Introduction of Garlic Cultivation Technology Packages in West Java, Indonesia

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Abstract. Massive import of garlic products has caused a declining interest of Indonesian farmers to plant garlic due to losing competition in clove size and lower selling price. This has discouraged the farmers from applying the innovation of garlic farming technology that caused low garlic productivity in Indonesia (8.7 t/ha). The purpose of this research was to improve the technology package of garlic cultivation at the farmer level. The study was conducted from July to October 2021 in Cianjur Regency, West Java, Indonesia. The technology packages experimental design was randomized block design with nine replications. The technology packages tested were farmer's technology package, introduced technology package-1, and introduced technology package-2. The components of the technology package tested were cultivar, mulch types, number of cloves per hole, biofertilizer, biopesticide, and chemical fertilizers. The observed variables were plant growth, bulb yield, and input-output of farming. The results showed that the technology package introduction could increase the plant performance, namely the plant height, stem diameter, bulb fresh weight and bulb diameter. The highest R/C ratio was reached by the technology package introduction-1 (1.47). The introduced technology package-1 was more profitable than package-2 as indicated by the MBCR value of 12.46 and 8.83 respectively.

1 Introduction

Annual Indonesia's garlic consumption reached 600,000 ton, while national production was only 30,000 ton/year. To overcome the shortage, Indonesian government has imported garlic until around 95% of the national demand [1]. Garlic productivity in Indonesia has been low at around 6.39 ton/ha, while in the world average is 9.73 ton/ha [2]. The low production was due to the smaller size of local garlic bulbs than imported garlic, the diameter of Indonesian

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garlic bulbs was only 3-5 cm [3–7]. This has caused Indonesian farmers to be reluctant to plant garlic due to losing competition in terms of bulb size and lower selling price of imported garlic [8]. In addition, the low domestic garlic production and the undersupply of imported garlic related to international mobility restriction due to the Covid-19 pandemic have caused the lack of garlic stock in the market and escalated garlic price [9]. Therefore, the enhancement on national garlic production needs to be increased by introducing the updated technology [10].

Several studies attempted to increase the national garlic production either by increasing bulb size with the application of benzyl amino purine, vernalization for 4 and 8 weeks, the use of silver plastic mulch, the use of superior garlic cultivar, and the use of gliocompost [8, 10]. Indonesia Vegetable Research Institute (IVEGRI) introduced a technology package which was an innovated technology based on farmer practices. The IVEGRI technology package was able to increase the garlic bulb diameter to 32.69 % and bulb weight to 11.5 g [11]. However, the application of introduced technology could increase the cost of farming and burdening the farmers [12]. [13] reported that 20% of farmers in Turkey experienced losses when implementing the introduced technology. Accordingly, the introduction of technology package must consider economic condition of the farmers. The purpose of this research was to improve the technology package for garlic cultivation at the farmer level.

2 Methodology

The research was carried out in July to October 2021 in Pacet District, Cianjur Regency, Indonesia (-6º45'38,598" S, 107º1'6,234" E). Based on the soil analysis result, the soil was classified as neutral soil pH, low CN ratio, very high P and K content. The experimental design used a randomized block design with nine replications. The technology package treatments were farmer's technology package introduced technology package-1 and introduced technology package-2. The components of the technology package tested were cultivar, mulch types, number of cloves per hole, bio-fertilizer, bio-pesticide, and chemical fertilizers (Table 1). Each unit was 30 m^2, so the total research area was 800 m^2. The spacing used was 10x15 cm. Maintenance was done by watering, weeding, and controlling pest and disease.

Table 1. Components of technology package in each treatment.

Technology Component	Technology Package		
	Introduction-1	**Introduction-2**	**Farmer's**
Cultivar	Lumbu Hijau; Tawangmangu Baru	Lumbu Hijau; Tawangmangu Baru	Lumbu Putih
Mulch	Straw mulch	Plastic mulch	Plastic mulch
Number of cloves per hole	1	1	3-4
Bio Fertilizer	Trichoderma	Gliocompost and mycorrhizae	Natural gliocompost
Bio Pesticide		Bioprotector every 10 days	
Chemical fertilizer:			
• Basic fertilizer	376 kg SP36/ha; 14 DBP	250 kg SP36/ha; 14 DBP	500 NPK kg/ha; 14 DBP
• Supplementary fertilizer	286 kg ZA/ha + 50 kg KCl/ha; 21, 35, 49, 63 DAP	280 kg ZA/ha + 30 kg KCl/ha; 25, 55 DAP	200 kg NPK/ha, 30 DAP; 200 kg KCl/ha, 60 DAP

Description: DAP = Day After Planting, DBP= Day Before Planting

The agronomic data observed were plant height (cm) at 30, 60, and 90 DAP, number of leaves at 60 DAP, stem diameter (mm) at 60 and 90 DAP, bulb diameter (cm) and yield (ton/ha) at 120 DAP. The agronomic data was analyzed using analysis of variance and if there was significant difference, the test was continued using Duncan test at 95% confident level. The economic data collected were production inputs, total yields (kg) and prices (IDR/kg). The economic analysis includes farming analysis and Margin Benefit Cost Ratio (MBCR) analysis [14].

3 Results and discussion

3.1 Vegetative Growth

The technology packages affected the plant height at 30, 60, and 90 DAP and the stem diameter of the garlic plant at 60 and 90 DAP but did not affect the number of leaves at 60 DAP (Table 2). This showed that the differences in cultivar, number of cloves per hole, mulch type, biofertilizer, biopesticide, and chemical fertilizer treatments did not affect the number of leaves of garlic plants. Generally, the number of leaves was strongly influenced by the type of cultivar [15]. However, in this study, the number of leaves of Lumbu Putih and Lumbu Hijau cultivar was not significantly different with a range of 6-8 leaves per plant (Table 2).

Table 2. Garlic plant growth in various technology packages.

Technology packages	Plant height (cm)			Number of leaves		Stem diameter (mm)
	30 DAP	**60 DAP**	**90 DAP**	**60 DAPS**	**60 DAP**	**90 DAP**
Introduction-1	40.6^a a	63.99 a	69.69 a	7.24^a	10.56^a	12.03^a
Introduction-2	39.01 a	61.37 a	66.4^a	7.33^a	11.13^a	11.96^a
Farmer	29.73 b	50.23 b	60.00 b	6.9^a	7.97^b	10.50^b
CV (%)	6.71	7.15	7.39	7.75	9.7	11.16

Note: numbers followed by different letters indicate a significant difference at 95 confident level.

Garlic planted with farmer’s technology package had lower plant height and stem diameter compared to the two introduced technology packages (Introduction-1 and Introduction-2) (Table 2). This showed that the technological components of the cultivar, number of cloves, types of mulch, bio-fertilizer, bio-pesticide, and chemical fertilizer, in the farmer’s technology package caused lower performance than the Introduction-1 and Introduction-2. The main difference between the introduced technology packages and the farmer’s package was the cultivar and number of cloves per hole (Table 1). Thus, it was suspected that the use of the Tawangmangu Baru or Lumbu Hijau cultivar with one clove per hole could increase plant height and stem diameter than the Lumbu Putih cultivar with 3-4 cloves per hole.

The difference among cultivar, mulch, number of cloves, biofertilizer, biopesticide, and chemical fertilizer between Introduction-1 and Introduction-2 technology treatments did not affect the plant height and diameter of the base of the garlic stem (Table 2). The main differences between these two treatments were the type of mulch, biofertilizer, bio protector, and chemical fertilizer (Table 1). Therefore, the type of mulch, differences in biofertilizers, use of bio protectors, and differences in dosage and timing of applying chemical fertilizers did not affect the plant height and stem diameter. The high use of chemical fertilizers in the Introduction-1 technology treatment (a total of 1,720 kg/ha) did not affect the plant height and the stem diameter (a total of 870 kg/ha). In addition, differences in the use of biofertilizer types or types of mulch also have no effect. This was presumably because the land was classified as fertile with neutral soil pH, low CN ratio, high P and K content and the use of bio protector in introduction-2 treatments which could also functioned as organic fertilizers. Study from [16] also showed insignificant effect of the use of mulching on garlic productivity, which plastic mulch and without mulch resulted in the same weight of garlic bulbs, namely 16.44 g and 16.47 g.

3.2 Production

The wet weight per plant and bulb diameter of the farmer's technology package were lower than the introduction-1 and introduction-2 technology package (Table 3). In fact, the wet weight per plant in farmer's technology was almost half of the wet weight of the introduction-1 and introduction-2 treatments. In detail, the combination of Lumbu Putih cultivar, installation of plastic mulch directly after land preparation, 3-4 cloves per hole, the use of natural biological fertilizer gliocompost, basic chemical fertilizers of 500 kg NPK/ha, and supplementary fertilizer of NPK and KCl in the farmer's technology package resulted in lower wet weight and bulb diameter than the introduction-1 and introduction-2 technology package. Garlic plants required appropriate cultivation technology to optimize the growth and the yield production. Comparison between fertilizer applications SP36 281.25 $kg.ha^{-1}$, ZA 858 $kg.ha^{-1}$, KCl 150 $kg.ha^{-1}$ and SP36 375 $kg.ha^{-1}$, ZA 1144 $kg.ha^{-1}$, KCl 200 $kg.ha^{-1}$ resulted in the same bulb diameter of 33.09 mm and 33.13 mm [17]. This was in line with our results of vegetative growth; the results for farmer's technology were also relatively lower than the treatment of introduction-1 and introduction-2 technology. The low vegetative growth of garlic planted with farmer's technology package was directly proportional to the low bulbs' variable. This was because low vegetative growth would result in low food material needed for bulb growth. Factors affecting the high yield of garlic bulbs were steady vegetative growth, optimum photosynthetic activity and mineral absorption, high dry matter accumulation as well as the increase in growth performances due to bio-fertilizer application [18].

Table 3. Garlic production in various technology packages

Technology packages	Wet weight per plant (g)	Bulb diameter (cm)
Introduction-1	235.28^{a}	3.76^{a}
Introduction-2	222.44^{a}	3.74^{a}
Farmer's	129.75^{b}	3.24^{b}
CV	20.8	12.08

Note: numbers followed by different letters indicate a significant difference at 95 confident level.

Similar to vegetative growth, the difference in treatment did not affect the wet weight per plant and bulb diameter in the introduction-1 and introduction-2 technology (Table 3). Although the use of chemical fertilizers in introduction-2 treatment was lower, the wet weight/plant and bulb diameter were not significantly different from introduction-1 technology.

The technology package treatments affected the production of garlic per hectare and the survival rate of the plants (Table 4). Production per hectare and survival rate of garlic under the treatment of introduction-1 and introduction-2 were higher than the farmer's treatment. Production per hectare on introduction-1 and introduction-2 technology reached around 20 t/ha under conditions of frequent rain and no dry period during the bulb swelling and maturation phase. In those climatic conditions, the production of garlic bulbs was not optimal because garlic required a dry period for filling and ripening the bulbs [8]. Hence, the production potency in this research still could be increased when meeting the favorable climatic conditions. The interaction of varieties and fertilizer types affected the days of bulb maturity, plant height, leaf area index, mean bulb weight, mean clove weight, total fresh biomass yield, total bulb yield and harvest index [19]. Present global research lead toward the concern of the effects of climate change on garlic yield, the increases in temperature and unpredictable rainfall season will considerably decrease the crop yields [20]. Besides, the breeding development of varieties will also very influence the determination of the production value of garlic [15, 21, 22].

Table 4. Production of garlic bulbs in various technologies.

Technology package	Production (ton/ha)	Survival rate (%)
Introduction-1	20.19	96.91
Introduction-2	19.68	96.71
Farmer	10.28	39.51

3.3 Analysis of garlic farming based on the use of technology

The use of the three technology packages was quite varied in terms of production costs, bulb yields, and profits (Table 5). Both introduced technology packages had higher production compared to production in farmer's technology packages. Moreover, the garlic bulbs produced from the introduced technology packages had a larger size. Due to smaller number of garlic clove used as seedling per hole resulting bigger size of bulbs, it can be concluded that the profit from the introduced technology packages were higher. It indicated by a higher B/C ratio value of introduced packages than the farmer's package. Garlic agribusiness in Indonesia was financially profitable despite the lack of comparative advantage and the urgent need of advanced innovation [23].

In terms of the financial feasibility, the two introduced technology packages had MBCR values more than 1 (Table 5). This indicated that the additional benefits from using the introduced technology were higher than the additional costs. In other words, that garlic farming using introduced technology had a higher financial feasibility than using farmer's basic technology. Based on the MBCR value, the most profitable garlic farming was using the introduced technology package 1. This was indicated by the highest MBCR value (12.46). It meant that combination of Lumbu Hijau or Tawangmangu Baru cultivars, straw mulch, 1 clove per hole, Trichoderma as biofertilizer, 376 kg SP 36/ha at 14 DBP, and 286 kg ZA/ha and 50 kg KCl/ha at 21, 35, 49, and 63 DAP was the most profitable technologies.

Table 5. Marginal Benefit Cost Ratio value (MBCR) of the application of introduced technology in the garlic production business (in 800 m^2 area).

No.	Description	Technology Package Models		
		Introduction-1	Introduction-2	Farmer's
1.	Labor cost (IDR)	2,465,000	3,390,000	4,210,000
2.	Production input (IDR)	9,620,000	8,934,000	7,105,000
3.	Total cost (IDR)	12,085,000	12,324,000	11,315,000
4.	Difference total cost from farmer's technology (IDR)	770,000	1,009,000	
5.	Total Production (Kg)	1,615	1,574	822
6.	Price (IDR/Kg)	11,000	11,000	9,000
7.	Revenue (IDR)	17,765,000	17,314,000	7,398,000
8.	Profit (IDR)	5,680,000	4,990,000	-3,917,000
9.	Profit difference against farmer's technology (IDR)	9,597,000	8,907,000	
10.	R/C ratio	1.47	1.40	0.65
11.	B/C ratio	0.47	0.40	-0.35
12.	Value of MBCR	12.46	8.83	

4 Conclusion

Garlic farming using the introduced technology packages had better plant growth and production than the farmer's technology. Production of garlic with the technology of introduction-1 and introduction-2 reached 20.19 and 19.68 t/ha, respectively. Meanwhile, production of farmer technology was 10.28 t/ha. Financially, the introduced technology packages were more profitable than the farmer's technology package and the highest MBCR value achieved by the introduced technology package-1 (12.46).

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