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Yield Response of Upland Rice (*oryza sativa l.*) Through Nutrient Omission Trial in Vertisols of Fogera Districts, North West Ethiopia

Demsew Bekele[1, *], Yihenew Gebreselassie[2], Tilahun Tadesse[1]

[1]Fogera National Rice Research and Training Center, Wereta, Ethiopia

[2]Collage of Agricture and Enviromental Sciences, Bahir Dar University, Bahir Dar, Ethiopia

Email address:
bekeledemsew720@gmail.com (D. Bekele)
[*]Corresponding author

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Abstract: The experiment was conducted with the objectives of investigating the yield-limiting nutrients through nutrient omission trial on upland rice in 2020/2021 cropping season on the vertisols in Fogera District, Northwestern Ethiopia. The experiment was laid out in randomized complete block design with nine treatments and three replications. The treatments were Control, Recommended NP, NPKSZnB, PKSZnB (-N), NKSZnB (-P), NPSZnB (-K), NPKZnB (-S), NPKSB (-Zn) and NPKSZn (-B). Yield attributing characters of biomass yield, plant height, panicle length, effective tillers, grain and straw yields of rice were significantly influenced by the treatments. The highest grain yield (7.2 ton ha^{-1}) was recorded from NPKSZnB treatment which was not significant with NPKSZn (-B), NPKSB (-Zn) and NPSZnB (-K). The lowest grain yield of 2.2 ton ha^{-1} was recorded from the control followed by omission of N, P and S nutrients. The omission of N, P and S reduced the grain and straw yields significantly over the treatment receiving all the nutrients. The omission of N reduced the grain yield by 46%, omission of P reduced the grain yield by 17% while S omission reduced grain yield by 11% over the treatment that received all nutrients. Based on percent grain yield reduction, the limiting nutrients were found in the order of N > P > S. Overall, this result shows that nitrogen phosphorus and sulfur were the most vibrant factors to increase the yield and yield component of rice.

Keywords: Nutrient Omission, Nutrient Uptake, Yield Reduction, Agronomic Efficience

1. Introduction

Soils in Africa are typically highly variable in fertility and their response to inputs. Soil nutrient depletion and likely degradation have been considered serious threats to agricultural productivity and which is identified as major causes of decreased crop yields and per capita food production in SSA [30]. A World Bank report estimated the rate of cereal yield increase in Africa over the years at a very low rate of 0.7% compared to growth rates in other developing regions of the world of 1.2 - 2.3% [1].

Low soil fertility and inadequate nutrient management are among the major factors determining its yield level. Balanced nutrient use ensures a high production level and helps to maintain soil health and ensures sustainable agriculture. Improving the yield potential of genotypes and the use of chemical fertilizer are important determinants to improve its productivity. Poor soil fertility is among the major factors limiting rice production in Ethiopia [53].

Rice is an important staple crop that plays an important economic role and feeds approximately half the world's population [20]. Rice (*Oryza sativa l.*) is one of the most important staple food for more than 50 percent of the global population. Now a day, the cultivation of rice in the intensive subsistence agriculture becomes synonymous with agriculture. India is the second largest producer of rice in the world being superseded only by China in the gross annual output. In South Asia, rice was cultivated on 60 million hectares, and production was slightly above 225 million tonnes of rice, accounting for 37.5 and 32 per cent of global area and production, respectively.

In Ethiopia, rice production was started three decades ago in the early 1970's. Although rice is a recent introduction to the country, its importance is well recognized as the production area coverage of about 10,000 ha in 2006 has increased to over 63,000 ha in 2018 [16].

Upland rice is suitably grow in many parts of Ethiopia. Predominant potential areas include west central highlands of Amhara Region (Fogera, Gonder Zuria, Dembia, Takusa and Achefer), Northwest lowland areas of Amhara and Benshangul Regions (Jawi, Pawi, Metema and Dangur), Gambella Regional State (Abobo and Etang districts), South and Southwest low lands of Southern Nations, Nationalities and Peoples Region (SNNPR) (Beralle, Weyito, Omorate, Gura Ferda and Menit), Somali Region (Gode), Afar and South western highlands of Oromia Region [18]. The Amhara region takes the lion's share of producing the crop and accounted for 65-81% of the area coverage and 78-85% of the production in the years 2016-2018. The national average productivity of rice in Ethiopia is still however too low about 2.8t ha^{-1} [15].

Soil analyses and site-specific studies indicated that elements such as S, Ca, Mg, and micronutrients were becoming depleted and deficiency symptoms were observed in major crops in different parts of Ethiopian soil [6]. The status of micronutrients in central highlands of Ethiopia soils were low [5].

The site-specific nutrient management (SSNM) strives to enable farmers to dynamically adjust fertilizer use to optimally fill the deficit between the nutrient needs of a high-yielding crop and the nutrient supply from naturally occurring indigenous sources such as soil, organic amendments, crop residues, manures, and irrigation water. It aims to apply nutrients at optimal rates and times to achieve high yield and high efficiency of nutrient use by the rice crop, leading to the high cash value of the harvest per unit of fertilizer invested [9].

Improving the genotype yield capacity and the use of chemical fertilizer are essential determinants for improving rice productivity. Balanced fertilizers applications sustain optimal crop production, better quality product and ensues profitability. Nutrients such as N, P, K, S, B, Zn and Fe are plant nutrients found deficient in Ethiopian cultivable land soil though there are variations among location types. Newly developed fertilizer formula of the Ethiopian soils comprised these elements as well. Most soils are deficient in N, P, S, and B [19].

Therefore, it is indispensable to investigate the actual yield-limiting nutrients impeding the rice productivity from reaching its genetic potential. Because of these problems in the study area, this activity was initiated to identify the limiting nutrients on yield and yield component of upland rice production on Vertisols of Fogera District, Northwestern Ethiopia.

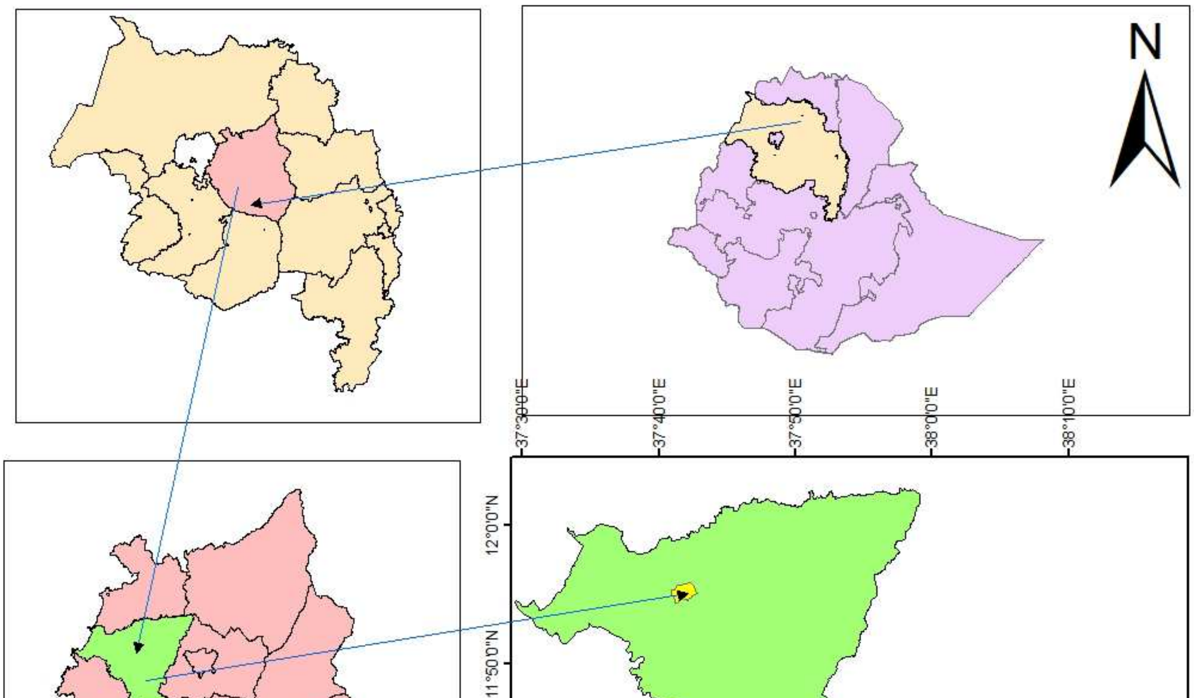

Figure 1. *Location map of the study area.*

2. Materials and Methods

2.1. Description of the Study Area

Location: The experiment was conducted on the Vertisols of Fogera district, South Gondor, Amhara Region, North-western Ethiopia. Fogera district is situated at 11° 46 to 11°59 latitudes north and 37° 33 to 37° 52 longitudes East. The district is bordered with Farta woreda in the east, Dera woreda in the south, Lake Tana in the west and Libokemkem woreda in the north. The experimental area was geographically located with altitude of 1815 meters above sea level. It is located at about 45 km away from Zonal capital city of Debre Tabor, 60 km from the capital city of Amhara Region, Bahir Dar and 625 Km from Addis Ababa.

2.2. Experimental Design and Procedures

The experiment was executed in the Fogera National Rice Research and Training Center site of Fogera District. Nine treatments were laid out in a randomized complete block design with three replications. The experiment gross plot size was 5m × 5m. Nerica-4 was used as attesting varity of upland rice. The rice was drill row planted at a spacing of 20 cm between rows with a seed rate of 100 kg ha^{-1}. The spacing between block and plots were 1m and 0.5m respectively. The net plot was formed by disregarding three rows each side of the plot. Moreover, 0.5 m length from end of each row were regarded to avoid border effects. Thus, the net plot for data collection was 3.8 m by 4m. From the 19 rows within the net plot, after the border effect, the two end rows were used for destructive sampling of plants for laboratory analysis. The remaining 15 central rows in the net plot were used for data gathering for biomass and grain yields.

The rates of fertilizer were 138N kg ha^{-1}, 46 P_2O_5 kg ha^{-1}, 60 K_2O kg ha^{-1}, 30 S kg ha^{-1}, 5 Zn kg ha^{-1} and 2 B kg ha^{-1}. The recommendations for N and P for the study area were 138 and 46 kg ha^{-1}. The experimental treatments were set up by omitting one of the nutrients. Whenever N (Urea) is existing, it was added in three splits 1/3 at planting, 1/3 at tillering and 1/3 at panicle initiation. The application of nitrogen and phosphorous fertilizer rates of 138 N and 46 P_2O_5 kg ha^{-1} was the best recommended for rainfed upland rice production in Fogera [58]. According to [27], results depicted that the highest biological yield (straw + grain) and grain yields were increased with K rates. But the partial budget analysis revealed that 60 K_2O kg/ha is the economically feasible rate on Vertisols. The highest benefit to cost ratio of rice was recorded with the application of Sulphur at 30 kg/ha through gypsum [47]. Borax at 3 kg B ha^{-1} produced a higher yield than the levels of 1 and 2 kg B ha^{-1} [39]. Growers should apply Zinc at sowing with recommended rates of 11 kg Zn ha^{-1} preferred for Zn-deficient soils [42].

Table 1. *Treatment setup and description.*

Treatments	Description
Control	without any nutrient application.
Recommended.NP	to use as a comparison with those treatments.
NPKSZnB	to determine the maximum attainable yield with the full dose
PKSZnB (- N)	to determine indigenous N supplying
NKSZnB (-P)	to determine indigenous P supplying
NPSZnB (-K)	to determine indigenous K supplying
NPKZnB (- S)	to determine indigenous S supplying
NPKSB (-Zn)	to determine indigenous Zn
NPKSZn (-B)	to determine indigenous B supplying

2.3. Data Collection

2.3.1. Soil Data

One composite surface (0-20 cm) soil sample was collected from the experimental site before planting. The soil collected before planting were analyzed for soil pH, texture, organic carbon, total N, available P, Available S, exchangeable K, CEC and micronutrients (Zn and B) following the standard procedure.

Soil pH was determined using a pH meter in 1:2.5 soil: H_2O ratio as described by [11]. Soil texture was determined by the Bouyoucos hydrometer method [12]. Soil organic carbon was determined by the Walkley–Black wet digestion method [60]. Total N was determined by the Kjeldahl method [13]. Available soil P was determined using the Olsen $NaHCO_3$ extraction method [35, 43]. Cation exchange capacity was determined by the ammonium acetate extraction method as described by [10]. Exchangeable K was extracted with ammonium acetate solution.

2.3.2. Yield and Yield Component Data of Rice

All agronomical data including plant height, panicle length, number of tillers, fertile and unfertile panicles, thousand seed weight, biomass, straw, yield and other necessary parameters were collected.

2.4. Statistical Analysis

The collected data were subjected to statistical analysis with analysis of variance. Analysis of variance (ANOVA) was performed using SAS version 9.4 statistical software programs. The significant difference between and among treatment means was assessed using the least significant difference (LSD) at 0.05 level of probability [25].

3. Results and Discussion

3.1. Soil Physico-chemical Properties

Soil is a complex matter and comprises minerals, soil organic matter, water, and air. These fractions greatly influence soil texture, structure, and porosity. These properties subsequently affect air and water movement in the soil layers, and thus the soil's ability to function. Therefore, soil physicochemical properties have a great influence on soil quality.

The results of particle size analyses are the proportions of sand, silt and clay were used with the familiar triangular texture diagram to determine the textural class of the soil. The Result indicated that the textural class of experimental site was heavy clay with the textural proportion of clay (76%), silt (20%) and sand (4%) contents.

The pH of the experimental site was slightly acidic with a value of 6.23 which is preferable soil pH range for rice production. The soil was found to be slightly acidic in reaction with a pH of 6.25 as per the rating of [56, 40]. Cation-exchange capacity (CEC) measurements are commonly made as part of the overall assessment of the potential fertility of the soil, and possible response to fertilizer application. The CEC results can sometimes also be used as a rough guide to the types of clay minerals present. The result of soil cation exchange capacity was 57.98 Cmol($_+$) kg^{-1} which ranges very high. Cation exchange capacity (CEC) was high according to the rating of [35, 29].

Table 2. *The Soil physicochemical properties of the experimental site before planting.*

Soil Properties	Unit	Value	Rating	Reference
pH (1:2.5 H_2O)	-	6.23	Slightly acidic	Tekalign, 1991
EC	dS/m	0.098	Very Low	Landon, 1991
CEC	Cmol($_+$) kg^{-1}	57.98	Very high	Landon, 1991
TN	(%)	0.14	Low	Landon, 1991
Avail. P	Ppm	16.36	High	Olsen *et al.* (1954
Ex.K	Cmol($_+$) kg^{-1}	0.562	Medium	FAO, 2006
Zn	ppm	1.244	Medium	Jones 2003
S	ppm	0.512	Low	Landon, 1991
B	ppm	0.71	Medium	Horneck 2011
OC	%	1.78	Very Low	Landon, 1991
Soil Texture				
Sand	%	4		
Silt	%	20		
Clay	%	76		
Soil Textural Class		Heavy Clay		

Electrical conductivity measurements were used as indicaters of the total quantities of soluble salts in soils. The quantities of salts that pass into the solution depend on the relative amounts of soil and water used. Electrical conductivity of the experimental site was salt-free with the value of 0.098 dS/m which was the preferable soil EC range for most crops [35].

Total nitrogen is the sum of total kjeldahl nitrogen (organic and reduced nitrogen) and nitrate-nitrite. Total nitrogen exists organic forms and inorganics (or mineral) forms such as plant available ammonium (NH_4^+) and nitrate (NO_3^-). According to [35], the results of organic carbon and total nitrogen in the soils were 1.78% and 0.141% which are very low and low, respectively. The% ranges in OC were classified as > 20 very high, 10-20 high, 4 – 10 medium, 2 – 4 low and < 2 very low [35]. For soil to be productive, it needs to have OC content in the range of 2% to achieve a good soil structural condition and structural stability [14].

The available phosphorus contents were 16.32 ppm which is in the high range as stated by [43]. The available phosphorus contents were classified as > 10 high, 5-10 medium and < 5 low (Olsen *et al.* 1954). The exchangeable K of the experimental site was medium [21] with the value of 0.562 Cmol ($_+$) kg^{-1}. The percent ranges in exchangeable K were classified as < 0.2 very low, 0.2 - 0.3 low, 0.6 – 1.2 high, > 1.2 very low [21]. Zinc contents of the soil were 1.244 ppm which is classified as medium according to [32], ranging as > 1.5 adequate, 1.0 – 1.5 medium and 0.0 – 0.9 low. The sulfur of the experimental site value was 0.512 ppm which is classified as low range according to [35]. The available boron content of soil 0.71 ppm was recorded in the experimental site. According to [31] ratings the soil boron content < 0.2 ppm is rated as very low, 0.2-0.5 ppm low, 0.5-1 ppm medium, 1- 2 ppm high and > 2 ppm excessive.

3.2. Rice Phenology and Growth Parameters

3.2.1. Effect of Nutrient Omission on Heading Date

Nutrient omission had a significant ($p < 0.01$) effect on the mean of heading date of rice. Heading date were significantly affected by different nutrients that the minimum number of days to heading 91.7, 91.3 and 90.7 was recorded in the application of NPKSZn, NPKSB and NPKSZnB, respectively. On the other hand, the maximum number of days to heading (96.3 and 96) were recorded from PKSZnB (-N) and control respectively. According to [59], days to heading were delayed with absence of N. In line with this nitrogen fertilized plots had faster heading than the plots not treated with nitrogen and phosphorus [24]. This is consistent with the suggestion of [57] that N supply promotes the uptake of other nutrients, enhancing growth and development. A similar result was also reported by [44] who reported that it delays heading date.

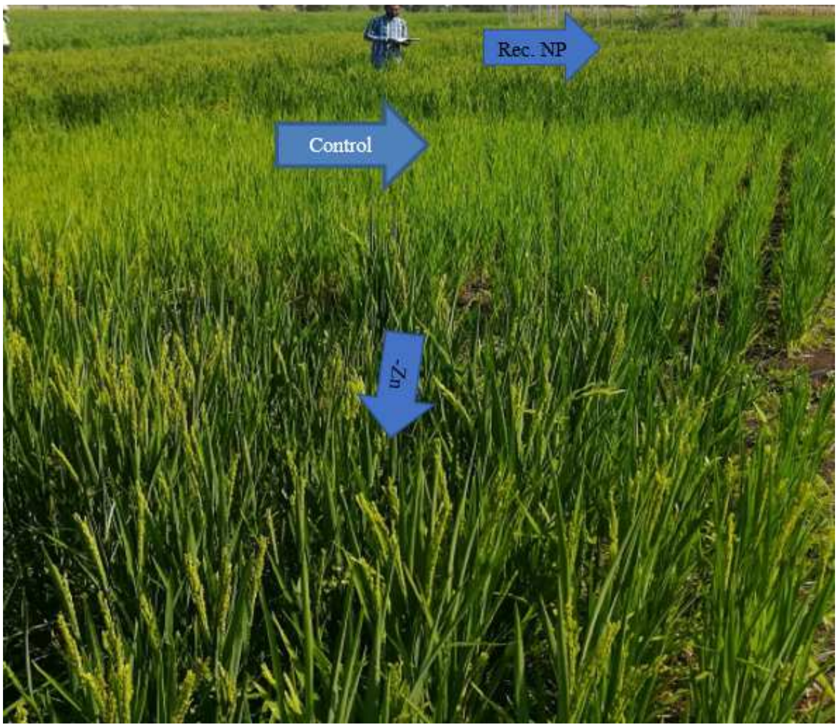

Figure 2. *Heading date of rice NP, control and NPKSB-Zn.*

3.2.2. Effect of Nutrient Omission on the Physiological Maturity Date of Rice

Nutrient omission had a significant ($p < 0.01$) effect on the mean of the physiological maturity date of rice. The minimum number of days to maturity (124.3) was recorded after the application of NPKSZnB. On the other hand, the maximum number of days to maturity (140 and 143) were recorded from the control and omission of N, respectively.

In line with this nitrogen fertilized plots had faster maturity date than the plots not treated by N and P fertilizer [24]. The application of zinc as well decreases the maturity period of rice [26]. The longest days of physiological maturity was recorded from the control [24]. This is consistent with the suggestion of [57] that N supply promotes the uptake of other nutrients, enhancing growth and development.

Figure 3. *Physiological maturity of rice with omission of-S, -N and the control.*

3.2.3. Effect of Nutrient Omission on Plant Height of Rice

Plant height is one of the most important characteristics which indicate nutrients absorption capacity as well as the health of the soil and plant. The combined application of macro and micronutrients significantly increased plant height. The omission of different nutrients had a significant effect on the plant height of rice. The highest plant height of rice (84.67cm) was recorded from the application of without zinc but with no statistical difference with NP, NPKSBZn and NPSKZn. Since N is an important constituent of amino acids, proteins, its application had an effect on plant growth and development through better utilization of photo-synthases and more vegetative growth.

Table 3. *Omission effect on heading date, maturity date, plant height (cm) and panicle length (cm).*

Treatments	Heading date	Maturity date	Plant height (cm)	Panicle length (cm)
Control	96.0a	143.0a	54.47d	14.00e
Rec. NP	92.0bc	130.0b	84.53ab	23.13ab
NPKSZnB (All)	90.7c	124.3c	84.07ab	24.03a
PKSZnB -N	96.3a	140.0a	60.40d	17.07d
NKSZnB -P	93.7b	128.3bc	67.33c	18.53d
NPSZnB -K	92.0bc	130.7b	78.27b	22.00bc
NPKZnB -S	92.0bc	130.7b	71.00c	21.53bc
NPKSB -Zn	91.3c	129.0b	84.67a	20.53c
NPKSZn -B	91.7c	126.7bc	78.60ab	21.63bc
Mean	92.8	131.3	73.7	20.27
LSD (0.05)	1.83	4.1	6.3	1.9
P	**	**	**	**
CV (%)	1.14	1.8	4.9	5.4

Where, LSD=Least Significant Difference at 5% level; CV=Coefficient of Variation. Means in columns followed by the same letters are not significantly different at 5% level of significance. **=significant at $P < 0.01$.

Result showed that significantly higher plant heights of 84.67cm, 84.53cm, and 84.07cm were obtained from plots treated with 138 + 46 + 60 + 30 + 2 kg ha^{-1} NPKSB, 138+46 Rec. NP and 138 + 46 + 60 + 30 +5 + 2 kg ha^{-1} NPKSZnB kg ha^{-1} respectively as compared to other treatments, while the shorter plant heights of 54.47cm and 60.4cm were recorded from the non-fertilized and N-omitted plots respectively. Significantly next to control lower plant height were recorded under the treatments missing N, P and S nutrients respectively. The significant crop response to P application was also reported by [2]. These results conform to the findings of [9]. It is in line with [51] who stated a significant reduction in plant height of upland rice with omission of S.

3.2.4. Effect of Nutrient Omission on Panicle Length of Rice

The analysis of data showed that the treatments produced a significant effect on panicle length. The longest panicle length (24.03 cm) was recorded from the treatment receiving all the nutrients at rate of 138 + 46 + 60 + 30 + 5 + 2 kg ha^{-1} NPKSZnB as compared to other treatments. However, it was not statically different with the recommended NP, while the shorter panicle lengths (14.00cm, 17.07cm and 18.53cm) were recorded from non-fertilized, N-omitted and P omitted plots, respectively. Application of all necessary nutrients resulted in best performances which increase the growth and numbers of the panicle. This showed that nitrogen and phosphorus fertilization had positive roles in increasing the length of the panicle. The results confirm the findings of [4] who reported the lowest length of panicle from N and P omitted treatments. Similar results were also obtained by [34] who confirmed that nitrogen fertilization had a great role in increasing the length of the panicle. Nath D. et al. [41] also reported that N has a great contribution on panicle length.

3.2.5. Effect of Nutrient Omission on Flag Leaf Length of Rice

Rice flag leaf is the main photosynthetic organ and plays a key role in grain yield. Rice leaf represents a photosynthetic organ, in which morphological characters directly affect the structure of the population, light distribution, and energy utilization. Flag leaf length of rice did not differ significantly concerning the application of different treatments in this study.

3.3. Effect of Nutrient Omission on Yield and Yield Component of Rice

3.3.1. Effect of Nutrient Omission on Biomass Yield of Rice

Nutrient omission trials were significantly influenced with biomass yield. The maximum biomass 15750 kg ha^{-1} was recorded from the application of 138 + 46 + 60 + 31 + 5 + 2 kg ha^{-1} NPKSZnB. In contrast, the minimum 722 Kg ha^{-1} and 9500 Kg ha^{-1} biomasses were recorded from non-fertilized and N-omitted plots, respectively. Significant increases in plant height, tillering, panicle length and grain yield from the application of macro and micronutrients have a contribution to increasing biomass yield of upland rice.

The reduction of rice biomass yield because of omission of different plant nutrients, from where all the nutrients applied, were also calculated out. It was noticed that omission of N reduced the biomass yield by 40% and that of P omission caused a biomass yield reduction of 21%. Apart from the omission of N and P, yield reductions due to S and Zn omission were also noticed. It was observed that S omission reduced rice yield with 17%. Percent reduction in rice biomass yields under different nutrient omitted plots as presented in may be put in the order of N > P > S. Large reductions in the biomass yield of rice were observed with the omission of N and P as compared to the other nutrient omissions. Result indicates that N is the most critical nutrient that affects the biomass yield followed by P. [48] also presented that full application of macro and micronutrients records maximum biomass yield of upland rice.

3.3.2. Effect of Nutrient Omission on Grain Yield and Yield Reduction of Rice

Macronutrient and micronutrient combinations significantly increased the grain yield of rice. The omission of all macro and micronutrients from the experimental plot drastically decreased yield than plots fertilized with complete treatments which is NPKSZnB. The rice grain and straw yields were significantly affected with the application of different treatments in Vertisols. The highest grain yield of 7220.7 kg ha^{-1} was obtained from the NPKSZnB application which was statistically similar to that obtained from NPKSB (-Zn), NPKSZn (-B) and NPSZnB (-K) respectively. In contrast, the lowest grain yield of rice 2229.7 kg ha^{-1} was obtained from the control followed by PKSZnB (-N), NKSZnB (-P) all the other fertilization treatments performed in between.

Kaizzi KC *et al.* [33] also reported that the application of Zn, S and B together with nitrogen, phosphorus and potassium fertilizer (NPK) increased paddy yield by 19% above the NPK yield. Our result is also in agreement with the finding of [55] who reported that omission of major N, P and S nutrients individually from the complete treatment (NPKSZnB) significantly decreased rice yield and was significantly higher than the control. Furthermore, the finding of [17] showed that the highest significant grain yield was recorded when rice received primary secondary and micronutrients (NPKSZnB).

The reduction in rice grain yield because of omission of different plant nutrients, from treatment where all the nutrients applied, was also calculated. Large reductions in the grain yield of rice were observed with the omission of N and P as compared to the other nutrient omission treatments. The yield reductions were more pronounced with N omission. Result indicates that N is the most critical nutrient that affects the grain yield considerably in all the soils followed by P. Omission of N reduced the grain yield by 46%, P omission caused a yield reduction of 17% and sulfur has yield penality of with 11%. This indicates that N was the most yield-limiting nutrients in soils followed by P. The percent reductions in rice yield under different omitted plots were in the order of N>P>S.

This result was also in agreement with the findings of [50] who reported that the long-term omission of major nutrients individually from the complete treatment (NPKSZn) significantly decreased rice yield. Furthermore, the finding of [17] showed that the highest significant grain yield was recorded when rice received primary, secondary and micronutrients (NPKSBZn) and yield decreased by 19.4- 27% due to omission of NPK or PK and by 17.1- 32.6% in absence of S and Zn both as combined and individually. The yield reductions were more pronounced with N and P omission with a magnitude of 43.2% and 41.7%, respectively [61].

Table 4. *Effect of nutrient omission on biomass yield (BY), grain yield (GY), straw yield (SY) and yield reduction of rice.*

Treatments	BY kg ha^{-1}	SY kg ha^{-1}	GY kg ha^{-1}	BY reduction (%)	SY reduction (%)	GY reduction (%)
Control	5555.6f	3361.1d	2229.7e	65	61	69
Rec. NP	13555.6bcd	7333.3ab	6225.7bc	14	15	14
NPKSZnB	15750.0a	8666.7a	7220.7a	-	-	-
PKSZnB -N	9500.0e	5666.7c	3898.8d	40	35	46
NKSZnB -P	12444.4d	6583.3bc	5959.2c	21	24	17
NPSZnB -K	14166.7bc	7750.0ab	6568.6abc	10	11	9
NPKZnB -S	13000.0cd	6694.4bc	6424.7bc	17	23	11
NPKSB -Zn	14166.7bc	7250.0ab	7003.6ab	10	16	3
NPKSZn -B	14277.8b	7527.8ab	6810.3ab	9	13	6
Mean	12490.74	6759.3	5815.7			
LSD (0.05)	1275.5	1500.4	782.07			
P	**	**	**			
CV (%)	15.9	12.8	7.8			

Where, LSD=Least Significant Difference at 5% level; CV=Coefficient of Variation. Means in columns followed by the same letters are not significantly different at 5% level of significance. **=significant at $P < 0.01$.

3.3.3. Effect of Nutrient Omission on Straw Yields

Significant response in straw yield was observed due to the nutrient omission treatments. The highest straw yield was recorded with application of full of NPKSZnB that was 8667 kg ha^{-1} but statically no difference with the application of NPSZnB, NPKSB and recommended NP. The lowest straw yield of 3361 kg ha^{-1} was recorded from control followed by the omission of N, P and S. The omission of N, P and S resulted in significantly lower straw yields. Omission of N reduced the straw yield by 35%, while P omission caused a straw yield reduction of 24% and omission of S reduced straw yield by 23%.

The percent reductions in rice straw yield under different omitted plots were in order of N>P>S. Omission of N, P and S caused significant reductions in straw yields of rice in comparison to the treatment receiving all the nutrients. In line with the current result, the finding of [9] showed that the mean straw yields of rice were significantly affected by different nutrient omission treatments. Omission of N, P and S significantly reduced the straw yield as compared to treatment which received all the nutrients. Singh SP et al. [52] also reported a decrease in the straw yield of rice with the omission of N, P and S.

3.3.4. Effect of Nutrient Omission on Harvest Index

Harvest index is defined as the economical yield (grain yield) of the crop expressed as a decimal fraction of the total biological yield, but the meant total aboveground dry matter production. The harvest index of rice did not differ significantly concerning the application of different treatments in this study.

3.3.5. Effect of Nutrient Omission on Thousand-Grain Weight

Thousand-grain weight is an important character that determines the yield per hectare. Analysis of variance indicated that thousand grains weight was significantly affected by the nutrient omission treatments. The highest thousand-grain weight of 27.0 g was recorded at a nutrient combination of NPKSBZn when the plot received all nutrients, followed by NPKSZn and NPKSB. In contrast, the lower values of 22 and 21.67 gm were recorded from non-fertilized and N-omitted plots followed by P and S omitted plots, respectively. This showed that nitrogen fertilization had great role in increasing the weight of grain. The combined application of primary secondary and micronutrients resulted in the highest thousand-grain weight, which was significantly higher than the control and recommended NP.

However, the omission of N and P plots had reduced the test weight as compared to those of all other treatments. It is universal truth that N and P are the most important major nutrients required for tillering, root growth and they affect ultimately filled grains and test weight. The reduced effective tillers and thousand-grain weight were recorded in the present study caused due to omission of N and P treatments.

The present result is in line with the finding of [22] (who observed that NPKZn combinations significantly increased 1000 grains weight of rice over NPK. Moreover, a significant increase in thousand grain weight of rice by 13.6% through S incorporation in NPKBZn combination was reported by [17]. An increase in thousand grains weight of rice upon Zn fertilization might also be due to its involvement in the carbonic anhydrase activity and more carbohydrate accumulation in the seeds [54].

3.3.6. Effect of Nutrient Omission on the Total Number of Tillers

Applying secondary and micronutrients in combination with primary macronutrients significantly ($p \leq 0.01$) affected the number of total tillers. The highest total number of tiller was recorded at NPKSZnB from which all nutrients were applied which was statically non-significant with recommended NP and NPKSB treatments. The lowest value of this parameter (4983333 ha^{-1}) was obtained from the control followed by omission of N, P and S. In contrast, Control and treatment missing N, P and S were observed significantly lower numbers of tillers of rice as compared to treatment with application of all nutrients. N plays a key role in tillers bearing of rice followed by P and S. Many researchers have also concluded the importance of N and P in tillering of the crops.

The current result is in line with the finding of [9] who observed that a significantly higher number of tillers at the treatment that received all the nutrients. However, N, P and S nutrients omission treatments showed significantly a smaller number of tillers in comparison to treatment that receives all nutrients. Omission of N and P reduced the total number of tillers as these two nutrients have a major role in tillers of rice. Similarly, [23] recorded maximum total number of tillers from the application of NPKSZn and a minimum from Control.

3.3.7. Effect of Nutrient Omission on Number of Effective Tillers

The number of effective tillers was significantly ($p \leq 0.01$) influenced by the nutrient omission treatments. The grain yield of cereals is highly dependent upon the number of effective tillers. The highest numbers of effective tillers were observed in NPKSZnB that received all nutrients that were statistically similar to that obtained from NPKSB and Rec. NP respectively.

Omission of N, P and S nutrients significantly reduced the effective tillers of rice, as compared to treatment that received all nutrients. A similar result was reported by [23] that the maximum total number of tillers and number of effective tillers was found from the application of NPKSCaZn and minimum total and effective tillers were found from Control. Rana KW et al. [48] also reported increased effective tiller production with NPKSZn compared to the recommended NP and NPK. Similarly [45] mentioned that nutrient omission trial had a significant effect on the number of effective tillers.

3.3.8. Effect of Nutrient Omission on Number of Non-Effective Tillers

The number of non-effective tillers was significantly ($p \leq 0.01$) responding to nutrient omission treatments. The highest total number of non-effective tillers (350000 ha^{-1}) was recorded at the control plots and was non-significantly different from omission of N. The lowest value of this parameter (50000 ha^{-1}) was obtained from the full application of NPKSZnB, which was statically non-significant with NP and NKSZnB treatments. However, omission of N, omission of P and the control plots had the maximum number of the non-effective tillers as compared to those of all other treatments. It is universal truth that N is the most yield limiting nutrients require for tillering and growth purposes.

Table 5. Nutrient omission effect on thousand grains weight (TGW), total number of tillers (TNT), number of effective tillers (NET), and number of non-effective tillers (NNT).

Treatments	TGW	TNT	NET	NNT
Control	21.67f	4983333c	4650000d	350000a
Rec. NP	24.67cd	5550000ab	5433333ab	116667de
NPKSZnB (All)	27.00a	5900000a	5850000a	50000e
PKSZnB -N	22.00f	5033333bc	4766667cd	266667ab
NKSZnB -P	23.67e	5316667bc	5083333bcd	233333bc
NPSZnB -K	25.00c	5383333abc	5266667bc	100000de
NPKZnB -S	24.00de	5066667bc	4933333bcd	133333de
NPKSB -Zn	26.00b	5583333ab	5466667ab	150000cd
NPKSZn -B	25.33bc	5466667abc	5300000bc	166667cd
Mean	24.4	5364815	5194444	174074
LSD (0.05)	0.95	553844	548686	88133
Sig.level	**	*	**	**
CV (%)	12.3	6	6.1	19.2

Where, LSD=Least Significant Difference at 5% level; CV=Coefficient of Variation. Means in columns followed by the same letters are not significantly different at 5% level of significance. **=significant at $P < 0.01$ and *=significant at $P < 0.05$.

3.4. Correlation Among Growth, Yield, and Yield Component of Rice

Yield is a dependable complex entity associated with several component characters as a result of the interaction of several contributing factors that may be related or unrelated [8]. The association of different component characters among themselves and with yield is important for devising a selection for yield. The correlations of the investigated characters are shown in. Yield is a cumulative interaction effect of all the dependent and independent variables in the experiment.

The data showed that there was a significant ($P < 0.01$) positive and linear relationship among most of the yield and yield components of rice but negative with non effective tillers. Accordingly, grain yield was significantly and positively correlated with biomass yield of r=0.94**, plant height of r=0.84**, total tiller of r=0.52**, effective tiller of r=0.63**, panicle length r=0.84**, thousand-seed weight r=0.88** and harvest index r=0.70** at $P < 0.01$. The positive direct effect of plant height on grain yield is supported by [7] Similarly, [46] reported positive contribution of effective tillers and panicles would likely be effective in improving the grain yield. The important roles of productive tiller number and grain number panicle have been reported by many workers [62]. Moreover, a high and positive association of grain yield with tiller number was mainly attributable to indirect effect with productive tiller number. Panicle length, dry matter yield, harvest index and 1000 grain weight had significant positive associations with grain yield [3].

Plant height showed a highly significant positive relationship with effective panicle per plant through the application of macro and micronutrients. Suprio C. et al. [55] found effective grains per panicle revealed a significant positive relationship with plant height. It indicated that increasing plant height caused to increase in effective tiller and panicles per plant. The presence of significant and positive correlation among yield and other variables indicates the improvements of growth parameters of rice through the combined application of macronutrients with micronutrients, which ultimately increased yield in the study site. This implies that increased growth parameters and yield components might contribute to rice yield increment.

Table 6. *Correlation coefficients between growth and yield component of rice.*

Variable	PH	PL	TT	ET	NET	BY	GY	HI	TGW
PH	1	0.80**	0.60**	0.70**	-0.75**	0.86**	0.84**	0.44*	0.87**
PL		1	0.57**	0.68**	-0.86**	0.86**	0.84**	0.42*	0.78**
TT			1	0.98**	-0.50**	0.57**	0.52**	0.16ns	0.66**
ET				1	-0.66**	0.66**	0.63**	0.28 ns	0.74**
NET					1	-0.77**	-0.815**	-0.57**	-0.724**
BY						1	0.94**	0.44*	0.88**
GY							1	0.70**	0.86**
HI								1	0.46*
TGW									1

Where, **=significant at $P < 0.01$, *=significant at $P < 0.05$, ns=non-significant. PH=Plant Height, PL=Panicle Length, TT=Total Tiller, ET=Effective Tiller, NET=None Effective Tiller, TGW=Thousand Grain Weight, GY=Grain Yield BY=Biomass Yield; HI=Harvest Index.

4. Conclusion

Soil nutrient deficiencies are among the major yield limiting factors of the rice production. Balanced nutrient supply based on limiting nutrients for cereal crops improved yield and nutrient uptake of rice. The growth, development, and production of rice depend on the availability of macro and micro nutrients in the soil.

Depending on the response of indigenous soil nutrients of N, P, K, S, B and Zn, it can be concluded that nitrogen and phosphorus are the most limiting factors to increase grain yield in the Vertisols of Fogera district followed by sulfur. Omission of one macro nutrient has an impact on growth and yield parameters of rice. However, the effect of other micronutrients was low when comparing to those of N and P. It is concluded that the omission of N, P and S have the highest yield limiting nutrients in Vertisols of fogera district.

References

[1] AGRA (Alliance for a Green Revolution in Africa). 2007. AGRA at work. Retrieved 13th March, from *www.agra-alliance.org/work.*

[2] Ahmed S., Elahi N., Khan R., Faridullah J. and Din N. 2010. Wheat response to phosphorus under climatic conditions of Juglote, Pakistan Sarhad. *Journal of Agri*culture, 26: 229–33.

[3] Aminul I, Jatish, Sirajul K, and Salmapervin M. Abu Saleque. 2015. Effects of potassium fertilization on growth and yield of wetland rice in grey terrace soils of Bangladesh. Research on Crop Ecophysiology Vol. 10/2, Issue 2, Pages: 64–82.

[4] Aryal K., Adhikary K. R., Gairhe J. J, Tripathi B. P and Kandel B. P. 2019. Assessment of native nutrient supplying capacity of soil for site specific nutrient management to increase early rice (*Oryza sativa* L.) productivity in Morang, Nepal. Crop Res. 54 (1 & 2): 1-7 Printed in India.

[5] Ashenafi Ali, Abayneh Esayas and Sheleme Beyene. 2010. Characterizing soils of delbo wegene watershed, wolaita zone, southern Ethiopia for planning appropriate land management. Journal of Soil Science and Environment Management 1 (8): 184-199.

[6] Ayalew Abay, Boke Shiferaw. and Haile Wassie. 2010. Review of soil and water technologies: case of southern nations nationalities and peoples regional state.

[7] Babu VR, Shreya K, Dangi KS, Usharani G. and Shankar AS. 2012. Correlation and path analysis studies in popular rice hybrids of India. International Journal of Scientific and Research Publicaton; 2 (3).

[8] Balasubramanian V., Sie M., Hijmans R. and Otsuka K. 2007. Increasing rice production in sub-Saharan Africa: challenges and opportunities. Advances in Agronomy, 94, pp. 55-133.

[9] Bhupendra K, Sharma G., Mishra V., Chandrakar T., Pradhan A., Singh D. and Thakur K. 2018. Assessment of yield limiting nutrients through response of rice (*oryza sativa l.*) to nutrient omission in inceptisols of Bastar District of Chhattisgarh State in India. Int. J. Curr. Microbiol. App. Sci. 7 (08): 3972-3980.

[10] Black, C. A. 1965a. *Determination of exchangeable Ca, Mg, K, Mn and effective cation exchange capacity in soil*. In C. A. Black (Ed.), Methods of Soil Analysis (Vol. 9). USA: American Society of Agronomy.

[11] Black, C. A. 1965b. pH 1:1 water: Soil ratio. In C. A. Black (Ed.), Methods of soil analysis (Vol. 9). USA: American Society of Agronomy.

[12] Bouyoucos, G. J. 1951. A recalibration of the hydrometer method for making mechanical analysis of soils. Agronomy Journal, 43, 434 438. doi: 10.2134/agronj1951.00021962004300090005x.

[13] Bremner, J. M., & Mulvancy, G. S. 1982. Nitrogen total. In A. L. Page, R. H. Miller, & D. R. Keeney. *Methods of soil analysis*: part 2 (Eds.) Keeney, Chemical and microbiological properties (pp. 595–624). WI, USA: ASA, Madison.

[14] Charman P. E. V. and Roper M. M. 2007. *Soil organic matter*. In: Soil properties and their management'. 3rd edition 276-285 pp.

[15] CSA (Central Statistical Agency). 2018. Agricultural sample survey 2017/2018: Report on area and production of major crops, Ethiopia (vol. 586, pp. 53). Addis Ababa: Central Statistical Agency. Statistical Bulletin.

[16] CSA (Central Statistical Agency). 2019. Report on area and production of major crops (private peasant holdings, meher season). The federal democratic republic of Ethiopia central statistical agency agricultural sample survey Volume I. Statistical bulletin 589, Addis Ababa, Ethiopia.

[17] Dash A. K., Singh H. K., Mahakud T., Pradhan K. C. and Jena D. 2015. Interaction effect of nitrogen, phosphorus, potassium with sulphur, boron and zinc on yield and nutrient uptake by rice under rice - rice cropping system in inceptisol of Coastal Odisha. Int. Res. J. Agric. Sci. Soil Sci. 5 (1): 14-21.

[18] Dawit Alemu, Tesfaye Agajie, Abebaw Assaye, Degu Addis, Tilahun Tadesse and Thompson J. 2018. A Historical Analysis of Rice Commercialization in Ethiopia: The Case of the Fogera Plain APRA Working Paper 18, Future Agricultures Consortium.

[19] EthioSIS (Ethiopian Soils Information System). 2016. Soil fertility status and fertilizer recommendation Atlas of Amhara National Regional State, Agricultural Transformation Agency.

[20] Fahad S., Adnan M., Noor M., Arif M., Alam M., Khan I. A., Ullah H., Wahid F., Mian I. A., Jamal Y., Basir A., Hassan S., Saud S., Riaz M. A., Wu C., Khan M. A. and Wang D. 2019. *Major constraints for global rice production.* Elsevier, Cambridge, UK, pp. 1-22.

[21] FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome, Italy.

[22] Fayez A., and Khan H. 2016. Effect of different fertilizer treatments on the performance of some local rice varieties under system of rice intensification and conventional management practices at district Swat. Pure and Applied Biology 5 (1): 37-47.

[23] Ferdous A, Syeda M, Noor HM, Hoque M, Hossain Md. and Hasan KA. 2018. Enhancing rice yield in acidic soil through liming and fertilizer management. Journal of Bangladesh Agricultural 16 (3): 357-365.

[24] Getahun Dereje, Dereje Alemu, Tigist Adisu and Bekele Anbessa. 2018. Response of yield and yield components of tef [*Eragrostis Tef (Zucc.) Trotter*] to optimum rates of nitrogen and phosphorus fertilizer rate application in Assosa Zone, Benishangul Gumuz Region. Ethiop. J. Agric. Sci. 28 (1) 81-94.

[25] Gomez K. A. and Gomez A. A. 1984. Statistical procedure for agricultural research, 2nd ed. John Willey and Sons, New York.

[26] Hafeez B., Khanif Y. M. and Saleem M. 2013. Role of zinc in plant nutrition. A Review. American Journal of Experimental Agriculture 3 (2): 374-391.

[27] Hagos Brhane, Tekalign Mamo and Kassa Teka. 2017. Optimum potassium fertilization level for growth, yield and nutrient uptake of wheat in Vertisols of Northern Ethiopia. Cogent food and agriculture, soil & crop sciences research article.

[28] Hairmansis A., B. Kustianto, Supartopo and Suwarno. 2010. Correlation analysis of agronomic characters and grain yield of rice for tidal swamp areas. *Indonesian Journal of Agricultural Science* 11 (1): 11-15.

[29] Hazelton, P. and B. Murphy. 2007. Interpreting soil test results: What do all the numbers mean? 2nd Edition. CSIRO Publishing. 152p.

[30] Henao J and Baanante C. 2006. Agricultural production and soil nutrient mining in Africa: Implication for resource conservation and policy development. IFDC Tech. Bull. International Fertilizer Development Center. Muscle Shoals, Al. USA.

[31] Horneck D. A., Sullivan D. M., Owen J. S and Hart J. M. 2011. Soil test interpretation guide.

[32] Jones, J. B. 2003. Agronomic Handbook: Management of Crops, Soils, and Their Fertility. CRC Press LLC, Boca Raton, Florida, USA. 482p.

[33] Kaizzi KC, Nansamba A, Kabanyoro R, Lammo J. and Rware H. 2018. Upland rice response to fertilizer in three agroecological zones of Uganda. African Journal of Plant Science 12 (3): 65-72.

[34] Karki S., Sharma N., Poudel, G., Bhusal S., Simkhada B. R., Regmi, A. B. and Poudel, S. 2018. Growth parameters and yield attributes of rice as influenced by different combinations of nitrogen sources. World J. Agric. Res. 6: 58-64.

[35] Landon J. R. 1991. *Booker tropical soil manual*: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. pp. 474.

[36] Mishra, V. N., Patil S. K., Das R. O., Shrivastava L. K., Samadhiya V. K. and Sengar S. S. 2007. Site-specific nutrient management for maximum yield of rice in Vertisol and Inceptisols of Chhattisgarh. Raipur, India. pp. 136.

[37] Molla Haddis and Sofonyas Dargie. 2018. Response of Upland Rice to Nitrogen and Phosphorus Fertilization on Vertisols of Tigray, Ethiopia. Asian Research Journal of Agriculture, 10 (4): 1-7.

[38] Morris CE. and Sands DC. 2006. The breeder's dilemma yield or nutrition? Nature Biotechnology 24: 1078–1080.

[39] Muhammad Saleem, Mohd Khanif Vusop, Fauziah Ishak, Abd Wahid Samsuri and Babar hafeez. 2011. Boron fertilizers borax and colemanite application on rice and their residual effect on the following crop cycle. Soil Science and Plant Nutrition, 57, 403-410.

[40] Murphy, H. F. 1968. A report on fertility status and other data on some soils of Ethiopia. Collage of Agriculture HSIU. Experimental Station Bulletin No. 44, Collage of Agriculture, Alemaya, Ethiopia: 551p.

[41] Nath D, Haque F, Islam MSh, Saleque MA. 2012. Farmers participatory site specific nutrient management in Gangas Tidal floodplains soil for high yielding boro rice. International Conference on Environment, Agriculture and Food Science.

[42] Nathan A. Slaton, Richard J. Norman, and Charles E. Wilson. 2005. Effect of zinc source and application time on zinc uptake and grain yield of flood-irrigated rice. American Society of Agronomy. 97: 272–278.

[43] Olsen S. R., Cole, C. V., Watanable, F. S., & Dean, L. A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate Washington, DC., USA: U.S. Government Printing Office. pp. 1–19.

[44] Ottman MJ. 2009. Response of wheat and barley varieties to phosphorus fertilizer. University of Arizona, USA.

[45] Pedda BP, Shanti M, Rajendra PB, Minhas PS. 2007. Effect of zinc on rice in rice black gram cropping system in saline soils. Andhra Agriculture Journal 54 (2): 47-50.

[46] Qamar Zia-Ul, Ashraf A. A. C., M. U. H. A. M. M. A. D., Rashid M. U. H. A. M. M. A. D. and Tahir, G. R. 2005. Association analysis of some yield influencing traits in aromatic and non-aromatic rice. *Pakistan Journal of Botany*, *37* (3), pp. 613-627.

[47] Ram D, Khan 1 O A, Raina S K, Dar M A, Malik M A and Wan J A. 2018. Effect of different sources of sulphur on yield and quality of cauliflower under temperate conditions of Kashmir. *Indian Journal of Agricultural Sciences* 88 (2): 284-8.

[48] Rana KW and Kashif RS. 2014. Effect of different zinc sources and methods of application on rice yield and nutrients concentration in rice grain and straw. *Journal of Environmental and Agricultural Sciences*. ISSN: 2313-8629.1: 9.

[49] Sahu, N., Mishra, V. N., Srivastava, L. K., & Jatav, G. 2017. Crop response based assessment of limiting nutrients using site specific nutrient management for yield maximization in vertisols of Bemetara District of Chhattisgarh, India. 6 (6), 1784–1791.

[50] Shah AL, Haque MM and Zaman SK. 2008. Implications of long-term missing element trial: efficacy of potassium fertilizer to increase rice yield. Bangladesh Rice Journal 14: 55.

[51] Singh K. A. Bhushan M., Meena M. K. & Upadhyaya A. 2012. Effect of sulphur and zinc on rice performance and nutrient dynamics in plants and soil of indo gangetic plains. *Journal of Agricultural Science*; Vol. 4, No. 11.

[52] Singh SP, KK Paikra and Chanchala Rani Patel. 2020. Nutrient omission: A plant nutrient deficiencies assessment technology of rice in Inceptisols. *Journal of Pharmacognosy and Phytochemistry*; 9 (1): 27-30.

[53] Subedi P, Shrawan KS, Santosh Ma, and Dil RY. 2019. Effects of need-based nitrogen management and varieties on growth and yield of dry direct seeded rice. *Pertanika Journal of Trop Agric. Sc.* 42 (2): 453-466.

[54] Sudha S and Stalin P. 2015. Effect of zinc on yield, quality and grain zinc content of rice genotypes. International Journal of Farm Sciences 5 (3): 17-27.

[55] Suprio, C., Pradip K. D., Biswajit G., Kalyan K. S. and Bhubaneswar B. 2010. Quantitative genetic analysis for yield and yield component in rice. *Not Sci. Biol*, *2* (1), pp. 117-120.

[56] Tekalign Mamo. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. Center for Africa, Addis Ababa, Ethiopia.

[57] Temesgen Kebede. 2012. Response of tef [*Eragrostis Tef (Zucc.) Trotter*] cultivars to nitrogen and phosphorus fertilizer rates at Menzkeya District, North Shewa, Ethiopia. M.Sc. Thesis.

[58] Tilahun Tadesse, Abebaw Assaye and Dawit Alemu. 2018. Ethiopia: Enriching Livelihoodswith Rice Research. https://www.future-agricultures.org/blog/ethiopia-enrichinglivelihoods-with-rice, retrieved on June 18, 2020.

[59] Wakene Tigre, Walelign Worku and Wassie Haile. 2014. Effects of nitrogen and phosphorus fertilizer levels on growth and development of barley at Bore District, Southern Oromia, Ethiopia. American Journal of Life Sciences, 2 (5), 260–266.

[60] Walkley A. and Black I. A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, *37* (1), pp. 29-38.

[61] Yushma S, Gajendra S and Madan K. 2018. Site specific nutrient management for crop yield maximization using two soil types of Bilaspur District of C. G. on grain and straw yield. Journal of Pharmacognosy and Phytochemistry; 7 (1), pp. 8-10.

[62] Zahid, M. A., M. Akhtar, M. Sabir, Z. Manzoor, and T. H. Awan. 2006. Correlation and path analysis studies of yield and economic traits in Basmati rice (*Oryza sativa l.*). Asian J. Plant Sci. 5: 643–645.