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RESEARCH ARTICLE

Increasing Cauliflower Yields through Fertigation

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Abstract

Cauliflower is one the important vegetable crops in the tropics; the curd contains high fibres, potassium, carotene and vitamin C. However, the production and productivity of cauliflower in Indonesia has been low and cannot meet the demand, resulting in high importation of cauliflowers into Indonesia. Bogor Agricultural University has developed potential lowland cauliflower genotypes, BOB017 and BOB020, with higher productivity. In this study, we evaluated three fertigation methods on the growth, yield and economic returns of the two lowland cauliflower genotypes. The experiment was arranged in a split-plot design with four replications. The main plot contained two cauliflower genotypes, BOB017 and BOB020. The subplot was three fertilizer application methods: through drip irrigation, soil drench, and drilled. The results showed that BOB020 had an earlier harvest time (60 days) compared to BOB017 (71 days). The soil drench fertigation method showed the highest curd weight (351.64 g), curd diameter (14.65 cm) and yield (12.39 t.ha^{-1}) compared to the other two fertigation methods. The BOB017 genotype fertilized with soil drench method resulted in the highest B/C ratio (3.32). The study concluded that growing cauliflower using the soil drench method resulted in the optimum growth of cauliflower, high yield and net income.

Keywords: drip irrigation, fertigation, yield, economic return, lowland cauliflower

Introduction

Cauliflower (*Brassica oleracea* var. *Botrytis*) is an annual vegetable grown for their large, edible, and very young inflorescences. Cauliflower heads (curds) are mostly consumed as a cooked vegetable which contains high fiber, potassium, carotene, and vitamin C. It is one of several vegetables in the family Brassicaceae (Cruciferae) along with cabbage, choy sum, pak choi, and broccoli (Van der Vossen, 1994). Cauliflower is a cool season crop and is produced in many areas all over the world (Koike et al., 2009).

Despite being classified as a highly valuable horticulture product, cauliflower production and productivity has declined over the past years. In 2015 and 2014, cauliflower production and productivity in Indonesia has declined by 13.27% (18,120 ton) and 12.44% (1.5 ton ha^{-1}), respectively. This directly affects the import volume of Indonesian cauliflower which has increased by 15.98% (196 ton) on the same period (MOA, 2016). Moreover, cauliflower productivity in Indonesia (12.08 t.ha^{-1}) is still low compared to several Asian countries. In 2014 the data showed cauliflower productivity in Thailand, Vietnam, India, China, and Taiwan to be 16.21 t.ha^{-1}; 17.66 t.ha^{-1}; 19.76 t.ha^{-1}; 19.58 t.ha^{-1} and 24.29 t.ha^{-1}, respectively (FAOSTAT, 2014).

Various studies to improve cauliflower production and productivity are needed in order to meet the increasing demand. The use of technology in cauliflower production in Indonesia includes a fertigation to provide regular and accurate amount of nutrients and water for the crops. Fertigation has been potentials to be used for vegetable growers to obtain higher yields and quality of cauliflower.

Fertigation is an irrigation method which was given along with fertilizer application. Drip irrigation is one of the fertigation methods that supplies water directly and continuously into the root of plants, either onto the soil surface or directly onto the root zone (Poerwanto and Susila, 2014). Combining a drip irrigation system with polyethylene mulch is an effective method to increase water use efficiency and soil temperature, cut the cost for weed control, promoted earlier harvest, increase yield and net income (Aujla et al., 2007; Sibale et al., 2016).

Soil drench method was the most conventional fertigation method because it is easiest to apply. Soil drench requires no advanced technology but requires a high cost for water use and labor because it is applied manually to each plant (Fitriana et al., 2015). The drilled fertilizer application method was one of the most widely conventional methods used by Indonesian farmers.

Even though it is well known the fertigation method has many advantages, there was no available recommendation for fertilizer application by fertigation to be applied by farmers in Indonesia. The availability of a standard operational procedure (SOP) for fertilizer application by fertigation, can increase the yield of cauliflower, especially in West Java region.

Proper cultivar selection is very important for cauliflower production. Cauliflower curd develops as a specific time based on plant age and temperature (Koike et al., 2009). A mistake in cultivar selection can result in broken florets, lightweight or yellow curds (Koike et al., 2009). One of the efforts to increase cauliflower yield in Indonesia was the use of elite cauliflower genotypes which have potentials to be grown efficiently in lowland region in Indonesia. Evaluating yield of the cauliflower elite genotypes may lead to producing new superior varieties which directly affect the yield of Indonesian cauliflower. Therefore, Bogor Agricultural University (IPB) under Center for Tropical Horticulture Studies (PKHT) has been developing new cauliflower varieties since 2016. During those years, genotypes have been evaluated in multi-location trial plots to compare the yields on highland and lowland regions. Some superior genotypes proved to have greater growth parameters, higher yields, an earlier anthesis and days to harvest. The study was then undertaken to evaluate the effects of fertilizer application by fertigation on growth, yield and economic return of two cauliflower genotypes.

Materials and Methods

The field experiment was conducted during January to May 2017 at Center for Tropical Horticulture Studies (PKHT) Experimental Station at Tajur, Bogor, West Java (6°38'11.0''S, 106°49'23.4''E) with an altitude of 350 m above sea level. The soil in this site is classified as strongly until very strongly acidic with pH range 5.06 - 5.48. Soil texture was classified as clay with composition 70.35% clay, 14.96% silt and 14.70% sand. According to the data by Indonesian Agency for Meteorology, Climatology and Geophysics (2017) rainfall intensity in Tajur was classified as moderate to very high with range 243 to 529 mm per month, temperature range of 25 to 26.4°C, and relative humidity of 84 to 88% during January to May 2017.

Plant Materials, Growing Conditions and Fertilizer Application

Cauliflower seeds genotype BOB017 and BOB020 were assigned as main plot in a split plot design were from the collection of Center for Tropical Horticulture Studies (PKHT), Bogor Agricultural University (IPB), Bogor, Indonesia. Seeds were germinated on a 72-cell-plastic tray and grown for 21 days (from Feb 15th until Mar 9th, 2017) in PKHT nursery. The seedlings were transplanted to the field on 9th of March 2017 with a spacing of 40 cm x 40 cm and the population of 24 plants per plant bed. The total area for the study was 9 m x 17 m (153 m^2). Each treatment combination was allocated to a bed of 5 m long and 0.7 m wide. Bed height was 15 cm with a spacing of 1 m between beds.

Land preparation for the study consisted of land clearing, application of goat manure and inorganic fertilizer equal to recommended rate of 99, 112, and 135 $kg.ha^{-1}$ of N, P_2O_5, and K_2O, respectively for one growing season (Susila, 2006). Pesticides used were an insecticide with active ingredients of carbofuran (30 g kg^{-1}), cypermethrin (0.7 ml l^{-1}), abamectin (1 ml l^{-1}) and fungicide with active ingredient of *propineb* (0.7 g l^{-1}). Pesticides were applied once a week from seedling stage until a week before harvesting.

Fertilizer application methods were assigned as sub plots and consist of drip irrigation, soil drench and drilled fertilizer. The experiment was conducted with four replications and six treatment combinations. Drip irrigation system had one dripper line laid at the center of each treatment bed with emitters (each with a discharge of 0.96 L per hour) spaced at 0.2 m and total 25 emitters per bed. Fertilizer application for soil drench was conducted by dissolving granule mixed fertilizer with 7 L of tap water, and applied with a volume of 250 mL each plant.

Fertilizer was applied once a week totaling six times in one growing season using 60% Urea and 60% ZK in drip irrigation as well as soil drench. For the drilled method, each 30% Urea and ZK was applied on three, and five weeks after transplanting (Table 1).

Data Collection

During the course of the study data collected involved growth parameters of cauliflower such as plant height with 60 cm ruler, number of leaves per plant, and stem diameter using digital caliper, collected weekly from one to six weeks after transplanting. Cauliflower

Table 1. Recommended fertilizer rates for cauliflower (Susila, 2006)

Plant age (WAT)	Drip irrigation and soil drench			Drilled fertilizer		
	SP-36	Urea	ZK	SP-36	Urea	ZK
Preplanting	235.00	66.00	81.00	235.00	66.00	81.00
1	-	16.50	20.25	-	-	-
2	-	16.50	20.25	-	-	-
3	-	16.50	20.25	-	49.50	60.75
4	-	16.50	20.25	-	-	-
5	-	16.50	20.25	-	49.50	60.75
6	-	16.50	20.25	-	-	-

Note: WAT= weeks after transplanting

curds were harvested just as the leaves covering the curd begin to spread apart. Data on yield and quality parameters includes days to anthesis, days to harvesting, curd diameter and curd weight at harvest, and predicted cauliflower yield per ha.

Statistical Analysis

Data collected were analyzed using analysis of variance (ANOVA) at the level of 5% to determine the differences between the treatments. If the results showed significant differences, LSD (Least Significance Different) was further performed with STAR 2.0.1 software.

Result and Discussion

Effect of Genotypes on Growth and Yield of Cauliflower

Genotype BOB020 significantly had more number of leaves per plant comparing to genotype BOB017 (Table 2), this means more leaf area index (LAI) for conducting the photosynthesis as well as to produce biomass. Higher LAI can lead to improved yield up to 10% in tomato according to research by Heuvenlink et al. (2004). Plant height and stem diameter are not significantly different in both genotypes. This result indicates that both genotypes can reach a similar plant height and stem diameter of about 36 cm and 10 cm, respectively.

Genotype BOB020 reached anthesis and harvesting date earlier than genotype BOB017, i.e. by 11 and 10 days, respectively. This implies that the growers can harvest cauliflower earlier if they use genotype BOB020 compared to genotype BOB017, therefore reducing production costs such as labor and fertilizer.

All the yield parameters of this study were not affected by cauliflower genotypes; both genotypes had similar average curd weight of 295 g, average curd diameter of 13.5 cm, and the estimated yield of 10.7 $t.ha^{-1}$.

Effect of Fertilizer Application Methods on Growth and Yield of Cauliflower

Soil drench fertilizer application had significantly higher values for all growth parameters comparing to dripped and drilled fertilizer. Among the three different treatments, both fertilizer application through drip irrigation and drilled methods had the similar plant height (32 cm), stem diameter (9 cm), number of leaves (14), days to anthesis (54) and days to harvesting (68). The yield parameters from both fertilizer methods of application were also similar, i.e. average curd weight of 270 g, average curd diameter of 13 cm, and estimated yield of 10 $t.ha^{-1}$.

Effects of Genotypes and Fertilizer Application Methods on Growth, Yield and Economic Return of Cauliflower

Genotypes and fertilizer application methods did not interact in affecting the predicted cauliflower yield. The predicted yield was based on conversion of yield per bed area to a hectare of production area. Interaction between genotype BOB017 with soil drench significantly increased the cauliflower yield (13.86 $t.ha^{-1}$) by 27% compared to others treatment combinations (10.06 $t.ha^{-1}$ in average) (Table 3). The best fertilizer application method for genotype BOB 017 was drench, whereas for for genotype BOB 020, drench or drilled application methods were not significantly different.

The estimated yield result directly affects the economic return of the different treatment combinations (Table 4), which demonstrated that the maximum gross return of 15,500 $USD.ha^{-1}$, net return of 12,000 $USD.ha^{-1}$ and B/C ratio of 3.32 were recorded from treatment combination BOB017 and drench fertilizer which is directly proportional to their estimated yield. The combination of BOB017 and drench fertilizer

Table 2. The effects of genotypes, fertilizer application methods, and their interaction on growth and yield parameters of cauliflower

Treatment combination	Plant height (cm)	Number of leaves	Stem diameter (cm)	Days to anthesis	Days to harvest	Curd weight (g)	Curd diameter (cm)	Estimated cauliflower yield (t.ha^{-1})
Genotypes (G)								
X (BOB017)	36.13	13.91 b	10.70	57.42 b	70.65 b	301.51	13.66	11.25
Y (BOB020)	36.12	17.15 a	10.68	46.92 a	60.02 a	292.81	13.97	10.13
	ns	*	ns	*	**	ns	ns	ns
Fertilizer application methods (F)								
1 (drip irrigation)	31.21 b	13.55 b	8.73 b	56.62 a	69.66 a	252.58 b	13.32 b	9.11 b
2 (soil drench)	42.92 a	18.49 a	13.55 a	46.25 b	59.74 b	351.64 a	14.65 a	12.39 a
3 (drilled)	34.26 b	14.55 b	9.80 b	53.62 a	66.60 a	287.27 b	13.48 b	10.57 b
	**	**	**	**	**	**	*	**
G X F	ns	**	ns	ns	ns	ns	ns	*

Note: * significantly different at 5%; ns = not significantly different according to LSD at 5%.

Table 3. Interaction between genotypes and fertilizer application methods in affecting cauliflower yield Estimated cauliflower yield (t.ha^{-1})

Fertilizer application methods	Genotypes	
	BOB017	BOB020
1 (drip irrigation)	9.13 c	9.10 b
2 (soil drench)	13.86 a	10.91 a
3 (drilled)	10.76 b	10.38 ab

Note: Values with different letters within the same column are not significantly different according to LSD at 5%.

Table 4. Total cost of production, gross return, net return, and benefit/cost ratio of cauliflower under different treatment and combination

Treatment combination	Total cost of production (USD.ha^{-1})	Gross return (USD.ha^{-1})	Net return (USD.ha^{-1})	B/C ratio
BOB017-drip	2,998	10,271	7,273	2.43
BOB017-drench	3,611	15,595	11,984	3.32
BOB017-drilled	3,426	12,105	8,679	2.53
BOB020-drip	2,998	10,231	7,233	2.41
BOB020-drench	3,611	12,276	8,665	2.40
BOB020-drilled	3,426	11,683	8,257	2.41

recorded a gross return of 12,000 USD.ha^{-1}, net return of 8,600 USD.ha^{-1} and B/C ratio of 2.53. The lowest gross return of 10,200 USD.ha^{-1}, net return of 7,200 USD.ha^{-1} and B/C ratio of 2.41 were recorded in treatment combination of BOB020 with drip irrigation. In terms of economic return, it could be inferred that a combination of genotype level BOB017 and soil drench method is the most profitable for cauliflower production, followed by combination of genotype BOB017 and drilled fertilizer application.

The results of this study is similar when compared to the previous research conducted by Fitriana et al. (2013) that the use of the soil drench method was more profitable than drip irrigation method with B/C ratio 1.33 and 0.75, respectively, for a similar study on chili pepper conducted in Plukaran, Pati region, Central Java, Indonesia.

Conclusion

Cauliflower fertilized with soil drench method had an optimum growth, high yield and high net income

under agronomic and climatic conditions of Tajur in Bogor region of West Java, Indonesia. Genotype BOB020 with drench fertilizer application had the greatest number of leaves per plant, earlier anthesis and harvest. Production of cauliflower BOB017 with soil drench fertilization was the most profitable with B/C ratio of 3.32.

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