15	±0.2	±0.6	±0.4	±0.45	±0.05	±0.15	±0.4	0.1	±0.1	±0.2
	M	0.56	0.42	0.27	0.25	0.13	0.07	0.73	0.69	0.07	0.21	0.12	0.13
		±1	±0.45	±0.2	±0.55	±0.2	±0.1	±0.01	±0.5	±0.2	±0.35	±0.03	±0.2
S-L	T	0.49	0.25	0.22	0.30	0.26	0.14	0.59	0.33	0.13	0.36	0.33	0.28
		±0.3	±0.45	5±0.1	±0.3	±0.3	±0.1	±0.35	±0.2	±0.2	±0.4	±0.1	±0.2
	M	0.86±	0.31±	0.36	0.37	0.34	0.22	0.34	0.30	0.04	0.75	0.05	0.28
		0.15	0.3	±0.05	±0.63	±0.2	±0.1	±0.2	±0.17	±0.42	±1.14	±0.46	±0.67
Chickpea sorghum experiment													
S	T	0.43	0.39	0.34	0.38	0.25	0.34	0.21	0.23	0.25	0.14	0.37	0.26
		±1.25	±2.1	±2.2	±18.5	±0.5	±0.4	±0	±0.3	±0.66	±0.8	±0.7	±0.7
	M	0.48	0.34	0.32	0.38	0.19	0.35	0.31	0.34	0.32	0.28	0.50	0.47
		±0.3	±1.1	±1.1	±0.93	±3.8	±0.1	±1.3	±1.7	±0.6	±0.4	±0.1	±0.4
S/C	T	0.52	0.43	0.34	0.34	0.26	0.32	0.16	0.23	0.35	0.28	0.35	0.22
		±0.5	±2.5	±4.4	±2.5	±1.5	±0.2	±1.1	±0.93	±0.8	±0.6	±0.8	±0.7
	M	0.42	0.46	0.38	0.42	0.31	0.33	0.21	0.39	0.62	0.34	0.50	0.49
		±0.6	±0.6	±0.5	±0.6	±4.7	±0.5	±0.5	±1.9	±0.3	±0.9	±0.3	±0.5
S-C	T	0.50	0.25	0.35	0.30	0.20	0.63	0.35	0.39	0.51	0.24	0.30	0.45
		±5.29	±7	±18.4	±1.3	±0.1	±0.3	±0.3	±0.23	±1.6	±0.2	±1.2	±0.9
	M	0.23	0.38	0.34	0.32	0.11	0.14	0.17	0.14	0.32	0.35	0.25	0.31
		±0.75	±0.17	±0.64	±0.52	±0.5	±0.1	±0.1	±0.3	±0.7	±0.51	±0.9	±0.7

Key; Aver. = average, C= cropping system; SRS= short rain season; LRS = Long rain season; S= Sorghum monocroping system; / intercropping; -= rotation; L= Lupin; C= chickpea; M= Minjingu phosphate rock; P= phosphorus source; T= triple superphosphate; S1= seedling; S2= 50% flowering; S3= maturity; LS= lupin sorghum experiment; CS= chick pea sorghum experiment; - =rotation; /= intercropping

4.2: Treatment effects on Plant P

Lack of significant differences in P content of sorghum with use of either TSP or MPR applied shows that both were equally competitive in supply of P for nutrition by sorghum. This suggests that MPR can become a viable alternative P nutrient source [22]. The effectiveness of MPR was enhanced by legumes. Legumes crops exude acids from their roots providing an acidic environment that allows for MPR solubilization [23]. MPR works best in low pH soils of less than 5.5 [24]. Besides, acids produced during decomposition of incorporated legume residues lowered soil pH resulting in MPR solubilization and increased P availability for uptake by sorghum [25].

A higher plant P realized at the seedling and flowering stages of sorghum was due higher P requirement for root growth and reproduction. Adequate P is required for optimum sorghum growth and reproduction [26]. A lower plant P generally observed at harvest stage was due to low plant uptake. There is low plant P requirement after grain filling.

Competition for P by the two crops standing on the field at the same time could have caused the lower plant P in the intercropping system in both experiments. A higher plant P was observed in the monocropping system in the CS experiment because there was no competition for nutrients since there was only one standing crop. The higher P content in sorghum in the rotation system in the LS experiment was due to enhanced P availability due to decomposition of residues of previously grown legumes [23].

4.3: Treatment effects on sorghum grain

Fertilizer type did not significantly affect grain yield in LS experiment. This implied that both fertilizer sources were effective in their supply of P to sorghum for increased sorghum grain yield. Phosphorus is a critical plant nutrient element for optimum sorghum growth and reproduction [6]. MPR could thus serve as a viable alternative to TSP as it is also cheaper and environmentally friendly.

Although cropping systems did not significantly affect sorghum grain yield in both experiments, the intercropping system may be best system on focus compared to the other two systems.

Table 6: Sorghum grain yield (t ha^{-1}) as affected by fertilizer type and cropping system interaction (Mean ± SD

P	2012 LRS				2012 SRS				2013 LRS			
	Mono	Inter	Rot	Aver.	Mono	Inter	Rot	Aver.	Mono	inter	Rot	Aver.
Lupin sorghum experiment												
TSP	11.27	16.3	12	13.19	10.53	17.7	12.7	13.6	13	18	15	15.3
	±5.1	±4.04	±2.6	±3.9	±4.7	±4.2	±2.9	±3.93	±6.08	±3.5	±2.6	±4.1
MRP	18.3	14.7	17.3	16.8	18.3	16.7	17.7	17.6	18.3	17	16	17.1
	±3.74	±9.3	±3.78	±5.6	±4.7	±7.6	±3.2	±5.2	±4.7	±7	±4.9	±5.4
Chickpea-sorghum experiment												
TSP	21.3	15.7	16.3	17.8	21.7	16.7	14.3	17.6	21	17.3	14.7	17.6
	±1.5	±5.7	±5.1	±4.1	±0.6	±6	±2.1	±2.9	±1.73	±5	±3.05	±3.26
MRP	24	21.7	20.6	22.1	23	21.7	17.7	20.8	22	21.6	19.3	20.9
	±3.5	±2.5	±2.3	±2.8	±1.7	±1.5	±3.2	±2.13	±2	±1.5	±3.05	±2.18

Key; P= phosphorus source; SRS= short rain season; LRS = Long rain season; Mono= Sorghum monocroping system; Inter = intercropping; Rot = rotation

Intercropping system is well known for its opportunity to exploit nature's principle of diversity farms as well as contributing to crop production by its effective utilization of resources [27].

Conclusion

Integrating legumes white lupin and chickpea in sorghum based cropping systems with application of either MPR or TSP enhanced N and P contents and yield of sorghum. Sorghum grain yield did not differ with fertilizer type used in LS experiment. In the CS experiment, however, a greater yield was obtained in MPR than TSP plots. Since MPR is cheaper than TSP, is environmental friendly, has a very high phosphate level and can raise the soil pH creating suitable environment for the survival of rhizobium bacteria responsible for N fixation, it is thus preferred to TSP. MPR can thus be an attractive alternative in the supply of P to soils and subsequent uptake by sorghum for improved grain yields.

Sorghum grain yield increased with season with the highest observation in LRS of 2013. Although sorghum grain yield was not significantly different in various cropping systems, intercropping sorghum with either lupin or chickpea with application of MPR is recommended for resource poor farmers. Intercropping system is well known for its opportunity to exploit nature's principle of diversity farms as well as contributing to crop production by its effective utilization of resources [27].

Acknowledgment

The authors' acknowledge the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for sponsoring the research through scholarship grant to the first author. We also thank the Department of Crops, Horticulture and Soils for providing laboratory facilities and experimental site.

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Ms. Tunya obtained a scholarship grant from the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) to support her M. Sc. Study.