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Investigation of Response of Upland Rice *(Oryza sativa* L.*)* to Blended NPSZnB Fertilizer in Fogera and Libo Kemkem Districts of Amhara Region

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Abstract

A field experiment was conducted for three years to determine the economic optimum rate of NPSZnB blended + urea fertilisers for upland rice production in Fogera and Libokemkem districts of the Amhara Region. Blended NPSZnB fertiliser rates of 100, 150, 200 and 250 kg ha $^{-1}$ were factorially combined with 100, 150, 200 and 250 kg urea ha $^{-1}$.. Zero fertiliser as a control treatment and recommended NP fertiliser as a reference treatment were included in the study. The treatments were laid in a randomised complete block design with three replications. The results indicated that the highest grain yields of 4 and 6 t ha $^{-1}$ at Libokemikem and Fogera districts, respectively, were obtained from 250 kg NPSZnB + 200 kg urea ha $^{-1}$.. The highest biomass yields at both districts were obtained from 250 kg NPSZnB + 250 kg urea ha $^{-1}$.. The partial budget analysis of the pooled data indicates that, in the Libokemikem district, the maximum net economic return (NER) of Ethiopian Birr (Birr) 37,474.80 with a marginal rate return (MRR) of 2617.5% was obtained from 250 kg NPSZnB + 200 kg urea ha $^{-1}$.. At Fogera district the maximum NER of Birr 62,548.60 with MRR 1214.6% was obtained from 100 kg NPSZnB + 250 kg urea ha $^{-1}$.. However, it is not possible to draw conclusions that the significant yield increment recorded was due to the contribution of S, B and Zn blends in the NPSB blended fertiliser. Because there were confounding effects of N and P nutrients in the NPSZnB blended fertiliser. As it is revealed in the results, the significant yield response recorded, however, was due to the increasing levels of N. Therefore, we recommend further investigation of the response of NERICA-4 (upland rice) to each nutrient (P, S, Zn and B) through nutrient omission studies.

Keywords: *upland rice, Blended, NPSZnB and Partial budget*

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INTRODUCTION

Studies show that the use of chemical fertilizers in Ethiopia have made a contribution to crop yield growth to date (Asnakew *et. al.,* 1991; Tekalign and Mohamed, 2001) although there is a potential for further improvement. Fertilizer is applied by less than 45% of farmers, on about 40% of area under crop, and most likely at below optimal dosage levels (Dercon and Hill, 2009). However, recent study reports indicated that nutrients like potassium (K), sulfur (S), calcium (Ca), magnesium (Mg) and all micro-nutrients except iron (Fe) are becoming depleted. Deficiency symptoms are reported on major crops in different areas of the country (Abyie *et. al.,* 2003; Asgelil *et al.,* 2007; Wassie and Shiferaw, 2011). Recently acquired soil inventory data from EthioSIS (Ethiopian Soil Information System) revealed that in addition to nitrogen (N) and phosphorus (P), S, born (B), zinc (Zn) and K deficiencies are widespread which all potentially limit crop productivity despite continued use of N and P fertilizer as per the recommendation (EthioSIS, 2015). Studies indicated that nutrient mining due to sub-optimal fertilizer use on one hand and unbalanced fertilizer uses on the other have favored the emergence of multi-nutrient deficiency in Ethiopian soils that in part may have contributed to fertilizer factor productivity decline experienced over recent past (Abyie *et. al.,* 2003, Wassie and Shiferaw, 2011). Hence, following an extensive soil fertility assessment survey in the country, district and kebele-based blended fertilizer recommendations have been produced by EthioSIS (EthioSIS, 2015).

Two blended fertiliser types, NPSB and NPSZnB, are recommended for almost all areas of Fogera and Libokemkem districts in the South Gondar Zone of the Amhara Region (Figure 1). However, fertiliser trials involving multinutrient blends that include micronutrients are rare in Ethiopia. Although there is a general perception that the new fertiliser blends are better than the conventional fertiliser recommendation (urea and DAP), their economic and agronomic advantages are not examined and understood under various production environments.

Rice (*Oryza sativa* L.) production is a recent phenomenon in Ethiopia, as compared to other cereal crops. However, rice production has brought a significant change in the livelihood of farmers and created job opportunities for a number of citizens in different areas of the country. Currently, the Amhara, Southern Nations, Nationalities and Peoples Region (SNNPR), Oromiya, Somali, Gambella, Benishangul Gumuz, and Tigray regions are rice-producing areas in Ethiopia (MoARD, 2010). The Amhara region takes the lion's share of rice production in the country and accounted for 65-81% of the area coverage and 78-85% of the production in the years 2016-2018 (CSA 2017, 2018 and 2019). At present, Fogera and Libokemkem Districts are the two major rice-growing districts in the Amhara Region. The area coverage in rice production has increased considerably, linked with the expansion of production in the wetland and upland areas with the introduction of suitable rice varieties for the different agro-ecologies. Even though there is huge potential and increasing demand for the crop, lack of high-yielding varieties, terminal moisture stress, low soil fertility, disease and cold effects are the constraints that hinder the expansion and productivity of the crop (Abebaw, 2018). This study was therefore conducted with the objectives of determining optimum NPSZnB blended fertiliser rates for rice and assessing the economic feasibility of the recommended blended fertiliser rates.

a) b)

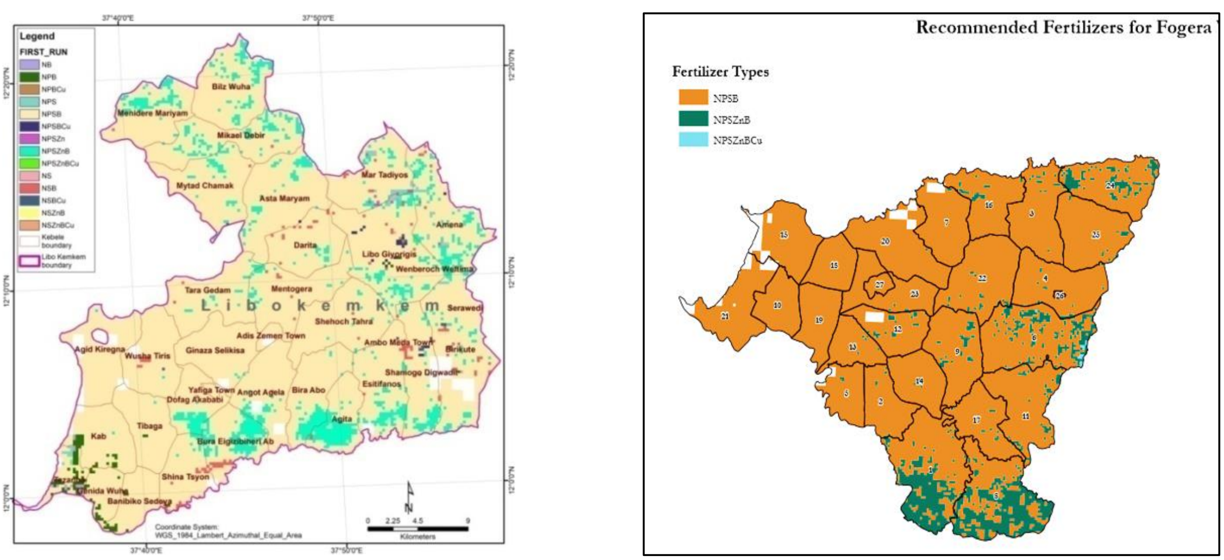


Figure 1. Blended fertilizer recommendation maps of a) Libokemikem district and b) Fogera district of Amhara Region (EthioSIS, 2015).

MATERIALS AND METHODS

Site Description

The experiment was executed from 2017 to 2019 in the Fogera Plain, in two districts, Fogera and Libokemkem, in the Amhara Region of Ethiopia. It was conducted on farmers' fields and on a research station at Fogera National Rice Research and Training Centre (FNRRTC) in the Amhara Region. Fogera Plain, which covers Fogera District and part of Libokemkem District, is an extended wetland area around Lake Tana and is situated between latitude 11°49'55'' N and longitude 37°37'40'' E at an altitude of 1815 meters above sea level (Figure 2). The dominant soil type of the study area is classified as Pellic Vertisol. Rainfall in the area is uni-modal, usually occurring from June to September, and its average annual total rainfall is 1363.7 mm. The mean minimum and maximum temperatures of the study area are 12.7°C and 27.4°C, respectively. The ecology and type of rice cultivation practised in Fogera and Libokemkem districts are categorised as rain-fed lowland and rain-fed upland rice culture.

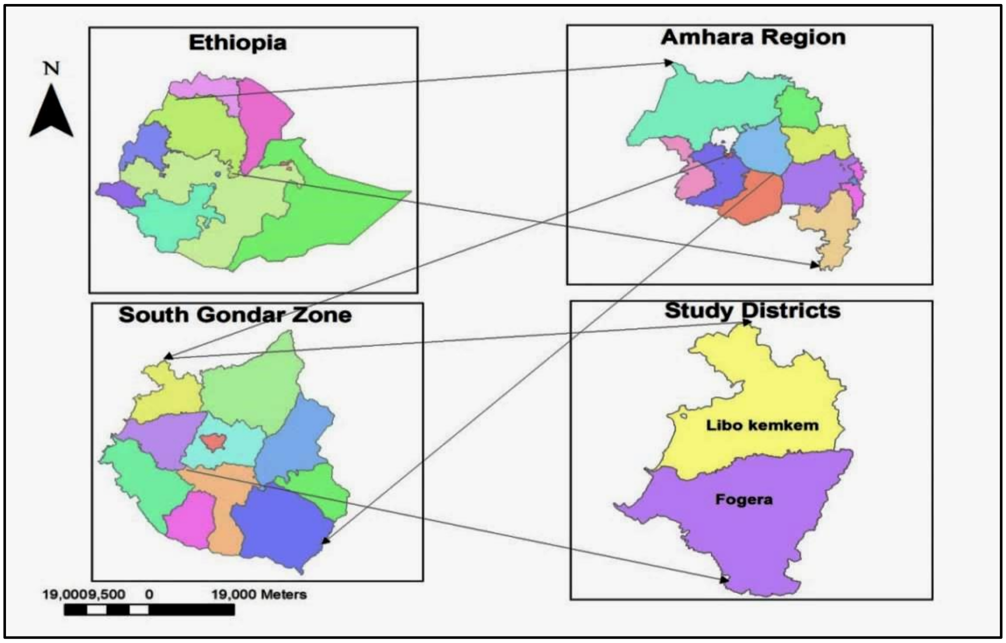


Figure 2. Location map of the study Districts (Fogera and Libo kemkem Districts)

Treatments and Experimental Design

The study factorially combined four rates of NPSZnB blended fertiliser (100, 150, 200, and 250 kg ha^{-1}) with four rates of urea (100, 150, 200, and 250 kg ha^{-1}). In the first year, 17 (seventeen) treatments, including the control treatment (without fertiliser), were evaluated, while in the second year, the previous recommended NP (69/23 N/P_2O_5 kg ha^{-1}) was included to form eighteen (18) treatments (Table 1). The treatments were laid in a randomised complete block design with three replications. The blended fertiliser was band-applied as basal, and the N fertiliser was applied in splits: 1/3 at planting, 1/3 at mid-tillering and 1/3 at panicle initiation stages. Upland rice variety NERICA-4 was planted with 20 cm spacing at a seed rate of 100 kg ha^{-1}.. The gross and net plot sizes were 2 m *x 3 m and 1.2 m* x 3 m, respectively. The other crop management practices were applied uniformly for all plots as per the recommendations.

Table 1. Treatment set up

Treatment	2017 NPSZnB (kg ha^{-1})	2017 Urea (kg ha^{-1})	2018 & 2019 NPSZnB (kg ha^{-1})	2018 & 2019 Urea (kg ha^{-1})	N, P_2O_5, S, Zn, B (kg ha^{-1})
1	0	0	0	0	0, 0, 0, 0, 0
2	100	100	100	100	62.9, 33.8, 7.3, 2.2, 0.7
3	100	150	100	150	85.9, 33.8, 7.3, 2.2, 0.7
4	100	200	100	200	108.9, 33.8, 7.3, 2.2, 0.7
5	100	250	100	250	131.9, 33.8, 7.3, 2.2, 0.7
6	150	100	150	100	71.35, 50.7, 10.95, 3.3, 1.05
7	150	150	150	150	94.35, 50.7, 10.95, 3.3, 1.05
8	150	200	150	200	117.35, 50.7, 10.95, 3.3, 1.05
9	150	250	150	250	140.35, 50.7, 10.95, 3.3, 1.05
10	200	100	200	100	79.8, 67.6, 14.6, 4.4, 1.4
11	200	150	200	150	102.8, 67.6, 14.6, 4.4, 1.4
12	200	200	200	200	125.8, 67.6, 14.6, 4.4, 1.4
13	200	250	200	250	148.8, 67.6, 14.6, 4.4, 1.4
14	250	100	250	100	88.25, 84.5, 18.25, 5.5, 1.75
15	250	150	250	150	111.25, 84.5, 18.25, 5.5, 1.75
16	250	200	250	200	134.25, 84.5, 18.25, 5.5, 1.75
17	250	250	250	250	157.25, 84.5, 18.25, 5.5, 1.75
18	-	-	50 kg DAP	150	69, 46, 0, 0, 0

Soil Sampling and Analysis

One composite surface soil sample by taking five sub-samples at a depth of 0-20 cm was collected before planting from each testing site. The collected soil samples were analysed for texture, pH, electrical conductivity, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, extractable zinc and cation exchange capacity (CEC) following the standard soil analysis procedure.

Data Collection

Rice plants were harvested above ground level from net plot areas to determine biomass and grain yields. Biomass yield of rice was weighed with a graduated balance after sun drying of harvested plants, and each plot biomass yield was converted into a hectare basis. After sun drying and threshing, grains of each plot were sorted out from straw and debris and weighed with a sensitive balance. Rice grain yield obtained from each net plot area was adjusted to 14% moisture content and converted to a hectare basis.

Data Analysis

The collected data were subjected to analysis of variance (GLM procedure) using SAS software version 9.00 (SAS, 2004). The mixed model procedure was used for the combined analysis of the testing sites and study years, with treatments as a fixed variable and site, replication, and year as random variables. Treatment means separation was done with Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$. The farm-gate prices of Ethiopian Birr (ETB) 12.50, 15.62 and 16.66 per kg for variable factors; paddy rice, urea fertiliser and NPSZnB blended fertiliser, respectively, were used for partial budget analysis following the CIMMYT procedure (CIMMYT, 1988). The other factors were constant as they were applied uniformly to all treatments. The mean grain yields used in the partial budget analysis were adjusted to 90% of the measured yield.

RESULTS AND DISCUSSION

Soil physico-chemical characteristics of the study sites

The physico-chemical characteristics of surface soil (0-20 cm) of the study sites are presented in Table 2 below. The surface soil of the study sites had moderately acidic to neutral soil reaction (Jones, 2003), was non-saline (James et al., 1982), had low to medium organic carbon (Tekalign, 1991), had medium total N (Tekalign, 1991), had very low to very high available P (Jones, 2003), had high to very high CEC (Hazelton and Murphy, 2007), had high exchangeable potassium (FAO, 2006), had medium extractable zinc (Jones, 2003) and had clay to heavy clay soil texture.

Table 2. Physico-chemical properties of the composite soil samples collected from the study sites before planting in 2017 and 2019

	2017		2019	
Soil parameter	**Libokemikem**	**Fogera**	**Libokemikem**	**Fogera**
pH (H_2O)	6.20	5.98	6.65	5.08
Electrical conductivity (ds m^{-1})	0.059	0.067	0.141	0.112
Organic carbon (%)	1.60	1.95	0.66	1.25
Total nitrogen (%)	0.13	0.16	0.11	0.16
Available phosphorus (mg kg^{-1})	7.80	2.08	17.2	48.5
Exchangeable potassium ($Cmol_c$ kg^{-1})	Nd	Nd	0.63	0.67
Extractable zinc (mg kg^{-1})	Nd	Nd	0.74	0.41
Cation Exchange Capacity ($Cmol_c$ kg^{-1})	50.0	36.0	Nd	Nd
Texture				
Sand (%)	7	13	12	18
Silt (%)	15	20	16	30
Clay (%)	78	62	72	52

Nd: Not determined.

Effect of NPSZnB blended and urea fertilizer on the yield of upland rice

The data analysis results show that there was a significant ($p<0.05$) effect of the combined use of NPSZnB blended fertilizer with urea on the grain and biomass yield of upland rice in Libokemikem and Fogera districts (Table 3, 4 and 5). In the first experimental year (2017), in both districts, the highest grain yield was obtained from 250 kg NPSZnB + 250 kg urea ha-1 (157.25N, 84.5P2O5, 18.25S, 5.5Zn, 1.75B) (Table 3). However, the pooled analysis of the second and third experimental years (2018 and 2019) indicate that the highest grain yield at both districts was obtained from 250 kg NPSZnB + 200 kg urea ha-1 (134.25N, 84.5P2O5, 18.25S, 5.5Zn, 1.75B) (Table 4 and 5). But, there was no significant difference with the grain yield obtained from 150 kg NPSZnB + 250 kg urea ha-1 (140.35N, 50.7P2O5, 10.95S, 3.3Zn, 1.05B) at Libokemikem district and 100 kg NPSZnB + 250 kg urea ha-1 (131.9N, 33.8P2O5, 7.3S, 2.2Zn, 0.7B) at Fogera district. The highest biomass yields at both districts were obtained from 250 kg NPSZnB + 250 kg urea ha-1 (157.25N, 84.5P2O5, 18.25S, 5.5Zn, 1.75B). The data analysis of the pooled grain yield over the two experimental years (2018 and 2019) in both districts show that the yield obtained from the recommended NP (69N, 46P2O5 kg ha-1) was significantly lower than the highest yield recorded.

The current study agrees with Mulugeta et al. (2017), who found that using K, S, Zn, Mg, and B fertilisers greatly improved bread wheat yields compared to no fertiliser. Melkamu (2019) also noted that blended fertilisers significantly boosted the aboveground biomass, grain yield, and straw yield of food barley. John et al. (2000) reported that adding S, Zn, B, and K nutrients increased maize yields by 40% compared to the standard NP fertiliser recommendation. A similar study showed that the best grain, stover, and total biomass yields of maize came from using blended fertilisers (Dagne, 2016). However, in this study and the others mentioned, it was difficult to determine which specific nutrient contributed most to the higher yields because the levels of N and P increased along with the NPSZnB blended fertiliser.

However, in the present study and in the other studies mentioned above, there was a confounding effect of increasing levels of N and P as the level of the NPSZnB blended fertilizer were increasing. Thus, with all the aforementioned studies including the present study, it is hardly possible to identify which nutrient had significant contribution for the higher yields recorded. Therefore, yield response studies to each nutrient should be investigated through nutrient omission trials.

Table 3. Mean table of effect of the combined application of the NPSZnB blended and urea fertilizer on the grain and biomass yields (kg ha-1) of upland rice in Libokemikem district (Burah testing site) and Fogera district (Quhar micheal testing site) in 2017

NPSZnB-blended + Urea (kg ha^{-1})	**N, P_2O_5, S, Zn, B (kg ha^{-1})**	**Libokemikem (Burah)**		**Fogera (Quhar Micheal)**	
		Grain yield	**Biomass yield**	**Grain yield**	**Biomass yield**
0 + 0	0, 0, 0, 0, 0	1332f	2943g	2138g	3424g
100 + 100	62.9, 33.8, 7.3, 2.2, 0.7	2055e	4927f	3111bcdefg	8085cde
100 + 150	85.9, 33.8, 7.3, 2.2, 0.7	2953bc	5350def	2682efg	6238def
100 + 200	108.9, 33.8, 7.3, 2.2, 0.7	2941bc	6368bcde	2869defg	6610def
100 + 250	131.9, 33.8, 7.3, 2.2, 0.7	2753cd	6360bcde	4024ab	8503bcd
150 + 100	71.35, 50.7, 10.95, 3.3, 1.05	2265de	5215ef	2122g	5108fg
150 + 150	94.35, 50.7, 10.95, 3.3, 1.05	2804bcd	6238bcde	2271fg	5577efg
150 + 200	117.35, 50.7, 10.95, 3.3, 1.05	2828bcd	5626cdef	3160bcdef	7897cde
150 + 250	140.35, 50.7, 10.95, 3.3, 1.05	3167bc	6657bcd	3995abc	8489bcd
200 + 100	79.8, 67.6, 14.6, 4.4, 1.4	2735cd	5708cdef	2314fg	5481efg
200 + 150	102.8, 67.6, 14.6, 4.4, 1.4	3123bc	5918bcdef	4065ab	7968cde
200 + 200	125.8, 67.6, 14.6, 4.4, 1.4	3142bc	6559bcd	3972abc	9472bc
200 + 250	148.8, 67.6, 14.6, 4.4, 1.4	3409b	7214ab	3746abcd	9802bc
250 + 100	88.25, 84.5, 18.25, 5.5, 1.75	3076bc	6461bcde	3025cdefg	6110def
250 + 150	111.25, 84.5, 18.25, 5.5, 1.75	3277bc	6385bcde	3383abcde	14059a
250 + 200	134.25, 84.5, 18.25, 5.5, 1.75	3043bc	6925bc	3090bcdefg	7932cde
250 + 250	157.25, 84.5, 18.25, 5.5, 1.75	4035a	8183a	4231a	10898b
Rec. NP	69, 46, 0, 0, 0	-	-	-	-
Mean		2878.6	6061.0	3184.6	7668.7
CV (%)		11.4	11.3	15.5	16.2

Means followed by the same letter are not significantly different at 5% probability level. Rec. NP = Recommended nitrogen and phosphorus fertilizer.

Table 4. Mean table of effect of the combined application of the blended NPSZnB and urea fertilizer on the grain and biomass yield (kg ha^{-1}) of upland rice at Burah testing site in Libokemikem district in 2018 and 2019

NPSZnB-blended + Urea (kg ha^{-1})	N, P_2O_5, S, Zn, B (kg ha^{-1})	2018		2019		Pooled over two years	
		Grain yield	Biomass yield	Grain yield	Biomass yield	Grain yield	Biomass yield
0 + 0	0, 0, 0, 0, 0	917i	2830h	1426g	5278de	1172i	4054h
100 + 100	62.9, 33.8, 7.3, 2.2, 0.7	2581h	4938g	2357cdef	4583e	2469fgh	4796gh
100 + 150	85.9, 33.8, 7.3, 2.2, 0.7	2558h	5598fg	2120efg	5556cde	2339gh	5577efg
100 + 200	108.9, 33.8, 7.3, 2.2, 0.7	3234fg	6558def	2615bcde	5833bcde	2924def	6195def
100 + 250	131.9, 33.8, 7.3, 2.2, 0.7	3452f	6932de	3090abcd	8750a	3271cd	7659bc
150 + 100	71.35, 50.7, 10.95, 3.3, 1.05	2779gh	5805efg	1743fg	4722e	2261h	5263fg
150 + 150	94.35, 50.7, 10.95, 3.3, 1.05	3370f	6451def	2298def	6852abcde	2834defg	6651bcd
150 + 200	117.35, 50.7, 10.95, 3.3, 1.05	3327fg	6656def	2496bcdef	6204bcde	2911def	6430def
150 + 250	140.35, 50.7, 10.95, 3.3, 1.05	4087cde	8440bc	3288ab	7685abc	3688abc	8063ab
200 + 100	79.8, 67.6, 14.6, 4.4, 1.4	3272fg	6386def	2060efg	4722e	2666efgh	5554efg
200 + 150	102.8, 67.6, 14.6, 4.4, 1.4	3598ef	7239d	2377cdef	5556cde	2988def	6397def
200 + 200	125.8, 67.6, 14.6, 4.4, 1.4	4416abc	9011ab	3150abc	7222abcd	3783abc	8117ab
200 + 250	148.8, 67.6, 14.6, 4.4, 1.4	4184bcd	8619bc	2595bcde	7222abcd	3390bcd	7921ab
250 + 100	88.25, 84.5, 18.25, 5.5, 1.75	3597f	6502def	2377cdef	4722e	2987def	5612efg
250 + 150	111.25, 84.5, 18.25, 5.5, 1.75	3658def	7593cd	2853abcde	6389bcde	3256cd	7112bcd
250 + 200	134.25, 84.5, 18.25, 5.5, 1.75	4670ab	9096ab	3288ab	6667abcde	3979a	7881ab
250 + 250	157.25, 84.5, 18.25, 5.5, 1.75	4804a	9873a	2892abcde	8056ab	3848ab	8964a
Rec. NP	69, 46, 0, 0, 0	2532h	5780efg	3546a	6481abcde	3039de	6131def
Mean		3391.0	6906.0	2587.5	6230.9	2989.2	6578.1
CV (%)		9.4	9.7	16.6	18.3	14.2	14.3

Means followed by the same letter are not significantly different at 5% probability level. Rec. NP = Recommended nitrogen and phosphorus fertilizer.

Table 5. Mean table of effect of the combined application of the NPSZnB blended and urea fertilizer on the grain and biomass yields (kg ha^{-1}) of upland rice at the research station testing site in Fogera district in 2018 and 2019

NPSZnB-blended + Urea (kg ha^{-1})	N, P_2O_5, S, Zn, B (kg ha^{-1})	2018		2019		Pooled over two years	
		Grain yield	Biomass yield	Grain yield	Biomass yield	Grain yield	Biomass yield
0 + 0	0, 0, 0, 0, 0	3239h	6572i	2585cde	5556e	2978i	6318g
100 + 100	62.9, 33.8, 7.3, 2.2, 0.7	5121fg	10377h	5111a	8148cde	5117cd	9262ef
100 + 150	85.9, 33.8, 7.3, 2.2, 0.7	5948bcdef	12871efg	3249cde	8056cde	4598cdefg	10945cde
100 + 200	108.9, 33.8, 7.3, 2.2, 0.7	6820abc	14196cde	3526bcd	11667a	5173bc	13184ab
100 + 250	131.9, 33.8, 7.3, 2.2, 0.7	7514a	16361abcd	4596ab	12778a	6055a	14569a
150 + 100	71.35, 50.7, 10.95, 3.3, 1.05	4367g	9564h	2258e	7037de	3313hi	8300f
150 + 150	94.35, 50.7, 10.95, 3.3, 1.05	6489abcd	14010def	2635cde	7778cde	4176efg	10271de
150 + 200	117.35, 50.7, 10.95, 3.3, 1.05	6332abcdef	14455bcde	2318e	8333bcde	4325defg	11394cd
150 + 250	140.35, 50.7, 10.95, 3.3, 1.05	7061ab	16792ab	3328cde	11296ab	5194bc	14044ab
200 + 100	79.8, 67.6, 14.6, 4.4, 1.4	5422defg	11533gh	2239e	9722abcd	3830gh	10809cde
200 + 150	102.8, 67.6, 14.6, 4.4, 1.4	6122bcdef	13292efg	2476de	8333bcde	4299efg	10812cde
200 + 200	125.8, 67.6, 14.6, 4.4, 1.4	6825abc	15085abcde	4517ab	12407a	5902ab	13746ab
200 + 250	148.8, 67.6, 14.6, 4.4, 1.4	5789cdef	13274efg	3586bcd	10833abc	4688cdef	12298bc
250 + 100	88.25, 84.5, 18.25, 5.5, 1.75	5213efg	11658fgh	2684cde	7963cde	3949fgh	9810def
250 + 150	111.25, 84.5, 18.25, 5.5, 1.75	6375abcde	14145cde	3491bcd	12037a	4933cde	13091ab
250 + 200	134.25, 84.5, 18.25, 5.5, 1.75	7519a	16521abc	4596ab	12593a	6058a	14557a
250 + 250	157.25, 84.5, 18.25, 5.5, 1.75	6815abc	16927a	4487ab	12407a	5884ab	14667a
Rec. NP	69, 46, 0, 0, 0	6273abcdef	13133efg	3645bc	7593de	4696cdef	9809def
Mean		6057.18	13368.3	3345.6	9838	4728.01	11673.75
CV (%)		10.3	9.3	16.9	15.0	12.5	11.4

Means followed by the same letter are not significantly different at 5% probability level. Rec. NP = Recommended nitrogen and phosphorus fertilizer.

Yield response curve to N at different levels of P, S, Zn and B

The yield response curves at Libokemikem and Fogera districts, as shown in Figures 3a and 3b below, indicate that there was a significant yield response to increasing levels of N, while the other nutrients, such as P_2O_5, S, Zn, and B, were uniform, as shown in Table 6. The graphs also indicate that there was a significant yield difference among the different levels of the combined use of blended NPSZnB and urea fertiliser in both districts. The graphs show the maximum grain yields in both districts were obtained from the combined use of 250 kg PSZnB + the fourth level of N (134.25 kg ha^{-1}) with 84.5 P_2O_5, 18.25 S , 5.5 Zn and 1.75 B kg ha^{-1} (Figure 3a and b). This indicates, regardless of the amount of the blended fertiliser (PSZnB), the yield was increasing as the level of N increased, which implies the increasing yield response was only due to the increasing levels of N.

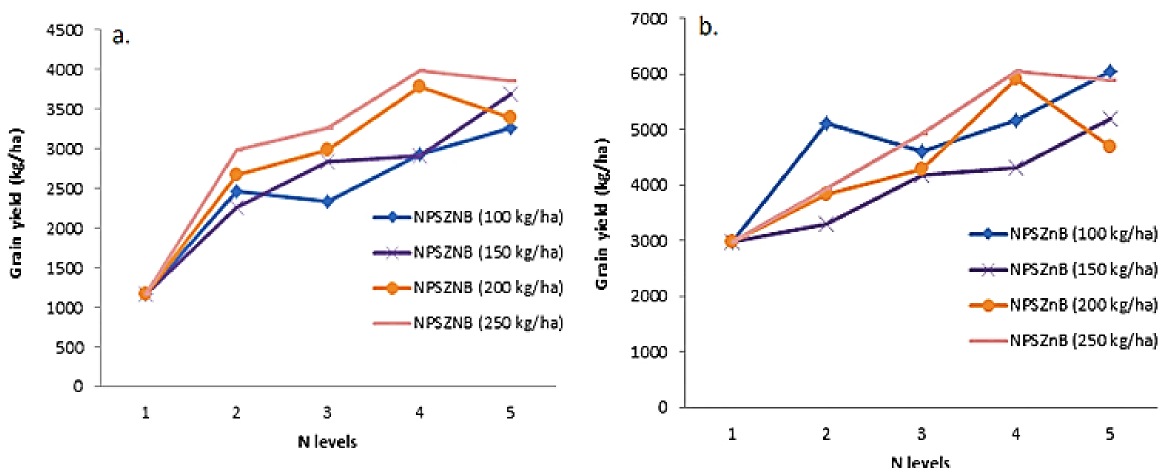


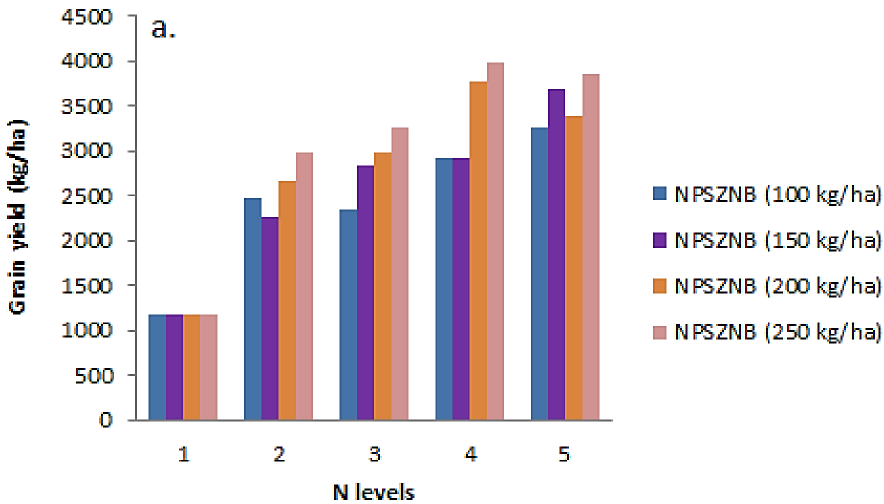
Figure 3. Grain yield response curve (pooled over 2018 and 2019) to N at different levels of the NPSZnB blended fertilizer in a. Libokemikem and b. Fogera districts

Table 6. Amount of N in the different levels of the NPSZnB + Urea fertilizers

	100 kg NPSZnB ha^{-1}	**150 kg NPSZnB ha^{-1}**	**200 kg NPSZnB ha^{-1}**	**250 kg NPSZnB ha^{-1}**
N levels	**Levels of P_2O_5, S, Zn and B in kg ha^{-1}**			
(kg ha^{-1})	**33.8, 7.3, 2.2, 0.7**	**50.7, 10.9, 3.3, 1.05**	**67.6, 14.6, 4.4, 1.4**	**84.5, 18.2, 5.5, 1.7**
1	0	0	0	0
2	62.9	71.35	79.8	88.25
3	85.9	94.35	102.8	111.25
4	108.9	117.35	125.8	134.25
5	131.9	140.35	148.8	157.25

Yield response graphs to different levels of NPSZnB blended fertilizer

The bar graphs, shown below, indicate that there was a significant yield difference obtained at both districts due to the effect of the blended fertilizer (Fig 4a. and b.). As it is shown in the graphs, the yield increased as the level of the blended fertilizer increased from 100 to 250 kg ha^{-1} at all levels of N. However, the significant yield raise as the level of the blended fertilizer increased could be due to the increased level of N and P in the blended fertilizer. The graph also indicates the significant yield improvement as the level of N increased from 1 to 5 (i. e from 0 level to 157.25 kg ha^{-1}).



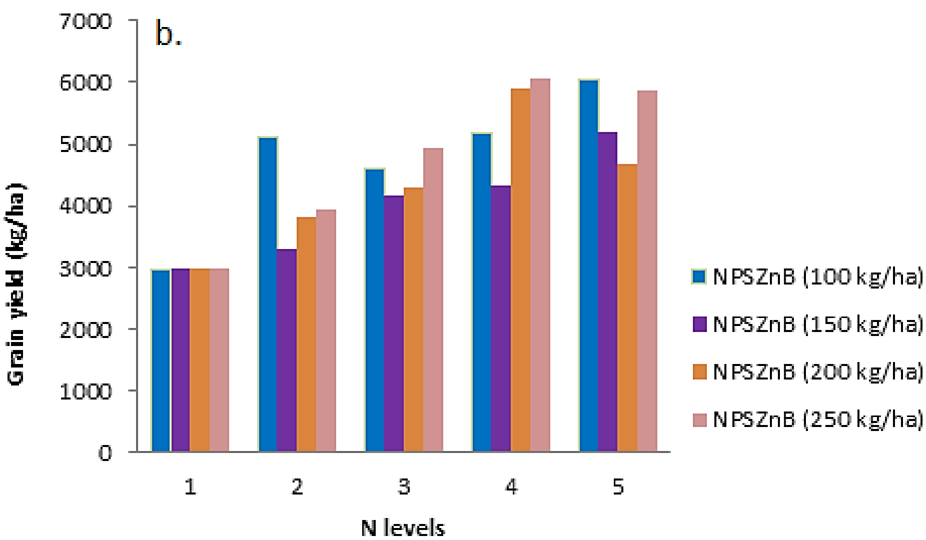


Figure 4. Effect of the NPSZnB blended and urea fertilizer on the grain yield of upland rice pooled over 2018 and 2019 at a. Libokemikem and b. Fogera districts

Partial Budget Analysis

The partial budget analysis of the pooled data over 2018 and 2019 indicates that, at Libokemikem district, the maximum net economic return of Ethiopian Birr (Birr) 37,474.80 with marginal rate return of (MRR) 2617.5% was obtained from application of 250 kg NPSZnB + 200 kg urea ha-1 (134.2N, 84.5P2O5, 18.2S, 5.5Zn and 1.75B). The other treatments are dominated (Table 7). At Fogera district the maximum net economic return of Birr 62,548.60 with MRR of 1214.6% was obtained from application of 100 kg NPSZnB + 250 kg urea ha-1 (131.9N, 33.8P2O5, 7.3S, 2.2Zn and 0.7B) (Table 8).

Table 7. Partial budget analysis of the combined use of the NPSZnB blended fertilizer with urea for the grain yield of upland rice (pooled over 2018 and 2019) at Libokemikem district

NPSZnB/DAP+Urea (kg ha^{-1})	Adj. Yield (kg ha^{-1})	Gross return	Cost of NPSZnB /100 kg	Cost of Urea /100 kg	Total Fertilizer Cost	Net return	MRR (%)
0 + 0	1054.8	13185.0	0	0	0	13185.0	-
Rec. NP (50+134.4)	2735.1	34188.7	830.7	2092	2923.1	31265.6	618.5
100 + 100	2222.1	27776.2	1666.3	1562	3227.9	24548.4	D
100 + 150	2105.1	26313.7	1666.3	2342	4008.6	22305.1	D
150 + 100	2034.9	25436.2	2499.5	1562	4061.0	21375.2	D
100 + 200	2631.6	32895.0	1666.3	3123	4789.4	28105.6	D
150 + 150	2550.6	31882.5	2499.5	2342	4841.8	27040.7	D
200 + 100	2399.4	29992.5	3332.7	1562	4894.2	25098.3	D
100 + 250	2943.9	36798.7	1666.3	3904	5570.2	31228.6	D
150 + 200	2619.9	32748.7	2499.5	3123	5622.6	27126.2	D
200 + 150	2689.2	33615.0	3332.7	2342	5675.0	27940.0	D
250 + 100	2688.3	33603.7	4165.9	1562	5727.4	27876.3	D
150 + 250	3319.2	41490.0	2499.5	3904	6403.3	35086.7	565.3
200 + 200	3404.7	42558.7	3332.7	3123	6455.8	36103.0	1939.2
250 + 150	2930.4	36630.0	4165.9	2342	6508.2	30121.8	D
200 + 250	3051.0	38137.5	3332.7	3904	7236.5	30901.0	D
250 + 200	3581.1	44763.7	4165.9	3123	7288.9	37474.8	2617.5
250 + 250	3463.2	43290.0	4165.9	3904	8069.7	35220.3	D

Adj: Adjusted yield, MRR: Marginal Rate of Return, All the cots are in Ethiopian Birr.

Table 8. Partial budget analysis of the combined use of the NPSZnB blended fertilizer with urea for the grain yield of upland rice (pooled over 2018 and 2019) at Fogera district

NPSZnB/DAP+Urea (kg ha^{-1})	Adj. Yield (kg ha^{-1})	Gross return	Cost of NPSZnB /100 kg	Cost of Urea /100 kg	Total fertilizer Cost	Net return	MRR (%)
0 + 0	2680.2	33502.5	0	0	0	33502.5	-
Rec. NP (50+134.4)	4226.4	52830.0	830.7	2092	2923.1	49906.9	561.2
100 + 100	4605.3	57566.2	1666.3	1562	3227.9	54338.4	1454.1
100 + 150	4138.2	51727.5	1666.3	2342	4008.6	47718.9	D
150 + 100	2981.7	37271.2	2499.5	1562	4061.0	33210.2	D
100 + 200	4655.7	58196.2	1666.3	3123	4789.4	53406.8	D
150 + 150	3758.4	46980.0	2499.5	2342	4841.8	42138.2	D
200 + 100	3447.0	43087.5	3332.7	1562	4894.2	38193.3	D
100 + 250	5449.5	68118.7	1666.3	3904	5570.2	62548.6	1214.6
150 + 200	3892.5	48656.2	2499.5	3123	5622.6	43033.7	D
200 + 150	3869.1	48363.7	3332.7	2342	5675.0	42688.8	D
250 + 100	3554.1	44426.2	4165.9	1562	5727.4	38698.8	D
150 + 250	4674.6	58432.5	2499.5	3904	6403.3	52029.2	D
200 + 200	5311.8	66397.5	3332.7	3123	6455.8	59941.7	D
250 + 150	4439.7	55496.2	4165.9	2342	6508.2	48988.1	D
200 + 250	4219.2	52740.0	3332.7	3904	7236.5	45503.5	D
250 + 200	5452.2	68152.5	4165.9	3123	7288.9	60863.6	D
250 + 250	5295.6	66195.0	4165.9	3904	8069.7	58125.3	D

Adj: Adjusted yield, MRR: Marginal Rate of Return, All the cots are in Ethiopian Birr.

CONCLUSION

The study results indicated that the grain and biomass yields of upland rice were significantly affected by the combined use of blended NPSZnB + urea fertilisers. The highest yield and the maximum net economic benefit were obtained from the application of 250 kg NPSZnB + 200 kg urea ha^{-1} (134.2N, 84.5P_2O_5, 18.2S, 5.5Zn and 1.75B) at Libokemikem district. At Fogera district, the highest yield and the maximum net economic benefit were obtained from the application of 100 kg NPSZnB + 250 kg urea ha^{-1} (131.9N, 33.8P_2O_5, 7.3S, 2.2Zn and 0.7B). However, it is not possible to draw conclusions that the significant yield increment recorded was due to the contribution of S, B and Zn blends in the NPSZnB blended fertiliser. Because there were confounding effects of N and P nutrients in the NPSZnB blended fertiliser. As it is revealed in the results, the significant yield response recorded, however, was due to the increasing levels of N. Therefore, we recommend further investigation on the yield response of NERICA-4 (upland rice) to each nutrient (P, S, Zn and B) through nutrient omission studies.

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