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Effects of blended fertilizer types and rates on fruit yield and nutrient use efficiencies of hot pepper (*Capsicum annuum* L.) at Asossa, Western Ethiopia

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A field experiment was conducted to evaluate the effects of different blended fertilizer types (NPSB and NPSBZn) and their rates on fruit yield, nutrient concentration, nutrient uptake and nutrient use efficiency of hot pepper at Assosa, Western Ethiopia. The experiment was set with eight treatments (recommended NP, three different blended rates for each NPSB and NPSBZn and unfertilized plot) laid out in randomized complete block design with three replications using a hot pepper variety Mereko Fana. In the blends since N content was low, supplementary N was applied from Urea to optimize N needs of the crop. The results of the study revealed that the crop phonological parameters (days to flowering and maturity, fruit dry yield and average dry fruit weight) were significantly ($p<0.05$) affected by blended fertilizer type and rates. The days to flowering and maturity were significantly ($p<0.05$) improved by application of 100 kg NPSBZn + 29 N kg ha^{-1}. The maximum total dry fruit yields (2.44 t ha^{-1}), the highest fruit uptake of nitrogen (50.1), phosphorus (9.9) and sulfur (4.1 kg ha^{-1}), and the highest apparent nutrient recovery for N (47.91%) were recorded with the application of 150 kg + 44 N kg ha^{-1} NPSBZn; while higher agronomic efficiency of N (9.59 kg pod kg^{-1}) and P (12.80%) were recorded with the application of 100 kg + 29 N kg ha^{-1} blended fertilizer rate. In general, the nutrient use efficiency of the blended fertilizers tested was acceptable and high. The uptake of N, P, K and S were significantly and highly correlated ($p< 0.01$) with total dry fruit yield. Therefore, the study recommends 150 kg NPSBZn + 44 N kg ha^{-1} blended fertilizer for sustainable hot pepper production in Assosa area of Western Ethiopia.

Key words: Blended fertilizer, Mareko Fana, nutrient uptake, fruit yield, nutrient use efficiency.

INTRODUCTION

Hot pepper (*Capsicum annuum* species) is an economically important crop belonging to the family of Solanaceae (Bosland and Votava, 2000). The productivity of hot pepper is still constrained by lack of proper nursery and field agronomic management practices, such as adequate nutrient supply, diseases, poor aeration, unbalanced nutrient supply and lack of high yielding cultivars. Among these, nutrient deficiency is the most

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yield limiting factor in vegetable crop production in Ethiopia (Alemu and Ermias, 2000). Application of balanced fertilizers is the basis to produce more crop output from existing land under cultivation (Amalfitano et al*.,* 2017; Caruso et al., 2019). It enhances sustainable production and provides nutrient needs to crops according to their physiological requirements and expected yields (Ryan, 2008). Previous fertilizer research work in Ethiopia has been focused on nitrogen (N) and phosphorous (P) fertilizer sources under different soil types and various climatic conditions, while very limited work has been reported with other essential macro- and micro-nutrients (K, S, Fe, Zn, B, etc).

Understanding plant nutrients requirement of a given area has vital role in enhancing crop production and productivity on sustainable basis. Nevertheless, increasing crop yields through the application of N and P alone can deplete other nutrients (FAO, 2000). Fertilizers are efficient exogenous source of plant nutrients (Akram et al., 2007), since plant growth and crop production require adequate and balanced supply of nutrients in order to maximize productivity by optimizing the plant nutrient uptake (Mengel and Kirkby, 2001). Several studies reported that chemical fertilizers are the major nutrient sources to improve crop productivity (Tamene et al., 2017). For instance, application of N, P and K fertilizers improved dry marketable fruit yield and yield contributors through better nutrient uptake, growth and development (Obidiebube et al., 2012). In addition, some reports also indicated that supply of micronutrients along with NPK fertilizer can increase nutrient use efficiency of crops (Malakouti, 2008).

In Ethiopia, farmers produce vegetable crops including hot pepper using blanket fertilizer recommendation such as 100 kg Urea + 100 kg DAP ha^{-1} (EIAR, 2007). Balanced application of mineral fertilizer was reported to maximize crop yields and reduce N and P losses to the environment (Melkamu, 2010). In contrast, chemical fertilizers specifically DAP and Urea were used for major crops production including hot pepper over decades in Ethiopia. Taking into account this gap, the Agricultural Transformation Agency (ATA) of Ethiopia suggested the general improvement of soil fertility management system by considering inclusion of more nutrients in the fertilizer program. For instance, the ATA suggested some blended fertilizers such as NPS, NPSB, NPSBCu, NPSCu, NPSZnBCu and K fertilizers for crop production in Assosa area of Ethiopia (ATA, 2016). However, specific blended fertilizers type and rate for hot pepper production in western parts of Ethiopia were not well identified and recommended. Nevertheless, essential micronutrients required for successful plant growth and productivity have never been included in the fertilizer program of Ethiopia. Thus, unbalanced application of plant nutrients may aggravate the depletion of other important nutrient elements in soils such as K, Mg, Ca, S and micronutrients (Wassie and Shiferaw, 2011). As a result, the current productivity of hot pepper is very low compared to the potential yield of the crop, in all parts of the country. Ethiopia is a big country which has diverse soil types, climates and agro-ecologies. In view of these different fertilizer rates, recommendation may be required for different parts of hot pepper production areas of Ethiopia. This indicates that the actual amount of fertilizer to apply depends on soil fertility, crop variety and fertilizer use efficiency of the variety. Recent acquired soil inventory data from Ethiopian Soil Information System (EthioSIS) revealed that in addition to N and P, nutrients such as S, B, and Zn are deficient in most soils of Ethiopian including Asossa area (ATA, 2013). Therefore, the present study was designed to evaluate and determine optimum blended fertilizer types, rates and use efficiency for sustainable production of hot pepper in Assosa areas of Western Ethiopia.

MATERIALS AND METHODS

Description of the experimental site

The experiment was conducted during 2017/2018 cropping season at Assosa Agricultural Research Center, during 2017 cropping season, Benishangul Gumuz Regional State of Ethiopia. The study site is located at 10° 02' 05'' N latitude and 34° 34' 09'' E longitudes; it is situated at 1553 m a.s.l (Figure 1). The study area is characterized by uni-modal rainfall pattern, which starts in early May and extends to mid-November, with maximum rain in June to September and annual total rainfall of 1316 mm (Figure 2). The soil of the area is reddish, brown, Nitosol, slightly acidic with average pH of 5.5 (EARO, 2004).

Experimental materials and nursery management

Marako Fana variety of hot pepper which is adapted to the agro-ecology of the area was used for the study. The seedlings were raised on a seed bed with 5 m length and 1 m width by hand drilling the seeds at the inter-row spacing of 15 cm. Uniform, healthy and vigorous seedlings were transplanted into experimental plots after 4 weeks of sowing on seedbed or when they were about 20 cm height (Lemma and Shimelis, 2008). The seedlings were spaced 30 cm along the rows which were 70 cm apart (EARO, 2004).

Experimental design and treatments

NPSB and NPSZnB blended fertilizers were selected for specific area of Assosa based on EthioSIS soil fertility map (ATA, 2013). In both blended fertilizers, nitrogen adjustment was done for the shortfall of N fertilizer in blended fertilizers. Furthermore, blanket recommended N and P from Urea and TSP fertilizers was employed as a test treatment. Blended fertilizers and TSP (the P sources) were applied at planting and half of N was applied after 30 days of transplanting. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The experimental plot size was 12.6 m^2 (3 m wide and 4.2 m long) with 0.75 m space between plots and 1 m between blocks. There were six rows per plot and ten plants per row with a total of 60 plants per plot (Table 1).

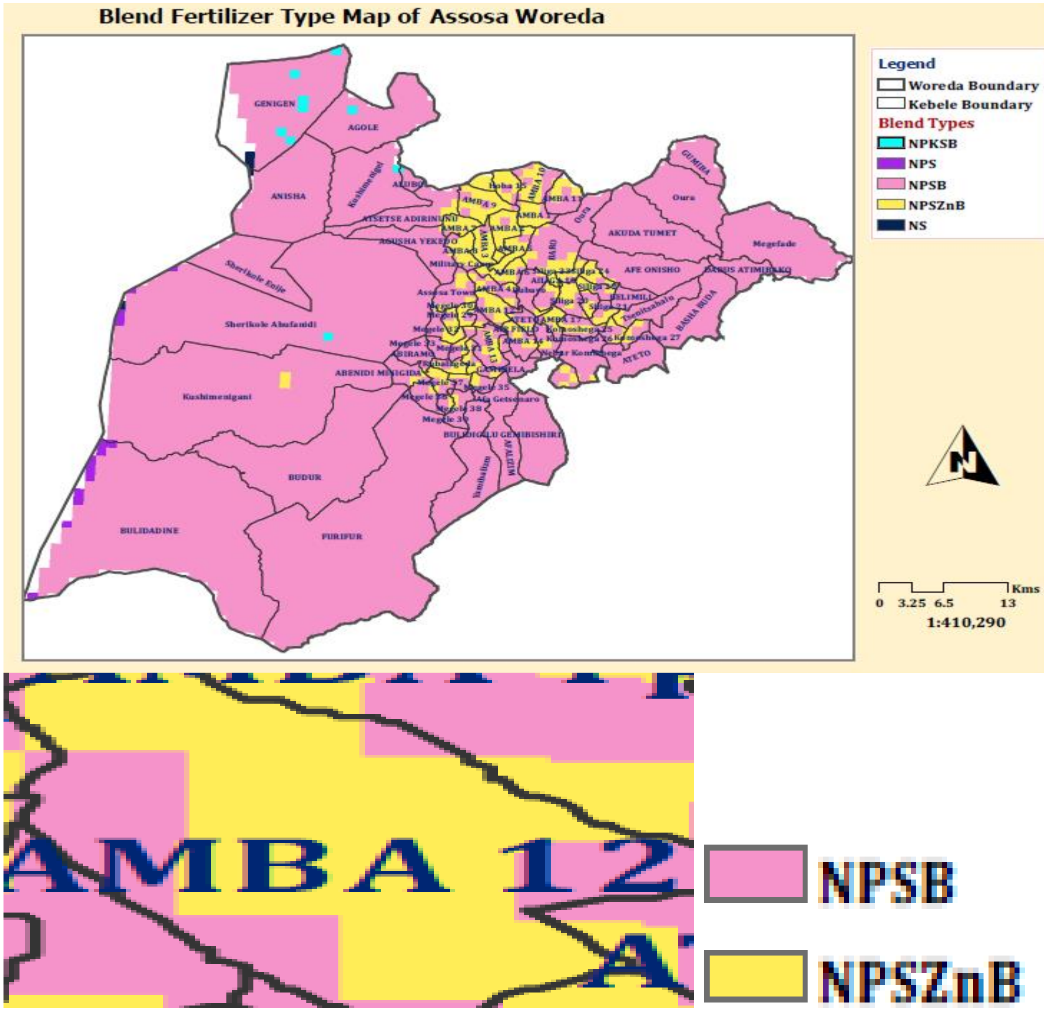

Figure 1. Map of the study area.

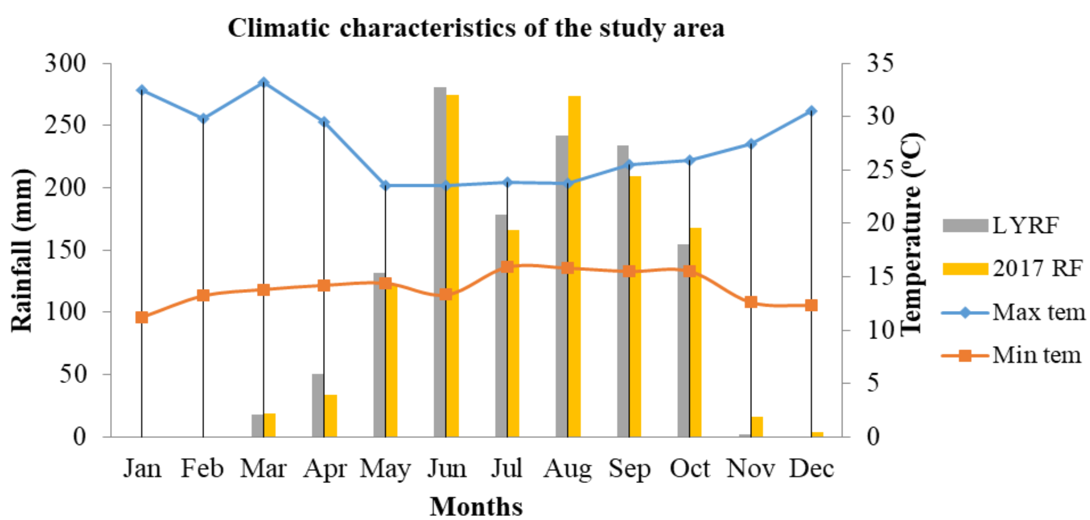

Figure 2. Monthly rainfall, minimum and maximum temperature of the study area during 2017 versus long term average monthly rainfall.
Source: AsARC Metrology Station (2017).

Table 1. Treatment setup and nutrient supply.

No.	Treatment (kg ha^{-1})	N : P_2O_5 : S : B : Zn (kg ha^{-1})
1	Control	0 : 0 : 0 : 0 : 0
2	100 Urea & 100 TSP	46 : 46: 0: 0: 0
3	100 NPSB + 28 N	46.1 : 36.1 : 6.7 : 0.71: 0
4	150 NPSB + 42 N	69.1 : 54.15 : 10.1 : 1.1: 0
5	200 NPSB + 56 N	92.2 : 72.2 : 13.4 : 1.42: 0
6	100 NPSBZn + 29 N	45.9 : 33.8 : 7.3 : 0.7 : 2.2
7	150 NPSBZn + 44 N	69.4 : 50.7 : 10.9 : 3.4 : 1.0
8	200 NPSBZn + 58 N	91.8 : 67.6 : 1.6 : 4.5 : 1.3

Soil sampling and analysis

Prior to field experiment, twelve representative soil samples (0-20 cm depth) were collected and then, bulked as one composite soil sample to determine selected soil physico-chemical properties (pH, OC, N, P, K, CEC, S, B, Zn and texture). On the other hand, bulk density was determined from undisturbed soil samples.

Determination of particle-size distribution was done by using hydrometer procedure method (Sahlemedhin and Taye, 2000). Organic carbon was determined following wet digestion method (Walkley and Black, 1934). Total nitrogen contents were analyzed by Micro-Kjeldhal method (Horneck et al., 2011). The pH of the soil was determined using 1:2.5 soil sample to water ratio using a digital pH meter (FAO, 2009). Cation exchange capacity (CEC) was measured after saturating the soil with 1 N ammonium acetate (NH_4OAc) and displacing it with 1 N NaOAc (Chapman, 1965). Available phosphorous was determined by Olsen's method (Olsen et al., 1954). Available potassium was determined with a flame photometer (Hesse, 1971). The available S in the soil samples was extracted with monocalcium phosphate extract, while available Zn and B in the soil samples was extracted with diethyline triaminepenta acetic acid (DTPA) and quantified by atomic absorption spectrophotometer.

Data collection and measurements

Field data were collected at different stages of hot pepper growing period and after harvesting from the representative samples. These parameters include: phenology (flowering and maturity), yield (total fresh pod yield t ha^{-1}), total dry pod yield t ha^{-1} and average pod dry weight (g).

Plant tissue sampling and analysis

The vegetative above ground parts and pods were sampled from one row of each treatment at early flowering stage and at maturity, respectively. The samples were dried at 65°C for 72 h in oven and fine ground to less than 1 mm size and wet digested for determination of nutrients content of the tissues and pods using standard procedures. Total N was analyzed by Kjeldhal method (Bremner and Mulvaney, 1982). After the digestion of the plant material with di-acidic (HNO_3-$HClO_4$), the concentration of P in this solution was determined using spectrophotometer (FAO, 2006). Potassium (K) was determined by dry ashing and using atomic absorption spectrophotometer (Motsara and Roy, 2008). The concentration of sulfur was determined by Turbidimetric method using calorimeter (Morberg, 2000) and the concentration of Zn was determined by an atomic absorption spectrophotometer described by Okalebo et al. (2002).

Plant nutrient uptake and use efficiencies

The nutrient accumulation and partitioning were calculated by multiplying nutrient concentration with the dry matter of the respective plant parts and the uptake of nutrient in economic and by-product of hot pepper plant parts were estimated.

Shoot and fruits nutrients uptake

Nutrients (N, P and S uptakes) in the shoot and fruits were calculated by multiplying N, P and S concentrations with total biomass weight for shoot and total dry fruit weight for fruit uptakes.

$$\text{Nutrient Uptake} = \text{Nutrient concentration x total dry weight} \quad (1)$$

Agronomic nutrient use efficiency (AE)

AE is the amount of additional yield produced for each additional kg of fertilizer applied (Mengel and Kirkby, 2001) calculated by using procedures described by Mengel and Kirkby (1987); as fruits yield of each fertilized treatment minus fruits yield of control divided by the fertilizer applied.

$$AE = \frac{\text{fruits yield of fertilized treatement} - \text{fruits yield of control treatement}}{\text{Fertilizer applied Kg/ha}} * 100 \quad (2)$$

Apparent fertilizer nutrient recovery (AR)

AR is a measure of the ability of the crop to extract nutrients from the soil. Thus, the above ground biomass nutrient uptake was calculated as per the procedure described (Pal, 1991; Fageria and Baligar, 2005) as follows:

$$ANR = \frac{\text{TU fertilized treatment} - \text{TU of controls}}{\text{Amount of fertilizer applied Kg/ha}} * 100 \quad (3)$$

Where ANR=apparent nutrient recover and TU=total nutrient uptake.

Physiological efficiency (PE)

PE is the yield obtained per unit of nutrient uptake (Fageria, 2009).

$$PE = \frac{\text{Yield of fertilized in kg} - \text{Yield of control in kg}}{\text{Nutrient Uptake of fertilized in kg} - \text{Nutrient uptake of control in kg}} \quad (4)$$

Table 2. Effects of blended fertilizer types and rates on days to flowering and maturity, total fresh fruit yield, weight of total dry fruit yield and fruit dry weight of hot pepper.

Treatment (kg ha^{-1})	DF	DM	TFFY	TDFY (t ha^{-1})	FWt (g)
Control	82.00	134.33	9.45	1.02	3.18
Recommended NP	73.00	125.33	10.82	1.66	4.08
100 NPSB + 28 N	71.67	124.33	12.02	1.94	3.80
150 NPSB + 42 N	73.00	127.00	11.98	2.27	4.06
200 NPSB + 56 N	77.33	130.33	11.79	2.03	3.61
100 NPSBZn + 29 N	64.67	117.0	11.27	2.05	4.14
150 NPSBZn + 44 N	72.33	125.33	13.02	2.44	4.33
200 NPSBZn + 58 N	73.67	127.67	11.24	1.92	3.83
LSD (0.05)	7.3258	7.257	1.3493	0.619	0.6067
CV (%)	5.7	3.27	6.73	18.46	8.93

Means within a column sharing common letter(s) are not significantly different. CV: Coefficient variance; LSD: list significance difference; NS: non-significance; DF: days to flowering, DM: days to maturity, TFPY: total fresh fruit yield (t ha^{-1}), TDPY: total dry fruit yield, PWt: fruit dry weight (g $fruit^{-1}$).

Statistical analyses

All data were subjected to analysis of variance (ANOVA) using Proc Mixed procedure with SAS software version 9.2(SAS Institute Inc. Cary NC, 2008). All significant treatment mean differences were separated using the Least Significant Difference (LSD) test at P≤0.05 probability level.

RESULTS AND DISCUSSION

Soil physiochemical properties of the study area

The soil of experimental site was clay loam in textural class having the bulk density of 1.36 g cm^{-3}. It is suitable for hot pepper production, due to its good ability to retain nutrients and water (Ryan and Rashid, 2001). For good plant growth, bulk densities should be below 1.4 g and 1.6 g cm^{-3} for clay and sand soils, respectively (Miller et al., 1995). According to Jones (2003), the experimental soil was moderately acidic in reaction (pH=5.5), low in total N (0.18%) (Landon, 1991), low in organic carbon (1.47%) Berhanu (1980) and low to moderate in organic matter (2.53%) (Tekalign, 1991). The available P (5.0 mg kg^{-1} soil) content of the study soil appeared to be very low (Olsen et al., 1954; Cottenie, 1980). Many previous studies reported that most Ethiopian soils were characterized by low concentration of available P in north west and western part of Ethiopia (Yihenew, 2002; Wakene and Heluf, 2003); the current study also revealed that available K (16.67 mg kg^{-1} soil) content was very low (Jones, 2003) which probably is due to leaching caused by high precipitation, which needs to add K fertilizer. On the other hand, CEC (22.6 Cmol(+) kg^{-1}) of the study soil was observed to be moderate (Hazelton and Murphy, 2007), implying that the nutrient status of the experimental soil is not in bad condition. This shows that moderate capacity of the soil to retain cations in exchangeable form the plant growth. According to the rating established by Jones (2003), the contents of S (2.12 mg kg^{-1}), Zn (0.34 mg kg^{-1}) and B (0.64 mg kg^{-1}) were insufficient to low, respectively, in the soil of study sites.

Effect of blended fertilizers on crop phenology

Days to flowering and maturity was significantly (P ≤ 0.05) shortened by application of blended fertilizer as compared to unfertilized treatments. Early flowering and maturity days were recorded with the application of blended fertilizer with 100 kg NPSBZn + 29 kg N ha^{-1}, followed by 100 kg NPSB + 28 kg N ha^{-1}. Hot pepper flowering and maturity dates were delayed as the amounts of NPSBZn applied were increased from 100 to 200 kg ha^{-1} (Table 2). On the other hand, the shortening in days to flowering with the increase of blended fertilizer rates might be attributed to P and S level that are known to enhance flowering, fruiting and maturity. This result agreed with Brady and Weil (2002) who stated that P is helpful in hastening flowering and maturity of crops. Similarly, Amare et al. (2013) also observed that the earliest days to flowering (66.3 days) for Marako Fana variety was recorded from the plot treated with 138 kg P_2O_5 ha^{-1} and the delayed flowering (93.3 days) was observed in plots that received a combination of 92 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1}.

Application of blended fertilizer (100NPSBZn +29N) hastened days to flowering by 8 and 18 days as compared to the recommended NP fertilizers and with unfertilized plot, respectively. This could be attributed to the impact of positive interaction of B in the blended fertilizer, which is according to the finding of Fageria et al. (2002) who reported positive relations between B, K and N fertilizers for improving crop yields and maturity. These authors stated B fertilization along with N fertilizers required for protein formation, which is associated with high photosynthetic reactivity, vigorous vegetative growth and promoting flower formation, perhaps, boron plays an important role in flowering and fruit formation of crops (Nonnecke, 1989; Naz et al., 2012).

Effect of blended fertilizers on fruit yield

Total fresh fruit yield (t ha^{-1})

Total fresh fruit yields were significantly (P≤ 0.05) influenced by application of blended fertilizers rates. The highest total fresh fruit yields (13.02 t ha^{-1}) was recorded then 150 kg NPSBZn + 44 kg N ha^{-1} was applied as compared to other rates and types of blended fertilizer. The lowest total fresh fruit yield (9.45 t ha^{-1}) was recorded from unfertilized plot (Table 2). This is due to the fact that the nutrient uptake increased through application of blended fertilizer to nutrient deficient soil as a result of enhanced nutrient use efficiency of hot pepper, thus increasing its fruit productivity. This could be because of the effectiveness of Zn and S functions in plant physiology, including protein and tryptophophan synthesis, carbohydrates metabolism, activated enzyme carbonic anhydrase, synthesis of RNA, and ribosome functions (Uchid, 2000). This perhaps indicates S and Zn deficiency in the study area. In addition, N fertilizer had positive influence on Zn uptake; therefore, it is important to concentrate on management of N fertilizer on Zn uptake as well. Similar to this finding, Jones et al. (2011) stated matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and improve crop yield. Thus the increase in yield and yield attributes of hot pepper was due to improvement in the level of carbohydrates owing to greater photosynthesis and ultimately increase in number and weight of the pods (Tutia et al., 2015).

Total dry fruit yield (t ha^{-1})

Total dry fruit yield was significantly (P≤0.05) affected by blended fertilizer types and rates (Table 2). Blended fertilizer level at 150 kg NPSBZn + 44 kg N ha^{-1} produced the highest total dry fruit yield (2.4 t ha^{-1}) as compared to the recommended NP (1.6 t ha^{-1}) and the control (1.0 t ha^{-1}). Thus, the application of blended fertilizers improved the hot pepper dry fruit yield. This could be attributed to the higher mean fruit length, width, weight, seed number and relatively larger number of marketable fruits obtained at this level of fertilizer supply. However, there was a yield decline at the highest rate of fertilizers supply, implying that hot pepper yield increase occurs up to a certain optimum level of fertilizer supply and then decrease afterwards (Roy et al., 2011). Here, the results were highly influenced by those nitrogen and phosphorus which are mostly influenced by those micronutrient levels as Zn in the treatment. The optimum amount of B stimulated the phosphorus uptake by plant roots and promoted development of flower clusters and flowering directly which is related to fruit set (Day, 2000).

Average fruit dry weight (g)

The application of blended fertilizers showed significant (P≤ 0.05) influence on average dry fruit weight (Table 2). The highest average dry fruit weight per plant (4.33g) was obtained when 150 kg NPSBZn + 44 kg N ha^{-1} was applied, while the lowest dry fruit weight (3.18 g) was obtained from unfertilized plot. However, supplemental supply of S, Zn and B with blended fertilizer might have confounded effect on fruit dry weight per plants. Thus, the increase might be attributed to the increase in assimilate partitioning towards the fruit ultimately increasing the seed number, seed weight, length and width of individual dry fruits at this level of blend fertilizers, resulting in increased weight of fruits per plant. The increase in pod dry weight in this study is in conformity with the work of Hedge (1997) and Guerpinar and Mordogan (2002) who reported that pod dry matter content of peppers was directly related to the amount of nutrient taken from the soil, which was proportional to the nutrients present in the soil or the amount of organic and inorganic fertilizers applied to the soil. It is also in conformity with Russo (2003) who reported that fruit weight increased linearly with seed number in sweet pepper.

Nutrients concentration and uptakes of hot pepper

Shoot and fruit nutrients concentration

The shoot and matured fruit nutrient concentrations were significantly (p ≤ 0.05) affected by the application of different sources of blended fertilizers as compared with control (Table 3). Both the shoot tissue and fruit N and P concentrations showed increasing trend with increase in the amount of nutrient added. Accordingly, the highest value of nitrogen (5.03%), phosphorus (0.45%) and sulfur (0.13%) concentration in the shoot was obtained from application of blended fertilizer at the rate of 200 kg NPSB + 56 kg N ha^{-1}. Also, the highest nutrient concentrations of N, P and S in pods of 2.07, 0.43 and 0.20%, respectively were obtained when 200 kg NPSBZn + 58 kg N ha^{-1} was applied while the least nutrient concentration in shoot and fruits were recorded from the unfertilized plots thus, might be attributed to low P and N availability in the experimental soil, as confirmed by soil analysis before planting.

The increase in N uptake as a result of S application may be due to an increment in protein synthesis and

Table 3. Effects of blended fertilizers rates and recommended NP on nutrient concentration of shoot and fruitof hot pepper at Assosa.

Treatment (kg ha^{-1})	N		P		S	
	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit
Control	3.13	1.26	0.25	0.31	0.06	0.13
Recommended NP	4. 32	1.63	0.41	0.39	0.11	0.14
100 NPSB + 28 N	4. 47	1.92	0.37	0.40	0.10	0.19
150 NPSB + 42 N	4.41	1.96	0.38	0.39	0.10	0.18
200 NPSB + 56 N	5.03	1.87	0.45	0.41	0.12	0.17
100 NPSBZn + 29 N	4.81	1.73	0.37	0.38	0.12	0.16
150 NPSBZn + 44 N	4.82	1.93	0.36	0.41	0.10	0.16
200 NPSBZn + 58 N	4.74	2.07	0.43	0.43	0.10	0.20
LSD(0.05)	1.0288	NS	0.0802	0.0646	NS	NS
CV%	13.15	16.07	12.03	9.47	24.94	18.24

Means within a column sharing common letter(s) are not significantly different. NS: Non-significance at ($P \leq 0.05$); N: nitrogen, P: phosphorus, S: sulfur shoot and fruit concentration.

enhance photosynthesis (Zhao et al., 2008). In the absence of S, amino acids cannot be transformed into proteins, which results in reduced N acquisition (Varin et al., 2009). The present shoot nutrient concentration agreed with Portree (1996) who reported that the range of sufficiency of nitrogen in the leaf tissue of pepper is 3.5 to 5.5% in leaf dry matter. Therefore, it is evident from the results of this study that the pepper plants took up sufficient nitrogen (4.82%) from the soil with 150 kg NPSBZn + 44 kg N ha^{-1} fertilizer application, implying that concentration alone may be a misleading in predicting yield. However, unlike fruit yield which was reduced at the highest level of N supply, the concentration of the nutrient in the shoot did not decrease. This shows that there was luxury consumption of the nutrient, at the highest level of nutrient fertilizer, which led a decline in yield attributable to the promotion of vegetative growth at the expense of pod development (Roy et al., 2011). As Nigussie (2001) investigated that plants supplied with P had significantly increased P concentration in potato, cabbage and carrot shoots than those not supplied with P at all stages of growth. Moreover, the N and P nutrient concentrations in the shoot were greater than the N and P nutrient concentrations in pods. In pepper more nutrient concentration of NPK are highest in leaf followed by fruit (Hedge, 1997). As cited by Reis and Monnerat (2000), nutrient concentration varies with the sampled organ on the plant and sampling time, this makes their difference in the nutrient concentration at shoot and pod parts of hot pepper plant and in different sampling stage at flowering and maturity stage.

Shoot and pod nutrient uptakes

The shoot and fruit N and P uptakes were significantly ($P \leq 0.05$) affected by the application of different blended fertilizer rates, while S effect was non-significantly different among the fertilizers tested. The maximum shoot uptake values of N, P and S were 32.22, 2.87 and 0.77 kg ha^{-1}, respectively with application of blended fertilizer rate of 150 kg NPSB + 42 N kg ha^{-1} with this rate high above ground total biomass was also produced. The results showed very low amount of P and S uptake in shoot biomass, perhaps due to the fact that the study soil is strongly acidic and hence P fixation occurred in Al and Fe oxides.

The maximum fruit uptake of N (50.14 kg ha^{-1}) and P (9.93 kg ha^{-1}) was obtained from blended fertilizer rate (150 kg NPSBZn + 44 kg N ha^{-1}) which also gave the highest fruit yield, while higher S (4.10 kg ha^{-1}) uptake were from 150 kg NPSB + 42 kg N ha^{-1}. The least nutrient uptakes for tissue and fruits were from the unfertilized plots (Table 4). This result shows that fruit and tissue uptake linearly increased in response to increasing specially N and P fertilizer rates in blended fertilizers. This could be because of the fact that N and P fertilizer application do have synergistic effect and hence N might have stimulated the uptake of P and vice versa (Sharma and Tandon, 1992). And also S availability can improve the efficiency and uptakes of N and P. Fazli et al. (2008) reported that lack of S limits the efficiency of added N; therefore, S addition becomes necessary to achieve maximum efficiency of applied nitrogen fertilizer. The pod N uptake was higher than the shoot N uptakes; this can be expected due to partition of nutrients from plant parts to pod formation at maturity stage and also yield difference at flowering biomass produced was low in relative to total pod production at maturity stage. Thus, 150 kg NPSBZn + 44 kg N ha^{-1} treatment increased the total nitrogen, phosphorus and sulfur uptake compared to other treatments. This is due to the application of combination of macronutrients with micronutrients in balanced form of fertilizer to nutrient deficient soil;

Table 4. Nutrient uptake of fruit and shoot of hot pepper Mareko Fana variety with recommended NP and blended fertilizers rates at Assosa.

Treatment (kg ha^{-1})	N		P		S	
	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit
Control	19.62	16.11	1.68	3.69	0.28	1.55
Recommended NP	23.91	29.32	2.03	6.43	0.61	2.33
100 NPSB + 28 N	28.06	37.25	2.27	8.34	0.56	3.88
150 NPSB + 42 N	26.17	44.63	2.25	8.88	0.59	4.10
200 NPSB + 56 N	32.23	38.07	2.87	8.34	0.77	3.46
100 NPSBZn + 29 N	26.62	33.54	2.04	7.80	0.67	3.29
150 NPSBZn + 44 N	29.90	50.14	2.21	9.93	0.62	3.88
200 NPSBZn + 58 N	30.41	36.98	2.75	8.24	0.64	3.64
LSD(0.05)	6.035	13.787	0.622	2.6113	NS	NS
CV	12.71	22.10	15.68	19.61	17.26	27.26

Means followed by the same letter(s) with in a column are not significantly different at ($P \leq 0.05$); N: Nitrogen, P: phosphorus, S: sulfur shoot and fruit uptake, NS: non-significance.

thereby it improves the nutrient concentration and uptake, as a result yield is increased. On the other hand, a treatment that accumulates the maximum of N, P and S nutrients gave the highest yield. Similar to this finding, Assefa (2008) reported that the grain yield at maximum accumulation of nutrient occurs when increase in nutrient rate does not increase uptake and yield.

Agronomic efficiency, apparent recovery and physiological efficiency

Agronomic efficiency

Applications of blended fertilizers improved the agronomic efficiency (AE) of hot pepper as compared to the plot treated with recommended NP fertilizer. The highest improvement of agronomic efficiency was 9.59 and (9.25 kg kg^{-1}) when100 NPSBZn + 29N and 150 NPSBZn + 44N kg^{-1}, was applied, respectively. This implies that nutrient use efficiency increased by increasing nutrient supply that leads to more plant nutrient uptake and utilization, while nutrient losses from the soil-plant system decreases (Table 5). This improvement of AE is due to the nutrient uptake increase through application of blended fertilizers containing macronutrients and micronutrients in appropriate forms. Thus, perhaps the effectiveness of S, Zn and B functions improves due to their balanced supply in plant physiology, including protein synthesis, carbohydrates metabolism, activated enzyme carbonic anhydrase, synthesis of RNA, and ribosome functions (Uchid, 2000). Similar to this finding, Jones et al. (2011) stated matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield. Fertilizer use efficiency for different crops increased by the application of suitable micronutrients (Malakouti, 2008).

High AE would be obtained if the yield increment per unit applied is high (Fageria et al., 2002; Roberts, 2008), nevertheless what amount can be considered as high agronomic efficiency could be different from crop species to species. Furthermore, increasing the nutrient levels may lead to decrease in AE after certain point. This suggests that higher nutrient addition (above optimum level) results in luxury nutrient uptake that might not contribute to physiological processes or perhaps become toxic mostly for micronutrients. It may be due to the application of excess nutrients, which was not effectively utilized by the crop and the rate of production was lesser per unit of nutrients application (Senthil et al., 2008). On the other hand, fertilization with recommended NP resulted in the lowest AE of nutrients. According to Fageria et al. (2015) an efficient plant is the one that produces higher economic yield with a limited quantity of applied or absorbed nutrient. Fageria and Baligar (2005) also reported that high AE is obtained if the yield increment per unit of nutrient applied is high because of reduced losses and increased uptake of nutrient.

Physiological efficiency

Physiological efficiency (PE) of N and P was improved with application of blended fertilizers as compared to recommended NP (Table 5). However, the highest physiological N use efficiency (30.47 kg kg^{-1}) was recorded when 100 kg NPSBZn + 29 kg N ha^{-1} was applied whereas the lowest (20.33 kg kg^{-1}) was obtained when 200 kg NPSBZn + 58 kg N ha^{-1} was applied. Application of blended fertilizers increased PE of N by 10% against the recommended NP fertilizers. The observed higher PE might be due to relatively higher yield produced with low absorption of N against other

Table 5. Effects of blended fertilizer applications on agronomic efficiency (AE), apparent recovery (AR), and physiological efficiency (PE) of hot pepper at Assosa.

Treatment (kg ha^{-1})	AE (kg fruit kg^{-1})	PE (kg kg^{-1})		Apparent recovery (%)		
		PEN	PEP	ARN	ARP	ARS
Control	-	-	-	-	-	-
Recommended NP	4.30	21.75	122.07	18.12	6.08	-
100 NPSB + 28 N	8.36	25.45	136.30	43.87	12.88	34.81
150 NPSB + 42 N	8.58	27.90	173.67	39.94	9.57	25.25
200 NPSB + 56 N	4.70	21.94	133.12	22.77	6.43	14.24
100 NPSBZn + 29 N	9.59	30.47	173.70	35.75	12.17	23.80
150 NPSBZn + 44 N	9.25	25.54	169.56	47.91	12.10	21.35
200 NPSBZn + 58 N	4.03	20.33	118.86	21.69	6.73	14.33

Agronomic efficiency (AE) kg pod kg^{-1} nutrients supply, physiological efficiency (PE) kg fruit kg^{-1} N and P uptake and apparent recovery efficiency (ARE) % kg N, P and S uptake kg^{-1} N, P and S supply, respectively.

treatments. The lower PE might indicate that the crop did not utilize the absorbed N for the production of maximum pod yield. Related findings on PE of N on potato were reported by Banerjee et al. (2015). The authors indicated that at high uptake of N the PE decreases a luxury consumption of N that might not contribute to physiological processes.

Physiological efficiency of P was higher at lower rate of P application than higher rate, but the trend was not uniform which produce the highest PE of P as 173.70 kg kg^{-1} while the lowest was 118.86 kg kg^{-1} at highest P applied. The mean PE of P was 146.80 kg pod/kg total P uptake, which was low relatively with other vegetables and tuber crops. The lowest physiological efficiency which might indicate that the crop did not utilize the absorbed P for the production of maximum pod yield. This showed that at high P uptake the PE of crops decreases and it would also depend on crops. Nutrient efficient plants produce high yield with low uptake of nutrients (Fageria et al., 2015). This result of PE on P was high in relative to N because it is not the sole phosphorus rate while due to confounding effect of other macro and micro nutrients in blended effect.

Apparent recovery (AR) of N and P in fruits of hot pepper

The apparent recovery of N showed positive response to application of blended fertilizers where the maximum (47.91%) and the minimum (18.12%) N recoveries were recorded at rate of 69 and 46 kg N ha^{-1}, respectively. Further increase of N to 92 kg N ha^{-1} declined N recovery to 21.69%, while the highest application of nutrients resulted in low N recovery (Table 5). This perhaps happened due to reduction in nutrient use efficiency. The apparent recovery of N increased by 30% in response to 46 kg N ha^{-1} relative to the lowest N rate (0 kg/ha^{-1}). The mean apparent recovery of N (32.86%) was somewhat lower than other crops of barley which is about 49.6% on Nitisols (Mekonnen, 2005). Thus, in vegetable crop production, higher AP would not be expected because of the fact that all plants cannot be accounted for. In addition, such low apparent recovery of N might be attributed to the susceptibility of N to different losses through leaching or denitrification, and hence, exhibits low recovery under conditions of high rainfall area where this study was conducted.

The apparent recovery of P showed a decreasing trend with increasing levels of P fertilizer (Table 5). This is due to antagonistic effect of P and Zn at high level of fertilization. Consequently, the maximum (12.80%) and minimum (6.08%) P recovery was recorded at 36 and 67 kg P ha^{-1} rates, respectively. The phosphorus apparent recovery efficiency ranged from 10 to 15%. In line with the current finding, the apparent recovery of P due to P fertilizer application on wheat was 14.0% when 10 kg P ha^{-1} was applied and declined to 12.7% when the P rate was increased to 30 kg P ha^{-1} (Getachew and Tekalign, 2003). Similarly, Sandana (2016) reported that the level of nutrient fertilization affects the nutrient availability in soil. At high contents of soil nutrients, more nutrients might be taken up by plants and their utilization depends on the fact that the crops may vary in the recovery of the applied nutrients. Also, Dobermann (2005) noted that recovery efficiency of a nutrient is mainly a function of indigenous nutrient supply, favorable climatic condition, sufficient water supply and low pest pressure.

Correlation of nutrient uptake and total dry fruit yield

The result revealed highly significant correlations between total dry fruit yield and nutrients uptake (Table 6). The correlations between N, P, S and K uptakes and total dry fruit yields were highly significant. This indicates the improvement of total dry fruit yield production of hot pepper by application of blended fertilizers; Fageria and

Table 6. Correlation coefficient analyses among total nutrients (NPSZn) uptake and dry fruit yield as influenced by blended fertilizer at Assosa area.

Correlation	TPY	N	P	S	Zn
TPY	1				
N	0.8447**	1			
P	0.8995**	0.8782*	1		
K	0.7037**	0.6176*	0.6209*		
S	0.7839**	0.7704*	0.7701*	1	
Zn	0.1137^{ns}	0.0487^{ns}	0.174^{ns}	0.3324^{ns}	1

* ,**Significant correlation at P < 0.05 and P < 0.01 probability levels, respectively; ns: non significant; TFY: total fruit yield; N: nitrogen, P: phosphorus; K: potassium; S: sulfur; Zn: zinc.

Baligar (2005) reported similarly high yields obtained due to increased uptake of nutrient, that perhaps led to reduced losses of nutrient applied. Particularly, the results revealed that N, P and S uptakes were significantly correlated at high probability level (P < 0.01) with total dry pod yield, while the zinc uptakes were positive, but non-significantly (P < 0.05) correlated. All the aforementioned positive and strong association of nutrient uptakes imply these factors are most important for dry pod yield and hot pepper production improvement at Assosa area. Significantly, positive correlation was also reported between applied nitrogen dose and dry matter production by Deshmukh (2008) on pepper.

Conclusion

The low hot pepper production in the study area appears to be attributed to low soil fertility and poor management practices. To overcome the critical problems of soil fertility, blended fertilizer experiment was conducted during 2017/2018. The results revealed significant (p<0.5) difference in total fresh fruit of (+37.78%) and dry fruit (+139.22%) yield compared to control. Nutrient concentrations and uptakes were linearly increased in response to the application of blended fertilizers rates increase. In addition, the highest agronomic efficiency (9.59 kg kg^{-1}), apparent recovery of N (48.97%) and P (12.80%) and physiological efficiency of N (49.49kg kg^{-1}) and P (210.0 kg kg^{-1}) were obtained from plots that received 150 kg NPSBZn + 44 kg N ha^{-1} blended fertilizer. All the crop yield parameters were linearly increased with rising blended fertilizer rates up to certain level and declined afterwards. Finally, the application of 150 kg NPSBZn + 44 kg N ha^{-1} blended fertilizer rate elucidated a higher fruit yield as, compared to recommended NP fertilizer practiced at the study area. This could be attributed to its greater solubility in the soil, total nutrient uptake and fertilizer use efficiency, and apparent recovery and the inclusion of micronutrients in its formulation. Therefore, this blended fertilizer rate can be recommended for hot pepper production in Assosa area of Western Ethiopia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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