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Partial budget analysis of on-farm hot pepper (*Capsicum annuum* L.) production under varying rates of NPS fertilizer application and improved varieties: The case of Arba Minch Zuria District, Southern Ethiopia

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Abstract

Hot pepper is among economically high value crops growing in Arba Minch areas and contributes alot to the livelihood of smallholder farmers who engaged in this on-farm business. In this important on-farm business, there are production costs related to purchasing inputs that can improve the productivity of crop and analyzing the financial profitability of the business is found to be very important. Therefore, this study was conducted to assess on-farm financial profitability of hot pepper production under different improved varieties and varied rates of NPS fertilizer at Arba Minch through partial budget analysis. The study consisted of three hot pepper varieties (Bako Local, MarekoFana and Melka Shote) and six rates of NPS fertilizer (0, 50, 100, 150, 200 and 250 kg ha^{-1}). The treatments were laid-out in factorial arrangement in randomized complete block design with three replications. The results of the partial budget analysis indicate that application of 200 kg NPS ha^{-1} for Melka Shote variety gave the highest net benefit (185,649.90 ETB ha^{-1}) with a maximum marginal rate of return (5411.20%) as compared to other treatment combinations. Moreover, the net benefit curve also revealed that application of NPS fertilizer beyond 200 kg ha^{-1} decrease the net benefit obtained from the production of hot pepper across the three varieties. Therefore, production of Melka Shote variety with the application of 200 kg ha^{-1} NPS fertilizer could make the producers financially profitable and improve their income.

Keywords: Pepper; On-farm business; Optimum fertilizer; Marginal rate of return; Profitability

1. Introduction

Hot pepper (*Capsicum annuum* L.) is extensively growing in Ethiopia under both irrigation and rain-fed conditions at an altitude ranging from 1000 to 1900 meters above sea level although the crop requires frost-free season with the temperature between 15 and 30°C for optimum production [1, 2]. As a result, the supply of this important vegetable crop is year-round in the country.

Based on the form they are used, there are three groups of pepper in Ethiopia. These are chili ('*mitmita*'), green pepper ('*karia*', physiologically green matured fruit) and hot pepper ('*berbere*', dried fruits changed into powder form) [1]. All these groups are highly demanded by the consumers because the Ethiopian diet mostly includes one of these and it becomes one of the high economic value vegetable crops. During the 2018/2019 production season, the production of dry fruit hot pepper covered an area of 172,143 ha with a total production of 307,458 tons in Ethiopia [3]. Similarly, the crop is one of the most cash-generating vegetable crops produced by smallholder farmers in Arba Minch Zuria district.

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Due to its multiple harvesting, high economic value and quick return in addition to the availability of labor, land and irrigation water and favorable climate, production of hot pepper in Arba Minch Zuria district is increased and considered as the main on-farm business commodity. However, on-farm profitability of hot pepper production under different rates of NPS fertilizer and improved varieties at the district is not yet studied. As of the research conducted with different varieties and rates of fertilizer application, analyzing financial profitability was found to be very important. Therefore, partial budget analysis was selected for scrutinizing financial profitability. Because partial budget analysis is a farm management analytical tool that could be used to determine the profitability of alternative farm management practices and help to estimate comparative financial returns by quantifying net economic effects of changes proposed [4, 5, 6]. In addition, studies on hot pepper conducted at Arba Minch areas mostly focused on the adaptation, irrigation interval and nitrogen rate only [7, 8, 9]. Therefore, this study was conducted to assess on-farm financial profitability of hot pepper production under different improved varieties and rates of NPS fertilizer at Arba Minch Zuria district through partial budget analysis.

2. Material and methods

2.1. Description of experimental site

The experiment was conducted at Chano research farm of Arba Minch Agricultural Research Center, Arba Minch, Southern Ethiopia during the 2018/2019 cropping season. Geographically, the farm is situated at a latitude of 06°03'43" and longitude of 37°33'41" with an altitude of 1220 meters above sea level. The area received an annual rainfall of 808 mm with the minimum and maximum temperatures of 17 and 30°C, respectively during the 2018/2019 cropping season. The soil of the study site is clay in textural class with pH of 7.60 and deficient in available phosphorus and sulfur [10].

2.2. Experimental treatments and design

The combination of three hot pepper varieties (Bako Local, Marako Fana and Melka Shote) and six rates of NPS fertilizer (0, 50, 100, 150, 200 and 250 kg ha^{-1}) were set as an experimental treatments for this study. They were laid- out in a factorial arrangement in Randomized Complete Block Design with three replications. Seedlings were raised for three varieties on three well-prepared seedbeds (1 m width by 5 m length). Healthy and vigorous seedlings were selected through visual observation and transplanted in a plot size of 3.6 m length and 2.8 m width. The recommended spacing (0.7 and 0.3 m between rows and plants, respectively) was used to transplant the seedlings [11]. The proposed NPS fertilizer rates were applied during transplanting in the respective plots. Moreover, 46 kg N ha^{-1} in the form of Urea was given in split application (50% during transplanting and the remaining 50% at 45 days after transplanting).

2.3. Data collected

Data on marketable dry fruit yield was collected. The marketable dry fruit yield was measured from each plot basis and converted to ton per hectare. Data on input costs and net benefit obtained were collected and estimated on a hectare basis.

2.4. Partial budget analysis

The partial budget analysis procedure [12] was used for this study to assess the profitability of NPS fertilizer application for hot pepper varieties. It was done using the prevailing market prices for inputs during planting and output during harvesting. Average marketable dry fruit yield for each treatment, adjusted yield, gross field benefit and the total costs that vary due to treatments were considered for the partial budget analysis. The average marketable dry fruit yield was adjusted downwards by 10%, taking into consideration that farmers could get 10% less yield [12]. The minimum acceptable marginal rate of return used in this study was assumed to be 100% for farmers' recommendation domain. The marketable dry fruit yield from the control plot is taken as a reference. The farm-gate price of marketable dry fruit yield of hot pepper varieties in the local market was 65.00 Ethiopian Birr kg^{-1} during the harvesting period. The partial budget analysis was done by using the formulas developed by CIMMYT [12] and described as follows:

Adjusted marketable dry fruit yield (AjMDFY) = AvY–(AvY*0.1), where, AvY is the average gross marketable dry fruit yield per hectare.

Gross field benefit (GFB) = AjMDFY*farm gate price for the marketable dry fruit yield.

Total variable costs (TVC)= sum of the cost of fertilizers (NPS and Urea), labor cost for fertilizer application and transportation and seed costs, whereas costs incurred for land preparation, nursery seedbed management and transplanting, weeding, pest management and harvesting were constant costs along with proposed treatments.

Net benefit (NB)= GFB–TVC.

Marginal rate of return (MRR %) = $(\mathrm{MRR}(\%) = \frac{\Delta \mathrm{NB}}{\Delta \mathrm{TVC}} \times 100$ where, MRR is = Marginal rate of return in percent, ΔNB and ΔTVC= are change in net benefit and change in total variable costs, respectively.

3. Results and discussion

One of the partial budget analysis importances is its capacity of capturing change in production technology in agricultural research [12]. For this study, rates of NPS fertilizer (0, 50, 100, 150, 200 and 250 kg ha^{-1}) application were considered as changing agronomic practices to obtain optimum profitability level of its application. When the rates of blended fertilizer application varied from zero (control treatment) to 250 kg ha^{-1}, associated additional inputs costs were incurred to purchase each additional item. Variable costs incurred to acquire additional inputs were indicated in Table 1.

Table 1 Total variable costs considered in this study during 2018/2019 cropping season at Arba Minch, Southern Ethiopia

Variety	NPS rate (kg ha^{-1})	Variable costs for each treatment per hectare in Ethiopian Birr (ETB)						
		Fertilizers cost		FA cost	TC		Seed cost	TVC
		For NPS	For Urea		For fertilizer	For yield		
Bako Local	0	0	0	0	0	164.30	1,479.10	1,643.40
	50	706.20	1,345.54	350.00	55.00	220.14	1,479.10	4,155.94
	100	1,412.40	1,345.54	450.00	110.00	261.54	1,479.10	5,058.54
	150	2,118.60	1,345.54	550.00	165.00	420.66	1,479.10	6,078.86
	200	2,824.80	1,345.54	650.00	220.00	549.54	1,479.10	7,068.94
	250	3,531.00	1,345.54	750.00	275.00	455.40	1,479.10	7,836.00
Marako Fana	0	0	0	0	0	163.80	1,474.20	1,638.00
	50	706.20	1,345.54	350.00	55.00	180.54	1,474.20	4,111.48
	100	1,412.40	1,345.54	450.00	110.00	233.46	1,474.20	5,025.60
	150	2,118.60	1,345.54	550.00	165.00	293.94	1,474.20	5,947.28
	200	2,824.80	1,345.54	650.00	220.00	427.86	1,474.20	6,942.40
	250	3,531.00	1,345.54	750.00	275.00	433.60	1,474.20	7,809.54
Melka Shote	0	0	0	0	0	131.40	1,182.60	1,314.00
	50	706.20	1,345.54	350.00	55.00	309.60	1,182.60	3,948.94
	100	1,412.40	1,345.54	450.00	110.00	345.06	1,182.60	4,845.60
	150	2,118.60	1,345.54	550.00	165.00	416.34	1,182.60	5,778.08
	200	2,824.80	1,345.54	650.00	220.00	592.20	1,182.60	6,815.14
	250	3,531.00	1,345.54	750.00	275.00	536.94	1,182.60	7,621.08

FA= Fertilizer application cost; TC= Transportation cost; TVC= Total variable cost. The cost of NPS and Urea fertilizers was 1412.4 and 1345.54 Ethiopian Birr per 100 kg, respectively [13]. Fertilizer application cost= 50 birr/person/day; Fertilizer transportation cost from Union to field gate= 55 birr/quintal; Transportation cost of dry fruit yield to near market= 20 birr/quintal.

The cost-benefit was estimated for 15 treatments combinations and three controls. The results are presented in Table 2. Each variety combination at all rates of NPS fertilizer compared to identify which variety provides a high net benefit to the growers. The highest adjusted marketable dry fruit yield of 2,961.0 kg ha^{-1} was obtained from Melka Shote variety at the application of 200 kg ha^{-1} NPS fertilizer followed by 2,747.7 and 2,684.7 kg ha^{-1} obtained from Bako Local variety at 200 kg ha^{-1} NPS and Melka Shote at the application of 250 kg ha^{-1} NPS fertilizer, respectively. The highest net benefit of 185,649.90 Ethiopian Birr ha^{-1} was obtained from Melka Shote at 200 kg ha^{-1} NPS fertilizer application followed by 171,531.60 Ethiopian Birr ha^{-1}, which was obtained from Bako Local at the same fertilizer rate. This showed that adoption of different varieties with different rates of NPS fertilizer differs in producing dry fruit yield and net benefit. However, the grower had a chance to obtain a high yield with a high net benefit such as growing of Melka Shote with the application of 200 kg ha^{-1} NPS fertilizer.

The three hot pepper varieties showed varied performance for dry fruit yield along with the rates of NPS fertilizer. Melka Shote had the lowest adjusted marketable dry fruit yield of 657.00 kg ha^{-1} and the lowest net benefit of 41,391.00 Ethiopian Birr ha^{-1} without NPS fertilizer application. On the other hand, Melka Shote had a higher net benefit than the other two hot pepper varieties with the application of NPS fertilizer starting from 50 to 250 kg ha^{-1}. Mareko Fana followed by Bako Local without NPS fertilizer application would be brought higher net benefit as compared to Melka Shote without NPS fertilizer application. However, starting from 50 to 250 kg ha^{-1} NPS fertilizer, Bako Local had a higher net benefit than the Mareko Fana variety (Table 2). The results from the comparison of varieties suggested that production of Melka Shote variety with the application of NPS fertilizer at all rates had advantages for growers to obtain the highest net benefit. However, the production of all varieties with more than 200 kg ha^{-1} NPS fertilizer application reduced the net benefit due to lower dry fruit yield and increase in prevailing production costs (Figure 1).

The hot pepper producers may have different criteria for adoption of technology or preference of technology such as the technology with higher net benefit, high benefit to cost ratio and high yield, but most of the growers prefer to obtain the combination of high yield with high net benefit. Therefore, it is necessary to estimate the marginal rate of return (MRR) to check the technology (improved varieties and rates of NPS fertilizer) could allow a minimum economic return. The MRR was estimated to identify the treatment combination that has the minimum acceptable rate of return [12] to recommend the technology to the growers. In this regard, the highest MRR of 5411.20% was obtained from Melka Shote at the application of 200 kg ha^{-1} NPS fertilizer followed by Bako Local at 150 kg ha^{-1} NPS fertilizer, which had MRR of 4968.41% (Table 2). This suggested that growing of Melka Shote with the application of 200 kg ha^{-1} NPS fertilizer is recommended to growers since the growers would have 54.11 Ethiopian Birr return for every one Ethiopian Birr investment in the hot pepper farming business. However, recommending treatment/s based on the MRR alone is not reliable rather than based on the minimum acceptable rate of return. In this study, 100% was considered as the minimum acceptable rate of return for farmers' recommendation (i.e., for every one Birr investment, farmers are supposed to recover one Birr and more) [12]. Accordingly, the lowest MRR was 1.1995 (119.95%) and all treatment combinations had above the minimum acceptable marginal rate of return indicated that the growers had a wide range of alternatives.

The growers not only make the decision based on MRR to adopt the variety in a combination of specific rates of NPS fertilizer rather a variety with higher yield and net benefit at varying rates of fertilizer. Therefore, it is necessary to combine the MRR change with the net benefit curve to make a recommendation that may satisfy most of the growers. In this regard, Melka Shote with a range of 50 to 200 kg ha^{-1} NPS fertilizer offer growers with higher or increased net benefit than other varieties at similar rates of NPS fertilizer (Figure 1; Table 2).

The net benefit curve and MRR suggested that production of Melka Shote variety with the application of 200 kg ha^{-1} NPS fertilizer gave the highest net benefit of 185,649.90 Birr ha^{-1} and highest (5,411.20%) MRR (Table 2). It is also observed that production of Melka Shote at 200 kg ha^{-1} NPS fertilizer, Bako Local at 150 and 200 kg ha^{-1} NPS and Mareko Fana variety at 200 kg ha^{-1} NPS fertilizer offer growers with higher net benefit and higher MRR than at other rates of NPS fertilizer, but production of Melka Shote variety may not be preferred without NPS fertilizer application. The net benefit curve also indicates that application of NPS fertilizer more than 200 kg ha^{-1} decreases the net benefit obtained from hot pepper across the three varieties, which is associated with the increase of input costs and decrease in fruit yield. This is in agreement with the report of Tesfaw and Alemu [14], Biratu [15] and Melese et al. [16] who reported that optimum application of organic and inorganic fertilizers maximize the profitability of hot pepper production.

Table 2 Partial budget analysis of on-farm hot pepper production under varying rates of NPS fertilizer application and improved varieties during 2018/2019 cropping season at Arba Minch, Southern Ethiopia

Variety	NPS rate (kg ha^{-1})	MDFY (kg ha^{-1})	Adj.MDFY (kg ha^{-1})	TVC (ETB ha^{-1})	GFB (ETB ha^{-1})	NB (ETB ha^{-1})	MRR	MRR (%)
Bako Local	0	913.00	821.70	1,643.40	53,410.50	51,767.10		
	50	1,223.00	1,100.70	4,155.94	71,545.50	67,389.56	6.2178	621.78
	100	1,453.00	1,307.70	5,058.54	85,000.50	79,941.96	13.9069	1,390.69
	150	2,337.00	2,103.30	6,078.86	136,714.50	130,635.60	49.6841	4,968.41
	200	3,053.00	2,747.70	7,068.94	178,600.50	171,531.60	41.3057	4,130.57
	250	2,530.00	2,277.00	7,836.00	148,005.00	140,169.00	D	-
Mareko Fana	0	910.00	819.00	1,638.00	53,235.00	51,597.00		
	50	1,003.00	902.70	4,111.48	58,675.50	54,564.02	1.1995	119.95
	100	1,297.00	1,167.30	5,025.60	75,874.50	70,848.90	17.8148	1,781.48
	150	1,633.00	1,469.70	5,947.28	95,530.50	89,583.22	20.3263	2,032.63
	200	2,377.00	2,139.30	6,942.40	139,054.50	132,112.10	42.7374	4,273.74
	250	2,410.00	2,169.00	7,809.54	140,985.00	133,175.50	1.2263	122.63
Melka Shote	0	730.00	657.00	1,314.00	42,705.00	41,391.00		
	50	1,720.00	1,548.00	3,948.94	100,620.00	96,671.06	20.9796	2,097.96
	100	1,917.00	1,725.30	4,845.60	112,144.50	107,298.90	11.8527	1,185.27
	150	2,313.00	2,081.70	5,778.08	135,310.50	129,532.40	23.8434	2,384.34
	200	3,290.00	2,961.00	6,815.14	192,465.00	185,649.90	54.112	5,411.20
	250	2,983.00	2,684.70	7,621.08	174,505.50	166,884.40	D	-

MDFY= Marketable dry fruit yield; Adj.MDFY= Adjusted marketable dry fruit yield; TVC= Total variable cost; ETB= Ethiopian Birr; GFB= Gross field benefit; NB= Net benefit; MRR=Marginal rate of return; D=Dominated. The price of marketable dry fruit at the harvesting period was 65 ETB kg^{-1} for all varieties.

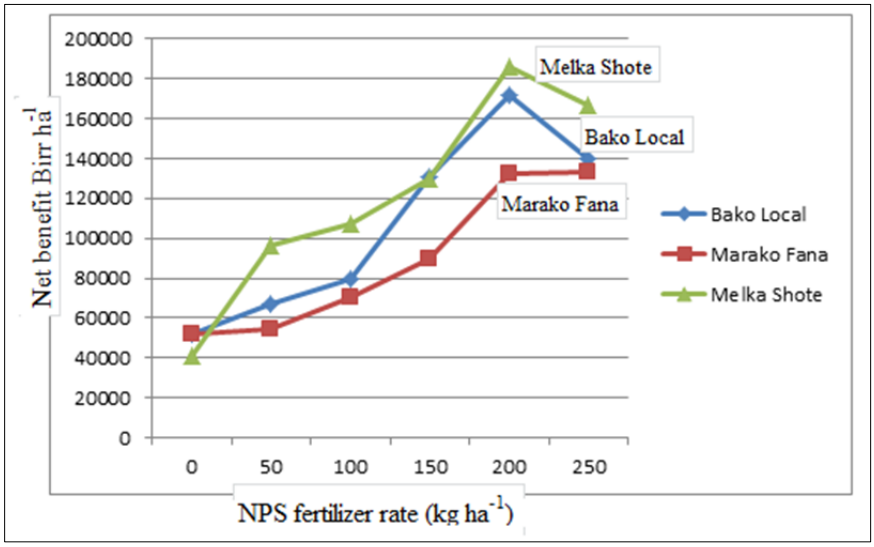

Figure 1 Net benefit curve (Ethiopian Birr ha^{-1}) for three hot pepper varieties with rates (0 to 250 kg ha^{-1}) of NPS fertilizer evaluated at Arba Minch during 2018/2019 cropping season

4. Conclusion

The application of optimum rate of NPS fertilizer, type of hot pepper variety grown, input costs and market price of fruit yield determines the profitability of hot pepper production. Production of Melka Shote variety with the application of 200 kg ha^{-1} NPS fertilizer gave the highest marketable dry fruit yield, maximum net benefit and marginal rate of return as compared to other varieties and rates of NPS fertilizer. As a result, application of 200 kg ha^{-1} NPS fertilizer for Melka Shote variety could be optimum and more profitable in the study area. Hence, production of Melka Shote variety with the application of 200 kg ha^{-1} NPS fertilizer is recommended because it would offers the highest marketable dry fruit yield and maximum net benefit with highest marginal rate of return to hot pepper growers in the study area.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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