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Original Paper

Growth and Yield Response of Turmeric (*Curcuma Longa L.*) to NPSB and Urea fertilizer in Yeki District, Southwest Ethiopia

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***Abstract*— Besides its significance in human nutrition and being cash crop in Ethiopia, turmeric is produced far below the countries potential, due to the depletion of major soil nutrients. This crop requires adequate fertilizer application. The purpose of this field experiment was to evaluate the effectiveness of the blended NPSB fertilizer indicated by the Ethiopian soil information system (EthioSIS) soil fertility map for turmeric production in the study area. The treatments were laid out in a randomized complete block design with three replications. The treatments included two controls (control and recommended NP fertilizer) and nine combinations of NPSB fertilizer (100, 150, and 200 kg ha-1) and, N fertilizer (Urea) (150, 200, and 250 kg ha-1) arranged in RCBD with three replications. The showed that the applying increased rate of blended NPSB along with urea did not brought significant improvement) in growth and yields components of turmeric over existing treatment groups compared to negative control. The highest fresh rhizome yield (41.52 t ha-1) was obtained from the application of 100 NPSB with 250 urea. Since the blended fertilizer, non-significantly increased turmeric yield, farmers in the study area and similar agro ecologies could use the previously recommended NP fertilizer for turmeric production.**

Keywords*— Blended fertilizer, fresh yield, mother rhizome, primary finger, turmeric

I. INTRODUCTION (*HEADING 1*)

Turmeric (Curcuma long L) was domesticated in Southeast Asia. This spice is now commonly available throughout the tropical region. It is used directly as a spice or coloring agent in ground form, as well as for the manufacture of solvent extracted oleoresin [1]. In Ethiopia, turmeric is known as ‘Ird’ and was introduced in the 1970s. In the southwest of Ethiopia, this crop is mostly farmed as a cash crop. It is one of our country's exported spices and is mostly appreciated in the textile sector for its cured dry rhizome [2]. It has therapeutic significance in pharmaceuticals, but it also has a pleasant aroma and flavor, hence, it is classified as a spice.

Soil nutrient management remains the most challenging aspect of crop production. Ethiopian farmers, across different agroecologies, utilized comparable types and quantities of fertilizer. This blanket fertilizer recommendation does not consider the soil's fertility status or the nutrient requirements of the plant. To tackle this problems, the Ethiopian soil information system (EthioSIS) utilizes a precise soil map that offers up-to-date soil fertility data. The findings revealed that, in addition to nitrogen and phosphorus, sulfur, boron, and zinc deficiencies are common in Ethiopian soils, with some soils also deficient in potassium, copper, manganese, and iron [3-6], all of which could limit crop productivity despite continued use of N and P fertilizers as recommended.

In Yeki district southwest Ethiopia fertilizer formulation like NPS, NPSB, NPSBCa and NPSCa where identified [5]. The EthioSIS map recommended different types of fertilizer formulation for each location but the rate of this fertilizer not studied so far for this very important cash crop in the specific location. To address these issues and boost turmeric production and productivity, a novel fertilizer was studied in Yeki district with the following objectives.

- To determine optimum NPSB fertilizer rate for turmeric production in Southwest Ethiopia.
- To evaluate comparative advantage of using blended fertilizer over recommended NP rate for better growth and yield of turmeric in yeki district, southwest Ethiopia.

II. MATERIALS AND METHODS

A. *Description of the Study Area*

The experiment was conducted at Bechi kebele farmer’s field during 2020 and at Teppi Agricultural Research Center (TARC) experimental site during 2021 in the Yeki district of Southwest Ethiopia regional state (Figure 1). Bechi is located in South West Ethiopia people regional state at an altitude of 1188 m with a 7° 13'547" N and 35o 33'19" E while TARC is found at 07° 11′ 05″ N, 035° 25′ 08″ E with an altitude of 1200m above sea level, at a distance of 611 kilometers to southwest of Addis Ababa. The average annual rainfall in the area is 1559 mm, with a hot to moderate humid lowland agro-ecology with maximum and minimum temperatures of 29.7 °C and 15.5 °C, respectively, with the area dominated by Nitisols [7].

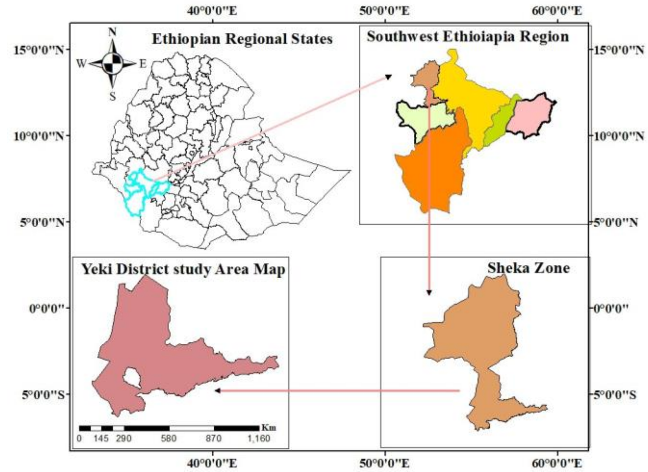

Fig. 1. Study area map.

B. *Experimental Materials and Design*

The experiment took place during the main season (mid-April–December) of the 2020 and 2021 cropping years. Treatments were arranged in randomized complete block design in three replications. The trial consists of 11 treatments, with two controls: fertilizer (negative) and recommended NP (positive). Treatments combined as three rates of NPSB (100, 150, and 200 kg ha-1) with three urea rates (150, 200, and 250 kg ha-1) as indicated in Table 1. Turmeric Variety Dame was used as a test crop, which is released for agro-ecologies having lowland and mid altitudes. The nitrogen and phosphorus fertilizer for the positive control were obtained from urea, and triple superphosphate (TSP), respectively. Phosphorus fertilizer from TSP and NPSB fertilizer was applied at planting time, whereas urea was applied in three splits: 1/4th at early emergency, ½ at full emergency (6–8 leaf stage), and 1/4th at tillering. Turmeric was planted with a spacing of 30 cm by 15 cm between rows and plants within rows, respectively. All agronomic practices, such as weeding, pest management, and earthing up, were equally treated regardless of treatment types

TABLE I. TREATMENT DESCRIPTIONS

Treatment codes	Treatment description (kg ha^{-1})
T1	Control (0)
T2	RNP (69N +23 P_2O_5)
T3	100 NPSB + 150 urea
T4	150 NPSB + 150 urea
T5	200 NPSB + 150 urea
T6	100 NPSB + 200 urea
T7	150 NPSB + 200 urea
T8	200 NPSB +200 urea
T9	100 NPSB + 250 urea
T10	150 NPSB + 250 urea
T11	200 NPSB + 250 urea

RNP: recommended rate of nitrogen &phosphorus

C. *Data Collection and Measurements*

Soil sample was collected from the plough depth 0-20cm from different spot and then composited to one sample before planting and analyzed for physicochemical parameters. Soil texture was determined by Bouyoucos hydrometer method [8], soil reaction (pH) in a 1:2.5 soil water suspension by a glass electrode pH meter [9], total nitrogen by modified Kjeldahl method [10], available phosphorus by Olsen method [11], available potassium by ammonium acetate extracts flame photometer [12], available sulfur and boron by Mehlich-3 method [13], cation exchangeable capacity (CEC) by ammonium acetate method [14], organic carbon by Walkley and Black method [15].(Table 2)

TABLE II. SOIL PHYSICOCHEMICAL PROPERTIES OF EXPERIMENTAL SITES

Soil properties		**Bechi**	**Tepi**
Physical properties	Clay (%)	58	54
	Silt (%)	24	28
	Sand (%)	18	18
	Texture class	clay	clay
Chemical properties	Soil pH	6.09	5.7
	Total Nitrogen (%TN)	0.34	0.27
	Olsen P (mg kg^{-1})	20.	10.1
	av. K (ppm)	982	556
	av. S (ppm)	14.1	12
	av. B (ppm)	1.79	0.9
	Zn (ppm)	16.8	11.6
	CEC cmol (+)/kg	31.7	27
	OC (%)	3.43	2.6

WHERE CEC-IS CATION EXCHANGE CAPACITY, OC-REPRESENTS ORGANIC CARBON

At maturity stage, ten plants were randomly sampled from net harvestable plot. Plant height (cm) was measured from soil base up to the longest leaf tip and the mean was taken. Number of tiller and leaf per plant was counted from the same plant sampled for plant height and the mean of ten observation recorded for analysis. During harvest, five plants were selected from net harvestable area and number of mother rhizome, primary finger and secondary finger counted while their respective weight (gm plant^{-1}) was weighed on sensitive balance (0.001g). For fresh rhizome yield, the net harvestable area was harvested and weighed (kg/plot) after soil is carefully removed from rhizome. The value was then converted in to Mg ha-1 based on national standards [16].

D. *Experimental Materials and Design*

The analysis of variance was carried out using the one-way ANOVA procedure provided by R software 4.2.3. The assumption of ANOVA was first checked before data analysis.

LeveneTest package for homogeneity of variance and Shapiro test for normality were performed from the Car R package [17]. Data for each year was analyzed separately across cropping seasons and combined analysis was also made separately to determine overall effects. Means were separated using the LSD procedure ($p < 0.05$) whenever there was a significant difference among treatments.

III. Results And Discussion

A. *Effect of NPSB fertilizer application on yield and yield components of Turmeric*

TABLE III. Effect of NPSB and urea fertilizer on yield component of Turmeric in Bechi site during 2020

Treatments (kg ha^{-1})	PH	Tiller plant^{-1}	Leaf plant^{-1}	MRPP	PFPP	SFPP	MRPPwt	PFPPwt	SFPPwt
Control	67.1^{bc}	3.7	15.1^{c}	2.6^{c}	7.4^{c}	18.7^{b}	44.7^{d}	176	51.3^{d}
RNP (69N +23 P_2O_5)	76.9^{a}	5.5	21^{ab}	3.7^{ab}	14.5^{a}	24.5^{ab}	162^{ab}	211.3	123.7^{abc}
100 NPSB + 150 urea	71.3^{ab}	5.7	23.3^{ab}	2.8^{bc}	10.4^{b}	20.9^{ab}	143.3^{b}	224.7	109.7^{c}
150 NPSB + 150 urea	63.73^{c}	4.8	20.5^{ab}	3.5^{abc}	10.7^{b}	21.7^{ab}	154.7^{ab}	225.3	140.7^{ab}
200 NPSB + 150 urea	76.93^{a}	5.1	22.3^{ab}	3.4^{abc}	10.7^{b}	23^{ab}	146.7^{ab}	234.7	109.3^{c}
100 NPSB + 200 urea	68.1^{bc}	5.3	23.9^{a}	3.9^{a}	10.7^{b}	27.1^{a}	164.5^{a}	202	109.3^{c}
150 NPSB + 200 urea	70.9^{ab}	5.3	22.5^{ab}	3.8^{ab}	9.9^{b}	25.3^{ab}	154^{ab}	208.7	106.7^{c}
200 NPSB +200 urea	71.1^{ab}	5	21.7^{ab}	3.9^{a}	11.2^{b}	23^{ab}	162.7^{ab}	228	120.7^{c}
100 NPSB + 250 urea	68.7^{cd}	4.4	18.7^{bc}	3.5^{abc}	11^{b}	23^{ab}	152.7^{ab}	217.3	144^{a}
150 NPSB +250 urea	72.4^{ab}	4.6	21.2^{ab}	4.2^{a}	11.1^{b}	23.7^{ab}	122^{c}	203.3	107.7^{c}
200 NPSB + 250 urea	71.6^{ab}	5.5	24.9^{ab}	4.1^{a}	13.1^{a}	23.9^{ab}	158.7^{ab}	197.3	128.3^{abc}
CV (%)	5.71	17.9	13.5	16.21	9.91	17.9	7.98	17.23	11.51
LSD	6.69	NS	4.92	0.99	1.86	7.08	19.35	ns	22.3

ǂ*PH =plant height in cm,* MRPP =*Number of mother rhizome per plant,* PFPP = *Number of primary finger per plant, SFPP= Number of secondary finger per plant,* MRPPwt =*weight of mother rhizome per plant in grams,* PFPPwt = *weight of primary rhizome per plant in grams,* SFPPwt = *weight of secondary rhizome per plant in grams, , CV=coefficient of variation, LSD=least significant difference ($p \leq 0.05$)*

TABLE IV. Effect of NPSB and Urea fertilizer on yield component of turmeric in Teppi site during 2021

Treatments kg ha^{-1}	PH	Tiller plant^{-1}	Leaf plant^{-1}	MRPP	PFPP	SFPP	MRPPwt	PFPPwt	SFPPwt
Control	68.2^{c}	3.2^{c}	14.1^{e}	2.73^{e}	8.11^{c}	17.6^{b}	49.39^{f}	174.1^{b}	81.1^{f}
RNP (69N +23 P_2O_5)	91.93^{ab}	5.1^{ab}	17.4^{de}	4.1^{cd}	12.9^{ab}	28.8^{a}	172.4^{a}	227.1^{ab}	133.9^{ab}
100 NPSB + 150 urea	90.4^{ab}	4.7^{bc}	19.4^{cd}	4^{bcd}	13.4^{ab}	27^{a}	108.8^{e}	230.3^{a}	112.9^{cde}
150 NPSB + 150 urea	95.06^{ab}	5.3^{ab}	22.7^{abc}	4.7^{abcd}	12.4^{ab}	25.1^{a}	124.4^{cde}	258.6^{a}	108.1^{e}
200 NPSB + 150 urea	96.07^{ab}	5.7^{ab}	24.8^{ab}	3.9^{d}	13.4^{ab}	27.1^{a}	116.9^{de}	244.3^{a}	110.6^{de}
100 NPSB + 200 urea	96.4^{ab}	5.9^{ab}	26.6^{a}	5.2^{ab}	13.6^{ab}	28.6^{a}	135.3^{cde}	227.6^{ab}	117.3^{bcde}
150 NPSB + 200 urea	99.2^{ab}	5.8^{ab}	25^{ab}	4.4^{bcd}	13.3^{ab}	25.6^{a}	147.2^{abc}	255.6^{a}	129.3^{abc}
200 NPSB +200 urea	98.67^{ab}	5.5^{ab}	23.8^{abc}	5.1^{abc}	12.2^{b}	26.9^{a}	127.2^{cde}	228.6^{a}	138.3^{a}
100 NPSB + 250 urea	99.93^{a}	4.9^{ab}	20.8^{bcd}	4.8^{abcd}	13.6^{ab}	26.9^{a}	116.4^{de}	227.6^{ab}	116.1^{cde}
150NPSB +250 urea	88^{b}	5.1^{ab}	23.6^{abc}	5.4^{ab}	12.4^{ab}	31.5^{a}	164.4^{ab}	228.6^{a}	127.1^{abcd}
200 NPSB + 250 urea	95.4^{ab}	6.4^{a}	27.7^{a}	5.6^{a}	14.6^{a}	28.9^{a}	138.5^{bcd}	222.8^{ab}	126.3^{abcd}
CV (%)	7.25	17.9	13.07	13.3	10.6	14.2	13.4	13.7	8.7
LSD	11.45	1.6	4.97	1.04	2.3	6.46	29.07	53.7	17.6

ǂ*PH =plant height in cm,* MRPP =*Number of mother rhizome per plant,* PFPP = *Number of primary finger per plant, SFPP= Number of secondary finger per plant,* MRPPwt =*weight of mother rhizome per plant in grams,* PFPPwt = *weight of primary rhizome per plant in grams,* SFPPwt = *weight of secondary rhizome per plant in grams, , CV=coefficient of variation, LSD=least significant difference ($p \leq 0.05$)*

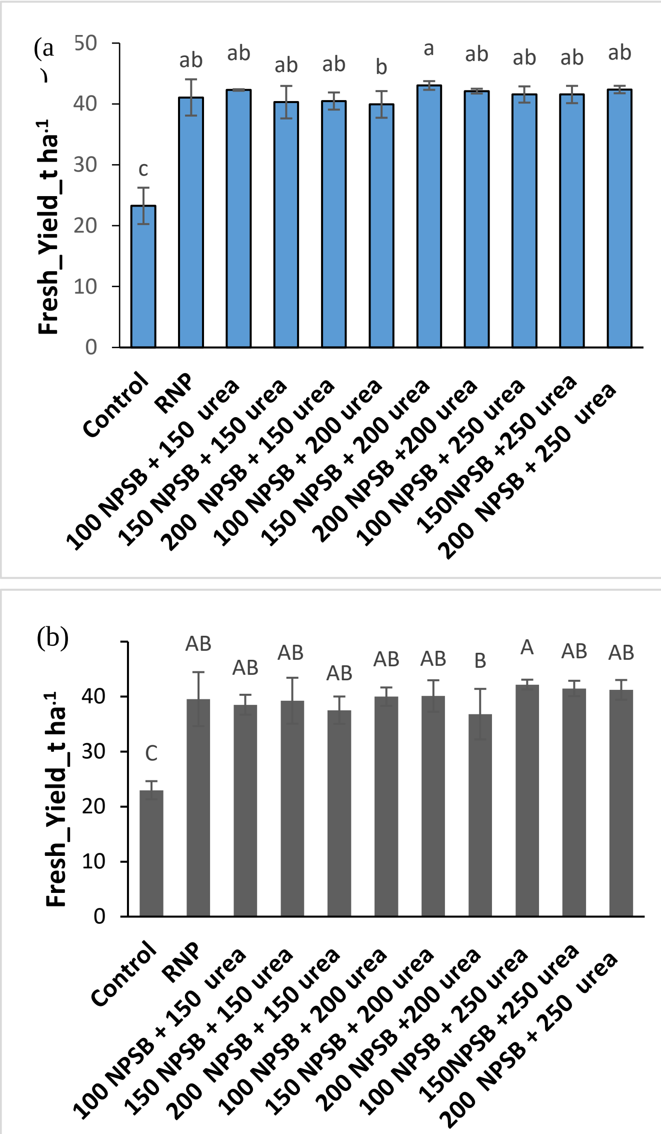

Fig. 2. Turmeric fresh rhizome yield (t ha^{-1}) of (a) 2020, and (b) 2021 as influenced by application of NPSB and Urea fertilizers

Overall two year analysis of variance; NPSB fertilizers applications were non-significantly ($p>0.05$) influenced yield and yield components of turmeric compared to the application of recommended NP fertilizer, but it was significantly ($p<0.05$) different compared to the control (Table 5). Numerically the application of 100 NPSB with 250 urea kg ha-1 fertilizer gave the highest fresh yield (41.9 t ha-1) (Figure 3). This might be due to protein synthesis by the help of nitrogen which enhance vegetative growth of turmeric plant. Also, the highest turmeric yield might be related to the high dose nitrogen application; since nitrogen were applied in split for all treatments which might be improved nitrogen uptake and increased the fresh rhizome yield [18].

Behailu and Weyessa, (2019) has also reported that the application of 115 kg ha-1 N in three splits could give a 692.52 Q ha-1 fresh yield and improve the quality of turmeric in the Teppi area[18]. Several studies have reported that turmeric is a nutrient-exhaustive crop, especially because it is a heavy feeder of N, [18-21]. Application of NP fertilizer influenced rhizome weight and phosphorus alone significantly influenced rhizome weight [20]. The high nutrient requirement of turmeric is due to its shallow rooting and potential to produce large amounts of dry matter per unit area [19].

Many research papers in Ethiopia suggest that applying the new fertilizer along nitrogen boosted grain crop production and yield components. A study on cereal crop yield showed that applying additional nitrogen fertilizer increased grain yield [22-25]. This research finding also had similar trends with turmeric crop. Micronutrients are required in small amounts and they directly or indirectly influence photosynthesis, and the vital process in plant such as respiration, protein synthesis, and reproduction phase substantiating [26].

Micronutrients (Zn and B) improved the growth of turmeric over no fertilizer [27-28]. Improvement in growth characters as a result of application of micronutrients might be due to enhanced photosynthetic and other metabolic activities leading to an increase in various plant metabolites responsible for cell division and elongation [29].

Since turmeric is a long-duration crop, it is crucial to apply fertilizers in an ideal quantity and to gradually extend their nutrient release to meet the crop's requirement during its growth cycle [30]. N, P, K, S, and micronutrients are needed for the best fresh yield production of turmeric [31-33]. The fresh yield of turmeric is much increased by the split application of micronutrients [34]. Turmeric fresh rhizome production increased with the application of S and Mg, according to [35].

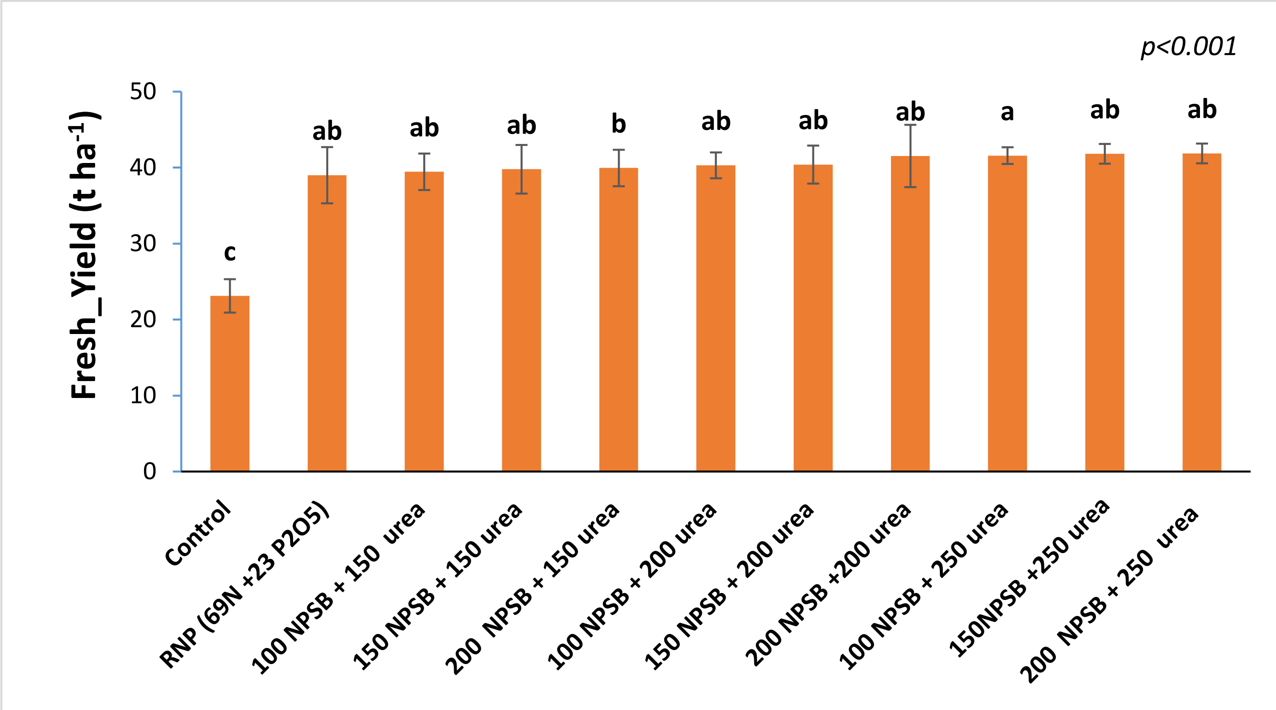

Fig. 3. Two year combined effect of NPSB and urea fertilizer on turmeric fresh yield (t ha^{-1})

TABLE V. COMBINED MEAN EFFECT OF NPSB AND UREA FERTILIZER ON TURMERIC YIELD COMPONENTS

Treatments (kg ha^{-1})	**PH_cm**	**Tiller plant^{-1}**	**Leaf plant^{-1}**	**MRPP**	**PFPP**	**SFPP**	**MRPPwt**	**PFPPwt**	**SFPPwt**
Control	67.7^{c}	3.4^{ab}	14.6^{f}	2.7^{e}	7.8^{d}	18^{b}	47^{e}	175^{b}	66^{d}
RNP (69N +23 P_2O_5)	84.4^{ab}	5.3^{c}	19.2^{e}	3.9^{cd}	14^{ab}	26.7^{a}	167^{a}	219^{a}	129^{a}
100 NPSB + 150 urea	80.9^{ab}	5.2^{ab}	21.3^{cde}	3.6^{d}	12^{c}	24^{a}	126^{d}	228^{a}	111^{bc}
150 NPSB + 150 urea	79.4^{b}	5.1^{ab}	21.6^{cde}	4.1^{bcd}	11.6^{c}	23.4^{a}	139.5^{bcd}	242^{a}	124^{ab}
200 NPSB + 150 urea	86.5^{a}	5.4^{ab}	23.6^{abc}	3.7^{d}	12.1^{c}	25^{a}	131^{cd}	239^{a}	110^{c}
100 NPSB + 200 urea	82.2^{ab}	5.6^{ab}	25.3^{ab}	4.5^{abc}	12.1^{c}	28^{a}	149.8^{b}	215^{ab}	113^{bcs}
150 NPSB + 200 urea	85.1^{ab}	5.6^{ab}	23.8^{abc}	4.1^{bcd}	11.6^{c}	25.4^{a}	150.6^{ab}	232^{a}	118^{abc}
200 NPSB +200 urea	84.9^{ab}	5.3^{ab}	22.8^{bcd}	4.5^{abc}	11.7^{c}	25^{a}	145^{bc}	228^{a}	130^{a}
100 NPSB + 250 urea	84.3^{ab}	4.6^{b}	19.8^{de}	4.2^{abcd}	12.3^{bc}	25^{a}	134.5^{bcd}	222^{a}	130^{a}
150 NPSB +250 urea	80.2^{ab}	4.9^{b}	22.4^{bcde}	4.8^{ab}	11.7^{c}	27.6^{a}	143^{bc}	216^{a}	117^{abc}
200 NPSB + 250 urea	83.5^{ab}	5.9^{a}	26.3^{a}	4.8^{a}	13.8^{a}	26.4^{a}	148.6^{bc}	210^{ab}	127^{a}
CV (%)	6.7	17.9	13.3	14.5	10.3	15.9	10.7	15.4	10
LSD ($p<0.05$)	6.47	1.07	3.39	0.69	1.4	4.6	16.9	39.7	13.7

ǂ *PH =plant height in cm,* MRPP =*Number of mother rhizome per plant,* PFPP = *Number of primary finger per plant, SFPP= Number of secondary finger per plant,* MRPPwt =*weight of mother rhizome per plant in grams,* PFPPwt = *weight of primary rhizome per plant in grams,* SFPPwt = *weight of secondary rhizome per plant in grams , CV=coefficient of variation, LSD=least significant difference* ($p\leq0.05$)

IV. CONCLUSION

In the current study different rates of blended NPSB fertilizer combined with varying rate of urea for improved growth and yield of turmeric. Unlike its initial hypothesis, blending micronutrients, Sulfur and Boron into fertilizer formulation did not brought outshining result compared to recommended NP fertilizer. This experiment showed that new site recommended fertilizer was statistically non-significant to improve the turmeric yield when compared with the previously recommended fertilizer type but it was significantly different from the control plot, which did not received any fertilizer. The lowest fresh rhizome yield (23.1 t ha^{-1}) was obtained from the control and the highest fresh rhizome yield (41.9 t ha^{-1}) was obtained from the application of new site specific fertilizer at the rate of 100 NPSB with 250 urea kg ha-1 and the previously recommended fertilizer NP which give fresh rhizome yield (40.3 t ha-1). Therefore, farmer in Yeki district can use the previously recommended NP fertilizer for Turmeric crop production. For future research ought to focus on yield the most yield-limiting nutrient. In addition, our current finding only focused at evaluating effectiveness of this fertilizer from growth and yield data. The future works are encouraged to evaluate effect on qualities like essential oil and oleoresin content since the influence of micronutrient could be explained more in quality data.

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