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Improving Growth and Production of Cabbage (*Brassica oleraceae* L.) with Compound Fertilizer Application

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Abstract

Natural soils at times do not supply sufficient amount of nutrients for the crops including cabbage, an important vegetable crop in the tropics. Therefore it is necessary to add fertilizer to supplement the soil nutrients to optimize crop growth and production. A study was conducted to examine seven different rates of inorganic fertilizers Cap Daun at 0.5, 0.75, 1, 1.25 and 1.5 of the recommended rate with the no fertilizer as the control. The results showed that inorganic fertilizer treatment generally improved the growth and yield of cabbage compared to the control. The number of leaf, yield per plant, yield per plot, and yield per ha of cabbage treated with inorganic fertilizers was significantly higher than the control treatment. The recommended rate for cabbage plants is 0.5 recommendation rate, which means applying 136 $kg.ha^{-1}$ of inorganic fertilizer and urea fertilizer of 64 $kg.ha^{-1}$ and SP-36 27 $kg.ha^{-1}$ applied twice, 50% at 1 WAP and the rest at four WAP to get the best results

Keywords: inorganic fertilizer, recommendation rate, relative agronomic effectivity value

Introduction

Cabbage is a vegetable of great importance in Indonesia and world wide due to its adaptability to a wide range of climatic conditions and soil, and its nutritional values.

More than 70 cabbage varieties have been registered at the Directorate of Horticultural Seeds, Ministry of Agriculture of the Republic of Indonesia (Ditbenih, 2017), and most varieties are hybrids. In general hybrid varieties require high nutrients for their growth and to have a good photosynthetic efficiency, resulting in high productivity.

The availability of nutrients that can be absorbed by cabbage plants is one of the determinants of the productivity of this crop. Generally, plants require macro and micro nutrients to support growth and optimum production. The macro nutrients are needed in large quantities by the plant, and are directly involved in the metabolic process and their existence cannot be replaced by other elements. The macro nutrient element consists of three non-mineral elements carbon (C), hydrogen (H) and oxygen (O) with six mineral elements such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S). In addition there are micro nutrients that are needed in less amounts including Ferrum (Fe), Manganese (Mn), Molibdenum (Mo), Boron (B), Cuprum (Cu) and Zinc (Zn).

Inorganic fertilizers are synthetic fertilizers produced by industry (Utomo, et al., 2016). Balanced fertilization is one of the keys to the successful increase of cabbage production.

Cabbage (*Brassica oleracea* L. cultivar '"White Head") in the tropics is generally grown at altitudes > 800 m above sea level (Van der Vossen, 1994). In Indonesia, vegetables are usually grown on the highlands. Intensive cultivation depletes nutrient concentration in the soil due to crop removal after harvesting and soil erosion. In addition, leaching may also occur due to intensive culture; nutrients are present in the soil but they are not readily available to the plants as they had leached down the soil column. Cabbage is a heavy feeder and requires supplemental fertilisation in the form of manure or compost, nitrogen, phosphorus and potassium (DAIS, undated). Cabbage also needs micronutrients for proper growth and development, particularly Calcium and Molibdenum (DAIS, undated). While fertilizers serve an important purpose, growers must be careful to use the right amount, at the right time, to avoid potential negative effects to the environment. Application of fertilizer containing macro and micro nutrients at the optimum rates can potentially restore the balance of nutrients in the soil. The aim of this experiment is to examine the effects of inorganic fertilizer application at different rates to the growth and production of cabbage grown in the highland tropics in West Java, Indonesia.

Materials and Methods

The experiment was conducted at the Bogor Agricultural University (IPB) experimental station in Pasir Sarongge, Cianjur, West Java, Indonesia, in 2017. The treatment consists of five rates of inorganic fertilizer Cap Daun, standard fertilizer practice, and without fertilizer as the control (Table 1). The standard fertilizer practice was 200 kg.ha^{-1} of Urea, 100 kg.ha^{-1} of SP-36, and 100 kg.ha^{-1} of KCl (Table 1).The experiment was arranged in a randomized complete block design with four replication totalling 28 experimental units. Each experimental unit was a plot of land with an area of 25 m^2. Based on the analysis of Sucofindo Laboratory, Surabaya dated March 23th, 2017, the actual content and composition of inorganic fertilizers are presented in Table 2.

The land for the study was prepared by double-tillage, followed by preparing raised beds of 1m x 5 m, with 50 cm distance between beds. Each experimental unit consists of five beds or 25 m^2.

Seeds were sown and 21-day-old seedlings were transplanted to the soil, one seedling per planting hole, with a spacing of 60 cm between rows and 40 cm within row. Inorganic fertilizers were applied twice, 50% at one week after planting (WAP) and the rest at four WAP. Pest and disease control was conducted when required throughout the experimental period.

The parameters measured include plant height, number of leaves, yield per plant, yield per plot, and yield per ha, which was converted from yield per plot. Scoring was conducted on five sample plants which were randomly selected from the experimental plots. Data were analysed using general linear model (GLM) ANOVA (F-Test). Mean separation was performed by Duncan Multiple Range Test (DMRT) at α = 5% to identify means different to the control (without fertilizer).

Result and Discussion

Fertilized cabbage crops in general had better growth as compared to the control treatment (without

Table 1. Fertilizer treatments and rates

Treatment	Inorganic fertilizer (kg.ha^{-1})	Urea (kg.ha^{-1})	SP-36 (kg.ha^{-1})	KCl (kg.ha^{-1})
Control (no fertilizer)	-	-	-	-
Standard fertilizer practice	-	200	100	100
Inorganic fertilizer				
0.5 recommendation rate	136	64	27	-
0.75 recommendation rate	205	95	41	-
1.0 recommendation rate	273	127	55	-
1.25 recommendation rate	341	159	68	-
1.5 recommendation rate	409	191	82	-

Table 2. Nutrient content of inorganic fertilizers Cap Daun

Parameter	Unit	Content
Nitrogen (N) (Dry matter)	%	12.24
Total P_2O_5 (Dry matter)	%	6.04
K_2O (Dry basic)	%	22.32
Moisture	%	1.17
Magnesium as Magnesium oxide (MgO)	%	3.19
Boron (B) as B_2O_3	%	0.01
Manganese (Mn) as $MnSO_4$	%	0.10
Iron (Fe) as $FeSO_4$	%	2.11
Zinc (Zn) as $ZnSO_4$	%	0.01
Copper (Cu) as $CuiSO_4$	ppm	13.9

fertilizer). Cabbage treated with 1.0 recommended rate were taller (15.1 cm) then the control (11.1 cm), but it was not significantly different from the 0.5 (14.3 cm) and 0.75 (14.9 cm) fertilizer rates. Plants treated with inorganic fertilizer were significantly taller compared to the control plants at four to five weeks after planting (WAP). The tallest plants at six WAP were those treated with the 0.75 rate (33.2 cm), even though it was not significantly different from 1.0, 1.25 and 1.5 rate, i.e. 32.0, 31.4 and 32.6 cm, respectively (Table 3). Increased availability of dissolved nutrients in soil solution increases the nutrient uptake potential by plant roots. Uninterrupted/continuous availability of nutrients will ensure optimal plant growth and produce maximum yield.

The number of leaves at five WAP was three to four leaves and increased to 12 to 13 leaves at six WAP (Table 4). The plants treated with 0.75 recommendation rate of inorganic fertilizers consistently had more leaves per plant than control plants. The other treatments produced the number of leaves more than control at three to five WAP, but they had similar number of leaves at six WAP.

Cabbage yields were measured based on yield per plant, yield per plot and yield per ha. Plants treated with 0.5 to1.5 of the fertilizer recommendation rate produced a higher yield per plot (771.5g) and the expected yield per hectare was higher relative to the control (676.5g). The 1.0 recommended fertilizer rate produced the largest yield per plant, but it was not significantly different from the treatment of 0.75, 1.25 and 1.5 fertilizer rates.

Application of inorganic fertilizers increased yields as compared to control. The range of relative agronomic effectiveness values are 133 to 198% (Table 6). The plants treated with 0.5 recommendation rate produced the highest relative agronomic effectiveness compared to other treatments (Table 6).

The relative agronomic effectiveness is a measure of the effectiveness of a fertilizer application. Fertilizer application is considered to be agronomically effective if it has a relative agronomic effectiveness value of >100, which indicated an increase in yield relative to

Table 3. Effect of inorganic fertilizer on cabbage plant height at three to six weeks after planting

Treatment	Plant height (cm)			
	3 WAP	4 WAP	5 WAP	6 WAP
Control	11.1d	18.3c	23.9b	27.7d
Standard fertilizer	13.9c	21.6b	27.1a	29.4cd
Inorganic fertilizer				
0.5 recommendation rate	14.3abc	23.4a	27.1a	30.2bcd
0.75 recommendation rate	14.9ab	24.0a	27.7a	33.2a
1.0 recommendation rate	15.1a	23.6a	27.3a	32.0abc
1.25 recommendation rate	14.1bc	23.2a	26.3a	31.4abc
1.5 recommendation rate	13.7c	23.8a	26.8a	32.6ab

Note: Values followed by different letters in the same column are significantly different according to Duncan's Multiple Range Test (DMRT) at α = 5%.
WAP: week after planting

Table 4. Effect of inorganic fertilizer on cabbage number of leaf at three to six weeks after planting

Treatment	Number of leaf per plant			
	3 WAP	4 WAP	5 WAP	6 WAP
Control	3.7c	4.7c	7.3b	12.1b
Standard fertilizer	3.9c	5.1bc	8.4a	13.1ab
Inorganic fertilizer				
0.5 recommendation rate	4.0bc	5.1bc	8.3a	13.7ab
0.75 recommendation rate	4.3ab	5.7ab	9.0a	13.9a
1.0 recommendation rate	4.3ab	5.9a	8.8a	13.3ab
1.25 recommendation rate	4.5a	6.0a	8.9a	13.0ab
1.5 recommendation rate	4.5a	5.6ab	8.5a	13.3ab

Notes: Values followed by different letters in the same column are significantly different according to Duncan's Multiple Range Test (DMRT) at α = 5%. WAP: week after planting

Tabel 5. Effect of inorganic fertilizer on cabbage yield

Treatment	Yield per plant (g)	Yield per plot (kg)	Yield per ha (kg/ha)
Control	676.5d	32.3d	12,933d
Standard fertilizer	726.5cd	36.0c	14,400c
Inorganic fertilizer			
0.5 recommendation rate	771.5bc	43.0a	17,200a
0.75 recommendation rate	850.0ab	39.0b	15,600b
1.0 recommendation rate	923.5a	38.3b	15,333b
1.25 recommendation rate	906.5a	41.3a	16,533a
1.5 recommendation rate	870.0a	41.7a	16,667a

Notes: Values followed by different letters in the same column are significantly different according to Duncan's multiple range test (DMRT) at α = 5%

Table 6. Relative agronomic effectiveness values of inorganic fertilizer treatment

Treatment	Relative agronomic effectiveness value (%)
Control	-
Standard fertilizer	-
Inorganic fertilizer	
0.5 recommendation rate	198
0.75 recommendation rate	142
1.0 recommendation rate	133
1.25 recommendation rate	175
1.5 recommendation rate	180

the control.

The crop growth and production with standard fertilizer or inorganic fertilizer treatment in general were better than control. The estimation of yield per hectare and relative agronomic effectivity value were highest from the 0.5 recommendation rate treatment of inorganic fertilizer.

Cultivars that have high production potentials such as hybrids generally need more nutrients for their biomass production. Fertilization applied to the root areas will provide additional nutrients that can potentially be absorbed by the plants. Horticultural growers, especially those growing annual vegetables, have applied fertilizers to their crops, but not necessarily in accordance with the rates and type of nutrients required by the plants.

The fertilizer tested in this experiment was a compound inorganic fertilizer containing predominantly elements of N, P and K (Table 2). Soepardi (1983) reported that Nitrogen (N), Phosphor (P), Potassium (K), and Magnesium (Mg) are macro elements required by plants in large quantities and their availability could not be replaced with other elements. Iron (Fe), Manganese (Mn), Molybdenum (Mo), Boron (B), Copper (Cu), Zinc (Zn) and Chloride (Cl) are micro nutrients that are required for growth and crop production in a fewer amount, but essential for crop growth.

Compound fertilizers are mixed fertilizers that generally contains more than one plant nutrients, both macro and micro nutrients, especially N, P, and K (Rosmarkam and Yuwono, 2002). The advantages of NPK fertilizer is that it contains several macro nutrients, so it is more efficient than simple fertilizer which only contains one nutrient element (Hardjowigeno, 2003).

Nutrients supplied by inorganic fertilizers will likely result in better plant growth and production, and these elements are used by plants as a source of materials for photosynthesis. Nitrogen (N) is absorbed by plants in the form of nitrate (NO_3) and ammonium (NH^{4+}). The greatest need of plants for N elements was taken in the form of NO^{3-}. Root absorption of these ions depends on the metabolic process, whereas the rate of absorption depends on the root surface (Schenk, 1996). In addition to the formation of amino acids, proteins and nitrogen, N also plays significant roles in the formation of nucleic acids, nucleotides, amides and amines. Furthermore, N is important for chlorophyll formation and cell wall developments (Bennett, 1996). The availability of nitrogen in the correct amount increases growth, vegetative plant tissue formation, and function as a regulator for the uptake of potassium, phosphorus and other nutrients (Tisdale et al., 1995).

Phosphorus (P) was absorbed by plants in one of two forms, monovalent phosphate ions (H_2PO^{4-}) and divalent phosphate ions (HPO_4^{2-}) (Tan, 1996). The ion form is absorbed depending on the soil pH conditions; H_2PO^{4-} dominates on soils with a pH less than 7.2, whereas HPO_4^{2-} dominates at pH of more than 7.2 (Bennett, 1996). P acts as an ATP molecule-forming element which is the rich energy molecule needed in metabolic processes such as protein synthesis, so P nutrient deficiency can cause stunted growth (Vanlauwe et al., 2001).

Potassium (K) has many different roles in plants; potassium regulates the opening and closing of stomata during photosynthesis, and therefore regulates CO2 uptake. Potassium triggers activation of enzymes and is essential for production of Adenosine Triphosphate (ATP). In addition K may increase resistance to disease, cell enlargement, opening and closing of stomata (Dietrich et al., 2001). With sufficient amounts of potassium, the cell walls will be thicker and more stable thus prevents the penetration of pathogens to cause disease (Wang et al., 2013).The shelf life of fruits and vegetables were longer when the produce contains optimum levels of potassium (Marschner, 1995). Lægreid et al. (1999) reported that the used of potassium by plants depends not only on the availability of potassium in the soil, but also on other nutrients. For instance, excessive amounts of NH^{4+} or Mg^{2+} can reduce the absorption of potassium by plants.

Conclusion

This study demonstrated that inorganic fertilizer treatment generally improved the growth and yield of cabbage as compared to the control/without fertilizer. Inorganic fertilizer application resulted in significant increases in the number of leaves and yield per plant, and yield per plot which ultimately increased cabbage yield per hectare. The recommended rate for cabbage crop from this study is 136 $kg.ha^{-1}$ of inorganic fertilizer applied as Urea at 64 $kg.ha^{-1}$ and SP-36 27 $kg.ha^{-1}$ which were applied twice, 50% at one WAP and the rest at four WAP.

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