Asian Journal of Research and Review in Agriculture

Volume 6, Issue 1, Page 622-635, 2024; Article no.AJRRA.1742

Effect of NPSZn Blend Fertilizer with Adjusted Nitrogen on Yield and Some Yield Components of Bread Wheat on Vertisols and Cambisols under Rain-fed Condition at Shibta in Enderta, Tigray

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.globalpresshub.com/review-history/1742

Original Research Article

Received: 26/08/2024
Accepted: 29/10/2024
Published: 04/11/2024

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Cite as: *Birhanu, Fisseha Hadgu, Hagos Brhane Gebreslassie, Sofonyas Dargie Tefera, Tsigabu Mehari, Aklil Gebremedhin, Lijalem Gebre-egziabher, and Molla Hadis Teka. 2024. "Effect of NPSZn Blend Fertilizer With Adjusted Nitrogen on Yield and Some Yield Components of Bread Wheat on Vertisols and Cambisols under Rain-Fed Condition at Shibta in Enderta, Tigray". Asian Journal of Research and Review in Agriculture 6 (1):622-35. https://jagriculture.com/index.php/AJRRA/article/view/138.*

ABSTRACT

Field trials were conducted to evaluate the effects of NPSZn fertilizer adjusted with urea on performance of bread wheat on Vertisols and Cambisols at farmer's fields in three replications using Randomized Complete Block Design (RCBD) on Vertisols and Cambisols at Shibta in Enderta district during main rainy seasons of 2017 and 2018 comprised of 8 treatments including 0, 50, 100, 150, 200, 250, 300 kg/ha NPSZn (adjusted with N to 64kg/ha) and recommended nitrogen (N) and phosphorus (P), (64kg/ha N and 45 kg P_2O_5/ha). Composite soil samples were also collected and analyzed. The blended rates were applied at sowing while N was applied in the form of urea in two applications. Phosphorus in the form of triple super phosphate (TSP) was also applied at planting time. Yield and yield components data were collected and statistically analyzed. Significant differences (P≤0.05) were observed on plant height; spike length, straw yield and grain yield whereas the differences were not significant for harvest index (HI). Combined analysis of the two seasons' data showed highest biological performance of the parameters at the rates of 300 kg NPSZn/ha blended adjusted with 25 urea/ha for Enderta Cambisols and highest results were obtained at 250 kg/ha blended adjusted with 42 urea/ha for Enderta Vertisols. Partial budget analysis showed highest and profitable yield at 50 NPSZn/ha adjusted with115 urea/ha and 100 kg NPSZn/ha adjusted with 100 urea/ha for Vertisols and Cambisols at Shibta in Enderta, respectively. These rates could be recommended for Vertisols and Cambisols of study area and other similar areas in Tigray.

Keywords: Vertisols; cambisols; NPSZn; wheat.

1. INTRODUCTION

Wheat (*Triticum aestivum L*.) is one of the most staple foods and economically important widely used cereal crop in Ethiopia next to teff and maize [Ethiopian Central Statistical Agency (CSA), [1]). "Ethiopia is the second producer of wheat in Africa (next to Egypt) and produces 5.4 Mt (metric ton) wheat, which is equivalent to 21.7% of wheat produced and 18.3% wheat area harvested in Africa" [2]. According to CSA [3], wheat accounts for about 12.2% harvested area (1.9 million ha), 20.2 % total production and employment for 4.9 million subsistence smallholder farmers in Ethiopia. Regionally, Tigray produces 5 % wheat area and 3–6% of the wheat production [3]. "The wheat yield gap analysis in Ethiopia has been conducted at national and regional levels" [2]. "Yield gap is the difference between irrigated crops, rainfed crops or partially- irrigated crops and actual yield. According to Global Yield Gap Atlas (GYGA) (www.yieldgap.org), the yield gap of wheat in Ethiopia for the period 1998–2017 was 6.1 t/ha, where the actual yield was only 2.2 t/ha compared to the yield potential of 8.3 t/ha" [2]. Similarly, Mann and Warner [4] used climate cluster methodology in four major wheat producing regions of Ethiopia [Oromiya, Amhara, SNNP (South Ethiopian Nations, Nationalities and peoples) and Tigray] and found a yield gap of between 14 and 90%. Wheat production in Ethiopia is dominated by a subsistent smallholding farming system and the production is affected by complex and interwoven biophysical and socio-economic challenges. "Wheat yield gaps from various studies in major wheat producing regions of Ethiopia indicated that actual yield (t/ha) of wheat for Tigray is 1.7 and the yield gap, which is the difference between water limited potential yield and actual farmers yield is 40%" [2]. "Enderta is one of the districts where in wheat is grown in cluster in Tigray. Wheat is an important cereal crop that provides ample nutritious calories for humans and animals. Nutrients play vital role in the production. Both macro and micronutrients are necessary for wheat plants. Every nutrient has its own character and is involved in different metabolic processes of plant life. Nutrient deficiency and toxicity conditions inhibit normal plant growth and exhibit characteristic symptoms. For optimal growth, development, and production, plants need all the necessary nutrients in balance" [5]. However, low soil fertility is among the problems causing low wheat production in Tigray, including in Enderta district.

"From the higher to the lower locations geological formations of the Enderta district are Amba Aradam formation, Agula shale, Mekelle Dolerite, Antalo limestone and quaternary alluvium and freshwater tufa. The soils of Enderta district reflect its longstanding agricultural history, highly seasonal rainfall regime, relatively low temperatures, overall dominance of limestone and dolerite lithology and steep slopes. Outstanding features in the soilscape are wide plains with Vertisols. The district has complex geology and topography and it has been organized into land systems - areas with specific and unique geomorphic and geological characteristics, characterized by a particular soil distribution along the soil catena. There are different soil types classified in line with World Reference Base for Soil Resources (WRB) and reference made to main characteristics that can be observed in the field in the Enderta district. Specifically, the study area has shallow loamy soil on limestone (Calcaric Cambisol) and Vertic Vertisols, which is deep, dark cracking clays on calcaric material" (WIKIPEDIA; The Free Encyclopedia).

"A Cambisol in the World Reference Base for Soil Resources [IUSS (International Union of Soil Sciences) Working Group WRB [6] is a soil in the beginning of soil formation. The horizon differentiation is weak. This is evident from weak, mostly brownish discoloration and/or structure formation in the soil profile. A Vertisol is a Soil Order in the USDA (United States Department of Agriculture) soil taxonomy [7] and a Reference Soil Group in the World Reference Base for Soil Resources" [6]. Vertisols have a high content of expansive clay minerals, many of them belonging to the montmorillonites that form deep cracks in drier seasons or years (WIKIPEDIA; The Free Encyclopedia).

Mulata Haftu and Filimon Gidey [8] had selected localities of Raya Azebo and Enderta, northern Ethiopia and sampled as well as described ten soil profiles. From this study, they identified five soil groups (Vertisol, Calicsol, Cambisol and Luvisol) according to World Reference Base soil classification from which Cambisols and Vertisols were chosen for the study. They had also identified soil mineral nutrients especially N, P, Su, Fe, Zn and B which were scarce in the investigated soils. Based on their study, they also defined three types of fertilizers (NPSFeZn, NPSZn, and NPSFeZnB) suitable for the identified soils. Similarly, based on previous recommendations on fertilizer types for Enderta by Ministry of Agriculture (MOA) and Ethiopian Agricultural Transformation Agency (ATA) [9], NPSZn blend fertilizer was selected to determine its optimum rate for wheat. Among the key strategies that were identified to help increase agricultural production and productivity in Growth and Transformation Plan I (GTP I) period was the soil fertility mapping of the country's agricultural lands. The soil fertility status and fertilizer recommendation atlas of Tigray National Regional State (TNRS) was completed in the year 2014 and published by the MOA and ATA) [9] as part of the strategy. The necessity to transform agricultural sector with respect to soil fertility requires application of proper amounts of blended fertilizers for different crops. The meaning of blended fertilizer in this paper is fertilizer made by physical mixture of different fertilizer compounds and or elemental fertilizer nutrients.

Seven soil nutrients (N, P, K, S, Fe, Zn and B) were found to be deficient in the soils of Tigray Region [9]. Blended fertilizer types containing N, P, S, B, Fe and Zn in blended form have been recommended to solve site specific nutrient deficiencies and thereby increase crop production and productivity. The NPSZn (17.7 N – 35.3 P2O5 + 6.5S + 2.5 Zn) was recommended for Shibta in Enderta district. According to soil fertility status and fertilizer recommendation atlas for Tigray National Regional State prepared by Agricultural Transformation Agency (ATA) and Ministry of Agriculture, MOA [9], nitrogen (N), sulfur (S) and zinc (Zn) were low and phosphorus (P) was very low in most part of Enderta district (ATA and MOA, [9]) including Shibta. NPSZn is hence the proper fertilizer types to minimize the yield reduction due to limitation of these four nutrients. Vertisols and Cambisols are common cultivated soil types wherein wheat is grown by farmers at Shibta. Site specific fertilizer trials are needed because even though the site is the same, soil types have different properties which cause variability in crop productivity. Moreover, recently balanced fertilizers containing N, P, K (potassium), S, boron (B) and Zn in blend form have been recommended to ameliorate site specific nutrient deficiencies and thereby to increase land, water and labor productivity.

1.1 Problem Statement

Land degradation and crop depletion without replenishment for many years have led to poor soil fertility and extreme exhaustion of plant nutrients from the soil which is the major factors limiting crop production in different agro-ecological zones of Tigray. Nutrient mining due to sub optimal fertilizer use coupled with unblended fertilizer uses have favored the emergence of multi nutrient deficiency in Ethiopian soils which in part explain fertilizer factor productivity decline and stagnant crop productivity conditions encountered despite continued use of blanket recommendations.

Experiments on blended fertilizers were carried out for the last few years in Tigray. However, in most of the study sites there were no significant differences among the different blended fertilizers as compared to the conventional N and P recommendations. The probable reasons could be (i) Blends were compared to each other, (ii) The formulation NPSZn contains insufficient amount of N.

The needs for site-specific fertilizer prescriptions are increasingly apparent, however, fertilizer trials involving multi-nutrient blends that include micronutrients were rare in the Tigray context. Although there was a general perception that the new fertilizer blends were better than the traditional fertilizer recommendation [urea and di ammonium phosphate (DAP)], their comparative advantages is not explicitly examined and understood under various production environments. Previous study on soil fertility status of Enderta district indicates that low soil fertility is one of the crop production problems. Enderta district in Tigray is one of the wheat-producing areas in Ethiopia with low productivity. Research to improve and increase wheat production is one of the solutions to fight against food crisis in the study area [9]. Although NPSZn blend fertilizer was one of the major blended fertilizers identified for the districts, optimum rates of the fertilizer for different crops, agro ecologies and soil types were not yet determined. Most smallholder farmers in Tigray including in Enderta district use limited inorganic fertilizers. Furthermore, evaluations of yield response to multi-nutrient fertilization have not been undertaken. Validation of fertilizer blend formula prescribed based on soil fertility maps and provisional area specific fertilizer recommendations were undertaken. Besides, verifying the soil fertility status and fertilizer recommendation atlas for wheat grown in these districts on different soil types was urgently needed to increase wheat yield grown in the region. Responses of crops to soil groups vary in different locations. For instance, Elias et al. [10] revealed that Ethiopian Vertisols exhibit a wide variation in properties that express themselves in the yields of teff and wheat. Therefore, these experiments were conducted to evaluate NPSZn fertilizer on yield, yield component of bread wheat in Enderta on wheat under rain-fed conditions on Cambisols and Vertisols which are common soil types in cultivated areas in the study district.

1.2 Objectives

1.2.1 General objective

The general objective of the study was to determine optimum rate of NPSZn blend fertilizer adjusted with urea for wheat at Shibta in Enderta district of Tigray and to verify whether this type of fertilizer works in the study area or not for Cambisols and Vertisols soil groups in the area.

1.2.2 Specific objective

- To determine optimum rate of NPSZn and urea for wheat on Cambisols and Vertisols by comparing to existing recommended N and P rates.
- To validate the previously recommended NPSZn blend fertilize for Enderta district on different soil groups (Cambisols and Vertisols soil groups).

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The experiments were conducted in 2017/18 cropping seasons at Shibta peasant association in Enderta district, South Eastern Zone, Tigray National Regional State on two different soil types (Vertisols and Cambisols) (Fig. 1).

Enderta district comprises of altitudes ranging between 1750 meters above sea level (m.a.s.l.). The district has three major agro ecological zones: highland (38.5%), midland (39%) and lowland (22.5%) and the temperature ranges between 21- 25 °C. The topography of the district is varied and consists flat land (43217.2 ha), mountain (41999.5 ha), valley and undulated (36.5 ha). The farming system in the area is mixed farming system (crop and livestock production). The major crops grown in the area are wheat, barley, teff, sorghum and grass pea. The yield gap of Tigray for the period of 1998-2017 was 6.83 t/ha, where the actual yield was 1.47 t/ha [2]. Shibta is located at 13.4502 N latitude and 39.5213° E longitude altitude ranges from 1400 to 2700 meter above sea level. The experimental areas are found at about 7 km south east of Mekelle City which is the capital city of Tigray National Regional State in Ethiopia. The average annual rainfall for Shibta was calculated from meteorological data taken from Alula Aba Nega Airport, the nearby metrological station, for the period of 2008 to 2017, and it was 440.5 mm, of which 359.5 mm was calculated for the period of June to September.

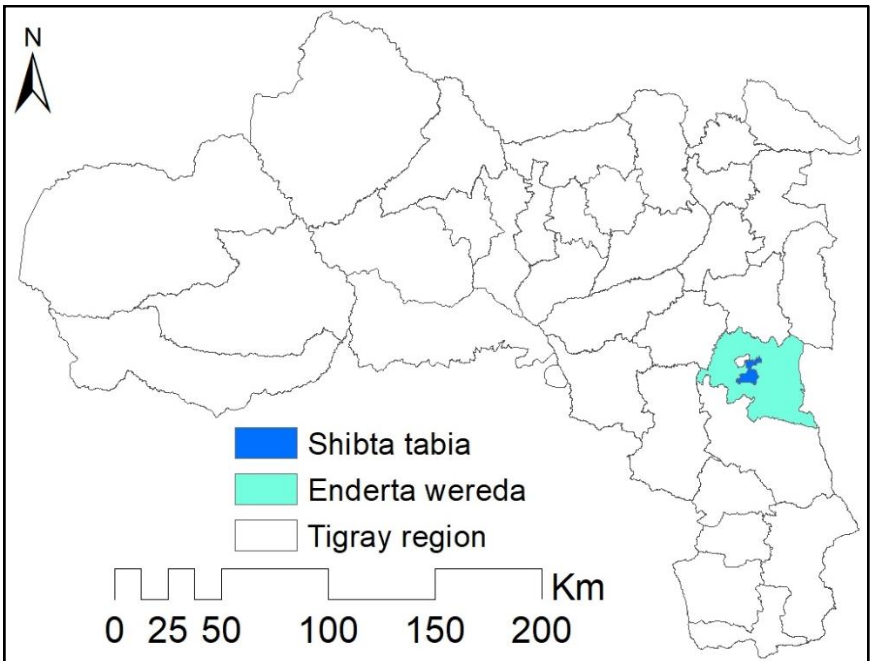

Fig. 1. Location map of the experimental area

Table 1. Initial soil characteristics of the experimental field at Shibta, Enderta district

Parameter*	Shibta (Cambisols)	Shibta (Vertisols)
Sand (%)	46	40
Silt (%)	30	6
Clay	24	54
Textural class	Loam	Clay
EC	0.23	0.07
pH (1:2.5)	6.85	7.03
CEC	18.42	34.64
OC (%)	0.76	1.32
T.N (%)	0.10	0.112
Olsen P	10.48	21.08
Av. K (ppm)	34.2	64.3

The area was found to have clay textural class with a swelling and cracking nature of black colored Vertisols neutral in reaction with a montmorillonitic clay content in excess of 54% and loam textural class Cambisols neutral in reaction (personal observation, Table 1). Similar to vertic horizon described by WRB [6], the Vertisols in the area has vertic horizon which is a clay-rich subsurface horizon that, as a result of shrinking and swelling, has slickensides and wedge-shaped soil aggregates. According to WRB [6], "a vertic horizon consists of mineral material and has ≥ 30% clay; wedge-shaped soil aggregates; having slickensides on ≥ 10% of the surfaces of soil aggregates; and has shrink-swell cracks; and a thickness of ≥ 25 cm. The Vertisols in the experimental site fulfills these criteria. Likely, the cambisols in the site has a cambic horizon, not consisting of claric material and starting ≤ 50 cm from the mineral soil surface" [6]. The two soil types are located in the same location with the area description mentioned above.

2.2 Treatments, Experimental Designs and Procedures

Eight treatments [0, 50, 100, 150, 200, 250, 300, NPSZn kg ha-1) adjusted with N to the recommended level as well as N and P fertilizers (64 kg Nha^{-1}, 46 kg P_2O_5 ha $^{-1}$)]. Blended fertilizer treatments including 0, 50, 100, 150, 200, 250 300 NPSZN kg/ha as well as recommended rate of N and P were applied at the time of sowing.

The treatments with the blended rates were supplied with adjusted N in the form of urea. The blended fertilizer rates were applied at the time of sowing while N was applied in the form of urea in two applications, ½ applied at sowing and ½ of the rate top dressed at full tillering stage. Phosphorus in the form of TSP was applied at the rate of 100 kg /ha. Mekelle 3 wheat variety with 150 kg seed /ha was used and seed rate per plot was considered by calculating the 3 m * 3 m area for each plot and sown uniformly by hand within the rows made by hoe on on 16 July and 18 July 2018, respectively. Mekelle 3 wheat variety is bread wheat variety well adapted to altitudes of 1500 – 2200 m.a.s.l. with uniform distribution in its growing period. Two times hand weeding for each of the two sites was done during the cropping season in each year. Net plot size of 2m x 2.4m = 4.8 m2 (10 rows excluding margins) was used for the data collection. For each experiment, the sites for the first and second seasons were in different nearby places on each respective soil types. This was done to prevent the residual effects of the first year applied fertilizers on the second year treatments. Details of the applied treatments are indicated in Table 2.

NPSZn and urea were chosen because of the deficient nutrients in the soil (N. P,S and Zn) of the study area. The levels of urea and NPSZn were determined considering nutrient requirement of potential of wheat based on the experience from previously conducted experiments on wheat. The experiments were laid out in randomized complete block design with three replications at Shibta, at two sites with different soil types, for two cropping seasons.

According to MOA and ATA [9] nutrient contents in 100 kg of NPSZN were reported to be NPSZn: 17.7 N – 35.3 P2O5 + 6.5S + 2.5 Zn . Sowing was done manually. The plot size was 3 m x 3 m (9 m^2). The spacing between rows, plots and blocks were 0.2 m, 0.5 m and 1 m, respectively. Mekelle 3 wheat variety with 150 kg seed /ha was used and seed rate per plot was considered by calculating the 3 m * 3 m area for each plot and sown uniformly by hand within the rows made by hoe on 16 July and 18 July 2018, respectively.

Representative composite soil samples from each field were taken before planting from 0-20 cm depth, following the standard soil sampling procedure. Each composite soil sample was used for selected physic-chemical analysis [soil texture, soil reaction (pH), electrical conductivity (EC), organic carbon (OC), cation exchange capacity (CEC), total N, and Olsen P]. Particle size distribution was determined using the Bouyoucos hydrometer method [11]. The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter [12]. Walkely and Black [13] used for determination of organic carbon. Total N was determined using the Kjeldahl method as described by [14]. Available P was determined following the Olsen method [15] using ascorbic acid as reducing agent. Cation exchange capacity was determined by ammonium acetate method.

2.3 Data Collection and Measurement

Data on plant basis was recorded from the ten central rows out of the fifteen rows per plot. Plant parameters recorded were: plant height, spike length, grain yield and straw yield and harvest index (HI) calculated from yield and biomass.

Table 2. Applied treatments with respective nutrient contents

NPSZn (kg ha^{-1})	N	P_2O_5	P	S	Zn	Adjusted N	Total N applied	Total nutrient (kg/ha)
0	-	-		-	-	-	-	
50	8.85	17.65	7.766	3	1.25	55.15	64	76.016
100	17.7	35.3	15.532	6	2.5	46.3	64	88.032
150	26.55	52.95	23.298	9	3.75	37.45	64	100.048
200	35.4	70.6	31.064	12	5	28.6	64	112.064
250	44.25	88.25	38.83	15	6.25	19.75	64	124.08
300	53.1	105.9	46.596	18	7.5	10.9	64	136.096
64N and46 P2O5	64	46	20.24	-	-	-	64	66.24

Measurements of yield attributes were taken at physiological maturity of the crop prior to harvest. The crop was harvested from the net plot areas manually using sickle at the ground level and dry mater yield of the above ground biomass was determined. Plant height and spike length were measured at physiological maturity on 10 randomly selected plants per plot. Biomass yield was recorded from the net plot area by weighing the total above ground biomass at harvesting. Grain yield was measured at harvesting after adjusting at 12.5% of moisture content. Straw yield was obtained by deducting grain yield from biological yield. Harvest index is the ratio of grain to the total biomass and is estimated as

HI = grain yield/biological yield

Plant height was measured from ground surface to the tip of the panicle at maturity from ten randomly sampled plants. Spike length was measured from its base to the tip. The average spike length in cm was considered.

2.4 Soil Sampling and Analysis

Surface soil samples (0-20 cm depth) were collected from the experimental fields before sowing using auger sampler in a zigzag pattern sample for initial soil nutrient as well for organic carbon, electrical conductivity (EC), pH, cation exchange capacity (CEC) and soil texture analysis. Wheat roots concentrate their biomass in the uppermost soil layers, particularly within the 0-20 cm range (Fan et *al*., 2016). The collected soil sample was air dried and ground with a pestle and mortar. The samples were sieved through a 2-mm sieve for selected chemical and physical soil properties and analyzed based on the standard laboratory procedures at Mekelle Soil Research Center soil and plant analysis laboratory. Determination of soil particle size distribution was carried out using the hydrometer method [11]. Once the sand, silt, and clay separates were calculated in percent, the soil was assigned to a textural class based on the soil textural triangle using International Soil Science Society (ISSS) system (Rowell, 1994). Soil pH was measured using digital pH meter in 1:2.5 soil to water ratio as described in Rhoades [12]. The EC of the soil was measured according to the method described by Peech (1965). Potassium (K) was determined using flame photometry [16]. Cation exchange capacity of the soil was determined following the modified Kjeldahl procedure [17] and reported as CEC of the soil. Portions of the soil samples were taken and sieved using 0.5 mm diameter for the determinations of organic carbon OC) and total Nitrogen (TN). Organic carbon was determined following wet digestion methods as described by Walkley and Black [13]. The total N content in soils was determined using the Kjeldahl procedure by oxidizing the organic matter with sulfuric acid and converting the N into ammonium ion (NH_4^+) as ammonium sulfate [18]. The available P was measured by Olsen Method [15]. the bottom of the spike to the tip of the spike excluding the awns from ten randomly spikes. The grain yield was determined from each experimental plot and adjusted to constant moisture levels of 12%. Harvest index was calculated from the ratio of grain yield to biological yield.

2.5 Data Analysis

Data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using Statistix10 software program. Significant difference between and among treatment means was assessed using the least significant difference (LSD) at 0.05 level of probability [19]. Partial budget analysis was calculated to determine the more profitable blended fertilizer rates adjusted with N fertilizer.

2.6 Economic Analysis

Partial budget analysis was employed for economic analysis of main effects of NPS and urea fertilizer rates because the interaction effects of NPS and urea were not statistically significant. Analysis of marginal rate of return (MRR%) was carried out for non-dominated treatments and the MRRs were compared to a minimum acceptable rate of return (MARR) of 100% in order to select the optimum treatment International Maize and Wheat Improvement Center [20]. The net benefit per hectare for each treatment is the difference between the gross benefit and the total variable costs. The average yield was adjusted downward by 10% to reflect the difference between the experimental field and the expected yield at farmers' fields and with farmer's practices from the same treatments [20]. Only the variable costs of fertilizers at the time of sowing wheat were considered to calculate the variable costs.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Soil physicochemical properties of the experimental site

The soil of the study areas are Vertisols and Cambisols with a particle size distributions of 54% clay, 6% silt and 40% sand and 24% clay, 36% silt and 46% sand, respectively, which are clay and loam in textural classes, respectively (Table 1). The high clay content of the Vertisols indicate better nutrient and water holding capacity of the soil compared to the Cambisols. Electrical conductivity was The EC in the two sites was low which is none saline for both soil types which were neutral for Cambisols and mildly alkaline for Vertisols according to the ratings by Bruce and Rayment [21]. The pH of the soils of the experimental sites were neutral (7.03 for Cambisols and 6.85 for vertisols) which indicate the suitability of the soils reaction at for optimum growth and yield of most crops including wheat. Cabisols and Vertisols were moderate and high in CEC, respectively with reference by Metson [22]. The cation exchange capacities of the soils were 18.42 and 34.64 cmolc (+) kg soil for Cambisols and Verisols, respectively. Organic carbon was very moderate for Cambisols and Vertisols indicating that it is not optimum for wheat. Total nitrogen was low for both cambisols and Vertisols [21] whereas available P was moderate for Cambisols and high for Vertisols as indicated by Olsen [15], for the two soil types as indicated by Olsen [15] (Table 1).

3.1.2 NPSZn effect on wheat yield and yield components

Combined analysis of the data over two sites in each location showed significant differences (P< 0.05) in plant height, spike length as well as in grain and straw yields. No significant difference was observed for HI in the all experiments (Tables 3 and 4).

Highest plant height was recorded when 250 kg NPSZn/ha was applied showing 27.5% increment over the control but the differences were not statistically significant with that of the other NPSZn treatments for Vertisols at Shibta. Higher spike length was observed at 250 kg NPSZn/ha and higher grain and straw yields were obtained at the rate of 300 kg NPSZn/ha. However, spike length and grain yield differences were not significant for the treatments above 50 kg NPSZn/ha on Vertisols at Shibta (Table 3). Highest plant height, grain and straw yield were recorded when 300 kg NPSZn/ha was applied for Cambisols at Shibta (Table 4).

Table 3. Effect of blended fertilizer rates on yield and yield components of wheat grown on Vertisols at Shibta in Enderta district combined over years (2017 and 2018)

Trteatment	PL (cm)	SL (cm)	GY (kg ha^{-1})	SY (kg ha^{-1})	HI
0 kg	65.80d	6.07c	1186.1c	2205.6f	0.346
50 NPSZn	75.70c	7.15ab	1911.1ab	3516.7de	0.349
100 NPSZn	75.07c	6.87b	1972.2ab	3613.9cde	0.350
150 NPSZn	78.50bc	7.12ab	2069.4ab	4116.7bcd	0.331
200 NPSZn	77.90bc	6.98ab	2130.6ab	4252.8abc	0.333
250 NPSZn	83.87a	7.33a	2377.8a	4741.7ab	0.332
300 NPSZn	80.43ab	7.17ab	2344.4a	4861.1a	0.322
RNP	75.70c	7.10ab	1747.2c	3455.6e	0.333
LSD	4.5309	0.4221	491.46	655.51	NS
CV	5.0	5.12	21.12	14.41	7.77
P value	0.0000	0.0001	0.0009	0.0000	0.5236
Year 1	78.3	7.43a	2258.3	4352.1	0.342
Year 2	74.94	6.52b	1676.4	3338.9	0.332
LSD	NS	0.1788	NS	NS	NS
CV	8.06	3.20	50.46	33.55	16.48
P value	0.1326	0.0001	0.1121	0.0530	0.5950
P value of Year*Trt.	0.0211	0.0975	0.4438	0.1185	0.3178

** : LSD = Least significant difference, CV = Coefficient of variation,PL = Plant height, SL = Spike length, GY = Grain yield, SY = Straw yield, Trt = treatment, RNP = Recommended Nitrogen and phosphorus and HI = Harvest index*

Table 4. Effect of blended fertilizer rates on yield and growth parameters of wheat grown at Cambisols at Shibta in Enderta district combined over the years (2017 and 2018)

Trteatment	PL (cm)	SL (cm)	GY (kg ha^{-1})	SY (kg ha^{-1})	HI
0 kg	74.27c	6.70d	1505.60c	2697.2e	0.357
50 NPSZn	78.30b	6.92cd	2075.00c	4000.00d	0.340
100 NPSZn	78.90b	7.03bcd	2233.3abc	4375.00cd	0.336
150 NPSZn	81.07ab	7.25abc	2130.60bc	4705.6bc	0.328
200 NPSZn	81.67ab	7.05bcd	2500.00 ab	5180.6ab	0.323
250 NPSZn	84.00a	7.50a	2313.90abc	4672.2c	0.317
300 NPSZn	82.90a	7.23abc	2563.90a	5494.4a	0.315
RNP	81.23ab	7.40ab	1986.10c	4275.0cd	0.310
LSD	3.9798	0.3942	405.42	507.70	NS
CV	4.19	4.67	15.84	9.70	9.15
P value	0.0009	0.0058	0.0004	0.0000	0.1679
Year 1	78.30b	7.43	2258.3	4352.1	0.3415
Year 2	82.28A	6.84	2068.8	4497.9	0.3151
LSD	2.9132	0.3942	NS	NS	NS
CV	3.9798	5.19	47.54	22.79	17.64
P value	0.0192	0.0054	0.5579	0.6427	0.1887
P value of Year*Trt.	0.3260	0.7937	0.6148	0.5490	0.4021

** : LSD = Least significant difference, CV = Coefficient of variation,PL = Plant height, SL = Spike length, GY = Grain yield, SY = Straw yield, Trt = treatment, RNP = Recommended Nitrogen and phosphorus and HI = Harvest index*

Table 5. Partial budget analysis for Enderta Verttisols (combined over two years)

Treatment (NPSZn RNP)	Adjusted GY	Adjusted SY	Total fertilizer Cost	Fertilizer transport & application cost	TVC	Grain revenue	Straw revenue	Total revenue	Net revenue (TR-TVC)	MRR (ratio)	MRR (%)
0	1067.5	1985.0	0.0	0.0	0.0	14944.9	6352.1	21297.0	21297.0		
50	1720.0	3165.0	2316.8	254.8	2571.7	24079.9	10128.1	34208.0	31636.3	4.0	402.0
100	1775.0	3252.5	2791.6	301.0	3092.6	24849.7	10408.0	35257.8	32165.2	1.0	101.5
150	1862.5	3705.0	3266.4	347.1	3613.5	26074.4	11856.1	37930.5	34317.1	4.1	413.1
RNP	1572.5	3110.0	3695.1	358.7	4053.8	22014.7	9952.1	31966.9	27913.1	D	D
200	1917.5	3827.5	3741.1	393.3	4134.4	26845.6	12248.1	39093.6	34959.2	1.2	123.3
250	2140.0	4267.5	4215.9	439.4	4655.3	29960.3	13656.1	43616.4	38961.1	7.7	768.3
300	2110.0	4375.0	4690.8	485.6	5176.3	29539.4	14000.0	43539.4	38363.1	D	D

** GY = Grain yield; SY = straw yield; TVC = Total variable cost, MRR = Marginal rate of return*

Table 6. Partial budget analysis for Enderta Cambisols (combined over two years)

Treatment (NPSZn RNP)	Adjusted GY	Adjusted SY	Total fertilizer Cost	Fertilizer transport & application cost	TVC	Grain revenue	Straw revenue	Total revenue	Net revenue (TR-TVC)	MRR (ratio)	MRR (%)
0	1067.5	1985.0	0.0	0.0	0.0	14944.9	6352.1	21297.0	21297.0		
50	1720.0	3165.0	2316.8	254.8	2571.7	24079.9	10128.1	34208.0	31636.3	4.0	402.0
100	1775.0	3252.5	2791.6	301.0	3092.6	24849.7	10408.0	35257.8	32165.2	1.0	101.5
150	1862.5	3705.0	3266.4	347.1	3613.5	26074.4	11856.1	37930.5	34317.1	4.1	413.1
RNP	1572.5	3110.0	3695.1	358.7	4053.8	22014.7	9952.1	31966.9	27913.1	D	D
200	1917.5	3827.5	3741.1	393.3	4134.4	26845.6	12248.1	39093.6	34959.2	1.2	123.3
250	2140.0	4267.5	4215.9	439.4	4655.3	29960.3	13656.1	43616.4	38961.1	7.7	768.3
300	2110.0	4375.0	4690.8	485.6	5176.3	29539.4	14000.0	43539.4	38363.1	D	D

** GY = Grain yield; SY = straw yield; TVC = Total variable cost, MRR = Marginal rate of return*

3.1.3 Partial budget analysis

Partial budget analysis on grain and straw yields showed >100% marginal rate of return for the treatments 50 to 300 kg NPSZn/ha with adjusted N fertilizer as well as recommended N and P on Vetisols and Cambisols in Enderta (Tables 5 and 6). Partial budget analysis on grain and straw yields showed highest marginal rate of returns at the rates of 250 kg NPSZn/ha with adjusted N fertilizer on Vertisols at Shibta in Enderta (Table 5). Partial budget analysis on grain and straw yields showed highest marginal rate of returns at the rates of 100 kg NPSZn/ha with adjusted N fertilizer for wheat grown on Cambisols in the area (Table 6).

3.2 Discussion

Similar to our results, Sofonyas et al. [23] recommended 200kg NPSZn with 28.6 kg N (62 kg urea) for Ofla Cambisols and 100 kg NPSZn with 46 kg N (100 kg urea) for Emba Alaje Vertisols as optimum rates for wheat production based on both biological and economic analysis. These rates were within the ranges that gave higher biological grain and straw yields obtained in our results. Similar to our result, Abebaw Tadele Alem and Hirpa Legese [24] reported a significant and profitable effect of blended fertilizer (NPSZn) on wheat at the rate of 200 kg/ha at Arjo Didessa (Western Ethiopia). For durum wheat at DebreZeit, Bizuwork Tafes Desta [25] concluded that combined application of 100 kg NPSB and 92 kg N/ha gave economically profitable results on Vertisols.

Accordingly, Gessessew et al. [26] also examined the effect of NPSZnB blended fertilizer on bread wheat yield attributes, quality traits and use efficiency in Vertisols and Cambisols under rain-fed conditions in Emba Alaje district of Tigray. Based on their study result, they recommended 100 kg NPSZnB ha^{-1} and 125 kg NPSZnB ha^{-1} for Vertisols and Cambisols, respectively for the area which indicates that the rate of blend fertilizer varies in Tigray for different soil types and climatic conditions. In line to our significant effect of NPSZN on wheat production, Bezuayehu et al. [27] recommended “250 NPSZnB kg/ha blended fertilizer and 350 kg /ha urea for highest yield of wheat on Vertisols for farmers who afford to buy it. For those who do not afford, they recommended 250 Kg NPSZnB/ha and 250 kg urea/ ha as agronomical optimum for wheat production in Vertisols of Ambo district in Ethiopia and similar agro-ecologies”.

Elias et al. [10] had conducted “blended fertilizer trial on Vertisols in Endamohoni (a district in Tigray) for wheat. Contrary to our results, they concluded that NPSZnB levels up to 300 kg/ha for wheat had significant benefits but as S and Zn in the soils were not significantly correlated with wheat yields, and the treatments that include NPS + ZnB did not outperform NPS or DAP alone, there is no justification for the adoption of a blend fertilizer. They added that in the future, micronutrients may become limiting but then, N and P were the most limiting nutrients. Given the diversity in land use practices, biophysical settings and soil fertility management they concluded that, soil-, site- and crop-specific fertility recommendations should be adopted” [28-31].

Sofonyas Dargie et al. [23] had stated that “response of wheat to application of different rates of N, P, K and S under balanced fertilization based on the study carried out on four soil types and five agro-ecologies in order to determine soil-specific responses of wheat to N, P, K, and S under balanced fertilization. The study areas were in Tigray, Oromya, SNNP and Amhara regions in Ethiopia, including Adigolo, Ayba, Embahsti, Freweyni, and Mesanu areas a in Tigray region. Duration of the studies was 2013 to 2017 Based on the study, they concluded that across all four soil types (Cambisols, Vertisols, Luvispls and Nitisols) and AEZs, application of 46–92 kg N ha^{-1} and 10–30 kg P ha^{-1} with balanced application of K, S, B, and Zn could be sufficient. They revealed that grain yields of wheat significantly varied with applied N and P fertilizer rates with soil types and AEZs. With balanced application of other nutrients, the optimum N rates for wheat were 138 kg N ha^{-1} on Cambisols and Luvisols, 92 kg N ha^{-1} on Vertisols, and 176 kg N ha^{-1} on Nitisols, while the optimum P rate was 20 kg P ha^{-1} on Cambisols and Vertisols. They concluded that the nutrient dose–response curve did not show consistent pattern for K and S applications on all soil types. Likewise our results of NPSZn study were different for Cambisols and Vertisols” [32-36].

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

This study highlights how different levels (sex levels of blended fertilizer, and control) of blended fertilizer (NPSZn) affects crop yields compared to only DAP and urea (recommended

N and P) fertilizers type used in Enderta district for decades on all soil types. This study was conducted on Cambisols and Vertisols soil groups because these soil groups cover most of the cultivated areas in the district. Bread wheat was selected for the reason that most of the farmers in the district prefer to produce this crop as compared to the other crops. Two experiments, one on Cambisols and the other on Vertisols, were carried out for two seasons by arranging in RCBD in three replications in each experiment. Some soil properties were also analyzed in soil laboratory from two composite soil samples collected from each soil group.

Results of the experiments indicated significant differences (P≤0.05) on plant height, spike length, straw yield and grain yield whereas the differences were not significant for HI. Combined analysis of the two seasons' data showed highest biological performance of the parameters at the rates of 300 kg NPSZn/ha blend adjusted with 25 uea/ha for Enderta Cambisols. Highest results were obtained at 250 kg/ha NPSZn/ha blended adjusted with 42 urea/ha for Enderta Vertisols. Bread wheat grain yield was higher in Cambisols than in Vertisols. In this study, NPSZn blended fertilizer application increased bread wheat yield in both soil types at Shibta under rain-fed conditions. As a consequence, in both soil types, using a high NPSZn mixed fertilizer led to the maximum production of bread wheat.

Partial budget analysis showed highest and profitable yield at the rates of 50 NPSZn/ha adjusted with 115 urea/ha and 100 kg NPSZn/ha adjusted with 100 urea/ha for Vertisols and Cambisols, respectively. These profitable rates could be recommended for the respective soil types of the experimental areas and other areas with same soil type and agro-ecologies in Tigray. Although the mean yield differences of treatment that received 250 of NPSZn blends was higher compared to effects of other treatments, generally these treatments showed no significant differences compared to plots treated with 50 – 200 kg/ha blend levels. However, most of the plots treated with blend levels performed higher than that of treated with only recommended NP and control. This result depicted that adding S and Zn fertilizers to N and P in the current formulation has advantage as compared to the conventional N and P fertilizer.

4.2 Recommendation

Therefore, based on the results of these experiments and the above summary, the following recommendations could be made:

- The rates starting from 50 up to 250 kg/ha NPSZn and 115-42 kg/ha urea can be recommended for Vertisols in Shibta.
- For the Cambisols at Shibta and areas with similar agro-ecology and soil type, starting from 100 kg/ha NPSZn adjusted with 100 kg urea/ha could be recommended as this rate is more profitable. To know which one of the nutrients in the blend are (is) more effective calls for further detail study.
- Moreover, application of blend fertilizers had created a problem of identifying the effects of single plant nutrient on crop performance which calls for other alternative fertilizers in addition to the existing available blended fertilizers.
- The effects of individual elements in the blend (N, P S and Zn) on performance of wheat needs further study.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENTS

We would like to thank Mekelle Soil Research Center for its support in the implementation of this study by providing vehicles and for its financial sponsorship. We are also grateful to Mr. Girmay Hailu, Hagos W/Gebriel and other laboratory staff for their contribution in soil analysis at in the soil laboratory of Mekelle Soil Research Center.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.globalpresshub.com/review-history/1742