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Review Article

Review of Rice Response to Fertilizer Rates and Time of Nitrogen Application in Ethiopia

Tilahun Tadesse*, Zelalem Tadesse

Fogera National Rice Research Center, Woreta, Ethiopia

Email address:
tilahuntadesse2000@gmail.com (T. Tadesse)
*Corresponding author

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Abstract: Rice productivity in Ethiopia is estimated at 2.8 t ha^{-1}, which is much lower than the World's average of 4.4 t ha^{-1}. Weeds, pests, soil nutrient deficiencies and terminal moisture stress are the major causes of low rice productivity in Ethiopia. Poor soil fertility is among the major factors limiting the rice production. Appropriate fertilizer application is an important management practice to improve soil fertility and production of rice. Availability of plant nutrients, particularly nitrogen at various plant growth stages is of crucial importance in rice production. Recommendations on different period of nitrogen fertilizer application were given for various production systems. Traditionally, Diammonium phosphate and urea (supplying nitrogen and phosphorus) were the major fertilizers used by farmers in Ethiopia, creating nutrient imbalances in soils. Therefore, to make the soil well supplied with all the plant nutrients in the readily available form and to maintain good soil health, it is necessary to use organic manures in conjunction with inorganic fertilizers to obtain optimum yields. The integrated use of NP and FYM gave higher yields than application of either NP or FYM alone for many crops production. Different experiments were conducted to tackle rice soil fertility constraints. The major focuses of the experiments include inorganic fertilizers application rates, application times and their integration with organic fertilizers. The review paper summarizes the results of the experiments conducted on rice fertilizer rates and timings of nitrogen applications.

Keywords: Rice, Fertilizers, Rates, Nitrogen, Application

1. Introduction

The average rice productivity in Ethiopia is estimated at 2.8 t ha-1 [19], which is much lower than the World's average of 4.4 t ha-1 [10]. Weeds, pests, soil nutrient deficiencies and terminal moisture stress are the major causes of low rice productivity in Ethiopia [19, 12]. Poor soil fertility is among the major factors limiting rice production in Ethiopia. Appropriate fertilizer application is an important management practice to improve soil fertility and production of rice [16]. Productivity increments were observed in various experiments conducted on soil nutrient management for rice production in Ethiopia.

An inadequate fertilizer applied through improper application technique is one of the factors responsible for low yield of rice [1]. Availability of plant nutrients, particularly nitrogen at various plant growth stages is of crucial importance in rice production. Recommendations on different period of nitrogen fertilizer application were given for various production systems. The number of splits is affected by the total amount of nitrogen fertilizer to be applied based on the desired yield level [9].

To achieve potential rice yields, modern cultivars of rice require different kinds of fertilizers. Among all fertilizers, nitrogen (N) is the most essential for plant development, growth and grain quality. However, N use efficiency (NUE; defined as grain dry matter per unit of N available from the soil, fertilizer included), is very low and estimated to be approximately 33% of the applied N source. Because of the significance of nitrogen as a major nutrient for rice crop to attain high grain yield, it is crucial to determine the ideal amount and timing of N application for each rice cultivars [11].

Even though the inorganic fertilizers could result in higher crop yield, over reliance on them often associated with declined soil properties and degraded soils and in turn decreased yield in subsequent period [20]. Traditionally, Diammonium phosphate and urea (supplying nitrogen and phosphorus) were the major fertilizers used by farmers in Ethiopia, creating nutrient imbalances in soils [7]. Therefore, to make the soil well supplied with all the plant nutrients in the readily available form and to maintain good soil health, it is necessary to use organic manures in conjunction with inorganic fertilizers to obtain optimum yields. The integrated use of NP and FYM gave higher yields than application of either NP or FYM alone for many crops production [7].

Different experiments were conducted to tackle rice soil fertility constraints. The major focuses of the experiments include inorganic fertilizers application rates, application times and their integration with organic fertilizers [22, 4, 14, 23, 3, 6, 2, 18]. The objective of this paper is to summarize the results of the experiments conducted concerning rates and time of applications of fertilizers for rice production in Ethiopia.

According to Landon [15], available 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, most trial location had very low to medium available P. 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, All the experimental soils qualify for low total N. Similarly, the organic carbon (OC) content of the soil was also low in accordance with Landon, who categorized OC content as very low (<2%), low (2-4%), medium (4-10%), high (10-20%) (Table 1).

Table 1. *Some soil chemical characteristics of sample taken before planting of rice.*

Location	Reference	Soil chemical characteristics			
		Available P (Olsen)	Total N %	Organic Matter %	P^H
Fogera	[22]	12.639 (Moderate)	0.16 (Low)	3.20 (Low)	5.48
Metema		3.482 (extremely Low)	0.12 (Low)	2.40 (Low)	6.105
Maitsebri	[2]	3.8 (very low)	0.09 (Very low)	2.12 (Low)	6.3
Kamashi/ Assosa	[6]	9.8 (Low)	0.17 (Medium)	3.72 (Low)	5.46
Bambasi/Assosa		3.2 (extremely Low)	0.13 (Low)	4.346 (Medium)	5.25
Tepi—Kuja	[18]	5.9 (very low)	0.06 (Very low)	2.13 (Low)	5.66
Tepi---Gojeb		6.3 (very low)	0.09 (Very low)	2.98 (Low)	6.31

2. Inorganic Fertilizer Management for Rice Production

2.1. Effect of Nitrogen and Phosphorous Fertilizers on the Yield of Rice in Major Rice Production Areas of Ethiopia

A fertilizer rate trial was conducted on rainfed lowland rice from 2002 to 2004 cropping seasons at Fogera [22]. The results of the experiment indicated that the interaction effect of nitrogen and phosphorous, the 115-46 N-P_2O_5 kg/ha application gave the highest grain yield, 4076.4 kg/ha, with a yield advantage of 1325.9 kg/ha over the unfertilized (0-0 N-P_2O_5 kg/ha) level at Fogera (Table 2). However; the economic analysis done following the partial budget analysis of CIMMYT [8] for Fogera indicated that it was the 69-23 N-P_2O_5 kg/ha rate that was found the first profitable rate followed by 46-46 N-P_2O_5 kg/ha and 46-0 N-P_2O_5 kg/ha fertilizer (Table 3). Thus 69-23 N-P_2O_5 is the best recommended fertilizer rate for rice production in Fogera plain. In cases where farmers face economic difficulty, money shortage at the time of planting, the 46-46 N-P_2O_5 could be used as a second alternative.

An experimental conducted on upland rice at Assosa indicated that significant grain yields were obtained with the applications of N and P, but not their interaction [6]. The highest grain yield was obtained from plot that received maximum nitrogen and phosphorous rates (Table 4). Another field experiment carried out on upland rice at Bambasi District of Assosa Zone, revealed that most of yield and yield components of rice were significantly ($P<0.05$) affected by the main effect of N and P. The highest grain yield (3244 kg ha^{-1}) was recorded from 92 kg N ha^{-1} combined with 46 kg P_2O_5 ha^{-1} and the lowest grain yield (1415.6 kg ha^{-1}) was recorded from the control treatment (Table 5). Partial budget analysis also indicated that the highest net return (28548 Birr ha^{-1}) was obtained from the application of 92 kg N ha^{-1} combined with 46 kg P_2O_5 ha^{-1} fertilizer rate (Table 6). Thus, from the result of this study, it can be concluded that the application of 92 kg N ha^{-1} combined with 46 kg P_2O_5 ha^{-1} was found superior both agronomically and economically for rice NERICA-4 variety under main cropping season in the study area.

An experiment was conducted in 2014 and 2015 in Tigray, Ethiopia, on upland rice with the objectives of determining the economically optimum rates of N & P [2]. The interaction effects of N and P were significant ($P \leq 0.05$) for grain and straw yields (Table 7). The combination of 138 kg N/ha and 46 kg P_2O_5/ha resulted in grain yield of 5723 kg/ha and the control (i.e. no N with no P) resulted in the lowest grain yield (1601 kg/ha). On the other hand, highest straw yield of 12246 kg/ha was observed at the treatment combinations of 138 kg N /ha and 69 kg/ha of P_2O_5 and the lowest biomass yield (4528 kg/ha) was observed on the control treatment. Unlike that of the agronomic yield, the economic analysis of the combined result over two years and two locations revealed that net return of 22208.63 Birr/ha was obtained for the plot that received 69 kg N/ha and 23 kg P_2O_5/ha which gave 11185.12 Birr more than the net returns obtained from the control, Birr 11023.51 birr (Table 8). Therefore, farmers in Tselemti district and similar areas should use the most economically feasible fertilizer rate with highest value of marginal rate of return i.e. 69 kg N/ha with 23 kg P_2O_5/ha.

The experiment conducted on upland rice at Metema showed that the highest grain yield was obtained with the application of 60/20 N/P_2O_5 (3355kg/ha) followed by 60/40 and 80/20 N/P_2O_5 which gave 3198 and 2920 kg/ha, respectively (Table 9). Treatment 60/20 N/P_2O_5 had a yield advantage of 2009 kg/ha over the control treatment [22]. However, according to partial budget analysis application of 60/20 N/P_2O_5 was economically profitable and is the 1st recommendation for Metema area while application of 60/0 N/P_2O_5 could be the second option to be recommended (Table 10).

Table 2. *Effect of Nitrogen and Phosphorous Fertilizers on the Grain Yield (kg/ha) of Rice for low land rice production system at Fogera.*

Nitrogen (N kg/ha)	**Phosphorous (P_2O_5 kg/ha)**			
	0	**23**	**46**	**Mean**
0	2750.5	2925.5	3325.7	3000.5
46	3466.8	3524.1	3790.6	3593.8
69	3595.0	3922.4	3851.2	3789.5
92	3912.6	3694.7	3746.1	3784.5
115	3750.2	3938.2	4076.4	3921.6
Mean	3495.0	3601.0	3758.0	
	N	P_2O_5	N x P_2O_5	
$LSD_{5\%}$	345.5	NS	598.5	
CV%	27.18			

Table 3. *Economic Analysis of rice fertilizer rate determination for lowland production system at Fogera.*

Dominance Analysis				**MRR Analysis**				
N-P_2O_5 (kg/ha)	**TVC**	**NB.**		**N-P_2O_5 (kg/ha)**	**TVC**	**NB**	**MRR (%)**	**Rank**
0-0	0.0	5224		0-0	0	5224		
0-23	187	5351		0-23	187	5351	67.5	
46-0	338	6352		46-0	338	6352	663.2	
0-46	374	6026	D	69-0	507	6384	19.2	
46-23	459	6255	D	46-46	580	6721	463.2	3rd
69-0	507	6384		69-23	628	6806	175.0	2nd
46-46	580	6721		92-0	676	6855	102.6	1st
69-23	628	6806						
92-0	676	6855						
69-46	749	6583	D					
92-23	797	6363	D					
115-0	845	6504	D					
92-46	918	6189	D					
115-23	966	6602	D					
115-46	1087	6694	D					

*TVC=Total Variable Cost (Birr/ha)
**NB= Net Benefit (Birr/ha)

Table 4. *Yield and yield components of rice as influenced phosphorus and nitrogen rates, at Assosa.*

Source of variation	**Grain yield kg/ha**
Phosphorous (P)	
0	4205.9^{C}
10	4886.4^{BC}
20	5197.5^{AB}
30	5660.6^{A}
LSD	694.85***
Nitrogen (N)	
0	3867.0^{B}
46	5124.9^{A}
92	5265.7^{A}
138	5692.8^{A}
LSD	694.85***
CV%	24.14

Table 5. *Interaction effect of Nitrogen and Phosphorus rate application on straw and grain yields of Upland rice (NERICA - 4) at Bambasi District.*

N (kg/ha)	**P_2O_5 (Kg/ha)**	**Straw Yield (kg ha^{-1})**	**Grain Yield (kg ha^{-1})**
0	0	6333.5^{b}	1415.6^{f}
0	23	7926.0^{b}	1861.3^{de}
0	46	8259.5^{ab}	2117.3^{cde}
0	69	9518.5^{ab}	2160.7^{bcde}

N (kg/ha)	P_2O_5 (Kg/ha)	Straw Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})
46	0	10111.0^{ab}	2245.6^{bcd}
46	23	10537.0^{ab}	2312.0^{bc}
46	46	8000.0^{b}	2231.9^{bcd}
46	69	7389.0^{b}	2130.4^{cde}
92	0	11203.5^{ab}	1790.0^{ef}
92	23	7463.0^{b}	2151.1^{bcde}
92	46	15524.0^{a}	3244.0^{a}
92	69	8092.0^{ab}	2503^{bc}
138	0	11944.5^{ab}	2521.8^{b}
138	23	12944.5^{ab}	2443.7^{bc}
138	46	12240.5ab	2125.7^{cde}
138	69	12074^{ab}	2357.0^{bc}
LSD (5%)		4098.6	214.21
CV (%)		24.6	15.77

Table 6. *Partial Budget Analysis of N and P fertilizer application rates on rice at Bambasi district.*

Treatment Combination (kg N-P_2O_5 ha^{-1})	Total variable cost (ETB)	Net benefit (ETB)	Marginal Rate of return (%)
0-0	5075	10832.2	-
0-23	6012.5	14702.2	412.8
0-46	6950	16235.5D	-
0-69	7887.5	16318.1D	-
46-0	6560	18705.9	225.2
46-23	6742.5	19334	344.2
46-46	7425	16662.1D	-
46-69	8107.5	14760.6D	-
92-0	7045	14666.8D	-
92-23	7727.5	15363.9D	-
92-46	8410	28548	552.6
92-69	9092.5	17480.7D	-
138-0	9015	19653.5D	-
138-23	9697.5	18768.1D	-
138-46	10380	14871.6D	-
138-69	10614.5	16635.5D	-

Table 7. *Effect of N and P fertilizer sources on grain and biomass yields of upland rice at Tselemti District, N. W Tigray (combined over locations and years).*

N (kg/ha)	P_2O_5 (kg/ha)	GY (kg/ha)	Straw (kg/ha)
0	0	1601.19^{i}	4528^{ghi}
0	23	1734.28^{hi}	4582.23^{gh}
0	46	2080.58^{ghi}	7786.47^{fgh}
0	69	2124.10^{ghi}	8333.24^{bcde}
23	0	2717.64^{fghi}	8987.88^{bc}
23	23	3161.63^{efgh}	4527.61^{cdefg}
23	46	3082.91^{efgh}	6966.78^{cdefg}
23	69	3104.21^{efgh}	7550.85^{cdefg}
46	0	3393.11^{defg}	9004.33^{bcde}
46	23	3463.96^{defg}	10533.80^{bcd}
46	46	4042.20^{cdef}	5024.60^{cde}
46	69	4254.24^{bcde}	6773.94^{bcd}
69	0	3906.54^{cdef}	8699.70^{bcd}
69	23	4671.20^{abcd}	9147.16^{bcd}
69	46	4532.48^{abcde}	11927.33^{bc}
69	69	3975.54^{cdef}	5237.79^{cde}
138	0	4231.06^{bcde}	7167.94^{bcd}
138	23	5095.94^{abc}	8861.98^{bc}
138	46	5723.26^{a}	8457.12^{bcd}
138	69	5653.82^{ab}	12246.3^{a}
SEM		525.3	945
CV (%)		24	28
LSD (<0.05%)		1467.27	2640

Table 8. *Partial Budget Analysis (PBA) for the combined two Cropping Season (2 years and 2 locations) at Maitsebri in N. W Tigray, Ethiopia, 2014 and 2015.*

N (kg/ha)	P_2O_5 (kg/ha)	Gross return (Birr)	TVC (Birr/ha)	Net Return (Birr/ha)	DA	MRR (%)	Rank
0	0	11023.51	0	11023.51	-	-	
23	0	16651.9	663.5	15988.4	*	748	
0	46	10404.78	827.25	9577.53	D		
0	23	20665.78	1327	19338.78	*	1953	3
69	0	19035.25	1490.75	17544.5	D		
69	23	12863.13	1654.5	22208.63	*	2848	1
46	0	23309.78	1990.5	21319.28	D		
46	23	20792.67	2154.25	18638.42	D		
46	46	18546.48	2318	16228.48	D		
138	0	13214.88	2481.75	10733.13	D		
23	46	24949.14	2817.75	20131.39	*	2797	2
23	69	24178.21	2981.5	21196.71	D		
69	69	18940.22	3145.25	15794.97	D		
69	46	26645.88	3645	23000.88	*	1441	
138	23	25221.55	3808.75	21412.8	D		
23	23	25217.37	3981	21236.37	D		
138	46	23703.66	4472.25	19231.41	D		
0	69	30149.26	4808.25	25341.01	*	1818	
46	69	33934.74	5635.5	28299.24	*	357	
138	69	33877.75	6462.75	27415	D		

Key: PBA = Partial Budget Analysis; DA= Dominance Analysis; D= Dominated; TVC= Total Variable Cost. Note: Price of fertilizer and unpolished rice is as of 2014/15; Source: [6].

Table 9. *Effect of combined N and P fertilizer rates on upland rice grain yield at Metema.*

P_2O_5 (kg/ha)	N (kg/ha)				
	0	20	40	60	80
0	1181^{g}	2489^{cd}	2437^{d}	2904^{bc}	2559^{cd}
20	1575^{efg}	1789^{e}	1658^{ef}	3355^{a}	2920^{abc}
40	1346^{fg}	1887^{e}	1745^{ef}	3198^{ab}	2383^{d}
CV (%)	18.58				

Numbers followed by different letters indicate significance difference at 5% level of significance.

Table 10. *Economic analysis of fertilizer application on upland rice at Metema.*

N/P_2O_5	Yield (kg/ha)	GFB (Birr/ha)	Fert. Cost (Birr/ha)	Labor cost (Birr/man day)	TVC (Birr/ha)	Net benefit (Birr/ha)	Dom. analysis	MRR (%)	Rank
(0,0)	1346	2788	0	0	0	2788			
(20,0)	1658	4473	120	1.63	121	4352		1389	
(0,20)	1575	4025	152	1.63	154	3871	D		
(20,20)	1789	5180	218	2.53	221	4960		711	
(40,0)	1745	4943	239	3.26	243	4700	D		
(0,40)	1181	1897	304	3.26	308	1590	D		
(40,20)	2489	8961	345	4.25	349	8612		2951	
(60,0)	2559	9339	359	4.89	364	8975		2585	2nd
(20,40)	1887	5710	424	4.89	429	5281	D		
(40,40)	2437	8680	450	5.25	455	8225	D		
(60,20)	3350	13610	464	5.88	470	13140		4011	1st
(80,0)	2383	8388	478	6.52	485	7903	D		
(60,40)	3198	12789	569	6.88	576	12213	D		
(80,20)	2920	11288	584	7.52	591	10697	D		
(80,40)	2904	11202	689	8.51	698	10504	D		

** GFB=Gross field benefits, TVC =Total cost that vary

2.2. Nitrogen and Sulphur Fertilizers Rate Determination for Rice Production in Afar Region, Ethiopia

The nitrogen and sulphur fertilizers experiment on irrigated rice at Afar Region [14] indicated that application of S improved the grain and straw yield on average by 0.5 and 1.3 Mg ha^{-1}, compared to similar N rates without S (Table 11). The combined application of N with S increased on average the grain and straw yield by 0.82 and 2.27 Mg ha^{-1}, respectively, compared to the control (N0S0). The highest grain yield (4.0 t/ha) was obtained when N4 (105 kg ha^{-1}) was combined with S2 (40 kg ha^{-1}) (Table 12). The above findings on the effect of N fertilization on yield and yield components of upland rice variety are similar with the findings reported on the same crop by Shiferaw *et al.* [21].

Ample N supply enhances the assimilation of ammonia, increasing both the protein content and leaf growth of crop plants, resulting with an increase in net photosynthesis [17]. Growth and yield response to the application of S has been reported for many crops ([24, 13]), where, an insufficient S supply can affect yield and quality of crops, caused by the S requirement for protein and enzyme synthesis [24] [13]. Sulphur is also reported to enhance the photosynthetic assimilation of N in crop plants [5].

Table 11. *Response of grain and straw yields of rice to N and S for the 2010 crop season.*

N (kg ha^{-1})	Grain Yield (t ha^{-1})			Straw yield (t ha^{-1})		
	S (kg ha^{-1})			S (kg ha^{-1})		
	0	20	40	0	20	40
0	1.81	1.87	1.96	5.30	6.19	6.33
36	2.02	2.19	2.33	6.29	6.45	6.77
59	2.32	2.49	2.65	6.60	7.76	8.02
82	2.51	2.95	3.30	7.60	8.63	8.74
105	2.84	3.33	4.00	8.44	9.24	8.86
LSD	0.11			0.22		
CV (%)	21.1			35.6		

2.3. Time of Nitrogen Fertilizer Application for Low Land Rice Production System in Fogera Plain, Northwestern Ethiopia

An experiment consisting of two fertilizer rates (69/23 and 46/46 kg N/P_2O_5 ha^{-1}) and five nitrogen (N) application times (half at planting + half at tillering (control), half at planting + half at panicle initiation, one-third at planting + two-third at tillering, one-third at planting + two-third at panicle initiation and one-third at planting + one-third at tillering +one-third at panicle initiation) was conducted on the Vertisols of Fogera plain during the 2006 and 2007 cropping seasons [4]. Results showed significant difference in grain yield in response to the time of nitrogen fertilizer application. The highest mean grain yield (4409 kg ha^{-1}) was recorded when nitrogen fertilizer was applied at one-third at planting and two-third at the tillering stage of the crop. Hence, application of nitrogen fertilizer one-third at planting and two-third at tillering stage of rice, disregard of the fertilizer rate, is recommended for rice production in the Fogera plain (Table 12).

Table 12. *Effect of nitrogen fertilizer rate and nitrogen application time on the grain yield of rice in the vertisols of Fogera plain, combined over sites.*

Time of N application	Fertilizer rates (kg/ha)		
	46/46 N/P_2O_5	69/23 N/P_2O_5	Mean
Half at planting and half at tillering (control)	4001	3944	3972^{b}
Half at planting and half at panicle initiation	3899	3635	3767^{b}
One-third at planting and two-third at tillering	4357	4462	4409^{a}
One-third at planting and two-third at panicle initiation	3961	4215	4088^{ab}
One-third at planting, one-third at tillering and one-third at panicle initiation	4120	3425	3772^{b}
Mean	4067	3936	

Numbers followed by different letters on the same column indicate significant differences at 5% level of significance using Duncan's multiple range test.

2.4. Integrated Application of Inorganic and Organic Fertilizers for Rice Production in Ethiopia

An experiment was conducted at Maitsebri, in 2011/12, to evaluate the effect of integrated application of inorganic fertilizers (IF) and farm yard manure (FYM) on yield and yield components of upland rice [3]. The results indicate that the highest straw yield 49.99Ql/ha was observed when 9t/ha FYM is combined with 75kg/ha DAP + 75 kg/ha urea while the lowest straw yield (30.64 Ql/ha) was obtained in the control treatment (Table 13). Highest mean grain yield of 44.4 Ql/ha was also found from the combined application of both organic and inorganic fertilizers at the higher rates (Table 13).

Table 13. *Straw and Grain yield of upland rice as influenced by the integrated nutrient management, at Maitsebri, Ethiopia.*

FYM (t/ha)	IF (kg/ha)	Straw Yield	Grain Yield
0	0	30.64	24.27f
0	75kg/ha DAP + 75kg/ha Urea	43.94	38.11b
0	50kg/ha DAP + 50kg/ha Urea	36.8	34.6bcd
0	25kg/ha DAP + 25kg/ha Urea	34.26	29.25e
6	0	33.3	33.4cde
6	75kg/ha DAP + 75kg/ha Urea	43.8	38.74b
6	50kg/ha DAP + 50kg/ha Urea	42.7	37.11bc
6	25kg/ha DAP + 25kg/ha Urea	36.0	31.97de
9	0	36.5	36.66bc
9	75kg/ha DAP + 75kg/ha Urea	49.9	44.40a
9	50kg/ha DAP + 50kg/ha Urea	41.2	37.01bc
9	25kg/ha DAP + 25kg/ha Urea	43.8	35.8bcd
CV (%)		9.53	7.15
LSD (0.05)		6.362	4.251
SEM (±)		14.111	6.307

Another study conducted on integrated nutrient management of NP fertilizers with farmyard manure (FYM) at Gojeb in Kaffa Zone and at Kuja in Benchi Maji zone showed that the highest grain yields of 4050.00 kg ha^{-1} and 5064.20 kg ha^{-1} at Kuja and Gojeb, respectively, were obtained from the application of 5 t ha^{-1} FYM combined with 75% recommended inorganic NP followed by the application of 5 t ha^{-1} FYM with 50% recommended rate of inorganic NP (Table 14). The application of 5 t ha^{-1} FYM in combination with 75% inorganic NP has increased grain yield by 73.51% and 13.51% at Kuja and by 77.96% and 17.76% at Gojeb over the control and the application of 100% recommended rate of NP fertilizers, respectively (Table 14). The increase in yield of rice due to the integration of 5 t FYM ha^{-1} with 75% inorganic fertilizers over 100% of inorganic NP might be due to the addition of both macro and micro nutrients from the FYM, which indicates that even full rate of blanket inorganic NP was not adequate for rice production both at Kuja and Gojeb. The economic analysis revealed that the highest net returns of Birr 67521.8 ha^{-1} at Kuja and 78311.34 at Gojeb were obtained with the application of 5 t ha^{-1} FYM + 75% inorganic NP (Tables 15 and 16). Thus, from the economic point of view, it was apparent that 5 t ha^{-1} FYM + 75% of inorganic NP were more profitable than the other treatments both at Kuja and Gojeb since the highest income were from these treatments as compared with the other treatments [18].

Table 14. *Grain yield of rice as influenced by integrated nutrient management at Kuja and Gojeb, southwestern Ethiopia.*

Treatments	Grain Yield (Kg/ha)	
	Kuja	Gojeb
2.5 t FYM+25% RDF	3577.3^{c}	3737.7^{c}
2.5 t FYM+50% RDF	3635.3^{c}	4200.2^{bc}
2.5 t FYM+75% RDF	3684.3^{bc}	4455.1^{abc}
5 t FYM+25% RDF	3924.3^{a}	4685.2^{ab}
5 t FYM+50% RDF	4018.0^{a}	4878.5^{ab}
5 t FYM+75% RDF	4050.0^{a}	5064.2^{a}
7.5 t FYM+25% RDF	3911.0^{a}	4944.0^{ab}
7.5 t FYM+50% RDF	3904.0^{a}	5000.4^{a}
7.5 t FYM+75% RDF	3886.3^{ab}	5003.2^{a}
100% RDF	3502.7^{c}	4164.7^{bc}
Control	1072.7^{d}	1116.1^{d}
LSD (5%)	213.83	796.36
CV (%)	13.54	10.94

Table 15. *Results of partial budget analysis to estimate net benefit of integrated nutrient management on rice at Kuja, southwestern Ethiopia.*

Treatments	Total cost (ETB ha-1)	Net return (ETB ha-1)
2.5 t FYM+25% RDF	3005.8	59775.82
2.5 t FYM+50% RDF	3149.4	60650.12
2.5 t FYM+75% RDF	3271.9	61387.57
5 t FYM+25% RDF	3322.3	65549.17
5 t FYM+50% RDF	3531.4	66984.5
5 t FYM+75% RDF	3555.7	67521.8
7.5 t FYM+25% RDF	3822.8	64815.25
7.5 t FYM+50% RDF	3999.8	64515.4
7.5 t FYM+75% RDF	4056.5	64148.07
100% RDF	3028.6	58443.79
Control	1201.8	17624.09

Table 16. *Results of partial budget analysis to estimate net benefit of integrated nutrient management on rice at Gojeb, southwestern Ethiopia.*

Treatments	Total cost (ETB ha-1)	Net return (ETB ha-1)
2.5 t FYM+25% RDF	2844.6	57706.14
2.5 t FYM+50% RDF	2977.6	65065.64
2.5 t FYM+75% RDF	3052.9	69119.72
5 t FYM+25% RDF	3362.6	72537.64
5 t FYM+50% RDF	3436.1	75595.6
5 t FYM+75% RDF	3728.7	78311.34
7.5 t FYM+25% RDF	3825.4	76267.4
7.5 t FYM+50% RDF	3899.2	77107.28
7.5 t FYM+75% RDF	3906.6	77145.24
100% RDF	2906.4	64561.74
Control	1307.4	16773.42

From an experiment carried out at Fogera plain, in north-western Ethiopia during the main cropping seasons of 2010 and 2011. It was observed that the highest grain yield was attained at the combined application of the highest rates of all three fertilizers i.e., 15 t ha^{-1} manure with 100 kg P_2O_5 ha^{-1} and 120 kg N ha^{-1} (Table 17). Results of the economic analysis showed that the maximum net benefit (ETB 23751 ha^{-1}) with an acceptable MRR was obtained from the combined application of 7.5 t FYM ha^{-1}, 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} (Table 18). This combination has resulted in a net benefit advantage of Birr 7415 ha^{-1} over the control treatment (0-0 N-P_2O_5 kg ha^{-1}) [23].

Table 17. *The interaction effect of integrated FYM, N and P application on aboveground biomass and grain yields of rice at Fogera in 2010 and 2011.*

FYM (t ha^{-1})	Nitrogen (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})			Phosphorus (kg P_2O_5 ha^{-1})		
		0	50	100	0	50	100
		Aboveground biomass yield (t ha^{-1})			Grain yield (t ha^{-1})		
0	0	9.7^{hi}	9.5^{i}	11.2^{e-i}	2.27^{j}	2.29^{j}	2.32^{j}
	60	10.5^{ghi}	10.5^{ghi}	12.5^{c-g}	2.35^{j}	2.44^{ij}	2.51^{ij}
	120	12.0^{c-g}	13.5^{bcd}	12.7^{c-g}	2.48^{ij}	2.57^{ij}	3.67^{de}
7.5	0	10.8^{f-i}	10.5^{ghi}	9.5^{i}	2.34^{j}	3.10^{fgh}	3.42^{efg}
	60	11.5^{d-i}	11.7^{c-i}	11.9^{c-h}	2.92^{ghi}	3.48^{ef}	4.26^{cd}
	120	11.8^{c-h}	13.3^{b-e}	13.8^{b-e}	3.16^{fg}	3.76^{de}	4.42^{c}
15	0	10.8^{f-i}	11.0^{f-i}	10.5^{ghi}	2.92^{ghi}	3.44^{ef}	3.43^{ef}
	60	12.5^{c-g}	12.8^{b-f}	15.0^{ab}	3.23^{fg}	4.21^{cd}	4.93^{b}
	120	11.0^{f-i}	13.0^{b-f}	15.8^{a}	3.49^{ef}	3.87^{de}	5.01^{a}
	CV (%)	19.70			12.68		

Means followed by the same letters within each growth parameter are not significantly different at P=0.05.

Table 18. *Results of the economic analysis for integrated use of FYM, N and P in rain-fed lowland rice grown at Fogera plain in 2010 and 2011.*

FYM (tha^{-1})	N ($kg\ ha^{-1}$)	P_2O_5 ($kg\ ha^{-1}$)	TVC ($Birr\ ha^{-1}$)	NB ($Birr\ ha^{-1}$)	MRR (%)
0	0	0	0	16336	-
0	120	100	4368	21864	126.6
7.5	120	100	6528	23751	87.3
15	60	100	9993	25121	39.6

TVC = Total variable cost, NB = Net benefit, MRR = Marginal rate of return.

3. Conclusion

Different fertilizer experiments had been conducted on rice in different parts of the country. The experiments are mainly focusing on artificial fertilizers specifically on nitrogen and phosphorous nutrients. There are also few experiments conducted on the integrated application of farm yard manure and artificial fertilizers. Though the Ethiopian agriculture development is introducing other nutrients coming in the artificial fertilizers like sulfur, boron and zinc containing fertilizers, the research has so far not focused on them. Thus, the rice nutrient management research should give attention for the other nutrients other than N and P. It should also give more emphasis on the integrated nutrient management research.

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