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Effect of NPS and Nitrogen Fertilizer Application Rates for Small Pod Hot Pepper Production (*Capsicum Annuum* L) Variety at Kellem and West Wollega zones

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Abstract

Small pod hot pepper is grown as an annual crop and produced for its fruits. It is one of the most important vegetable crops for fresh consumption, for processing and as a spice (for making stew). A field experiment was conducted at HaroSabu Agricultural Research Center on station, Sedi Canqa and Lalo Qile sub sites of KellemWollega zone, Western Ethiopia, during the 2020 and 2021 main cropping seasons. Thirteen fertilizer combinations were used as experimental materials. The combined analysis of variance for total yield and other agronomic traits revealed highly significant differences in, plant height, plant canopy length, number of pods per plant and total dry pod yield; whereas days to flowering, days to maturity, number of primary branches per plant, pod length, pod diameter and pod weight revealed non-significant effect. In this experimentation, the combination of 150 kg/ha NPSand 150kg/ha N(urea) fertilizer rate was found superior in terms of economic yield (marketable yield), and yield component parameters. The marginal rate of return also directed the highest net benefit from the combined fertilizer rate of 150kg/ha NPS and 150kg/ha N(urea). Thus the combined fertilizer rate of 150kg/ha NPS and 150kg/ha N(urea) is recommended for the yield increment of small pod hot pepper in the studied areas of Western Oromia.

Keywords: fertilizer, hot pepper, Melka Dera, pod yield

Introduction

Hot pepper (*Capsicum annuum* L.) is an important spice and vegetable crop in tropical areas ofthe world and it belongs to the *Solanaceae* family, and the genus *Capsicum.* It is closely relatedto tomato, eggplant, potato and tobacco. The genus *Capsicum* is the second most importantvegetable crop of the family after tomato in the world (Berhanu *et al.*, 2011). It's animportant crop, not only because of its economic importance but also due to the nutritional andmedicinal value of its fruit (Nimona *et al,* 2018). The fruit is an excellent source of natural colours and antioxidant compounds whose intake is an important health protecting factor in the prevention of widespread human diseases (Howard *et al*., 2000).

It is one of the most important spice crops widely cultivated around the world for its pungentflavor and aroma (Obidiebub*et et al.,* 2012). Fine pungent powder of hot pepper ('berbere') isan indispensable flavoring and coloring ingredient in the daily preparation of different types ofEthiopian sauces ('wot'), whereas the green pod is consumed as a vegetable with other fooditems.

In the Oromia region, the total area under hot pepper for green pepper (*Karia*) and for dry pod (*Berbere*) in 2020 were estimated to be 6,429 ha and 75,691.85ha, respectively, while in West Wollega zones the total area covered with hot pepper for green pepper(*Karia*) and dry pod was 599.52 ha and 4,009 ha, respectively (CSA. 2021). which accounts 9.32% and 52.947% for green pod and dry pod, respectively of the total area coverage of the region. Despite the area coverage,thehot pepper productivity is still low attributed to a lack of proper nursery and field agronomic management practices (in adequate and/or unbalanced nutrient supply, diseases, poor aeration, and lack of high yielding cultivars).

Nutrient deficiency is the major yield limiting factor on vegetable production in Ethiopia; N, P and other nutrients as S, B and Zn deficiencies are the foremost constraints for production of vegetables and other crops (Alemu and Ermias 2000). Fertilizers are an efficient exogenous source of plant nutrients (Akram *et al.,* 2007). Plant growth and production necessitate sufficient and balanced nutrient supply as well as optimum uptake to maximize productivity (Mengel and Kirkby, 2001). The application of mineral NPK fertilizers enhanced yield and yield contributors through better nutrient uptake, growth, and development

(Obidiebube *et al.,* 2012). Supply of micronutrients along with NPK fertilizer can also increase nutrient use efficiency of crops (Malakouti, 2008).

In Ethiopia, chili (small pod hot pepper) has become an essential ingredient of the daily diet of the rich and the poor societies. It is an important commercial product supplied to the local market and exported to different countries. In its major area of production, with hot pepper has a huge potential for improving the income and livelihood of thousands of smallholder farmers and can play a vital role in food security in Ethiopia. In some parts of the country where pepper and chilies are dominantly grown, sales from these crops contribute 50-60% of the household income, as the green fresh fruits fetche a good price and are sold at Ethiopian Birr $80-100 per kg in the retail market (Gebeyehu and Shimelis, 2018). However, the productivity of chili pepper in KelemWolega(15.21 Qu/ha) is below the average yield estimation at the national level(18.25 Qu/ha) (CSA, 2017). This yield loss is due to a lack of improvedvariety, sowing methods, and use of improper rate of fertilizers. To tackle this problem, adaptation of five improved varieties was done and two varieties were recommended with blanket recommendation of fertilizer rate. Eventhough the recommended varieties were in good performance and higher yield than the local variety, the production per unit area is still low as compared to the potential productivity of the area. Since NPS is a newly introduced fertilizer and there was no recommended fertilizer rate for this crop, it is indispensable to evaluate optimum fertilizer rate to increase the productivity of chili pepper.

To narrow the yield gap,several options can be taken including evaluating different small pod hot pepper varieties for adaptationand determining the optimum fertilizer rate (Tesfaye *et al,*, 2020). Pepper requires an adequate amount of most major and minor nutrients, but the nutrients mostly used on pepper are nitrogen and phosphorous (Bosland and Votava, 2000). Girma*et al*. (2001) reported that application of 200 kg/ha of DAP and 100 kg/ha of urea was found optimum for better yield at Abobo. However, Jackson *et al*. (1985) recommended application of 140 kg/ha of P2O5 before sowing or transplanting, and split application of 130 kg/ha of N. Application of 207 kg of DAP and 137 kg of urea per hectare gave optimum yield of pods in hot pepper variety Odaharo at Bako (MoARD, 2005). However, the actual amount of fertilizer to apply depends on soil fertility, fertilizer recovery rate and soil organic matter content. Application of 100 kg DAP before planting and split application of 100 kg urea, 50 kg at 20 days after transplanting and the other 50kg at the time of flowering is, generally recommended for Ethiopian soil (EIAR, 2007). Although imported and local pepper varieties are available in Ethiopia, their adaptation and suitability for different agro-ecologies of the country has not been determined fully; data on appropriate N and P levels that are required to achieve at each locality is not available. This is particularly true to Kelem and West Wellegaareas where there had been no research effort to determine optimum rate and combination of NPS fertilizer for profitable hot pepper production.

Thus, the objective of this experiment was to evaluate the response of different NPS and N fertilizer rates on growth, yield, and yield components of small pod hot pepper production in West and KellemWollega zones and to determine the optimum and appropriate application rates of NPS and N fertilizer in the study area.

Material and Methods

Experimental location and experimental material

The experiment was conducted at HaroSabu Agricultural Research Center of Oromia Agricultural Reseach Insitute on three experimental sites(Haro Sabu main station, Sadi Chanka and Lalo Qile) for two consecutive years during the 2020 and 2021 main cropping seasons. Thirteen different rates of NPS and nitrogen fertilizers were evaluated on small pod hot pepper Malka Dera variety which was collected from Malkasa agricultural research center and recommended for the studied areas. The experiment was conducted with a randomized complete block design in three replications with a plot size 2.4 m length and 3.5m width.The source of nitrogen besides NPS is urea.

Experimental design and analyses

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each treatment was applied in the main field in a gross plot size of 2.4m*3.5m with recommended spacing of 70cm and 30cm between rows and plants, respectively. The three middle rows were used for data collection leaving the two rows as borders. Other agronomic practices (transplanting time, cultivation, and weeding) were applied uniformly for all plots according to the recommendation for the crop.

Data collection and data analyses

Ten plants were randomly sampled from the middle three rows. Data on plant height, plant canopy, number of primary branches per plant, number of pods per plant, pod yield per plant (g), average pod weight (g), pod length (cm) and pod diameter (cm) were recorded per plant and fruit basiswhile measurements such as days to flowering, days to maturity, marketable dry pod yield hectare^{-1}(kg) were taken on plot basis.

The collected data were subjected to analysis of variance using GenStat computer software (Gen Stat, 2016) and Least Significant Differences (LSD) was used to compare the treatment means using the procedures of Fishers protected at the 5% level of significance.

Result and Discussion

Soil physico-chemical properties of experimental site

The pre-transplanting soil analysis results revealed that the soil of experimental fields was clay with moderately acidicin organic carbon matter and high total nitrogen but low available phosphorus and medium cation exchange capacity (Table 1).

Table 1. Pre-planting soil physico-chemical properties of the experimental sites during 2020 and 2021 cropping seasons.

Soil properties	Value of Analysis			Status
	H/Sabu on Station	Igu/SadiChanqa	Sego/Lalo Qile	
Textural class	Clay	Clay	Clay	Slightly suitable for hot pepper production
Soil pH (1:2.5 H_2O)	5.7	5.6	5.4	Moderately acidic
Organic matter content (%)	8.69	7.34	5.88	High
Total nitrogen (%)	0.27	0.22	0.24	High
Phosphorus (ppm)	1.40	1.0	0.70	Low
Cation exchange capacity (cmol(+)/kg soil)	19.70	22.70	17.70	Medium soil fertility

The sandy loam, loam and clay loam soils are good for chili cultivation. The soil should be well drained and aerated as it gives a better yield. Highly alkaline or acidic soils are not recommended for chili cultivation. Saline, waterlogged, and clay soils are not recommended for chili cultivation (Anonymous, 2022). Peppers normally grow in light and well-drained soil that is rich in organic matter such as sandy loam or loams with a pH value between 6.5 and 7.5 (Haifa Chemicals, 2023, Gebresilassie and Israel, 2021).

ANOVA

The combined mean analysis of variance (ANOVA) for phenological growth parameters, yield and yield related data of thirteen fertilizer rate combinations at three locations in 2020 and 2021 revealed significance on plant height, plant canopy length, number of pods per plant and total yield of small pod hot pepper, Malka Dera variety, whereas other growth parameters and yield related parameters were non-significant (Tables2 and 3).

Table 2. Mean squares of ANOVA for days to 50% flowering (DF), days to 90% physiological maturity(DM), plant height(PH, cm),canopy length (CL, cm), and number of primary branches per plant(NBrP) of small pod hot pepper Malka Dera variety.* p<0.05; ** p>0.01.

Source of variation	d.f.	Mean squares			
		DF	DM	PH	NBrP
Replication	2	59.35	54.3	226.07	1.794
NPS_N	12	20.37	75.5	84.81*	0.978
Location	2	2615.59**	3197.9**	2422.62**	95.053**
Year	1	19662.5**	52.7	1770.18**	0.003
NPS_N *Location	24	14.77	111.7	39.79	0.878
NPS_N *Year	12	15.24	106.7	30.96	1.216
Location * Year	2	507.86**	10313**	797.44**	0.467
NPS_N * Location * Year	24	9.88	90.5	42.41	1.084
Residual	154	16.64	101.8	43.6	1.163

Table 3. Mean squares of ANOVA for number of pods per plant(NPPP), pod length (PL), pod diameter (PD), pod weight (PW) and total yield(TY) of small pod hot pepper Malka Dera variety. * p>0.05, ** p>0.01.

Source of variation	d.f.	Mean squares				
		NPPP	PLcm	PDcm	PWg	TYkg per ha
Replication	2	677.3	0.3489	0.01385	0.00355	446385
NPS_N	12	411.6**	0.654	0.08142	0.00807	97517*
Location	2	24715.2**	12.4089**	1.25282**	0.01357	9949618**
Year	1	132.5	2.3802*	7.75538**	0.1839**	342734*
NPS_N * Location	24	87.6	0.5733	0.05856	0.00929	33809
NPS_N *Year	12	152.9	0.4898	0.06575	0.00722	31905
Location * Year	2	46.5	11.2356**	11.82615**	0.09826**	1129948**
NPS_N * Location * Year	24	114.9	0.6596	0.0693	0.01012	49400
Residual	154	121.4	0.4791	0.07289	0.0101	51283

Days to flowering and maturity

From the combined means of analyses, days to 50% flowering and maturity werenot significant under the fertilizer combinations of NPS and nitrogen. The interaction effects of year and location revealed significant effects on days to flowering and days to maturity. This might be due to the fluctuations of soil moisture, temperature and rainfall in different years (Table 1).

Table 4. Combined means of NPS and N rate effects on phenologicaland growth parameters of small pod hot pepper production.

NPS*N rate	DF	DM	PH (cm)	NPrB
0*0	92.44	166.70	41.08c	3.944
150*50	89.11	164.80	47.54ab	4.27
150*100	90.94	165.30	45.92ab	4.21
150*150	89.00	164.80	49.26a	4.39
200*50	89.44	164.60	48.32a	4.38
200*100	91.28	165.20	46.61ab	4.11

200*150	90.83	165.30	46.91ab	4.06
250*50	91.22	165.50	45.84ab	4.34
250*100	91.50	165.90	45.6ab	3.89
250*150	91.67	158.90	43.47bc	3.71
300*50	91.33	165.80	46.66ab	3.88
300*100	91.83	167.60	48.61a	3.80
300*150	91.00	166.10	46ab	3.89
LSD(0.05)	NS	NS	4.35	NS
CV(%)	4.5	6.1	14.3	26.5

Where DF, DM, PH and NPrBare days to 50% flowering, days to 50% maturity, plant height(cm) and number primary branches per plant, respectively.

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Plant height

Analysis of variance for fertilizer combination showed that there was a significant ($P \leq 0.05$) effect on plant height and there were highly significant effects ($P \leq 0.01$) on year, location, and their interaction (Table 2). The longest (49.26cm) and the shortest (41.08cm)values were recorded forthe combination of 150*150 NPS and nitrogen and zero fertilizer application, respectively (Table 4). These differences in fertilizers rates on plant height might be due to the optimum application of nitrogen which favors cell elongation and maximum vegetative growth of the plant (Daniel and Abrham, 2020). This work is in line with Wakuma *et al.* (2021) who reported increasing in plant height with increasing NPSZn + urea rate,whichmight be attributed to nitrogen which is a component of aminoacids and chlorophyll, which is the primary light harvesting pigment for photosynthesis (Bhuvaneswari *et al*., 2014). On the contrary, Hintsa *et al*. (2019) reported a non-significant effect of NPS fertilizer rates on plant height, which might be due to different chemical properties of soil (total nitrogen, pH, organic carbon, available phosphorus, etc.) among the study areas.

Number of primary branches per plant and plant canopy

Analysis of variance showed that there was a highly significant ($P \leq 0.01$) effect on the number of primary branches per plant due to location, whereas the main effect of fertilizer combination, year and all the interactions were not significant (Table 2).

The main effects of fertilizer combination, location and year, and the interaction of location and year showed highly significant effects on plant canopy length, while other interactions are notsignificant(Table 2). The combined mean analysis of fertilizer combinations revealed significant effects on plant canopy. The widest (48 cm) and the narrowest (38.33cm) plant canopy was recorded forthe application of 150 NPS*150 urea and zero fertilizer rates (Table 4). These variations in canopy diameter between fertilizer rates might be due to the growing environment's soil type, and rainfall and soil pH which responded to different rates of fertilizer.

Table 5. Combined means of NPS and N rate effects on yield and yield components of small pod hot pepper production.

NPS*N rate	NPPP	PL (cm)	PD (cm)	PW(g)	TY (kg) per ha)
0*0	24.54e	6.20	3.12	0.61	441.3c
150*50	38.34ab	6.19	3.16	0.63	669.6ab
150*100	31.89b-e	5.68	2.94	0.60	614.4ab
150*150	41.54a	5.72	3.11	0.62	729a
200*50	37.87abc	6.23	3.11	0.61	715.6ab
200*100	30.73cde	5.72	3.01	0.55	673.6ab

200*150	35.5a-d	5.97	3.07	0.59	600.9ab
250*50	35.83a-d	5.98	3.03	0.57	678.6ab
250*100	30.76cde	5.97	3.20	0.59	611.1ab
250*150	28.72de	5.93	3.02	0.60	570.1bc
300*50	35.7a-d	5.90	3.06	0.59	617.4ab
300*100	39.76a	5.91	3.11	0.61	657.7ab
300*150	34.16a-d	5.71	3.09	0.60	608ab
LSD(0.05)	7.25	NS	NS	NS	149.12
CV(%)	32.2	11.7	8.8	16.6	36

Where NPPP, PL, PD,PW and TY, are number of pod per plant, pod length (cm), pod diameter (cm), pod weight (g), total yield(kg/ha), respectively.

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Number of pod per plant, pod length, pod diameter and average pod weight

The effect of fertilizer rates and location showed highly significant effectson the number of pods per plant and pod length;whereas the effects of year and all the interactions were not significant(Table 3). However, the effect of fertilizer rates and nearly all the interactions were notsignificant on pod length, pod diameter and average pod weight (Table 3). The highest(41.54) and the lowest(24.54) number of pods per plant were recorded from the combination 150NPS*150N (urea) and zero fertilizer rate, respectively (Table 5). The differences among fertilizers on pod per plant might be due to the application optimum of nitrogen which is an integral component of many essential plant compounds like chlorophyll, and proteins and it is a major part of all amino acids (Brady and Weil, 2002). This is in line with the work of Temesgen *et al.*(2019) who reported the highest number of pods per plant (80.18) at 150 nitrogen fertilizerrate. Similarly, in agreement with this result, Mebratu *et al.*(2019) reported the highest number of pods per plant (84.07) at 150kgha^{-1} of urea on hot pepper at the south-eastern part of Ethiopia.

Total dry yield (kg/ha)

Analysis of variance revealed that the main effect of combined fertilizer rates, location, year and the interaction effect of location and year showed highly significant (P<0.01) effects on total dry pod yield of small pod hot pepper, whereas interaction effects are nonsignificant (Table 2). The highest (729 kg/ha) and the lowest (441.3 kg/ha) yield were recorded from 150NPS*150N(urea) (Table 5).

The significant difference among fertilizer rates on total dry pod yield might be due to growth and yield related parameters such as plant height, plant canopy length, and number of pods per plant, which were higher at the same fertilizer rate with total dry pod yield. However, there was a yield decline at the highest rate of fertilizer supply, implying that hot pepper yield increase occurs up to a certain optimum level of fertilizer supply and then decreases afterward (Roy *et al.,* 2011).This is in line with the findings of Nimona and Girma (2019) who reported the highest dry yield of hot pepper at the 150 NPSBZn + 44 N of blended fertilizer and nitrogen rates which implies that.150 NPSBZn + 44 N is the optimum fertilizer rate for hot pepper production.Similarly, Awoke and Yimegnushal,(2021) stated that the highest dry pod yield of hot pepper was recorded with the application of 200 kg of NPS ha^{-1} for Melka Shote and Bako Local varieties due to the optimum application of blended NPS fertilizer coupled with yield contributing characters of the two varieties.

Partial budget analysis

Cost-benefit analysis was undertaken with different rates of NPS and nitrogen(urea) fertilizers to determine the highest net benefit with an acceptable marginal rate of return. The results of the partial budget analyses revealed that the maximum net benefit of Birr 125,152.50ha^{-1} with an acceptable marginal rate of returns

(MRR%) of 260 was recorded in the treatment combination of 150 kg/ha NPS and 150 kg/ha N(urea)(Table 6).

Table 6. Partial budget analysis of rate of fertilizer on small pod hot pepper production.

NPS * N rates	TY(kg/ha)	Adjusted yield(kg/ha)	GFB	TVC	NB	MRR
0*0	441.3	397.17	79,434	0.00	79,434.00	
150*50	669.6	602.64	120,528	4,272.50	116,255.50	861.83
150*100	614.4	552.96	110,592	5,170.00	105,422.00	D
200*50	715.6	644.04	128,808	5,397.50	123,410.50	7907.03
150*150	729	656.1	131,220	6,067.50	125,152.50	260.00
200*100	673.6	606.24	121,248	6,295.00	114,953.00	D
250*50	678.6	610.74	122,148	6,522.50	115,625.50	295.60
200*150	600.9	540.81	108,162	7,192.50	100,969.50	D
250*100	611.1	549.99	109,998	7,420.00	102,578.00	707.03
300*50	617.4	555.66	111,132	7,647.50	103,484.50	398.46
250*150	570.1	513.09	102,618	8,317.50	94,300.50	D
300*100	657.7	591.93	118,386	8,545.00	109,841.00	6830.99
300*150	608	547.2	109,440	9,442.50	99,997.50	D

Where TY, GFB, TVC, NB and MRR are total yield in kilogram per hectare, gross field benefit, total variable cost, net benefit, and marginal rate of return in Birr, respectively.
D= Dominated treatment

The marginal rate of returns measures the increase in the net income. MRR% becomes unnecessary when the treatment costs are less than the existing practices. When the treatment yield gives lower benefit, then the treatment is said to be dominated. A dominated treatment is any treatment that has net benefits that are less than those of a treatment with lower costs that vary (Stephen and Nicky, 2007).

MRR is calculated by dividing the marginal increase in net benefit with the marginal increase in variable cost and multiplying the result by 100. In the present study, the treatment 150 kg/ha NPS and 150 kg/ha N(urea) was most profitable. The highest MRR % was 260 for the best combination of NPS and N(urea) rates. The computed MRR % indicate what a producer can expect to receive by adopting technologies. Hence, high yield and low cost lead to high income.

Conclusion and Recommendation

The evaluation of combined fertilizer rates of NPS and N(urea) was done to study the effect of fertilize rates on small pod hot pepper of Melka Dera variety. A significant difference was shown in different yield related traits among fertilizer rates. The highest and the lowest plant height, plant canopy length and number of pods per plant were recorded from the combined fertilizer rate of 150 kg/ha NPS and 150 kg/ha N(urea) and unfertilized, respectively. Similarly, the highest combined mean of dry pod yield was recorded from the same fertilizer rates. In general, significant differences for a number of traits (plant height, plant canopy length and number of pods per plant) and dry pod yield among the tested combined fertilizer rates were observed.The partial budget analysis also implies the highest net benefit for the combination of fertilizer rates of 150 kg/ha NPS and 150 kg/ha N(urea). Thus,in the present study, a combination of 150 kg/ha NPS and 150 kg/ha urea wasfound superior in terms of economic yield (dry pod yield) and other yield related parameters which implies the highest net benefit. Therefore,a combination of 150 kg/ha NPS and 150 kg/ha urea isrecommended for yield increment of small pod hot pepper production in the studied areas of Western Oromia.

Confilct of interest

The authorts have no confilict of intrest.

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