Annals of Agricultural & Crop Sciences

Open Access

Austin Publishing Group

Research Article

The Effect of Nitrogen and NPS Fertilizer Rates and Inter-row Spacing on the Growth and Yield of Head Cabbage (Brassica oleracea L.) under Irrigation in Bako, Western Oromia, Ethiopia

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Received: December 26, 2024; **Accepted:** January 07, 2025; **Published:** January 14, 2025

Abstract

Head cabbage is a popular leafy vegetable consumed all over the world. However, a number of factors, such as diminished soil fertility and poor agronomic practices, frequently restrict the crop's production and productivity. A study was conducted at Bako Agricultural Research Center, under surface irrigation, during the cropping seasons of 2022 and 2023 for two years, to determine the effects of three levels of inter-row spacing, Nitrogen from urea, and Phosphorus from (NPS), were laid out in a randomized block design with three replications in a 3x3x3 factorial arrangement. The results analysis of variance indicated that the inter-row spacing of 55 cm had a substantial effect on the marketable yield (27483 kg ha^{-1}) and total yield, (31842 kg ha^{-1}). Likewise, 69 N ha^{-1} fertilizer rates from urea gave the highest marketable yield of 27861 kg ha^{-1} and total cabbage yield of 31824 kg ha^{-1}. The partial budget analysis across year showed the highest net benefit of, 274720.0 birr obtained. Therefore, application 69 N ha^{-1} fertilizers and 100 kg ha^{-1} NPS with inter-row spacing of 55 cm under irrigation can be recommended for the production of head cabbage in study area and similar agroecology ecology based on the study's findings

Keywords: Head cabbage, Nitrogen, Phosphorus, spacing

Introduction

The origins of cabbage may be traced to Western Europe and the coasts of the North Sea, where it was domesticated and used for human sustenance as early as antiquity. Worldwide, head cabbage is a significant and incredibly diversified collection of crops [1]. Commercial growers favor it since it is a cool-season crop [2] to be used in both fresh and processed forms, it can be grown anywhere in the world [3]. Furthermore, cabbage is a popular vegetable crop all over the world because of its adaptability to a range of soil and climate conditions.

Ethiopia's climate and edaphic conditions are perfect for growing cabbage, [4]. Cabbages prefer light sand soils with high quantities of organic matter over heavy clay soils. The pH of the optimal soil is between 5.5 and 6.5. In soils with a pH higher than 6.5, the leaf margins wither and the leaves become black. To produce healthy heads, cabbage requires 380 to 500 mm of even moisture, depending on the climate and length of the growing season [5]. In Ethiopia, cabbage is the second most important vegetable crop in terms of production and area covered, after red pepper, [6]. Cabbage yield in Ethiopia totals 561,042.34 tons, with a mean productivity of 84.37 quintal/ha^{-1}, according to the Central Statistics Agency's [7] annual report. Nonetheless, the global average. The optimal number of plants per unit area and the pattern in which the specified quantity of seeds or plant population is placed in the planting field have a significant impact on the likelihood of obtaining a good yield [8]. This is due to crop canopy, as per [9].

Similar to the plant density, low soil fertility is likewise regarded as one of the major production-restraining factors in the research area. Nitrogen and phosphorus accounted for the majority of the essential plant nutrients for cabbage yield. The fact that the type of soil has a direct impact on the response of nitrogen and phosphorus is noteworthy because it emphasizes how different soil types react to fertilizer, [8]. For higher cabbage productivity and long-term output, fertilizer must be applied at the right rate. Numerous studies show that adding phosphorus and nitrogen increases cabbage production overall [10]. Controlling plant density and fertilizer amount is necessary to yield a large amount of cabbage You can increase cabbage yield by using fertilizer and land use more efficiently if you understand how these factors interact. Farmers in Ethiopia's western Oromia region, particularly those in the Bako area, need to boost the yield of cash crops like cabbage in order to maximize their profits from their meager irrigated agricultural plots. Yet, local farmers who commonly cultivate cabbage pay less attention to the ideal plant population, the rate at which nitrogen and phosphorus fertilizers are applied, and watering techniques. Moreover, there is a lack of

Citation: Feyanbule MM, Wondimu T. The Effect of Nitrogen and NPS Fertilizer Rates and Inter-row Spacing on the Growth and Yield of Head Cabbage (Brassica oleracea L.) under Irrigation in Bako, Western Oromia, Ethiopia. Ann Agric Crop Sci. 2025; 10(1): 1175.

information on cabbage plant density, the rate at which nitrogen and phosphorus should be applied for the best production, and other agronomic methods. As the majority of the farmers in this region have, the yield is quite low. As a result, they earn less money and are unable to enhance their standard of living. To boost the revenue of farmers in the area, it is crucial to enhance the yield of cabbage. Thus, the following goals were the starting point of the current work:

❖ To determine optimum level of NPS and urea, fertilizer rates and inter row spacing for head cabbage production

❖ To determine the economically optimal inter-row spacing, fertilizer rates for NPS and urea yield of head cabbage under irrigation.

Materials and Methods

Description of the Study Areas

The experiment was conducted at the Bako Agricultural Research Center, distance from Addis Ababa 232 km, under irrigation during winter season. The soil of the area is acidic with a pH of 4.80, medium available P, organic carbon, and total nitrogen. The area has a warm-humid climate, mean annual rainfall of 1237 mm that varies between 887mm, annual minimum and maximum air temperatures ranges between 13.5 ^{0}C and 29.7 ^{0}C with a mean annual relative humidity of 52.15 % (Metrological data, Figure 1).

Experimental Materials and Design

A treatment was tested in a factorial arrangement laid out in Randomized Complete Block Design with three replications. A plot area of 3.5 m x 2.25 m (7.88 m^2) was considered at three levels of inorganic fertilizer; 50, 75, and 100 kg ha^{-1} NPS and 69, 92 and 138 N kg ha^{-1}of urea and three level of combined inter-row spacing; 35 cm, 45 cm, and 55 cm between rows; with uniform 50 cm between plants were used for the studies. The distance between block and plot was 1.5 m and 0.5 cm, respectively. Nitrogen fertilizer was applied in two-split application, 50 % during planting and 50 % at 45 days after emergence.

Data Collection and Measurements

In order to eliminate border effects, the middle row of plants was used for the collection of the following yield and yield-related parameter data.

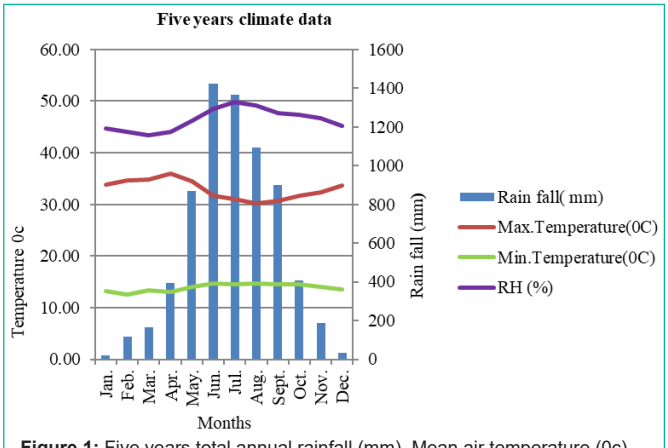

Figure 1: Five years total annual rainfall (mm), Mean air temperature (0c), and Relative humidity (%) from 2017-2021.

Phenological Parameters

Days with 50 % head initiation (DH): It was recorded when a net plot's plants included half heads

Days to 90 % maturity of heads (DM): It was recorded from the transplantation date until 90 % of the net plot's heads matured.

Growth Parameters:

Head height (HH cm): At 90 % of the way to head maturity, it was measured by setting a ruler from the ground to the top of the longest outer head of each individual plant. In order to further analyze the data, the mean of five plants from a single plot were recorded.

Yield Parameters

Number of leaves per plant (NLPP): Was recorded as the number of leafs per head when at least 90 % plants showed head maturity.

Head weight (HW kg): It was determined by the electronic balance between the plant's individual heads. For the sample plants, the head fresh weight per plant was noted and represented in kilo gram. The mean values were then used for further investigation

Marketable yield (MarY; kg ha^{-1}): It was calculated by weighing mechanically unharmed, insect and disease free heads from the net plot area with an electronic balance. The mean values were then used for analysis and translated to kilo grams per hectare.

Unmarketable yield (UMarY; kg ha^{-1}): It was calculated in kilo grams per hectare by weighing diseased, mechanically damaged, or injured heads on an electronic balance.

Total yield (TY; kg ha^{-1}): The total head yields, both marketable and nonmarketable, were calculated, and the outcome was converted to kilo grams per hectare.

Partial Budget Analysis

An analysis of the partial budget was conducted in order to look at the treatments' economic viability. Using the methods outlined by [11] economic assessments were conducted to compare the viability of the various treatments. To provide farmers with what they would get, the average yield was reduced by 10 %. Variable costs were taken into account when doing a partial budget analysis.

Results and Discussion

Phenological Parameters

Analysis of variance showed that the use of nitrogen from urea and phosphorus from blended NPS fertilizer and inter-row spacing had no significant (P 0.05) effect on the number of days to 50 % head initiation of cabbage and days to 90 % physiological maturity (Table 1 &Table 2). The results were in line with those of [12], who claimed that the three-way interactions were not significant for the analyzed parameters, such as the date of heading initiation and physiological maturity, except for location, year, and variety.

Growth Parameters

Interaction between use of inter-row spacing and nitrogen fertilizer rate did not significantly (P<0.05) affect the cabbage head height and number of cabbage leaves per plant (Table 2). But, cabbage

Table 1: Mean squares of anova for Days to heading, Days to 90 % physiological maturity, stand count, numbers of leaf per plant, head height, head diameters, head weight, marketable yield, unmarketable yield and total yield of head cabbage response to blended NPS, Nitrogen fertilizer rates and inter row spacing under irrigation at Bako Research center.

DF										
Treatments		**DH**	**DM**	**NLPP**	**HH**	**HD**	**HW**	**Mary**	**unMary**	**THY**
Itra	2	54.27ns	0.82ns	15.28ns	27.86ns	4.90ns	1.78**	135.09*	5.32ns	160.86*
N	2	51.94ns	1.86ns	0.81ns	22.21ns	1.48ns	1.48***	495.18*	0.14ns	481.73*
Itra*N	4	5.72ns	1.01ns	31.73ns	16.89ns	2.88ns	1.48ns	105.83ns	1.18ns	120.38ns
NPS	2	47.15ns	1.14ns	23.20*	44.37**	44.19***	0.83***	317.03*	2.48*	375.57*
Itra*NPS	4	18.09ns	2.44ns	1.72ns	2.43ns	1.57ns	0.61 ns	48.12ns	0.13ns	51.42ns
N*NPS	4	36.86ns	0.61ns	3.63ns	17.29ns	0.59ns	0.69ns	111.61ns	1.02ns	115.28ns
Itra*N*NPS	8	11.16ns	2.25ns	7.10ns	9.09ns	0.57ns	0.98ns	68.720ns	1.23ns	77.52ns
LSD (05%)		3.2	1	1.53	1.15	0.85	0.13	2.7	0.36	3.2
CV %		8.97	2.34	13.84	11.64	10.26	16.7	30.29	37.37	28.37

Table 2: Main effect of inter–row spacing, nitrogen from urea and phosphorus from blended (NPS) fertilizers, on day to head initiation, days to 90 % physiological maturity, head height and number of leaves per plant of head cabbage under irrigation.

Treatment	Days of head initiation	Days of 90 % physiological maturity	Head height (cm)	Number of leafs per plant
Inter–row spacing				
35 cm	62.19	85.22	18.54	21.91
45 cm	60.67	85.02	18.23	21.73
55 cm	61.76	85.35	17.77	21.28
LSD	Ns	Ns	Ns	Ns
Nitrogen from urea				
69	60.67	85.02	18.23	21.73
92	61.76	85.35	17.77	21.28
138	62.19	85.22	18.54	21.91
LSD	Ns	Ns	Ns	Ns
Phosphorus from (NPS)				
50 kg ha-1	62.82	85.43	17.32b	20.79b
75 kg ha-1	60.69	85.19	18.38a	22.42a
100 kg ha-1	61.09	84.98	18.82a	21.73ab
LSD	Ns	Ns	0.87	1.44
CV%	10.15	9.14	11.96	16.57

head height and number of leaves per plant were significantly (0.001) affected by application of phosphorus. The highest cabbage head height (18.82 cm) and number of leaves per plant (22.42cm) of head cabbage recorded from application of 100 kg ha^{-1} phosphorus from blended NPS which is statistically at par with all treatments except 50 kg ha^{-1} blended NPS. According to [13], the application of phosphorus had a substantial effect on the growth and yield characteristics of Chinese cabbage, the results supported their findings. The plant's height (30.73 cm), spread (2980.75 cm), and number of outer leaves all grew over time when phosphorus levels rose from 80 to 100 kg ha^{-1}.

Yield Parameters

The main effect of inter-row spacing nitrogen from urea and phosphorus from blended NPS fertilizer levels on head diameter and head weight of head cabbage (*Brassica oleracea* L.) under irrigation conditions was significantly different (P<0.05) (Table 3). The highest cabbage head diameter (18.82 cm) and head cabbage weight (1.52 kg/plant) recorded from application of Nitrogen (69) from urea,100 kg ha^{-1} phosphorus from blended NPS fertilizer which is statistically at par with all treatments except 50 kg ha^{-1} phosphorus from blended NPS. This result was similar with the findings of [14], nutrient levels markedly influenced the diameter, head mass, and yield of head cabbage. The treatment receiving 235 kg N and 82 kg P per hectare recorded the maximum average diameter (25.44 cm) and average head height (27.33 cm). The diameter of the head is a significant yield contributing characteristic of cabbage. From the present research, it was observed that yield marketable and unmarketable and total yield varied significantly (P<0.001) among the treatments tested due to the application of inter-row spacing, nitrogen from urea and phosphorus from blended NPS (Table 3). The highest marketable yield head yield with (27861 kg ha^{-1}) and total head cabbage yield (32095 kg ha^{-1}) was found from the treatment combination of inter-row spacing 55cm, Nitrogen (69) from urea, and phosphorus from blended (NPS) 100 kg ha^{-1}. While the lowest yield with Marketable head cabbage yield (20495, and 25173 ha^{-1}) was recorded in the treatment inter-row spacing (35cm and 45cm), Nitrogen (92) from urea and phosphorus from blended NPS (50 kg ha^{-1}) respectively. This result was in line with [15] who reported that more than 35 t ha^{-1} marketable head

Table 3: Main effects of inter–row spacing, nitrogen from urea and phosphorus from NPS fertilizers on head diameter, head weight, marketable yield, unmarketable yield, and total yield.

Treatments	Head diameter	Head weight kg/plant	Marketable head Yield kg ha-1	Unmarketable head Yield kg ha-1	Total head yield kg ha-1
Inter-row					
35 cm	14.57	1.37ab	25173a	4044	29217a
45 cm	14.16	1.30b	20495b	3169.4	23664b
55 cm	14.69	1.52a	27483a	4359.1	31842a
LSD	Ns	0.176	4380	Ns	5152
Nitrogen from urea					
69	14.41	1.35b	27861a	3963.5	31824a
92	14.41	1.31b	21047b	3291.8	24339b
138	14.59	1.52a	24243ab	4317.2	28560ab
LSD	Ns	0.18	4380	Ns	5152
Phosphorus from (NPS)					
50 kg ha-1	13.59b	1.29b	21918b	3251.8	25170b
75 kg ha-1	14.76a	1.39ab	23450b	3829.3	27280ab
100 kg ha-1	15.05a	1.51a	27627a	4467.8	32095a
LSD	0.7022	0.18	4382	Ns	5155
CV %	12.11	31.43	44.84	45.54	42.54

Table 4: Economic (partial budget and domain) Analysis effect of Inter–row spacing, Nitrogen (N) from urea and phosphorus from blended (NPS) fertilizers of head cabbage through irrigated at Western Oromia Bako.

Treatments			Head yield kg/ha-1	Adjusted marketable head yield kg/ha-1	Gross head yield field benefit ETB ha-1	Total field benefit ETB/ha-1	Total variable cost ETB/ha-1	Net benefit ha-1	Value to cost ratio	Marginal rate return (%)
Nitrogen (N) ha-1	NPS kg ha-1	Inter- row (cm)								
69	50	35	30454.6	27409.14	219273.1	219273.1	7696.35	211576.8	27.49D	
69	50	45	27407.41	24666.67	197333.3	197333.3	7696.35	189637	24.64D	
69	50	55	39087.83	35179.05	281432.4	281432.4	7696.35	273736	35.57D	
69	75	35	21797.46	19617.71	156941.7	156941.7	8659.57	148282.1	17.12D	
69	75	45	31661.38	28495.24	227961.9	227961.9	8659.57	219302.3	25.32D	
69	75	55	30560.85	27504.76	220038.1	220038.1	8659.57	211378.5	24.41D	
69	100	35	27193.65	24474.29	195794.3	195794.3	9622.79	186171.5	19.35D	
69	100	45	38926.98	35034.28	280274.3	280274.3	9622.79	270651.5	28.13D	
69	100	55	39492.06	35542.86	284342.8	284342.8	9622.79	274720.1	28.55	195.77
92	50	35	33329.1	29996.19	239969.5	239969.5	9619.65	230349.9	23.95	0.01
92	50	45	27238.1	24514.29	196114.3	196114.3	9619.65	186494.6	19.39D	
92	50	55	44165.08	39748.57	317988.6	317988.6	9619.65	308368.9	32.06D	
92	75	35	19365.08	17428.57	139428.6	139428.6	15386.4	124042.2	8.06D	
92	75	45	25587.3	23028.57	184228.6	184228.6	15386.4	168842.2	10.97D	
92	75	55	28950.27	26055.24	208441.9	208441.9	15386.4	193055.5	12.55D	
92	100	35	21077.25	18969.53	151756.2	151756.2	19233	132523.2	6.89D	
92	100	45	26984.13	24285.71	194285.7	194285.7	19233	175052.7	9.10D	
92	100	55	36253.97	32628.57	261028.6	261028.6	19233	241795.6	12.57	83.99
138	50	35	27513.23	24761.91	198095.3	198095.3	17309.7	180785.6	10.44	3.15
138	50	45	29214.82	26293.34	210346.7	210346.7	17309.7	193037	11.15D	
138	50	55	28308.46	25477.62	203820.9	203820.9	17309.7	186511.2	10.77D	
138	75	35	19682.54	17714.29	141714.3	141714.3	19233	122481.3	6.37D	
138	75	45	21394.71	19255.24	154041.9	154041.9	19233	134808.9	7.01D	
138	75	55	20052.91	18047.62	144381	144381	19233	125148	6.51D	
138	100	35	26116.4	23504.76	188038.1	188038.1	23079.6	164958.5	7.15D	
138	100	45	18476.19	16628.57	133028.6	133028.6	23079.6	109949	4.76D	
138	100	55	22518.52	20266.67	162133.3	162133.3	23079.6	139053.7	6.02D	

yields were recorded from 45 cm × 30 cm inter- and intra-row spacing combinations. [16] Reported that a spacing of 50 cm × 30 cm inter- and intra-row produced the highest yield of heads, while 50 cm × 50 cm spacing produced heavier heads. [17] Also reported that the highest cabbage head yield was obtained with 60 cm between rows and 30 cm between plants. Significantly, highest unmarketable head yield of 4 t ha^{-1} was recorded with treatment combinations of 30 cm inter- and intra-row spacing followed by 35 cm × 30 cm inter-and intra-row spacing.

Partial Budget Analysis

The effects of Inter–row spacing, Nitrogen (N) from urea and phosphorus from blended (NPS) fertilizers, on Head cabbage yield treatment resulted in higher net benefits, which consisted of 69:100kg: 55 cm Nitrogen from urea, Phosphorus from blended NPS and inter-row spacing respectively (Table 4). The highest net benefit ETB 274720.05 ha-^{1} was obtained from the application of 69 nitrogen from urea,100 kg Phosphorus from blended NPS, and 55cm inter-row spacing, with a marginal rate of return of 195.77 %, while the lowest net benefit ETB 109948.97 ha-^{1} was obtained from the application of 138:100 kg NPS:45cm Nitrogen, Phosphorus and inter row spacing respectively. As a result, nitrogen (69) from urea, 100 kg of blended NPS, and 55cm inter-row spacing (284342.84 kg ha-^{1}) was found economically feasible for head cabbage.

Conclusions and Recommendations

The application of 69 nitrogen from urea, 100 kg ha-^{1} phosphorus from NPS fertilizers and 55 cm inter–row spacing which gave significantly the highest marketable head yield per hectare compared to other treatment combinations. The lowest combination of nitrogen from urea, phosphorus from NPS, and inter-row spacing, 138:100 kg ha-^{1}: 45cm respectively gave the lowest average head weight of cabbage. The inter-row spacing of 55 cm had a substantial effect on the marketable yield (27483 kg ha-^{1}) and the total yield (31842 kg ha-^{1}) for cabbage heads weight 1.52 kg per plant**.** In nitrogen from urea rates of fertilizer, the highest cabbage head weight of 1.52 kg per plant, marketable yield of 27861 kg ha-^{1}, and total cabbage yield of 31824 kg ha-^{1} were influenced by 69 N of urea. Effect of phosphorus from blended (NPS) fertilizer rate, cabbage head height 18.81cm, Number of Leaves Per Plant (NLPP) 22.42; cabbage Head Weight per plant (HW) 1.52 kg, cabbage head diameter 15.05 cm, total marketable yield 27627 kg ha-^{1} and total cabbage head yield 32095 kg ha-^{1} influenced by 100 kg ha-^{1} phosphorus from blended NPS fertilizer. Moreover, over the study of two years, the treatments with the largest net benefit (274720.05-birr) were those that inter-row 55 cm, 69 N of urea, and 100 kg ha-^{1} phosphorus rates from NPS. The application of 55 cm rows, 69 N of urea, and 100 kg ha-^{1} of phosphorus from blended (NPS) level fertilizer through irrigation can be recommended for the economically productive production of head cabbage in western Oromia Bako Tibe district, Ethiopia, and similar ecology-based on the study's findings. Therefore, it is concluded that the application of 55 cm: 69 N: 100 kg nitrogen from urea, phosphorus from blended NPS, and inter-row spacing is suitable and recommended for the head cabbage production in the study area and similar agro-ecology.

Author Statements

Data Availability

The corresponding author can provide data used to support the study's conclusions upon request.

Conflicts of Interest

It is stated by the authors that they have no competing interests.

Authors' Contributions

Mamo Mekonnen Feyanbule collected, analyzed, and interpreted the data and Tilahun Wendimu edited the manuscript, the authors read and approved the manuscript.

Acknowledgement

The experiment was supported during execution by the Bako Agricultural Research Center, of the Oromia Agricultural Research Institute.

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