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Branch prunning and chicken manure application to improve growth and yield of brocolli in lowland area

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ABSTRACT

The objective of this study was to determine the effect of branch pruning and chicken manure application on improving the growth and yield of broccoli in the lowland. The research was conducted in the dry land of Kutasari Village, Baturraden District, Banyumas Regency at 138 m above sea level. The research was arranged in a Factorial Randomized Complete Block Design (RCBD) with three replications consisting of two factors of chicken manure application (without chicken manure and with chicken manure at doses of 10 ton.ha^{-1} and 20 ton.ha^{-1}) and branch pruning (without and with branch pruning of 25% and 50%). The pruning was performed when the plants initiated flowers. The observed data were analyzed with the F test and followed with Duncan's Multiple Range Test (DMRT) at α = 5%. The branch pruning resulted in a significant effect on the number of leaves, leaf width, head weight, and head diameter. Meanwhile, the chicken manure application showed a significant effect on all of the observed variables. There was an interaction effect of branch pruning and chicken manure application on the leaf width, head weight, and head diameter. The best result was obtained by the combined treatment of 50% branch pruning and 20 ton.ha^{-1} chicken manure, resulting in the head weight of 1048.33 g.plant^{-1} and leaf width of 1705.41 cm^2.

INTRODUCTION

Broccoli is a vegetable crop with a high economic value, containing essential minerals of vitamins of A, B complex, and E, as well as calcium, magnesium, zinc, and iron as reported by Gad and El-Moez (2011), which could fulfill the nutritional need as well as high anti-oxidant and beta-carotene, making its role even higher in preventing cancer within the human body (Wasonowati, 2009). Indonesia's broccoli production is around 183,816 ton.ha^{-1} (Badan Pusat Statistik, 2019), hence, it cannot meet the local market and international market demands that keep on increasing 20% to 30% annually. Besides, Indonesia's broccoli contains a lot of chemical residues with limited planting areas and expensive production costs for its fertilization. Most varieties of this plant can only be produced well at highland. Therefore, it is necessary to find technology to develop this plant in lowland area using organic fertilizer to decrease the use of synthetic fertilizers as well as to support sustainable broccoli production. For this purpose, it is also important to improve the broccoli quality by reducing the use of synthetic chemical subtances (Budiastuti et al., 2009). Ouda and Mahadeen (2008) reported that recently, consumers are demanding higher quality and safer food, and they are highly interested in organic products.

Broccoli cultivation in lowland area has agro-climatic obstacles because broccoli flowering requires a relatively low temperature (vernalization) at the end of its vegetative phase (Booij and Struik,

1990; Grevsen, 1998). If this low temperature is not met, then broccoli will continue its vegetative phase. Broccoli heads are also reportedly to experience a decrease in when the temperature in its growth environment is less optimal during the flowering process (Heather et al., 1992; Grevsen, 1998; Björkman and Pearson, 1998). Another problem of broccoli cultivation in tropical lowland is the high number of branches. Jaya et al. (2006) reported that the number of branches of broccoli planted in the lowland of Lombok Island (±125 m above sea level) could reach up to 12 branches. This high number of branches do not present any profit economically because they could decrease the main head size and increase the harvesting costs because they do not have different harvesting periods (Wien and Wurr, 1997).

The need for macronutrients becomes an important factor in broccoli cultivation for generating optimum production. Nitrogen element needs to be added to produce green leaves and big flower, yet the excessive use of urea will reduce the natural soil properties. One of the solutions could be applied to reduce the use of urea fertilizer is by using organic fertilizer. According to Simanungkalit et al. (2006), organic fertilizer consists of organic matters deriving from plants and or animal, which has undergone an engineering process and a change into solid or liquid. In addition to having macro-elements, organic fertilizers have microelements as their strength, which are not found in synthetic chemical fertilizers. Organic fertilizers are also eco-friendly, and they can easily be found in the land cultivation area. Chicken manure has greater N and P elements compared to cow or goat manure. It has N element three times greater than cow or goat manure because chicken only has one discharge hole, making its liquid and solid excretion mixed (Musnamar, 2004). Pinem et al. (2015) mentioned that the addition of chicken manure to plants has some effects on increasing plant growth performance. Thus, this study was conducted to determine the effects of branch pruning and chicken manure application on improving plant growth and yield of broccoli in lowland area.

MATERIALS AND METHODS

The study was carried out in Kutasari Village, Baturraden District, Banyumas Regency, from April to July 2015. The site is 138 m above sea level with Inceptisol soil type. The materials used consisted of broccoli seeds, organic fertilizer in the form of chicken manure, synthetic chemical fertilizer consisting of Urea, SP36, and KCl at a dose of 50% of recommendation doses and pesticides. Meanwhile, the tools used were hoe, scythe, electric scale, ruler, measuring tools (thermometer, lux meter, and measuring cup) and soil analysis tools.

This research was arranged in a Factorial Randomized Complete Block Design (RCBD) consisted of two factors, which were chicken manure doses (A0: 0 ton.ha^{-1}, A1: 10 ton.ha^{-1} and A2: 20 ton.ha^{-1}) and branch pruning (P0: without pruning, P1: 25% pruning and P2: 50%), with three replications, resulting in nine combined treatments and 27 plots with a size of 3 m $\times$ 2 m each and a plant spacing of 60 cm $\times$ 50 cm. There were 20 plants per plot.

The broccoli seeds were germinated for 15 days and then transplanted. Chicken manure application was carried out a week before transplanting as basic fertilizer. Urea, SP36, and KCl fertilizers were applied at a dose of 50% of recommendation dose at 10 days after planting. Branch pruning was done when the plant started flower initiation by cutting the base of the branch that was attached to the stem using a knife sterilized with alcohol.

The variables for observation included growth and yield components. The growth variables observed were plant height (cm), number of leaves, and leaf width before cut and leaf width after harvest (cm^2), while the yields components observed were canopy diameter (cm), head weight (g), and head diameter (cm). The observed data were analyzed with the F test and followed with Duncan's Multiple Range Test (DMRT) at α=5% (Gomez and Gomez, 1983).

RESULTS AND DISCUSSION

General condition of the research site

Based on the climatology data in the research site obtained from the nearest meteorology station during the experiment, the lowest temperature was 17.4°C and the highest was 34.3°C with the average daily temperature of 25.3°C. The lowest temperature occurred in July 2015 during the flower development phase. As reported earlier, broccoli requires relatively low temperatures to initiate flowering (Grevsen and Olesen, 1999) and to produce a good quality flower (Heather et al., 1992). The soil analysis conducted

in the Laboratory of Soil Resources, Department of Agrotechnology, Universits Jenderal Soedirman, indicated that the soil pH in the experiment site was 6.33, which was slightly acidic at a medium-fertility level, as can be seen from the elements contained in it. The nitrogen content was 188.916 ppm (medium), available phosphor content was 8.17 (low), potassium content was 0.625 % (medium), and carbon content was 3.616 (medium).

The statistical analysis results indicated that there were varied responses in the observed variables. The matrix of Duncan test results is shown in Table 1.

Effects of branch pruning on broccoli growth and yield

The analysis of variance indicated that branch pruning significantly affected the number of leaves, initial leaf width, canopy diameter, stem diameter, and head diameter. The effect of branch pruning was not significant on the plant height. The data of the observed variables are shown in Table 2.

Branch pruning significantly affected the number of leaves. The treatment of 50 % branch pruning (P2) produced 19.07 leaves, which was 8.43 % higher than that in the plants treated with 25 % branch pruning (P1) and without pruning (P0). The leaf width after pruning was significantly different between each treatment. This result was because branch pruning caused some leaves were also disposed, hence the higher the percentage of disposed branches the smaller the leaf width. Canopy diameter was also significantly between each treatment, with the best result being shown in P2 (75.67 cm). Similar result was also observed in the stem diameter with the best result being shown in P2 (3.35 cm). The treatment of P2 also resulted in the best values of yield component, including head diameter (24.56 cm) (Table 2).

Branch pruning treatment tended to decrease the plant's leaf width but increase the head diameter (Table 2). This result indicated that the light use efficiency was higher in those plants that have not so many leaves covering each other. The trimmed leaf surface did not overlap, thereby optimizing sunlight interception that will be used in the photosynthesis process (Niinemets et al., 2006), as what happened in he plants treated with 50 % branch pruning. Pasaribu et al. (2015) stated that leaves covering each other will be inhibit the light penetration and photosynthetic processes, causing lower assimilation rate.

The high rate of light interception resulted in the high photosynthetic process and photosynthate products allocated to the increasing dry plant biomass. This is because light is an important factor in plant metabolism (Lakitan, 1996). Earlier, Van den Boogaard et al. (2001) reported an increase in the relative growth rate of the cauliflower plant after cutting. The research conducted by Jaya (2009) also indicated that broccoli branch pruning could accelerate harvest period, increase head weight and head diameter. An increase of head weight of around 23.7 % occurred when the branch was cut 100 % compared to the plant whose branch was not cut. Results of another study showed that the cutting of two and three main branches in eggplant gave the

Table 1. Variance analysis (F test) on branch pruning and chicken manure application

Observed variable	P	A	P×A
Plant height (cm)	ns	ns	ns
Number of leaves	*	*	ns
Initial leaf width (cm^2)	*	*	ns
Pruning leaf width (cm^2)	*	*	*
Canopy diameter (cm)	*	*	ns
Stem diameter (cm)	*	*	ns
Head weight ($g.plant^{-1}$)	*	*	*
Head diameter (cm)	*	*	ns

Remarks: P=Pruning, A=Chicken manure application, P×A= Interaction of pruning and chicken manure; (*) = significantly different, (ns)= non-significant

Table 2. Effects of branch pruning on broccoli growth and yield

Treatment	PH (cm)	NL	ILW (cm^2)	CD (cm)	SD (cm)	HD (cm)
P0 (Without pruning)	45.11	16.29 c	1146.70 c	61.11 c	2.75 c	17.06 c
P1 (25% pruning)	49.01	17.59 b	1355.07 b	71.70 b	3.05 b	19.81 b
P2 (50% pruning)	47.89	19.08 a	1507.09 a	75.67 a	3.35 a	24.56 a
CV (%)	13.48	17.13 *	24.82 *	24.55 *	24.17 *	36.11 *

Remarks: Means in the same column followed by the same letters were not significantly different based on DMRT at α= 5%. PH: Plant Height, NL: Number of Leaves, ILW: Initial Leaf Width, PLW: after Pruning Leaf Width, CD: Canopy Diameter, SD: Stem diameter, HW: Head Weight, HD: Head Diameter

Table 3. Broccoli growth and yield as effect of chicken manure fertilization

Treatment	PH (cm)	NL	ILW (cm^2)	CD (cm)	SD (cm)	HD (cm)
A0 (Without chicken manure)	38.48	15.12 c	1164.88 c	63.70 c	2.79 b	18.10 c
A1 (10 ton.ha^{-1})	49.59	17.78 b	1317.13 b	70.19 b	3.09 a	19.89 b
A2 (20 ton.ha^{-1})	53.93	20.07 a	1526.85 a	74.59 a	3.27 a	23.44 a
CV (%)	13.48	17.13 *	24.82 *	24.55 *	24.17 *	36.11 *

Remark: Means in the same column followed by the same letters were not significantly different based on DMRT at α= 5%. PH: Plant Height, NL: Number of Leaf, ILW: Initial Leaf Width, PLW: after Pruning Leaf Width, CD: Canopy Diameter, SD: Stem diameter, HW: Head Weight, HD: Head Diameter

best result compared to without cutting. This was because too many leaves growing from the branches will act as sinks because they were covered by the leaves of the main stem, making it hard for the sunlight as the source in a photosynthetic process to be received optimally. According to Raden et al. (2009), the number of eggplants increased through controlling the number of the branch in the main stem by keeping the productive branch by which improving the allocation of the photosynthetic product. Reducing the branches could increase the intercepted light to the leaves, thereby improving the photosynthetic rate and directly increasing the weight and number of eggplants. The cutting of two and three main branches resulted in the higher weight of the eggplants (Maghfoer, 2014).

Effects of chicken manure application on broccoli growth and yield

Data analysis indicated that chicken manure had a significant effect on the number of leaves, initial leaf width, canopy diameter, stem diameter, and head diameter. The data of the observed variables were shown in Table 3.

The results indicated that chicken manure application could improve the growth of broccoli. The application of 20 ton.ha^{-1} chicken manure (A2) resulted in the highest number of leaves number (20.07). The similar results were also observed in leaf width before branch pruning, in which the highest values were resulted by the application of 20 ton.ha^{-1} chicken manure (A2), which were 1526.85 cm^2. Meanwhile, the highest canopy and stem diameter were found in the plants treated with 10 ton.ha^{-1} chicken manure (A1), which were 74.59 cm and 3.217 cm, consecutively. The application of 20 ton.ha^{-1} chicken manure (A2) was also found to improve the yield component, resulting in the highest head diameter (23.44 cm) (Table 3).

The organic fertilization in the form of chicken manure could improve soil's fertility by applying 20 ton.ha^{-1} chicken manure, producing the highest average in each observed variable than other treatments. This result was because the nutrient in chicken manure could be quickly absorbed by the plant, enhancing the growth rate. Nutrient contents

of chicken manure were water content of 57%, organic matter content of 19%, N content of 1.2%, P_2O_5 content of 1.1%, K_2O content of 0.6%, and C/N ratio of 7 (Laboratory of Soil Resources of Agriculture Faculty, Universitas Jenderal Soedirman). The ability of organic fertilizer to be absorbed by plants depends on its C/N ratio. The lower the C/N ratio, the quicker the fertilizer can be absorbed by the plants. When the C/N ratio is low, the mineralization process of N will be more dominant than N immobilization, enabling the organic matters to be the source of N for the plant. Besides, the use of organic fertilizer can also improve soil's biological quality, which could increase the microorganism activity and, thus could be expected to improve soil fertility (Mujiyati and Supriyadi, 2009).

An increased microorganism activity is an indicator of soil fertility that can improve soil structure (Dauda et al., 2008). Microorganisms are capable of turning hard soil into a more friable one, making the soil aeration better. As reported by Djazuli and Pitono's (2009), the application of chicken manure increased the weight of leaf, root, and entire plant of Purwoceng's (*Pimpinella pruatjan*) compared to the application of goat manure, cow manure, and compost.

Organic fertilizer has micronutrients content that are not contained in synthetic chemical fertilizers. Organic manure is also reported to be able to serve as alternative practice to mineral fertilizers (Naeem et al., 2006). According to Amannullah et al. (2010), chicken manure contains several macronutrients (N, P, and K) highly needed by plant and some micro-nutrients (mangan (Mn), calcium (Ca), and iron (Fe)) and several other nutrients that could enhance plant production. To dissolve the nutrients needed by plant, a sufficient amount of water is needed to be the nutrient solvent to enable its absorption by the plant. The research by Jigme's et al. (2015) indicated that the application of 200 g.polybag^{-1} chicken manure showed the best result in broccoli compared to other treatments. The MPHP^{+} of chicken manure treatment could increase the consumption weight by 159% to 165% higher than the treatment with no mulch in all types of fertilizers and increase the consumption weight by 144% to 206% higher than the straw mulch treatment in all types of fertilizers (Multazam, 2014).

The increase in available nutrients such as ammonium and nitrate as the effect of the chicken manure application resulted in the high total of tea yield (Gross et al., 2008). Thus, the application of chicken manure enhances soil aggregation, soil aeration, and water holding capacity. The favorable soil properties resulted in healthy plants with a large root system and vegetative growth by which gained the high yield and head diameter of broccoli plants. However, the highest yield was obtained by the application of inorganic treatment because of the high quantity of available nutrients.

Branch pruning significantly decreased the leaf width as the cutting percentage got higher. This phenomenon indicates that a high leaf width as a result of the many leaves growing on the broccoli

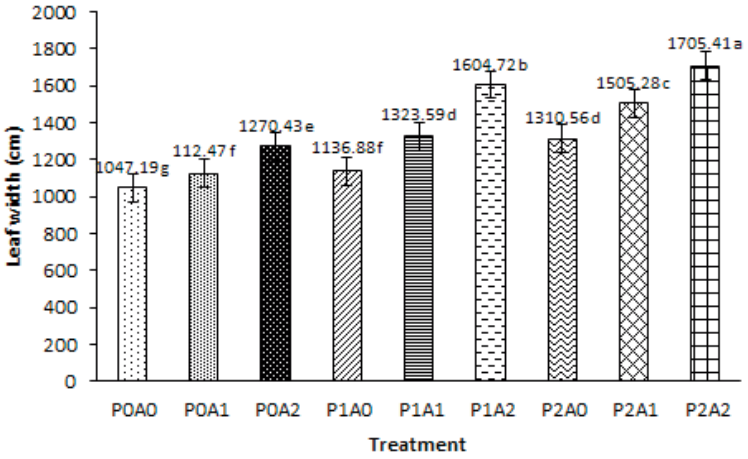

Figure 1. Effects of branch pruning and chicken manure application on the after pruning leaf width of broccoli; (P0)= without pruning; (P1)= 25% pruning; (P2)= 50% pruning; (A0)= without chicken manure; (A1)= 10 ton.ha^{-1} chicken manure; (A2)= 20 ton.ha^{-1} chicken manure.

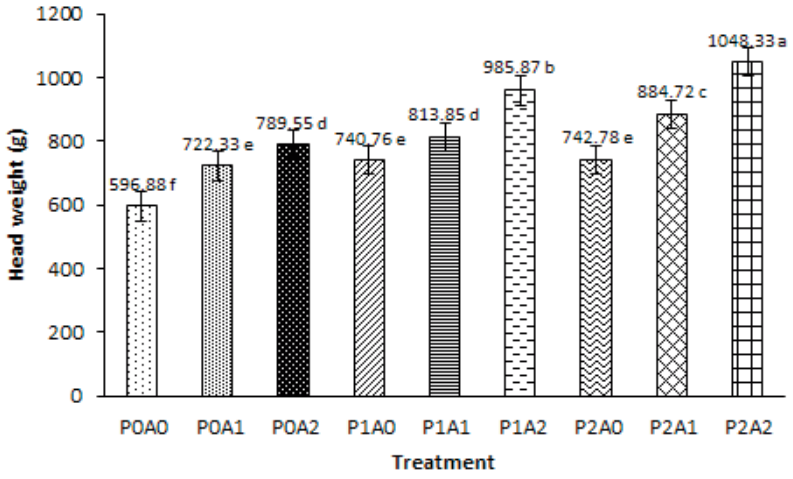

Figure 2. Effects of branch pruning and chicken manure application on head weight of broccoli; (P0)= without pruning; (P1)= 25% pruning; (P2)= 50% pruning; (A0)= without chicken manure; (A1)= 10 ton.ha^{-1} chicken manure; (A2)= 20 ton.ha^{-1} chicken manure.

branches is less effective in forming biomass. This happened because many leaves growing from the branches acts as sinks since they are covered by the leaves from the main stem and/or many leaves have not developed perfectly. To avoid the reduction of plant growth and yield, pruning is used to control the distribution of photosynthetic apparatus, as well as to enhance the capacity of source in developing leaves to support the growth of stems and roots (Iqbal et al., 2012). However, the optimal result depends on the plant growth and development, such as defoliation process, growth stages, and age of leaf tissues (Stagnari et al., 2018). The highest leaf width was generated in a combined treatment of 50% branch pruning and 20 ton.ha^{-1} chicken manure (P2A2), resulting in a leaf width of 1705.41 cm^2 (Figure 1). Similarly, the highest head weight was also produced in a combined treatment of 50% branch pruning and 20 ton.ha^{-1}. Chicken manure (P2A2), producing a head weight of 1048.33 g.plant^{-1} (Figure 2). Some similar results were observed by Van Den Boogaard et al. (2001) and Li et al. (2012), reporting that pruning reduce internal shading to increase light interception per unit leaf area and directly enhances photosynthetic rate.

The large area of leaves could result in higher photosynthetic rate to translocate photosynthate to sink and obtain high yield. The high head weight is also supported by the increase in the leaf and head diameter (Singh et al., 2018).

CONCLUSIONS

The treatment of 50% branch pruning could improve the growth and yield of broccoli in lowland area. The head weight of plants treated with 50% branch pruning increased by 26.90% compared to that of plants treated with 25% pruning and without pruning. The application of 20 ton.ha^{-1} chicken manure produced the highest head compared to the application of 20 ton.ha^{-1} chicken manure and without chicken manure. The combined treatment of 50 % branch pruning and 20 ton.ha^{-1} chicken manure produced the highest yield of broccoli of 1048.33 g.plant^{-1}.

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