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Effects of farmyard manure (FYM) and blended NPSB fertilizer rate on growth and yield of potato (*Solanum tuberosum* L.) in Gewata, Kaffa, southwest Ethiopia

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Summary: Potato (*Solanum tuberosum* L.) is an essential crop for nutrition and food security and generating income to small-holder farmers in Ethiopia. Productivity of the crop is, however, limited by poor nutrient management practices and low soil fertility. In most parts of potato growing areas of Ethiopia, soil are deficient in macro (nitrogen, phosphorus and sulfur) and micro nutrients (boron) which are known to affect production and productivity of potato. A field trail was accompanied to determine the growing response of potatoes 'Belete varieties' to combine the treatment of farmyard manure and blended NPSB (nitrogen, phosphorous, sulfur and boron) fertilizer at Gewata, southwest Ethiopia during 2019/2020 main cropping season. The variables are laid out four level of farmyard manure (0, 5, 10 and 15 t/ha) and four level of blended NPSB fertilizer (0, 50, 100, and 150 kg/ha). The treatments were organized in a completely randomized block design with three replications using a 4x4 factorial layout. SAS (version 9.4) was used for data were analyzed. The finding indicate that, combined application of FYM (farmyard manure) with NPSB significantly ($p<0.01$) affects plant height, average mass of tuber, number of marketable and unmarketable tuber per hill, and tuber yields per plot. It also significantly ($p<0.05$) influenced days to flowering, maturity, and tuber number per hill. The highest tuber weight (99.33 g), tuber number per hill (9.67), and yield (34.10 kg) per plot were recorded from the mixed fertilization of 15 t FYM with 150 kg/ha NPSB mineral nutrients. As a current finding, it can be stated that the combined use of FYM (15 t/ha) and NPSB blended fertilizer could improve potato growth and yield in the study area (150 kg/ha).

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Key words: inorganic fertilizer, potato tuber, soil fertility, soil nutrient, nitrogen

Introduction

Potato (*Solanum tuberosum* L.) belongs to the Solanaceae family (Olmstead et al., 1999), originated in Western South America (De Haan & Rodriguez, 2016). Potato ranks fourth in the world's food crops, after rice, wheat, and maize (FAOSTAT, 2019). Its production in the undeveloped country was enlarged, due to its use in food security (Aliche et al., 2018). Potato produces high yield quickly on a pieces of land compared with other crops (Liu et al., 2014: Arega et al., 2018), due to its adaptability to soil conditions and short growth time (Hayilu et al., 2017). In 1858, German botanist Schimper brought it to Ethiopia for the first time (Olmstead et al., 1999; Tesfaye, 2016).

The average national productivity of potatoes is 14.176 t/ha from 73677.64 ha cultivated land during the 2018/19 Maher season (CSA, 2019). This production capacity is little compared to world production potential. The reason for low productivity are poor fertilizer management and low soil fertility (Mohammed et al., 2018) as well as diseases, insect pests problems, lack of sufficient irrigation water (Kemaw et al., 2017). Inadequate fertilizer application rates on potatoes hinder their growth and production (Masrie et al., 2015).

Improvement of potato growth and performance, in modern agriculture, depends on extensive use of chemical fertilizers, certainly, this approach increased the growth of potatoes in the world (Koushal et.al. 2011; Chandini et al., 2019). In Ethiopia Fertilizer need to increase the growth and yield of all crops has been improved especially since 1990, but there is no associated yield increment in agricultural production and particularly in potato (Koroto, 2017). The reason was a lack of information for the small-scale grower on balanced uses of NPSB fertilizers (Assefa, et al., 2021), combined uses of chemical fertilizers with FYM (Bewket, 2019).

On the other hand, soils in the study area were known to be deficient in micro and macronutrients were, blended NPSB (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B) fertilizer was recommended to substitute Diammonium phosphate fertilizer (ATA, 2016). However, small-scale farmers in the research area find it is difficult to pay the higher cost of blended fertilizer containing phosphorus, sulfur, boron, and nitrogen to meet the nutrient needs of their crops (Mustefa, 2019). Combining the application of FYM with inorganic fertilizer like nitrogen and phosphate not only increases potato yield but also decreases the chemical fertilizer purchasing cost by half (Taha et al., 2017).

It is important to advance the fertilizer contents of agricultural soil to enhance crop growth and performance (Gedam et al., 2008. The application of organic inputs like farmyard manure with mineral fertilizers is used to increase soil productivity (Chandini et al., 2019). Integrated application of fertilizers could be the best strategy to restore highly depleted soils fertility and to enhance the economic production of potatoes (Masrie et al., 2015). It results to supplying balanced nutrients and reducing nutrient deficiencies, increasing crop growth, and restoring soil fertility to meet future food supply needs (Mohammed et al., 2018; Koroto, 2019; Alemayehu et al., 2020). It also recycles the nutrient, and help in maintaining soil fertility (Gunjal & Chitodkar, 2017; Taha et al., 2017).

However, the evidence on the mixed fertilization of FYM and blended NPSB fertilizer is not available and poorly understood by smallholders in the research area to improve the growth and production of potatoes. Therefore, this study was initiated with the objective to determine the response of the combined application of blended NPSB fertilizer and FYM on growth performance and production of potatoes in Gewata District, Kaffa zone, in southwestern Ethiopia.

Materials and methods

Description of the experimental site

The field trail was conducted in Achiwa Kebele FTC of Gewata district, Kaffa Zone in southwest Ethiopia during 2019/2020 main cropping season. Geographically, the site is to be found at the latitude of 7˚84'03'' North and longitude of 36˚82'58''East at an altitude of 1870 m.a.s.l. It receives an annual rainfall of 2115 mm. The research area's mean annual lowest and maximum temperatures are, respectively, 11.69 °C and 23.52 °C.

The soil fertility status before planting was analyzed. Soil pH was 5.53, organic carbon 1.37%, total nitrogen 0.12%, available phosphorus 11.11 ppm, cation exchange capacity 17.198 meq/100g, available sulfur 3.92 ppm, available boron 0.43ppm, and texture class of loam.

Materials, procedures, and designs used in experiments

The treatment was conducted by using the potato cultivar of "Belete." It was released from Holetta Agricultural Research Center since 2009. Moderate environmental condition for its growth 1600 – 2800 m altitude above sea level (Arega et al., 2018).

The experiment contains of two factors, namely four FYM application rates (0, 5, 10 and 15 t/ha) and four Blended NPSB fertilizer application rates (0, 50, 100 and 150 kg/ha). Where NPSB (nitrogen, phosphorus, sulfur and boron) is blended fertilizes with nutrient contents of N 18.9%, P_2O_5 37.75%, S 6.7%, and boron 0.01% composition. Factorial arrangement in a completely randomized block design with three replications was the experiment's design ***(Table 1)***.

Experimental procedures

To conduct the experiment, a 56.5 m by 13 m wide farm plot was selected. It was cleared, plowed, harrowed, and leveled. There were three blocks and 48 plots; the size of each plot was 3 m x 3 m (9 m^2) differentiated by a buffer of 0.5 m between plots and one meter between blocks.

Well decomposed FYM was applied as source of organic manure. All organic source nutrient varied depending on treatments were applied 14th days before planting and incorporated with the deep in the soil at a 20 cm (Boru et al., 2017). Blended NPSB fertilizer was applied as an inorganic nutrients. All dose, varying depending on treatments in each plot was applied at 8 cm deep at the time of planting. Uniform tubers of 42-85 g well sprouted, potato tuber was planted 75 cm with 30 cm of spacing (EIAR, 2007). A total of 40 potato seeds where planted in each plot.

Data collection

Data on the growth and performance of potatoes in this experiment were recorded from the net area (3.6 m^2) of the middle of two ridges from sixteen plants by counting, measuring, and weighting mechanisms.

Days to 50% flowering and maturity of potato were counting by the day from emergency of tuber to 50% of flowering and 90% of physiological maturity respectively.

Plant height (PH) was is measured by cent meter from base to apex of the plants. Numbers of stem per hill were measured by counting the stem that comes out from the soil independently.

Marketable and unmarketable tuber number per hill measured by categorizing the tuber which are frees from disease and pest as well as medium to large-sized in marketable and the rest as the reverse is an unmarketable tuber (Getie et al., 2018).

The average tuber number per hill was recorded by counting the numbers of the tuber from each hill. Then the average was taken by dividing the number of tuber by the number of hills. Average tuber mass (g) was measured by weighing the total tuber obtained from each net area of the plots and dividing by the total number of tubers obtained from it.

Total tuber yield per plot (kg) was measured by weighing the total amount of tuber from each net area. The total yield was converted yield per plot.

Data analyses

All data were subjected to analyses of variance (ANOVA), using SAS (statistical software) version 9.4., mean comparison and separation were done by using LSD at a 5% level of significance.

Results and discussion

Days to 50% flowering

Days to 50% flowering of potato was significantly ($P<0.05$) affected by the interaction of FYM and blended NPSB fertilizer rates.

The highest period required to reach 50% of flowering (65.66 days) of potato was gained from mixed fertilization of 15 t/ha FYM +150 kg/ha NPSB blended fertilizer, which was statistically in parity with days to attain 50% flowering (64.33 days) gained from the sole fertilization of 15 t/ha farmyard manure. The shortest duration of days to reach flowering (46.77 days) of potato plants was detected from control treatments ***(Table 1)***.

Table 1: Description of experimental treatment and NPSB nutrient combination.

Treatment	Treatment description	Nutrient content of NPSB			
		N (kg/ha)	P_2O_5 (kg/ha)	S (kg/ha)	B (kg/ha)
T1	Control	0	0	0	0
T2	0 t FYM + 50 kg NPSB/ha	9.45	18.85	3.45	0.05
T3	0 t FYM + 100 kg NPSB/ha	18.9	37.7	6.70	0.10
T4	0 t FYM + 150 kg NPSB/ha	28.35	56.55	10.35	0.15
T5	5 t FYM + 0 kg NPSB/ha	0	0	0	0
T6	5 t FYM + 50 kg NPSB/ha	9.45	18.50	3.45	0.05
T7	5 t FYM + 100 kg NPSB/ha	18.9	37.7	6.70	0.10
T8	5 t FYM + 150 kg NPSB/ha	28.35	56.55	10.35	0.15
T9	10 t FYM + 0 kg NPSB/ha	0	0	0	0
T10	10 t FYM + 50 kg NPSB/ha [1]	9.45	18.50	3.45	0.05
T11	10 t FYM + 100 kg NPSB/ha	18.9	37.7	6.70	0.10
T12	10 t FYM + 150 kg NPSB/ha	28.35	56.55	10.35	0.15
T13	15 t FYM + 0 kg NPSB/ha	0	0	0	0
T14	15 t FYM + 50 kg NPSB/ha	9.45	18.50	3.45	0.05
T15	15 t FYM + 100 kg NPSB/ha	18.9	37.7	6.70	0.10
T16	15 t FYM + 150 kg NPSB/ha	28.35	56.55	10.35	0.15

Note: FYM=farmyard manure, NPSB= blended nitrogen, phosphorous, sulfur and boron, t=tone

Table 2. Phenological and growth response of potato from application of FYM and NPSB.

Treatments		Df	Dm	PH
FYM (t/ha)	NPSB (kg/ha)			
0	0	46.77^{h}	83.667^{i}	65.30^{h}
	50	51.00^{g}	85.33^{hi}	67.30^{hg}
	100	51.33^{g}	87.67^{gh}	70.03^{g}
	150	52.00^{g}	88.00^{g}	79.50^{f}
5	0	54.00^{efg}	91.00^{ef}	80.06^{ef}
	50	52.00^{g}	89.00^{fg}	80.20^{ef}
	100	54.00^{fg}	93.33^{de}	81.06^{ef}
	150	55.33^{def}	95.00^{d}	84.00^{de}
10	0	58.00^{bcd}	94.00^{d}	85.58^{d}
	50	56.67^{de}	93.67^{d}	85.76^{dc}
	100	57.00^{de}	94.00^{d}	87.40^{cd}
	150	57.33^{cd}	95.67^{cd}	89.70^{bc}
15	0	64.33^{a}	100.67^{a}	92.76^{ab}
	50	60.33^{bc}	98.00^{bc}	93.23^{ab}
	100	60.67^{b}	99.00^{ab}	95.20^{a}
	150	65.67^{a}	99.67^{ab}	95.40^{a}
LSD (0.05)		3.13	2.50	4.12
CV (%)		3.35	1.61	2.38

Note: Df = Days to 50% flowering, Dm = Day to maturity, PH = Plant height (cm)

The delayed days to achieve 50% flowering were phosphorous and nitrogen availability in the soil from the mixed treatment of FYM with NPSB blended fertilizer. Those nutrients promote good leaf development and high photosynthesis processing that delays reproduction and extended vegetative growths. This result was consistent with Zewide et al. (2018); Bewket (2019) were combined treating of cattle manure with inorganic fertilizer delays the number of days for a potato to bloom to 50%, due to availability of NP in the soil, which enhance the growth of potato by improving soil structure. Days to 50% reproduction age of potato were prolonged by increasing FYM and NP fertilizer by increasing vegetative growth and delaying reproduction (Balemi, 2012; Masrie et al., 2015; Getie et al., 2015; Mohammed et al., 2018).

Days to maturity

The collaboration outcome of FYM and NPSB blended fertilizer significantly ($p<0.05$) impacts on days to maturity of potato.

High number of days to reach maturity (100.66 days) was obtained from the single fertilization of 15 t/ha farmyard nature, which are statistically at par to days to maturity (99.00 and 99.67 days) recorded from the mixed fertilization of 15 t FYM with 100 kg/ha and 150 kg/ha NPSB blended, respectively. The short duration of the day to attain maturity of potato (83.67 days) was recorded from control treatments, which are statistically in parity with days to maturity (85.33) gained from the sole fertilization of 50 kg/ha NPSB blended mineral nutrients ***(Table 2)***.

Increased days to maturity of potato was incremented of nitrogen and phosphorus in growing soil due to mixed fertilization of farmyard manure with NPSB blended inorganic nutrients ***(Table 5)***. It postpones the amount of time required to attain physiological maturity by increasing vegetative growth and leaf area, which enhances absorption of solar radiation, physiological functions, and the synthesis of carbohydrates.

The finding of the current investigation was agrees with Zewide et al. (2018) and Bewket (2019), where increased combined fertilization of cattle manure with mineral NP had a role on a crop by promoting vegetative growth, increasing leaf area that results from interception of high solar radiation and subsequently delays days to physiological maturity. Increasing essential nutrients in the soil by combining application FYM and NP, delays the number of days until potatoes blossom and mature while increasing vegetative growths (Masrie et al., 2015; Getie et al., 2015).

Plant height (cm)

The mixed fertilization of farmyard manure with NPSB had a significant ($p<0.05$) impact on the height of potato plants.

The highest potato plants height (95.4 cm) was found from a plot with 15 t/ha FYM with 150 kg/ha blended NPSB fertilizer, which was statistically matched with the height of plant (92.76, 93.23 and 95.20 cm) seen from the sole treatment of 15 t/ha farmyard manure, combined with 50 and 100 kg/ha NPSB blended fertilizer ***(Table 2)***, respectively. The shortest height of potato plant (65.30 cm) was observed from zero treatments, which was statistically matched to the plant height of (67.3 cm) that was seen after applying 50 kg/ha of blended NPSB fertilizer alone ***(Table 2)***.

The increased amount of nitrogen, phosphorous, sulfur, and boron in growing experiments increased cell division and vegetative growth, promoted the development of chlorophyll, and resulted in vigorous vegetative growth and taller plants, which was the reason for the increased heights via increased application of FYM and NPSB nutrients.

The present-day investigation is consistent with those stated by Mama et al. (2016); Koroto (2019); Alemayehu et al. (2020) that combined treating of FYM with phosphorus and nitrogen fertilizer, elongated the height of plant by increasing the of elongation cell,, and facilitates of cell division which causes the growth of plants vigorously.

Sulfur plays critical role for chlorophyll development and reaction on leaving the cell of potato to increase plant height (Alemayehu & Jemberie, 2018). Also, Shalini et al. (2002) reported that mixing of organic and mineral nutrients expressively increase growth, vigor, and height of plants over-treating of inorganic alone.

Potato stems per hill

The amount of potato stems per hill was high significantly ($p<0.01$) hindered by the main effects of both FYM and NPSB blended fertilizer, while it was not significantly affected by their combination ***(Table 3)***.

Potato fertilized with the increased level of farmyard manure (15 t/ha) resulted from a high stems number (6.87) per hill. The lowest stems number (6.14) per hill was gotten from non-treated which is statistically in similarity with the number of the stem per hill (6.23) grained from the fertilization of 5 t/ha FYM ***(Table 3)***. In contrast, potatoes fertilized by the highest NPSB blended fertilizer (150 kg/ha) showed the highest stems numbers (6.78) per hill. The lowest amount of the stems per hill (6.28) was gained from control treatments which are statistically in parity to stem numbers (6.28 & 6.36) noted from the treating of 50 and 100 kg NPSB blended fertilizer respectively ***(Table 3)***.

Table 3. Main response of FYM & blended NPSB fertilizer on number of stems per hill.

FYM (t/ha)	NS
0	6.14^{c}
5	6.23^{cd}
10	6.47^{b}
15	6.87^{a}
$LSD_{(0.05)}$	0.252
$CV_{(\%)}$	4.43
NPSB kg/ha	
0	6.28^{b}
50	6.28^{b}
100	6.36^{b}
150	6.78^{a}
LSD (0.05)	0.25
CV (%)	4.43

Note: NS= Number of stems per hill

An increase in the application level of FYM from 0 to 15 t/ha, enhances stems number per hill compared with control treatments. The current finding is in link with of Ababiya (2018), who reported an increase in stems number per hill from 6.5 to 8.2 by 26% as a result of the application of organic manure increased from zero to 30 t/ha. This investigation is also in line with the result of Girma (2017) who stated, an increase in the number of stems per hill as a result of the increasing application of FYM. The current study also match with the result of Monirul et al. (2013) who narrated an increased number of main stems as a result of improved cell division and plant growth due to increased organic fertilizer application.

The increased application of NPSB blended fertilizer from nil to 150 kg/ha, increased stems number per hill compared with control treatments ***(Table 3)***. The current finding is consistent with Mama et al. (2016) reported increasing the application of phosphorus and nitrogen fertilizer from 33.3% to 66.6% increase the stem number per hill by 108% compared to controls. Also, Alemayehu & Jemberie (2018) reported, an increased application rate of nitrogen fertilizer, increased the number of stems due to sulfur roles on chlorophyll formation and reaction in many living cells.

Marketable potato tuber amount per hill: The mixed fertilization of FYM & NPSB blended fertilizer highly significantly ($p<0.01$) affects marketable potato tuber quantity per hill.

The maximum marketable potato tuber number (9.13) per hill was documented from the mixed fertilization of 15 t/ha FYM with 150 kg/ha NPSB fertilizer. The lowermost number of marketable potato tuber numbers (3.32) per hill was gained from the unfertilized treatments ***(Table 4)***.

High marketable potato tuber amount per hill was seen from the high fertilization rate of FYM with NPSB blended fertilizer, due to phosphorus, boron, and nitrogen and sulfur availability in the soil. These nutrients increase vegetative growth, interceptions of solar radiation and mature slowly after full development. It promotes carbohydrate contents in the leaf area and progressively moves from source to sink area. This caused the development of medium to large-sized tubers per hill.

Table 4: Role of FYM and blended NPSB on the numbers of tubers.

Nutriment level		Mth	Uth	Ath	Atm (g)	Tty
FYM (t/ha)	NPSB (kg/ha)					
0	0	3.32^{l}	2.26^{a}	5.60^{i}	70.33^{j}	12.13^{k}
	50	4.33^{kj}	1.90^{cd}	6.23^{h}	77.33^{gh}	15.35^{j}
	100	6.00^{h}	1.42^{f}	7.43^{fg}	78.40^{gh}	15.70^{j}
	150	6.26^{hg}	1.32^{fg}	7.63^{f}	83.10^{ef}	16.57^{ji}
5	0	3.85^{k}	2.22^{a}	6.10^{h}	71.66^{j}	17.30^{hi}
	50	5.24^{i}	1.87^{d}	7.13^{g}	78.00^{gh}	18.63^{g}
	100	6.10^{h}	1.58^{e}	7.70^{f}	80.667^{fg}	18.70^{g}
	150	6.68^{fg}	1.12^{hi}	7.83^{ef}	83.33^{ef}	19.42^{g}
10	0	4.45^{j}	2.08^{b}	6.53^{h}	72.66^{j}	18.30^{hg}
	50	7.08^{ef}	1.26^{g}	8.26^{de}	85.00^{ed}	20.89^{f}
	100	7.30^{de}	1.22^{gh}	8.53^{cd}	87.33^{cd}	23.00^{e}
	150	7.69^{cd}	1.08^{i}	8.76^{c}	89.67^{c}	25.60^{d}
15	0	4.99^{i}	2^{cb}	7.03^{g}	75.733^{ij}	23.74^{e}
	50	7.88^{c}	1.06^{ij}	8.96^{bc}	90.67^{bc}	27.43^{c}
	100	8.38^{b}	0.97^{j}	9.33^{b}	94.07^{b}	30.07^{b}
	150	9.13^{a}	0.84^{k}	9.96^{a}	99.33^{a}	34.10^{a}
LSD (0.05)		0.48	0.48	0.46	3.59	3.5933
CV (%)		4.68	4.00	3.61	2.61	2.617

Note: Mth = Marketable tubers number per hill, Uth = Unmarketable number of tubers per hill, Ath = Average of number tuber per hill, Atm (g) = Average tuber mass in gram Tty= Total tuber yield per plot, and CV = coefficient of variance, LSD = Least the significant difference. ^{abcdefgh} Columns with different superscript letters are indicates means are statistically significant at ($P \leq 0.05$) and with the same a letter are statistically not different.

Table 5: Physicochemical properties of experimental soil after harvesting.

Treatment		pH	% OC	% TN	Av.P (ppm)	Texture %			CEC (meq/100g)	Av.B (ppm)	Av.S (ppm)
FYM (t/ha)	NPSB (kg/ha)					Sand	Clay	Silt			
0	0	5.48	1.45	0.11	10.25	40.00	28.00	32.00	15.72	0.41	4.21
	50	5.32	1.87	0.16	11.36	42.00	26.00	32.00	16.35	0.49	5.32
	100	5.40	2.09	0.20	11.53	44.00	27.00	29.00	17.27	0.50	5.49
	150	5.31	2.03	0.28	11.57	41.00	24.00	35.00	17.33	0.51	5.53
5	0	6.54	2.57	0.29	11.41	46.00	22.00	32.00	19.06	0.50	5.37
	50	5.58	2.05	0.30	12.07	42.00	25.00	33.00	17.58	0.54	6.03
	100	5.44	2.10	0.31	12.54	40.00	26.00	34.00	17.49	0.57	6.50
	150	5.31	2.12	0.27	12.72	46.00	22.00	32.00	17.85	0.59	6.68
10	0	6.57	2.61	0.30	12.67	41.00	27.00	32.00	20.06	0.58	6.63
	50	5.57	2.09	0.19	12.09	42.00	26.00	32.00	17.87	0.54	6.05
	100	5.50	2.75	0.25	12.38	48.00	22.00	30.00	18.66	0.56	6.34
	150	5.22	2.57	0.31	12.80	43.00	27.00	30.00	20.23	0.59	6.76
15	0	6.77	2.89	0.31	12.09	44.00	28.00	28.00	21.60	0.54	6.05
	50	5.57	2.12	0.26	12.88	47.00	22.00	31.00	18.89	0.56	6.84
	100	5.48	2.71	0.31	12.91	44.00	26.00	30.00	18.40	0.56	6.87
	150	5.48	2.40	0.30	12.94	39.00	30.00	31.00	20.19	0.56	6.90

Note: pH = Power of hydrogen, % OC = Organic carbon (%), % TN = Total Nitrogen (%), AV.P (ppm) = Available phosphorous (ppm), CEC (meq/100g) = Cation exarches capacity (meq/100g), AV.S (ppm) = Available sulfur (ppm) and AV.B (ppm) = Available boron (ppm)

The current finding supported with Monirul et al. (2013), who stated that mixed fertilization of cow and poultry drug, and nitrogen nutrients, increased marketable tuber per hill by creating favorable conditions for growth and development of tuber bearing stolon. The application of residue of crop, farmyard manure, and bio-fertilizer with inorganic fertilizer increased high grade, free from disease, and large size potato tuber due to availability of NP fertilizer from applied sources (Dasgupta et al., 2017). Also, Zewide et al. (2018) informed that mixed the application of cattle manure and NP inorganic fertilizer increased marketable tuber per hill from 50.2% to 56.7% compared with unfertilized fields, due to high

integration of nutrients trigger vegetative growth and developments. According to Bewket et al. (2018), the fertilization of a high amount of cattle manure and NPSZnB recovers the structure of the soil which was essential for water and nutrient absorption that results the development of large and medium sized tubers. Also, Ahmed et al. (2015) stated that, enhanced fertilization of FYM and NP fertilizer improved the potato tuber at marketable size.

Unmarketable number of tuber per hill

Unmarketable number of tuber per hill was highly significantly ($p<0.01$) influenced by the interaction of farmyard manure and NPSB blended fertilizer.

The highest unmarketable potato tuber number (2.26) per hill was observed from zero treatments, which are statistically at par with unmarketable potato tuber number (2.22) per hill obtained from the sole application of 5 t/ha FYM. The lowest unmarketable tuber number per hill (0.84) was obtained from a mixed fertilization level of 15 t/ha farmyard manure with 150 kg/ha blended NPSB fertilizer ***(Table 4)***.

Increased amount of unmarketable tuber per hill noted from control treatment was due to deficiency of nitrogen, phosphorus, and boron nutrients. Nutrients in the soil did not meet nutrient requirements of potato for growth, physiological processes, cell division, and stolon developments (Bewket. 2019). These results in early maturity without full development, susceptibility to disease and pest damages, increased small size, diseased and defected potato tubers.

The result of the current research is in line with Bewket et al. (2018), who narrated that, deficiency of boron in the soil, affects nitrogen and phosphorus absorption, as influenced cell division, chlorophyll synthesis, photo assimilation, and increase small-sized, defected and diseased tubers. Also, Zewide et al. (2018) informed that shortage of nitrogen and phosphorous increases unmarketable tuber number per hill by affecting vegetative growth of the potato. Dasgupta et al. (2017), reported that the size of potato tuber was deteriorated due to insufficient (nil) application of FYM or nitrogen and phosphorus fertilizers.

The average tubers number per hill

Average number potato tuber per hill was highly significantly ($p<0.01$) affected by the interaction of FYM and NPSB blended fertilizer.

The maximum tuber number (9.96) per hill was obtained from the mixed treatment of 15 t/ha FYM +150 kg/ha NPSB blended fertilizer. The lowest number of tubers per hill (5.60) was obtained from the control treatment ***(Table 4)***.

This was due to the availability of phosphorus and nitrogen in the soil. It might increase the number and length of tuber bearing stolen and promotes gibberellic acid biosynthesis as a result increased number of tubers.

The present-day result is in agree with the result of Kafle et al. (2019) were mixed fertilization with FYMF, Poultry manure, or Vermicompost and chemical fertilizer increased nutrient availability like N, P and K status in the soil and uptakes, as result increasing potato tuber number per hill. Also, Singh et al. (2018), reported that the combined application of cattle manure and nitrogen fertilizers improves soil aeration, root development, and biological activities in the rhizosphere, and in turn resulted in increased tuber number per hill.

The average number of tuber per hill increased, due to an increased level of nitrogen and phosphorus (Gebremariam et al., 2014; Ahmed et al., 2015). Increasing the application rate of organic FYM and inorganic NP fertilizer, increased tuber number per hill by increasing vegetative growth and increasing potato tuber sets per unit (Zewide et al., 2018)

Average tuber mass (g)

Average tuber mass of potato was highly significantly ($p<0.01$) influenced by the combination of FYM and NPSB blended fertilizer.

The large average tuber mass (99.33 g) was seen from the combined fertilization of 15 t/ha farmyard manure and 150 kg/ha NPSB blended fertilizer. The least potato tuber mass (70.33 g) was seen from the zero fertilized treatment, which was statistically similar to the average tuber weight (71.66, 72.66 and 75.733 g) recorded from the treatment of 5, 10, and 15 t/ha FYM, respectively ***(Table 4)***. This could be the nutrient consumption effectiveness of the potato. An applied nutrients promoted high fertilizer availability, increased vegetative growth, water use efficiency, and physiological process as a result increased the size and weight of tubers.

The result of the present work is similar with the finding of Masrie et al. (2015) and Singh et al. (2018), who informed that large in average tuber weight as a product of the application of increased rate combined cattle manure and NP fertilizer due to balanced nutrient supply released from those nutrient sources. Asfaw (2016) also confirms that the average weight of tuber was increased when the application of FYM, compost, or woody ash with inorganic soil amendments increased due to more luxuriant growth and a high supply of photoassimilates which helps to produce larger tuber weight.

Total tuber yield per plot (kg)

Yield of tuber per plot, was highly significant ($P<0.01$) affected by mixed fertilization of farmyard manure and blended NPSB fertilizer. The highest yield of potato tuber (34.10 kg) per plot was gained from combination application of 15 t/ha FYM with 150 kg/ha NPSB blended fertilizers and the lowest (12.13 kg) was obtained from control ***(Table 4).***

Tuber yield per plot improvement was attributed to the increased nutrient availability in the experimental field from the mixed fertilization of farmyard manure with blended NPSB fertilizers. Those results increased vegetative growth and the number of tuber-bearing stoles (Asfaw, 2016). The current study was in line with Masrie et al. (2015), the existences of essential nutrients in manure and balanced supply of NP, contributes to expansion of cell wall, cell division, meristematic activities, photosynthesis proficiency, and improving of water uptake resulting in enhancements of yield parameters. Potato yield increases due to increased tuber weight, tuber girth, and the high proportion of large and medium-sized tubers resulting from sufficient fertilization of cattle manure and NP fertilizers (Asfaw, 2016; Singh et al., 2018).

The physico-chemical properties of soil after harvesting of crops

Due to the high nutrient releasing the potential of farmyard manure, the highest total Nitrogen (0.31%) was noted from the sole treating of 15 t/ha farmyard manure and the least was (0.11%) observed from control ***(Table 5).*** The highest amount

of available phosphorus content (12.94 ppm) was seen from the mixed fertilization of 15 t/ha FYM and blended 150 kg NPSB fertilizer, the lowest (10.25 ppm) seen from the control. The highest available boron and sulfur obtained in the study site were (0.56 ppm and 6.90 ppm) respectively from the combined treatment of 15 t/ha farmyard manure with 150 kg/ha blended NPSB fertilizer. The highest organic carbon and Cation exchange capacity of experimental soil was (2.89% and 21.60 meq/100 g) respectively, recorded from the sole application of 15 t/ha farmyard manure and the lowest (1.4475% and 15.716 meq/100 g) was gained from the control treatment ***(Table 5).***

Available of K, P, and S as well as N, and B status increased in the soil gradually due to the combined application of inorganics like cattle manure, compost, vermicomposting, or poultry manure or FYM with organic fertilizers (Kafle et al., 2019). It gradually buildup up in the soil, organic carbon, pH, and electron conductibility's of the soils (Saviozzi & Cardelli, 2014; Jarvan et al., 2017). Different organic nitrogenous and phosphorus compounds changed from a simple to usable form, at decomposition time for organic manure like biochar, cattle manure, or FYM in the soils (Mustefa, 2019).

When large amounts of phosphorus bound in soil microbial biomass were fertilized with FYM, higher soil microbial activity improved (Eichler-Löbermann et al., 2007). The mixed application of FYM with NPSB blended fertilizers gradually improves essential nutrient status in the soil (Kafle et al., 2019). This explains that plots received FYM with NPSB had the highest N, P, S or B contents after potato tuber harvesting soil tests.

Conclusions

In most part of the country, potatoes (*Solanum tuberosum* L.) are grown up to 4200 meters above sea level, as a means of generating income and enhancing the growers' food security. Hence, growth and yield components of potato such as days to 50% flowering and maturity, plant height, marketable and average number of tuber per hill, average tuber weight; total yield of tuber per plot increased with an increase in fertilization rates of FYM and blended NPSB fertilizer. The current study indicated that the mixed fertilization of FYM with blended NPSB fertilizer improved the growth and performance of potatoes. Therefore, based on the current finding, in the study region, potatoes can grow effectively and provide benefits to farmers who use a mixed fertilizer application of 15 t FYM with 150 kg/ha NPSB blended fertilizer. However, in the future, the experiment should be conducted in different varieties, locations, and seasons.

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