EFFECT OF NPS AND UREA FERTILIZER RATE ON YIELD AND YIELD COMPONENT OF HEAD CABBAGE (*Brassica oleracea L.*) AT KOFALE DISTRICT, OROMIA REGIONAL STATE, ETHIOPIA

MSc. THESIS

MULUWERK ADDISU

HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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HAWASSA UNIVERSITY

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THESIS SUBMITTED TO THE SCHOOL OF PLANT AND HORTICULTURAL SCIENCE, COLLEGE OF AGRICULTURE, SCHOOL OF GRADUATE STUDIES HAWASSA UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN PLANT AND HORTICULTURAL SCIENCES (SPECIALIZATION: HORTICULTURE)

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SCHOOL OF GRADUATE STUDIES

ADVISORS'APPROVAL SHEET

(Submission Sheet –1)

This is to certify that the thesis entitled ''**Response of Head Cabbage (B*rassica oleracea* L.) to different rates of nitrogen from Urea and NPS fertilizer at Kofale district, Oromia regional state, Ethiopia**'', was submitted in partial fulfillment of the requirements for masters of sciences with a specialization in horticulture to the Graduate Program of the School of Plant and Horticultural Sciences, College of Agriculture, and has been conducted by Muluwerk Addisu under my supervision, and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during this investigation have been well acknowledged. Therefore, I recommend that the student fulfill the requirements and, hence, submit the thesis to the department.

________________________ ______________________ ______________________

Major Advisor **Signature** **Date**

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(Submission Sheet-2)

We, the undersigned members of the Board of Examiners of the final open defense by Muluwerk Addisu, have read and evaluated her thesis entitled Response of head cabbage (*Brassica oleracea* L.) to different rates of nitrogen from Urea and NPS fertilizer at Kofale district, Oromia regional state, Ethiopia' 'and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirement.

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Name of Major Advisor	**Signature**	**Date**
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Final approval and acceptance of the thesis are contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School of Graduate Committee (DGC/SGC) of the candidate.

DEDICATION

This Thesis is dedicated to all my family for their sacrifice throughout my education and the success of my life.

DECLARATION

I declare that this MSc Thesis is an original report of my work and has not been submitted to any other institutions anywhere for the award of any academic degree, diploma, or certificate. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others. This thesis is submitted in partial fulfillment of the requirements for a MSc. degree at Hawassa University, deposited in the Hawassa University library, and made available to users under the rules of the library.

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Place: College of Agriculture, Hawassa University, Hawassa, Ethiopia

Date of Submission: ________________________________

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LIST OF ABBREVIATIONS AND ACRONYMS

ARARI	Amhara Regional Agricultural Research Institute
CSA	Central Statistical Agency
FAO	Food and Agricultural Organization
MANRS	Ministry of Agriculture Natural Resource Sector
N	Nitrogen
NPS	Nitrogen, Phosphorus and Sulfur

Table of Contents

Lists of tables

Table

Page

LIST OF TABLES IN APPENDIX

Effect of NPS and UREA Fertilizer rate on yield and yield component of Head Cabbage (*Brassica oleracea L.*) at Kofale District, Oromia regional state, Ethiopia

Abstract

Cabbage is one of the most popular and widely grown vegetable crops in the world. Among the factors responsible for low yields in cabbage, unbalanced use of N and NPS fertilizer was considered the major problem causing a high reduction in the potential yield of cabbage. Hence, a field experiment was conducted in 2023 main cropping season to investigate the effect of N and NPS fertilizer on growth, yield, and yield components of cabbage in Kofale district. The experiment consisted of a factorial combination of three rates of NPS (0, 100, and 200 kg ha^{-1}) and four rates of nitrogen (0, 100, 200, and 300 kg ha-1). The interaction effects of N and NPS fertilizer were found to have a significant impact on days to 50% head initiation, days to 90% head maturity, plant height, leaf length, leaf width, head length, head width, folded number of leaf head diameter, fresh and dry head weight, and marketable head yield. The highest head dry weight (0.174 kg $plant^{-1}$) and marketable 118.34 t ha^{-1}) head yields were obtained by 200 kg ha^{-1} NPS and 300kg ha^{-1} N rate of fertilizer, which were significantly on par with 100 kg ha^{-1} NPS and 300 kg ha^{-1} N rate of fertilizer that recorded 118.01 t ha^{-1} marketable head yields of cabbage. Therefore, the use of 200 kg ha^{-1} NPS and 300 kg ha-1 N can tentatively be recommended for cabbage producers in the study area.

Keywords: Cabbage, Fertilizer, head yield, Nitrogen, NPS

1.INTRODUCTION

1.1. Background

Cabbage (*Brassica oleracea* var. capitata L.) is the fifth most important vegetable crop belonging to the family Cruciferae, and it is a biennial crop with overlying leaves from a compact head (Gelaye and Tadele, 2022). Cabbage is an important and highly diverse group of crops grown worldwide (Gelaye and Tadele, 2022). It is cool season crop that is famous with gardeners and industrial producers (Seid *et al*., 2021) Currently, head cabbage is produced in most temperate countries and becomes very popular in tropical Africa (FAO, 2022).

Cabbage contain different amounts of nutrients with savoy type being more superior (Teshome, 2018). Initially cabbage was used for medicinal purposes such as treatment for gout, stomach problems, headaches and deafness, while now it is mainly used as a fresh market crop and for processing. cabbage can be mixed with other vegetables or sold as stir-fry and for making sauerkraut (Teshome, 2018). Cabbage is one of the most significant vegetables in the world in terms of area coverage, production, and availability (FAO, 2022).
The major cabbage growing countries of the world are China, India, Russia, Japan and the Republic of Korea (FAOSTAT, 2017). Vegetables, including cabbage, are important crops for food security as well as to generate income for subsistence farmers (FAO, 2009; Uddin ***et al***., 2009). Cabbage is known for its nutritional importance and rich in vitamins such as A, B_1, B_2 and C. Researchers also revealed that cabbage, provides significant cardiovascular benefits and reduces the risks of lung, colon, breast, ovarian and bladder cancers (Degarege, 2022). It is also known for its cooling effect, an appetizer, digestion, prevent constipation and protects against cancers and it contain different amounts of nutrients, with the savoy type being superior (Degarege, 2022).

Cabbage is one of the most ancient vegetables cultivated for more than 4,000 years (Kidane, 2016). Cabbage is produced in more than 150 countries globally, with China being the world's top producer with 35,092,621.83 metric tons, followed by India and total of

71,707,238.96 metric tons of cabbage are produced worldwide, with average yields of 29.26 metric tons per hectare grown on 24,506.01 hectares of available land (FAOSTAT, 2022). Ethiopia is one of the top five African countries producing head cabbage (Fertilizer & Oromia, 2018). Head cabbage is the second most important vegetable crop in Ethiopia, in terms of area covered and level of production (CSA, 2022). Its prophesied annual production in Ethiopia is 43, 5863 tons, with an average yield of 9.64 tons per hectare from 46,446 ha, which is far below the world average (29.26 tons/ha) (Fasika, 2021). Despite the high nutritional value of cabbage and its production potential, biotic and abiotic factors are limiting its productivity. Among them, drought, poor soil nutrients, and a lack of improved cultivars are the most important ones (CSA, 2022). In Oromia Regional country the area blanketed by way of head in 12 months 2008/2009 used to be 2188.9 hectares while the production was once 15,601.9 ton and the yield is 7 t/ha (CSA, 2017).

The area under head cabbage production in Oromia regional state was 4198.46 ha with a productivity of 9.3 t ha^{-1} in the country (CSA, 2021),. Head cabbage is widely produced in Kofele and Kore districts due to its suitable environmental conditions, and it is also one of the cash crop vegetables produced and marketed by farmers in the districts (DoA, 2013).
Despite the production is high, there are many constraints which affect head cabbage production around the area, lack of nitrogen results in poor and slow growth, but the excess use of nitrogen results in delayed maturity and low quality of leaf. Cabbage demands 130 to 310 kg/ha of nitrogen to achieve a high yield (Fasika, 2017), and Richard *et al*. (2016) also reported that 375 kg/ha of nitrogen fertilizers gave the maximum head yield of cabbage. Adequate application of nitrogen fertilizer promotes vigorous vegetative growth and the dark green color of cabbage (Fasika, 2017).

NPS fertilizer in agriculture already has and will continue to have fundamental determinate influence on agriculture (Herel, *et al*., 2007). Plant takes up NPS in the shape of nitrate or ammonium for natural matter, in organic rely and fixation of free NPS by using microorganisms. NPS play essential function in protein formation as factor of chlorophyll. Chlorophyll is required for light electricity absorption method of photosynthesis. Therefore, adequate NPS supply enhances the quantity of chlorophyll as result of amplify photosynthesis and deficiency of NPS reduces statistics of chlorophyll, and nechrotic or symptomas end result flowers lose their inexperienced shade main to reduction of the fee of photosynthesis (More, 2006).

The principle behind nutrient management is balancing soil nutrient inputs with crop requirements (Fekadu and Dandena, 2006). The recent and future identification of the use of nitrogen fertilizer in agriculture has and will continue to have a major and determinate impact on agriculture (Gebeyaw and Belete, 2020). Nitrogen plays an important role in protein formation as a component of chlorophyll. Chlorophyll is required for the light energy absorption process of photosynthesis. Therefore, an adequate nitrogen supply enhances the amount of chlorophyll as a result of increased photosynthesis (Gebeyaw and Belete, 2020).
The use of integrated nutrient management and correct agricultural practices, such as optimum application of nutrients, has to be adhered to for successful vegetable production (Teshome *et al*., 2018).

Nitrogen is an important constituent of chlorophyll and proteins, which are vital for vegetative growth. Phosphorus play a crucial role in physiological processes such as photosynthesis, respiration, energy storage, cell division, and cell enlargement (Nair *et al*., 2020). Most smallholder farmers in Ethiopia practice the application of inorganic fertilisers below the recommended rates for crop production (Teshome *et al*., 2018). Research findings from different researchers indicate that nitrogen has a significant influence on the head cabbage. Kwame ***et al***. (2017) also found significantly higher head length, head diameter, head weight, and marketable head yields using a higher rate of nitrogen. Teshome and Amide (2020) also found reliable and optimal yield and quality of vegetables using the proper rate of nitrogen-containing fertilizer. The same author reported that an adequate supply of nitrogen is essential for vigorous vegetative growth, head formation, and the optimum yield of cabbage. Moreover, blended NPS (19% N, 38% P2O5 and 7% S) fertilizer has been recently introduced to substitute the previous DAP fertilizer as source of phosphorous (MoANR, 2013). The newly recommended blended fertilizer, therefore, has optimum rates for economical production of crops, including vegetable crops. NPS is one of the vital plant vitamins in cabbage yield, and it is important to note that it is immediately associated with the soil type, emphasizing that soils of various fertility types react differentially to the fertilizer utilized, and it plays an essential function in the protein of amplify photosynthesis (Seid *et al*., 2021).

Kofele district is one of the potential areas for the production of head cabbage, with an average productivity of 9.5 t/ha, which is very low compared to the world average (17.67 t/ha). reference Limited soil fertility is one of the key factors in the limited productivity of cabbage. Cabbage producers are also using fertilizers without knowing the optimum rate and type for each crop in the area. It is assumed that synchronization of crop demand for N fertilizer and time of application with sufficient amounts improves the yield of cabbage and reduces waste of N, reducing production costs and environmental pollution due to unused excess N leaching in different forms (Geisseler *et al.*, 2022). However, the optimum amount of N that matches the crop demand during the growth period is little explored. Therefore, this work was conducted to determine the optimum N and NPS rates for growth and yield and the economically feasible rate of cabbage production.

1.2 Objective

1.2.1 General objective

- To study assess the effect of different rates of nitrogen and NPS fertilizers on the growth, yield, and yield components of head cabbage.

1.2.2 Specific objectives

- To determine the optimum level of nitrogen and NPS fertilizer for the growth and yield of head cabbage
- To determine the interaction effects of nitrogen and NPS fertilizer on the growth and yield of head cabbage.

2. LITERATURE REVIEW

2.1. The Cabbage plant

Cabbage (*Brassica oleraceae* L.) originates from wild non-headed colewort (*Crambecordifolias*) from Western Europe and the northern shore of the Mediterranean. Where it has been grown for more than 3000 years. The genus Brassica includes about 100 species, the majority of which are native to the Mediterranean region. It has chromosome number 2n=2x=18 (Gebeyaw & Belete, 2020). Currently, head cabbage is produced in most temperate countries and becomes very popular in tropical Africa (FAO, 2022).

Cabbage is an important group of crops worldwide and an antiquated vegetable crop cultivated long before the dawn of human history, the majority of them are located near the Mediterranean (Yebirzaf, 2017).

2.2. Soil and Climatic Requirements

Cabbage can be grown in wide range of soils from light sand to heavier clays. Soils with high organic matter content give the best yields. Early cultivars grow well in light soils, whereas, late cultivars perform better on heavy soils. Well-drained soils however give larger yields. Although cabbage is relatively tolerant to salt, in saline soils cabbage plants show leaf margin dieback and dark foliage which may increase the susceptibility of plants to diseases like black leg (ARARI, 2005; Rail and Yadav, 2005). The optimum pH of soil for cabbage cultivation is between 6.0 - 6.5 (Yano *et al*., 1999). As cool season vegetable, cabbage grows best under cool moist conditions. The optimum temperature ranges for growth and head formation of cabbage is 15-20^{O}C. The growth of most cabbage varieties is arrested when the temperature rises above 25^{O}C (Chadha, 2006). However above 27^{0}C it may bolt and causing the heads to split open and The crop is grown in diverse ecologies with altitudinal range of 500 - 3000 m.a.s.l (Kidane, 2016)

2.3. Importance of the Head Cabbage

Cabbage is grown for its leaves and is frequently used as a vegetable. Cabbage is an awesome source of minerals such as calcium, iron, sodium, potassium, and phosphorus. It has a large quantity of beta-carotene, ascorbic acid, and others. It has energy (27%), fat (0.1%), and carbohydrate (4.6%). It is a good supply of protein (1.3%), which consists of all critical amino acids, in particular Sulphur-containing amino acids (Rai and Asati, 2005). Cabbage is one of the most important, high nutritive and palatable leafy vegetables. It is a rich source of protein, minerals and vitamin A (Uddin *et al.*, 2009). Head cabbage is used for medicinal purposes such as treatment for gout, stomach problems, headaches, and deafness, and also protects against cancer (Ruzawlah *et al*., 2002).

Today, it is mainly used as a fresh market crop and for processing. Fresh market cabbage is used for cooking as the main dish or mixed with other vegetables in stews and salads. It is also an excellent source of vitamins, calcium, dietary fibre, and protein when it is eaten raw as salad and boiled or cooked as stew or soup (Kidane, 2016). There are three types of heading cabbage, namely green, red, and savoy, and their leaves are eaten as salads or cooked (Singh *et al*., 2019). They contain different amounts of nutrients, with savoy being more superior, and it can be mixed with other vegetables or sold as stir-fry or for making sauerkraut (Pierce, 2007).

2.4 Effect of NPS Fertilizer on the Growth and Yield of Head Cabbage

The sources of plant nutrients for Ethiopian agriculture over the past five decades have been limited to urea and Di Ammonium Phosphate (DAP) fertilizers which contain only nitrogen and phosphorus that may not satisfy the nutrient requirements of crops In this regard however, Shiferaw (2014) reported that Ethiopian soils lack most of the macro and micro nutrients that are required to sustain optimal growth and development of crops.to avoid this condition, the Ministry of Agriculture of Ethiopia has recently introduced a new compound fertilizer This fertilizer containing nitrogen, phosphorous, and Sulphur (NPS) with a ratio of 19% N, 38% P2O5, and 7% S. is currently substituted for DAP in the Ethiopian crop production system as the main source of phosphorous (Alemayehu and Jemberie, 2018). NPS is one of the vital plant vitamins in cabbage yield, and it is important to note that nitrogen fertilizer's response is immediately zing that soils associate of various fertility types react differentially to the fertilizer utilized (Tehulie and Belete, 2021). NPS fertilizer, which is fairly vital for first-class cabbage development, should be an excellent alternative. And investigating the highest quality of NPS fertilizer for cabbage in our country is a vital condition. Generally, it may additionally cause a magnificent loss in the growth, productivity, and dietary quality of cabbage.

Therefore, appropriate use of NPS fertilizer for the plant can resolve the impacts on the growth of the cabbage. However, NPS rates have to be regulated to attain excessive yields from phosphorus is claimed to be the second most often limiting plant nutrient (Tisdale *et al*., 1995). It is an essential component of deoxyribonucleic acid (DNA), the seat of genetic inheritance, and of ribonucleic acid (RNA), which directs protein synthesis in both plants and animals. Miller and Donahue (1995), and Tisdale *et al*. (1995) have reported that the use of P fertilizer becomes imperative because the concentration of P in many soils is very low and it is also liable to different chemical reactions that make it unavailable to plants. Plants supplied with an adequate amount of P were reported to form a good root system, have a strong stem, mature early, and give a high yield, whereas plants grown on P-deficient soils showed stunted growth, a low shoot-to-root ratio, poor fruit and seed formation, and purple-coloured leaves with a reddish coloration of the stem. Biochemically, deficiency causes changes in the functions of the plant, including the accumulation of sucrose, reducing sugars, and sometimes starch. Sulphur plays an essential role in chlorophyll formation and many reactions in living cells (Tisdale *et al.,* 1995). Phosphorus plays a significant role in physiological and biochemical reactions such as photosynthesis and the conversion of sugar into starch (Alemayehu and Jemberie, 2018).

Kumar *et al*. (2012) stated that phosphorus increases photosynthesis and indicated that translocation of photosynthesis from source to sink has occurred up to maturity as a result of increased nutrient absorption.

2.5. Effects of Nitrogen Fertilizer on the Growth and Yield of Head Cabbage

Crop species differ in their nutrient requirements depending on their stages of development and high requirement for nitrogen while large amounts of potassium are a requisite for good growth of marketable part is the underground organs like sweet potato and Irish potato and cabbage (Preece and Read, 2005)

According to Tehulie and Belete (2021), N is a constituent of amino acids, nucleotides, nucleic acids, and a number of coenzymes, auxins, cytokines, and alkaloids, which resulted in increased cell elongation, cell enlargement, and cell division in plants, which contributed to increased plant height. maximum number of outer leaves, head length, head width, total and net head weight and total yield were obtained with the application of 120kg N/ha and 100kg P/ha Prasad *et al*. (2009). Where as the maximum plant height, plant spread, leaf area and head diameter were recorded with the application of 140kg N/ha and 120kg P/ha. Application of 120kg nitrogen and 100kg phosphorous ha^{-1} also gave the best yield of head cabbage in the Gangetic plains of West Bengal (Prasad *et al*., 2009). In the research from Westerveld *et al*. (2003), cabbages received the highest nitrogen rates were larger and had a darker green color compared to those received the lowest nitrogen rates.

Excess nitrogen in fertilizer can be just as troublesome as not enough. It can lead to excessive vegetative growth in the plant at the expense of flowering and fruiting. Besides these undesirable effects on the crop or plant, excess nitrogen can cause problems in the environment at large. Rainwater runoff can carry the excess nitrogen from fertilizers into ground water or into surface water. When this occurs, nitrogen becomes a pollutant. In surface waters, it stimulates excessive growth of algae and other nuisance plants. Abraham *et al*. (2009) cabbage -size reduced with nitrogen deficiency the foliage became yellowish -green (chlorothic).The symptoms starts from the older leaves and after a while the whole plant became chlorotic, some leaf parts may have a reddish or orange flush the shape of the leaves remain normal. Growth is strongly restricted crop development is delayed and older leaves may decay with sever nitrogen deficiency, no head is formed (Adina, 2009). According to Tehulie and Belete (2021) mentioned that plant increase and productiveness were accelerated with increasing degrees of nitrogen utility. Everaarts and Demoe (1998) stated that growing uniformity with increasing amount of nitrogen applied. In cabbage manufacturing uniformity in head is important. Increase in relative core size was found when nitrogen applications charge increases, whereas dry count content of the head decreased. This was associated with softer head tissue at greater nitrogen availability, these by using having physical resistance to stalk elongation. It is widely grown as cool-season crop and is very popular with gardeners. Cabbage has high requirements for all nutrients, especially nitrogen, and cabbage demands for achieving high yields ranged from 130 to 310 kg N ha-1 (Lawande *et al*., 2001).

2.6. Interaction effect of Nitrogen and NPS Fertilizer on Growth and Yield of Head Cabbage

Prasad *et al.* (2009) maximum number of outer leaves, head length, head width, total and net head weight and total yield were obtained with the application of 120kg N/ha and 100kg P/ha. Whereas the maximum plant height, plant spread, leaf area and head diameter were recorded with the application of 140kg N/ha and 120kg P/ha. Application of 120kg nitrogen and 100kg phosphorous ha-1 also gave the best yield of head cabbage in the Gangetic plains of West Bengal (Prasad *et al.,* 2009). via Sardana and Verma (2010) three stages of NPS fertilizer charge that applied in split (60 kg/ha, one hundred twenty kg/ha and one hundred eighty kg/ha) on clay loam soil ought to the maximum yield of cabbage (65.11 + /ha) had been found from the plot receiving fertilizer fee of Table 1180 kg/ha NPS Singh *et* al.,

(2011) said that leaf area/plant, precise leaf weight, whole dry mass/plant, flower number/plant, reproductive efficiency, wide variety of head/plant, yield have been significantly elevated with both foliar application of Nitrogen and Nitrogen along with Micronutrient treated plant life over control. Mitra *et al*., (2006) mentioned that inexperienced gram yield accelerated with growing levels of P and S fertilizers. Phosphorus at 60 kg P2O5 and S at forty kg ha-1 gave the perfect cabbage growth and yield (1655 kg ha-1), and net return on cabbage crop.

3.MATERIALS AND METHODS

3.1 Description of the Study Area

This study was conducted during the 2023 main cropping season at Kofele district, West Arsi zone of Oromia National Regional State, Ethiopia. Kofele district is located at 275 km from Addis Ababa towards Southern direction The district covers an area of 1187 square kilometers and has 38 rural and two urban Kebeles. From rural kebeles, 34 kebeles are high land while 4 kebeles are midland. The major agro-ecologies of the district are high land (90%) and mid-land (10%) having clay loam soil type of 90% and the remaining 10% red and black. The district was found within 2460 to 2790 m-a-s-l. It receives an average rainfall of 1800 mm with minimum 2000 mm and maximum 3050 mm. The average temperatures were 19.5°C per year with minimum of 17°C and maximum of 22°C (DOANR, 2017).

3.2 Experimental Materials, Treatment and Design

The experiment consisted of factorial combinations four levels of nitrogen from urea fertilizer (0 (0).,100 (46)., 200 (92). and 300 (138). kg $_{ha-1}$) and the three levels of NPS fertilizer (0, 100, and 200 kg/g ha-1aking a total of twelve treatment combinations in3 replications and it was laid out in a randomized complete block design (RCBD).

Cabbage seed of the Green Boy F_1 variety was used as a test crop in this experiment. The choice of this variety was due to its good adaptability and short vegetative cycle. The level of treatment used was based on the suggestion of Kidane (2016) 150 kg of DAP and 100 kg of urea are recommended for fertile soils, while 200 kg of DAP and 100 kg of urea per hectare of land were recommended for non-fertile soils. (Kidane, 2016).

Plant spacing between row 50 cm and between plant 30 cm, plot size 6.3m2, total number rows per plot 36 and 36 plants per row, space between blocks is 1m and 0.5 m between plots; total experimental area is 337.7m^2 & net plot of experimental area is 226.8m^2.

Table 1 . The combination of different rate of NPS with Nitrogen from urea

No.	Treatments	Combination
1	T1	0kgNPS +0Kg N
2	T2	0kgNPS +100Kg N
3	T3	0kgNPS +200Kg N
4	T4	0kgNPS +300Kg N
5	T5	100kgNPS +0Kg N
6	T6	100kgNPS +100Kg N
7	T7	100kgNPS +200Kg N
8	T8	100kgNPS +300Kg N
9	T9	200kgNPS +0Kg N
10	T10	200kgNPS +100Kg N
11	T11	200kgNPS +200Kg N
12	T12	200kgNPS +300Kg N

3.3 Experimental Procedures and Field Management

Cabbage seeds were sown in the nursery in May 2023 with a standard nursery bed, and allowed to grow until they were ready for transplanting. Then healthy and uniform seedlings of 4 week old seedlings were transplanted to the experimental field at a spacing of 50 cm between rows and 30 cm between plants when they reached two to three pairs of leaves.

The total number of rows per plot was 6, and each plot had 36 plants. The nitrogen fertilizer was applied based on the treatment level in the form of urea in a split application, half dose of nitrogen was applied during transplanting, and the remaining half was applied before head formation or one month after transplant and all doses of NPS were applied once at the time of transplanting Other agronomic practices, including weeding, irrigation, and cultivation, were done uniformly on all plots.

3.4 Soil Sampling and Analysis

Soil samples were collected at depths ranging from 0 to 20 cm. The soil was air-dried and sieved to pass through a 5 mm sieve. For all analyses, soil samples were air-dried and ground to pass through a 2 mm sieve, except for soil organic carbon (SOC) and total nitrogen (TN), which were passed through a 0.5 mm sieve. Soil texture was determined by using the hydrometer method (Bouyoucos, 1962), OC by dichromate oxidation (Walkley and Black., 1934), pH in a 1:2.5 soil: water ratio (Van Reeuwsk, 2002), electrical conductivity (EC) in a 1:2.5 soil: N by the micro Kjeldahl method (Bremner and Mulvaney, 1982), and available P extracted with NaHCO3 (Olsen *et al*., 1954) were determined before planting.

Table 2. Physical and chemical properties of experimental soil before planting

Soil properties	Value
PH	5.8
Organic carbon (%)	2.34
Total Nitrogen (%)	0.24
Available phosphorus (ppm)	16.95
Cation exchange capacity (Cmol/ kg-1 soil)	14
Total available sulfur (mg/ kg of soil)	20.63
l, Clay, silt (%)	l5:27
ural class	l clay loam

3.5. Data Collection and Measurement

Data was collected at different stages, during phonological, physiological, and yield-related traits measured from sample plants accordingly.

Phonological and Growth Data

- **Days to 50% head formetion (days):** The number of days elapsed for head initiation was counted from the date of transplanting up to the date when 50% of the plants in each plot formation of their heads.
- **Days to 90 % head maturity (days):** It was measured by counting the number of days starting from transplanting until the head of the cabbage physiologically matured.

Morphological parameter

- **Plant height (cm):** The height of the plant was measured by placing a meter scale from ground level to the tip of the outer longest leaf of an individual plant at the time of 90% days to head maturity. from five selected sample plants.
- **Leaf length (cm):** It was measured length of the leaf, using a ruler, from five plants at the time of maturity. Then average height was taken into account and finally expressed in cm.
- **Leaf width (cm):**the spread of the plant measured at its wider part from leaf tip to leaf tip at maturity
- **Number of folded leaves** (count): The data collected by taking sample plants from each experimental net plot area at the time of maturity. Randomly five sampled plants were collected, and folded leaves were counted.

- **Number of unfolded leaves** (count): The data were collected by taking sample plants from each experimental net plot area at the time of maturity. Randomly five sampled plants were collected by means of random selection, and unfolded leaves were determined by counting from each sample plant.

- **Total number of leaves** (count): It was recorded by the summation of number of folded leaves and number of unfolded leaves of head cabbage.
  - **Root length**. (cm) : It was done by uprooting the plant and measuring the length of the root from the surface collar point to the tip of the root using ruler from five plants at the time of harvesting.

Yield and Yield Components

- **Head height (cm):** Cabbage head height was measured cutting vertically from the tip head down to the collar of five randomly selected plants grown in the net plot area using a ruler at the time of maturity
- **Head width (cm):** It was measured by cutting horizontally, using a ruler, from five plants at the time of harvesting.
- **Head Diameter (cm):** It was measured by sectioning the five head vertically with a sharp knife at the middle portion each treatment. The diameter was measured as the horizontal distance from one side to another of the five selected head.
- **Fresh biomass yield (g plant^{-1}):** It was determined by recording all the above-ground plant parts from five sampled plants.

  - **Dry biomass yield (g plant^{-1}:** Sample of plant per plot taken and chopping then and put in the oven dry at 120^{0}c for 24 hours and dry mass will measured by sensitive balanced and weighted in gram (Tesfaye, 2009).

- **Marketable head yield (t ha^{-1}**): It was measured from the net plot area using a scaled balance. Head cabbages that were free from any damage or decay, as well as those that had no loose or open heads, were considered to have marketable yields. The weight of such head cabbages was harvested and converted to tons per ha.

- **Unmarketable head yield (t ha^{-1}):** Head cabbages that split, damaged, and rotted were considered unmarketable. The weight of the head cabbage obtained from each net plot area was measured using a scaled balance and expressed as % ha^{-1}.

3.6. Data Analysis

The data considered in this study were subjected to an analysis of variance (ANOVA) appropriate to the factorial arrangement in the complete randomized design (RCBD) in SAS software version 9.2 (SAS version 9.2, 2002). The means were separated by using the least significant differences (LSD) test at the 5% level of significance.

4. RESULTS AND DISCUSSION

4.1. Crop phenology

4.1.1. Days to 50% of head initiation

Interaction of Nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on mean days to 50% head initiation (Appendix Table 1). The shortest (52.03) mean days to 50% head initiation of cabbage was recorded by 300 Nitrogen and 200 NPS rate. The longest (76.13 days to 50% head initiation of cabbage was obtained by the zero Nitrogen and NPS rate.

At both NPS (100 and 200 kg ha^{-1}) rate and nitrogen (300 kg ha^{-1}) rate, and mean days to 50% of head formetion of cabbage was decreased with increasing nitrogen rate from 0 kg ha^{-1} to 300 kg ha^{-1}. The control treatment resulted in early finish of head initiation before attaining of fully required physiological maturity as compared to those higher doses. This could be due to the fact that there might be the lower N and P rates not enough to enhance the development of the crop and hastening head formation. This result is consistent with the finding of Solomon and Arega (2020). The results are in agreement with the findings of Hossain *et al.* (2011) who reported that the earliest head formetion (53 days) was observed on cabbage 40 plants which were supplied with nitrogen, phosphorous, and sulfur with the ratio of 240:45:45 kg ha^{-1}, respectively. This result agreed with Chaubey *et al*., (2006) who found significantly shorter time (57.45) of cabbage for head initiation under the treatment receiving nitrogen and NPS fertilizer On the other hands plants with no fertilizer application required longer time (77.0 days) to to form heads.

Similarly, Hoque *et al.* (2002) found shorter head initiation time in cabbage plants which received organic and inorganic fertilizers. Moniruzzaman, 2011; Hasan *et al*., 2018). Head initiation of cabbage also depends onnitrogen fertilizer that had the higher rates of nitrogen used faster head formation than control

Table 3. Interaction effects of N and NPS fertilizers on days to 50% of head initiation

NPS rate ($kgha^{-1}$)	Nitrogen rate ($kgha^{-1}$)			
	0	100	200	300
0	76.13[a]	69.03[d]	71.60[b]	70.60[c]
100	69.60[d]	56.00[f]	55.17[g]	52.14[i]
200	62.20[e]	54.93[g]	53.37[h]	52.03[i]
LSD (0.05)	0.60			
CV (%)	0.57			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance.

4.1.2. Days to 90 % of head maturity

Days to 90% of head maturity in cabbage was significantly ($p<0.001$) affected by the interaction effects of nitrogen and NPS (Appendix Table 1). The shortest (87.77) mean days to 90% head maturity of cabbage were recorded by 300 kg $ha-^{1}$ nitrogen and 200 kg $ha-^{1}$ NPS rate. The longest (98.) mean days to 90% head maturity of cabbage was obtained at the lowest zero nitrogen and NPS rate. (**Table 3**).

Days to 90% the head maturity of cabbage was influenced by the interaction effect of nitrogen and NPS rate. At both the NPS and nitrogen (200 and 200 kg ha^{-1}) and (200 $kgha^{-1}$ and 300 kg ha^{-1}) rates, the mean days to 90% of head maturity of cabbage decreased with increasing nitrogen rates from 0 kg ha^{-1} to 300 kg ha^{-1} Solomon and Arega (2020).

significant effect of fertilization on the maturity of cabbage heads, where fertilizer application reduced the date of maturity compared to zero fertilization Fatema (2012),. the shortest duration of carrots to reach maturity at the highest levels of N (309 kg ha^{-1}) and P (68 kg ha^{-1}) as compared to the low levels of N. Sisay *et al*. (2008)

Table 4. Interaction effects of N and NPS fertilizers on Days to 90 % of head maturity

NPS rate (kgha^{-1})	Nitrogen rate (kgha^{-1})			
	0	100	200	300
0	98.00^{a}	94.10^{b}	92.53^{d}	90.13^{ef}
100	94.43^{b}	93.43^{c}	89.90^{f}	88.33^{gh}
200	92.33^{d}	90.67^{e}	88.57^{g}	87.77^{h}
LSD (0.05)	0.60			
CV (%)	0.39			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance.

4.2. Growth parameter

4.2.1. Plant height

The combined use of nitrogen and NPS rate had a highly significant ($p<0.001$) effect on plant height (Appendix Table 1). The shortest (20.33cm) plant height of cabbage was recorded by zero nitrogen and NPS (200 kg ha-1) rate. The tallest (31.10 cm) plant height of cabbage was obtained by the highest 300 nitrogen and 200 NPS rates. Head cabbage planted in combination of nitrogen (0 kg ha^{-1}) and NPS rate (200 kg ha-1) was shorter (20.33 cm) as compared to other treatments (Table 4). From the above paragraph, it is clear that plant height of cabbage was influenced by the interaction effect of Nitrogen and NPS rate. At both NPS (100 and 200 kg ha^{-1}) rate and Nitrogen (300 kg ha^{-1}) rate, and plant height of cabbage was increased with increasing Nitrogen rate.. This could be due to the fact that there might be noted significant difference in plant height of head cabbage due to different source of nutrients. This result is consistent with the finding of Moniruzzaman, *et al*. (2006) and Neethu *et al*. (2015). Similar results were noted by Sarker *et al*., (1996); Solomon and Arega (2020) that significance in plant height of cabbage was observed as the rate of N and FYM increased. Sanderson and Ivany (1999) have also reported that increase in Nitrogen levels up to 150 kg ha-1 and phosphorus levels up to 120 kg ha-1 increased plant height of head cabbage over its lower levels. Baloch *et al.*, (2001) experiment on head cabbage result signifies that increased use of nitrogen leads to increased plant height.

The results of the study are in agreement with the findings of Hossain (1998), Kacjan Marsic and Osvald (2004) and Pramanik (2007) obtained the maximum plant height of cabbages with increased nitrogen rates. Moreover, in the research results of Moniruzzaman *et al.* (2006) increased plant height was obtained from cabbage and broccoli plants treated with 240 kg N, 100 kg P and 80 kg S ha^{-1}. Similarly, Thapa and Prasad (2011) obtained the maximum plant height (32.57 cm) using the combined application of 120 kg nitrogen and 100 kg phosphorus ha^{-1}. Similarly, Akand *et al.* (2015) also obtained the maximum plant height (36.82 cm) by the application of 200 kg ha^{-1} of nitrogen. Hossain *et al*. (2011) also obtained significantly maximum plant height (37.5 cm) of cabbage by the application of nitrogen, phosphorous potassium and sulfur with the rates of 240 kg, 45 kg, 180 kg and 45 kg per hectare, respectively.

Table 5. Interaction fertilizers on plant height effects of N and NPS

NPS rate (kgha^{-1})	Nitrogen rate (kgha^{-1})			
	0	100	200	300
0	20.33^{fg}	26.50^{d}	24.43^{e}	25.83^{d}
100	22.50^{f}	27.67^{c}	29.56^{b}	30.77^{a}
200	20.33^{f}	28.33^{c}	29.43^{b}	31.10^{a}
LSD (0.05)	0.7847			
CV (%)	1.74			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance.

According to Yebirzaf (2015), the level of nitrogen revealed a non-significant ($P > 0.05$) effect on mean plant height. This is because nitrogen is responsible for the vegetative growth of plants, and by increasing the head diameter rather than the plant length. This experiment was in contravention of that of Easmine *et al*. (2009), which state that increasing nitrogen from 0 to 250 kg ha1 increases plant height from 36.16 cm to 47.72 cm, respectively. According to Demoz (2016), the combined application of 120 kg nitrogen and 100 kg phosphorus ha^{-1} recorded the maximum plant height (32.57 cm) of cabbage. Similar results were observed by Prasad *et al*. (2009), who reported that the combined application of 120 kg and 100 kg ha^{-1} of nitrogen and phosphorous, respectively, gave the maximum plant height (32.6 cm) of head cabbage.

4.2.2. Head height (cm)

The head height of cabbage was significantly ($p<0.001$) affected by the interaction effects of nitrogen and NPS rate (Appendix Table 2). The lowest (13.5 cm) head height of cabbage was recorded by zero nitrogen and NPS. The highest (22.33 cm) head height of cabbage was obtained by the highest (300 kg ha^{-1}) nitrogen and (200 kg ha^{-1}) NPS rates (Table 4). At both the NPS (0 and 100 kg ha^{-1}) rate and the nitrogen (0 kg ha^{-1}) rate, the plant height of cabbage decreased with a decreasing nitrogen rate from 300 kg ha^{-1} to 0 kg $_{ha}{}^{-1}$. This could be due to the fact that there might the increase in head height might be attributed to the beneficial effect of nutrient on stimulating the meristimic activity for producing more tissues and organs, in addition to its vital contribution in several biochemical processes in the plant, related to growth and yield development. This result is consistent with the finding of Marschner (1994).

Table 6. Interaction effects of N and NPS fertilizers on head height

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	13.50^{i}	14.00^{hi}	15.43^{fg}	16.17^{f}
100	14.00^{hi}	17.50^{e}	19.43^{d}	20.83^{bc}
200	14.70^{gh}	19.83^{cd}	21.18^{b}	22.33^{a}
LSD (0.05)	1.00			
CV (%)	3.40			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance.

4.2.3. Head width

The interaction of nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on head width (Appendix Table 2). The lowest (13cm) head width of cabbage was recorded at null kgha-1 nitrogen and null kgha^{-1} NPS rate. The highest (21.67 cm) head width of cabbage was obtained at the highest (300 kg ha-1) nitrogen and NPS (200 kg ha-1) rates (Table 5). From the above paragraph, it is clear that the head width of cabbage was influenced by the interaction effect of nitrogen and NPS rate. At both the NPS (0 and 100 kg ha^{-1}) rate and the nitrogen (0 kg ha^{-1}) rate, the head width of cabbage decreased with a decreasing nitrogen rate from 300 kg ha^{-1} to 0 kg ha-1. This could be due to the fact that there might the increase in head weight might be attributed to the beneficial effect of nutrient on stimulating the meristematic activity for producing more tissues and organs, in addition to its vital contribution in several biochemical processes in the plant, related to growth and yield development.

This result is consistent with the finding of Marschner (1994). Similar results was observed by Prasad *et al.* (2009) who reported that the combined application of 120 kg and 100 kg ha^{-1} of nitrogen and phosphorous, respectively, gave the maximum head width (22.6 cm), leaf area (972.43 cm^2) and head weight (1.63 kg) of cabbages. The application of NPK at the rate of 470:222:371 kg ha^{-1}, respectively, increased different yield parameters of head cabbage.

Table 7: Interaction effects of Nitrogen and NPS fertilizers on head width

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	13.00^{d}	14.13^{d}	15.87^{c}	16.90^{c}
100	13.30^{d}	19.03^{b}	19.50^{b}	21.13^{a}
200	19.17^{b}	19.00^{b}	19.67^{b}	21.67^{a}
LSD (0.05)	1.14			
CV (%)	3.81			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.2.4. Total number of leaves

The interaction of nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on the total number of leaves (Appendix Table 1). The lowest (10.0) total number of leaves of cabbage was recorded at 0 kgha-1 nitrogen and 0 kgha^{-1} NPS rate. The highest (17.33) total number of leaves of cabbage was obtained at the highest 300 kgha^{-1} nitrogen and 200 kg ha^{-1} NPS rates (Table 6). From the above paragraph, it is clear that the total number of leaves of cabbage was influenced by the interaction effect of nitrogen and NPS rate, and the total number of leaves increased with increasing nitrogen rate from 0 kg ha1 to 300 kg ha1. This could be due to the fact that the increase in photosynthetic activity of leaves further encourages vegetative growth of plants, as reported by Archer (1988) and Marschner (1995). These results are in accordance with Magnusson's (2002) observation on chinensis cabbage

(Brassica chinesis) that the highest numbers of leaves were obtained by applying 10 tons of organic manure with a combination of 200 kg of nitrogen fertilizer.

The treatments with high rates of NPS and nitrogen in the study resulted in a in a relatively high number of cabbage leaves, which is in good agreement with the findings of Moniruzzaman *et al.* (2006) and Kidane (2016), who reported that the maximum number of leaves in Chinese cabbage was produced when nitrogen was applied at higher rates. Similarly, Akand *et al*. (2015) and Shahbazi (2005) reported that the maximum number of leaves in cabbage (14.3) was obtained by the application of 200 kg ha1 of nitrogen, and the minimum number of leaves (12.7) was recorded from treatments where nitrogen was not applied. Similar results were also observed by Shahbazi (2005). However, Gulser (2005) also reported significantly the highest (17) number of leaves at the combined application of 200 kg N ha^{-1} and 15 t ha^{-1} FYM. This could be due to the fact that there might be a greater role for nitrogen in photosynthesis and protein formation, resulting in a higher number of folded leaves than unfolded leaves at physiological maturity. This result agrees with the findings of Pankaj (2006) and Yebirzaf (2015).

Table 8. Interaction effects of N and NPS fertilizers on total number of leaf of head

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	10.00^{g}	12.00^{ef}	12.67^{de}	13.67^{cd}
100	10.67^{fg}	13.67^{cd}	15.00^{bc}	17.33^{a}
200	11.67^{ef}	13.00^{de}	16.00^{ab}	17.00^{a}
LSD (0.05)	1.43			
CV (%)	6.21			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.2.5. Number of folded leaves

The interaction of nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on the folded number leaf (Appendix Table 1). The lowest (12.8) folded number of leaf cabbages was recorded at a null nitrogen and null NPS rate. The highest (28.60) folded number leaf of cabbage was obtained at the highest 300 kg ha^{-1}) nitrogen and 200 $kgha^{-1}$) NPS rates (Table 8). From the above paragraph, it is clear that the folded number leaf of cabbage was influenced by the interaction effect of nitrogen and NPS rate, and the unfolded number leaf of cabbage increased with an increasing nitrogen rate from 0 to 300 kg ha^{-1}.

Table 9. Interaction effects of N and NPS fertilizers on number of folded leaf

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	12.80^{i}	19.33^{g}	24.27^{e}	24.27^{e}
100	18.90^{g}	22.90^{f}	26.10^{d}	26.10^{d}
200	16.97^{h}	17.86^{h}	28.60^{b}	28.60^{b}
LSD (0.05)	0.92			
CV (%)	2.37			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.2.6. Number of unfolded leaves

The interaction of nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on unfolded number leaf (Appendix Table 1). The lowest (7.0) unfolded number of leaf cabbage was recorded by zero kg ha^{-1} nitrogen and NPS kgha-1 rate. the highest (9.4) unfolded leaf of cabbage was obtained by the highest 300 nitrogen and 100 NPS rates (Table 8)

This could be due to the fact that nitrogen might have a role in photosynthesis and protein formation, resulting in a higher number of unfolded leaves and even a lower number of folded leaves at physiological maturity.

Table 10 Interaction effects of N and NPS fertilizers on number of unfolded leaf

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	7.00^{h}	8.40^{de}	8.97^{abc}	9.13^{ab}
100	8.67^{bcd}	8.23^{de}	8.97^{abc}	9.4^{a}
200	8.43^{cde}	7.6^{fg}	7.5^{fg}	8.3^{de}
LSD (0.05)	0.54			
CV (%)	3.8			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance.

4.2.7. Leaf length

The interaction of nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on leaf length (Appendix Table 2). The lowest (9.0cm) leaf length of cabbage was recorded by zero nitrogen and NPS rate. the highest (20.1cm) leaf length of cabbage was obtained by the highest 300 kg ha-1 nitrogen and 200 NPS kg ha-1 rates (Table 10).

At both the NPS (0 and 100 kg ha1) and nitrogen (300 kg ha1) rates, the leaf length of cabbage increased with an increase in the nitrogen rate from 0 kg ha1 to 300 kg ha1. This could be due to the fact that there might be a response to the application of higher rates of nitrogen, and NPS due to the maximum vegetative growth of the plants as a result of increased availability of N, P, and S, less competition for nutrients, and, thus, an increased leaf length or size of individual leaves. In line with this, it has been reported that nitrogen helps in chlorophyll formation; phosphorus establishes a strong root system; and sulphur enhances the formation of chlorophyll and encourages vegetative growth (Tiwari *et al.*, 2013).

Souza *et al*. (2008) also reported that the application of 200 kg of nitrogen per hectare significantly enhanced the length of cabbage leaves. Singh and Chaure (1999) also indicated that application of nitrogen at 150 kg ha1 gave the best result with regards to cabbage leaf length. Similar results were also observed by Prasad *et al.* (2009), who reported that the combined application of 120 kg and 100 kg ha^{-1} of nitrogen and phosphorous significantly enhanced the length of the cabbage leaf.

Table 11. Mean Interaction effects of N and NPS fertilizers on leaf length

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	9.00^{h}	9.40^{h}	11.17^{f}	11.27^{f}
100	10.20^{g}	10.90^{f}	12.27^{e}	12.23^{e}
200	14.47^{d}	15.80^{c}	18.57^{b}	20.1^{a}
LSD (0.05)	0.47			
CV (%)	2.13			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.2.8. Leaf width

The interaction of nitrogen and NPS rate had very highly significant ($p<0.001$) effect on leaf width (Appendix Table 2). The lowest (14.87cm) leaf width of cabbage was recorded by yero nitrogen and NPS rate. The highest (26.57cm) leaf width of cabbage was obtained at the highest 300 nitrogen and 200 NPS rates (Table 10). From the above paragraph, it is clear that the leaf width of cabbage was influenced by the interaction effect of nitrogen and NPS rate. At both the NPS (0 and 100 kg ha^{-1}) and nitrogen (300 kg ha^{-1}) rates, the leaf width of cabbage increased with an increase in the nitrogen rate from 0 kg ha1 to 300 kg ha^{-1}. This could be due to the fact that there might be a response to the application of higher rates of nitrogen, and NPS might be due to the maximum vegetative growth of the plants as a result of increased availability of N, P, and S, less competition for nutrients, and, thus, an increased number and surface area or width of individual leaves.

According to Mekonnen and Belete (2020), the widest leaf was 21.81 cm was obtained from 150 kg N/ha. However, it was not significantly different from that of 100 kg of nitrogen ha^{-1} (18.7), while the narrowest leaf was (16.93 cm) obtained from 0 kg of nitrogen ha^{-1}.

Table 12. Mean Interaction effects of N and NPS fertilizers on leaf width

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	14.87^{h}	16.70^{fg}	17.53^{ef}	18.90^{cd}
100	15.80^{gh}	17.30^{f}	18.63^{de}	20.00^{c}
200	18.53^{de}	19.97^{c}	22.63^{b}	26.57^{a}
LSD (0.05)	1.21			
CV (%)	3.77			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.2.9. Root length (cm)

Interaction of Nitrogen and NPS rate had a very highly significant ($p<0.001$) effect root length (Appendix Table 2). The lowest (8.67) root length of cabbage was recorded at null Nitrogen and null NPS rate. The highest (19.5) root length of cabbage was obtained at the highest (300 kg ha^{-1}) Nitrogen and (200 kg ha^{-1}) NPS rate (Table 11).

From the above paragraph, it is clear that root length of cabbage was influenced by the interaction effect of Nitrogen and NPS rate. At both NPS (0 and 100 kg ha^{-1}) rate and Nitrogen (300 kg ha^{-1}) rate ,and root length of cabbage was increased with increasing Nitrogen rate from 0 kg ha^{-1} to 300 kg ha^{-1}. This could be due to the fact that there might the nitrogen element may be playing an important role in increasing cell elongation and cell division. These results are in accordance with Kahilil (2010) and Abdou *et al.* (2014) who stated that increasing nitrogen levels significantly increased root length in beet root.

Table 13. Mean Interaction effects of N and NPS fertilizers on Root length

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	8.67^{h}	9.80^{g}	10.37^{fg}	11.00^{ef}
100	9.67^{g}	11.00^{ef}	13.50^{d}	15.90^{bc}
200	11.66^{e}	15.43^{c}	16.67^{b}	19.50^{a}
LSD (0.05)	0.81			
CV (%)	3.75			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.3. Yield and yield components

4.3.1. Head diameter

Interaction of Nitrogen and NPS rate had a very highly significant ($p<0.001$) effect head diameter (Appendix Table 3). The lowest (13.0) head diameter of cabbage was recorded by zero Nitrogen and NPS rate. The highest (21.67) head diameter of cabbage was obtained by the highest 300 Nitrogen and 200 NPS rate (Table 12).

At both NPS (100 and 200 kg ha^{-1}) rate and Nitrogen (300 kg ha^{-1}) rate, and head diameter of cabbage was increased with increasing Nitrogen rate.this could be due to the fact that there might be the higher synthesis of carbohydrate and their translocation to the sink, that is; cabbage head which subsequently helped in the formation of larger and comparatively broader head of the cabbage. The highest head diameter (11.04 cm) was obtained at 150 kg nitrogen. ha^{-1} while the lowest head diameter (8.69 cm) was obtained with application of 0 kg ha^{-1} of nitrogen Yebirzaf (2015).This finding is also in agreement with those of Keteseeman (2006) who reported, head diameter increased from 98 to 218 mm when the nitrogen level increased from 0 to 120 kg/ha, respectively.

According to Demoz (2016) the maximum average head diameter (13.88 cm) was obtained in T11 who received 102.5:115:21.18 of N: P2O5: S kg ha^{-1}. The average minimum head diameter (6.99 cm) was recorded in control plants, without NPS fertilizer. The increase in head diameter in this study is obviously associated with the increase in nitrogen, phosphorous as well as sulfur which is in agreement with the findings of Hossain *et al*. (2011) who reported the maximum average head diameter (17.2 cm) was found with the application of 240:45:180:45 kg ha^{-1} of N, P, K and S. The minimum head diameter (8.0 cm) was recorded from control plants, without fertilizer application. Similarly, Din *et al*., (2007) reported significant high head diameter was obtained from NPK fertilizer with the level of 120-90-60 kg ha^{-1}. Similarly, Thapa and Prasad (2011) obtained the maximum head diameter (48.98 cm) by the application 100 kg nitrogen and 100 kg phosphorus ha^{-1}. Moreover, Akand *et al*., (2015) reported maximum head diameter (12.43 cm) was observed in nitrogen fertilizer with the rate of 200 kg ha-1 and the minimum (10.73 cm) was observed in plants without nitrogen fertilizer. It was also observed that fertilizer application at different levels result a remarkable change in diameter of the head. This result was corroborated with the findings of (Singh *et al*., 2015). significantly higher diameter of head cabbage by the application of 120-90-80 NPK ha^{-1}, respectively (Din *et al*., 2007). That means application of higher nutrient to some level induced maximum diameter of cabbage.

Table 14.Mean Interaction effects of N and NPS fertilizers on head diameter

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	13.00^{d}	14.13^{d}	15.87^{c}	16.90^{c}
100	13.30^{d}	19.03^{b}	19.50^{b}	21.13^{a}
200	19.17^{b}	19.00^{b}	19.67^{b}	21.67^{a}
LSD (0.05)	1.14			
CV (%)	3.81			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.3.2. Head fresh weight

The interaction of nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on head fresh weight (Appendix Table 3). The lowest (1.42 kg $plant^{-1}$) head fresh weight of cabbage was recorded by zero nitrogen and NPS rate. The highest (3.92 kg $plant^{-1}$) head fresh weight of cabbage was obtained by the highest 300 kg ha^{-1} nitrogen and 200 kg ha^{-1} NPS rates (Table 13). At both the NPS (100 and 200 kg ha^{-1}) and nitrogen (300 kg ha^{-1}) rates, the head fresh weight of cabbage increased with an increase in the nitrogen and NPS rates. This could be due to the fact that nitrogen and NPS, which are sources of more dry matter synthesis and translocation to storage organs, significantly increased growth parameters, which in turn synthesized more plant metabolites, thereby increasing head fresh weight. That means as the rate of nitrogen and NPS increases to a certain level, the mass of the head increases.

According to Yebirzaf (2015) increasing nitrogen level from 0 to 150 kg ha^{-1} resulted in progressive increase in head fresh weight of cabbage. Cabbage grown at 100 kg/ha and 150 kg ha^{-1} of nitrogen rate had the highest head weight per plant (0.771 kg /plant while cabbage grown without nitrogen fertilizer had the lowest (0.442 kg/plant) fresh head weight. These results are in accordance with (Mengel and Kirkby, 1987). According to Kidane (2016) the combined application of 120 kg nitrogen and 100 kg phosphorus ha-1 recorded maximum total head weight (1.63 kg) of cabbage. Similar, results were observed by Prasad *et al.* (2009) who reported that the combined application of 120 kg and 100 kg ha^{-1} of nitrogen and phosphorous, respectively, head weight (1.63 kg) of cabbages.

Table 15 : Mean Interaction effects of N and NPS fertilizers on head fresh weight in kg

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	1.41667^{f}	1.5417^{f}	1.81233^{e}	2.95000^{e}
100	1.47333^{f}	2.75433^{d}	3.78733^{a}	3.84667^{a}
200	2.85267^{d}	3.06867^{c}	3.35667^{b}	3.92333^{a}
LSD (0.05)	1.9776			
CV (%)	4.41			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.3.3. Head dry weight

The interaction of nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on head dry weight (Appendix Table 3). The lowest (1.041 kg $plant^{-1}$) head dry weight of cabbage was recorded by zero nitrogen and NPS rate. The highest (1.745 kg $^{-1}$) head dry weight of cabbage was obtained by the highest 300 kg ha^{-1} nitrogen and 200 kg ha^{-1} NPS rates (Table 14). At both the NPS (100 and 200 kg ha^{-1}) and nitrogen (300 kg ha^{-1}) rates, the head dry weight of cabbage increased with an increase in the nitrogen rate from 0 kg ha1 to 300 kg ha^{-1}. This could be due to the fact that nitrogen and NPS, which are sources of more dry matter synthesis and translocation to storage organs, significantly increased growth parameters, which in turn synthesized more plant metabolites, thereby increasing head dry weight. This is due to Nitrogen and NPS that increases the vegetative growth and produces good quality foliage and promotes carbohydrate synthesis through photosynthesis and ultimately increased yield of plants. According to Yebirzaf (2015) increasing nitrogen level from 0 to 150 kg ha^{-1} resulted in progressive increase in head weight of cabbage. The maximum dry weight of cabbage head (0.114 kg per plant) were recorded with application of 150 kg ha^{-1} of N whereas, the minimum dry weight (0.043 kg per plant), were detected in the controls plot (Yebirzaf ,2015). There were no significant difference between plots that received 100 and 50 kg N/ha (Mengel and Kirby, 2006).

Table 16: Mean Interaction effects of N and NPS fertilizers on head dry weight

NPS rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})			
	0	100	200	300
0	1.041^{c}	1.3689^{abc}	1.559^{ab}	1.6121^{a}
100	1.0608^{c}	1.3711^{abc}	1.6233^{a}	1.7294^{a}
200	1.0793^{bc}	1.3788^{abc}	1.6212^{a}	1.7474^{a}
LSD (0.05)	12.8			
CV (%)	5.26			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.3.4. Unmarketable head number

Interaction of Nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on unmarketable head yield (Appendix Table 3). The lower (0.0001 ton/ha-1) unmarketable head yield of cabbage was recorded by 300 kg ha^{-1} Nitrogen and 200 kg ha^{-1} NPS rate. The highest (16.333 ton/ha-1) unmarketable head yield of cabbage was obtained by zero kg ha^{-1} Nitrogen and NPS rate (Table 15).

At both NPS (0 and 100 kg ha^{-1}) rate and Nitrogen (300 kg ha^{-1}) rate, and unmarketable head number of cabbage was decreased with increasing Nitrogen and NPS rate from 0 kg ha^{-1} to 300 kg $ha^{-1.}$This could be due to the fact optimal application can decrease u

Table.17 Interaction effects of N and NPS fertilizers on un marketable yield of head cabbage

NPS rate ($kgha^{-1}$)	Nitrogen rate ($kgha^{-1}$)			
	0	100	200	300
0	16.333^{A}	0.8800^{B}	0.1367^{B}	0.3900^{B}
100	2.2567^{B}	2.1467^{B}	0.1033^{B}	0.2033^{B}
200	2.0300^{B}	1.3733^{B}	0.6300^{B}	0.0001^{B}
LSD (0.05)	5.36			
CV (%)	143.48			

unmarketable yield that resulted in decrease cracking and unimproved size.

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

4.3.5. Marketable head cabbage yield

The interaction of nitrogen and NPS rate had a very highly significant ($p<0.001$) effect on marketable head yield (Appendix Table 3). lowest (16.67 ton/ha^{-1}) the marketable head number of cabbage was recorded at the zero level of N and NPS control rate. The better (118.36 ton/ha^{-1}) marketable head yield of cabbage was obtained from 200 kg ha^{-1} nitrogen combined with 100 kg ha^{-1} NPS rates and it was statistically similar with 200 NPS combined with 100 to200 N and 100 NPS combined with 300 N (Table 16). The marketable head yield of cabbage was increased with increasing of NPS (0 to 200 kg ha^{-1}) and nitrogen (0 to 200 kg ha^{-1}) rates.

This could be due to more vegetative growth, development, photosynthesis, dry matter synthesis, and translocation to storage organs. Similar results were found by Supe and Marbhal (2008), Singh *et al.* (2008*)* and Din *et al.* (2007), who also reported that maximum head yield was recorded in treatments receiving 120 kg N, 90 kg P, and 80 kg S/ha (Solomon *et al.*, 2018).

According to Kidane (2016), the maximum head yield was recorded in treatment receiving an NPS level of 102.5:69:12.71 kg ha^{-1}, which was statistically similar with 102.5:92:16.95 and 102.5:115:21.18, which were 42.787 kg ha^{-1}. Hossain *et al*. (2011) also reported that the maximum marketable yield (87.09 t ha^{-1}) was recorded in treatment receiving 240 kg N, 45 kg P, 180 kg K, and 45 kg S ha^{-1}, and the lowest marketable yield (24.67 t ha^{-1}) was noted by control having no nutrients applied. Din *et al*. (2007) reported that the maximum head yield was recorded in treatment receiving an NP level of 120–90 kg ha^{-1} in cabbage. Akand *et al*. (2015) also reported that the maximum (61.57 tonnes) yield per ha was recorded from nitrogen (200 kg ha^{-1}) and the minimum (49.53 tonnes) was recorded from null nitrogen (0 kg ha^{-1}).

Table 18. Interaction effects of N and NPS fertilizers on marketable yield of head cabbage

NPS rate (kgha^{-1})	Nitrogen rate (kgha^{-1})			
	0	100	200	300
0	17.67^{F}	111.2^{C}	117.68^{A}	116.24^{AB}
100	100.80^{E}	101.6^{E}	117.79^{A}	118.01^{A}
200	101.11^{E}	106.6^{D}	113.58^{BC}	118.36^{A}
LSD (0.05)	3.31			
CV (%)	1.9			

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance

5. CONCLUSION

Head cabbage is the second most important vegetable crop in Ethiopia, in terms of area covered and level of production Despite the high nutritional value of cabbage and its production potential, biotic and abiotic factors are limiting its productivity. Among them, drought, poor soil nutrients, and a lack of improved cultivars are the most important ones cabbage (Brassica Oleracea var. capitata L.) is the fifth most important vegetable crop belonging to the family cruciferae, and is a biennial crop with overlying leaves from a compact head. Cabbage is an important and highle diverse group of crops grown worldwide, to get a higher yield, it depends on proper consideration of balanced nutrients rates of Nitrogen and NPS. Different works noted that different nutrients played a role in regulating plant growth amd development, but the combination role of Nitrogen wits NPS in overcoming soil nutrient deficits and the performance of head cabbage has rarely been reported. This experiment was done to see the effect of different Nitrogen and NPS rates on the phenology, yield and yield component of head cabbage. The combined use of Nitrogen and NPS enhanced head cabbage productivity and yield by increasing plant hight, leaf number, and nutrient uptake and utilization. Using optimal rates of Nitrogen and NPS has also shortened the days of head formation and maturity.

Combination of NPS and nitrogen fertilizer will improve yields of head cabbage soil fertility decline is noted as the principal cause for crop yield reduction in west Arsii Oromia. This serious aspect may assume serious dimension in horticultural crops production, particulary head cabbage, as the crop is heavy feeder of nutrients, because it gives high yield in a relatively short period.

In the study area, lack of appropriate agronomic techniques is known to be one of the major contributing factors to the existing low yield per unit area, despite the existence of highly suitable climatic condition for head cabbage production. Head cabbage like other crops is dependent on the supply of nutrients. Optimum plant nutrient supply is a pre requisite for best growth and high yield of head cabbage. So far no fertilizer recommendation rate was made for vegetable like head cabbage production in West Arsi Zone. Soil nutrient, soil moisture content, soil structure and soil texture vary from area to area. As a result, crop production at a specific site requires specific rate of fertilizers on the basis of soil type, variety, moisture supply and management practices.. The study was conducted to investigate the effect of nitrogen and NPS rates on the phenology, yield and yield component of head cabbage. The result revealed that the interaction effects of nitrogen and NPS rates had a significant effect on Days to 50% head formation, days to 90% head maturity, plant height, total number of leaves, number of folded leaves, number of unfolded leaves, root length, leaf length, leaf width, head width, head diameter, head fresh weight, head dry weight, unmarketable head yield, and marketable head yield.

The highest values of the above-mentioned parameters were obtained from the combination of 300 kg ha^{-1} nitrogen and 200 kg ha^{-1} NPS fertilizer rates. Therefore, it can be concluded that the combined use of 300 kg ha^{-1} nitrogen and 200 kg ha^{-1} NPS fertilizer could maximize cabbage production in the study area and similar environments. However, since the study results are only for one season and location, repeating the experiment across locations may be helpful to validate the results. So the maximum yield achievement by crop relies on the application of the correct level of nutrients. In addition, especially for production of crop, the effect of fertilizer levels is important. It is therefore, important for the end user to determine the best combination of optimum nitrogen and NPS levels.

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7. APPENDICES

Appendix Table 1. Analysis of variance for days to 50% head initiation (HI), days to 90 % head maturity (HM), plant height(PH), total number of leaves (TNL), number of folded leaves (NFL), number of unfolded leaves (UFL) and root length (RL)

Source of variation	Df	Days to 50% head initiation	Days to 75 % head maturity	Plant height	Total number of leaves	Number of folded leaves	Number of unfolded leaves	Root length
Rep	2	0.097***	0.14***	0.68ns	0.19ns	0.09ns	0.06ns	0.29***
NPS	2	909.57***	44.89***	99.56***	15.86***	32.27***	1.29***	103.51***
N	3	225.83***	66.16***	63.44***	45.41***	292.46***	1.78***	47.92***
NPS*N	6	22.23***	2.16***	4.17***	3.16***	11.39***	1.42***	4.76***
Error	22	0.12	0.13	0.21	0.71	0.29	0.1	0.23

*, **, and *** are significant at 5%, 1%, and 0.1% probability levels, respectively, and ns stands for non-significant (p > 0.05).

Appendix Table 2. Analysis of variance for leaf length, leaf width, head length and head width

Source of variation	Df	Leaf length	Leaf width	Head length	Head width
Rep	2	0.29^{ns}	0.02^{***}	1.59^{ns}	0.09^{***}
NPS	2	169.60^{***}	80.16^{***}	69.77^{***}	71.83^{***}
N	3	22.30^{***}	48.30^{***}	55.44^{***}	35.48^{***}
NPS*N	6	2.34^{***}	4.32^{***}	4.71^{***}	7.53^{***}
Error	22	0.08	0.51	0.35	0.45

*, **, and *** are significant at 5%, 1%, and 0.1% probability levels, respectively, and ns stands for non-significant (p > 0.05).

Appendix Table 3. Analysis of variance for head diameter, head fresh weight, head dry weight, unmarketable head yield and marketable head yield

: variation	Df	Head diameter	Head fresh weight	Head dry weight	Unmarketable head yield	Marketable head yield
Rep	2	0.01^{ns}	5675.11***	27.20***	2.5x10^{4ns}	240975^{ns}
NPS	2	138.40***	8705331.03***	24605.37***	6.1x10^{7***}	6.19x10^{6***}
N	3	37.34***	3120158.55***	7813.9***	4.1x10^{7***}	4.13x10^{6***}
NPS*N	6	5.89***	737771.88***	2910.15***	1.9x10^{7***}	19.7x10^{6***}
Error	22	0.23	13640.14	57.57	1.5 x10^{5}	1.5x10^{5}

*, **, and *** are significant at 5%, 1%, and 0.1% probability levels, respectively, and ns stands for non-significant (p > 0.05).

8. BIOGRAPHICAL SKETCH

The author was born in Shashemene District, in the Oromiya Regional State, on January 29, 1986 G.C. She attended her elementary education at Shashemene Abyot Chora School in 1993 G.C. and her secondary school at Shashemene in 2001 and 2002, respectively. She also attended her high school education at high school in 2003 G.C. After the completion of her preparatory school in 2004 G.C., she joined Hawassa University in 2005 G.C. and graduated with a Bachelor of Science degree in Horticultural Science in 2008, G.C. After graduation, she was employed by the Agricultural and Natural Resources Office as an expert in fruit and vegetables in 2009 G.C. After serving the woreda for about 13 years, she got an opportunity to join the School of Graduate Studies at the Hawasa University College of Agriculture to pursue her MSc. Degree in Horticulture in 2021 G.C.