Physiological Productivity of CABBAGE (*Brassica oleracea* var. capitata L.) in Response to Planting Distance and Rate of Nitrogen Application

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ABSTRACT

Cabbage is one of the most important vegetables in the world, known for being a heavy nutrient feeder crop, especially nitrogen (N), and is influenced by planting distance, which plays a big role in production to attain a higher yield while producing the best quality cabbage suited to consumers' preferences. A study aimed to determine the levels of nitrogen and planting distance that influence the growth parameters, yield attributes, and yield of cabbage, as well as the economic efficiency of the treatments. Results show that the yield of cabbage is significantly influenced by planting distances and rate of nitrogen application, wherein 30 cm x 30 cm spacing proved to be the most productive when applied with 150-200 kg N/ha, obtaining the same highest yield in tons per hectare. Moreover, the same treatment combinations influenced other key physiological parameters, e.g., polar and equatorial head sizes and cabbage head weight. Economic analysis revealed that planting cabbage at a closer distance (e.g., 30 cm x 30 cm) with 150 kg/ha N, which will eventually provide more plant population density per area, would lead to a highly profitable venture for cabbage production.

Keywords: nitrogen, planting distance, cabbage, physiology

INTRODUCTION

Cabbage (*Brassica oleracea* var. capitata L.) is by far the most important member of the genus Brassica grown in the world, belonging to the family Crucifereae, and is the most popular vegetable in the sector in terms of area, production, and availability (Smith, 1995). Cabbage is an important vegetable in almost all parts of the world. It is one of the five best vegetables in the world (Rashid, 1999). The Food and Agriculture Organization (FAO, 1988) has recognized cabbage as one of the top twenty vegetables and an important source of food globally. Currently, the estimated production is about 58 million tons from about 3 million ha of agricultural land cultivated with cabbages. China remained the leading producer of cabbage (740230 ha), followed by India (300500 ha) and the Russian Federation (115600 ha) (FAOSTAT, 2011).

In the Philippines, the Cordillera Administrative Region in northern Luzon is the main producer of cabbage, cultivating approximately 79% (98,942 metric tons) of the country's overall production in 2011 (125,309 metric tons). The Central Visayas region ranked second (6%) with 7,947 metric tons, while Northern Mindanao ranked third (5%) with 5,751 metric tons. In Mindanao, the northern and southern regions are the

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top cabbage producers, constituting about 47% and 34%, respectively, of Mindanao's total production in 2011 (BAS, 2012).

The N fertilizer application has additionally been used to increase crop yields globally (Miao et al., 2011; Linquist et al., 2013). Plant density acts as a key factor in regulating plant competition within the population, and optimal plant densities are very important for efficient agronomic practice. Plant spacing varies with the growth of plants and the growing environment. Plant population studies are common features of many horticultural crops, including cabbage (Stoffela and Bryan, 1988). Fageria et al., (2003) reported that cabbage contains vitamin A (2000 IU), thiamine (0.06 mg), riboflavin (0.03 mg), and vitamin C (124 mg) per 100 g edible part. It is rich in minerals, including phosphorus (44 mg), potassium (114 mg), calcium (39 mg), sodium (14.1 mg), and iron (0.8 mg). The taste of cabbage is due to the "Sinigrin glucoside," and it is rich in minerals and vitamins A, B1, B2, and C (Singh et al., 2004). Beecher (1994) referred to the fact that the consumption of cabbage is known to reduce the risk of several cancers, especially lung, colon, breast, ovarian, and bladder cancers.

Many countries have incorporated cabbage as part of their national cuisine (Olaniyi et al., 2008). Cabbage can be variedly used, viz., for salad boiled vegetables, cooked in curries, pickling, as well as dehydrated vegetables. It has a high nutritional value, and is comprised of vitamins A, B1, B2, and C, along with minerals like Ca, Mg, P, K, Na, and S. Besides, it is a rich reserve of essential nutrients, delicious in taste, and also the source of 'roughage' for human beings (Verma and Nawange, 2015).

This study is conducted to determine the physiological productivity of cabbage in response to planting distances and rates of nitrogen application. Specifically, it aimed to determine the effect of planting distances and levels of nitrogen application on growth parameters, yield attributes, and yields of cabbage; to find out the optimum dose of nitrogen for yield of cabbage; to determine the physiological parameters of cabbage as affected by planting distances and rates of nitrogen application; and to determine the economic analysis of cabbage with nitrogen application and distances.

MATERIALS AND METHODS

Location and Duration of the Study

The study was conducted in the field area of the Research Development Extension Unit located (NO 8º36.44'E124º52.947') from July 2018 to November 2018. The study used the following materials: cabbage seeds, seedling trays, an oven machine for oven drying of plant samples, plastic bags, pencil, pen, notebook, SPAD meter, ruler, Vernier caliper, digital weighing scale, Bolo knife, plastic crates, shovel, net bags, sacks, and paper bags.

Experimental Design and Treatments

The study was arranged in a Split Plot designed in a Randomized Complete Block Design (RCBD) with three replications and four treatments. The different levels of nitrogen were designated as the main plot and the planting distance served as a subplot. Each treatment plot measured 3m x 4m. The treatments were the following:

Main Plot (A): Rate of Nitrogen

N1: 150-90-60 kg ($N-P_2O_5-K_2O$)

N2: 200-90-60 kg ($N-P_2O_5-K_2O$)

Subplot Plot (B): Planting Distance

PD1: 30cm x 30cm (105,555 plants per hectare) PD2: 40cm x 40cm (59,375 plants per hectare)

PD3: 40cm x 50cm (47,500 plants per hectare)

PD4: 50cm x 50cm (38,000 plants per hectare)

Cultural Management and Practices

Land Preparation

An area of 24m x 18m was used for the field cultivation, which was plowed and harrowed to pulverize soil clods, level the area, and remove the weeds. Ally way of 0.5m was provided in between replications.

Soil medium Preparation

A well-prepared seedbed is important, and preparation must commence well before transplanting. The vermicast was used as a planting medium for the cabbage seedlings cultivated in a seedling tray. Seedlings were raised in an enclosed nursery to be safe from infestations before transplanting. In most areas, cabbages are transplanted into raised beds to lessen the impact of heavy rain, which would waterlog the soil. Beds should be formed as soon as possible to allow them to stabilize before transplanting.

Irrigation

Cabbages need regular irrigation to ensure rapid growth and evenness of maturity. They can be irrigated through a manual process.

Spacing

Spacing depends on the planting distance of the cabbage. The study was done to show the right spacing when planting cabbage.

Transplanting

Seedlings were transplanted about four to five weeks after sowing.

Pest Management

Pests and diseases were controlled by spraying insecticides two times every week interchangeably from the day after the transplant to break the resistance of pests.

Weeds Management

Weeds were controlled every week through manual weeding to produce and provide productive cabbage.

Fertilizer and Fertilizer Application

The basal application was done by using Well Grow bio-organic fertilizer (analysis of 1.1 – 2.83 – 1.61 of N-P_2O_5-K_2O with 5.78% Ca and some amount of trace elements, e.g., 0.87% Fe, 0.019% Cu, 8.312 ppm Mg, 927 ppm Mn, and 339 ppm Zn), Urea (46-0-0), Solophos (0-18-0), and Muriate of Potash (0-0-60) were the applied fertilizers used as sources of nitrogen, phosphorus, and potassium, respectively, and were applied in three (3) split applications using the given rates depending on the specific levels.

Harvesting

Harvesting was done when the head was fully round and compact, about 60-80 days after transplanting.

Data Gathered

Growth Parameters

- Plant stand. This was obtained by counting the number of plants that survived 60 days after transplanting.
- Relative Chlorophyll Content – This was determined by using a SPAD -502 (Soil and Plant Analyzer Development) and done by clamping the meter and measuring the fully expanded bottom, middle, and top leaf of five (10) randomly selected plants per treatment.

Physiological Parameters

- Dry Matter Yield. The marketable and non-marketable-marketable yield of cabbage from two (2) plants were selected per plot and uprooted from the ground level, weighed, air dried under ambient conditions, and subjected to oven drying at 70˚C for 72 hours. Fresh weight and oven-dry weight were recorded.

Economic Yield

Harvest Index = Economic Yield / Biological Yield x 100

Yield and Yield Parameters

- Head weight – After harvesting, the heads were classified as marketable and non-marketable, counted, and weighed.
- Yield per hectare (tons) – The yield per plot was recorded and converted to yield in tons per hectare by using this formula:

Plot yield (kg) 10,000 (m 2) 1 ton

Yield (tons/ha) = Plot yield (kg.) x 10,000 (m 2) x 1 ton_
Plot area (m 2) 1 hectare 1,000 kg.

- Head size (polar and equatorial length) – Head size was derived from measuring the polar and equatorial lengths of ten (10) heads using a ruler and a Vernier caliper.

Economic analysis

Cost and Return Analysis- This was estimated by recording all production costs throughout the conduct of the study and income realized from the crops. Gross income was calculated by multiplying the total weight of marketable weight according to the prevailing market price of cabbage per kilogram. The difference between the gross income and the production cost represents the net income. elaborated which were computed using the formula below:

Gross income (GI) = (Weight of Marketable heads (kg) x (Price (Php/kg)

Statistical Analysis

The data was subjected to an analysis of variance (ANOVA) to determine the level of significance. Tukey's

Studentized Range Test was used to compare the significant differences among treatment means.

RESULTS AND DISCUSSION

Growth Parameters

Plant Stand Count

The plant stand count of cabbage is presented in Table 1. Results revealed no significant interactions were imposed on the levels of nitrogen at the different planting distances on the cabbage. Though it was non-significant, the planting distance of 40 cm x 50 cm had the lowest plant survival within 60 days after transplanting, while the treatment of 30 cm x 30 cm obtained more survival plants. Thus, cabbage applied with 150 kg N/ha showed the highest plant survival regardless of planting distance. N increases the utilization of carbon dioxide for photosynthesis and, as a result, causes an increase in the production of assimilates for plant growth (Weerakoon et al., 1999). Cultivation of any crop relies on numerous factors. It is well established that plant spacing has a significant influence on the growth and yield of different crops (Rashid and Mannan, 1983).

The optimum plant spacing depends on several factors, including the growing environment, doses of fertilizer, sources of nutrients, cultivar(s) used, fertility level of the land, etc. In addition, among the nutrients, nitrogen plays the most important role in the vegetative growth of the crop. Phosphorus is also an essential nutrient element that helps in the good growth of the roots of vegetable crops. Potassium exerts a balancing role in the effects of both nitrogen and phosphorus. The boron nutrient is important in cell division, nitrogen, and carbohydrate metabolism, and water relations in plant growth (Brady, 1990).

Chlorophyll Content

The study observed no significance on 35, 50, and 60 DAT, respectively; thus, the lowest chlorophyll uptake was observed at 60 DAT levels of nitrogen applied at 150 kg N/ha (53.55) and plots with 50 cm x 50 cm spacing (53.30). However, the highest chlorophyll content uptake was observed in 50 DAT plant spacings of 40×40 with 65.25 on the plot applied with 200 kg N/ha (61.83).

Table 1. Effects of varying levels of N and planting distance on the relative chlorophyll content and plant stand of cabbage.

TREATMENTS	CHLOROPHYLL CONTENT			PLANT STAND
	35 DAT	50 DAT	60 DAT	
Levels of Nitrogen (MP)				
150 kg N/ha	58.84	60.59	53.55	62.41
200 kg N/ha	57.76	61.83	57.23	58.33
F-test	ns	ns	ns	ns
Planting Distance (SP)				
30×30	57.20	59.78	54.00	63.16
40×40	59.85	65.25	54.88	60.50
40×50	58.65	59.60	59.38	58.16
50×50	57.51	60.21	53.30	59.66
F-test	ns	ns	ns	ns

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MP x SP				
F-test	ns	ns	ns	ns
C.V. (%)				
(MP)	7.97	9.16	21.47	18.52
(SP)	5.35	7.39	8.34	26.09

ns = not significant

Follet et al., (1981) reported that chlorophyll coloration is related to the amount of nutrients absorbed by the plant from the soil. Nitrogen plays a role in chlorophyll synthesis (Jasso-Chaverria et al., 2005). This concurs with the findings of other researchers who reported that chlorophyll content was strongly related to N concentration in the soil (Blackmer and Schepers, 1995; Sumeet et al., 2009), and thus leaves that differ in nitrogen content will differ greatly in chlorophyll content (Witt et al., 2005). The higher rate of 100 kg N ha^{-1} made nitrogen more readily available to the plants, which accounted for the higher chlorophyll content index. The relatively high CCI added value to the crop in that consumers perceives the greenness of leafy vegetables as a positive quality attribute (Maseko et al., 2015).

Nitrogen is important for plant growth and affects the growth and yield of leafy vegetables through its effect on cell division, expansion, and elongation, resulting in large stems and leaves, and enhanced quality (Onyango, 2002). Nitrogen is a vital macronutrient that is absorbed by plants in the form of nitrate and ammonium ions. This essential macronutrient is needed for the formation of all amino acids, enzymes, and proteins. The strong relationship between nitrogen and chlorophyll content is associated with the role of nitrogen. Nitrogen is a structural element of chlorophyll and protein molecules, and thereby affects the formation of chloroplasts and the accumulation of chlorophyll in them (Tucker, 2004).

Chapman and Barreto (1995) reported that nitrogen is part of the enzymes associated with chlorophyll synthesis due to its role in the formation of proteins. Therefore, the measurement of leaf chlorophyll content is a very good criterion for estimating crop nitrogen status (Gitelson and Merzlyak, 1997), since the total amount of nitrogen in plants can influence the photosynthesis process. Another factor that caused insignificant results in this parameter was the amount of light received by the plants.

Physiological Parameters

Dry Matter Yield

The dry matter yield of cabbage in response to varying levels of nitrogen and different plant spacing is presented in Table 2. The result revealed that the planting distance and levels of nitrogen did not influence the dry matter of marketable cabbage.

Table 2. Influence of N levels and varying plant distances on the dry matter yield and harvest index of cabbage.

TREATMENTS	DRY MATTER YIELD, g		HARVEST INDEX
	Marketable	Non-Marketable	
Levels of Nitrogen (MP)			
150 kg N/ha	13.96	28.26	16.98
200 kg N/ha	13.68	29.25	16.01
F-test	ns	ns	ns
Planting Distance (SP)			

30×30	15.01	28.00	17.69
40×40	13.58	26.21	17.15
40×50	14.19	30.77	15.83
50×50	12.50	30.03	15.31
F-test	ns	ns	ns
MP x SP			
F-test	ns	ns	ns
C.V. (%)			
(A)	7.40	16.84	14.68
(B)	19.90	24.61	23.29

ns = not significant

It means that at the harvesting stage, 30 cm x 30 cm gained more yield among all treatments because it matters for a greater number of heads, and that particular treatment got the highest plant survival with 63%, which, taking into account the highest dry matter marketable regardless of the rate of nitrogen applied, shows the comparable effect on that treatment.

Planting distance 30×30 with 105,555 PPD per hectare resulted in the highest dry matter accumulation with 150 kg N/ha nitrogen fertilizer applied. It's because more crops are harvested. Mekdad (2015) reported that the increase in yield as a result of increasing nitrogen fertilizer levels may be due to the importance of nitrogen as one of the macronutrient elements for plant nutrition and its role in increasing vegetative growth through enhancing leaf initiation, and increment chlorophyll concentration in leaves, which may be reflected in improving the photosynthesis process.

It was followed by treatments 40×50, 40×40, 14.19, and 13.58, respectively, while the lowest dry matter marketable was observed in 50×50 plant spacing. Znidarcic et al., (2007) reported that heads grown at high densities produce less dry matter than those grown at low densities. Previous studies demonstrated that the absorption and remobilization of N in plants were both affected by planting density and N management (Ciampitti and Vyn, 2013; Kosgey et al., 2013). Meanwhile, levels of nitrogen applied at 150 kg N/ha and 200 kg N/ha result in comparable dry matter marketable for cabbage at 13.96, 13.68, respectively, regardless of planting density.

The non-marketable dry matter for yield of cabbage showed a negative influence on the planting density and two levels of nitrogen presented in Table 2. It was observed that cabbage applied with an N rate of 200 kg N/ha gained more non-marketable dry matter, and plots experimented with plants with 40 cm x 50 cm (30.77) plant spacing gained more non-marketable dry matter. Observed that plant spacing of cabbage 40×50 when applied 200 kg N/ha tends to produce more non-marketable heads. Nutrient imbalance could lead to low yields and deterioration of product quality such as those associated with physiological disorders in plants (Inthichack, 2012). Then it is followed by treatments 50 cm x 50 cm, 30 cm x 30 cm, and 40 cm x 40 cm (30.03, 28.00, and 26.21), respectively, regardless of the N application presented in Table 2. Planting date affects crop growth, development, yield, pest, and disease incidence (Brown et al. 1992).

Harvest Index

Cabbage in response to nitrogen levels and plant spacing is presented in Table 2. Results revealed that nitrogen levels and spacing did not influence the H.I. of the test crop. However, 150 kg N/ha levels of nitrogen obtained the highest harvest index regardless of planting distances, while plots with a spacing of 30 cm x 30 cm (17.69) obtained the highest H.I. It means that when cabbage is experimented with at a 30×30

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planting distance with the rate of nitrogen application 150-200 kg N/ha, which favors the crops to produce more yield, which is observed in the yield tons per hectare of cabbage, which is also the highest, it is possible in that particular treatment that more heads are harvested. It's taken into account that in the decreasing distance, more plants are being planted than those at higher distances. It seems that higher yields have been achieved by higher rates of fertilizer, closer spacing, new cultivars, better pest control, and attention to water management (Halsey et al., 1966).

It was followed by treatments of 40 cm x 40 cm and 40 cm x 50 cm with 17.15, and 15.83, respectively, regardless of nitrogen application. When crops are planted at high densities, the efficiency of light interception is improved as a consequence of increases in LAI (Alessi et al., 1977; MacGowan et al., 1991; Xinyou et al., 2003). A reasonable LAI is critical to maintain high photosynthetic rates and yield (Xiaolei and Zhifeng, 2002). The planting distance of 50 cm x 50 cm is the lowest, gaining a harvest index of 15.31 with a rate of nitrogen application of 150 and 200 kg per hectare. Adjusting planting density is an important tool to optimize crop growth and the time required for canopy closure, and to achieve maximum biomass and grain yield (Liu et al., 2008).

Yield and Yield Parameters

Head Size

The different levels of N showed no significant effect on the polar and equatorial head sizes of cabbage (Table 3).

Table 3. Yield and yield parameters of cabbage as influenced by N rate and planting distance.

TREATMENTS	HEAD SIZE (cm)		HEAD WEIGHT (kg)		YIELD (t ha^{-1})
	Polar	Equatorial	Marketa-ble	Non-marketa-ble	
Levels of Nitrogen (MP)					
150 kg N/ha	9.92	13.68	0.44	0.19	39.30
200 kg N/ha	10.16	14.16	0.45	0.17	37.48
F-test	ns	ns	ns	ns	ns
Planting Distance (SP)					
30×30	9.79b	13.41b	0.39b	0.16b	57.90a
40×40	10.06ab	13.95ab	0.44ab	0.19a	37.90b
40×50	10.39a	14.51a	0.51a	0.19a	33.68b
50×50	9.92ab	13.81ab	0.46ab	0.17ab	24.10c
F-test	*	*	**	*	**
MP x SP					
F-test	*	*	ns	*	*
C.V. (%)					

(A)	9.25	5.08	13.64	6.79	9.96
(B)	2.95	3.51	11.01	8.93	8.30

** Significant at a level of 1% probability

* Significant at a level of 5% probability

ns = not significant

Significant results were observed on plots with a planting distance of 40 cm x 50 cm and the biggest polar and equatorial head sizes of 10.39cm and 14.51cm, respectively (Figures 1 and 2). Head size is closely related to the amount of space available to each plant. As spacing increases, the heads become larger, increasing to a maximum that is characteristic of that cultivar. Head size is also directly influenced by the availability of major nutrients for the plant. For satisfactory yields, there must be adequate levels of N, particularly during the early head formation stage, and P and K during the earlier stage of outer leaf expansion. Presumably, any stress factor that results in poor plant growth would also bring about reduced final head size. Drought during frame development and the earliest stages of head development may influence yield by reducing frame size and restricting growth in the outermost head leaves (Radovich et al., 2005).

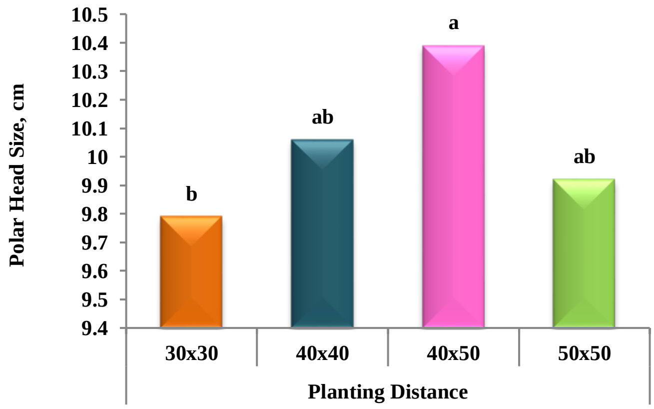

Figure 1. Influenced by planting distance on the polar head size of cabbage.

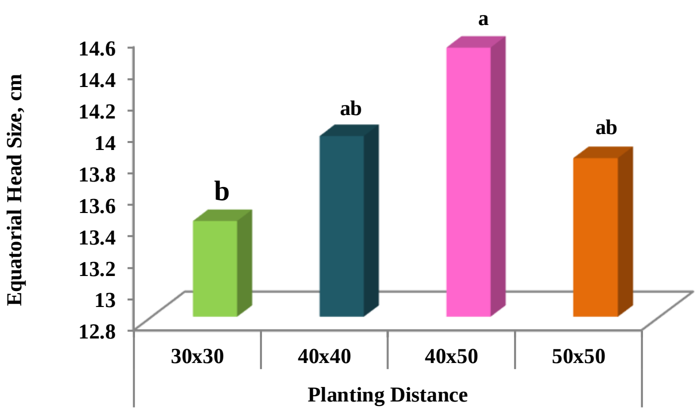

Figure 2. Effect of planting distance on equatorial head size of cabbage.

Significantly smaller head sizes were obtained from planting distances of 30 cm x 30 cm with 9.79cm and

13.41cm only for polar and equatorial head sizes, respectively. Reduced head size might be achieved mainly by the use of high-density planting, cultivar choice, and the application of other factors such as method of cultivation, rate of water supply, and fertilization level. Pramanik, (2007) reported a similar result: the diameter and thickness of the head increased with the increasing level of nitrogen that favored the growth of plants.

This finding was confirmed by 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. This was possibly due to the higher synthesis of carbohydrates and their translocation to the sink, which is the cabbage head, which subsequently helped in the formation of a larger and comparatively broader head of the cabbage.

According to Semuli (2005), it is possible that as plant spacing was reduced, competition for nutrients, light, air, and moisture increased which would have resulted in decreased diameter and weight of heads. The lowest plant spacing resulted in a significantly wider equatorial diameter than the polar one (Žnidarčič, et. al. 2007). It was found that significant results on the interaction between the two treatments but non-significant observed in the levels of nitrogen, plot applied with 200kg N/ha got the highest equatorial size with 14.16. Stofella and Fleming (1990) reported quadratic increases in the cabbage head height and head width as intra-row spacing was increased from 8 to 38 cm.

Weight of the Cabbage Head

Levels of N showed no significant effect on the head weight of cabbage, both marketable and non-marketable. However, the cabbage head weight of cabbage was positively influenced by the planting densities. Planting distance of 40 cm x 50 cm got the biggest weight for both marketable (0.51g) and non-marketable (0.19cm) which was significantly higher compared with the rest of the planting distances evaluated (Figures 3 and 4).

Varying amounts of nitrogen showed no significant effects, but the plot applied with 150 kg N/ha got the highest non-marketable head weight, followed by 0.17 at 200kg at N/ha. Singh and Agarwal (2001) stressed that the increase in leaf number due to enough nutrition can be explained in terms of a possible increase in the nutrient absorption capacity of plants, as a result of better root development and increased translocation of carbohydrates from sources to growing points.

The relative impact of N on cell division and cell expansion depends on the developmental stage of the leaf (del Amor, 2006).

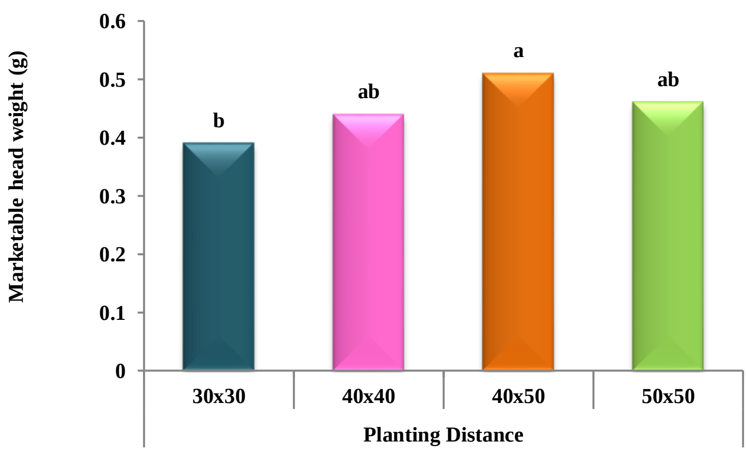

Figure 3. Effect of planting distance on the marketable head weight of cabbage

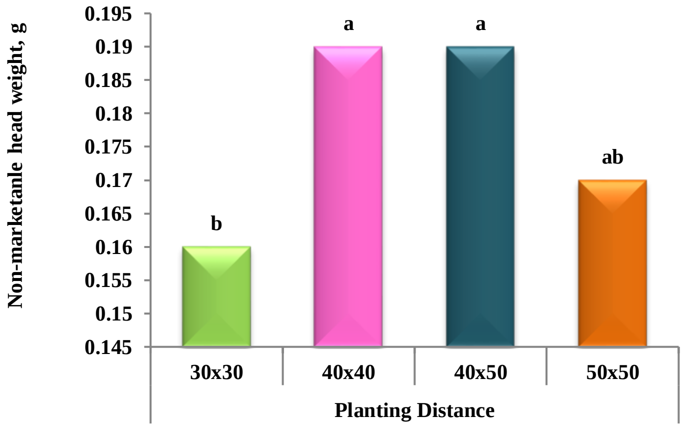

Figure 4. Effect of planting distance on the weight of non-marketable cabbage head

Cabbage Yield

The data showed no significant results on the yield of cabbage as influenced by the levels of nitrogen., Through, yield was influenced by the different planting distances and the interaction effects of the two factors under study.

The planting distance of cabbage at 30 cm X 30 cm obtained the highest yield with 57.90 t ha^{-1} (Figure 5). This higher yield in cabbage could be associated with an increased number of heads harvested per area due to increased plant population density using close planting distances during transplanting. Spacing is another vital factor that was reported to have a great influence on cabbage production. Yield-contributing characteristics are highly affected by spacing and become less if the spacing between plants is decreased (Ullah et al., 2013).

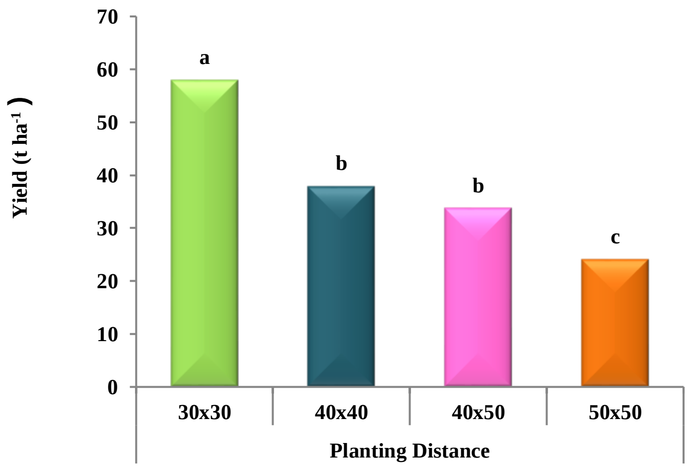

Figure 5. Effect of planting distance on the yield (tons ha^{-1}) of cabbage.

The higher nitrogen levels favored the growth of plants with larger leaf area, and they were more effectively utilized in head formation, head diameter, and the number of marketable heads. Nitrogen is one of the most important nutrients for higher yields and good quality heads. The amount and type of N fertilizer used for this crop vary in different cultivation areas, depending on soil type and nutritional conditions. Being a heavy feeder of nutrients, cabbage requires special attention for harvesting a good yield. The heads will not form unless an adequate N is given (Knavel and Herron, 1981). A judicious and balanced use of fertilizer can nevertheless bring about a substantial increase in crop productivity (Halsey et al., 1966).

The interaction effect interaction effect showed that planting cabbage at 30cm x 30cm with 150kg/ha of nitrogen resulted in the highest yield of 63.45 tons $^{ha-1}$. Therefore, nitrogen and spacing levels showed positive influences on the cabbage head. In addition, cabbage requires heavy manuring for a better yield. It has been shown in many fertilizer trials that all three major nutrients, viz., nitrogen, phosphorus, and potassium are essential for the high yield of cabbage.

The highest tons per hectare were obtained at a planting distance of 30×30 cm (105,555 PPD per hectare) with a yield of 57.90 t ha-1. These results are in agreement with Saha et al., (1994), and Hossain (1983). The higher gross yield per hectare at closer spacing was possibly due to larger number of plants per unit area. It was followed by 40 cm x 40 cm (59,375 PPD per hectare) with a yield of 37.90 t ha-1 and 33.68 t ha-1 (40×50 cm), respectively, and the lowest was observed in 50×50 cm (38,000 PPD per hectare) with 24.10 t ha-1. This low yield may be attributed to a great extent to the low production management practices adopted by the farmers. Of the many factors of improved cultivation practices, the use of proper spacing for transplantation and suitable cultivars indeed influences the yield contributing characteristics and consequently the yield. The use of proper spacing is an important factor for securing a higher yield of desirable heads of cabbage.

Increasing the plant population with cabbage has the potential to increase yield and profit. Although in cabbage, high plant density reduced head size and head weight (Csizinsky and Schuster, 1985), a greater number of heads per unit area increased total yield (Stepanovic et al., 2000). In addition, nutrients such as nitrogen play a major role in the growth and development of plants (Scott, 2008). This essential nutrient improves the chemical and biological properties of the soil and therefore enhances plants. Silberbush et al., (2003), Kim et al., (1998), and Engelbrecht (2004) have emphasized supplying nutrients to the soil during the growth of plants to increase their quality or productivity. Optimum plant density is another important factor for high plant growth and yield.

Cost, Return, and Analysis

Harvested cabbage heads were sold at a farm gate price of PhP 25.00 per kilogram. The production cost, gross sales, net income, and return on investment for the different planting distances and rates of nitrogen applied to cabbage are presented in Table 4.

Results showed that cabbage applied with 150 and 200 kg/ha N planted at a distance of 30 x 30 obtained the highest ROI of 17.9PhP and 15.2 PhP, respectively. ROI is highly influenced by the harvested marketable heads per hectare, showing that a higher number of marketable heads harvested per hectare, would result in higher net income. With this, planting cabbage at a closer distance (e.g., 30cm x 30cm), which eventually will provide more plant population per area would lead to a highly profitable venture for cabbage production even if the amount of nitrogen applied for fertilization is up to 150 kg/ha N only.

Table 4. Cost and return analysis of 0ne-hectare cabbage production as influenced by N levels and planting distance.

TREATMENTS	PRODUCTION COST (PhP)	GROSS SALES (PhP)	NET INCOME (PhP)	ROI (PhP)
N1 (150-90-60)				
30 x 30 cm	57,780.00	1,089,679.45	1,031,899.45	17.9

40 x 40 cm	55,380.00	632,343.75	576,963.75	10.4
40 x 50 cm	54,180.00	604,239.58	550,059.58	10.2
50 x 50 cm	52,980.00	418,031.67	365,051.67	6.9
N2 (200-90-60)				
30 x 30 cm	58,980.00	957,911.63	898,931.63	15.2
40 x 40 cm	56,580.00	690,085.94	633,505.94	11.2
40 x 50 cm	55,380.00	614,095.83	558,715.83	10.1
50 x 50 cm	54,180.00	458,723.33	404,543.33	7.5
** Price/kilo: 25.00				

CONCLUSION

The study aimed to determine the effect of N fertilization and planting distances on the growth parameters, yield attributes, and yield of cabbage. The experiment was conducted at the Agricultural Experiment Station of UST-Claveria, Claveria, Misamis Oriental, from July 2018 to November 2018. The plant stand of cabbage was not significantly influenced by the rate of nitrogen and planting distances. The highest chlorophyll content in cabbage was observed at 50 DAT with 61.83, particularly for plants applied with 200 kg/ha N. Planting distances of 40cm x 40cm gained the highest chlorophyll content during 50 DAT when applied with 150kg N/ha. Consistently, a planting distance of 40cm x 50cm resulted in a heavier weight per head of both marketable and non-marketable heads of harvested cabbage applied at a rate of 200 kg/ha. This could be associated with the relatively bigger head sizes for both polar and equatorial measurements of cabbage heads obtained from the same treatments (40cm x 50cm), which were significantly bigger than the rest of the treatments. Dry matter yield and harvest index were not significantly affected by either of N levels or planting distances nor was the interaction effect of the two factors evaluated. Cabbage yield was significantly affected by the interaction effect of both N levels and planting distances, particularly when planted at 30cm x 30cm with 150 kg/ha N, resulting in 63.45 tons $^{ha-1}$ while the lowest yield (25.03 tons $^{ha-1}$) was observed at 50×50 even when applied with 200 kg/ha of N. Consequently, the highest return on investment was obtained in growing cabbage at a planting distance of 30cm x 30cm applied with 150 kg/ha N with an ROI of 17.9PhP, which was followed by production of the same planting distances but applied with 200 kg/ha of N with an ROI of 15.2 PhP. ROI, which is highly influenced by the weight or total yield of harvested marketable heads per hectare, showed that the more marketable heads harvested per hectare would result in higher total weight and thus a higher net income. With this, planting cabbage at a closer distance (e.g., 30cm x 30cm) with 150 kg/ha N, which will eventually provide more plant population density per area, would lead to a highly profitable venture for cabbage production.

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