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Effect of Blended Fertlizer Rates and Planting Density On Yield and Yield Components of Irish Potato (*Solanum Tuberosum* L.) at Gombora Condition, Hadiya Zone, Southern Ethiopia

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Abstract

In most parts of our country, potato is an important food and cash crop and also it has high yielding potential in Southern Ethiopia however, its production and productivity is low owing to a number of constraints. Disordered agronomic practices, like application of low rates of inorganic fertilizers and inappropriate spacing were among the major problems. The experiment was conducted to determine the effect of five rates of blended fertilizer rates (0, 100, 150, 200, and 250 kg NPS ha^{-1}) and intra-row planting spacing of 20cm, 30cm and 40cm and laid out in a factorial arrangement by randomized complete block design replicated three times. The analysis of variance revealed that almost all of yield and yield component parameters were significantly influenced by the treatments. Nevertheless, marketable tuber yield, total tuber yield, stem number per hill, total fresh mass, underground fresh and dry mass were significantly influenced by the interaction of NPS blended fertilizer and intra-row spacing. The highest plant height (96.60cm), highest marketable tuber yield (34.29 tha^{-1}), highest total tuber yield (38.36 t ha^{-1}) and highest total fresh biomass (1274.2 g plant^{-1}) were recorded from NPS rate of 250 kg NPS ha^{-1} and intra-row spacing of 20cm while the lowest recorded from control treatment in wider intra-row spacing (40cm). However, the highest marginal rate of return of (62,824%) with its net benefit value of 306,262.00 ETB ha^{-1} was recorded at rate of 250 kg NPS ha^{-1} in intra-row spacing of 30 cm. And also, application of 250 kg NPS ha^{-1} at closer intra-row spacing of 20 cm had resulted optimum marginal rate of return (62,162.0%) and optimum net benefit (312,427.00 ETB ha^{-1}). Therefore, these two options can alternatively be chosen by depending on the need of farmers. Furthermore, as the study was done at only one location in a single season, it is recommended to repeat the study for more than one season at different locations; even with locally available cultivar.

Keywords: Blended NPS Fertilizer; Crop Management; Intra-Row Spacing; Planting Density; Marginal Rate of Return; Yield

Introduction

Potato (*Solanum tuberosum* L.), family Solanceae or the night shade family, genus Solanum [1] is an herbaceous annual crop cultivated for a tuber in which edible food materials are stored. The crop is native to South America and has been introduced to Ethiopia since 1859 by a German Botanist called Schimper [2]. The crop has been identified as a cheap source of human diet, since it produces more food value per unit time, land and water than any other major crops. It was introduced to Ethiopia around 1858 by Schimper, a German botanist [3]. As agriculture is the pillar for the Ethiopian economy, horticultural crops production is one of the components of the Ethiopian agriculture. It includes different types of fruit and vegetable crop husbandry, of which potato crop production is a major activity.

It is an important food and cash crop in Eastern and Central Africa. It plays a major role in national food security, nutrition, poverty alleviation, income generation, and increased employment in production, processing and marketing sub-sectors (Lung *et al.*, 2007). Nowadays, potato is one of the major world's agricultural crops with annual production of 330 million metric tons and area coverage of 18,651,838 ha [4]. Its production in ton and area in hectare was estimated to be about 17,625,680 tons and 1,765,617 ha in Africa and 572,333 tons and 69,784 ha in Ethiopia [5]. It is one of the major food crops in world producing high food per unit area per unit time. How over, the national average yield is about 8.2t ha^{-1}, which is very low as compared to the world's average production of 17.67 t ha^{-1} [4,5].

Potato is one of the high yielding crops in most parts of our country. However, its production can be constrained by low soil fertility and due to disordered management practices. In our country there is a problem of soil nutrient depletion due to continuous cultivation without adequate replenishment of the mined nutrients [1]. Nutrients such as, Nitrogen, Phosphorous and Potassium can be absorbed in large quantity during the whole growing period of potato and the soil need their increased application for its fertility [6, 7].

The crop requires application of optimum amount of blended fertilizer for its better growth and enhanced yield. It has relatively shallow root and high input crop. And the crop requires an efficient crop management practice to ensure adequate nutrient uptake to attain optimum crop growth and yield [8]. Sulfur is fourth major nutrient after NPK, required by plants. Sulfur plays an essential role in chlorophyll formation and therefore helps to give plants their green color. Sulfur is known to take part in many reactions in all living cells [9]. It is a key component of balanced nutrition required for the production of potato where intensive cropping and use of high grade fertilizers resulted in depletion of soil sulfur. And also, the findings of [8]. it is reported that the use of N and P fertilizer becomes imperative because the concentration of these nutrients in many soils are very low and P could also be liable to different chemical reactions that make it unavailable to plants (Ross, *et al.*, 2007).

Moreover, increment in the number of plant population per unit area due to plant spacing has direct effect for the increment of potato tuber yield and also the pattern in which the given amount of seed or plant density is arranged in the field of planting [1,6]. Effect of increasing plant density on potato has revealed high increment on the yield of the crop as reported by Kabira, (2007). Blanket spacing recommended in Ethiopia for ware potato production was 75 cm between rows and 30 cm between plants. Yet research evidence from different parts of the country indicated an inter-row spacing of 50 -60 cm in Eastern Ethiopia and 65-70 cm Southern Ethiopia [10]. The variation in plant spacing at different locations according to the scholars was associated with soil type, soil fertility status, plant architecture, growth habit, soil moisture, rainfall, nutrient availability, and other environmental conditions. This recalls the need to develop site specific recommendations. Apart from spacing, soil nutrient status is also the most important parameter that limits the marketable yield of potato. Soil fertility survey made over 150 districts in Ethiopia indicated that soil lacks about seven nutrients (N, P, K, S, Cu, Zn, and Boron. Shifarew 2014 also reported that Ethiopian soil lacks most of the macro and micronutrients that are required to sustain optimum growth and development of crops. To fill such gaps, ministry of Agriculture of Ethiopia introduced a new compound fertilizer NPS (19% N, 36% P_2O_5 and 7% S) and other blended fertilizers instead of DAP. In the finding of [11] it is reported that the highest marketable and total tuber yield was recorded at 65cm inter row spacing and the lowest was at wider inter row spacing of 85 cm. On the contrary to the above finding, [5] reported that the wider spacing of 75cm * 30 cm was appropriate for high yield of potato. Therefore, adequate plant density and amendment of low soil fertility with inorganic fertilizer should be considered to address potato production problems. To increase the production and productivity of the crop, providing proper management practices is a key factor.

It is known that potato crop requires large amount of essential mineral elements for its better growth and yielding. The crop is considered as a major crop at Belg season in the study area. Even if the crop has high potential in the area, the production and productivity of the crop is low due to the lower rates using of inorganic fertilizers, poor land preparation, pests' infestation, inappropriate row spacing and local varieties are some of major yield limiting factors in the area. Farmers in the area are not using appropriate plant spacing, yet large numbers of farmers are using wide plant spacing while some others were using the close plant spacing from nationally recommended row spacing. This has contributed for low productivity of the crop. However, there is no research conducted regarding on optimum rate of inorganic fertilizer and appropriate planting density specific to the study area.

HI= Application of different rates of blended fertilizer and row spacing has significant response on the growth and yield of potato crop.

Ho= There is no significant response by applying of different rates of blended fertilizer and row spacing on the growth and yield of potato crop.

Therefore, this study was designed with the objective to evaluate effects of different rates of blended NPS fertilizer and intra-row spacing on yield and yield components of potato and evaluate the economics feasibility of potato cultivation at Gombora Woreda, Hadiya Zone, and Southern Ethiopia.

Materials and Methods

Description of Study Area

The study was conducted at Gombora Woreda, in Hadiya zone, Southern Ethiopia during 2019 Belg cropping season and which is situated at an elevation of 2350 m.a.s.l., and the site is located on 7014' to 7° 45' North latitude and 370 5' to 37° 50' East Longitude, representing a high altitude and high rain fall environment which is preferable location for potato production. The site has silty loam soil textural class with PH of 5.4. The rainy season extends from January to March, where the maximum rainfall is received in the months of February and March. And regarding the climatic condition, the area receives average annual rainfall of in between 1000 mm to 1400.and the average minimum and maximum air temperature is 12^o_c to 16^o_c and characterized with Dega agro-ecological zones.

Experimental Design

The study was carried out on potato variety namely (Belete) and grows well at altitudes from 1600-2800 m.a.s.l; with annual precipitation 1000- 1400 mm. Blended fertilizer product was used as source of N, P and S fertilizers. The field experiment comprised five blended fertilizer rates; control (0), 100, 150, 200, 250 kg ha^{-1} and three planting density (intra row spacing) of 20cm, 30cm and 40cm. The treatments were combined in 5 x 3 factorial experiments with randomized complete block design in three replications. The experimental area is divided to each experimental plot sized with 13.5 m^2 spaced at 1m between block and 0.5 m between plots.

Treatments and their Combinations

The experiment consisted of (0kg, 100 kg, 150 kg, 200 kg and 250 kg) NPS ha^{-1}, and planting density of 75*20; 75cm*30cm, and 75cm*40cm. The treatments were combined as fertilizer rates and spacing respectively like (0 *20, 0*30, 0*40, 100* 20, 100*30, 100*40, 150*20, 150*30, 150*40, 200*20, 200*30, 200*40, 250*20, 250*30 and 250*40). The experiments consisted 45 numbers of plots.

Soil Sampling and Analysis

A soil sample of 0.5 kg from the depth of 30 cm was collected from the top, middle and lower portion of the site before planting from 10 representative spots and composited at the end. The soil samples were air-dried, crashed and sieved through 2 mm mesh to analysis soil Physio-chemical characteristics: Soil organic matter was determined by following Walkley and Black (1934) method. Available P was determined by [12] method. The soil had medium OC in accordance with [13, 14] classified organic matter content of 3-5% as high and more than 5% as very high. But, soil with OC 1.24% which is rated low according to [15]. Thus the experimental site of available OM content was rated as high (2.14%). According to Olsen *et al.* (1954), P content of < 3 is very low, 4 to 7 is low, 8 to 11 is medium, and > 11 is high. Total N of the soil (0.11%), is low; as rated by [16]. The pH of the soil was 6.2, which is within the range of 5.5 to 6.8 suitable for potato production (FAO, 2008). Soil pH was determined in 1:2.5 soil: water ratio using a glass electrode attached to a digital pH meter.

Data Collection

Days to emergence: was recorded by counting the number of days from planting to when 50% of plants in each plot emerged. The number of days from planting to 50% emergence was used as days to emergence for statistical analysis.

Days to 50% flowering: This was recorded by counting the number of days from planting to when 50% of plants in each plot flowered. The number of days required for potato to flower was used as days to 50% flowering for statistical analysis.

Days to 90% maturity: recorded when 90 percent of the plants in each plot was ready for harvest as indicated by senescence of leaves and haulms. The number of days required to attain maturity from planting was used as days to 90% maturity for statistical analysis.

Plant height (cm) of five randomly selected plants from the middle rows was measured from the ground surface to the tip of the main stem at physiological maturity. Average of five plants expressed in centimeter was used for statistical analysis.

Average stems number per hill: Number of stems raised from the ground from randomly selected five plants was counted when 50% of the plants in each plot attained flowering stage and mean number of stem number per hill was used for statistical analysis.

Leaf area (cm^2) was determined five randomly selected plants are tagged from the middle rows. The individual leaf area of the selected potato plant was calculated by using portable leaf area meter model (LI-3000C, panomex Inc.) from available source. Average leaf area expressed in cm^2 per plant used for statistical analysis.

The above ground and underground fresh mass for each factors are made by keeping their scientific recommendation and the for the dry mass too.

Average tuber number per hill: The number of tubers per hill from potato plants in net plot area was counted during harvesting. All the plants were harvested and the average was taken by dividing the number of tubers to the number of plants. The average tuber number per hill was used for statistical analysis.

Average tuber weight (g/tuber): The average tuber weight was determined by dividing total tuber yield (weight) harvested from randomly sampled five plants to total tubers numbers harvested from five plants. The average tuber weight expressed in gram was used for statistical analysis.

Marketable tuber yield (t ha^{-1}): Weight of tubers which are free from diseases, insect pests with mean weights of above 25g was collected from net plot area harvested tubers. Weight of tuber expressed in t ha^{-1} used as marketable tuber yield for statistical analysis.

Unmarketable tuber yield (t ha^{-1}): Weight of tubers unhealthy, injured by insect pests with less than 25g size category was recorded from net plots harvested. Weight of tuber expressed in t ha^{-1} used as unmarketable tuber yield for statistical analysis.

Total tuber yield (t ha^{-1}): The total tuber yield per hectare was recorded by Sum of weights of marketable and unmarketable tubers expressed in t ha^{-1} were used as total tuber yield for statistical.

Tuber dry matter: Five tubers representing all size categories of the variety was collected and chopped into 1-2 cm small cubes. The cuttings were mixed thoroughly, and two sub-samples each having 200 g was prepared. Each sub-sample was placed in a paper bag and put in an oven at 72 °C until constant dry weight was attained after checking the weight at intervals. Each sub sample was immediately weighted and recorded as dry weight. Dried samples were weighed by using sensitive balance but the dry matter content was determined using the following formula: Dry matter content (DM) % = ((Dry weight/Fresh weight) x 100) according to CIP (2006). And dry matter was calculated according to Williams (1968).

Harvest index: It was calculated as the ratio of dry mass of tubers to the dry mass of total biomass. At first the tubers from five randomly selected plants were obtained and dried in the sun for five days and put in an oven at 72 °C until constant dry weight was attained and also the total dry matter was done as done for tuber

$$\text{Harvest Index (HI)} = \frac{\text{Tuber dry matter}}{\text{Total dry matter}}$$

Data Analysis

The data was subjected to analysis of variance (ANOVA) of RCBD in factorial arrangement using the general linear model of SAS statistical software package updated version 9.3 (SAS Institute Inc. Cary NC, 2008). DMRT (Duncan's multiple range test) at

5% probability was used to separate means when the analysis of variance indicates the presence of significant differences among treatments.

Economic or partial budget analysis

Economics of potato cultivation under blended fertilizer application was analyzed with partial budget analysis according to CIMMYT (1988). The total tuber yield produced by each treatment was calculated and it was adjusted down by 10 percent to minimize plot management variation. The field price of 1 kg of potato tuber yield during harvest was 10.50 Ethiopian birr (ETB kg^{-1}) and 16.50 Ethiopian birr (ETB) kg^{-1} during planting season. The price of blended fertilizer (NPS) 15.50 Ethiopian birr (ETB kg^{-1}) was estimated based on the cost at the time of purchase.

Net benefits, gross benefit, identification of dominant and dominated treatments, marginal rate of return were calculated for partial analysis. Gross benefit was calculated as average adjusted total tuber yield (kg ha^{-1}) × field price of a crop (ETB kg^{-1}). Net benefit was calculated by subtracting total variable cost from the gross benefit. The equation used to calculate net benefit was: NB= GB-TVC where, NB= Net benefit and TVC= Total variable cost. The marginal rate of return (MRR) was calculated as the ratio of difference between net benefits of successive treatments to difference between total variable costs of successive treatments i.e. it was calculated by using the formula: MRR= Ratio of change in net benefit to change in total variable cost × 100.

Results and Discussion

Days to 50% emergence

The result showed that effect of blended NPS fertilizer application significantly increased or delayed the time required to attain 50% emergence of potato. Average days to 50% emergence ranged from (19.0) to (23.7) days. The minimum and maximum number of days to reach days to 50% emergence was recorded for the application of 0 and 250kg NPS ha^{-1} blended fertilizer rates, respectively (Table 1). The result of present study was supported by [17] who reported that increased application of blended fertilizer showed delayed time on potato crop emergence by 6.0 days.

And also increasing intra-row spacing has significantly ($P<0.05$) influence on days to 50% emergence. Thus, minimum and maximum days to flowering ranged from 21.05 to 22.55 days (Table 1). Increased intra-row spacing prolonged days to reach 50% emergence on average of 1.5 days. The prolonged days might be due to lesser competition for resource like water, light and nutrients and poor nutrient use efficiency of the crop because of the wider spacing. In this experiment, earlier plant emergence was obtained in closer intra-row spacing (20cm) and the delayed time to attain days to 50% emergence was obtained at wider intra-row spacing (40 cm). This result was in line with the findings of Zenenay *et al.* 2018; [5] who reported that increasing intra-row spacing resulted in delayed time is required to attain 50% emergence.

Days to 50% flowering

Mean days to 50% flowering ranged from 60.77 to 70.22 days where the minimum and maximum days to 50% flowering was recorded from 0 Kg NPS ha^{-1} and 250 Kg NPS ha^{-1} respectively (Table 1). Nutrients have high influence in delaying the flowering of potato by prolonging its vegetative growth. The optimum blended fertilizer application rates might led to a general increment of most metabolic processes including cell division, cell expansion, respiration and photosynthesis however increase in N rate can delay the time to flowering [11]. In this study, the faster days to 50% flower was obtained in the lower rate of N fertilizer application of 0 Kg NPS ha^{-1} than that of the higher rate of 250 Kg NPS ha^{-1}. The present investigation was also supported by Onasanya *et al.* (2009) who reported increasing Nitrogen fertilizer application extended time of potato flowering.

In the same way, intra-row spacing showed significant influence on days to 50% flowering of potato. Potato with narrow intra-row spacing flowered earlier in the season than a potato with wider intra-row spacing. The result indicated stiff competition among plants for available resources that might have led plants to stress conditions and ultimately the plants flowered early instead of shortened vegetative growth thereby continuing photosynthesis [18]. And also [19 20] has reported that significant differences in days to 50% of flowering and maturity for potato crop and they reported that, the wider the plant spacing the delayed days to reach 50% flowering.

Days to 90% maturity

In this finding, mean days to 90% maturity has ranged from (103.86 to 117.97) days due to the application of different rates of blended fertilizers. Maximum means days to 90% maturity was recorded from application of 250 Kg NPS blended fertilizer ha^{-1} whereas the minimum days was attained from control treatment. The result suggested that increased rate of blended NPS fertilizer has extended the physiological maturity of potato. This delaying might be due the role of Nitrogen fertilizer in extending the vegetative growth of the crop. Therefore, the present investigation was supported by the findings of [21] Erdogan *et al.* (2010) who they reported extending maturity of potato was observed with the increased rate of N and P inorganic fertilizers fertilizer.

Days to 90% maturity was also significantly affected by intra-row spacing (Table 1). Mean maximum of (114.53 days) to 90% maturity of potato was recorded at wider (40cm) intra-row spacing and minimum of (111.70 days) was recorded from 20 cm intra-row spacing. The result indicated that wider plant spacing allowed lesser competition for sun light, water and nutrient which enhanced potato plant to maintain physiological activity for a long period. But, a crop with narrow intra-row spacing took less number of days in the season than a crop which planted at wider intra-row spacing; because in narrow intra-row spacing there is a stiff competition among plants for available resources. This result was supported with the findings of [22, 23] who reported that decreasing intra-row spacing resulted in shortening the time required to reach 90% maturity.

Plant height (cm)

Analysis of variance revealed that the effects of blended fertilizer (NPS) has significantly (P< 0.05) influenced the height of potato plant (Appendix Table 2).

Increased application of NPS fertilizer from 0 to 250 kg NPS ha^{-1} had increased the plant height from (69.62 cm) to (96.60 cm) and that the highest plant height was recorded when 250 kg NPS ha^{-1} and the lowest plant height (69.62 cm) which was recorded when with no fertilizer application (Table 2). There is significant and linear increase in plant height in response to increasing the rate of NPS blended fertilizer application and this may be attributed to the critical role phosphorus, Nitrogen and Sulfur and which plays in enhancing cell division, growth, and elongation to meet the demand for the increased plant height at the narrower spacing (Marschner, 2012) [24].

Table 1: Days to 50 % emergence, days to 50% flowering and days to 90% maturity of potato crop as affected by blended NPS fertilizer rates and intra-row spacing at Gombora condition during 2019 cropping season, Hadiya Zone

Treatments	Days to 50% emergence	Days to 50% flowering	Days to 90% maturity
NPS rate (kg NPS ha^{-1})			
0	19.00^{c}	60.77^{c}	103.86^{e}
100	19.78^{d}	64.22^{b}	108.53^{c}
150	21.11^{b}	64.22^{b}	105.86^{d}
200	21.56^{b}	65.66^{b}	114.08^{b}
250	23.67^{a}	70.22^{a}	117.97^{a}
DMRT (0.05)	0.65	1.90	1.31
Spacing (cm)			
20	21.05^{b}	64.27^{c}	111.70
30	21.77^{b}	66.66^{b}	112.92^{b}
40	22.55^{a}	69.50^{a}	114.53^{a}
DMRT (0.05)	0.73	1.34	0.89
CV (%)	4.36	5.05	8.48
Mean	21.31	65.69	111.18

Whereas, means followed by the same letter(s) are not significantly different at P<0.05. NPS= Nitrogen, Phosphorous and Sulfur blended fertilizer, DMRT=Duncan's multiple range test, CV= coefficient of variance

And also widening the intra-row spacing from 20 to 40 cm had significantly influenced the plant height at which it was increased from (73.46 cm) to (101.79 cm) respectively. The highest plant height (101.79 cm) was recorded from closer intra-row spacing and the shorter plant height (73.46 cm) was attained from the wider intra-row spacing of 40 cm. The taller plant growth in the narrower might be attributed due to the stiff competition for sun light in closer intra-row spacing.

Generally, closer spacing stimulated plants to grow taller with sufficient NPS fertilizer in the soil in order to meet the light demand of the crop. This result has supported by the finding of [25] and [27] that the highest plant height was recorded from closer or narrower intra-row spacing.

Leaf area (cm^2)

Analysis of variance has revealed that, potato leaf area per hill was significantly ($P< 0.05$) influenced by the main effect of NPS blended fertilizer application and intra-row spacing.

The highest leaf area per hill (25.48 cm) was obtained at a fertilizer rate of 250 kg NPS ha^{-1} than the leaf area per hill which was recorded at control or at blended fertilizer application of 0 kg NPS ha^{-1} which is about (20.01 cm) (Table 2). Therefore, the increased leaf area expansion rate at higher rates of NPS fertilizer might be due to increased epidermal cell expansion with the sufficiency of nutrients. In consistent to this study, [21, 27] confirmed that leaf area per hill increased in the high fertilizer rate and that the wider leaf area per hill was obtained from higher fertilizer rate application.

Similar to above result, leaf area per hill was significantly ($P< 0.05$) affected by increasing intra-row spacing. Thus, widening plant spacing from 20 to 40 cm had increased the leaf area per hill from (20.67 to 26.03 cm). That the largest leaf area per hill (26.03 cm) was obtained from the wider intra-row spacing of 40 cm and the smaller leaf area per hill (20.67) was recorded at closer intra-row spacing of 20 cm.

Consequently, the increased leaf expansion rate at wider intra-row spacing might be either due to increased epidermal cell expansion due to lesser plant population which allows free space that a given crop can occupy and so that the crop can grow in free manner [21].

Table 2: Plant height and leaf area as influenced by the effect of NPS fertilizer rates and intra-row spacing on potato crop under Gombora condition, Hadiya Zone 2019 cropping season

Main effect	Plant height (cm)	Leaf area (cm^2)
NPS fertilizer rates (Kg ha^{-1})		
0	69.62^d	20.01^e
100	81.67^c	21.76^d
150	87.87^b	22.71^c
200	92.22^a	24.15^b
250	96.60^a	25.48^a
DMRT (0.5%)	4.40	0.71
Spacing(cm)		
20	101.79^a	20.67^c
30	86.28^b	23.47^b
40	73.46^c	26.03^a
DMRT (0.5%)	3.08	0.51
CV (%)	13.60	10.28
Mean	86.19	23.03

Whereas, means followed by the same letter(s) in rows and columns under each parameter are not significantly different at $P<0.05$ level of significance, NPS= Nitrogen, phosphorous and sulfur blended fertilizer, DMRT= Duncan's multiple range test, CV= coefficient of variation

Average stem number per hill

The maximum number of stem per hill (9.66) was obtained with fertilizer rate of 250 kg NPS ha^{-1} in wider intra-row spacing of 40 cm and the lower number of stem per hill (8.66) was recorded in the same rate of blended fertilizer rate of 250 kg NPS ha^{-1} at closer intra-row spacing of 20 cm. However, the least number of stems per hill (4.66) were recorded in the control at closer intra-row spacing or from blended fertilizer rate of 0 kg NPS ha^{-1} at closer intra-row spacing (Table 3). There is an increment in stem number with increased application of N, P and S nutrients. This was due to the fact that stem number could also be determined by nutrient application in addition to the early ontogeny of yield potential and the free space around the crop root [3]. Even if, it is known that the number of stem per a single plant depends on the number of eyes on tuber seed at planting, it could also be further facilitated by the available amount of fertilizers to be applied and the type of management practices undertaken during the crop production.

However, Anil *et al. (*2008) stated that stem number is basically determined by the number of eyes present on tubers and the physiological age of the tubers during the storage period and in some amount by manipulating the supply of fertilizers. The increment in number of stem per hill with the increased application NPS fertilize with the combined effect of wider intra-row spacing might be due role of N, P and S which found in this fertilizer that could trigger the initiation and energy transfer of a crop and the availability of resources [28]. Similar with the results of this study, some researchers reported that stem number per hill was significantly affected by the application of phosphorus fertilizer and intra-row spacing [11, 26, 27].

Average tuber number per hill

In this study increasing the rate of NPS fertilizer from 0 to 250 kg ha^{-1} increased average tuber number per hill by about (65.83%). The highest average tuber number per hill was recorded in response to applying 250 kg NPS ha^{-1}. However, the lowest tuber number per hill was obtained in the control treatment of 0 kg NPS ha^{-1} (Table 4). Correspondingly, [24, 29, 30] have found that increasing the rate of phosphorus fertilizer significantly increased average tuber number per hill of potato.

Widening plant spacing to 40 cm significantly reduced number of tuber per hill, whereas, narrowing to 20 cm has increased small sized tuber number per hill. Accordingly, the average tuber number per hill obtained from plants cultivated at the intra-row spacing of 20 cm was about (10.13%) higher than the total tuber yield obtained from plants grown at the intra-row spacing of 40 cm. An increment in the average numbers of tubers per hill at closer plant spacing might be due to the higher canopy coverage of the ground with green leaves earlier at earlier growth season. In similar to the current study, decreased plant population density revealed increased small sized tubers per hill was reported by different scholars [5] and [31] who reported lower tuber numbers per hill at closer plant spacing than the wider plant spacing.

Mean tuber weight (g plant^{-1})

The main effect of blended fertilizer application rate and intra-row spacing has significantly (P<0.05) affected the mean tuber weight as shown in Table 4. With regard to blended fertilizer, the highest mean weight of tubers 77.45 g plant^{-1} was observed in the treatment that received 250 kg NPS ha^{-1} and the lowest

Table 3: Average stem number per hill as influenced by the interaction effect of NPS blended fertilizer and intra-row spacing on potato crop at Gombora condition at Hadiya Zone, 2019 cropping season

Average stem number per hill (count)					
	NPS fertilizer rates (Kg ha^{-1})				
Spacing(cm)	0	100	150	200	250
20	4.66h	5.00gh	6.33f	8.66cd	8.66cd
30	5.00gh	6.00f	7.66e	8.33de	9.33bc
40	5.66fg	6.33f	8.66cd	9.66b	9.66b
DMRT (0.5%)	0.85				
CV (%)	8.66				
Mean	7.31				

Whereas, means followed by the same letter(s) in rows and columns under each parameter are not significantly different at P<0.05 level of significance, NPS= Nitrogen, phosphorous and sulfur blended fertilizer, DMRT= Duncan's multiple range test, CV= coefficient of variation mean weight of tubers (57.96 g plant^{-1}) was obtained in the treatments that received no phosphorus fertilizer or in the control treatment. Increased application rate of phosphorus fertilizer from 0 to 250 kg NPS ha^{-1} increased average tuber weight by 25.2%. Increment on the mean tuber weight with the increased application of blended fertilizer might be due to the role of N, P and S fertilizers in this blended fertilizer and that can trigger tuber enlargement and initiation of cell expansion and production in the crop. Similar to the result of this study [24, 30, 32] who reported that the heavier average tuber weight were obtained from the increased application of NP fertilizer.

And also different plant spacing has significantly (P<0.05) affected the mean tuber weight as shown in Table 4. Thus, plants grown in wider spacing shown the larger mean tuber weight while, those grown in narrower intra-row spacing had shown the lower mean tuber weight. And the highest mean tuber weight was recorded at wider intra-row spacing of 40 cm and the lowest mean tuber weight was obtained from closer intra row spacing of 20 cm. This result is also in agreement with [5] who reported the highest average tuber weight from the effect of wider intra row spacing.

Unmarketable tuber yield (t ha^{-1})

The main effect of NPS blended fertilizer application and intra-row spacing has highly significant (P<0.01) influence on unmarketable tuber yield ha^{-1} of potato crop. Consequently, increasing the rate of NPS blended fertilizer from 0 to 250 kg NPS ha^{-1} significantly has also increased the unmarketable tubers produced per hectare (Table 4). The highest unmarketable tuber yield was obtained from the plots which are treated with 250 kg NPS ha^{-1} and the lowest unmarketable tuber yield was recorded control treatment. This may be due to the role NPS fertilizer which can highly contribute for increased tuber production in which both marketable and unmarketable tuber yield could be increased [18].

And also unmarketable tuber yield per hectare was influenced (P<0.01) by increasing the intra-row spacing. The lowest unmarketable tuber yield (2.63 t ha^{-1}) was obtained at 40 cm intra-row spacing, whereas the highest unmarketable tuber yield (3.67t ha^{-1}) was recorded at 20 cm intra-row spacing (Table 4). This could be due to the presence of intense inter-plant competition at closer spacing contribute to the higher unmarketable yield. And also [5, 27] also reported that average tuber size is decreased because of increased intra-plant competition with closer spacing and resulted is high unmarketable yield per hectare.

Table 4: Tuber number per hill, Average tuber weight, unmarketable tuber yield of potato as influenced by the increased application of blended fertilizer and intra-row spacing at Gombora condition, Hadiya Zone

Main effect	Tuber number per hill	Average tuber weight (g/plant)	Unmarketable tuber (tha^{-1})
NPS rate (kg P_2O_5 ha^{-1})			
0	15.98^{e}	57.96^{e}	3.69^{b}
100	19.65^{d}	64.43^{d}	4.34^{a}
150	23.88^{c}	73.52^{c}	4.11^{ab}
200	34.32^{b}	75.34^{b}	3.40^{b}
250	46.77^{a}	77.45^{a}	4.48^{a}
DMRT (0.05)	1.77	1.25	0.51
Spacing (cm)			
20	34.54^{a}	66.18^{c}	3.67^{a}
30	31.87^{b}	72.49^{b}	3.10^{b}
40	31.04^{b}	75.55^{a}	2.63^{c}
DMRT (0.05)	0.82	0.88	0.36
CV (%)	15.24	13.26	17.18
Mean	29.76	70.37	3.68

*Means followed by the same letter are not significantly different at P<0.05 level of significance, DMRT= Duncan's multiple range test and CV= coefficient of variation, ATW= Average tuber weight, ATNPH= Average tuber number per hill, UMTY= Unmarketable tuber yield

Marketable tuber yield (tone ha^{-1})

Analysis of variance revealed that the interaction effect of NPS blended fertilizer and intra-row spacing has significant effect ($P< 0.05$) on marketable tuber yield (Table 5). The highest amount of marketable tuber yields 34.29 tone ha^{-1} was recorded at fertilizer application of 250 kg NPS ha^{-1} in combination with intra-row spacing of 20 cm. But the lower marketable tuber yield 28.17 tone ha^{-1} was recorded at the same fertilizer rate of 250 kg NPS ha^{-1} in combination of 40 cm intra-row spacing. The higher marketable tuber yield recorded at a closer spacing combined with the increased application NPS fertilizer which is attributed to more tubers produced at the higher plant population per hectare and the role of NPS fertilizer on tuber formation than that planted in wider intra-row spacing of (40) at the same rate of NPS fertilizer (250 kg NPS ha^{-1}). The increase in tuber yield in response to increased application of blended fertilizer is consistent with the results of [18]. The present result is also agreed with the findings of many authors [33] (Anil *et al.,* 2008) that they reported increased application of inorganic fertilizer and plant grown in the closer spacing has revealed the higher increment in the marketable yield of a crop.

Total tuber yield (tone ha^{-1})

Analysis of variance shown that, total tuber yield per hectare was significantly ($P< 0.05$) affected by the interaction effect of NPS fertilizer application and intra row spacing on potato crop. The highest tuber yield (38.36) ton per hectare was obtained from fertilizer application of 250 kg NPS ha^{-1} with the closer intra row spacing of 20 cm, while the lower total tuber yield (28.80) ton per hectare was obtained from the at the same rate of (250 kg NPS ha^{-1}) in a wider intra-row spacing of 40 cm (Table 5). However, the lowest amount of total tuber yield (15.23) tone ha^{-1} was obtained from the plot which is planted with no fertilizer application at the wider intra-row spacing of 40 cm. It is known that crops grown with in closer plant spacing can have higher availability to get more plant population than that grown in the wider spacing and this could have direct effect on the total yield. Similar to the results of this study, [11, 33, 34] have reported that the increased rates of inorganic fertilizer has increased the number of potato tubers set per hill.

Total fresh weight (g plant^{-1})

The result of this study shown that increasing application rate of NPS blended fertilizer from 0 to 250 kg ha^{-1} and narrowing the intra-row spacing from 40 cm to 20 cm has linear increment on the total fresh weight yield of a crop. That is, the highest total fresh mass yield 1274..00 g plant^{-1} was obtained in the combined effect of higher NPS rate fertilizer of 250 kg NPS ha^{-1} in narrower intra-row spacing of 20 cm and the lower 1165.2 g plant^{-1} was recorded with the fertilizer application rate of 250 kg NPS ha^{-1} in the same spacing (20 cm) while, the lowest total fresh weight yield 756.60 g plant^{-1} was obtained in the treatment that planted without the application of NPS fertilizer in the wider intra-row spacing (40 cm) (Table 6). This increment in the rates of nutrients can help the crop to accumulate an increased biomass yield with the increased NPS fertilization application by narrowing intra-row spacing [35-40]. Similarly, [1] reported that increased fertilizer application revealed the highest biomass yield and [20] reported that narrower plant spacing has shown increment in total biomass yield of potato crop.

Table 5: Marketable tuber yield and total tuber yield of potato as influenced by the interaction effect of NPS blended fertilizer and intra-row spacing at Gombora conditions at Hadiya Zone, 2019 cropping season

Marketable tuber yield (t ha^{-1})						Total tuber yield (t ha^{-1})				
	NPS fertilizer rates (Kg ha^{-1})					NPS fertilizer rates (Kg ha^{-1})				
Spacing (cm)	0	100	150	200	250	0	100	150	200	250
20	14.68^{g}	15.81^{f}	21.07^{e}	28.17^{c}	34.29^{a}	18.36^{ef}	19.36^{e}	24.96^{d}	31.70^{b}	38.36^{a}
30	13.07^{gh}	15.34^{f}	19.63^{e}	26.68^{cd}	31.87^{b}	16.46^{fg}	18.56^{e}	23.23^{e}	29.93^{bc}	36.66^{a}
40	12.07^{h}	14.92^{fg}	17.33^{f}	23.92^{d}	25.25^{d}	15.23^{g}	17.90^{f}	20.70^{e}	26.93^{d}	28.80^{cd}
D M R T (0.5%)		2.41				2.52				
CV (%)		9.55				15.40				
Mean		24.48				24.43				

*Means followed by the same letter are not significantly different at P<0.05 level of significance, CV= coefficient of variation, NPS = blended Nitrogen, Phosphorous and Sulfur fertilizer and DMRT= Duncan's multiple range test

Table 6: Total fresh mass of potato crop as influenced by the interaction effect of interaction effect of NPS blended fertilizer and intra-row spacing on at Gombora Woreda condition in Hadiya Zone, 2019 cropping season

Total fresh mass (g plant^{-1})					
	NPS fertilizer rates (g ha^{-1})				
Spacing(cm)	0	100	150	200	250
20	756.60^{f}	982.20^{de}	1161.10^{bc}	1115.31^{c}	1165.20^{b}
30	802.52^{ef}	1016.62^{d}	1115.90^{c}	1212.71^{a}	1224.22^{a}
40	853.20^{e}	1108.31^{cd}	1197.88^{b}	1244.60^{a}	1274.2^{a}
DMRT (0.5%)	61..20				
CV (%)	7.50				
Mean	1082.04				

Whereas, means followed by the same letter(s) in rows and columns under each parameter are not significantly different at *P*<0.05 level of significance, NPS= Nitrogen, phosphorous and sulfur blended fertilizer. DMRT= Duncan's multiple range test, CV= coefficient of variation

Underground fresh and dry weight (g plant^{-1})

In this experiment, both fresh and dry weight of underground part of the crop was enhanced with increased application blended of NPS fertilizer in combination with closing intra-row spacing. Maximum underground fresh mass 869.87 g plant^{-1} was obtained at blended NPS fertilizer rate of 250 kg NPS ha^{-1} in closer intra-row spacing of 20 cm, whereas, the reduced underground fresh mass 835.24 g plant^{-1} was recorded at a blended NPS fertilizer rate of 250 kg NPS ha^{-1} with wider intra-row spacing of 40 cm (Table 7). However, minimum underground fresh mass of 531.40 g plant^{-1} was recorded in the treatment that planted in closer spacing with no NPS application [40-43]. According the findings of Kinde and [22] and [30] higher plant population per unit area at closer intra-row spacing has enhanced efficient resources utilization with an increased application of inorganic fertilizer and increase in biomass.

More specifically, maximum underground dry mass 212.88 g plant^{-1} was obtained when applying blended NPS fertilizer rate of 250 kg NPS ha^{-1} at intra-row spacing of 20 cm, whereas, the reduced underground dry 204.72 g plant^{-}[1] was obtained at a blended NPS fertilizer rate of 250 kg NPS ha^{-1} under wider intra-row spacing of 40 cm (Table 7). Thus, high plant population per unit area at closer intra-row spacing has enhanced efficient resources utilization. The finding of the present study was in agreement with the finding of [5], and [23] who reported that increased application of blended fertilizer and narrow intra-row spacing had significant increment in the total underground mass of potato crop.

Table 7: The interaction effect of blended rates NPS fertilizer and intra-row spacing has significant influence at underground fresh and dry mass of potato crop at Gombora condition, Hadiya Zone during 2019 cropping season

NPS fertilizer rates (g plant^{-1})						**NPS fertilizer rates (g plant^{-1})**				
	Underground fresh mass (g plant^{-1})					Underground dry mass (g plant^{-1})				
Spacing (cm)	0	100	150	200	250	0	100	150	200	250
20	531.40^{d}	676.67^{cde}	722.72^{c}	844.64^{a}	869.87^{a}	114.80^{h}	155.85^{e}	196.55^{c}	206.58^{b}	212.88^{a}
30	548.80^{d}	676.83^{c}	807.82^{b}	840.98^{a}	863.51^{a}	123.92^{g}	159.82^{e}	194.15^{c}	205.62^{b}	206.15^{b}
40	566.03^{d}	682.84^{c}	810.60^{b}	855.56^{a}	835.24^{ab}	139.02^{f}	171.32^{d}	196.55^{c}	208.42^{ab}	204.72^{b}
DMRT (0.05)		56.70				6.52				
CV (%)		5.84				6.98				
Mean		742.29				179.76				

Whereas, means followed by the same letter (s) in rows and columns under each parameter are not significantly different at *P*<0.05 level of significance, NPS= Nitrogen, phosphorous and sulfur blended fertilizer, DMRT= Duncan's multiple range test, CV= coefficient of variation

Harvest index

Increasing the application rate of fertilizer from 0 to 250 kg NPS ha^{-1} increased the harvest index of potato crop from 0.59 to 0.74. The highest harvest index 0.74 was obtained from the treatment that contained fertilizer rate of 250 kg NPS ha^{-1} blended fertilizer which is at par with 200 kg NPS rate application while the lowest harvest index of (0.59) was obtained in the treatment with no fertilizer application (Table 8). Since, harvest index is a measure of the proportion of assimilates partitioned to harvested organs [30]. And also, widening the intra-row spacing has increased the harvest index of potato crop from 0.67 to 0.71 Thus, the highest harvest index 0.71 was obtained from the wider plant spacing 40 cm while, the lowest harvest index was from closer intra-row spacing 20 cm. This, the larger harvest index at wider plant spacing might be due to the wider availability for resources like water, nutrient and sun light than that of closer spacing and which can allow the presence of larger assimilates in the tuber portion of the crop [43-48].

Economic analysis

The results of economical analysis revealed that net benefit ranged from 306,262.00 to 312,427.00 birr. The maximum net benefit was attained when applying rate of blended NPS fertilizer of 250 kg ha^{-1} with intra row spacing of 20cm, whereas the minimum net benefit about 117,523.00 birr on potato cultivation was recorded from rate of blended fertilizer rate of 0 Kg NPS ha^{-1} and spacing of 40 cm. (Table 9). The analysis revealed that the value of increase in yield of a crop is enough to compensate for the increase in costs for that extent of blended fertilizer application in the study area.

Maximum marginal rate of return (62,824%) with its net benefit value of (306,262.00 ETB ha^{-1}) was recorded at blended fertilizer application rate of 250 kg NPS ha^{-1} in intra-row spacing of 30 cm [49-50]. Nevertheless, application of 250 kg NPS ha^{-1} at closer intra-row spacing of 20 cm has also shown higher MRR (62,162%) and highest net benefit (312,427.00 ETB ha^{-1}). The rate application of 250 kg NPS ha^{-1} in combination with an intra-row spacing of 30 cm might be recommended in the study area farmers. And also, the same rate of 250 NPS fertilizer ha^{-1} in closer intra-row spacing of 20 cm has higher marginal rate of return of 62,162%.

From this result, it is advisable to apply fertilizer for potato production with the fertilize rate of 250 kg NPS ha^{-1} at intra-row spacing of 30 cm and this could be more effective. This reveals that application of fertilizer rate of 250 kg NPS ha^{-1}and intra-row spacing of 30 cm and the same rate application of NPS blended fertilizer of 250 kg NPS ha^{-1}at closer intra-row spacing of 20 cm for potato production was both economically practicable when compared to the production of potato without the application of fertilizer in the study area farmers who are highly depending in potato production [51].

Table 8: The main effect of NPS blended fertilizer and intra-row spacing has influenced harvest index of potato yield at Gombora condition

Main effect	Harvest index
NPS rate (kg NPS ha^{-1})	
0	0.59^{d}
100	0.65^{c}
150	0.69^{ab}
200	0.71^{a}
250	0.74^{a}
DMRT (0.05)	0.03
Spacing (cm)	
20	0.67^{c}
30	0.69^{b}
40	0.71^{a}
DMRT (0.05)	0.01
CV%	13.96
Mean	0.68

Whereas, means followed by the same letter(s) in rows and columns under each parameter are not significantly different at *P*<0.05 level of significance, NPS= Nitrogen, phosphorous and sulfur blended fertilizer, DMRT= Duncan's multiple range test, CV= coefficient of variation

Table 9: Partial budget analysis of potato cultivation as affected by blended NPS fertilizer and intra row spacing at Gombora condition, Hadiya Zone during 2019 Belg cropping season

Kg NPS ha^{-1}	Spacing (cm)	AV.TY(t ha^{-1})	Adj.TY (t ha^{-1})	GB. Of TY (ETB)	CTS (ETB)	CNPS (ETB)	TVC (ETB)	NB (ETB)	MRR (%)
0	40	15.23	13.707	143,923.50	26,400.00	0	26,400.00	117,523.00	-
100	40	17.90	16.11	169,155.00	26,400.00	1550.00	27,950.00	141,205.00	23,682.0
150	40	20.70	18.63	195,615.00	26,400.00	2325.00	28,725.00	166,890.00	25,685.0
200	40	26.93	24.237	254,488.50	26,400.00	3100.00	29,500.00	224,988.00	58,098.0
250	40	28.80	25.92	272,160.00	26,400.00	3875.00	30,275.00	241,885.00	16,897.0
0	30	16.46	14.814	155,547.00	36,300.00	0	36,300.00	119,247.00	**D**
100	30	18.56	16.704	175,392.00	36,300.00	1550.00	37,850.00	137,542.00	18,295.0
150	30	23.23	20.907	219,523.50	36,300.00	2325.00	38,625.00	180,898.00	43,356.0
200	30	29.93	26.937	282,838.50	36,300.00	3100.00	39,400.00	243,438.00	62,540.0
250	30	36.66	32.994	346,437.00	36,300.00	3875.00	40,175.00	**306,262.00**	**62,824.0**
0	20	18.36	16.524	173,502.00	46,200.00	0	46,200.00	127,302.00	**D**
100	20	19.36	17.424	182,952.00	46,200.00	1550.00	47,750.00	135,202.00	7,900.0
150	20	24.96	22.464	235,872.00	46,200.00	2325.00	48,525.00	187,347.00	52,145.0
200	20	31.70	28.53	299,565.00	46,200.00	3100.00	49,300.00	250,265.00	62,918
250	20	38.36	34.524	362,502.00	46,200.00	3875.00	50,075.00	**312,427.00**	**62,162.0**

* Av. TY = Average tuber yield, Adj. TY= Adjusted tuber yield GB= Gross benefit of total tuber yield, CTS (ETB) = Cost of tuber seed, CNPS= Cost of Nitrogen, sulfur & phosphorous fertilizer, TVC= Total variable cost, NBT= Net benefit, MRR= Marginal rate of return, tha^{-1}= Tone per hectare & ETB= Ethiopian Birr, D= Dominated alternative

References

1. Naz F, Ali A, Iqbal Z, Akhtar N, Asghar S, et al. (2011) Effect of different levels of NPK fertilizers on the proximate composition of potato crop at Abbottabad. Sarhad J Agric 27: 353-6.

2. Anna O, Ekaterina K, Tatjana G, Tamara S, Mikhail Z, et al. (2010) Taxonomy of cultivated potatoes (Solanum section Petota: Solanaceae). Botanical Journal of the Linnean Society 165: 107-55.

3. Allison JH, Flower JH, Allen EJ (2001) Effects of soil and foliar applied phosphorus fertilizers on the potato (*Solanum tuberosum*) crop. *J of agri sci.* 137: 379-95.

4.FAOSTAT (2020) World food and agricultural organization data of statistics, Rome, Italy. http://faostatJao.org/site/567/default.aspX#ancor.

5.Bikila Akassa, Derbew Belew, Adugna Debele (2014) Yield and yield of potato (Solanum tuberosum L.) seed tuber as influenced by inter and intra-row spacing at Bako, Western Ethiopia. Journal of Biological Sciences. 3: 11-19.

6. Mekides Mekashaw, Melkamu Alemayehu, Getachew Shumiye, Amare Hailesilassie (2020) Effects of blended NPS fertilizer rates on yield and yield components of potato (*Solanum tuberosum L.)* varieties at Dessie Zuria district, Northeast Ethiopia.

7. Fantaw S, Derajew A, Aleminew T (2019) Effect of blended chemical fertilizer (sulfur, nitrogen and phosphorus) on yield and yield components of potato (*Solanum tuberosum* L.) in the rainy season. J Hortic and For 11: 54-61

8. Hailu Gebru, Ali Mohammed, Nigussie Dechassa, Derbew Belew (2017) Assessment of production practices of smallholder potato (Solanum tuberosum L.) farmers in Wolaita zone, southern Ethiopia. Agriculture and Food Security, Jimma University 6: 2-11.

9. Sharma D (2015) Effect of Sulphur on Growth, Yield and Economic of Potato Cultivar. *Annals of Plant and Soil Research,* 17: 45-9.

10. Fanuel L (2020) Carbon stock, sequestration and soil properties among field in smallholder farms in Southern Ethiopia, Environ Sci Res Vol. 9: 16.

11. Harnet Abrha, Derbew Belew, Gebremedhin Woldegiorgis (2014) Effect of Inter- and Intra-Row Spacing on Seed Tuber Yield and Yield Components of Potato at Ofla Woreda. Bahirdar, Ethiopia.

12. Olsen SR, Cole CV, Watanbe FS, Dean LA (1954) Estimation of Available phosphorus in soils by extraction with sodium bicarbonate. USDA-ARS Circ. 939.

13. Sahlemedhin Sertsu (1999) Draft guideline for regional soil testing laboratories. NFIA. Addis Abeba, Ethiopia.

14. Ren LJ, Zhang R (2003) Estimating nitrate leaching with a transfer function model incorporating net mineralization and uptake of nitrogen. Journal Environ. Qual 32: 1455-63.

15. Roy ML, Hasanuzzaman MK, Nahar TS, Rahman MZ, Ahmed JU (2009) Tiller Dynamics and Dry Matter Production of Transplanted Rice as Affected by Plant Spacing and Number of Seedling per Hill. Academic J Plant Sci 2: 162-8.

16. Havlin D, James DR, Samuel L (1999) Soil fertility and fertilizers. Soil and crop sciences. Colorado state university 83: 20-1.

17. Kinde Lamessa, Asfaw Zewdu (2016) Effect of spacing and fertilizer dose on growth and yield of potato (*Solanum tuberosum* L) Gudenie variety at West Hararghe, Eastern Ethiopia. Int J Horticul and Ornament Plants 2: 011-8.

18. Rosen C, Bierman P (2008) Potato yield and tuber set as affected by phosphorus fertilization. Am J Potato. 85: 110-20.

19. Tadele Fanos, Derbew Belew, Solomon Tulu (2013) Combined effect of plant spacing and time of earthing up on tuber quality parameters of potato (*Solanum tuberosum L.)* at Degeme district, North Shewa Zone of Oromiya regional state. "Aslan J. Crop Sci. 5: 24-32.

20. Amin F, Meysan M (2014) Effect of Plant density to Yield and Yield components of Maize (*Zea mays L.*) Cultivars. J Bulletin Environ, Pharmacol and Life Sci 3: 123-7.

21. Zamil MF, Rahman MM, Rabbbani MG, Khatun T (2010) Combined effect of nitrogen and plant spacing on the growth and yield of potato with economic performance. Bangladesh Res. Pub. J 3: 1062-70.

22. Kinde Lamessa, Asfaw Zewdu (2016) Effect of spacing and fertilizer dose on growth and yield of potato (*Solanum tuberosum* L) Gudenie variety at West Hararghe, Eastern Ethiopia. International Journal of Horticulture and Ornamental Plants 2: 011-8.

23. AlemayehuTilahun, Nigussie Dechassa, Tamado Tana (2015) Response of Potato (Solanum tuberosum L.) Yield and Yield Components to Nitrogen Fertilizer and Planting Density at Haramaya, Eastern Ethiopia. Journal of Plant Sciences. 3: 320-8.

24. Israel Zewide, Ali Mohammed & Solomon Tulu [2012] Effect of different rates of nitrogen and phosphorus fertilization on Yield and yield component of potato (*Solanumtuberosum*L.) at Mashan, Southwestern of Ethiopia. Afr J Plant Sci 3: 016-24

25. Ali H, Anjum MA, Rand hawa SA (2004) Influence of phosphorus on yield potential of potato (*Solanum tuberosum* L.) crops. Int J Agric 119-31.

26. Kifle Zerga, Beza Getu, Kedija Mohammed (2017) Effects of Intra-Row Spacing on Vegetative Growth Performance of Potato *(Solanum tuberosum L.)* at Wolkite University, Ethiopia. International Journal of Photochemistry and Photobiology. 2: 108-12.

27. Tesfaye Getachew, Derbew Belew, Solomon Tulu (2012) Yield and Growth Parameters of Potato (*Solanumtuberosum*L.) as Influenced by Intra Row Spacing and Time of Earthing Up: In Boneya Degem District, Central Highlands of Ethiopia. Int J Agric Res 7: 255-65.

28. Achbani EH, Khalid D, Mrabet R, Benbouaza A (2014) Responsiveness of different potato (*Solanum tuberosum* L.) varieties to phosphorus fertilizer. Procedia Engineering 83: 344-7.

29. Menberu Kitila, Derbew Belew, Ali Mohammed, Yehenew Getachew (2012) Effect of intra-row spacing and variety on fruit yield and quality of fresh market potato (*Solanumtuberosum*L) under Jimma condition, Ethiopia. J. Appl. Sci. Technol. 3: 32-2.

30. Zelalem Aychew, Tekalign Tsegaw, Nigussie Dechassa (2009) Response of potato (*Solanum tuberosum* L.) to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia. Ethiopia. Afr J Plant Sci 3: 16-24.

31. Robert M, Upenyu M, Taurira AM, Admire S (2015) Growth, Yield and quality responses to plant spacing on Irish potato. Crop Science department. University of Zimbabwe. Zimbabwe. Afr J Agric Res 10: 727-30.

32. Husna Shaaban, Kisetu Eliakira (2014) Response of Irish Potato to NPK Fertilizer Application and its Economic Return when Grown on an Ultisol of Morogoro, Tanzaina. J Agric and Crop Sci 2: 188-96.

33. Desalegn Regassa, Wakene Tigre, Dawit Mellise, Tolessa Taye (2016) Effects of Nitrogen and Phosphorus Fertilizer Levels on Yield and Yield Components of Irish Potato (*Solanum tuberosum*) at Bule Hora District, Eastern Guji Zone, Ethiopia. Int J Agric Econ 1: 71-7.

34. Amasis Mama (2018) Integrated use of NPS blended fertilizer and cattle manure for growth, yield and quality of potato (Solanum tuberosum l.) under daboghibe, kebele, seka werada of jimma zone, southwest Ethiopia.

35**.** Biruk Masrie (2014) Influence of Combined Application of Inorganic N and P Fertilizers and Cattle Manure on Quality and Shelf-Life of Potato (*Solanum tuberosum* L.) *J Postharvest Technol* 2: 152-68.

36. Bussan AJ, Mitchell PD, Copas ME, Drillas MJ (2007) Evaluation of the effect of density of potato yield and tuber size distribution. Crop Sci 47: 2462-72.

37. CIP World Potato Atlas; FAOSTAT; World Potato Congress; Potatoes South Africa Beukema, H.P. and D.E. Van der Zaag, 1990. Introduction to Potato Production. Pudoc Wageningen, The Netherlands.

38. Fayera Wakjira (2017) Yield and yield components of potato (*Solanum tuberosum* L.) as influenced by planting density and rate of nitrogen application at Holeta, West Oromia region of Ethiopia. Afr J Agric Res 12: 2242-54.

39. Hakoomat A, Muhammad AA, Shakeel AR (2004) Influence of Phosphorus on Yield Potential of Potato (*Solanum tuberosum* L.) Crops. Int J Agric & Biol Pakistan. 6: 165-7.

40. Masarirambi MT, Mandisodza FC, Mashingaidze AB, Bhebhe E (2012) Influence of plant population and seed tuber size on growth and yield components of potato (*Solanum tuberosum*). Int. J Agric Biol 14: 545-9.

41. Mengistu Tesfu, Yamoah Charles (2010) Effect of sowing date and planting density on seed production of carrot (Daucuscarota Var. sativa) in Ethiopia. Afric.J. plant. Sci. 4: 27-9.

42. Mohr RM, Tomasiewicz DJ (2011) Effect of phosphorus fertilizer rate on irrigated Russet Burbank potato. Communications in Soil Science and Plant Analysis 42: 2284-98.

43. Muhammad R, Abdur R, Hasnain A, Salahuddin SS, Zeeshan A (2015) Effect of Potash Levels and Plant Density on Potato Yield. J Biol, Agric and Healthcare. Pakistan. 5: 301-9.

44. Muhammad N, Hussain Z, Rahmdil, Ahmed N (2015) Effect of Different Doses of NPK Fertilizes on the Growth and Tuber Yield of Potato. Life Sci Int J 9: 3098-105.

45. Mulubrhan Hagos (2004) The effects of nitrogen, phosphorus and potassium fertilization on the yield and yield components of potato *(SolanumtuberosumL.*), Grown on vertisols of Mekelle area Ethiopia. MSc. Thesis, School of Graduate Study Haramaya University, Ethiopia 83.

46. Rahemi A, Hasanpour A, Mansoori A, Zakerin B, Taghavi TS (2005) The effect of intra-row spacing and N fertilizer rate on the yield of two foreign cultivars in Iran.Int. J. Agric Biol 7: 705-7.

47. Rodrigues M, Martins F, Coutinho J (1998) Influence of Mineral and Organic Nitrogen on Tuber Dry Matter and Specific Gravity of Potato. *European Society of Agronomy* 2: 1-4

48. Salahuddin KM, Chowhdury SH, Munira S, Islam MM, Parvin S (2009) Response of Nitrogen and Plant spacing of transplanted man rice. *Bangladesh J Agric Res* 34: 279-85.

49. Sebastiani S, Mgonja A, Urio F, Ndondi T (2007) Agronomic and Economic Benefits of Sweet Potato (*Ipomoea batata* L.) Response to Application of Nitrogen and Phosphorous Fertilizer in the Northern Highlands of Tanzania. *Afr Crop Sci Conference Proceedings* 8: 1207-10.

50. Shahzad JS, Roghayyeh ZM, Asgar Y (2010) Yield and Yield Components of Potato (*Solanum Tuberosum* L.) Tuber as Affected by Nitrogen Fertilizer and Plant Density. Australian J Basic and Appl Sci 4: 3128-31.

51. Shahzad JS, R Zabihi, A Mahmood, Y Asgar (2011) Yield and yield components of potato (Solanum tuberosum L.) tuber as affected by nitrogen fertilizer and plant