Ethiop. J. Agric. Sci. 31(2) 33-43 (2021)

Evaluation of NPSZn Blended Fertilizer on Yield and Yield Traits of Bread Wheat (*Tritcum aestivum* L.) on Cambisols and Vertisols in Southern Tigray, Ethiopia

Sofonyas Dargie*, Fisseha Hadgu, Hagos Brhane, Tsigabu Mehari , Molla Hadis, Girmay Hailu and Daniel Berhe

Tigray Agricultural Research Institute, Mekelle Soil Research Center, P. O. Box 1070, Mekelle, Ethiopia

**Correspondence: sofifidel97@gmail.com*

አህፅሮት

የግብርና ምርትና ምርታማነት ለማሳደግ የተለያዩ ዓይነት ምጥን ማዳበርያዎች፣ ዳፕ እና ዩርያን በመተካት ወደ ሃገራችን ለሙከራ የገቡት በቅርቡ ነው፤ NPSZn ምጥን ማዳበርያም አንዱ ነው፡፡ የተለያየ መጠን NPSZn (0፣ 50፣ 100፣ 150፣ 200፣ 250፣ 300 ኪ.ግ በሄክታር) እና የተለመደው ዩርያና ዳፕ ማዳበርያ እንደ መወዳደርያነት በማካታት በራንደማይዝድ ኮምፕሊት ብሎክ ዲዛይን (RCBD) በሶስት ድግግሞሽ በ2009ዓ.ም እና 2010ዓ.ም በትግራይ በኦፍላ እና እምባ አላጀ ወረዳዎች ተሞክሯል፡፡ የቅድመ ተከላ የአፈር ናሙና እንደሚያመለክተው የናይትሮጅን መጠን በአብዛኛው የምርምር ሳይቶች ዝቅተኛ ሲሆን የፎስፎረስ መጠን ደግሞ መካከለኛ ነበር፡፡ በተለያየ የምርት መለኪያ መንገዶች እና በኢኮኖሚያዊ አዋጭነት መሰረት 200ኪ.ግ NPSZn ምጥን ማዳበርያ ከ62 ኪ.ግ ዩርያ በኦፍላ እንዲሁም 100ኪ.ግ NPSZn ምጥን ማዳበርያ ከ100ኪ.ግ ዩርያ በእምባ አላጀ ከሌሎች የማዳበርያ መጠኖች በተሻለ በስንዴ ምርት ላይ የተሻሉ እንደሆኑ ተረጋግጧል፡፡

Abstract

A field experiment was carried out in 2017 and 2018 main cropping seasons in Ofla and Emba Alaje Woredas in Tigray Regional State, Ethiopia. The experiment has seven levels of NPSZn (0, 50, 100, 150, 200, 250, 300, kg ha^{-1}) adjusted for N from urea to the recommended N level (64 kg N ha^{-1}) and the recommended P fertilizers (46 kg P_2O_5 ha^{-1}). The treatments were also arranged in a randomized complete block design (RCBD) with three replications and executed on two farmers fields. Soil samples were collected before planting and analyzed for selected physicochemical properties. As a result, application of different rates of NPSZn blended fertilizer significantly influenced yield and yield components of wheat at both sites. At Ofla, the highest grain and straw yields were obtained from plots that received 200 kg NPSZn ha^{-1} . At Emba Alaje, the highest grain and straw yields were harvested from the application of 200 kg NPSZn ha^{-1} and 100 kg NPSZn ha^{-1}, respectively. Application of Zn in the blended fertilizer had no significant effect on grain Zn concentration of bread wheat at both sites. Partial budget analysis revealed that the optimum marginal rate of return was 22.25ETB and 16.06ETB at Emba Alaje and Ofla, respectively. Both biological and economic analysis showed that applications of 200kg NPSZn with 28.6 kg N (62 kg urea) at Ofla and 100 kg NPSZn with 46 kg N (100 kg urea) at Emba Alaje were optimum for wheat production and these rates could be recommended for areas where the rainfall distribution and soil types are similar with the study locations. Further study should be done on effects of NPSZn in grain quality and single nutrient based experiment should be carried out to evaluate the effect of each nutrient in the blended fertilizer for crop production.

Keywords: *NPSZn, Wheat, Recommended NP, Tigray*

Introduction

Ethiopia's current wheat production and productivity is getting improved. Despite this, with Ethiopia's rising population and urbanization, demand for wheat surpasses the national supply which makes the current production insufficient to meet domestic needs, forcing the country to import up to 50% to fill the gap (Minot *et al.*, 2015). Bread wheat yield in Ethiopia is low compared to other wheat producing countries in Africa and the world. Poor agronomic and soil management, inadequate level of technology generation and dissemination are the most significant constraints to increased bread wheat production in Ethiopia. Low soil fertility followed by slow progress in developing bread wheat cultivars with durable resistance to disease, pests and weed are considered the most important constraints limiting bread wheat production in Ethiopia (Demeke and Di Marcantonio, 2013). Varietal development and adoption of improved agricultural technology including adequate plant nutrient management are among the essential tools to improve productivity of wheat per unit area.

The use of different blended fertilizers for crop production in Ethiopia is a recent history. For the past 5 decades fertilizer recommendation in Ethiopia was based on very general crop specific guidelines or more often, a single recommendation for all crops 100 kg DAP ($18N-46P_2O_5-0K_2O$) and 100 kg Urea ($46N-0P_2O_5-0K_2O$). This blanket recommendation often fails to take into consideration differences in resource endowment (soil type, labor capacity, climate risk) or make allowances for dramatic changes in input/output price ratio, thereby discouraging farmers from fertilizer application. Moreover, the nutrients in the previously used fertilizer products were not well balanced agronomically and its continued use will gradually exhaust other soil nutrient reserves. Low level of one or more nutrients besides N and P can depress yield significantly. Therefore, neither yields nor profits can be sustained using imbalanced application of fertilizers, as the practice results in accelerating deficiencies of other soil nutrients. This could explain, in part, the modest crop yield improvements observed over the last few decades in contrast to significant increases in fertilizer use and investment made in the country. NPSZn blended fertilizer is one of the newly introduced fertilizers to improve crop production based on the ATA soil atlas map of Ethiopia (Ethiosis, 2014). Different levels of NPSZn with adjusted N for wheat production were not yet investigated in our study area. Hence, the experiment was initiated to evaluate different rates of NPSZn blended fertilizer on yield and yield components of wheat.

Materials and Methods

Description of the study area

The experiment was carried out for two consecutive raifed cropping seasons (2017 and 2018) in Ofla at two farmers' field and in 2018 in Emba Alaje at two farmers' fields (Figure 1).

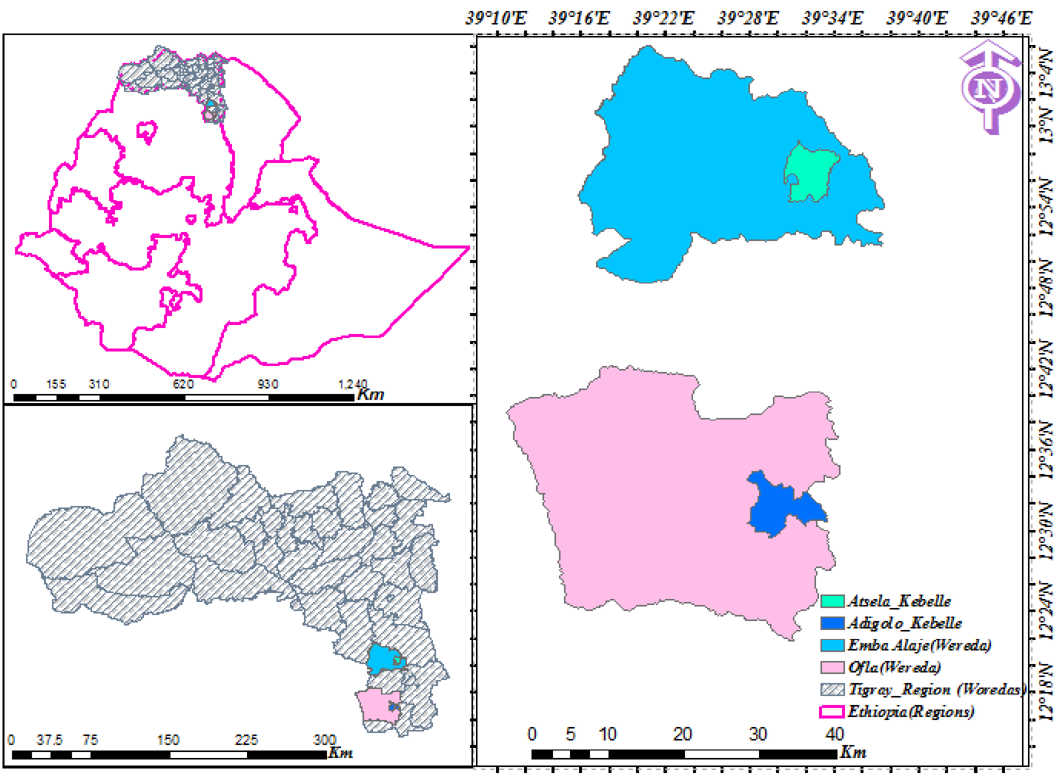

Figure 1. Location map of Emba Alaje and Ofla Woreda, Tigray, Ethiopia

The trial was laid out in RCBD with three replications. The treatments were seven levels of NPSZn (0, 50, 100, 150, 200, 250, 300, kg ha^{-1}) adjusted with N to the recommended level. Recommended N and P fertilizers (64 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}) were also included as a positive control. King bird wheat variety was used as test crop.

Table1. Treatments with respective nutrient composition

Treatments (kg ha^{-1})	N	P_2O_5	S	Zn	Adjusted N	Total N applied
0	-	-	-	-	-	-
50 NPSZn	8.85	17.65	3	1.25	55.15	64
100 NPSZn	17.7	35.3	6	2.5	46.3	64
150 NPSZn	26.55	52.95	9	3.75	37.45	64
200 NPSZn	35.4	70.6	12	5	28.6	64
250 NPSZn	44.25	88.25	15	6.25	19.75	64
300 NPSZn	53.1	105.9	18	7.5	10.9	64
64 N and 46 P2O5	64	46	-	-	-	64

Soil Sampling and Analysis

Representative composite soil samples from each field were taken before planting following the standard soil sampling procedure. From each experimental farm land 10 subsamples were taken at 0-20 cm depth. The composite samples was Each composite soil sample was used for selected physico-chemical analysis [particle size analysis, soil reaction (pH), electrical conductivity (EC), organic carbon (OC), cation exchange capacity (CEC), total N, and available P]. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using pH meter (Rhoades, 1982). Wet digestion method (Walkley and Black, 1934) was used for determination of organic carbon. Total N was determined using the Kjeldahl method as described by (Bremner and Mulvaney, 1982). Available P was determined following the Olsen method (Olsen *et al.*, 1954) using ascorbic acid as reducing agent. Cation exchange capacity was determined by ammonium acetate method.

Data collection

Plant height (PH) was measured from ground surface to the tip of the panicle at maturity from 5 randomly sampled plants using tape meter (cm). Spike length (SL) was measured from the bottom of the spike to the tip of the spike excluding the awns from five randomly tagged spikes from the net plot. Grain yield was harvested from the five middle rows of each plot, sun dried and manually threshed separately then grain was weighed by using sensitive electronic balance. The weight of above ground crop biomass in middle five rows in each plot was recorded after sun drying. Harvest index was calculated from the ratio of grain yield to biological yield.

Wheat grain samples were collected for analysis of Zn after threshing. The samples were cleaned for any contamination, ground with a stainless grinder and digetsed using a wet digetion method (di-acids HNO_3-$HClO_4$ at 2:1 ratio) to obtain full recovery of Zn (Esteffan *et al.*, 2013). The aliquots of the digest were determined for Zn using Fast Sequential Flame Atomic Spectrometry (Varian AA

240FS) at accredited laboratory of Ezana Analytical Laboratory, Mekelle, Ethiopia.

Data analysis

Collected data were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedures of SAS 9.1.3 (SAS, 2002). Mean separation was carried out following Gomez (1884) and economic feasibility following International Maize and Wheat Improvement Center (CIMMYT) manual (CIMMYT, 1988). Marginal rate of return (MRR) was calculated as the change in net revenue (NR) divided by the change in total variable cost (TVC) of the successive net revenue and total variable cost levels (CIMMYT, 1988). Revenue was calculated by considering the prevailing market price, which was 13 Birr kg^{-1} of wheat grain yield. The prices of NPSZn fertilizer (2792 Birr for 100 kg) was calculated based on Enderta union blended fertilizer factory.

Results and Discussions

Before planting soil properties

The physicochemical properties of the soils of the experimental sites are indicated in Table 2. Textural class at both sites was clay loam. According to Tekalign (1991) rating of soil pH, the pH of Cambisols of Ofla was slightly acidic except for site 2 in 2017 cropping season and neutral in Emba Alaje district. The OC contents of soils of the experimental sites were low at ofla and medium at Emba Alaje (Tekalign, 1991). According to Birhanu (1980), total N content was low at all sites except in Ofla site 2. Available P was medium (Olsen, 1954) and CEC was medium at both sites (Landon, 1991).

Table 2. Pre-planting soil physico-chemical properties in Ofla and Emba Alaje Woredas

Parameters	Emba Alaje Woreda		Ofla Woreda			
	2018		2017		2018	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
pHwater (1:2.5)	6.97	6.83	5.86	6.96	6.46	6.69
ECwater (1:2.5), dS m^{-1}	0.115	0.138	0.09	0.66	0.132	0.075
Organic carbon (%)	1.609	2.116	1.14	0.87	0.935	1.566
Total N (%)	0.102	0.113	0.078	0.144	0.08	0.12
P-Olsen (mg kg-1)	11.2	14.8	13.48	20.28	17.342	18.54
CEC (cmol (+) kg-1)	33.36	35.97	25.9	19.7	39.7	43.79
Clay (%)	36	22	22	66	56	58
Silt (%)	38	52	36	14	26	24
Sand (%)	26	26	42	20	18	18
Texture class	Clay loam	Silt loam	Loam	Clay	Clay	Clay

Yield and yield components

Results showed that application of different rates of NPSZn blended fertilizer had a significant (P<0.001) effect on plant height and spike length in Ofla and Emba Alaje Woredas (Tables 4 and 5. Even though there was some inconsistency, plant height increased with rate at both sites. Numerically, the highest plant height and spike length was recorded from the application of 300 kg of NPSZn ha^{-1} at both sites. Application of NPSZn rates ranging from 100 to 300 kg ha^{-1} showed statistically (P<0.001) higher plant height than the recommended NP at Ofla. Grain and straw yields increased consistently up to 200 kg NPSZn ha^{-1} at both Woreda, and started to decrease with rates. In Emba Alaje the highest grain and starw yields were obtained from the application of 200 kg NPSZn ha^{-1} and 100 kg NPSZn ha^{-1}, respectively, whereas in Ofla Woreda the highest grain and starw yields were recorded on plots treated with 200 kg NPSZn ha^{-1} and 300 kg NPSZn ha^{-1}, respectively.

Table 3. Effect of different levels of NPSZn on yield and yield components of wheat in Ofla

	Ofla					
Treatments	Two Years and Sites Combined analysis					
	Plant H (cm)	Spike L (cm)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index	Zn grain content (gm kg^{-1})
0 NPSZn	65.25e	5.175d	1697.6c	2722.3d	0.38c	29.363
50 NPSZn	73.3d	5.9917c	2979.9b	3879.8c	0.42ab	27.383
100 NPSZn	75.65cd	6.525b	2997.6b	3933.4c	0.43a	26.177
150 NPSZn	77.533bc	6.6917ab	3037.4b	4074.7c	0.43a	25.272
200 NPSZn	80.16a	6.658b	3580.2a	4956.8a	0.42ab	25.749
250 NPSZn	79.5ab	6.66ab	3168.0ab	4555.6ab	0.41ab	24.124
300 NPSZn	80.967a	7.0a	3388.4ab	4972.7a	0.4b	37.906
Rec.NP(64N,46 P_2O_5)	77.083bc	6.74ab	3035.2b	4174.6bc	0.41ab	26.568
LSD (0.05)	2.42	0.3417	423.7	439.5	0.022	NS
CV (%)	3.9	6.51	17.39	12.95	6.59	57.2
P Value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	NS
Year	NS	<0.0001	<0.0001	<0.0001	<0.0001	0.0178
Site	<0.0001	NS	<0.0001	<0.0001	<0.0001	NS
Trt*Year	NS	NS	NS	NS	NS	NS
Trt*Site	0.0017	NS	NS	NS	0.0194	NS
Trt*Year*Site	0.0408	<0.0001	NS	0.0019	NS	NS

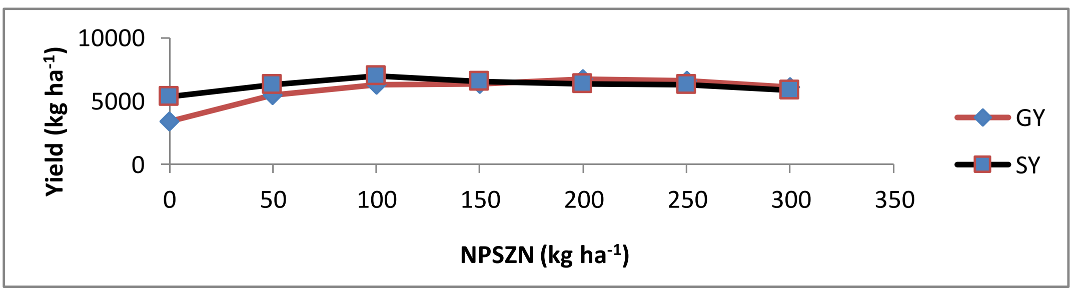

Figure 2. Wheat reponse curve to NPSZn rates at Emba Alaje

Table 4. Effect of different levels of NPSZn on yield and yield components of wheat in Emba Alaje

Treatments	Emba Alaje					
	Two Sites Combined analysis					
	Plant H (cm)	Spike L (cm)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index	Zn grain content (gm kg^{-1})
0 NPSZn	85.8b	8.26	3380.2c	5364.3b	0.40b	22.367
50 NPSZn	88.0ab	8.6	5463.9b	6313.9ab	0.46ab	18.948
100 NPSZn	88.4ab	8.18	6327.8ab	7011.1a	0.47ab	18.085
150 NPSZn	88.6ab	8.4	6344.4ab	6555.6ab	0.49a	20.09
200 NPSZn	87.4ab	8.28	6755.6a	6344.4ab	0.52a	18.215
250 NPSZn	88.4ab	8.38	6619.4a	6269.4ab	0.51a	21.407
300 NPSZn	90.5a	9.1	6108.3ab	5830.6ab	0.50a	18.825
Rec.NP(64N,46 P_2O_5)	87.5ab	8.8	6682.2a	6095.6ab	0.53a	18.742
LSD (0.05)	3.83	NS	927.7	1413.9	0.0735	NS
CV (%)	3.71	10.39	13.3	19.42	12.83	14
P Value	0.0271	0.103	<0.0001	0.0022	0.0251	0.096

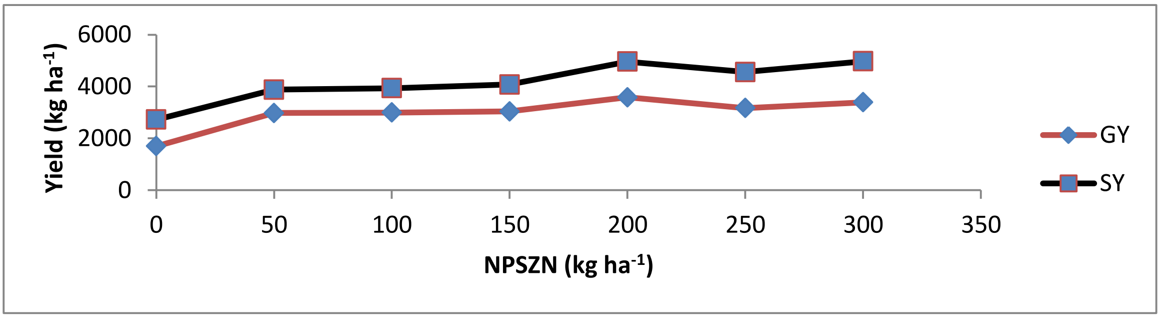

Figure 3. Wheat response curve to NPSZn rates at Ofla

Effect on Zn grain content

Results depicted that application of different levels of NPSZn had no significant effect across years, sites and treatments on wheat Zn grain content in Emba Alaje and Ofla Woredas (Table 3 and 4). The insufficient amount of grain Zn concentration may be due to the insufficient amount of Zn in the blended fertilizer and soil application of Zn. Cakmak et al (2010) reported that Soil Zn applications are, however, less effective in increasing grain Zn, while foliar Zn applications result in remarkable increases in grain Zn concentration in wheat. The same author indicated that form of Zn fertilizer has also significant effect in grain Zn concentration.

Partial budget analysis of NPSZn rates

Partial budget results showed that highest marginal rate of return was obtained from the application of 200 kg NPSZn with 28.6 kg N ha^{-1} at Ofla and 100 kg NPSZn with 46 kg N ha^{-1} at Emba Alaje (Table 5 and 6). According to the manual for economic analysis of CIMMYT (1988), the recommendation is not necessarily based on the treatment with the highest marginal rate of return compared to that of neither next lowest cost, the treatment with the highest net benefit, and nor the treatment with the highest yield. The identification of a recommendation is based on a change from one treatment to another if the marginal rate of return of the change is greater than the minimum rate of return (100%). The marginal rate of return revealed that recommended NP had negative rate or return in Ofla. The marginal rate of return ratio was 22.25 and 16.06 at Emba Alaje and Ofla, respectively.

Table 5. Partial budget analysis in Emba Alaje

Treatments	Adjusted (10% down) grain yield (kg ha^{-1})	Adjusted (10% down) straw yield (kg ha^{-1})	Fertilizers cost (Birr)	Fertilizer transport and application cost (Birr)	Total variable cost (TVC)	Grain revenue*13	Straw reve-nue*3.2	Total revenue	Net revenue [TR-TVC]	MRR (ratio)	MRR (%)
0	3042.2	4827.9	0	0	0	39548.3	15449.2	54997.5	54997.5		
50	4917.5	5682.5	2317	255	2572	63927.6	18184.0	82111.7	79540.0	9.5	954.3
100	5695.0	6310.0	2792	301	3093	74035.3	20192.0	94227.2	91134.6	22.3	2225.8
150	5710.0	5900.0	3266	347	3614	74229.5	18880.1	93109.6	89496.1	D	D
Rec NP	6014.0	5486.0	3695	359	4054	78181.7	17555.3	95737.1	91683.3	D	D
200	6080.0	5710.0	3741	393	4134	79040.5	18271.9	97312.4	93178.0	18.5	1853.0
250	5957.5	5642.5	4216	439	4655	77447.0	18055.9	95502.9	90847.5	D	D
300	5497.5	5247.5	4691	486	5176	71467.1	16792.1	88259.2	83083.0	D	D

D: Dominated treatment (MRR less than 100%)

Table 6. Partial budget analysis in Ofla

Treatments	Adjusted grain yield (kg ha^{-1})	Adjusted straw yield (kg ha^{-1})	Fertilizers cost (Birr)	Fertilizer transport and application cost (Birr)	Total variable cost (TVC)	Grain revenue*13	Straw revenue*3.2	Total revenue	Net revenue [TR-TVC]	MRR (ratio)	MRR (%)
0	1527.8	2450.1	0	0	0.0	19861.9	7840.2	27702.1	27702.1		
50 NPSZn	2681.9	3491.8	2317	255	2571.7	34864.8	11173.8	46038.7	43467.0	6.1	613
100 NPSZn	2697.8	3540.1	2792	301	3092.6	35071.9	11328.2	46400.1	43307.5	D	D
150 NPSZn	2733.7	3667.2	3266	347	3613.5	35537.6	11735.1	47272.7	43659.2	D	D
Rec. NP	2731.7	3757.1	3695	359	4053.8	35511.8	12022.9	47534.7	43480.9	D	D
200 NPSZn	3222.2	4461.1	3741	393	4134.4	41888.3	14275.6	56163.9	52029.5	16.1	1606
250 NPSZn	2851.2	4100.0	4216	439	4655.4	37065.6	13120.1	50185.7	45530.4	D	D
300 NPSZn	3049.6	4475.4	4691	486	5176.3	39644.3	14321.4	53965.7	48789.4	D	D

D: Dominated treatment (MRR less than 100%)

Conclusion and Recommendation

Application of different rates of NPSZn blended fertilizer significantly influenced yield and yield components of wheat at Emba Alaje and Ofla WoredaWoredas. The response curve revealed that grain and straw yields increased with rate at both sites. In Ofla the highest grain and straw yields were obtained from plots that received 200 kg NPSZn ha^{-1} . At Emba Alaje, the highest grain and straw yields were harvested from the applications of 200 kg NPSZn ha^{-1} and 100 kg NPSZn ha^{-1} , respectively. Both biological and economic analysis showed that applications of 200kg NPSZn with 28.6 kg N (62 kg urea) at Ofla and 100 kg NPSZn with 46 kg N (100 kg urea) at Emba Alaje were optimum for wheat production and these rates could be recommended for areas where the rainfall distribution and soil type is similar with the Woredas where in this experiment was conducted. Further study should be done on effects of NPSZn in grain quality and single nutrient based experiment should also be carried out to evaluate each nutrient contribution for wheat production.

Acknowledgement

The authors are grateful to AGP II (Agricultural Growth Program II Research Component) for their financial support.

References

Bouyoucos J. 1962. Hydrometer method improved for making particle size analysis of soil. Agronomy Journal, 54:464-465.

Bremner J M and Mulvaney C S.1982. Nitrogen - Total, Methods of soil analysis. Part 2-Chemical and microbiological properties. Agronomy, 9 (2):595-624. American Society of Agronomy Madison, Wis.

Cakmak I, Pfeiffer WH, McClafferty B. 2010. Biofortification of durum wheat with zinc and iron. Cereal Chem. 87, 10e20.

Demeke M and Di Marcantonio F. 2013. Analysis of incentives and disincentives for wheat in Ethiopia. Technical notes series, MAFAP, FAO, Rome.

Esteffan G Sommer R and Ryan J. 2013. *Methods of soil, plant and water analysis*. ICARDA (International Center for Agricultural Research in the Dry Areas), Beirut, Lebanon.

EthioSIS (Ethiopian Soil Information System).2014. Atlas for Tigray regional state. Soil fertility status and fertilizer recommendation, EthioSIS, report.

Gomez and H Gomez.1984. Statistical analysis for agricultural research.John Willy and Sons Inc. pp.120-155.

International Maize and Wheat Improvement Center (CIMMYT).1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico.

Landon J R.1991. Booker Tropical Soil Manual: A hand book for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p. OR John Wiley & Sons Inc., New York.

Minot N, Warner J, Lemma S, Kassa L, Gashaw A, and Rashid S.2015. The wheat supply chain in Ethiopia: Patterns, Trends, and Policy options. International Food Policy Research Institute (IFPRI) Washington, DC.

Olsen R, Cole S, Watanabe F and Dean L.1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture Circ. 939.

Rhoades J and Corwin D.1990. Soil electrical conductivity: effects of soil properties and application to soil salinity appraisal. Communication in Soil Science and Plant Analyses, 21(9): 836-860.

SAS.2002. SAS/STAT User's Guide, Version 9.1.3. SAS institute Inc., Cary, NC.

Tekalign Tadese.1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Walkley A and Black IA.1934. An examination of the Degtjareff method for determining soil organic matter and proposed chromic acid titration method. Soil Science,37: 29-38.Wisconsin, USA.