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To cite this article: A L Sayekti et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 637 012004

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Seasonal variation in hybrid seed adoption: The case of chilli in Indonesia

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Abstract. Chilli is one of important vegetables in Indonesia, which is produced all year long despite the seasonal variation. While seasonality in consumer demand and producer supply of agricultural commodities is well understood, relatively little is known regarding seasonal variation in adoption of farm technologies, such as hybrid seeds, whose effectiveness may vary across seasons. Hybrid seed adoption studies in developing countries tend to suffer from a problem of temporal aggregation where data is either (1) measured in a snapshot of time, in which case seasonal variation cannot be analysed, or; (2) aggregated over a year or multiple years, where cyclical seasonal variation is washed out. This study uncovers seasonal dynamics in hybrid seed demand by analysing the case of chilli in hybrid seed use by farmers will be critical for improving seed-system. Factor demand functions were estimated using a unique dataset of 597 chilli producers. The study tested for structural change in demand for hybrid seeds going from dry season to wet season and identify season-specific constraints to hybrid seed use. Results showed that hybrid seed adoption is likely associated with water supply, especially during dry seasons. The adoption of hybrid seed could be lower in irrigated land during the rainy season.

1. Introduction

Chilli is one of the most important vegetables in Indonesia as the majority of local culture food ingredients use this commodity [1]. The indications are the high consumption rate, achieved 2.931 kg per capita in 2016, and are considered as one of the main contributors for the national inflation rate [2,3]. Seasonal nature of chilli and its dependency on weather situation contribute to the fluctuation of production and supply [4,5]. On the other hand, there is a certain occasion where the demand for chilli increase significantly, such as during important Moslem festivals (Ramadhan, Eid al-Fitr, etc.) [6]. The fluctuation of supply-side and demand-side are often miss-matched, which eventually cause the high price volatility.

The seasonal variation in chilli production is highly affected by the changing climate pattern. For example, previous studies identified that climate variability could result in destructive interaction between plant and pests/diseases [7–9]. Especially for chilli farming, the extreme weather conditions such as heavy rainy season or drought during dry season influence on the threat of pest or disease outbreaks and productivity [4]. Another example is, the level of the production frequently decreases significantly during rainy season as a response to physiological stress. Regarding its vulnerability to



the climate/weather pattern, chilli farming systems in different seasons may need different technological supports including the varietal choices [10].

Whilst the chilli farmers concern on the climate/weather variability, some farmers indicate that they aware if some chilli varieties available in the market has a better performance in a certain situation such as during rainy season. Different from perennial crops which have a technological lock-in, especially in changing variety to suit to a certain climate situation [11-15], chilli farmers can easily change varieties across seasons using an improved variety which more adaptable to the current or future climate. In the breeding programs, many improved seeds are designed to adapt across seasons, such as have the potential to capitalise on good rainfall years and adapt well during dry season [16]. Hybrid seeds, for example, are genetically superior seeds that could contribute to higher and more stable crop yields, lower losses to pests, disease and adverse weather conditions, so that it could be more profitable for farmers.

Even though the claim of superiority of hybrid seeds is well known, evidence to date suggests that many smallholders in Indonesia regularly use more open-pollinated seeds and seeds saved from previous harvests [17]. This is because smallholder farmers face constraints to adopt hybrid varieties. The farmers' behaviours to select seed types are associated with the different characters of farmers and land types [4, 18-20], the household assets [18, 21], cash flow and others income [22, 23], the output and input prices related costs [23], and the institutional factors such as organization membership [20, 21]. Those constraints may differ across seasons as the land's characteristics, household assets, and income, so that the costs may also be different.

Ensuring reliable access to improved seeds for smallholder farmers, the robust seed systems is required all year across seasons. However, little is known the factor associated with the varietal adoption across seasons. The limited of the hybrid seed adoption studies on high value commodities also to date tend to focus on the yearly adoption, and tend to neglect the dis-adoption in the short term. On the other hand, some studies conclude that technology adoption is an ever-changing process over time [24-26]. For example, [25] disscusses one fundamental limitation of micro-level adoption studies is that cross-sectional data collected in one time do not permit analysis of the dynamics of technology adoption.

To fill these gaps, this study uses data from large-scale survey in chilli farmers in Indonesia in three seasons, rainy season, first dry season, and second dry season to show the dynamic of hybrid seeds adoption across the seasons. Principally, this study contributes to give new information on the adoption process in detail since the limited adoption and dis-adoption literature on chilli and hybrid seed by seasons. This study also gives a guideline to the policy makers and supporting program on chilli farming by identifying the significant factors associated with hybrid seed adoption by seasons and targeting of hybrid seed diffusion programs.

2. Materials and methods

2.1. Data

This study used data obtained from a survey of ACIAR (Australian Centre for International Agricultural Research) Indohort project in West Java Province, Indonesia. This province was selected as it is the biggest chilli production centre in Indonesia. The survey was conducted in three districts (Garut, Ciamis, and Tasikmalaya District). The survey covered 597 chilli farmer households which selected randomly from 15 sub-district and 43 villages. Data was collected from three planting seasons, which were rainy season, first dry season, and second dry season to capture the adoption dynamic across the seasons.

2.2. Conceptual and empirical model

Farmers' adoption decisions on the chilli hybrid seeds are assumed to be based upon utility maximization. Define the varietal choices by j, where j = 1 for the hybrid seeds and j = 0 for the openpollinated or saved seeds. The non-observable of utility function ranked the preference of the *i*th farmer is given by $U(M_{ji}, A_{ji})$ (27). Thus, the utility derivable from the varietal adoption depends on M and A. M is a vector the adopters' characteristics and farm-specific attributes where A is a vector of the attributes associated with the varietal attributes. The relation between the utility derivable from a *j*th variety is postulated to be a function of the vector of the observed farmer or household characteristics, farm characteristics (e.g., farm size, age, experience, etc), and the technology-specific characteristic (e.g., yield, taste, tillering capacity, etc.) [27] and a disturbance term having a zero mean:

$$U_{ii} = \alpha_i F_i(M_i, A_i) + e_{ji} \quad j=1,0; \ i=1,...,n$$
[1]

The function of F is not restricted to be linear. In Indonesia, typically land ownership is not in a single overlay but several plots. One farmer household has more than one plots and selects more than one variety of chilli. Consequently, the farmer's selection of varieties cannot be generated into a single selection in every household. To account the farmer's choices of varietal and the intensity of adoption across seasons, Tobit Model is preferable. Tobit Model estimates the likelihood of adoption and the intensity of adoption [28]. Jumping from 0 for non-adopting chilli area to something which is a continuous decision is irrelevant employing a binary function. In addition, not all plots are planted by hybrid seed in every season, sometimes are only in one season or two seasons. Tobit Model allows for non-linearity of those conditions in the adoption decision. In this condition, the continuous decision could be interpreted as the intensity of adoption reflected by the size of the area planted with hybrid seeds.

Following Adesina and Zinnah [27], the functional form of Tobit Model is specified as μ_i is an independently, normally distributed error term with zero mean and constant variance σ^2 :

$$Y_i = X_i \beta \quad if \ i^* = X_i \beta + \mu_i > T$$

$$Y_i = 0 \quad if \ i^* = X_i \beta + \mu_i \le T$$
(2a)
(2b)

Where Y_i is the probability of adopting decision and the intensity of adoption the hybrid seeds; i^* is a non-observable latent variable, and *T* is a non-observed threshold level.

This study employs Random-effect Tobit Model by panelling across villages to estimate data to control for village level unobserved factors like elevation and soil type. The dependent variables are area planted for hybrid seed estimated in each season, first dry season, second dry season, and rainy season. The dependent variables are household characteristics, household assets, institution, and farm/plot characteristics.

3. Results and discussion

Descriptive statistics show that area planted for hybrid varieties is different from each season (Figure 1). During the rainy season, farmers tend to use the hybrid seed even though the area just slightly higher compared with dry season 1. Since dry season 1 still has relatively enough rain, the difference of planting area is not much different from the rainy season. Based on this fact, we argue that the farmers' decision to use hybrid seeds seems to have a relationship with water availability.

Table 1 shows the estimation results of the determinant factors associated with the hybrid seeds adoption across seasons. Distance from home to asphalt road is associated negatively to hybrid seeds adoption in dry season 1. It indicates that if the farmers' house is more remote from asphalt road, they are more likely to grow open-pollinated or saved seeds in this season. It also implies that better access to transportation infrastructure seems to have a relationship with the farmers' preferences toward hybrid seed. This finding is in line with research in Kenyan farmers where farmers who have access to good road and public transportation are more likely to adopt the technology [18].

Household assets are associated with hybrid seeds adoption. For example, farmers with larger land ownership are more likely to adopt hybrid seeds in dry seasons 1 and rainy season. This finding is supported by a study in Malaysia about the determinant factors of technology adoption by vegetable farmers which shows that farm size has a positive correlation on the adoption behaviours [20]. This study also in lines with the adoption rate of Bt eggplant in India where the increasing adoption rate is associated with farm size [29]. In the case of chilli, farmers are more likely to adopt hybrid seeds if

they have larger land ownership [4]. Despite the land ownerships, other production assets also associated with hybrid seeds adoption. For example, mobile phone ownership is associated with a higher probability to use the hybrid seed in dry season 1, while the ownership of cattle/buffalo, goats/sheep asset has a negative relationship. Ownership of mist blower and motorbike have a higher probability to use hybrid seed in dry season 2. The ownership of power tiller has a similar relationship in dry season 1 and rainy season regarding the probability of the farmers to use the hybrid seeds.



Figure 1. Area planted hybrid varieties in dry season 1, dry season 2, and rainy season (ha)

	dry1 - hybrid		dry2 - hybrid		rainy - hybrid	
Variables	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Age of respondents (years)	-0.02*	(0.011)	0.00	(0.007)	0.00	(0.007)
Education of respondent (year)	-0.01	(0.021)	-0.01	(0.014)	-0.01	(0.014)
Education of spouse (years)	0.02	(0.024)	0.03	(0.017)	0.00	(0.017)
Age of spouse (years)	0.01	(0.011)	-0.01	(0.008)	-0.01	(0.007)
Household member (person/s)	-0.00	(0.036)	0.00	(0.025)	0.00	(0.024)
Chili farming experience of respondent (year)	-0.01	(0.008)	-0.00	(0.006)	0.01	(0.005)
Proportion of adult between 15 and 65 years (%)	-0.00	(0.003)	0.00	(0.002)	-0.00	(0.002)
Distance from home to asphalt road (km)	-0.21**	(0.103)	-0.00	(0.002)	0.00	(0.001)
Owned area (ha)	0.38***	(0.086)	0.10	(0.063)	0.47***	(0.058)
Rent it out, pawned, share cropped, lent (ha)	-0.48	(0.380)	-0.03	(0.244)	-0.25	(0.230)
Pawned, rented, share cropped, borrow from (ha)	0.26**	(0.117)	0.07	(0.077)	0.09	(0.080)
Own of mobile phone (number)	0.15***	(0.051)	-0.02	(0.038)	-0.02	(0.036)
Own of mist blower (number)	0.07	(0.063)	0.10**	(0.043)	0.06	(0.044)
Own of power tiller (number)	1.00***	(0.292)	-0.02	(0.220)	1.01***	(0.205)
Own of motorbike (number)	-0.11	(0.080)	0.11*	(0.058)	0.02	(0.055)
Poultry (number)	-0.00	(0.000)	0.00	(0.000)	-0.00	(0.000)
Cattel/buffalo, goats/sheep asset (number)	-0.04**	(0.018)	-0.01	(0.012)	-0.00	(0.011)
Irrigated land (ha)	0.20*	(0.118)	0.27***	(0.081)	-0.18**	(0.087)
Non-agricultural income (000,000 IDR)	-0.00	(0.000)	-0.00	(0.000)	0.00	(0.000)
Constant	0.02	(0.384)	-0.75***	(0.282)	0.03	(0.274)
Observations	579		579		579	
Number of villages	41		41		41	

Table 1. Estimation results of hybrid seeds adoption across seasons

Note: The standard error in parentheses. *', '**', '***' significant at 10%, 5%, and 1% probability levels

The 7th International Conference on Sustainable Agricult	ture and Environment	IOP Publishing
IOP Conf. Series: Earth and Environmental Science 637	(2021) 012004 doi:10	0.1088/1755-1315/637/1/012004

The area of irrigated land is the only variable which significant to the probability of the farmers to use hybrid seed which implies the important role of this variable on hybrid seeds adoption. Moreover, the different sign for the rainy season and dry season indicates that the adoption of hybrid seed seems likely to have a relationship with water availability. It means that the probability of farmers to use hybrid seeds may increase if they have better irrigation support, especially during the dry season.

However, the negative sign of irrigated land with the adoption in rainy seasons might be associated with the farmers' preferences to grow staple food during the rainy season. Farmers in Indonesia typically are subsistent farmers who think to make them secure, they have to plant paddy, at least one season per year [6]. The next possible explanation is that farmers may prefer open-pollinated or saved seed to be grown during rainy in irrigated land, as this type of land potentially experiences water logging during the rainy season which could cause physiological stress for chilli or more massive disease infection. For this case, open-pollinated or saved seed may perform better. However, this argument needs further investigation.

On the other hand, irrigation system in Indonesia is facing crucial issues. Tertiary irrigation based on regulation is the farmers' responsibility. However, most of the farmers are smallholder who do not have sufficient budget to fix the damaged irrigation. Consequently, the irrigation system is getting worse. For example, in 2012, the damage irrigation chain is more than the good irrigation chain [30]. Total good condition irrigation is 3,481,298 hectares and damaged irrigation is 3,748,885 hectares [30]. The availability of sufficient irrigation all season may play an important role for the farmer to decide planting chilli.

This study reveals that variables which influence positively on hybrid seeds adoption in one season could affect negatively in other seasons or vice versa. For example, the ownership of mist blower is significantly associated with hybrid seeds adoption during the second dry season as the driest season all year but not during the rainy season. The impacts of household characteristics are also different between seasons, but the previous studies only focus on the adoption in all year long despite the seasons [31, 32].

4. Conclusion

This study attempt to understand the factors associated with the pattern of the adoption high-quality chilly hybrid seed by small-scale farmers with the case study in three districts in West Java, Indonesia. An important finding is that the farmers' decision to use hybrid seed seems to be associated with the water supply, especially during dry seasons. Factors determining the farmers' behaviours could be different across seasons, implies that it is important to understand the adoption behaviours in different time frames, especially which related to climate/weather situations. For further research, it is important to understand the relationship of chilli farmers behaviours in their decision to use a certain type of seeds with climate change issues.

Acknowledgements

I gratefully acknowledge ACIAR (Australian Centre for International Agricultural Research) for financial support during this study and to the team of "Improving Market Integration for High-Value Fruit and Vegetable Production System in Indonesia" for excellent cooperation during this study.

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