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Determinants of Shallot Innovation Adoption and Yields in Temanggung Regency, Central Java

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ABSTRACT

The adoption of shallot innovations continues to be disseminated to increase production, food security, and the welfare of shallot farmers in Indonesia. This paper aims to analyze production, prices, and farmers' perceptions regarding factors that influence innovation adoption and yields. A survey was conducted in Temanggung Regency, Central Java Province. A structured questionnaire with 62 interviewers selected proportionally randomly on a village basis based on the criteria of having received program assistance and growing shallots. The findings of this study show that the expansion of the harvested area is the main factor driving shallot production growth. An indicator that deserves attention is negative yield growth, which indicates a downward trend in productivity. The coefficient of variation of 25.90% indicates that the price of shallots in Temanggung Regency is classified as unstable. Shallots pose a smaller price risk to cultivate than regular chilies and curly chilies. Climate conditions, access to information, relative advantage, and the role of extension are perceived by farmers as the most important factors influencing innovation adoption. The focus of intervention strategies must shift from expanding harvested area-which is unsustainable in the medium- and long term, given the scarcity of available land-to increasing productivity.

1. INTRODUCTION

Approximately 28.60% of the 135.30 million working population, or 38.70 million individuals, were employed in the agriculture, forestry, and fisheries sector as of August 2022 [1]. According to study [1], the percentage of Indonesia's informal workforce employed within the agricultural sector reached 88.89% in 2022. Shallot farmers are among the most numerous vegetable crop farmers in Indonesia. In 2021, shallot production reached 2 million tons and consumption reached 790,630 tons, and Central Java Province became the largest shallot producer in Indonesia with a production value of 564.26 thousand tons [1].

The shallot commodity (*Allium cepa L.*) is one of the priority vegetable crops for Indonesians because they play an important role not only as a flavoring ingredient in various daily culinary options [2, 3] and as a spice for herbal remedies that can be used to treat bronchitis, fever, flatulence, and sore throats [4, 5]. Time series data for 1970-2020 reveal varying yearly shallot production, but they also demonstrate a noteworthy pattern of rising production at an average annual growth rate of 4.35%. In general, the growth of shallot production in Indonesia is mostly dominated by the contribution of growth/increase in harvested area, not by the yield (productivity). During 2010-2020, Central Java was consistently the largest contributor of shallot production in Indonesia averaging 33.5% per year. However, the production growth rate during that period (1.9%) was the lowest compared to the other provinces. It was also noted that the yield growth rate in that period was negative (-1.7%). Therefore, the time series data suggest that there is an urgent need to revitalize the program priorities that put more emphasis on innovation break-troughs (both HYVs and "best practices") with the main target of accelerating yield increase as the main driver of production growth [6].

Temanggung Regency is one of the largest shallot-producing regencies in Central Java. With the expectation of increasing its contribution to Central Java's total shallot production, several innovations have been introduced in Temanggung Regency, encompassing superior seeds, raised bed techniques, optimized row planting spacing, TSS seeds, and plastic mulching. Apart from increasing production, these

innovations also most likely offer a solution to overcome the problem of shallot seed supply in Temanggung Regency. Innovation adoption will lead to the availability of good quality seeds for local needs throughout the year.

Many studies suggest that the characteristics of farmers, such as users' age [7, 8], education [9], gender [10], experience [11], progressiveness [12], higher annual income [13, 14], and the availability of family labor [15] affect the adoption of new technology or innovation. Farm characteristics that play a key role in technology adoption include the size of landholding [16] and land tenure status [17]. Institutional factors such as social capital [18], extension services [8], and access to credit facilities [19] are also examined in many previous studies on how they influence technology adoption. The dynamic interaction between technical attributes and other environmental factors and circumstances also affects farmers' adoption decisions [20]. According to some authors, the "relative advantage, compatibility, complexity, trialability, and observability" of the innovation are crucial pillars in the adoption process [21, 22].

However, some previous studies indicated that in most cases, the level of innovation acceptance remains predominantly low [23], affecting the level of income and efficiency of shallot farmers [24]. Therefore, the main objective of this paper is to elaborate on farmers' perceptions regarding factors affecting shallot innovation adoption and yields in Temanggung Regency in helping policymakers better target initiatives at the factors that hinder and drive the uptake of innovations by shallot farmers.

2. METHODOLOGY

A survey was conducted in two villages (Bansari and Central Mranggen Villages), Bansari Subdistrict, Temanggung Regency, Central Java Province. The selection of these two villages was based on: (1) the largest shallot-harvested area in Temanggung Regency, and (2) farmers participating in the shallot area development program organized by the Temanggung Regional Government. The survey was carried out from May to December 2023. A structured questionnaire was used for collecting data through face-to-face interviews with 62 selected using village-based proportionally random sampling.

Some topics covered in the questionnaire were respondents' characteristics (4 items), characteristics of natural resources (3 items), socioeconomic conditions of farmers (5 items), characteristics of innovation (5 items), external supports (4 items), adoption behavior (3 items), and increase in yields (3 items). There were three types of questions on the questionnaire: Likert scale, closed-ended, and open-ended. The respondents' replies were quantified using a five-point Likert scale, ranging from 1=never to 5=always, or from 1=very disagree to 5=very agree, or from 1=not important to 5=very important, or from 1=extremely poor to 5=very good, etc. [25].

Whenever necessary, ordinal data were converted into interval data by using the Method of Successive Interval (MSI) in Excel so that they could be analyzed by parametric statistics. Descriptive statistics (frequency distributions, percentages, means, and standard deviations) were calculated. Kendall Tau Correlation was used to measure rank correlation-the similarity of the orderings of the data when ranked by each of the quantities. It is a non-parametric correlation analysis to measure the strength and direction of the relationship between two variables. The statistical software used was SPSS v. 25.

Kendall's Tau tests are designed to work with ordinal or continuous data without requiring normal distribution assumptions; therefore, they are ideal for correlation analysis in ordinal data contexts. In this study, the variable tested is a composite of several compositor variables. The use of the Indicator Score Model (MSI) is essential to ensure that each composer variable contributes proportionately to the composite [26]. Composite variables allow researchers to capture a holistic picture of complex concepts by combining several related indicators. By combining several indicators, the variability caused by individual measurement errors can be reduced, thus resulting in a more stable and consistent score. The use of composite variables can help in statistical analysis by simplifying models and focusing on relationships between major variables. Using MSI to compose variables also gives a proportional weight to each indicator based on its contribution to the overall variable.

3. RESULTS AND DISCUSSION

3.1 Overview of shallot commodities in Temanggung Regency

In 2022, Central Java contributed 28.07% to the national shallot production. Brebes Regency is the biggest contributor in both production and harvested area. Except for Brebes and Tegal City, the yields in other regencies are still lower than the average shallot yield of Central Java (10.38 t/ha). Figure 1 shows the condition of shallot commodities in Temanggung District.

From 2018 to 2022, the Average Annual Growth Rates (AAGR) for production, harvested area, and yield of shallots in Temanggung Regency are all positive. Meanwhile, the calculation of the Compound Annual Growth Rates (CAGR) suggests that the growth of production (14%) is mainly caused by the growth of harvested area (15%). It should be noted that the negative growth of yield (-1%) indicates a downward trend in yields or productivity (Figure 1) during 2008-2022. This is perhaps the reason that best justifies Temanggung's inclusion in the shallot development program organized by the Central Java Provincial Government.

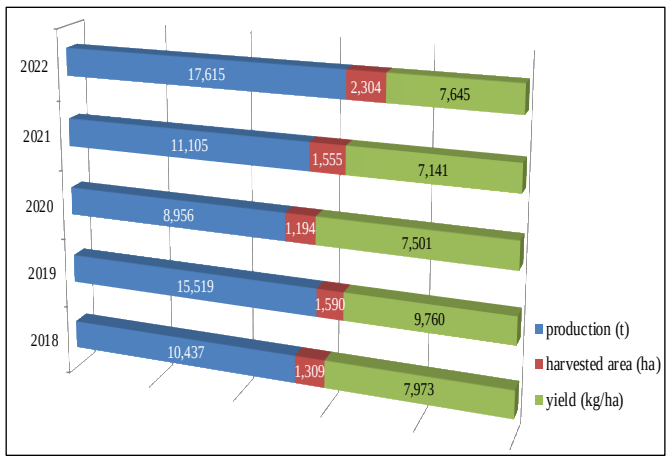

Figure 1. The condition of shallots in Temanggung Regency
Source: Study [6]

Temanggung Regency's agricultural productivity grew at a negative rate of -1% between 2018 and 2022, suggesting underlying problems that have an impact on agricultural production. Soil deterioration, climatic variability, pest and disease challenges, conventional agricultural techniques, market volatility, and shifts in traditional institutions are possible reasons for this reduction. Crop yields may be harmed by the overuse of chemical herbicides and fertilizers, which can also degrade the soil fertility and structure. Extreme weather events such as droughts and strong rains can also cause disruptions in plant development conditions and lower yields when they occur more frequently. Plant production and health can also be affected by an increase in pest and disease assaults. Reduced production is also a result of relying too heavily on old farming techniques, which may be less effective than contemporary agricultural techniques. The capacity of farmers to invest in technology that increases production and income levels can be influenced by significant price fluctuations. Small-scale farmers are experiencing more operating costs as a result of the shift from free labor exchanges, known as solidarity labor practices, to commercial labor systems.

These issues can be successfully resolved by implementing technologies such as precision agricultural techniques, raised bed methods, and the use of better seeds. Better seeds can increase the yield because they are more resilient to diseases, pests, and extreme weather conditions. Raised bed planting and precision agriculture techniques can enhance plant health and resource efficiency. While sustainable techniques, such as crop rotation, organic fertilizers, and soil conservation can enhance and preserve soil fertility, integrated pest management (IPM) techniques can reduce the effects of pests and diseases.

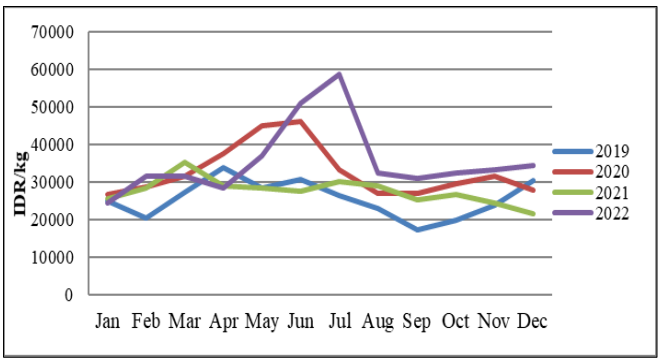

Figure 2. Monthly shallot prices in Temanggung Regency

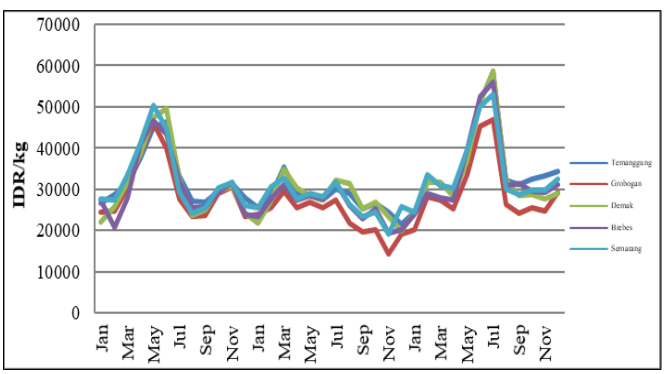

Figure 3. Monthly price of shallots in several cities/regencies of Central Java

Figure 2 shows that shallot prices in Temanggung Regency fluctuate most sharply in 2022 as evidenced by the highest coefficient of variation (CV) of 27.3%. The level of price fluctuations decreased successively in 2020 (CV=20.9%), 2019 (CV=19.5%), and 2021 (CV=12.4%). Also in Figure 2 shows that shallot prices in Temanggung Regency experienced the most fluctuations in 2022During the 2019-2022 periods, shallot prices in Temanggung Regency are relatively less fluctuated in 2021 with the lowest coefficient of variation. Similar price fluctuation patterns are seen across numerous significant shallot-producing regions in Central Java according to monthly pricing data series (2020-2022) (Figure 3). Shallot prices in Temanggung Regency were significantly constant in 2021, with the lowest CV of 12.4%, over the 2019-2022 period. Similar fluctuation trends are revealed by monthly pricing data series from 2020 to 2022 in many significant shallot-producing regions in Central Java (Figure 3).

However, there are differences in when shallots reach their highest prices in those years. The highest prices for shallots occurred in May-June (2020), March-April (2021), and July-August (2022). The coefficient of price variation in the shallot-producing districts data series is not much different, namely as follows: Temanggung (24.0%), Grobogan (26.8%), Demak (27.6%), Brebes (27.5%), and Semarang (24.9%). In this case, Semarang is assumed to function as a consumer market. The similarity of price fluctuations and price variation coefficients may imply that the shallot markets have price integration.

Price fluctuations can put farmers at risk, influencing their capacity to make decisions and maintain financial security. Crop rotation and intercropping are two examples of diverse cropping systems that may operate as hedges against market swings. Better market access and lower transportation costs may be achieved by enhancing infrastructure and logistics. Additionally, government initiatives such as buffer stock plans and minimum support prices can assist in price stabilization and ensure farmer income. This report aims to provide more thorough knowledge of the difficulties and potential solutions for shallot farmers in Temanggung Regency and other places by delving into the possible causes of decreased production and offering a deeper examination of price changes.

3.2 Characteristics of respondents

Some findings of the survey are shown in Table 1. The mean age of the farmers in Bansari Village is 39 years and about 27.6% are less than 30 years old; and about 34.5% are between 30-40 years old. Meanwhile, the average age of farmers in Central Mranggen Village is 48 years old, and they are predominantly aged >50 years old (48.3%). The average age of farmers in Bansari Village is younger than farmers in Central Mranggen Village. Regarding education, around 79% of Bansari Village farmers have junior high school, high school, and college education. In comparison, most of the farmers in Central Mranggen Village have only graduated from elementary school (69%). Education is correlated with acceptance of innovative technologies. Judging from their experience as farmers, most Bansari villages have between 11-20 years (41.38%), as a comparison in Mranggen Tengah village with experience between 21-30 years (31.03%). Long farming experience has led to an understanding of the management of profitable shallot cultivation. The characteristics of research respondents in Temanggung Regency can be seen in Table 1.

Table 1. The Characteristics of respondents in Temanggung Regency

No.	Variables	Bansari (n=32)		Central Mranggen (n=30)	
		∑	%	∑	%
	Age (years)				
1	a. < 30	8	27.59	1	3.45
	b. 30-40	10	34.48	6	20.69
	c. 41-50	8	27.59	9	31.03
	d. > 50	6	20.69	14	48.28
	Average farmer's age	39		48	
	Education (years)				
2	a. Elementary School (1-6)	9	31.03	20	68.97
	b. Middle School (7-9)	10	34.48	7	24.14
	c. High School (10-12)	11	37.93	2	6.90
	d. College (>12)	2	6.90	1	3.45
	Average farmer's education	10		7	
	Farming experience (years)				
3	a. 1-10	12	24.14	7	24.14
	b. 11-20	17	41.38	8	27.59
	c. 21-30	1	3.45	9	31.03
	d. > 30	2	6.90	6	20.69
	Average farming experience	11		22	
	Number of household members (person)				
4	a. 0-2	2	6.90	12	41.38
	b. 3-4	23	79.31	14	48.28
	c. 5-6	6	20.69	4	13.79
	d. 7-8	1	3.45	0	0
	Average number of household members	4		3	

Table 2. Farmers' perceptions regarding factors influencing the adoption of shallot innovations

Description	1	2	3	4	5	Means
	%	%	%	%	%	
Characteristics of natural resources						
a. Water sufficiency	6.5	33.9	9.7	50.0	0.0	2.9539
b. The intensity of environmental stress	11.3	11.3	29.0	48.4	0.0	2.6968
c. Weather/climate conditions	1.6	4.8	45.2	48.4	0.0	3.4989
The socioeconomic conditions of farmers						
a. Landholding	11.3	43.5	27.4	14.5	3.2	2.6968
b. ICT proficiency	27.4	46.8	24.2	1.6	0.0	2.2152
c. Accessibility	8.1	25.8	32.3	33.9	0.0	2.8547
Characteristics of technology/innovation						
a. Relative advantages	0.0	0.0	14.5	80.6	4.8	4.5713
b. Ease of trial	0.0	3.2	16.1	77.4	3.2	4.2398
c. Level of appropriateness	0.0	0.0	24.2	71.0	4.8	4.2906
d. The complexity level (of usage)	6.5	54.8	29.0	9.7	0.0	2.9539
e. Ease of observation	0.0	1.6	19.4	79.0	0.0	4.4989
External supports						
a. Group dynamics	0.0	1.6	6.5	90.3	1.6	4.4989
b. The role of an extension agent	0.0	0.0	8.1	87.1	4.8	4.8547
c. Infrastructure support	3.2	33.9	16.1	46.8	0.0	3.2398
d. Social capital	0.0	0.0	14.5	51.6	33.9	4.5713
Adoption behavior by farmers						
a. Farmers' knowledge	0.0	16.1	32.3	50.0	1.6	3.5165
b. Attitude/response toward innovation	19.4	17.7	30.6	32.3	0.0	2.4180
c. Skills in implementation	0.0	9.7	37.1	51.6	1.6	3.7705
Increase in farmers' productivity						
a. Farm productivity	0.0	27.4	19.4	53.2	0.0	3.2152
b. Cost savings in farming	0.0	30.6	17.7	51.6	0.0	3.1454
c. Value-added savings	0.0	30.6	17.7	51.6	0.0	3.1454

3.3 Farmers' perceptions of factors influencing the adoption of shallot innovations

Shallot farmers in the research area have traditionally adapted their planting patterns to the ecological conditions and challenges they face. It is hoped that the introduction of shallot cultivation technology will increase productivity. Technological innovations that have been introduced include the introduction of superior seeds, Bedengan techniques, plant spacing, and the use of plastic mulch. This new technology in shallot cultivation has increased productivity, but its impact has created economic dependence on the commercialization of agricultural inputs such as synthetic fertilizers, pesticides and water availability.

The most important thing to solve in the business of garlic is optimal productivity. The main factor is the adoption of a

package of technology recommendations as well as suitable soil and environmental conditions. Adoption of technology package recommendations on garlic will result in optimal growth and productivity that is environmentally friendly. The package is composed of recommendation technology components that contribute, including perfect soil processing + cage fertilizer so that the soil remains fertile burning and bulbs grow optimally, material (high 30-50cm, width 90-120cm) as a water drainage to avoid flooding in heavy rainfall, as well as mulching to reduce weeds/grasses and keep evaporation in hot weather, seeds are molded and certified by New Hollow Varieties (VUB) have been tested adaptive to soil-specific locations, inorganic fertilizer recommendations (the same type, correct dosage, timely, correct method and target) so as not to inhibit and prevent the growth of burning, integrated control of humidity (PHT) that is friendly to the environment, and proper process of maintaining the crop quality suitable for red onions. Problem solving avoids the always fluctuating price of garlic, with a patterned planting system, like garlic-pepper, or other vegetables. The new findings this study offers compared to previous research is the use of the MSI to analyze the determinant factors of adoption and the outcome of red garlic innovation on high plains.

Table 2 shows that half of the respondents' state that water availability is sufficient. The intensity of environmental stress (flood or drought) is considered high by about half (48.4%) of respondents. The proportion of respondents who state that weather/climate conditions are extreme (48.4%) is not much different from respondents who are indifferent (45.2%). Only 14.5% of respondents stated that their land ownership is quite large, 43.5% is small, and 27.4% are indifferent (did not respond). Farmer group dynamics are running quite well as indicated by most respondents (90.3%). Extension workers play a good role in helping farmers solve problems in shallot farming, as stated by 91.9% of respondents. Nearly half of the respondents' state that infrastructure support is adequate (46.8%), inadequate (33.9%) and indifferent (16.1%).

Most farmers agree (80.6%) that the introduced shallot innovation results in more profits. Farmers are mostly in agreement (77.4%) concur that the newly released shallot innovation has the potential to provide them the chance to try it out on a small-scale basis. About three-fourths of respondents (75.8%) agree that the introduced shallot innovation is compatible with their values, experiences, and needs. More than half of respondents (54.8%) state that the shallot innovation introduced is not complicated and not difficult to learn. Around 10% of respondents thought that the innovation was quite complicated to put into practice, and 29% of them were indifferent. Regarding learning how to improve shallot cultivation through introduced innovations, 79.0% of respondents agree that they could learn from observing demonstration plot results during the dissemination activities. Kendall Tau Correlation is shown in Table 3.

Table 3. Kendall Tau Correlation

Description	Charact. of Natural Resources	Socio-Economic Conditions	Charact. of Technology	External Supports	Adoption Behavior	Yield Increase
Characteristics of natural resources	1	0.020	0.220	0.269**	-0.430	-0.470
Socio-economic conditions		1	-0.480	-0.190*	-0.204*	-0.380
Characteristics of technology			1	0.108	0.027	-0.067
External supports				1	0.061	-0.179
Adoption behavior					1	0.373**
Yield increase						1

Note: ** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Farmers' knowledge of innovation is stated as sufficient by 50% of respondents, insufficient by 16.1% of respondents, and 32.3% of respondents do not respond. One-third (32.3%) of respondents are aware (knowing), give positive responses, and have tried the technological innovations introduced. More than half (51.6%) of respondents state they are skilled in the implementation stage of introduced innovation. Implementation skills are perceived as the most important component of adoption behavior. There is an increase in farm productivity, cost savings, and added value of 5-10% as perceived by more than half of respondents (53.2%, 51.6%, and 51.6%). Yield is considered the most important component in increasing farm productivity.

The average number of shallot farmers in the research location is graduates from secondary high school education, with a length of education of approximately 8.5 years. A higher level of education, farmers tend to be more likely to apply the innovations introduced [9, 27]. The age and level of education of a farmer will affect their physical ability and decision-making to adopt an innovation based on their knowledge. The older you are, the more mature you are in thinking and acting, the faster you will be in adopting innovation [28]. Additionally, farmers with a higher education level have broader insights, making it easier to accept innovation [29].

Kendall's analysis indicates that characteristics of natural resources and external supports have a positive correlation of 0.269, and their correlation is statistically significant at the 0.001 level (Table 3). Farmers' socioeconomic conditions and external supports have a negative correlation of -0.190, which is statistically significant at the 0.005 level. Farmers' socioeconomic conditions and adoption behavior have a negative correlation of -0.204, and their correlation is statistically significant at the 0.005 level. Adoption behavior and increased yield/productivity have a positive correlation of 0.373, and their correlation is statistically significant at the 0.001 level.

Interpretation of farmer characteristics data suggests that that the effect of agriculture entrepreneurial (AE) attitude on Bansari farmers' AE preparation is stronger than for Central Mranggen farmers. In contrast, the effect of AE commitment on Bansari farmers' AE preparation is weaker than for Central Mranggen farmers [30]. In the meantime, age and technology adoption are negatively correlated in some studies [31], but

positively correlated in others [32]. The previous findings show that farmers with higher levels of education were more likely to use the introduced innovation [27]. More educated and progressive farmers will believe that scientific developments will lead to faster adoption of new technologies than conservative and non-progressive farmers [12]. The average farming experience of farmers in Bansari is 11 years, while farmers in Central Mranggen are averaging 22 years.

Longer farming experience can additionally assist farmers better appreciate how agriculture contributes to achieving social objectives including sustaining rural areas' viability, ensuring food security, and conserving cultural heritage, according to farmer characteristics [33]. As farmers gain more experience growing crops on their land, they can better understand the impact of problems that can be addressed with introduced technology. Therefore, experience is likely to have a positive relationship with adopting the proposed new technology [11]. On average, there are more members in the Bansari farm household (4 people) than in the Central Mranggen farm household (3 people), with at least one person helping with farming work. The availability of family labor for practicing the novel technology plays a key role in the adoption. Still, the labor requirement will depend on the type of technology introduced [15]. According to a study on precision livestock farming technologies in Irish pasture-based dairy systems, the level of adoption is adversely correlated with the number of household members [34].

By their very nature, shallot prices are usually more volatile than those of nonfood commodities, which helps to explain why price fluctuations occur frequently throughout time. Monthly shallot price data in Temanggung during 2019-2022 shows a pattern of price increases starting in March, reaching the highest point in June/July, then decreasing and reaching the lowest point in August/September. Shallot prices typically fall from their highest points in mid-July to September, when harvesting is at its busiest. Following that, prices will begin to rise, reaching their peak in the first or second quarter of the following year [6]. The coefficient of variations from all set price data is calculated to describe the deviation from the average and determine the price stability of shallots. A lower coefficient of variation suggests that prices are either relatively steady or fluctuate less. The price of a crop within a certain period is categorized as stable if the coefficient of variation is in the range of 5-9% [35]. The price variation coefficients for the monthly data series of 2019-2022 are all above 9%, so the price of shallots in Temanggung is classified as unstable.

Fluctuations in shallot prices can significantly impact farmers, particularly when decisions often rely on anticipated prices. These price variations tend to affect farmers more severely in cases of poverty and small-scale farming households. For small-scale farmers, such as in Temanggung, with mostly less than 0.25 ha of landholding, any price risk or fluctuation exacerbates existing inequalities among them and increases food insecurity [36]. These market changes reflected as price fluctuations are often more detrimental to farmers than traders because generally, farmers cannot have the capacity to make time adjustments for their sales to get a more profitable selling price [24, 37]. When faced with adverse effects due to price risk or price fluctuations, farmers in Temanggung develop strategies either to mitigate the impact, for example by replacing crops (ex-post) or reducing the risk to a manageable level, for example by using improved and better-quality seeds (ex-ante).

Market risk, commonly known as price risk, is linked to the volatility of output or product prices [38]. Market changes reflected in price fluctuations can significantly influence producers' resource allocation and investment decisions. Moreover, price risk is the most influential factor in farmers' decision-making processes. Generally, fluctuations in output prices prompt farmers to decrease input utilization in their production processes. The specific response methods vary based on farmers' risk tolerance, the relationship between price and production, and market size [39].

The economics of agriculture in Indonesia grows and develops mainly based on the experience of its actors. Ecological differences influence the socio-economic and cultural behavior of farmers. Human culture cannot be shaped instantly, but rather through an intensive process of relationship between humans and the environment in which they live [40]. During this process, farmers in Temanggung adopt shallots as one of the vegetable crops, which is quite promising as one of the main sources of income. Farmers develop shallot cultivation practices through adaptation to the local ecological conditions and other challenges they face. Shallots in Temanggung are generally cultivated using mono-cropping, inter-cropping, and relay-cropping systems with other vegetable crops, such as hot pepper, broccoli, tomato, and cabbage. Shallots are a high-value vegetable crop and the estimated average production cost in 2020 is around IDR 90 – 100 million per ha. The production costs consist of seeds (41.1%), labor (30.3%), fertilizers (8.6%), pesticides (11.0%), land rent (7.1%), and others/miscellaneous (2.3%). Seeds and labor are the 1st and 2nd largest components of shallot production costs. In 2022, Temanggung Regency will be the 5th biggest contributor of shallot harvested area and production to Central Java.

The average education level of the respondents was relatively low, namely between elementary and middle school. The level of education correlates with the acceptance of the innovation technology introduced, the higher the level of education, the more farmers tend to be able to apply the innovation introduced [27, 29]. Even though the average education level of respondents was relatively low, they had a long experience as shallot farmers. This shapes their understanding of the shallot innovations offered, production risks, and market uncertainty. Farmers can develop sufficient adaptive capacity to farming failures by adjusting (reducing or adding) the inputs or cultivating shallots through intercropping or relay planting. To save labor costs for land preparation and weeding, farmers use plastic mulch to cover beds and herbicides to eradicate weeds. Shallots are a high-cost crop and all inputs except family labor must be purchased. This means that shallot farming must be managed using commercial principles. As a result, gradually there is a change in the production system which initially upheld social relations to become commercial (value) relations. Cooperative groups that ten years ago functioned as a forum for community cooperation have now changed their function to providing paid services for land preparation, spraying pesticides, fertilizing, harvesting, and so on. Thus, among farmers in the study area, there has been a change in the socio-cultural order from a "communal" society to an "individualist" and "commercial" society. However, there are still farmer groups registered as a forum for farmers to exchange ideas about agricultural problems and as an official forum for distributing government aid. Group meetings are held regularly every “selapan” (35 days). So far, farmer groups have not collected funds for savings and loans or social funds. Therefore, informal

financial sources with high interest are rampant in the area. Farmer groups also do not organize the procurement of production inputs or collective marketing efforts.

From 2018 to 2022, the Compound Annual Growth Rate of production is 14%/year, the harvested area is 15%/year, and yield/productivity is -1%/year. The growth in shallot production in Temanggung is mostly driven by the growth in harvested area. The negative contribution of yield/productivity to production growth throughout 2018-2022 should be noted as an alarming situation. The negative growth in crop yields is motivated by risk-minimizing behavior. Various types of commodities are planted intercropped and rotated on the same plot, the main one being tobacco which is then intercropped with various horticultural crops. Climate greatly influences agricultural productivity, but price fluctuations at the farm level affect farmers' income. When there is a large harvest, prices at the farmer's level are generally cheap, and increase if the harvest is small. Thus, intercropping can minimize farmers' risks while simultaneously minimizing the amount of harvest per field.

Technological intervention is needed, which has been carried out by the Central Java Provincial Agriculture Service for the last five years by holding dissemination activities on shallot innovation (use of superior seeds, raised bed techniques, optimization of planting distances, TSS seeds, and plastic mulching). Until now, efforts to increase production are still dominated by strategies to increase harvested area, which in the medium/long term is certainly not sustainable due to the undeniable land availability limitation. Therefore, there must be a shift in strategy that places greater emphasises on increasing yield/productivity through technological intervention. Innovation and technology dissemination activities that have been carried out over the last five years still need to be improved to increase the yield/productivity of Temanggung shallots in 2022 (8.4 t/ha), which is still below the average yield/productivity of Central Java (10.38 t/ha).

It becomes interesting not only to evaluate intervention strategies but also to decipher how farmers respond to those interventions. Field observations show mixed responses from Temanggung shallot farmers to the innovations introduced. While technology adoption is fundamental to improving crop yield/productivity, studies show that adoption of innovations/new technologies among smallholders in developing countries remains low, and the pace of adoption is very slow [23, 41]. If we use only an economic approach, technological intervention in society is relatively difficult to accept. With limited capital, efforts to improve community welfare are difficult. Furthermore, the limited quality of human resources is an obstacle to introducing innovation, considering that many people continue to stick to traditional agricultural activities. This can be seen from statistical data which states that the agricultural sector is still dominated by workers who have a low level of education (Figure 1).

It is, however, challenging to transfer technology to farmers since the suggested innovations and technologies, as well as the manner in which they are presented and introduced to the target groups, frequently conflict with the customs, institutions, values, and socio-cultural practices of those communities. Therefore, further studies regarding innovation/technology adoption that acknowledge the local socio-cultural and agroecological context in determining the decision-making of Temanggung shallot farmers are very necessary.

Climate conditions are considered the most important natural resource characteristics influencing innovation adoption. Climate risks in terms of high variability in temperature and rainfall, and other environmental stresses affect the probability and the level of decisions to adopt farm technologies for rainfall [42, 43]. According to several studies, the size of the farm has a beneficial impact on whether new technologies are adopted. However, effect levels varied in different situations, since farmers with small farm sizes had exhibited a trend to embrace more when thinking about an input-intensive technology [44, 45]. Previous studies also reveal that land tenure is positively related to adopting new technologies [46]. Most respondents (74.2%) state that they do not master ICT. Ease of access to information and input is only obtained by a third (33.9%) of respondents. Still, this component is considered the most important socio-economic condition of farmers to affect innovation adoption. According to some studies, users of information and communication technology benefit from a timely understanding of market information and government incentives, which boosts their motivation and allows them to promote a favorable attitude toward the adoption of agricultural technologies [47, 48].

Relative advantage (providing more benefits) is perceived by respondents as the most important innovation attribute for them in either adopting or rejecting the innovation. Characteristic of a technology or attribute of an innovation is a precondition for adoption. Farmers' subjective preferences for the characteristics of new agricultural technologies could play a critical role in the adoption decision process [49, 50]. Furthermore, the range of socio-economic, sociocultural, and agro-ecological factors interact dynamically with the features of the technology to influence farmers' decisions on whether and how to use it [20, 51, 52].

There is a strong tendency for farmers to adopt new technologies when they have access to financial infrastructures, according to numerous earlier studies. It is also emphasized that these funding sources may come from formal or informal sources. Adopting technology will benefit from having access to any of these funding options [19]. Social capital is considered quite important by 51.6% of respondents and very important by 33.9%. Adopting a particular technology will be influenced by social capital as an institutional component. A social network will make it easier to exchange opinions, knowledge, and even experiences with cutting-edge technology. Peer learning will also occur in a social network as farmers are adults. Social networks will thereby aid people in making decisions on the adoption of new technology [18, 53]. The role of extension workers is considered the most important component of external support that can influence the adoption of shallot innovations by farmers. The extension system offers a variety of options for the stakeholders to take part in training, demonstrations, and other activities that present chances to learn about the new technologies that are available and promoted. It has been suggested that farmers who interact with extension services frequently are more likely to adopt new technology than farmers who interact with them less frequently [54].

Given that labor and seeds account for the majority of cost-production components and the average land ownership was less than 0.5 hectares, it will be necessary to focus on implementing good agricultural practices to enhance farm productivity. It has been suggested that in farming operations where small-scale farmers predominate and certain technologies are crucial, the degree of collaboration in business management influences whether the various technologies employed affect productivity growth [55].

Participation in farmer groups increased yield and technical efficiency. This is because collectively formed environmental circumstances will facilitate the attainment of maximum productivity. Based on this evidence to enhance innovation adoption and productivity in farm yield for farmers in the Temanggung Regency, we recommend policy implications through the formulation of cooperative efforts in the form of farmer corporations, which allow farmers to work together to execute good agricultural practices.

When the environmental stresses happen more often, and weather/climate becomes more extreme, external supports tend to increase. As the socioeconomic conditions decrease, external supports increase. As the socioeconomic conditions increase, adoption behavior decreases. This correlation is difficult to interpret because it contradicts the empirical results of previous studies, which prove that socio-economic conditions are positively correlated with adoption behavior. When the adoption behavior improves, yield/productivity tends to increase. Furthermore, this study has not succeeded in revealing a positive or negative relationship between the variable of characteristics of natural resources, socio-economic conditions of farmers, external support, characteristics of innovation, and the variable of adoption behavior, as well as increasing yields.

4. CONCLUSIONS

Temanggung's 2022 shallot production and harvested area is the 5th largest contributor to the shallot production and harvested area in Central Java. From 2018 to 2022, the growth of shallot production is 14%/year, the growth of harvested area is 15%/year, and yield growth is -1%/year. These indicators indicate that the growth of shallot production in Temanggung is mainly driven by the growth of the harvested area. An indicator that deserves attention is negative yield growth, which shows a downward trend in shallot productivity during 2018-2022.

Weather/climate conditions, ease of access to information, innovation attribute of relative advantage, and the role of extension workers are perceived by farmers as the most important factors that can influence innovation adoption. Adoption behavior and increased yield/productivity have a significant positive correlation, meaning that the better the adoption behavior, the higher yield/productivity tends to increase.

It is recommended that the focus of intervention strategies be shifted from expanding harvested area-which is undoubtedly unsustainable in the medium- and long term, given the scarcity of available land-to increasing productivity. For policy implications in relation to enhancing innovation adoption and productivity in farm yield for farmers in the Temanggung Regency, it is recommended to formulate a cooperative approach in the form of farmer corporations, which allows farmers to work together to execute good agricultural practices.

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