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Effect of Fertilizer Micro-Dose and Moisture Management Practices on Agronomic and Economic Performances of Groundnut in Semi- Arid Areas

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ABSTRACT

Low soil fertility and drought condition are main crop production challenges that threatening food security in semi-arid areas. Use of fertilizer at micro dose rates together with in-situ rainwater harvesting using infiltration pits (IP) or tied ridges (TR) are low-input strategies to cope with these challenges. This research was conducted to investigate effects of integrating fertilizer micro dose rates and in-situ rainwater harvesting using IP and TR on groundnut yield and its household profitability to Tanzania smallholder farming groups. Field experiments were conducted from 2015/2016 to 2016/2017 cropping seasons. Infiltration pits and tied ridges increased groundnut yield significantly by 20.2 to 32.6 % and 34.2 to 46.6% respectively over flat cultivation. Fertilizer micro dose at 50% of recommended rate significantly increased yield by 50.8 to 64.7 % over zero application. Integration of TR with fertilizer at RR resulted into highest groundnut yield ranged from 1,034 to 1,096 kg/ha and highest NP ranged from 1,027 to 1,081 USD/ha. The integrations of TR and fertilizer micro dose at 50% of recommended had significant higher yield ranged from 748 to 1,086 kg/ha and higher NP ranging from 405 to 662 USD/ha compared to famer practice. The integrations of micro dose rate of 50% of recommended rate and tied ridges is therefore recommended to small holder's famers located in semi dry areas of central Tanzania. This will enable farmers to achieve highly agronomic and economic performances compared to farmer practices.

1.0 Introduction

Groundnut is among very important crop worldwide. It is ranked 6 th most important oilseed crop in the world and 4rd most important source of edible oil (Redae *et al.*, 2017; Upadhyaya *et al.*, 2006). Groundnut is also important crop for nutritional as its kernel contains about 40-50% fats, 20-50% protein and 10-20 % carbohydrates (Redae *et al.*, 2017; Janila *et al.*, 2013; Bhatia *et al.*, 2006). It is also a source of vitamin E and minerals including niacin, falacin, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine and potassium (Katundu *et al.*, 2014; Janila *et al.*, 2013; Yaw *et al* 2008). The production of groundnuts is concentrated in Asia with 64% of global production and less in Africa with 28% of global production (Redae *et al.*, 2017; Janila *et al.*, 2013; Nigam *et al.*, 2004). In African countries, particularly Tanzania, it is produced in only 2.9% of the global area under small-scale level with less application of improved technologies (Tamba, 2016; FAOSTAT, 2013). This resulted into the average yield of 964 kg/ha which is less compared to other African countries (1,264.6 kg/ha in Nigeria; 1,724 kg/ha in Guinea-Bissau) and Asia (Kamhambwa, 2014; FAOSTAT, 2011). The effort of increasing productivity of this crop in semi-arid areas is very important as it can boost health and improve economic welfare of smallholder's farmers.

Low soil nutrients especially phosphorus is among major groundnut production constraints that face small holder's famers in semi-arid areas of sub-Sahara African (SSA). Low soil nutrients is caused by production of crops without or with little fertilizer input (Kamhambwa, 2014; Kimenye, 2014), off-season field grazing activities and removal of crop residues in the field and soil erosion (Sharma *et al.*, 2015; Serme *et al.*, 2015; Pimentel and Burgess, 2013). Nutrients are also lost through crop harvest (8 to 88 kg N/ha per annum) in Africa farming communities (Mwinuka, *et al.*, 2017; Henao and Baanante, 2006). Despite the presence of organic materials such as farm yard manure in famers communities, which is also recommended for use in crop production, the availability in terms of quantity needed (10-15 t/ha) is limited to most of the smallholder farmers (Kamhambwa, 2014; Kanyeka *et al.*, 2007). On the other hand it was realized that high cost of inorganic fertilizer at recommended rate limit smallholder farmers from using due to their financial limitations (IDRC, 2014; Odhiambo and Magandini, 2008). Collaborative researches in the Sahel, developed an effective technique to increase fertilizer use efficiency and reduce investment costs to small-scale farmers.

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It also reduces the risk of environmental pollution, as it decreases N and P leaching into groundwater, ammonia volatilization into the atmosphere, and N_2O emissions (Lian *et al*., 2017). The technique is known as fertilizer micro dosing, which is the localized application of fertilizer at reduced amount than that recommended (Camara *et al*., 2013; ICRISAT, 2009). This technology is used in some semi-arid SSA countries and helps farmers to improve returns, in particular for cereals production [Ouattara *et al*., 2018; Abdalla *et al*., 2015, Sime and Aune, 2014). But for legume crops such as groundnuts, the information on the agronomic and economic performance of this technology very little.

Drought condition due to poor and erratic rainfall (300-600 mm annually) and high evapotranspiration rates are among major factors limiting crop production in semi-arid areas (Yabe *et al.*, 2018; Knipp

er, 2017; Kahimba *et al*., 2015; Yosef and Asmamaw, 2015). Large amount of water is lost in these areas due to surface runoff because of slopy topography, uncovered surfaces, surface crusting and high rainfall intensity (Graef and Haigis, 2001; Graef and Stahr, 2000). Therefore, efficient use of water resources is needed in these areas. Tied ridges and infiltration pits are among *in-situ* rainwater harvesting and soil moisture conservation practices that can be used (Kilasara *et al*., 2015; Mudatenguha *et al*., 2014; Nyamadzawo *et al*., 2013). These technologies improve soil water and increases crop productivity up to 65% compared to flat cultivation (Kilasara *et al*., 2015; Yoseph, 2014). The integration of soil moisture and fertilizer contents have synergistic effects on crop growth, which can increase the crop yield, water use efficiency (WUE), and nutrients use efficiency (NUE) (Lian *et al*., 2017; Yang, 2015). However, the synergistic effects of low to high fertilizer rates and different soil moisture conservation technologies on yield is poorly understood.

The objectives of this study were to investigate the effects of integrating both micro-dose fertilizer rates and *in-situ* rainwater harvesting practices on agronomic and economic performances of groundnut in semi-arid areas, with Tanzania central part as a case study. We hypothised that, the integrating both micro-dose fertilizer rates and in-situ rainwater harvesting practices can increase agronomic and economic value of groundnut. Ultimately, if such technology is found appropriate for increasing high agronomic and economic value compared to traditional production system, it would increase poor farmers livelihoods and food security.

2.0 Materials and Methods

2.1 Locations and climate

This study was conducted at Ilolo (latitude -6.345831 and longitude 035.903333) and Idifu (latitude -6.413632 and longitude 035.984143) villages located in Chamwino District, Dodoma region of Tanzania. The slope of experimental site at Ilolo was 3.2 % while the altitude of 1620 m.a.s.l. The experimental site at Idifu village had a slope of 2.2% and altitude of 1006 m.a.s.l. The area has a unimodal rainfall regime, with the rains, starting in December which gives the farmers the opportunity to start planting their crops usually up to mid-January. The area receives low and erratic rainfall ranging from 400 to 650 mm annually, and about 85% of its amount falls months between December and March. (Temu *et al*., 2011).

2.2 Experimental materials

Improved groundnut seed variety 'Pendo' obtained from Agriculture Research Institute (ARI) Naliendele was used. It is a spanish type with 90- 100 days to reach maturity and under optimal management it has a yield potential of 1500 kg/ha. Also, fertilizer material used was Di Ammonia Phosphate (DAP) of 46% P_2O_5 and 18% N).

2.3 Experimental design

A split plot experiment in a randomized complete block design was used with three replications. The main factor was soil moisture management practices with three levels which were tied ridges (TR) of 50 cm width and 15 cm heights; infiltration pits (IP) of 40 cm diameter and 40 cm depth; and flat cultivation (FC) that mimic farmer's practices. Sub factor was fertilizer rates of level 0% (F0) (0 kg P_2O_5/ha), micro dose at 25% of the recommended (MD1) (11.25 kg P_2O_5 /ha), micro dose at 50% of recommended (MD2) (22.5 kg P_2O_5 /ha), micro dose at 75% of recommended (MD3) (33.75 kg P_2O_5 /ha) and 100% of recommended rate (RR) (45 kg P_2O_5 /ha) were applied. Plant spacing used was 50 x 10 cm as recommended Kanyeka *et al*., 2007.

2.4 Data collection

2.4.1 Soil information

Pre-planting soil sampling at both research sites was done in mid-November, 2014 using the random soil sampling method as described by Clain, (2014). An aggregate of eight soil samples was gathered from each site. Analysis of physical and chemical soil characteristics was conducted at the Department of Soil and Geological Sciences laboratory of the Sokoine University of Agriculture. Soil analysis included particle size distribution for textural class by Hydrometer method, soil pH by pH meter in 1:2.5 soil-water, organic carbon by Walkley- Black Method, total nitrogen by micro-Kjedahl digestion method, available phosphorus by Bray and Kurtz 1, exchangeable cations (K^+) by NH4-acetate filtrates by Ammonium Acetate Saturation.

2.4.2 Rainfall

Daily precipitation was recorded by standard rain gauges at both experimental sites. It consists of a funnel emptying into a graduated cylinder, 2 cm in radius, which fits inside a larger container which is 20 cm in diameter and 50 cm tall. If the rainwater overflows the graduated inner cylinder, the larger outer container will catch it. When measurements are taken, the height of the water in the small graduated cylinder is measured, and the excess overflow in the large container is carefully poured into another graduated cylinder and measured to give the total rainfall.

2.4.3 Groundnut yield

One-meter squared where randomly marked on central rows of the plots, well matured groundnuts were uprooted by hand, the number of plants, number of pods, pods weight were recorded. Harvested pods were sun dried to constant weight and the weight of kernel/kernels were recorded.

2.4.4 Economic data

The costs of all experimental materials used in the study such as fertilizer and seeds in (Tsh /kg) and maximum and minimum market prices for 2015/2016 and 2016/2017 season in (Tsh /kg) were recorded. Furthermore, costs of crop management activities including planting, weeding, harvesting (Tsh/ha) were recorded. The costs were then transferred from TSH into USD based on the exchange rate of 1 USD =2,100Tsh.

2.5 Data analysis

Rainfall data were subjected into descriptive statistical analysis were cumulative rainfall were plotted. Inferential statistics were used for crop yield data where analysis of variance was done by Gen-start software at P=5% using the statistical model indicated in equation 1. Tukey's test at P=5% was used for separation of means (Montgomery, 2004).

$Y_{ijk}=\mu+\beta_i+A_j+\delta_{ij}+B_k+AB_{ik}+\varepsilon_{ijk}$. .... (1)

Y_{ijk}= Response level, μ = General effect or general error mean, β_i = Block effect, A_j = Main plot effect, δ_{ij} = the main plot random error (Error a), B_k = Sub-plot effect, AB_{ik}= Interaction effect between the main plot and the subject, and ε_{ijk}= Sub-plot random error effect (Error b). Simple economic analysis using net profit in USD of each technology were calculated by subtracting the total production costs to the total revenue of each technology (Sekumade, 2017; Adesoji *et al*., 2016).

3.0 Results

3.1 Soil characteristics on experimental units

The texture of the soil in in experimental unit was sandy clay loam for both sites with pH of 5.8 and 5.3 for Ilolo and Idifu, respectively (Table 1). The organic carbon of the soil was very low with 0.46% and 0.11% for Ilolo and Idifu respectively. Total nitrogen and extractable phosphorous of the soil was also very low at both sites. The potassium content was high at Ilolo and medium at Idifu (0.69 $cmolkg^{-1}$ and 0.43 $cmolkg^{-1}$, respectively). These physical and chemical soil characteristics are typical for Tanzanian and other SSA semi-arid regions.

Table 1.Soil characteristics on experimental units.

Particle size distribution	Values for Ilolo site	Values for Idifu site
% Clay	21.6	25.6
% Silt	2.92	4.92
% Sand	75.5	69.5
Textural class	SCL*	SCL*
Chemical characteristics		
Organic Carbon (OC) (%)	0.46^{VL}	0.11^{VL}
Soil pH (in H_2O)	5.88^{M}	5.30^{M}
Total nitrogen (N) (%)	0.06^{VL}	0.06^{VL}
Ext. Phosphorus (P) (mg/kg)	12.88^{L}	6.43^{VL}
Cation Exchange Capacity (CEC) ($cmol_c kg^{-1}$)	15.20^{M}	5.40^{L}
Exch. Bases K+ ($cmol_c kg^{-1}$)	0.69^{M}	0.43^{M}

SCL=sand clay loam, VL= very low, L= low, M= medium, +According to Landon 1991

3.2 Rainfall amount and distribution

The amount of rainfall and number of rainfall events during 2015/2016 and 2016/2017 cropping seasons are indicated in Figure 1. Idifu had relative higher amount of rainfall in both seasons of 425. 3 mm for 2015/2016 and 153.3 mm for 2016/2017 cropping seasons compared to Ilolo which site which had a total rainfall of 298.2 mm during 2015/2016 and 141.1 mm during 2016/2017 cropping season. Although Idifu received higher amount of rainfall but the distribution is poor as it has lower number of rainfall occurrence than Ilolo.

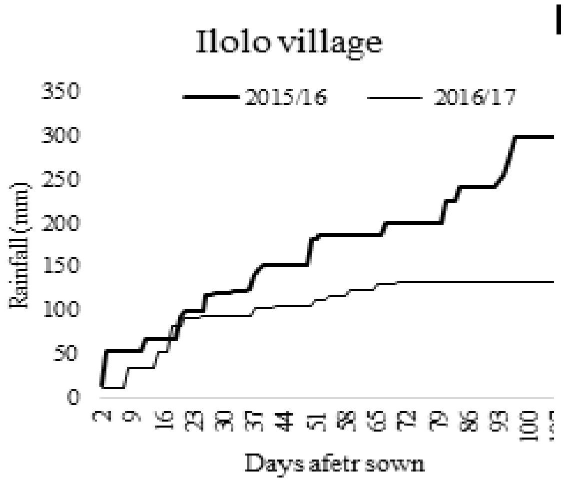

Figure 1. Cumulative amount of rainfall during 2015/16 and 2016/17 cropping season.

3.3 Spatial and seasonal variations of groundnut yield under famer's practices

The results showed that, the locations and seasons had no significant effect on grain yield (Table 2). Ilolo had relative higher yield compared to Ilolo. Also, 2016/2017 cropping season had better crop yield.

Table 2. **Spatial and seasonal variations of groundnut yield under famer's practices.**

		Kernel Yield (kg/ha)
Locations	Idifu Ilolo Lsd	512 544 92.7 ns
Seasons	2015/2016 2016/2017 Lsd	511 546 92.7 ns

Lsd = least significant difference, *=Significant deference, ns =non-significance

3.4 Kernel yield performance under in-situ rainwater harvesting practices

Tied ridges and infiltration pits resulted into significant increase kernel yield in all locations except at Idifu during 2016/17 cropping season (Table 3). Tied ridges had the highest kernel yield in all locations while flat cultivation scored the lowest yield. No significant increase in yield when tied ridges is compared to infiltration pit though tied ridges had relative better kernel yields.

Table 3. Effect of soil water management technologies on groundnut kernel yield (kg/ha).

	Ilolo		Idifu	
	2015/16	**2016/17**	**2015/16**	**2016/17**
FC	534.8 a	553.4 a	486.3 a	537.7 a
TR	654.6 b	699.8 b	643.2 b	739.0 a
IP	617.7 b	638.3 b	556.1 b	685.4 a
CV	2.7	3.0	5.7	11.4
F value	0.002	0.002	0.01	0.07

Means in the same column followed by the same letter are not significantly different according to Turkeys test at $p \leq 0.05$. FC= flat cultivation, TR= tied ridges, IP= infiltration pits, CV =coefficient of variation

3.5 Effect of fertilizer micro dose on groundnut kernel yield

The kernel yield increases significantly in all season across all locations when different fertilizer rates were applied (Table 4). Zero fertilizer treated plots (farmers practice) resulted to the lowest kernel yield in both seasons which ranged from 486.3 to 553.4 kg/ha while recommended rate had highest yield ranging from 878.9 to 1140.4 kg/ha. Micro-dose at 50% increases yield significantly compared to farmer practice except at Ilolo during 2015/16 where no significance yield increase was observed. Further, the results showed no significant yield increase when micro dose at 75% of recommended rate were compared with recommended rate.

Table 4. Effect of micro dose on groundnut kernel yield (kg/ha).

	Ilolo		Idifu	
	2015/16	**2016/17**	**2016/16**	**2016/17**
FO	534.8 a	553.4 a	486.3 a	537.7 a
MD1	602.4 ab	637.2 ab	636.2 ab	559.9 b
MD2	631.2 ab	757.2 b	834.0 bc	734.1 b
MD3	780.8 bc	989.8 c	972.3 c	959.6 c
RR	878.9 c	1,123.2 c	1,140.4 c	1,109.9 c
CV	10.7	5.7	10.7	10.8
F value	0.002	0.001	0.001	0.001

Means in the same column followed by the same letter are not significantly different according to Turkeys test at $p \leq 0.05$. FO= zero fertilizer, MD1= micro dose at 25% of recommended rate, MD2= micro dose at 50% of recommended rate, MD3= micro dose at 75% of recommended rate, RR= recommended rate, CV=coefficient of variation.

3.6 Kernel yield under integrated *in-situ* rainwater harvesting practices and fertilizer rates

Flat cultivation without fertilizer application which typically represent farmer practices resulted into the lowest kernel yield in both locations. (Table 5). Integrating tied ridges with fertilizer at recommended rate had the highest kernel yield (1,263.5 -1,543.5 kg/ha) followed by infiltration pits with recommended rate (1,135.8- 1,337.9 kg/ha). Integration of tied ridges and infiltration pits with fertilizer rates from 50% to recommended rate to recommended rate increased the yield significantly compared to farmer practice. The groundnut kernel yield increased by 652.3 kg/ha and 352.4 kg/ha at Ilolo during 2015/2016 and 2016/2017 cropping seasons, respectively, when tied ridges were integrated with fertilizer micro dose at 50% of recommended rate with similar trend for Idifu. The results also showed no significance increase in yield when micro dose rate at 50%, 75% and recommended rate were used under both tied ridges and infiltration pits.

3.7 Economic assessment of all technologies used in the study

The results showed that, the use of infiltration pits without application of fertilizer, with micro dose of 25% and at 50% of recommended rate in both locations resulted into negative net profit (Figure 2). Integration of tied ridges and fertilizer at recommended rate resulted into the highest NP of 884.4 and 650.7 USD for Idifu and Ilolo respectively. Integration of tied ridges and micro dose rates of 25%, 50% and 75 % of recommended rate increased NP by 140.3, 347 and 522.5 USD respectively compared to farmers practices at Idifu village. Further at Ilolo, Integration of tied ridges and micro dose rates of 25%, 50% and 75 % of recommended rate increased NP by 72, 303 and 436 USD respectively compared to farmers practices. More over the use of micro dose rate from 25% to 75% with flat cultivation gave positive NP ranged from 257.4 to 631.7USD and 188.5 to 332 USD at Idifu and Ilolo respectively

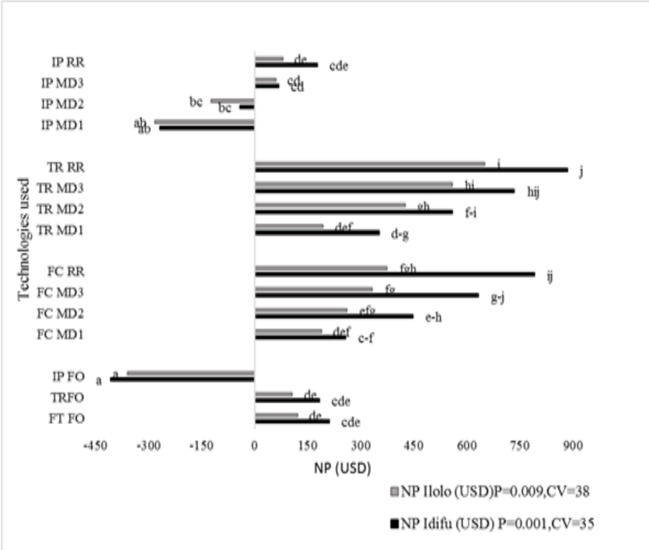

Figure 2. Net profit of technologies used in the study (USD/ha).

FC= flat cultivation, TR= tied ridges, IP= infiltration pits. FO= zero fertilizer, MD1= micro dose at 25% of recommended rate, MD2= micro dose at 50% of recommended rate, MD3= micro dose at 75% of recommended rate, RR= recommended rate, CV=coefficient of variation

Table 5. The effect integrations of micro dose fertilizer rates and *in-situ* rainwater harvesting management practices on groundnut kernel yield (kg/ha).

	Ilolo 2015/16	Ilolo 2016/17	Idifu 2015/16	Idifu 2016/17
FC x FO	534.8 a	553.4 a	486.3 a	537.7 a
FC x MD1	602.4 ab	637.2 ab	636.2 ab	559.9 a
FC x MD2	631.2 ab	757.2 a-d	834.0 a-d	734.1 ab
FC x MD3	780.8 ab	989.8 d-g	972.3 b-e	959.6 a-d
FC x RR	878.9 bcd	1,123.2 fgh	1,140.3 de	1,109.9 b-e
TR x FO	654.6 ab	699.8 abc	643.2 ab	739.0 ab
TR x MD1	823.7 abc	727.7 a-d	827.4 a-d	948.6 a-d
TR x MD2	1,160.1 def	906.0 c-f	981.7 b-e	1,197.7 c-f
TR x MD3	1,234.8 ef	1,134.3 fgh	1,118.7 cde	1,407.5 ef
TR x RR	1,338.5 f	1,263.5 h	1,284.0 e	1,543.7 f
IP x FO	617.7 ab	638.3 ab	556.1 a	685.4 ab
IP x MD1	819.3 abc	744.3 a-d	779.0 abc	800.7 abc
IP s x MD2	918.8 b-e	843.8 b-e	999.4 cde	1,021.5 b-e
IP x MD3	1,124.9 c-f	1,049.9 e-h	1,073.3 cde	1,174.3 c-f
IP s x RR	1,222.1 ef	1,187.8 gh	1,135.8 de	1,337.9 def
CV	12.1	10.0	12.9	14.4
F value	0.001	0.001	0.001	0.001

Means in the same column followed by the same letter are not significantly different according to Turkeys test at $p \leq 0.05$. FC= flat cultivation, TR= tied ridges, IP= infiltration pits. FO= zero fertilizer, MD1= micro dose at 25% of recommended rate, MD2= micro dose at 50% of recommended rate, MD3= micro dose at 75% of recommended rate, RR= recommended rate, CV=coefficient of variation

4.0 Discussions

4.1 Soils fertility and rainfall

Soils at experimental sites were sand clay loam, a soil texture which are ideal for the most crop growth (Birkas *et al.*, 2014 with very low nitrogen (N) and phosphorous (P) contents. Both sites had acidic soils with pH of 5.3 (Ilolo) and 5.2 (Idifu), which is slightly below of that required (5.5-7) for groundnut production (Putnam *et al*., 1991) and this affected its growth and productivity (Murata *et al*., 2011). The deficiency of P in the soils could have been due to unavailability of inherent soil P, fixation of P by aluminum, iron, or calcium as soils are acidic and poor management of on-farm organic and inorganic P resources in the soil (Cerozi and Fitzsimmons, 2016). Off season grazing activities in these areas which resulted into reduction of organic matter in the field also contributed to nutrients deficient in the soils. Is such soil, the application of lime to rise a pH to propriate range for groundnut production and to enhance availability of nutrients in the soil is very important as suggested by Goulding, 2016 and Rastija *et al*., 2014).

The amount of rainfall received in both experimental sites was below of that required by groundnut crop of 750-1200 mm per growing season (Temu *et al*, 2011; Kanyeka *et al*., 2007). Low amount and poor distribution of rainfall could be due to environmental degradation mainly deforestation. Large part of these area is covered by bare soils, grasslands and few scattered trees due to deforestation (FAO, 2001, Backéus *et al*., 1994), unlike other tropical areas which mostly covered with forests with high amount of rainfall. Increasing deforestation reduces the natural recycling of moisture from soils, through vegetation, and into the atmosphere, from where it returns as rainfall (Bagley *et al*., 2014; Oliveira *et al*., 2013). When forests are replaced by pasture or crops, water recycling process changes, leading to reduced atmospheric humidity and potentially suppressing precipitation (Devaraju, 2015; Spracklen and Garcia-Carreras, 2015; Deborah and Karen, 2014). Therefore, the strategies of in situ harvesting rain water by using technologies such as tied ridges and infiltration pits are vital for increasing crop productivity these areas.

4.2 Effects of in situ rain water harvesting technologies and fertilizer on kernel yield

Kernel yield increased by 32% and 46% during 2015/2016 and 25% and 34% during 2016/2017 at Ilolo when infiltration pits and tied ridges were used, respectively with similar trend for Idifu site. The increased in yield could have been due to available moisture in the soil resulted from in situ catchment and temporary stored rain water by tied ridges and infiltration pits which support physiological processes of the crop. And this explaining why crops that grown in tied ridges and infiltration pits performed better than that grown in flat land. The observation made by Kilasara *et al*., 2015 and Yoseph, 2014 showed that tied ridges can improve soil moisture and increased yield up to 67% compared to flat cultivation. Application of phosphorus at reduced amount just at 50 % of recommended rate increased kernel yield significantly compared to zero application. The added phosphorus in the soil through inorganic fertilizer (DAP) promotes groundnut growth and lengthening of root and shoots. It also stimulates the setting of pods, decreases the number of unfilled pods (pops) and hastens the maturity of the crop (Tamba, 2016; Kamara *et al*. (2011). The groundnut yield increased by 26.7 % in 2015/2016 and 34.8 % in 2016/2017 seasons when micro dose rate of 50 % were applied at Ilolo. It was also reported that, micro dosing is used as a strategy of increasing fertilizer use and income in west Africa and India and resulted into increased crop yields up to 120% and with increasing family income by 50 to130 % (Abdalla, *et al*., 2015; IDRC, 2014; Sime and Aune, 2014; ICRISAT, 2009). Small holder's farmers in the study areas with financial constraint of purchasing inorganic P fertilizer at recommended rate can reduce costs of purchasing of fertilizer by 50 % when micro dosing at 50 % of recommended rate is used.

4.3 Agronomic and economic responses of integrating fertilizer micro dose and in situ rain water harvesting technologies

Potentiality of using either fertilizer at micro dose rates alone or soil moisture management practices on yield performance was vivid, but integration of these technologies is very important for smallholder's famer in semi-arid areas as it simultaneously tackle the problem of low soil fertility and drought conditions. Integration of tied ridges with micro dose rate at 50% of recommended rate increased groundnut kernel yield by 63.7% to 117% at Ilolo and 101 to 122.7% at Idifu while infiltration pits with micro dose rate at 50% increased yield by 52 to 71 % and by 90 to 105% at Ilolo and Idifu respectively. It was also reported that, integration of in-situ rainwater harvesting technologies along with fertilizer micro dosing increased crop yield up to 80% compared to famers practices (IDRC, 2014). Significant increase of kernel yield when integrating in-situ rainwater harvesting and fertilizer, is due to the presence of enough moisture in the soil which facilitate the dissolution and absorption of soil nutrients. This enhance the availability of the nutrients in particular P for proper growth and development of the crop. Considering the economic worthiness of the technologies, all technologies that resulted to negative net profit is not economical to invest as it leads to economic losses (Adinya *et al*., 2010; DFA, 2006). The use of infiltration pits without fertilizer inputs and with fertilizer application up to 50 % of recommended rate resulted into economic losses to the famers. This is because of highly production costs especially during infiltration pits preparation (tedious and time consuming) and little harvests received from these treatments. The options that benefited small holder's farmers located in semi-arid areas were to integrate fertilizer micro dose at 50 % of recommended rate to recommended rate with tied ridges or with flat cultivation. These technologies resulted into higher economic and agronomic performances compared to farmers practices.

5.0 Conclusions and Recommendations

This study evaluated the effect of integrating fertilizer at different application rates and in-*situ* rainwater harvesting technologies on groundnut kernel yield in semi-arid environment, and their household profitability among smallholder farming communities in the central Tanzania. It was concluded that the amount of rainfall in these areas were below average amount to support crop production. Tied ridges and infiltration pits significant increased kernel yield compared to flat cultivation. Micro dose fertilizer application at 50% of recommended rate had higher yield than famer practice. Also, the integration of tied ridges or flat cultivation and fertilizer micro dosing at 50% of recommended rate to recommended rate had high agronomic and economic performance compared to farmer practices. The study therefore recommends the use of tied ridges and application of inorganic fertilizer at micro dose rate of 50% of recommended rate (22.5 kg P_2O_5/ha) for small holder groundnut farmers located in semi aid areas of central Tanzania. This will enable farmers to achieve high economic and agronomic performances compared to farmer practices. This recommendation will transmute negative thinking of most farmers on the use of inorganic fertilizers and inspire them toward use of tied ridged with micro dose rates and finally to recommend rate for improved groundnut productivity, and hence improved livelihood.

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