



## RESEARCH ARTICLE

# Biomass production and nutritional quality of potato tuber as affected by blended fertilizer (NPSB), cattle manure, vermicompost and mineral NP in southwestern Ethiopia

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## ABSTRACT

Keeping in view the declining soil fertility and people's nutritional issues, a research experiment on potato (*Solanum tuberosum* L.) was carried out in Belg (February to May) and Meher (June to October) seasons of 2020 at Abelo in Masha district, southwestern Ethiopia, to gauge the effects of blended mineral NPSB fertilizer, cattle manure (CM), vermicompost (VC) and mineral NP on growth, biomass and tuber nutritional quality. The fertilizer treatments consisted of 7.5 t CM ha<sup>-1</sup> + 75 and 50% of recommended dose of NP fertilizers (RDF), 7.5 t VC ha<sup>-1</sup> + 75, 50 and 25% of NP, 5 t VC ha<sup>-1</sup> + 75% NP, 100 kg NPSB ha<sup>-1</sup> + 61.5 kg P ha<sup>-1</sup> + 146 kg N ha<sup>-1</sup>, 150 kg NPSB ha<sup>-1</sup> + 53.7 kg P ha<sup>-1</sup> + 138 kg N ha<sup>-1</sup>, 200 kg NPSB ha<sup>-1</sup> + 46 kg P ha<sup>-1</sup> + 128 kg N ha<sup>-1</sup>, 100% of NP (165 kg N ha<sup>-1</sup> + 60 kg P ha<sup>-1</sup>) and one no-fertilizer treatment (control) making a total of 11 treatments. The effects of the treatments indicated that the application of 75% of NP and 7.5 t ha<sup>-1</sup> vermicompost significantly increased the plant height, dry shoot and root yields, specific gravity, total soluble solids and starch. On the other hand, the highest crude protein content was recorded at the application of 200 kg NPSB ha<sup>-1</sup> + 46 kg P ha<sup>-1</sup> + 128 kg N ha<sup>-1</sup>. It was summarized that the use of 7.5 t VC ha<sup>-1</sup> + 75% of NP (124 kg N ha<sup>-1</sup>, and 45 kg P ha<sup>-1</sup>) increased the biomass and improved the quality of potato fetching high economic return over the sole application of either 200% mineral NPSB ha<sup>-1</sup> or 150% mineral NPSB ha<sup>-1</sup> or 100% NP or no-application of fertilizer in the study area. In the light of present findings, there is a need to extend these studies using multiple combination ratios of NPSB fertilizer with vermicompost and cattle manure on different soils of varied agro-climatic zones to come up with conclusive recommendations.

## Introduction

Potato is a leading staple food in the world population and it is the second after maize in terms of the number of producer countries (1). Potato is a rich source of energy and supplies many essential nutrients including potassium, phosphorus, manganese, magnesium and vitamins C, B6 and folate (2). In Ethiopia, potato is extensively grown in central, eastern, northwestern and southern parts of the country and these areas together cover approximately 83% of the potato farmers. The southern state SNNPR of the country accounts for about 16.62% of the potato production. However, farmers also produce different crops like enset, maize, wheat, barley, bean, pea, coffee, haricot bean and fruits and vegetables. Among vegetables such as potato, onion, cabbage, beet root, tomato and carrot; potato is the dominant vegetable crop whereas, fruit crops such as papaya, mango,

avocado and coffee are important cash crops of small-scale farmers in the study area. In spite of such a substantial potential for potato production, the productivity is very low (13.8 t ha<sup>-1</sup>) as compared to the world average tuber yield of (19 t ha<sup>-1</sup>) (3). The most limiting factor for potato productivity is the declining soil fertility of Masha district (4). Undoubtedly, Ethiopia inherits a low input-based farming system and the cultivated lands have been supporting agricultural production for decades which has resulted in significant loss of natural fertility. Moreover, the rapid growth of population has necessitated the regular cultivation of fallow lands without the restoration of soil fertility causing nutrient deficiencies in soils. Although efforts are made to come up with improved production technologies, the productivity of potatoes in production fields has remained very low (5). Thus, the

soil fertility decline in subsistence farmers' field is felt as the major limiting factor for the low crop productivity in general and the productivity of potatoes in particular with respect to Sheka Zone, southwestern Ethiopia.

Thus, improving food production and soil resources has become an enormous challenge in the study area. Therefore, a strategy that includes a soil fertility replenishment program having the potential to supply nutrients and arrest the mining of soil fertility is preferable. There is, therefore, a need to take measures to reverse this trend. Due to the decreased use of organic matter like crop residues, cattle manure, compost, etc., there is a great increase in nutrient depletion, therefore the application of organic manure is a crucial component of soil fertility and crop yield (6). Further, sulfur is also an important nutrient for plant growth whose content varies from 0.2 to 0.5% in plant tissues. Sulfur has been found to be an indispensable element for crop production and it is an integral part of proteins, sulpholipids, enzymes etc. (7). Its fertilization helps to enhance the uptake of N, P, K and B in the plant which results in increased crop productivity. Sulfur application at 45 kg ha<sup>-1</sup> in potato has given the highest tuber yield, large and medium-size tubers yield, biomass, specific gravity, sugar and starch contents (8).

The integrated use of 611 kg lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl + 36 kg N ha<sup>-1</sup> have been recommended for higher barley production in acid soil (9). Similarly, grain and straw yields and nutrient (NPKS) uptake by rice crop were significantly increased due to the application of manures or bio-slurries with chemical fertilizers (10). In other agricultural approaches to enhance the nutrient availability, the strategy of the mixed fertilizer and biofertilizer *Trichoderma*-enriched fertilizer application or the inoculation of rhizobacteria is also gaining popularity in different countries. It has been found that microorganisms and plant growth promoting rhizobacteria (PGPR) *Bacillus* spp. enhance nutrient availability, nutrient use efficiency and increase the growth and yield of plants (11, 12). It has also been reported that *Bacillus cereus* and *Klebsiella variicola* were efficient in plant growth promoting activities. The use of PGPR, i.e. *B. cereus* and *K. variicola* significantly increased plant growth and Fe, Zn, Ca, Mg, Cu, Na and K contents of tomato plants (13). The field experiment on potato crop demonstrated that reproductive growth restricts vegetative growth and reduces tuber yield and dry matter content of potato. Fruiting in crop reduced tuber specific gravity and dry matter content while increased P, K, Mg, Fe and Mn content of the tubers. Reproductive growth did not affect tuber Ca, S, Cu and Zn concentrations (14).

The incorporation of organic and inorganic fertilizers apart from supplying essential nutrients it also creates some positive synergetic effect on crop yield and improves soil physical and chemical properties. Thus, there is a need to understand the effects and identify the optimum rates of the newly introduced NPSB fertilizer that contains sulfur and boron for economical production of potatoes.

Moreover, information on the effect of the application of cattle manure, vermicompost, mineral NP and NPSB fertilizers on the growth and nutritional quality of potato tubers is highly imperative too.

## Materials and Methods

### About study site

A farmer's field at Abelo kebele in Masha district was chosen for the experiment conducted in Belg (February to May) and Meher (June to October) cropping seasons during 2020 under rainfed conditions. The research site is located at 7°44'1714" N latitude and 35°30'16" E longitude. The total rainfall was 607.2 mm in Belg and 953.31 mm in Meher growing season. The maximum temperatures during cropping seasons varied from 23.97 °C (May) to 24.84 °C (February) and 24.39 °C (June) to 26.02 °C (October) with a mean maximum temperature of 24.57 °C and 25.38 °C in Belg and Meher seasons, respectively. The minimum temperatures varied between 17.13 °C (May) to 17.54 °C (February) in Belg and 14.93 °C (June) to 15.76 °C (October) in Meher season with a mean minimum temperature of 17.29 °C and 16.21 °C in Belg and Meher seasons, respectively (Fig. 1).

### Experimental materials

Urea (46% N), triple superphosphate (20% P) and NPSB (18.1% N-5.7% P-6.7% S-0.71% B) fertilizers were used apart from cattle manure (CM) and vermicompost (VC) as organic fertilizers. 'Belete' potato variety was used for the study which was released by Holeta Agricultural Research Center, Ethiopia in 2009. The variety matures in 90 to 120 days and gives an average yield of 29.13 t ha<sup>-1</sup> on farmers' field and 44.8 t ha<sup>-1</sup> on the research field (15).

### Treatment and experimental design

Six fertilizer treatments, three blended fertilizer treatments and two controls, i.e. 100% NP (165 kg N ha<sup>-1</sup> + 60 kg P ha<sup>-1</sup>) and no-fertilizer (control treatment) making a total of 11 treatments were arranged (Table 1). The experiment was laid out, exercising all precautions needed for the field experiments, in a randomized complete block design with three replications. The fertilizer was used at the rate of 61.5 kg P ha<sup>-1</sup> + 146 kg N ha<sup>-1</sup> adjusted NP for 100 kg NPSB ha<sup>-1</sup>, 53.7 kg P ha<sup>-1</sup> + 138 kg N ha<sup>-1</sup> adjusted NP for 150 kg NPSB ha<sup>-1</sup>, 46 kg P ha<sup>-1</sup> + 128 kg N ha<sup>-1</sup> adjusted NP for 200 kg NPSB ha<sup>-1</sup>. Whereas, 146 kg N ha<sup>-1</sup> + 61.5 kg P ha<sup>-1</sup>, 138 kg N ha<sup>-1</sup> + 53.7 kg P ha<sup>-1</sup> and 128 kg N ha<sup>-1</sup> + 46 kg P ha<sup>-1</sup> were added respectively to the blended fertilizer as triple super phosphate for 100 kg NPSB, 150 kg NPSB and 200 kg NPSB ha<sup>-1</sup> to bring the macronutrients of blended fertilizer equal to the recommended N and P and six fertilizer treatments used were selected based on their high yield and high economic net return both in Belg and Meher seasons from the two separate experiments conducted earlier.

### Experimental procedures

A month before planting, cattle manure at the rate of 7.5 t ha<sup>-1</sup> and vermicompost at the rates of 5 and 7.5 t ha<sup>-1</sup> were mixed in plots as per treatment

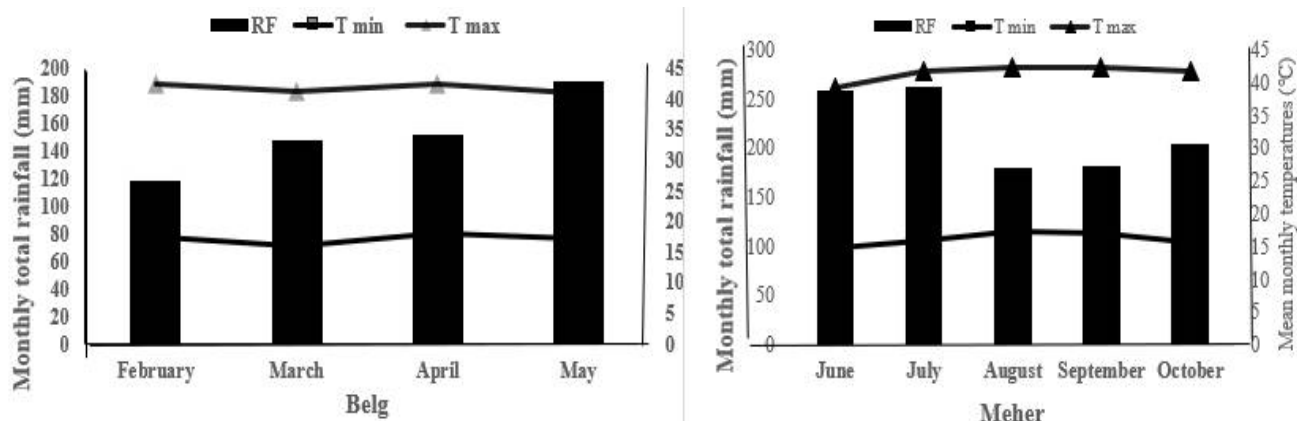


Fig. 1. Monthly mean maximum (Tmax) and minimum (Tmin) temperatures (°C) and monthly total rainfall (mm) of the study site in Belg and Meher cropping seasons.

Table 1. Description of treatment combinations

Treat ment	Description
T1	No-fertilizer (control)
T2	165 kg N ha <sup>-1</sup> + 60 kg P ha <sup>-1</sup>
T3	100 kg NPSB ha <sup>-1</sup> + 61.5 kg P ha <sup>-1</sup> + 146 kg N ha <sup>-1</sup>
T4	150 kg NPSB ha <sup>-1</sup> + 53.7 kg P ha <sup>-1</sup> + 138 kg N ha <sup>-1</sup>
T5	200 kg NPSB ha <sup>-1</sup> + 46 kg P ha <sup>-1</sup> + 128 kg N ha <sup>-1</sup>
T6	124 kg N ha <sup>-1</sup> + 45 kg P ha <sup>-1</sup> + 5 t Vermicompost ha <sup>-1</sup>
T7	82.5 kg N ha <sup>-1</sup> + 30 kg P ha <sup>-1</sup> + 7.5 t Cattle manure ha <sup>-1</sup>
T8	41.25 kg N ha <sup>-1</sup> + 15 kg P ha <sup>-1</sup> + 7.5 t Vermicompost ha <sup>-1</sup>
T9	124 kg N ha <sup>-1</sup> + 45 kg P ha <sup>-1</sup> + 7.5 t Cattle manure ha <sup>-1</sup>
T10	82.5 kg N ha <sup>-1</sup> + 30 kg P ha <sup>-1</sup> + 7.5 t Vermicompost ha <sup>-1</sup>
T11	124 kg N ha <sup>-1</sup> + 45 kg P ha <sup>-1</sup> + 7.5. t vermicompost ha <sup>-1</sup>

requirements. Pre-sprouted potato tuber of uniform size was planted on February 02, 2020, in Belg and on June 02, 2020, in Meher season. Triple superphosphate was mixed well with the soil near the hills, while urea was side-dressed @ 25%, 50%, and the rest 25% at plant emergence, mid-stage (40 days after planting) and tuber initiation stage, respectively. When plants reached physiological maturity, dehaluming practice was adopted to thicken the tuber periderm. When 70% of haulms were dried harvesting was done (16).

### Data collection

#### Phenology and growth parameters

Observations on 50% flowering, 70% maturity, plant height, number of main stems hill<sup>-1</sup> and dry root and shoot biomass were recorded (17).

#### Tuber quality parameters

##### Tuber size distribution (%):

All tubers from ten randomly selected hills were categorized into small (< 39 gm), medium (39-75 gm), and large (>75 gm) sizes (18).

##### Specific gravity of tubers (g cm<sup>-3</sup>):

Tubers amounting 5 kg were randomly sampled from each treatment. The selected tubers were washed, weighed in air and then reweighed by submerging them in water. Specific gravity was calculated using the following formula (19).

$$SG = \frac{W_a}{W_a - W_w}$$

Where, SG= Specific gravity in gm cm<sup>-3</sup>, Wa= Weight in the air, Ww= Weight in water.

#### Dry matter content of tuber

Ten tubers representing all size categories were chopped into small-sized 1-2 cm cubes, mixed thoroughly and subsamples each weighing 200 gm were taken and placed in a separate paper bag and placed in the oven until constant weight was attained. The dry weight of each subsample was recorded. The percent dry matter was calculated as follows (16):

$$DM(\%) = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times 100$$

#### Statistical analysis

Data were analyzed using SAS software program version 9.2 and homogeneity of variances was calculated (20). A separate analysis was used for the two seasons and the least significant difference (LSD 0.05) was employed to separate treatment means.

## Results and Discussion

### Phenology and growth parameters of potato

#### Days to flowering and maturity

The analysis of variance revealed that fertilizer management significantly ( $p < 0.01$ ) influenced days to 50% flowering and days to 70% maturity in both seasons (Table 2). Fertilizer management treatment indicated that 75% mineral NP + 7.5 t VC ha<sup>-1</sup> attained significantly delayed 50% flowering taking 68 days in Belg and 71 days in Meher pushing 70% maturity to 104 and 112 days, whereas the shortest days to flowering were counted to be 61 days in both seasons for the control treatment. It was observed that both processes of flowering and maturity were hastened as the rates of mineral NP and VC decreased. The possible reason might be attributed to the synergistic effects of the fertilizers in the stimulation of enhanced cell division, promoting cell growth and prolonging vegetative growth for a relatively long

**Table 2.** Days to flowering (DF), days to maturity (DM), Number of main stems (NMS) per hill, Plant height (PH) (cm), Shoot dry weight (SDW gm hill<sup>-1</sup>) and Root dry weight (RDW gm hill<sup>-1</sup>) of potato as affected by the application of blended NPSB, cattle manure, vermicompost and NP fertilizer in Belg and Meher seasons

Treatment	Belg season						Meher season					
	DF	DM	NMS	PH	SDW	RDW	DF	DM	NMS	PH	SDW	RDW
No-fertilizer (control)	61d	95c	5.26	56.0e	35.33f	5.95e	61e	93e	5.3	61.97e	38.45f	6.64d
100% NP	63cd	97d	5.00	56.3e	36.33f	6.27de	67d	107d	5.76	68.64e	52.34e	9.12c
100 kg NPSB ha <sup>-1</sup> + adjusted NP	64bc	99abc	6.60	61.3d	40def	6.61cde	68cd	108cd	5.56	68.79e	52.34e	9.35c
150 kg NPSB ha <sup>-1</sup> + adjusted NP	64bc	100abc	6.40	62.3cd	40.3def	7.26bcde	68cd	110abcd	5.96	70.97bc	53.67de	9.41c
200 kg NPSB ha <sup>-1</sup> + adjusted NP	64bc	100abc	6.40	63.3bc	42.7cde	7.73abc	68cd	108bcd	6.3	71.23de	54.79d	9.31c
50% NP + 5 t VC ha <sup>-1</sup>	65abc	101ab	5.40	66.0abc	45.7bcd	7.44bcd	71a	108bcd	6.63	73.14cd	57.34c	10.04ab
50% NP + 7.5 t CM ha <sup>-1</sup>	64bc	101ab	5.13	66.3ab	48abc	8.62ab	70.7ab	109abcd	6.23	73.53cd	58.12bc	9.49bc
75% NP + 5 t VC ha <sup>-1</sup>	66ab	101ab	4.93	66.3ab	50ab	7.89abc	69abc	110abcd	5.9	73.97bc	60.342ab	9.48bc
75% NP + 7.5 t CM ha <sup>-1</sup>	66a	104a	5.20	66.3ab	50.67ab	8.10ab	71ab	111abc	5.7	76.36ab	60.34ab	9.56bc
50% NP + 7.5 t VC ha <sup>-1</sup>	67a	104a	5.06	66.6ab	52.33a	8.62ab	71ab	111ab	6.23	77.60a	61.01a	10.04ab
75% NP + 7.5 t VC ha <sup>-1</sup>	68a	104a	5.20	68.3a	53.66a	8.94a	71a	112a	4.9	78.97a	62.01a	10.22a
LSD (5%)	2.21	5.31	NS	2.13	7.312	1.370	2.464	3.485	NS	2.628	2.377	2.09
Significance	**	*	NS	**	**	**	**	**	NS	**	**	**
CV (%)	2.00	3.11	19	3.65	9.54	10.74	2.12	1.90	16.53	2.13	2.51	3.86

Means followed by the same letter within a column are non-significant ( $p > 0.05$ ), \*denotes significantly ( $p < 0.05$ ) different, \*\* denotes significant at 1% level of probability, NS= Non-significant, VC= Vermicompost, CM= Cattle manure, 146 kg N ha<sup>-1</sup> + 61.5 kg P ha<sup>-1</sup> adjusted NP for 100 kg NPSB ha<sup>-1</sup>, 138 kg N ha<sup>-1</sup> + 53.7 kg P ha<sup>-1</sup> adjusted NP for 150 kg NPSB ha<sup>-1</sup>, 128 kg N ha<sup>-1</sup> + 46 kg P ha<sup>-1</sup> adjusted NP for 200 kg NPSB ha<sup>-1</sup>.

period owing to sufficient supply of NP from the mineral fertilizers as well as organic carbon and possibly other mineral nutrients including micronutrients from the VC and CM. The prolonged days required by plants to reach 50% flowering in response to increasing rates of nitrogen and phosphorus might also contribute to better root development and increased uptake of macro- and micronutrients, which lead to enhanced vegetative growth (21).

### Plant height

The analysis of variance revealed that fertilizer management treatment highly significantly ( $p < 0.01$ ) affected the potato plant height in both seasons. However, these treatments did not significantly influence the number of stems hill<sup>-1</sup> in both seasons (Table 2). The highest plant heights of 68.33 cm in Belg and 78.97 cm in Meher season were obtained at the combined application of 75% of recommended NP with 7.5 t VC ha<sup>-1</sup> which was statistically not different from the heights obtained in all treatments containing organic manure.

In contrast, no-fertilizer treatment (control) recorded the smallest plant height (56 cm) in Belg and 61.97 cm in Meher, which are statistically the same as those of 100% NP in Belg and 100% NP, 100 kg NPSB ha<sup>-1</sup> in Meher. The highest plant height of potato (69.33 and 78.67 cm) in Belg and Meher seasons, respectively obtained from the combined application of 7.5 t CM ha<sup>-1</sup> with 75% of NP as compared to the no-fertilizer treatment (control) (55.96 cm to 69.33 cm) in Belg and Meher seasons (22). Similarly, it has been demonstrated that the combined use of 3 t ha<sup>-1</sup> vermicompost + Panchagvaya spray (3% at 30, 60 and 75 DAS) + Liquid manure (2000 l ha<sup>-1</sup>) + Jeevamruta

(2000 l ha<sup>-1</sup>) caused a taller plants (26.8 cm) compared to the application of NPK alone or no-application of NPK (23).

### Biomass yield

#### Shoot dry weight

The results indicated that the dry biomass yield of aboveground parts were influenced ( $p < 0.01$ ) by fertilizer management in both seasons (Table 2). The maximum dry weights hill<sup>-1</sup>, 53.66 gm in Belg and 62.01 gm hill<sup>-1</sup> in Meher were recorded in the combined application of 75% mineral NP + 7.5 t ha<sup>-1</sup> vermicompost. The use of NP and vermicompost together resulted in better dry matter yield than the use of mineral fertilizer alone probably because of more nutrients made available from the vermicompost as well as the improved physicochemical and microbial conditions of the soil. This situation possibly resulted in increased leaf expansion and increased leaf number that led to increased concentration of chlorophyll in the leaves, thereby enhancing the rate of photosynthesis, resulting in a high rate of dry matter accumulation in the aboveground biomass. The highest shoot dry weight (59.33 gm hill<sup>-1</sup> and 56.67 gm hill<sup>-1</sup>) were recorded at the highest rate of 7.5 CM t ha<sup>-1</sup> + 75% of NP in Belg and Meher seasons respectively (22). In potato crop, maximum shoot dry matter (68 gm hill<sup>-1</sup>) with integrated use of 120 kg N ha<sup>-1</sup> + 10 t ha<sup>-1</sup> vermicompost was obtained as compared to the treatment that did not receive any of the fertilizer treatment combination (55 gm hill<sup>-1</sup>) (24). The present results agree with an earlier work (25) who demonstrated that the maximum amount of shoot dry matter could be obtained by the combined application of compost and chemical fertilizer.



## Root dry weight

Fertilizer treatment significantly ( $p < 0.05$ ) influenced the root dry weight both in the Belg and Meher seasons (Table 2). Accordingly, 75% NP + 7.5 t VC ha<sup>-1</sup> had resulted in the highest root dry weight of 8.94 gm in Belg and 10.22 gm in Meher season. However, the lowest root dry weights of 5.95 gm in Belg and 6.64 gm in Meher were obtained at no-fertilizer treatment (control). As mentioned earlier, this might be due to vermicompost addition which improves soil physico-chemical and biological properties, thereby increasing the availability of micro- and macronutrients in soil and enhance the uptake by plant tissues as there is a positive relation of the concentration of nutrients in the plant with root and shoot dry biomass of potato (22). Similar result was recorded earlier (26) who reported the maximum dry weight (87.07 gm plant<sup>-1</sup>) when 75% NP + 2 t ha<sup>-1</sup> VC + 20 kg ha<sup>-1</sup> sulfur + 20 kg ha<sup>-1</sup> zinc sulfate + Azotobacter (seed treatment) were administered which was superior to 100% NP and no-fertilizer treatment (control). Accordingly, the application of 7.5 t CM ha<sup>-1</sup> in combination with 75% of NP gave the highest root dry weight of 9.34 gm hill<sup>-1</sup> in Belg and 9.59 gm hill<sup>-1</sup> in Meher (22).

## Tuber quality parameters

### Potato tuber size category

There was a significant difference ( $p < 0.05$ ) between the medium and small-sized tuber categories due to fertilizer management treatment in both seasons, but the effect was nonsignificant for large-sized tubers (Table 3). The highest proportions of medium size tuber category of 47.7% in Belg and 68% in Meher season were obtained when 7.5 t vermicompost ha<sup>-1</sup> and 75% of the recommended rate of NP were added together. On the other hand, the lowest proportions of medium size tuber category (28%) in Belg and

46.19% in Meher season were from control treatment. It has been reported that using 2.0 t ha<sup>-1</sup> wood ash + 5.0 t FYM ha<sup>-1</sup> + 5.0 t CM ha<sup>-1</sup> + 100% NP (111 kg N + 40 kg P ha<sup>-1</sup>) yielded the greatest medium size tuber weight of 62.03% and the lowest (37.10%) in control treatment. Similarly, fertilizer management had a highly significantly ( $p < 0.01$ ) effect on the proportion of small size tuber categories in both seasons. The proportion of small tuber size category ranged from 48.57% and 26.99%, which was registered from the use of 7.5 t VC ha<sup>-1</sup> + 75% mineral NP. However, a higher percentage of small-sized tuber category of 63.52% and 48.57% were obtained from the control treatment (control) in Belg and Meher seasons, respectively. However, there was no significant difference among large-sized tubers in both seasons (27).

The significant decrease in small size tuber was due to vermicompost and mineral NP application which may have brought an improvement in soil structure that probably helped use nutrients efficiently resulting in an increase in tuber size than the number. Besides, N and P in the soil and vermicompost might have caused the increase in size of the tuber, reflecting the improved allocation of photosynthate to the tubers as a result of enhanced soil physical and chemical properties. It has been found that the application of vermicompost at 10 t ha<sup>-1</sup> together with mineral fertilizers to complete the rest of the 100% of the recommended fertilizer dose of 150 N, 75 P, 75 K (CFNP) + microbial consortium reduced the number of small size tubers from 13.4% in control treatment to 8.8% in the test treatment (28).

### Specific gravity (SG) of tubers

A highly significant ( $p < 0.01$ ) effect of fertilizers was observed on the specific gravity and dry matter content of potato tubers in both seasons (Table 4). Accordingly, the highest specific gravity of 1.107 gm

**Table 3.** Percentage of large size tuber (LST) (>75 gm), medium size tuber (MST) (75-39 gm) and small size tubers (SST) (<39 gm) of potato as affected by the integrated use of NPSB, cattle manure, vermicompost and NP fertilizers.

Treatment	Belg			Meher		
	LST	MST	SST	LST	MST	SST
No-fertilizer (control)	8.48	28.00d	63.52a	9.95	46.19g	43.86a
100% NP	9.50	28.98d	61.52a	15.45	50.44fg	34.11b
100 kg NPSB ha <sup>-1</sup> + adjusted NP	10.02	30.13d	59.85ab	12.14	54.88ef	32.98bc
150 kg NPSB ha <sup>-1</sup> + adjusted NP	12.49	30.31d	57.20bc	11.01	55.59def	33.40bc
200 kg NPSB ha <sup>-1</sup> + adjusted NP	14.04	30.65cd	55.31cd	10.43	56.20cdef	33.37bc
50% NP + 5 t VC ha <sup>-1</sup>	12.10	34.25cd	53.65cde	9.36	59.69bcde	30.95bcd
50% NP + 7.5 t CM ha <sup>-1</sup>	11.46	36.04cd	52.50def	10.74	61.47bcd	27.785d
75% NP + 5 t VC ha <sup>-1</sup>	9.80	38.66bc	51.54def	8.71	61.90bc	29.39cd
75% NP + 7.5 t CM ha <sup>-1</sup>	4.25	45.19ab	50.56ef	10.42	62.60ab	26.98d
50% NP + 7.5 t VC ha <sup>-1</sup>	5.05	45.38ab	49.57ef	6.53	65.69ab	27.78d
75% NP + 7.5 t VC ha <sup>-1</sup>	3.76	47.67a	48.57f	5.01	68.00a	26.99d
LSD (5%)	NS	8.105	4.297	NS	6.062	4.439
Significance	NS	**	**	NS	**	**
CV (%)	35.17	13.22	4.6	41.92	6.09	8.13

Means followed by the same letter within a column are non-significant ( $p > 0.05$ ) and \*\* denotes significant difference at 1% level of probability, NS=Non-significant, VC= Vermicompost, CM= Cattle manure, 146 kg N ha<sup>-1</sup> + 61.5 kg P ha<sup>-1</sup> adjusted NP for 100 kg NPSB ha<sup>-1</sup>, 138 kg N ha<sup>-1</sup> + 53.7 kg P ha<sup>-1</sup> adjusted NP for 150 kg NPSB ha<sup>-1</sup>, 128 kg N ha<sup>-1</sup> + 46 kg P ha<sup>-1</sup> adjusted NP for 200 kg NPSB ha<sup>-1</sup>.

cm<sup>-3</sup> in Belg and 1.11 gm cm<sup>-3</sup> in Meher were observed with the use of 7.5 t VC ha<sup>-1</sup> + 75% of the recommended rate of mineral NP, the lowest values of specific gravity (1.082 gm cm<sup>-3</sup>) in Belg and 1.084 gm cm<sup>-3</sup> in Meher were obtained in the no-fertilizer treatment. The increment in specific gravity might be associated with the vermicompost and mineral N that enhance the availability of nutrients to plant that ultimately increases the biomass. In line with this result, it was also reported that the increased nitrogen application from 0 to 56 kg ha<sup>-1</sup> significantly enhanced the specific gravity of potato tubers, which ranged from 1.05 to 1.06 gm cm<sup>-3</sup> (29). It has also been demonstrated that increasing vermicompost and mineral fertilizer tend to increase the highest specific gravity of 1.1 gm cm<sup>-3</sup> in Belg and 1.107 gm cm<sup>-3</sup> in Meher in the combined application of 75% of NP + 7.5 t ha<sup>-1</sup> VC (22).

#### Dry matter content (DMC) of tubers

Fertilizer management indicated that the highest dry matter contents of 26.71% in Belg and 25.9% in Meher were recorded in the treatment having 7.5 t VC ha<sup>-1</sup> + 75% NP. While, the lowest 21.28 gm in Belg and 21 gm in Meher season were obtained in control treatment (Table 4). The highest tuber dry matter content of 24.14% in Belg and 25.78% in Meher were recorded at the combination of 7.5 t ha<sup>-1</sup> VC + 75% mineral NP. The lowest dry matter content of 20.21% in Belg and 20.54% in Meher were recorded for the control (22). The significant increase in dry matter content was due to vermicompost and mineral NP application which may have brought an improvement in soil structure that probably helped to use nutrients efficiently. Besides, N and P in the soil and vermicompost might have caused the increase in size of the tuber, reflecting the improved allocation of photosynthate to the tubers.

#### Total soluble solids (TSS)

The effects of fertilizer management were significant ( $p < 0.05$ ) for total soluble solids, starch content and crude protein content of tubers (Table 5). The highest total soluble solids of 8.43 °Brix in Belg and 9.54 °Brix in Meher season were observed at 75% NP + 7.5 t VC

ha<sup>-1</sup> which were statistically the same as those obtained from the treatments consisting of VC and CM in Belg apart from those such as 50% NP + 7.5 t VC ha<sup>-1</sup>, 75% NP + 7.5 t CM ha<sup>-1</sup> in Meher. The content of total soluble solids (5.78 °Brix) in Belg and 4.52 °Brix in Meher under control treatment with rest of the treatments statistically the same. The combined organic and urea treatment at the rates of 309 kg ha<sup>-1</sup> and 68.5 kg ha<sup>-1</sup> respectively, resulted in better accumulation of total soluble solids in carrot at the time of harvest (29).

#### Starch content

Furthermore, the effect of fertilizer indicated that the highest starch content of 19.26% in Belg and 19.75% in Meher were obtained from the application of 7.5 t VC ha<sup>-1</sup> + 75% recommended rate of mineral NP (124 kg N ha<sup>-1</sup> and 45 kg P ha<sup>-1</sup>), while the lowest starch contents of 14.32% in Belg and 14.72% in Meher were obtained in control treatment (Table 5). The increase in starch content with the increase in nutrient dosage is attributed to the role of vermicompost in plant nutrition. The effect of mineral fertilizers and vermicompost on the starch content of the tubers has been studied and reported that the application of 82 kg N ha<sup>-1</sup> + 29 kg P ha<sup>-1</sup> and 7.5 t vermicompost ha<sup>-1</sup> increased the starch content by 12% as compared to the application of any fertilizer (30).

#### Crude protein content

As for the crude protein content, the highest values of 13.17% in Belg and 19.74% in Meher season were obtained by the application of 200 kg blended NPSB ha<sup>-1</sup> + 128 kg N ha<sup>-1</sup> while, the lowest crude protein contents of 7.29% in Belg and 8.32% in Meher were obtained in treatment receiving none of the fertilizers (Table 5). The increase of tuber nitrogen with increasing NPSB application rate observed in the present study is probably due to sulfur and boron which improve the accumulation and partitioning of nitrogen in tubers and sulfur is a component of protein enzymes involved in chlorophyll synthesis. Similarly, it was reported that using potassium sulfate for sulphur fertilization at 100 kg increased crude protein

**Table 4.** Specific gravity (SG g cm<sup>-3</sup>) and dry matter content (DMC%) of potato tubers as affected by the use of blended NPSB, cattle manure, vermicompost and NP fertilizers.

Treatment	Belg season		Meher season	
	SG	DMC	SG	DMC
No-fertilizer (control)	1.0826g	21.28g	1.084h	21.00g
100% NP	0863fg	22.10fg	1.086gh	21.27fg
100 kg NPSB ha <sup>-1</sup> + adjusted NP	1.089ef	22.70ef	1.087fgh	21.42efg
150 kg NPSB ha <sup>-1</sup> + adjusted NP	1.090ef	22.92de	1.089efgh	21.77defg
200 kg NPSB ha <sup>-1</sup> + adjusted NP	1.091de	23.19de	1.089efg	21.88def
50% NP + 5 t VC ha <sup>-1</sup>	1.093de	23.54de	1.092def	22.12cde
50% N P + 7.5 t CM ha <sup>-1</sup>	1.095de	24.11cd	1.0924cde	22.35cd
75% NP + 5 t VC ha <sup>-1</sup>	1.096cd	24.15cd	1.094de	22.54cd
75% NP + 7.5 t CM ha <sup>-1</sup>	1.098bc	24.54bc	1.096bc	22.92c
50% NP + 7.5 t VC ha <sup>-1</sup>	1.101b	25.41b	1.099b	24.03b
75% NP + 7.5 t VC ha <sup>-1</sup>	1.107a	26.71a	1.110a	25.90a
LSD (5%)	0.005	0.98	0.004	0.821
Significance	**	**	**	**
CV (%)	0.24	2.43	0.23	2.14

Means followed by the different letter within a column are significantly different from each other; \*\* denotes difference at 1% level of probability, VC= Vermicompost, CM= Cattle manure, 146 kg N ha<sup>-1</sup> + 61.5 kg P ha<sup>-1</sup> adjusted NP for 100 kg NPSB ha<sup>-1</sup>, 138 kg N ha<sup>-1</sup> + 53.7 kg P ha<sup>-1</sup> adjusted NP for 150 kg NPSB ha<sup>-1</sup>, 128 kg N ha<sup>-1</sup> + 46 kg P ha<sup>-1</sup> adjusted NP for 200 kg NPSB ha<sup>-1</sup>.

**Table 5.** Total soluble solids(TSS °Brix), starch content (SC%) and crude protein content (CP%) of potato tubers as affected by blended NPSB, cattle manure, vermicompost and NP fertilizers.

Treatment	Belg season			Meher season		
	TSS	SC	CP	TSS	SC	CP
No-fertilizer (control)	5.78c	14.32g	7.29c	4.52f	14.72h	8.32h
100% NP	5.78c	15.06fg	7.75bc	5.21ef	15.09gh	10.04gh
100 kg NPSB ha <sup>-1</sup> + adjusted NP	5.82bc	15.61ef	12.97a	5.73def	15.32fgh	15.18bc
150 kg NPSB ha <sup>-1</sup> + adjusted NP	6.04bc	15.81ef	13.08a	5.93de	15.55efgh	17.01b
200 kg NPSB ha <sup>-1</sup> + adjusted NP	6.45bc	16.05de	13.17a	6.26de	15.60efg	19.74a
50% NP + 5 t VC ha <sup>-1</sup>	6.80abc	16.37de	12.86a	6.33de	16.15def	11.30fg
50% NP + 7.5 t CM ha <sup>-1</sup>	7.23abc	16c.89cd	11.95a	6.93cd	16.29cde	13.07def
75% NP + 5 t VC ha <sup>-1</sup>	7.59abc	16.93cd	10.67ab	7.79bc	16.61cd	11.77fg
75% NP + 7.5 t CM ha <sup>-1</sup>	7.84abc	17.2bc	10.51abc	8.22abc	17.08bc	12.34ef
50% NP + 7.5 t VC ha <sup>-1</sup>	8.12ab	18.08b	11.148a	8.61ab	17.64b	14.36cde
75% NP + 7.5 t VC ha <sup>-1</sup>	8.43a	19.26a	11.33a	9.54a	19.75a	14.43cd
LSD (5%)	2.332	0.894	3.34	1.35	0.872	2.062
Significance	**	**	**	**	**	**
CV (%)	19.84	3.18	17.58	11.66	3.13	9.02

Means followed by the same letter within a column are non-significant ( $p > 0.05$ ); \*\* denotes difference at 1% level of probability, VC= Vermicompost, CM= Cattle manure, 146 kg N ha<sup>-1</sup> + 61.5 kg P ha<sup>-1</sup> adjusted NP for 100 kg NPSB ha<sup>-1</sup>, 138 kg N ha<sup>-1</sup> + 53.7 kg P ha<sup>-1</sup> adjusted NP for 150 kg NPSB ha<sup>-1</sup>, 128 kg N ha<sup>-1</sup> + 46 kg P ha<sup>-1</sup> adjusted NP for 200 kg NPSB ha<sup>-1</sup>.

content from 12.2 to 20.6% (31). In addition, it was also reported that the fertilization of sulphur raised up to 45 kg ha<sup>-1</sup> increased the crude protein content from 4.09% in the year 2002 to 4.82% in the year 2003 (32).

## Conclusion

The present study indicated that the growth, biomass, and nutritional quality of potato as well in both seasons of Belg and Meher were significantly affected by the fertilizer management treatments. Among the various treatments, the combined use of 7.5 t VC ha<sup>-1</sup> and 75% of the recommended rate of inorganic NP fertilizers (124 kg N ha<sup>-1</sup> and 45 kg P ha<sup>-1</sup>) gave the highest biomass yield of potato in both seasons. On the other hand, the highest crude protein contents among the potato quality parameters were recorded at the application of 200 kg ha<sup>-1</sup> of blended NPSB, whereas total soluble solid starch contents were highest at the application of 7.5 t VC ha<sup>-1</sup> + 75% of the recommended rate of NP (124 kg N ha<sup>-1</sup> + 45 kg P ha<sup>-1</sup>). Thus, the treatment 7.5 t VC ha<sup>-1</sup> + 75% of the recommended rate of NP (124 kg N ha<sup>-1</sup> + 45 kg P ha<sup>-1</sup>) gave the best results with respect to enhancing biomass and nutritional quality of potatoes in the study area than the use of mineral fertilizers alone. Since the present studies have been attempted only for two seasons and organic fertilizers such as CM and VC have long-term residual effects, there is a need to conduct a long-term study using multiple combination ratios of NPSB fertilizer with vermicompost and cattle manure on different soils in different agro-climatic zones to come up with conclusive recommendations.

## Authors' contributions

Author IZ designed and executed the experiments and drafted the manuscript. SS revised the manuscript critically and made it fit for publishing. HK coordinated the research with IZ and

performed the statistical analyses. All authors read and approved the final manuscript.

## Conflict of interests

The authors declare that they have no conflicts of interest.

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