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Participatory Approach to Optimizing Cabbage Fertilization System for Improved Yield, Quality and Shelf Life

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Abstract

Cabbage fertilization system was optimized following the participatory approach by factoring in farmers' practices, conducting optimization trials on farmers' field, and employing farmer-researcher co-management of on-farm trials. Five different rates of fertilizer application were documented in the survey of farmers in a vegetable-growing area in Central Philippines. They served as basis for the fertilizer treatments (2 organic fertilizer levels using chicken dung or CD and 5 inorganic fertilizer levels using complete fertilizer 14-14-14 and urea 46-0-0) tested in on-farm trials in the dry season (December to May) and wet season (June to November). Other cultural practices were those employed by farmers with some good practices introduced. Optimum fertilization rate was 2.3 tons CD/ha + 112-47-47 (336 kg 14-14-14 and 141 kg 46-0-0 per hectare) for both dry and wet season crops, giving yields of 29.5 and 10.7 tons/ha, respectively, with net profit-cost ratio of 4.41 and 2.14, respectively, or more than 2-3 times higher than that of unfertilized crops. In addition, the heads produced were flatter and more compact and had longer shelf life due to lower weight loss and trimming loss, particularly for dry-season crop, compared to other fertilizer treatments. The participatory approach equipped farmers with first-hand knowledge and skills on how to improve existing cultural practices to generate high quality yields and farm profits.

Keywords: Brassica oleraceae var; capitata; crop productivity; plant nutrition; participatory research.

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1. Introduction

Cabbage (*Brassica oleracea var. capitata* L.) is a high-value, nutrient-dense crop which is the most important leafy vegetable in the Philippines and the most widely cultivated cole crop in the world. It is rich in vitamins, minerals, fiber and antioxidants and contains organosulphur phytochemicals, specifically glucosinolates which increase the antioxidant activity [1,2]. Cabbage is usually produced for the fresh market and can be processed into Kraut, egg rolls and cole slaws. Increasing cabbage production supports food and nutrition security and income capacity especially for smallholder farmers who dominate vegetable industries in developing countries. It requires proper management of soil fertility. However, soil management practices have changed dramatically toward widespread use of synthetic chemical fertilizers. Problems associated with continuous use of chemical fertilizers include nutrient imbalance, increased soil acidity, degradation in soil physical properties, loss of organic matter, and increased hazards to the environment and human health [3,4]. Cabbage has high requirements for nutrients, especially nitrogen (130-310 kg N/ha) [5] but excessive nitrogen application is an environmental concern and could adversely affect cabbage quality by producing coarse and loose head with succulent leaves, reducing keeping quality, and increasing the nitrate content [6,7]. Sustainable agriculture promotes the use of organic fertilizers alone or in combination with inorganic fertilizer. Organic fertilizers are environment-friendly, improve soil health, and foster diverse populations of beneficial soil microorganisms [8]. Organic and inorganic nutrient management has profound effects on growth and yield of vegetables [6,7]. Growth and yield of cabbage significantly increased in response to the application of poultry manure or chicken dung (CD) in which the plants had higher plant height, stem girth, leaf number and head weight than that applied with inorganic NPK fertilization [9]. Organic-inorganic fertilizer application has been found to improve cabbage yields, quality and shelf life [7,10,11]. Crop technologies such as fertilization system can be easily adopted if they suit farmers' conditions. Technology adoption among small farmers has been a problem in the conventional research-extension-utilization process where researchers develop technologies at research stations, extension workers spread them, and farmers adopt or reject them [12]. The problem persisted despite strategic extension system, such as the Training and Visit System. The main cause was that the technologies were not appropriate for farmers. As a sustainable solution, participatory research was introduced as an approach aimed at creating appropriate technology for small farmers. It responds to problems and needs of farmers; develops technology options that build on local knowledge and resources; and ensures that technologies developed are appropriate for farmers [13,14]. This research employed a participatory approach to optimizing the fertilization system of cabbage to improve yield, quality and shelf life.

2. Materials and Methods

2.1 Participatory approach

The research involved cabbage farmers in a major vegetable-growing area to assess and optimize the fertilization practices [15]. The fertilization practices and fertilizer treatments for testing in the optimization trials were discussed and validated with farmers. The experimental trials were conducted at farmer's field employing farmer-researcher co-management. The rationale was that the change to be introduced is not entirely new to farmers as it only involves adjustment of an existing practice; farmers can have first-hand involvement in making and experiencing the results of the change; and the activity builds the capacity of farmers. Thus, technology adoption could be facilitated.

2.2 Study site

The study site is a major vegetable-growing area in Central Philippines (Visayas) comprising of upland villages of the coastal city of Ormoc, Leyte (geographic coordinates 11.0384° N, 124.6193° E; altitude 5.6 meters above sea level). These upland villages are near the Energy Development Corporation's Tongonan Geothermal Project which is the world's largest wet steam field. On-farm trials were conducted with farmers in the village of Cabintan (11.0947° N, 124.6884° E; 838.4 meters above sea level).

2.3 Survey of fertilization practices

A questionnaire was formulated, pretested and finalized for the survey of farming practices of cabbage farmers in the aforementioned vegetable-growing area with emphasis on fertilization practices and associated cultural management operations. Fifteen (15) farmer-respondents were randomly sampled. Results of the survey are reported here as frequencies and percentages.

2.4 On-farm trials

The different fertilizer treatments were formulated based on the fertilization practices of farmers. Other good cultural practices including the cabbage variety used, seedling production, and control of weeds, insect pests and diseases were essentially those employed by majority of the farmers surveyed. Plant survival was maintained at more than 90% by reserving seedlings for replanting within one week from transplanting. Before field planting, soil samples from up to 15 cm depth at strategic locations of the experimental area were taken for analysis of pH, organic matter, total nitrogen (N), available phosphorus (P) and available potassium (K). The field trials were conducted during the dry season (December-May) and wet season (June-November) with the first month devoted to seedling production; the succeeding months for field growing until harvest; and the last month for postharvest evaluation. Standard experimental protocols were followed including experimental design, number of replications, plot size per replicate and randomization.

2.5 Measurement of yield, quality and shelf life

At harvest, plant height of 10 sample plants from each fertilizer treatment per replicate was taken with a metric rule before cutting the base of the head with a sharp knife. Yellowed, wilted and senesced outer leaves and protruding butt stem were trimmed off. Marketable and non-marketable (insect-damaged, diseased/rotten, bursted and small sized) cabbage heads per plot except border plants were counted and weighed. The quality of marketable heads using 10 sample heads per treatment per replicate were characterized in terms of polar and equatorial diameters and their ratio (shape index), head weight and compactness measured by taking head volume by the water displacement method [16]. The ratio of head weight and head volume was taken as the solidity index. For postharvest evaluation, 10 heads from each fertilizer treatment per replicate were stored at ambient (26-33^{o}C; 65-85% RH). Weight loss was measured as percentage of the initial weight. Trimming loss due to wilting and/or senescence of outer leaves and bacterial soft rot at the butt end was determined as percentage of head weight. Head weight was taken before and after trimming to discount trimming loss from weight loss. Shelf life was estimated as the number of days to more than 25% weight loss and/or trimming loss.

2.6 Statistical analysis

The results presented are pooled means of two trials per growing season and were statistically analyzed by performing analysis of variance (ANOVA) and treatment mean comparison by the least significance difference test (LSD) at 5% level using MSTAT (Microcomputer Statistical Package, Michigan State University, USA).

3. Results and Discussion

3.1 Fertilization practices

Most cabbage farmers were aged 28-38 years old with low educational attainment (Table 1). Some farmers have been growing cabbage for 1-10 years while others were producing cabbage for 11-20 or 21-30 years. Cabbage was typically grown in small areas mostly ranging from 0.25-0.5 hectare. Majority of the farmers owned their farms. The 'Resist Crown/KY cross' was the commonly used cabbage variety (Table 2). Seedlings were prepared by the cellular method using fresh banana leaves and planted out in the field when 3-4 weeks old after a hardening treatment to acclimatize the plants to field conditions. Plant spacing was mostly 100 cm between rows and 30 cm within rows. Weeding was done manually usually two times per cropping. Commercial insecticides were sprayed to the plants mostly two times per week while fungicides were sprayed either two times per week or two times per cropping. Spraying ceased one week before harvest or when the cabbage heads matured. Some farmers watered their plants every 3 days at one liter per plant using a used 1-liter oil can while others did not.

Table 1: Demographic characteristics of cabbage farmers

Demographic Attributes	Frequency, %	Demographic Attributes	Frequency, %
1. Age (years)		4. Area of farm (hectare)	
17-27	17.7	1/8	6.2
28-38	46.9	1/4	50.0
39-49	17.7	1/2	37.5
50-60	17.7	3/4	6.3
2. Educational attainment		5. Tenure status	
Grade 4	50.0	a. Class	
Elementary graduate	33.3	Owner	73.4
High School graduate	16.7	Tenant	26.6
3. Years in farming		b. Sharing system if tenant	
1-10	47.1	None	80.0
11-20	23.5	1/5	20.0
21-30	23.5		
31-40	5.9		

Table 2: Cultural management practices of cabbage farmers

Cultural Practice	Frequency, %[1]	Cultural Practice	Frequency, %[1]
1. Cabbage variety used		5. Insecticide spray	100.0
Resist Crown	20.0	a. Frequency	
Resist Crown/KY cross	100.0	2 times/week	60.0
2. Seedling production		Once a wk	30.0
Cellular method	100.0	Once every 2 wk	10.0
3. Plant spacing (cm)		b. End of spraying	
30 x 100	70.6	One wk before harvest	50.0
30 x 60	29.4	When cabbage mature	50.0
4. Weeding		6. Fungicide spray	100.0
a. Method, manual	100.0	a. Frequency	
b. Frequency per cropping		2 times/wk	60.0
Once	20.0	Once a wk	10.0
2 times	60.0	2 times/cropping	30.0
3 times	20.0	b. End of spraying	
c. Interval if more than once		One wk before harvest	50.0
Not specific; when weeds luxuriantly growing	100.0	When cabbage mature	50.0
		7. Irrigation	60.0
		a. Amount, 1 liter/plant	60.0
		b. Frequency	
		Daily	20.0
		Every 3 days	40.0

[1]Some items are multiple responses (n=15)

Table 3: Fertilization practices of cabbage farmers.

Rate No.	Fertilization Rate		Fertilizer Used[3]	Frequency, %[4]
	Organic (tons/ha)[1]	Inorganic (kg/ha)[2]		
1	0	47-47-55	14-14-14; 0-0-60	13
2	0	140-140-140	14-14-14	33
3	2.33	180-33-100	Chicken dung (CD); 46-0-0; 16-20-0; 0-0-60	20
4	2.33	307-0-0	CD; 46-0-0	20
5	2.33	53-67-200	CD; 16-20-0; 0-0-60	20

[1]Applied basally per plant at planting (2.33 tons CD/ha=1/2 ‘sardine’ can CD/plant)

[2]Applied per plant at 2-week interval for 2 times if CD is applied and for 3 times if not

[3]Complete fertilizer 14-14-14; urea 46-0-0; ammonium phosphate 16-20-0; muriate of potash 0-0-60

[4]Multiple response (n=15)

All cabbage farmers applied inorganic fertilizer alone or in combination with chicken dung (CD) as organic fertilizer (Table 3). CD was applied at 2.33 tons/ha (1/2 of 140g-capacity ‘sardine’ can/plant). Five different rates of inorganic fertilizer application were practiced and ranged from 47-307 kg N/ha, 0-140 kg P2O5/ha and 0-200 kg K2O/ha. In general, most of the fertilizer rates had either equal amounts of the three macronutrients or had higher N than P and K. Only 20% of the farmers applied only N fertilizer in combination with CD. Complete fertilizer (14-14-14), urea (46-0-0), ammonium phosphate (16-20-0), and muriate of potash (0-0-60) were used as inorganic fertilizer materials. The desired amount of inorganic fertilizer was divided into two equal parts if CD was used and into three equal parts if not. Each part was applied at two weeks interval starting at planting.

Based on the above findings, the following fertilizer treatments were formulated:

Main treatments (amount of CD as organic fertilizer):

O1 = 0

O2 = 2.3 tons/ha (0.5 ‘sardine’ can per plant)

Sub-treatments (inorganic fertilizer rates)

T1 = 0

T2 = 79-47-47 (1 tablespoon 14-14-14 + 1/2 tbsp 20-0-0 per plant)

T3 = 112-47-47 (1 tbsp 14-14-14 + 1 tbsp 20-0-0 per plant)

T4 = 145-47-47 (1 tbsp 14-14-14 + 1.5 tbsp 20-0-0 per plant)

T5 = 140-140-140 (3 tablespoon 14-14-14 per plant)

The choice of the two rates of CD application was based on the farmers’ practice. The inorganic fertilizer levels, particularly the use of higher N than P and K, were formulated not only based on farmers practice but also based on the fact that cabbage is a leafy vegetable that needs higher N for more rapid vegetative growth. The fertilizer rate 140-140-140, which deviated from the fertilizer level interval, was included as it was employed by more farmers. The treatments were arranged in split plot design with three replicates [17]. Replicates, main plots and subplots (4m x 5m) were separated by one-meter alleyways. As practiced by farmers, the organic fertilizer was applied basally in each plant at planting. The total amount of inorganic fertilizer was divided into two equal parts if chicken dung was used, and into three equal parts if not. Each part was applied at two weeks interval starting at the time of planting. ‘Resist Crown/KY cross’ cabbage variety was used and the seedlings were produced by the cellular method and transplanted to the field when 3-4 weeks old following gradual exposure to field conditions in the nursery (hardening or acclimatization). Other cultural practices of farmers were followed with introduction of good practices such as use of seedling trays, raised seedbed construction, proper chemical spraying and harvesting using a customized sharp knife.

3.3 Climate and soil

The study site has Type IV climate in which rainfall is more or less evenly distributed throughout the year (http://bagong.pagasa.dost.gov.ph/information/climate-philippines). During the on-farm trials, monthly rainfall ranged from 20-200 mm in the dry season and 75-243 mm in the wet season. Minimum and maximum temperatures ranged from 18.0-21.8^{o}C and 29.5-32.8^{o}C in the dry season cropping, and 19.0-21.5^{o}C and 29.8-32.5^{o}C in the wet season cropping, respectively. The soil chemical properties differed slightly between dry and wet season plantings. The soil type was silty loam with 6.15-6.22 pH, 3.18-3.30% organic matter, 0.24-0.26% N, 46.3-49.0 mg P/kg and 1547.3-175.5 mg K/kg. The soil pH of the farm area was within the optimum range (5.75-7.0) for cabbage production [18]. Organic matter content was relatively high as the area was formerly a forested area and had not been cropped intensively. The NPK content could be used to determine the amount of NPK fertilizer to be applied. Farmers’ fertilization practices are not based on soil test results which can be correlated with crop responses. Soil analysis before planting is more useful than soil analysis after harvesting the crop because there are factors that affect soil nutrient supply other than the amounts of nutrients taken up by previous crops, such as nutrient fixation, leaching, crop uptake and nutrient-supplying power of the soil [19].

3.4 Yield and yield components

Plant height markedly increased with fertilizer application during the dry season (Table 4). Combined CD and NPK treatment was more effective in increasing plant height than NPK fertilization alone. NPK rate of 112-47-47 was sufficient to be combined with CD as higher NPK rates (145-47-47 and 140-140-140) had comparable effect. During the wet season, fertilizer application had no significant effect on plant height which ranged from 23-29 cm, shorter than that during the dry season (28-39 cm). Earlier, the integrated application of organic and inorganic fertilizers significantly increased the vegetative growth of cabbage [20]. During the dry season, more marketable heads were harvested from plots receiving NPK fertilizer with or without CD (37-42 per plot) compared to that without NPK fertilizer (30-33 per plot) as the latter had more non-marketable heads (small size, insect damage and bursting) (8-12 per plot) than the former (2-5 per plot) (Table 4). The number of marketable heads among NPK-fertilized plants did not significantly vary. The weight of marketable heads showed a different trend. It increased with increasing NPK application up to a certain level regardless of CD application. Highest marketable weight of 59 kg/plot or 29.5 tons/ha was produced by the combined application or CD and 112-47-47. Higher NPK rates did not further increase marketable weight yield. Non-marketable weight yield did not differ with treatments and ranged from 1.3-3.8 kg/plot. During the wet season, fewer marketable heads (15-27 per plot) and more non- marketable heads (8-19 per plot) were produced as compared to that in the dry season (Table 4). Highest number of marketable heads (28.3 per plot) was produced with the combined CD and 140-140-140 but this response was statistically comparable with that of CD + 112-47-47 (26.7 per plot) and CD + 145-47-47 (25.7 per plot) as well as with 145-47-47 alone (24.5 per plot). These four treatments also produced comparably higher marketable weight (18.8-21.4 kg/plot or 9.4-10.7 tons/ha) compared with the other treatments. Non-marketable heads did not differ among treatments. The dry season head yield was more than two times higher than that of the wet season yield. During the wet season, more heads were not fully developed resulting in small size, and insect damage and rotting were more prevalent which resulted in outright classification of the heads as non-marketable and/or excessive trimming to remove the damaged parts reducing the remaining head part to non-marketable size. In both dry and wet season cropping, the combined application of CD and 112-47-47 seemed to be the optimum rate of application. Previous

Table 4: Yield and yield components of cabbage in response to fertilizer treatment during dry and wet season planting.

Treatments	Plant height (cm)	Marketable yield per 20 m^2 plot		Non-marketable yield per 20 m^2 plot		Yield/ha (tons)
		Number	Weight (kg)	Number	Weight (kg)	
Dry season planting						
0 chicken dung (CD)						
0-0-0	28.6e	30.3b	24.8e	11.4a	3.8a	12.4e
79-47-47	32.6d	37.6a	33.9d	5.0b	3.5a	17.0d
112-47-47	35.5c	40.5a	44.6c	3.5b	3.2a	22.3c
145-47-47	36.0bc	38.9a	50.6b	4.4b	3.1a	25.3b
140-140-140	36.8bc	41.0a	51.2b	2.8b	2.2a	25.6b
2.3 tons/ha CD						
0-0-0	31.7d	32.3b	27.1de	8.7ab	2.6a	13.6de
79-47-47	35.9c	41.2a	45.3c	2.7b	2.4a	22.7c
112-47-47	38.4a	39.3a	59.0a	3.3b	1.3a	29.5a
145-47-47	37.9ab	39.3a	57.0a	4.5b	1.4a	28.5a
140-140-140	38.3a	41.0a	57.4a	2.7b	1.9a	28.7a
Wet season planting						
0 CD						
0-0-0	24.4a	15.0d	6.8f	18.6a	7.3a	3.4f
79-47-47	26.1a	16.6d	12.3e	15.2a	7.6a	6.2e
112-47-47	25.9a	22.9bc	18.3bc	10.0a	4.4a	9.2bc
145-47-47	28.5a	24.5ab	18.8abc	10.6a	6.4a	9.4abc
140-140-140	27.6a	22.3b	15.6cd	15.3a	8.3a	7.8cd
2.3 tons/ha CD						
0-0-0	23.8a	16.1d	8.9f	15.0a	5.0a	4.5f
79-47-47	27.7a	18.6cd	13.0de	14.1a	6.2a	6.5de
112-47-47	25.4a	26.7ab	21.4a	10.2a	5.7a	10.7a
145-47-47	29.0a	25.7ab	19.3ab	8.4a	5.9a	9.7ab
140-140-140	25.3a	28.3a	19.8ab	9.3a	5.8a	9.9ab

Mean separation within columns per planting season by LSD, 5%.

studies have also demonstrated the beneficial effect of combined application of organic and inorganic fertilizers, particularly with high N, in increasing cabbage yields [7,10,11, 21,22,23].

3.5 Head quality

Polar and equatorial diameters of cabbages in the dry season crop were highest (18.5 cm and 17.2 cm, respectively) with the combined application of CD and 112-47-47 (Table 5). This fertilizer treatment also reduced shape index (ratio of polar and equatorial diameter) to 1.08 indicating that the heads were flatter than that of the other treatments. Increasing the NPK rates to 145-47-47 and 140-140-140 did not correspondingly increase the polar and equatorial diameters and did not reduce shape index. Average head weight and head volume were similarly highest with CD + 112-47-47, amounting to about 1,501 g and 1840 ml, respectively, and their ratio of 0.82 was among the lowest (Table 5). A lower ratio of head weight and head volume indicates lower weight to displace equivalent volume of water (1 ml = 1 g), thus heads with lower ratio were more solid or compact and sank in water when immersed. The heads in the wet season were smaller than that in the dry season. Polar and equatorial diameters were comparable among NPK treatments but significantly higher than that without NPK (0-0-0) regardless of CD level (Table 5). Average polar diameter ranged from 13.8-14.7 cm while equatorial diameter ranged from 11-12.6 cm among NPK treatments, higher than that without NPK (9.2-9.4 cm and 6.5-7.7 cm, respectively). Lower shape index hence flatter heads were produced in treatments receiving CD with or without NPK. Unfertilized treatment (0-0-0 without CD) had the highest shape index. Highest head weight (801 g) and volume (982 ml) were produced with combined CD and 112-47-47 application and the resulting ratio of 0.82 was among the lowest (Table 5). The results indicate that the application of the optimum rate of fertilizer application (CD + 112-47-47) resulted in bigger, flatter and more compact heads compared to the other treatments. Flatter and more compact heads are more resistant to mechanical damage during harvesting and postharvest handling. Compact and spherical heads are also desired by most markets [24,25]. Earlier findings revealed that organic and inorganic fertilizer application increased cabbage head diameters and yields [11,22,26].

3.6 Shelf life

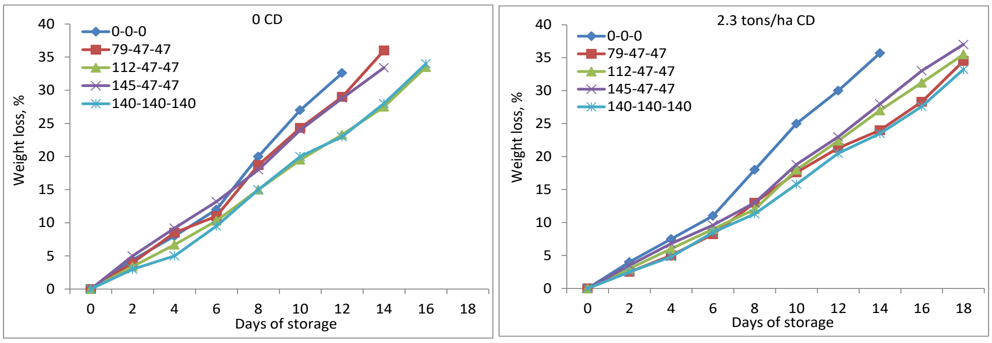
Weight loss of cabbage head increased continuously with advancing period of storage irrespective of fertilizer treatment and planting season (Figure 1). Combined CD and NPK application resulted in lower rate of increase in weight loss relative to that with CD alone in the dry season. Among NPK levels applied, no clear treatment effect was noted. Without CD, the increase in weight loss was relatively lower with 112-47-47 and 140-140-140 compared to the other treatments. This was also obtained in the wet season planting. With combined CD and NPK application, treatment differences did not widely vary. Trimming loss due to removal of wilted outer leaves and rotten part of each head increased with storage and was affected by fertilizer treatment in the dry season but not in the wet season (Figure 2). Dry-season crop had relatively lower trimming loss particularly at the later part of storage in response to 112-47-47 and 140-140-140 with or without CD. Trimming loss in the wet season had no

Table 5: Shape and compactness of cabbage in response to fertilizer treatment during dry and wet season planting.

Treatments	Head size/shape			Head solidity (compactness)		
	Polar diameter (PD) (cm)	Equatorial diameter (ED) (cm)	PD:ED ratio (shape index)	Weight (W) (g)	Volume (V) (ml)	W:V (solidity index)
Dry season planting						
0 chicken dung (CD)						
0-0-0	14.8d	11.9f	1.24a	818e	855g	0.96a
79-47-47	15.7d	13.4ef	1.17bc	902e	1,003f	0.90ab
112-47-47	17.3bc	15.2cd	1.14c	1,101d	1,322e	0.83bc
145-47-47	17.7ab	15.8abcd	1.12cd	1,301bc	1,526cd	0.85bc
140-140-140	16.9bc	15.6bcd	1.08d	1,249cd	1,430de	0.87abc
2.3 tons/ha CD						
0-0-0	15.3d	12.5f	1.22ab	839e	915g	0.92ab
79-47-47	16.6c	14.6de	1.14c	1,100d	1,387e	0.79c
112-47-47	18.5a	17.2a	1.08d	1,501a	1840a	0.82bc
145-47-47	17.9ab	16.8ab	1.07d	1,450a	1655bc	0.88abc
140-140-140	17.5abc	16.4abc	1.07d	1,400ab	1647bc	0.85bc
Wet season planting						
0 CD						
0-0-0	9.4b	6.5b	1.45a	453d	439g	1.03a
79-47-47	14.1a	11.0a	1.28b	741ab	801e	0.93ab
112-47-47	14.5a	12.2a	1.19bc	799a	885cd	0.90b
145-47-47	14.3a	11.6a	1.23bc	767ab	919b	0.83c
140-140-140	13.8a	12.0a	1.15bc	700b	836e	0.84c
2.3 tons/ha CD						
0-0-0	9.2b	7.7b	1.19b	553c	620f	0.89bc
79-47-47	13.8a	12.5a	1.10c	699b	805e	0.87bc
112-47-47	14.7a	12.6a	1.17bc	801a	982a	0.82c
145-47-47	14.2a	11.5a	1.23bc	751ab	905bc	0.83c
140-140-140	14.0a	12.1a	1.16bc	700b	866d	0.81c

Mean separation within columns per planting season by LSD, 5%.

Dry season cropping



Wet season cropping

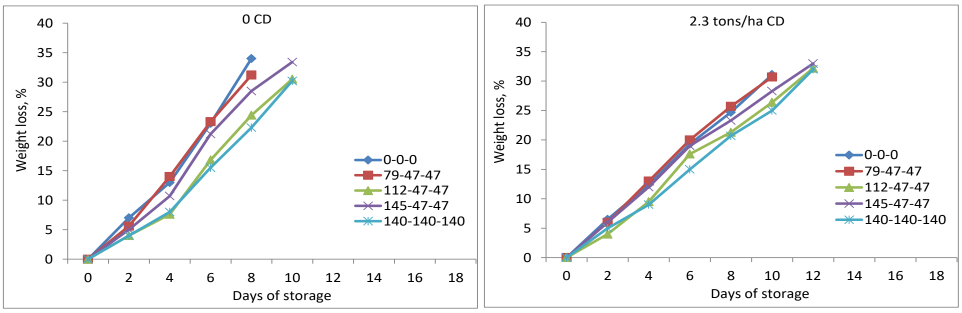
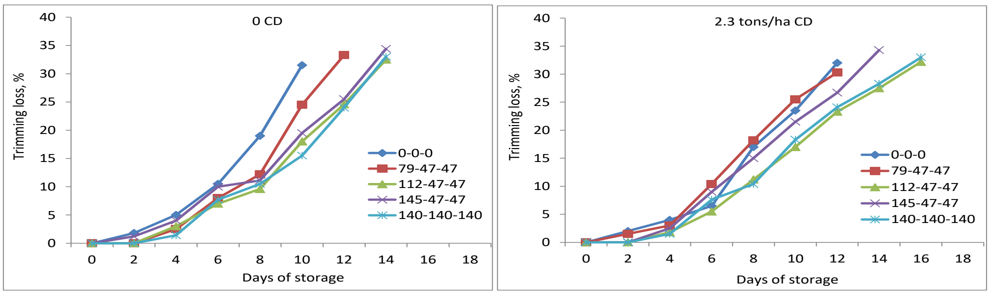


Figure 1: Weight loss (%) during ambient storage of cabbage in response to fertilizer treatment during dry and wet season planting.

Dry season cropping



Wet season cropping

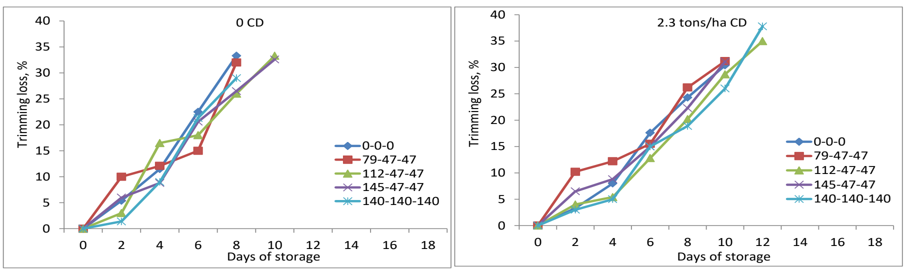


Figure 2: Trimming loss (%) during ambient storage of cabbage in response to fertilizer treatment during dry and wet season planting.

distinct treatment effect and was generally higher due to more rot incidence than that in the dry season. Similar to trimming loss, shelf life was significantly affected by fertilizer application only in the dry season (Table 6). Shelf life was longest (14 days) when CD was combined with 112-47-47 or 140-140-140. It decreased in the other treatments. Shortest shelf life was obtained in treatment without fertilizer (9 days) and with CD alone (10.5 days). In the wet season, treatment differences in shelf life were not significant. Shelf life ranged from 7-9 days, shorter than that in the dry season. The results show that fertilizer application could affect postharvest life of cabbage. The application of the yield-based optimum fertilizer application (CD + 112-47-47) increased shelf life of dry-season crop due to reduced weight loss and trimming loss. This is in agreement with the findings of an earlier study [10]. For wet season crop, fertilizer application had no significant effect on shelf life due to high decay incidence resulting in high trimming loss in all treatments. Wet season growing usually favors decay development due to the high moisture content and free water in the head which promote microbial growth.

Table 6: Shelf life of cabbage in response to fertilizer treatment during dry and wet season planting.

Treatments	Shelf life, days	
	Dry season	Wet season
0 chicken dung (CD)		
0-0-0	9.0c	7.0a
79-47-47	11.0cde	7.0a
112-47-47	13.0ab	8.5a
145-47-47	11.5cd	7.5a
140-140-140	13.0ab	7.8a
2.3 tons/ha CD		
0-0-0	10.5de	8.5a
79-47-47	13.0ab	7.0a
112-47-47	14.0a	8.5a
145-47-47	12.0bc	8.5a
140-140-140	14.0a	9.0a

Mean separation within columns by LSD, 5%.

3.7 Cost and return of optimum fertilization

The optimum rate of fertilizer application of 2.3 tons CD/ha plus 112-47-47 (336 kg/ha 14-14-14 + 141 kg/ha urea or 46-0-0) remarkably increased cabbage yield to 29.5 tons/ha in the dry season and 10.7 tons/ha in the wet season from 12.4 and 3.4 tons/ha, respectively, without fertilizer application (Table 4). The economic return of applying this optimum fertilization rate can be estimated by taking the total cost of production before fertilizer of about Philippine Peso (PHP) 120,606 per hectare (USD 2,412/ha) [27], the cost of fertilizer (added cost of the technology) and the three indicators of profitability - gross return, net return and net profit-cost ratio. Gross return is the gross value of production calculated by multiplying the marketable yield by the farmgate or producer price. Farmgate price varied with planting season and is usually lower during the dry season at about PHP 25/kg (USD 0.5/kg) due to higher market supply than during the wet season at PHP 40/kg (USD 0.8/kg). Net return or net profit is derived by subtracting total costs from the gross return. Net profit-cost ratio is the rate of return to farmers or the amount earned for every PHP spent in production. It is also referred to as benefit-cost ratio or return on investment (ROI). Table 7 shows the costs and returns of one-hectare cabbage production comparing the optimum fertilizer rate with no fertilizer applied and with the same NPK rate without CD. Using the optimum rate of fertilizer application, net return per cropping amounted to PHP 601,117 in the dry season and PHP 291,617 in the wet season with a net profit-cost ratio of 4.41 and 2.14, respectively, much higher than that with NPK alone and without fertilizer. The net profit realized using the optimum fertilization rate is more than 10-20 times higher than the net profit from the production of rice, the country's staple crop, which was estimated at PHP 22,000 per hectare [28]. Both technical and economic aspect of a technology are essential drivers of technology adoption which can be further facilitated by the involvement of farmers in technology development.

Table 7: Cost and return of one-hectare cabbage production with and without optimum rate of fertilizer application during the dry and wet season planting.

Particulars	Production cost, PHP			Yield (kg/ha)	Gross return (PHP; 25-40/kg)	Net return (PHP)	Net profit-cost ratio
	-Fertilizer	+Fertilizer	Total cost				
Dry season planting							
Optimum (2.3 tons/ha CD + 112-47-47 NPK)	120,606	15,777	136,383	29,500	737,500	601,117	4.41
NPK only (112-47-47)	120,606	11,637	132,243	22,300	557,500	425,257	3.22
No fertilizer	120,606	0	120,606	12,400	310,000	189,394	1.57
Wet season planting							
Optimum (2.3 tons/ha CD + 112-47-47 NPK)	120,606	15,777	136,383	10,700	428,000	291,617	2.14
NPK only (112-47-47)	120,606	11,637	132,243	9,200	368,000	235,757	1.78
No fertilizer	120,606	0	120,606	3,400	136,000	15,394	0.13

CD 2.3 tons/ha = 2,300 kg = 46 bags (1 bag=50 kg) x PHP 90/bag = PHP 4,140

NPK 112-47-47 = 336 kg 14-14-14/ha = 6.72 bags (1 bag=50 kg) x PHP 1,100/bag = PHP 7,392 +

141.3 kg 46-0-0 (urea)/ha = 2.83 bags x PHP 1,500/bag = PHP 4,245

4. Conclusion

Cabbage responded very positively to organic-inorganic fertilizer application, with optimum rate of 2.3 tons CD/ha plus 112-47-47, increasing yields to 29.5 and 10.7 tons/ha in the dry and wet season, respectively, or more than 2-3 times higher than the yield of unfertilized plants (12.4 and 3.4 tons/ha, respectively) and generating very high net return and net profit-cost ratio. In addition, the heads produced were flatter and more compact and had longer postharvest life due to lower weight loss and trimming loss, particularly for dry-season crop, as compared to other fertilizer treatments. The participatory approach pursued in this research was able to equip farmers with first-hand knowledge and skills on how to adjust and improve their fertilization practice in order to increase quality yields and farm profits. Subsequent activities could measure the impact of this intervention and use the findings in future scaling and expansion initiatives.

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