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Full Length Research Paper

Profitability of potato (*Solanum tuberosum* L.) as affected by NP nutrition and variety in Southern Ethiopia

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Profitability of different rates of nitrogen (N), phosphorus (P) and five potato varieties (*Bellete*, *Gudene*, *Jalene*, *Marachere* and local check) was investigated in southern Ethiopia to find out rates of the nutrients and varieties that would give acceptable returns and likely to be adopted by smallholder farmers in the locality. Factorial combination of N (0, 55.5 and 111 kg/ha) and P (0, 19.5 and 39 kg/ha) were applied to the main plots while the five varieties were to the sub plots of split-plot design and replicated three times. Both factors had significant effect on tuber yield, but there were no significant interaction effect. Significant treatments of this experiment were, therefore, subjected to economic analysis using partial budget procedure. Economic analysis showed that 0:19.5, 55.5:19.5 and 55.5:39 kg NP/ha and varieties *Bellete*, *Jalene* and *Marachere* were economically superior and stable even within a price variability range of 20% in the locality. In conclusion, application of NP nutrients with the rate of 0:19.5, 55.5:19.5 or 55.5:39 kg/ha for the varieties *Bellete*, *Jalene* and *Marachere* were identified profitable treatments for lucrative production of potato in the study area.

Key words: Dominance analysis, economic analysis, partial budget, smallholder farmers, tuber yield.

INTRODUCTION

Human population of Ethiopia increased from 76.2 million in 2004-06 to 99.0 million in 2014-16, which is an addition of about 22.8 million (29.9% increment) during the last ten years. However, prevalence of food inadequacy was 55.4% in 2004-06 and 41.3% in 2014-16 showing a decrease of only 14.1% within the ten years of time (FAO, 2016). This implies that Ethiopia's agricultural sector should also provide sufficient amount of food for the rapidly growing population. The need to raise productivity of smallholder farmers is, therefore, important to minimize the problem. The paradox increase of human population also puts high pressure on the static land and other limited resources. This is further aggravated by the impacts of climate change which occurs due to the misuse of manmade and natural resources. For instance, the unusually created drought in Ethiopia after fifty years has exposed more than 10 million citizens to a severe hunger (WFP, 2016). Such problems can be reduced by

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growing robust crops adaptable to a wide range of agro-ecology (Kyamanywa et al., 2011).

Potato (*Solanum tuberosum* L.), a food security crop (Kyamanywa et al., 2011), is one of the best choice crops to attempt such problems in Ethiopia in general and in the study area in particular. It produced for home consumption and sale by smallholder farmers in Wolaita zone, southern Ethiopia. Obviously potato has already considered as specialty crop in Ethiopia due to its role in improving food security of the nations. However, its low productivity in the areas is attributed to the present practices of its production without appropriate nutrient management practices (Zelalem et al., 2009) and lack of high yielding varietal options (Mitiku et al., 2015).

Nitrogen and phosphorus are among the essential macro-nutrients identified as the most yield-limiting factors in crop production. Nitrogen is required for good vegetative and reproductive development (Brady and Weil, 2000). It is a component of protein and nucleic acids and when it is inadequate, growth is reduced (Adediran and Banjoko, 1995). It forms part of many important compounds like chlorophyll and enzymes responsible for many physiological processes in the plant. Nitrogen serves as an intermediary in the utilization of P, K and other elements in plants (Brady and Weil, 2000). Phosphorus also has many vital functions in photosynthesis, utilization of both sugar and starches and in energy transfer processes. Therefore, young plants absorb P very rapidly, to provide rapid and extensive growth of roots (Asumadu et al., 2012).

Due to poor cultural practices mainly poor nutrient management practices and lack of high yielding varieties, productivity of potato is still limited to be 11.5 tonnes per hectare (t/ha) (CSA, 2015) in Ethiopia; which is very much less than its yield potential (100 t/ha) (Grewal et al., 1992). Although blanket recommendations of fertilizers that assume homogeneity of farming conditions have partly contributed to the low diffusion of fertilizer technologies within Ethiopia's smallholder farmers, the need for careful targeting and area specific fertilizer recommendation is crucial. A blanket recommendation of about 111 kg N and 39 kg P per hectare was being advocated by the development agents (DAs) to farmers. Smallholder farmers lacked the financial expense required to apply the recommendation due to their limited resource base, which pointed to the need for a lower rate of fertilizer in line with their low economic status.

Thus, awareness of the need to identify lower fertilizer rates for low smallholder farmers and the importance of raising potato productivity as specialty crop in the country in general and in Wolaita zone in particular is important for the ultimate goal of food security program in the zone where population per unit area is higher. This study was, therefore, designed to test a range of possible alternatives with the objective of selecting economically appropriate rates of NP kg/ha and profitable potato varieties in the study area.

MATERIALS AND METHODS

Description of the study area

Two year (2014 and 2015) field experiments were conducted at the research site of School of Agriculture, Wolaita Sodo University. It is located at 6° 49'N, 37° 45'E and an altitude of 1886 m above sea level. The soils are well drained sandy loam with low organic carbon. Monthly air temperature, rainfall, relative humidity and bright sunshine hour ranged from 15 to 28°C, 311 to 790 mm, 62 to 75% and 133 to 247 h, respectively, for 2014 cropping year. During 2015, the ranges were 15 to 30°C, 131 to 641 mm, 46 to 47% and 98 to 248 h, in that order (NMA, 2015). The soil was low in organic carbon (1.5 and 0.54%), total nitrogen (0.15 and 0.06%) and available phosphorus (7.8 and 8.10 ppm) with acidic pH (5.3 and 5.44) in 2014 and 2015, respectively.

Treatments and experimental design

The field experiment was laid in split-plot design with three replications. Factorial combinations of 3 levels of each N (0, 55.5 and 111 kg N/ha) and P (0, 19.5 and 39 kg P/ha) were assigned to main-plots and 5 varieties (*Bellete, Gudene, Jalene, Marachere* and local check) to the sub-plots. Urea and triple super phosphate were used as nutrient sources of N and P, respectively. The size of each sub-plot was kept 4.5 m x 3.6 m (16.2 m^2), consisting of six rows and each row consists of 12 plants. Sub-plots within the main-plots were arranged continuously without paths, but the end rows were used as boarder. One meter and 1.5 m paths were maintained between consecutive main-plots and between replications, respectively. Planting was done keeping row-to-row and plant-to-plant distances of 30 cm and 75 cm, respectively.

Cultural practices

Weeding, hoeing, and earthing up were adopted uniformly for all treatments as recommended by EARO (2004). Ridomil (MZ 63.5% WP) was applied at a rate of 2 kg/ha as soon as the first symptom of *Phytophthora infestans* was observed on the foliage parts. The vines were removed two weeks before harvesting for proper skin hardening and wound healing. Then, the tubers were harvested after 15 days of vine removal.

Statistical analysis

The data collected on yield parameter was subjected to statistical analysis and Duncan Multiple Range test was used at 0.05 p-values to compare treatment means (Gomez and Gomez, 1984) by employing the SAS computer program, version 9.2 (SAS, 2002). Homogeneity of the variances was tested using F-test (Gomez and Gomez, 1984) and it has shown that the variances of the two cropping years were homogenous. Therefore, combined analysis of the two-year data was carried out.

Economic analysis

The pooled experimental data were compared and analyzed for yield, input and output costs. Economic analysis was done using the existing market prices for inputs (NP fertilizers and seed tubers) at planting time while for the output (marketable yield) at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopia currency (Eth Birr/ha). Where, 20.5 Eth Birr was equivalent to 1US$. The tools used for economic analysis to assess the total costs and net benefits associated with the treatments were the partial budget analysis, dominance analysis, marginal analysis and sensitivity analysis (CIMMYT, 1988).

Partial budget analysis: This is used to evaluate the differences in costs and benefits among different rates of NP fertilization as well as among varieties. Its components are: (1) Average marketable tuber yield (kg/ha), which was the mean marketable tuber yield of the treatments. (2) Adjusted yield (kg/ha), in which the yield of all treatments were adjusted downward by 10% to minimize plot management effect by the research or to reflect the actual farm level performance. (3) Gross field benefit (GFB) which was the product of field price and the adjusted marketable tuber yield for each treatment:

$$GFB = P_f \times Y_{adj} \quad (1)$$

Where, P_f *= field price and* Y_{adj} *= adjusted yield.*

Total variable costs (TCV) (Eth Birr/ha): Is the sum of field cost of fertilizer and the cost of fertilizer applications. (5) Net benefits (NB) (Eth Birr/ha) which was the difference between the GFB and TCV for each treatment:

$$NB = GFB - TCV \quad (2)$$

Dominance analysis: Is the procedure used to select potentially profitable treatments from the range that was tested. The selected and discarded treatments using this technique are referred to as undominated and dominated treatments, respectively. The undominated treatments were ranked from the lowest to the highest cost treatment (CIMMYT, 1988).

Marginal rate of return (%): For each pair of ranked treatments, a per cent marginal rate of return (MRR) was calculated:

$$MRR = \frac{\Delta NB}{\Delta TCV} X100 \quad (3)$$

The MRR% between any pair of undominated treatments denotes the return per unit of investment in rates of NP fertilization and variety expressed as a percentage.

Sensitivity analysis: Before recommendation, it is better to test each treatment for its stability despite price changes. Sensitivity analysis, redoing a marginal analysis with alternative prices, is therefore the best way to test a recommendation for its ability to withstand price changes (CIMMYT, 1988).

RESULTS AND DISCUSSION

Statistical analysis of yield data showed that the main effects of rates of NP nutrients and variety significantly (P < 0.01) influenced marketable yield (t/ha) (Table 1). Significant interaction effect between the main effects was not observed on the marketable tuber yield. From the tested and undominated nutrient treatments, the net profit per hectare was highest (Eth Birr=105,864.73) in treatment 55.5:39 kg NP/ha followed by (Eth Birr=95967.99) in treatment 55.5:19.5 kg NP/ha and (Eth Birr=85826.55) in treatment 0:19.5 kg NP/ha and it was lowest (Eth Birr=51,781.68) in the control, 0:0 kg NP/ha. While from the undominated treatments of variety, the maximum (Eth Birr=97,444.80) net profit per hectare was

Table 1. Marketable tuber yield as influenced by rates of NP fertilization and variety

Rates of NP nutrients (kg/ha)	Marketable yield (t/ha)
0:0	15.98^{e}
0:19.5	26.97^{bc}
0:39	25.77^{cd}
55.5:0	19.27^{e}
55.5:19.5	30.62^{abc}
55.5:39	34.10^{a}
111:0	20.68^{be}
111:19.5	31.97^{ab}
111:39	30.86^{abc}
F-test	**
SEM (±)	1.85
CV (%)	28.53
Variety	**Marketable yield (t/ha)**
Bellete	34.52^{a}
Gudene	25.39^{b}
Jalene	27.09^{b}
Marachere	25.04^{b}
Local†	19.19^{c}
F-test	**
SEM ±	1.15
CV (%)	28.53

Where, 0:0=0+0 NP kg/ha; 0:19.5=0+19.5 NP kg/ha; 0:39=0+39 NP kg/ha; 55.5:0=55.5+0 NP kg/ha; 55.5:19.5=55.5+19.5 NP kg/ha; 55.5:39=55.5+39 NP kg/ha; 111:0=111+0 NP kg/ha; 111:19.5=111+19.5 NP kg/ha; 111:39=111+39 NP kg/ha; means within a column followed by the same letter are not significantly different at p < 0.05; **†=**the local check is the variety (often a mixture) commonly grown by farmers in the locality.

obtained from *Bellete* followed by *Jalene* (Eth Birr=75,761.88) and *Marachere* (Eth Birr=70,326.36) and comparatively, the least (Eth Birr=52,591.80) was obtained from the local variety. Thus, the per cent increase in net profit was highest (104.44%) in treatment 55.5:39 kg NP/ha over the control. It was followed by 55.5:19.5 kg NP/ha (85.33%) and 0:19.5 kg NP/ha (65.75%) treatments. Economic output is the ultimate target of any farm business and, thus, rates of NP nutrients confirmed to have significant effect on the output. Accordingly, an additional investment of 4,609.55 Eth Birr/ha towards cost of NP nutrients in case of 55.5:39 kg NP/ha treatment offered 54,083.05 Eth Birr extra money over control. In case of 55.5:19.5 kg NP/ha and 0:19.5 kg NP/ha treatments, an additional investment of 3,269.97 and 1,559.49 Eth Birr/ha gave an extra money of 44,186.31 and 34,044.87 Eth Birr, respectively, over control. Similarly, an additional investment of 14,400.00 Eth Birr/ha towards cost of tuber seeds in case of variety *Bellete* gave extra money of 44,853.00 Eth Birr over the local check. In case of *Jalene* and *Marachere*, an

Table 2. Partial budgets analysis of rates of NP fertilization and variety treatments at current prices

Components of partial budget	Rates of NP nutrients (kg/ha)								
	0:0	0:19.5	0:39	55.5:0	55.5:19.5	55.5:39	111:0	111:19.5	111:39
Average yield (kg/ha)	15982.0	26971.0	25764.0	19276.0	30629.0	34097.0	20684.0	31968.0	30858.0
Adjusted yield (kg/ha)	14383.8	24273.9	23187.6	17348.4	27566.1	30687.3	18615.6	28771.2	27772.2
GFB (Eth Birr/ha)	43151.4	72821.70	69562.80	52045.20	82698.30	92061.90	55846.80	86313.60	83316.60
Fertilizer, NP cost (Eth Birr/ha)	0.00	1188.92	2377.83	1318.68	2507.60	3696.60	2637.36	3826.28	5015.19
Transport cost (Eth Birr/ha)	0.00	28.80	57.90	36.30	65.10	93.90	72.30	101.10	130.20
Labor cost apply fertilizer (Eth Birr/ha)	0.00	200.00	200.00	400.00	400.00	400.00	400.00	400.00	400.00
Total costs that vary (Eth Birr/ha)	0.00	1417.72	2635.73	1754.98	2972.70	4190.50	3109.66	4327.38	5545.39
NB (Eth Birr/ha)	43151.4	71403.98	66927.07	50290.22	79725.60	87871.40	52737.14	81986.22	77771.21

Components of partial budget	Variety				
	Bellete	*Gudene*	*Jalene*	*Marachere*	Local†
Average yield (kg/ha)	34520.0	25399.0	27087.0	25039.0	19195.0
Adjusted yield (kg/ha)	31068.0	22859.1	24378.3	22535.1	17275.5
GFB (Eth Birr/ha)	93204.00	68577.30	73134.90	67605.30	51826.50
Tuber seed cost (Eth Birr/ha)*	12000.00	10000.00	10000.00	9000.00	8000.00
Total costs that vary (Eth Birr/ha)	12000.00	10000.00	10000.00	9000.00	8000.00
NB (Eth Birr/ha)	81204.00	58577.30	63134.90	58605.30	43826.50

Where, 0:0=0+0 NP kg/ha; 0:19.5=0+19.5 NP kg/ha; 0:39=0+39 NP kg/ha; 55.5:0=55.5+0 NP kg/ha; 55.5:19.5=55.5+19.5 NP kg/ha; 55.5:39=55.5+39 NP kg/ha; 111:0=111+0 NP kg/ha; 111:19.5=111+19.5 NP kg/ha; 111:39=111+39 NP kg/ha; †=the local check is the variety (often a mixture) commonly grown by farmers in the locality; *=since the costs that vary for the treatment variety is only costs for tuber seeds, tuber seed cost=total costs that vary

additional investment of 12,000.00 and 10,800.00 Eth Birr/ha for tuber seeds gave extra money of 23,170.08 and 17,734.56 Eth Birr, respectively, over the local variety (Table 4).

In agreement with the present study, while the inorganic fertilizer component gave a higher net benefit, lower net benefit was identical with no fertilizer components (Makinde et al., 2007; Yusuf et al., 2015). Similarly, the existence of a significant difference among potato varieties tested in their performances of tuber production potential and their economic profitability could be due to the fact that differences exists among varieties in their adaptability to the specific environment and nutrient use efficiency (Haile, 2009). Crop varieties vary in their physiology, morphology and growth habit and so do in their response to fertilizer application. Thus, species or cultivars having high growth rate respond to fertilizer application more favorably than those with low growth rate (Mengel, 1983).

Since the statistical results of the yield data have indicated a significant effect within the treatments, economic analysis is thus appropriate on the results of rates of NP fertilizers and variety treatments using the partial budget technique (CIMMYT, 1988). Consequently, the result of the partial budget analysis and the economic data used in the development of the partial budget is given in Table 2. While the resulting dominance analysis selected 0:19.5, 55.5:19.5 and 55.5:39 kg NP per hectare for the fertilizer treatments and *Bellete, Jalene* and *Marachere* for the variety treatments as the undominated treatments (Table 4).

For both treatments (rates of NP nutrients and variety), the calculations of marginal rate of return (MRR %) between 0:0 and 0:19.5, between 0:19.5 and 55.5:19.5 and between 55.5:19.5 and 55.5:39 treatments were 2183.07%; 592.90%; and 738.79%, respectively (Figure 1). Similarly, the MRR between local check and *Marachere,* between *Marachere* and *Jalene,* and between *Jalene* and *Bellete* were 1477.88, 452.96 and 903.46%, respectively (Figure 2).

The calculations of marginal rate of return realized that the MRR% between the selected nutrient treatments (0:0 and 0:19.5, 0:19.5 and 55.5:19.5 and 55.5:19.5 and 55.5:39) were above the minimum acceptable MRR (100%); that is, 2183.07, 592.90 and 738.79%, respectively (Figure 1).

Similarly, all MRRs between the selected variety treatments (local check and *Marachere, Marachere* and *Jalene,* and *Jalene* and *Bellete*) were greater than 100% (1477.88, 452.96 and 903.46%, respectively). Therefore, from the range of nutrient treatments tested against the check (0:0 NP kg/ha), 0:19.5, 55.5:19.5 and 55.5:39 NP kg/ha gave an economic yield response and also sustain acceptable returns when applied to the improved potato varieties *Bellete, Jalene* and *Marachere* (Figure 2).

Sensitivity analysis

The field prices of N and P nutrients were increased from

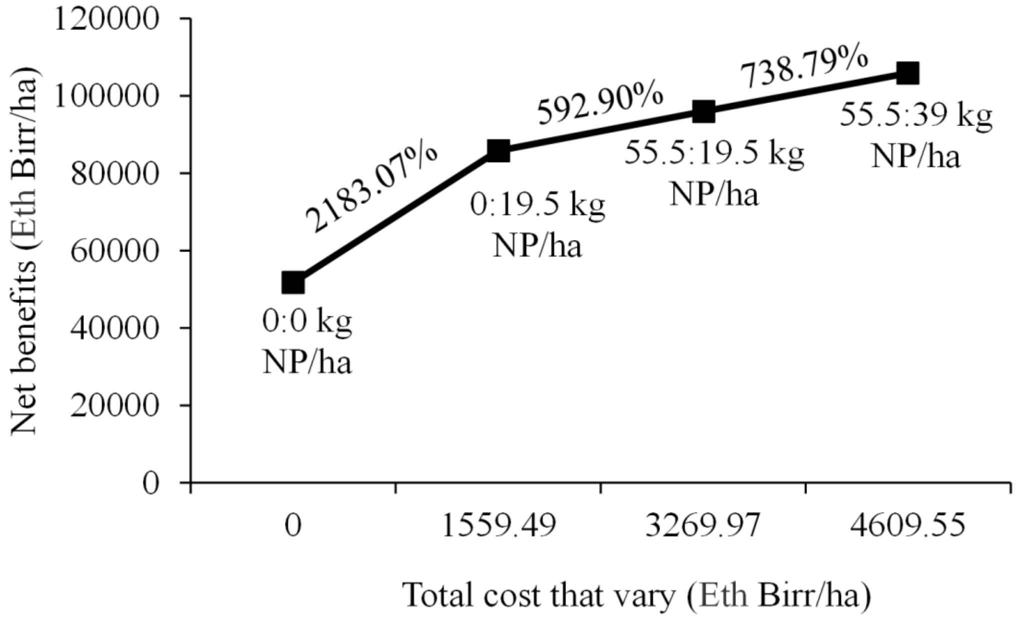

Figure 1. Net benefit curve and the marginal rate of return (%) for the rates of NP (kg/ha) nutrient treatments

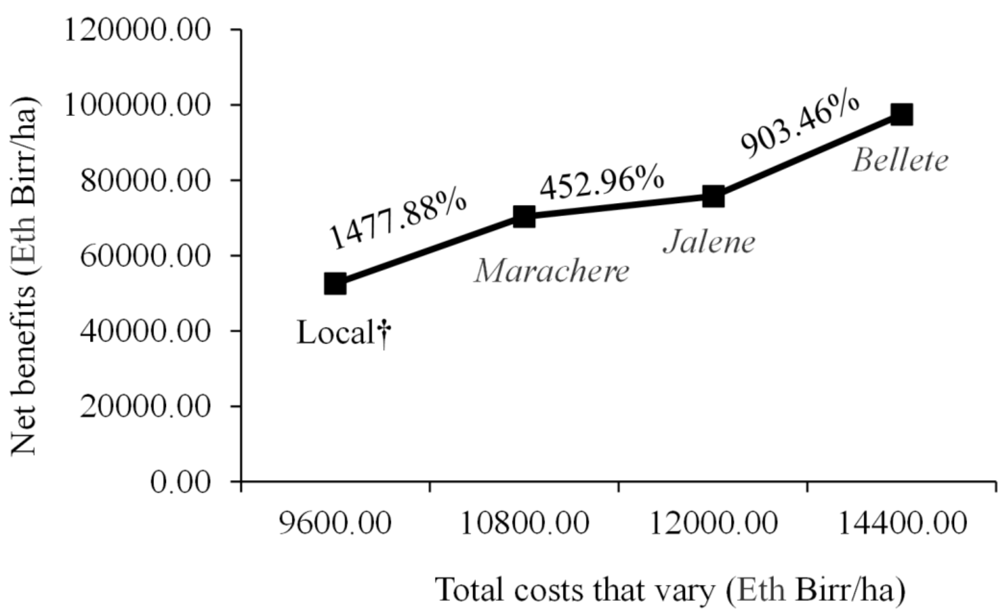

Figure 2. Net benefit curve and the marginal rate of return (%) for the variety treatments. Where, †=the local check is the variety (often a mixture) commonly grown by farmers in the locality

23.76 and 60.97 Eth Birr/kg to 26.14 and 67.07 Eth Birr/kg, respectively, by 10%. Similarly the field prices of the seed tubers of varieties local, *Marachere*, *Jalene* and *Bellete* increased from 4.00, 4.50, 5.00 and 6.00 Eth Birr/kg to the field prices of 4.80, 5.40, 6.00 and 7.20 Eth Birr/kg, in that order, by 20% and the new prices were used to make the partial budget (Table 3).

The calculations of marginal rate of return realized that the MRR% between the selected nutrient treatments (0:0 and 0:19.5, 0:19.5 and 55.5:19.5 and 55.5:19.5 and

Table 3. Partial budget analysis at future prices of rates of NP fertilization and variety treatments

Components of partial budget	Rates of NP nutrients (kg/ha)								
	0:0	0:19.5	0:39	55.5:0	55.5:19.5	55.5:39	111:0	111:19.5	111:39
Average yield (kg/ha)	15982.0	26971.0	25764.0	19276.0	30629.0	34097.0	20684.0	31968.0	30858.0
Adjusted yield (kg/ha)	14383.8	24273.9	23187.6	17348.4	27566.1	30687.3	18615.6	28771.2	27772.2
GFB (Eth Birr/ha)	51781.68	87386.04	83475.36	62454.24	99237.96	110474.28	67016.16	103576.32	99979.92
Cost to purchase fertilizers (Eth Birr/ha)	0.00	1307.81	2615.61	1450.55	2758.36	4066.26	2901.10	4208.91	5516.71
Cost to transport fertilizers (Eth Birr/ha)	0.00	31.68	63.69	39.93	71.61	103.29	79.53	111.21	143.22
Cost of labor apply fertilizer (Eth Birr/ha)	0.00	220.00	220.00	440.00	440.00	440.00	440.00	440.00	440.00
Total costs that vary (Eth Birr/ha)	0.00	1559.49	2899.30	1930.48	3269.97	4609.55	3420.63	4760.12	6099.93
NB (Eth Birr/ha)	51781.68	85826.55	80576.06	60523.76	95967.99	105864.73	63595.53	98816.20	93879.99

Components of partial budget	Variety				
	Bellete	*Gudene*	*Jalene*	*Marachere*	Local†
Average yield (kg/ha)	34520.0	25399.0	27087.0	25039.0	19195.0
Adjusted yield (kg/ha)	31068.0	22859.1	24378.3	22535.1	17275.5
GFB (Eth Birr/ha)	111844.80	82292.76	87761.88	81126.36	62191.80
Cost of tuber seed (Eth Birr/ha)*	14400.00	12000.00	12000.00	10800.00	9600.00
Total costs that vary (Eth Birr/ha)	14400.00	12000.00	12000.00	10800.00	9600.00
NB (Eth Birr/ha)	97444.80	70292.76	75761.88	70326.36	52591.80

Where, 0:0=0+0 NP kg/ha; 0:19.5=0+19.5 NP kg/ha; 0:39=0+39 NP kg/ha; 55.5:0=55.5+0 NP kg/ha; 55.5:19.5=55.5+19.5 NP kg/ha; 55.5:39=55.5+39 NP kg/ha; 111:0=111+0 NP kg/ha; 111:19.5=111+19.5 NP kg/ha; 111:39=111+39 NP kg/ha; †=the local check is the variety (often a mixture) commonly grown by farmers in the locality; *=since the costs that vary for the treatment variety is only costs for tuber seeds, tuber seed cost=total costs that vary

55.5:39) were above the minimum acceptable MRR (100%); that is, 2183.07, 592.90 and 738.79%, respectively (Figure 1). Similarly, all MRRs between the selected variety treatments (local check and *Marachere,* *Marachere* and *Jalene,* and *Jalene* and *Bellete*) were greater than 100% (1477.88, 452.96 and 903.46%, respectively). Therefore, from the range of nutrient treatments tested against the check (0:0 kg NP ha^{-1}), 0:19.5, 55.5:19.5 and 55.5:39 NP kg/ha gave an economic yield response and also sustain acceptable returns when applied to the improved potato varieties *Bellete, Jalene* and *Marachere* (Figure 2).

The input and output prices used in the economic analysis were those existing during the period of the experiment. Market prices are always changing and as such a recalculation of the partial budget using a set of likely future prices, that is, sensitivity analysis, is necessary to identify treatments which are likely to remain stable and sustain acceptable returns for farmers in spite of price changes. Accordingly, an assumption of price change of the nutrients (N and P) and the potato tubers is from our own experiences and represents a price fluctuation (increment) of 10 and 20% for the fertilizers and the tubers, respectively.

These price changes are currently realistic under the retailer and even union market conditions in Ethiopia. Some of the reasons for projection of the prices were absence of enough irrigation schemes to grow and access potato tubers all the times, semi perish-ability of the crop and lack of appropriate storage facilities are amongst. Deterioration of business environment in the country can also be the main reason for the price fluctuation of the nutrient treatments. Similar reasons were reported by many researchers previously (Shiluli et al., 2004; Odendo et al., 2006; Edward, 2015; Ayele et al., 2016).

Conclusion

From the range of rates of NP nutrient treatments tested, (19.5 kg P), (55.5 kg N and 19.5 kg P) and (55.5 kg N and 39 kg P) gave an economic yield response and also sustain acceptable returns even under a projected future market conditions. Whereas variety treatments such as *Bellete, Jalene* and *Marachere* gave an economically feasible yield returns sustainably under increased market prices. Thus, farmers could thus choose any of the three rates of NP nutrients to apply on either of the selected varieties *Bellete, Jalene* or *Marachere*, alternatively, depending on their income on the tentative basis. The results of this research can be used to make tentative recommendations, which can be rechecked through multi-location testing over a wider area. Furthermore, as it is difficult to individual farmer, bureaus of agriculture should regularly done soil analysis to monitor critical levels of soil nutrients which have the opportunity to reduce fertilizer costs significantly, maintain a

Table 4. Dominance analysis at (A) current and (B) future market prices.

(A) At current prices: **Field price of N=23.76 Eth Birr/kg** **Field price of P=60.97 Eth Birr/kg**				**MRR (%)**	**(B) At future prices:** **Filed price of N=26.14 Eth Birr/kg** **Field price of P=67.07 Eth Birr/kg**			
Rates of NP (kg/ha)	**TCV (Eth Birr/ha)**	**NB (Eth Birr/ha)**	**Dominance**		**Rates of NP (kg/ha)**	**TCV (Eth Birr/ha)**	**NB (Eth Birr/ha)**	**Dominance**
0:0	0.00	43151.40		1993	0:0	0.00	51781.68	
0:19.5	1417.72	71403.98		535	0:19.5	1559.49	85826.55	
55.5:0	1754.98	50290.22	D	669	55.5:0	1930.48	60523.76	D
0:39	2635.73	66927.07	D		0:39	2899.30	80576.06	D
55.5:19.5	2972.70	79725.60			55.5:19.5	3269.97	95967.99	
111:0	3109.66	52737.14	D		111:0	3420.63	63595.53	D
55.5:39	4190.50	87871.40			55.5:39	4609.55	105864.73	D
111:19.5	4327.38	81986.22	D		111:19.5	4760.12	98816.20	
111:39	5545.39	77771.21	D		111:39	6099.93	93879.99	D

(A) At current prices: **Local* = 4.00 Eth Birr/kg** ***Marachere* = 4.50 Eth Birr/kg** ***Jalene* = 5.00 Eth Birr/kg** ***Gudene* = 5.00 Eth Birr/kg** ***Bellete* = 6.00 Eth Birr/kg**				**MRR (%)**	**(B) At future prices:** **Local† = 4.80 Eth Birr/kg** ***Marachere* = 5.40 Eth Birr/kg** ***Jalene* = 6.00 Eth Birr/kg** ***Gudene* = 6.00 Eth Birr/kg** ***Bellete* = 7.20 Eth Birr/kg**			
Variety	**TCV (Eth Birr/ha)**	**NB (Eth Birr/ha)**	**Dominance**		**Variety**	**TCV (Eth Birr/ha)**	**NB (Eth Birr/ha)**	**Dominance**
Local†	8000.00	43826.50		1478	Local†	9600.00	52591.80	
Marachere	9000.00	58605.30		453	*Marachere*	10800.00	70326.36	
Jalene	10000.00	63134.90		903	*Jalene*	12000.00	75761.88	
Gudene	10000.00	58577.30	D		*Gudene*	12000.00	70292.76	D
Bellete	12000.00	81204.00			*Bellete*	14400.00	97444.80	

Where 0:0=0+0 NP kg/ha; 0:19.5=0+19.5 NP kg/ha; 0:39=0+39 NP kg/ha; 55.5:0=55.5+0 NP kg/ha; 55.5:19.5=55.5+19.5 NP kg/ha; 55.5:39=55.5+39 NP kg/ha; 111:0=111+0 NP kg/ha; 111:19.5=111+19.5 NP kg/ha; 111:39=111+39 NP kg/ha; †=the local check is the variety (often a mixture) commonly grown by farmers in the locality

profitable business, and keep the environment healthy and productive sustainably.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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