



Adoption Intensity of Agricultural Technology: Empirical Evidence from Smallholder Maize Farmers in Nepal

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Abstract – The use of improved high yielding crop varieties by farm households remains an option to increase agricultural production and ensure food security in developing countries. This study investigated the key factors associated with improved maize varieties (IMVs) adoption and intensity of adoption by farm households in Central Nepal. A multistage random sampling technique was used to select a sample of 416 farm households and interviewed by using structured survey questionnaires. We used Cragg's double-hurdle model to analyze the data. The results showed that education appeared to be positively influencing the adoption decisions while age of the household head had the negative influence on adoption decision. Additionally, farm size and livestock asset showed significant positive effect on adoption of IMVs. After the adoption, varietal characteristics such as yield potential and pest/disease resistance significantly affected the adoption intensity. Developing mechanisms to help promote IMVs adoption and its intensity by varietal specific characteristics for example yield, pest/disease resistance, palatability and storability is therefore a reasonable policy instrument to increase the adoption rate and use intensity. However, a comprehensive package that includes effective extension services and efficient input distribution system is certainly a requirement for increasing production and ensuring food security in rural areas.

Keywords – Adoption, Farm Household, Improved Crop Varieties, Double-Hurdle Model, Nepal.

I. INTRODUCTION

Adoption of improved agricultural technology is crucial to increase agricultural productivity to meet food demand and ensure food security in developing countries. Productivity improving technology facilitates the growth of agro-processing enterprise, thereby transforming the low productivity subsistence agriculture to a high productivity agro-industrial economy [1, 2]. However, many smallholders in developing countries have not been able to use improved crop technology and to realize the full potential of agricultural productivity.

Agricultural productivity in Nepal is among the lowest in the South Asian region [3]. Moreover, Nepal is the only country in South Asia where population growth rate surpasses the growth rate of cereals and thus become one of the most food-insecure countries in the region [4]. Because the sizable proportion of Nepalese farmers is still using traditional low yielding maize varieties, the yield of

the most important crop, maize, is considerably low as 2.1 tons ha⁻¹, which is far below the potential yield of 8-10 tons ha⁻¹ [4]. By area and production, maize is the second largest crop and taken as a major food crop in hilly areas of Nepal. It shared 60 percent of total agriculture production with covering 26 percent of the total cropped area in 2011 [5]. In this scenario, Nepal needs to increase production and productivity of major cereal crops by developing, disseminating and adopting improved production technology.

While there has been significant research devoted to improved agricultural technology adoption, there is surprisingly little information pertaining further impacts of adoption once the technology is adopted [6, 7, 8]. Hence, this study analyzes the adoption of improved high yielding maize varieties and its intensity among farming households in rural Nepal. It seeks to understand how policies might be changed to promote the improved seed supply mechanism and what policy options can be introduced to improve the ability of small-scale, resource-poor farmers to access, and benefit from new technologies.

One measure for increasing agricultural productivity would be greater application of modern technologies and inputs [4]. The adoption of modern technology by farmers in developing countries has been viewed as the solution to lower incomes in agriculture over the years [9]. As a result, many donor agencies have invested substantial resources in agricultural technologies in developing countries. However, most of the new agricultural technologies have not fully achieved the desired goals [10]. Factors responsible for failure of achieving goals in technology adoption can be varied. For example, some of the previous studies [1, 2, 11, 12] on technology adoption reveals that adoption decisions are based on risk, uncertainty, input rationing, information imperfections, human capital and social networks. Moreover, some studies investigated the reason why farmers discontinue technologies rather than intensifying it [13, 14, 15, 16]. Only the adoption of improved technologies will neither improves farmers' livelihoods with food security nor reduces poverty if barriers to their continued use and intensification are not identified and overcome [16]. Therefore, our study is little different in the sense that we further focused on the intensity of adoption in addition to factors influencing the adoption decisions.

Development and adoption of yield increasing seed varieties are the prerequisites for bringing accelerated

technological change and the means to increasing agricultural production and income [5]. Yield improving technologies involve bundling of improved seeds with appropriate fertilizer, pesticide and fungicide applications, and if the farmers fail to adopt the package higher outputs may not be realized [17]. In this respect, this study attempts to answer the policy questions for government and other stakeholders relevant to increase adoption, and strengthen its impact on higher income, food security and poverty reduction. Further, this study contributes to the adoption literatures by empirically identifying the determinants of the adoption of improved crop varieties and extent of adoption by smallholders maize farmers in Central Nepal. The organization of the paper is as follows: in the next section, we present the methodology describing empirical models and data used in this study. After this, we present results and discussion which is followed by conclusions at the final section.

II. METHODOLOGY

2.1 Theoretical and Empirical Framework

Coherent adoption analysis needs to view technology adoption within a conceptual framework that treats potential adopters as agents who make decisions in their own best interest. Adoption of agricultural technology and inputs use are the outcomes of optimizing by heterogeneous agents [18]. This optimization takes place in the presence of constraints on budget, information, credit access, and the availability of both the technology and other inputs. Thus, households are assumed to maximize their utility function subject to constraint resources [19, 20]. Modeling farmers' decision making about whether to adopt or not to adopt a technology constitutes a discrete (whether or not to take up the technology) and continuous (the intensity of use) decision. By following previous similar studies [1, 19,20], adoption decision is modeled in a random utility framework as follows:

$$G_i^* = X_i' \gamma + u_i \quad \text{with } G_i = \begin{cases} 1 & \text{if } G_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where G_i^* is a latent variable denoting the difference between utility from adopting improved varieties (U_{iA}) and the utility from not adopting the technology (U_{iN}), such that a utility maximizing farm household, i , will choose to adopt new technology if utility gained from adopting is greater than the utility of not adopting ($G^* = U_{iA} - U_{iN} > 0$). The term $X_i' \gamma$ provides an estimate of the difference in utility from adopting the technology ($U_{iA} - U_{iN}$), using the household and farm-level characteristics, X_i' , as explanatory variable, while the term γ is a vector of parameters to be estimated, and u_i is the error term.

To allow for the application of theoretical model, we assume that the adoption process involves two different decision stages [21]. First, farmer decides whether or not to adopt the technology (a dichotomous choice), and second, the intensity of adoption or the proportion of acreage under that particular technology once adopted (a continuous variable). By following [22, 23, 24], we

employed a relatively new and innovative econometric tool, Cragg's double-hurdle model, to analyze the data. The double-hurdle model assumes that two separate hurdles must be passed before a positive level of technology use intensity can be observed. In this study, farm households make two decisions with regard to adopting and intensifying IMVs, each of which is determined by a different set of explanatory variables. In the first-hurdle, we estimate the probit model to determine the probability of adopting IMVs by farm households and a truncated regression model to determine the extent or intensity of adoption in the second-hurdle. The model specification is as follows:

$$P_i^* = \alpha Z_i' + u_i \quad (2)$$

$$I_i^* = \beta X_i' + \mu_i \text{ if } P_i^* > 0 \text{ and } \beta X_i' + \mu_i > 0 \quad (3)$$

where, P_{i1}^* is a latent variable that represents the probability of the household's decision to adopt IMVs and I_i^* is a latent variable representing the extent of adoption (or proportion of IMVs cultivation). Z_i and X_i are covariates explaining the adoption decision and use intensity, respectively, α and β are the parameters to be estimated, while u_i and μ_i are the respective error terms assumed to be independent and normally distributes as $u_i \sim N(0,1)$ and $\mu_i \sim N(0,\sigma^2)$.

2.2 Data and Definition of Variables

The data used in this study were obtained from a survey conducted in four districts of Central Nepal during 2013 crop season (Fig. 1).

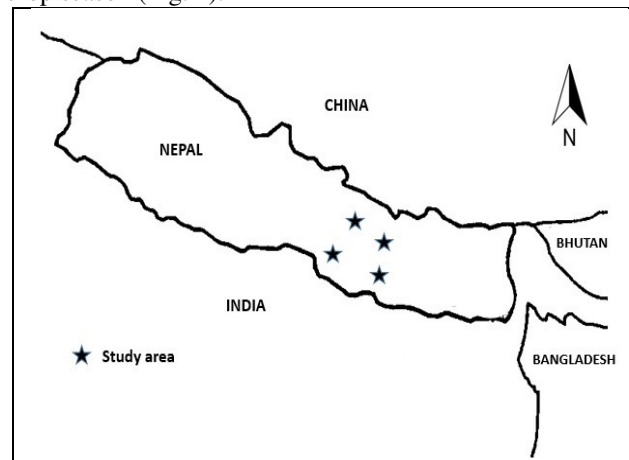


Fig.1. Map of Nepal showing study area.

Source: MoAD, 2013 (Edited)

Using a multistage random sampling procedure, four districts namely Kavre, Nuwakot, Chitwan and Rautahat were purposively selected based on the intensity of rice production, agro-ecology and accessibility. In the second stage, eight villages were randomly selected (two villages from each district) which was followed by the selection of 16 Wards (Ward is the lowest administrative unit at village level). Finally, a representative sample of 416 farm households (26 households from each Ward) was randomly drawn and interviewed using the standardized survey questionnaires. The number of sampled households and their adoption status by region are reported in Table 1.

Table 1: Number of Sample Households Surveyed and their Adoption Categories by Region

Region	IMVs adoption status		Regional total
	Adopters	Non-adopters	
Hill region	148 (52.11%)	60 (45.45%)	208 (50%)
Tropical plain region	136 (47.88%)	72 (54.54%)	208 (50%)
Total by status	284 (68.27%)	132 (31.73%)	416 (100%)

Source: Author's survey, 2013.

The selected districts represent major maize producing area, fertile and productive land and suitable agro-ecology for maize production where farmers have begun to adopt improved crop varieties. These districts also have the highest contribution to national production [5]. Kavre and Nuwakot represent hill districts with mild sub-tropical climate whereas Chitwan and Rautahat represent tropical plain districts with hot tropical climate. Nepal Agricultural Research Council (NARC) is also located in the area which is a big asset to Central Nepal in terms of information of quality seeds and other research outcomes.

In this paper, adopters are classified as farmers who planted any of the IMVs irrespective of the area planted, and non-adopters are those who did not cultivate any of the improved varieties. Many adopters did not fully allocate their land to improved varieties as they also grow traditional varieties. Our main interest in this paper is to see whether the adoption of IMVs is being continued and intensified by farm households. For this, similar to previous studies, the adoption decision is modeled here as binary variable at the household level [1, 25, 26, 27, 28], and further, continuous variable as the area under improved varieties to determine the factors of intensity of adoption [23].

The explanatory variables used in this paper were selected based on the adoption literatures that reflect the farm and farmers' characteristics, institutional and access related, and technology specific attributes which are described as follows:

The age of household head is incorporated as it is believed that with age, farmers accumulate more personal capital and, thus, show a greater likelihood of investing in innovations. However, it may also be that younger household heads are more flexible and hence likely to adopt new technologies. The expected sign of the coefficient on age is indeterminate. A dummy variable for gender of the household head is included to capture gender difference. It has been argued by some authors that women are generally discriminated against in terms of access to external inputs and information [29]. This hypothesis implies that males are more likely to adopt improved technology than females. More educated farmers are typically assumed to be better able to process information and search for appropriate technologies to alleviate their production constraints [12]. The expected sign on the coefficient on education is positive. Size of household is another variable used in the model. A large family often has the larger number of working members. Generally, an increase in family size is likely to increase the probability of adoption.

The size of the family farm is often argued as an important factor in affecting adoption decisions, with the

larger farms having positive influence in adopting improved technology [25, 27, 30]. The expected sign on the coefficient on farm size is positive. Other variables, for example, livestock assets, off-farm work participation, and access to seed were also expected to have positive effect on adoption of IMVs and use intensity.

Membership to a farmers group and cooperatives was included because it has been shown that farmers within a group learn from each other how to grow and market new crop varieties [31, 32]. The expected sign on the coefficient on membership in farmers group and cooperatives was positive. Availability of extension services is expected to have a positive effect on adoption based upon the innovation-diffusion theory. Such contacts, by exposing farmers to availability of information can be expected to stimulate adoption [33]. A positive relationship was hypothesized between extension services and the probability of adoption of a new technology. Distance to market is assumed to play an important role in technology adoption. The hypothesis here was that, the further away a household is from input and output markets, the smaller is the likelihood that they will adopt new technology [34]. The coefficient on the distance of the household to the nearest input or output markets was expected to be negative.

Farmers generally compare the available improved seeds with their choice of best local variety in terms of technology specific attributes such as yield, pest and disease resistance, palatability and consumer acceptability [23]. Therefore, the perceptions on these technological attributes of IMVs were hypothesized to have a positive impact on adoption. To reflect unobserved regional differences, the location of the farm household was specified as a dummy indicating whether the respondent lives in tropical plain region.

III. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

Descriptive statistics and explanation of the variables used in the study are shown in Table 2. As observed in the table, majority (68%) of sample households adopted IMVs. The average household size was 6 persons which is consistent with the national average in Nepal [35]. The average age of respondents was 44 years and the majority (70%) of the sample households was headed by male which is expected in Nepalese context. The average percentage area allocated for IMVs was about 66 % while the average farm size was 0.65 hectare which is comparable to the national average of 0.7 hectare. Furthermore, 76 percent of the respondents reported to

have income from off-farm activities and almost 58 percent reported to have livestock (cattle, buffalo, goat, oxen). The mean years of formal education was nearly 8 years which is comparable to national average of 8.1 years for adults [35]. Farmers, on average, reported that 59

percent had access to extension service when needed. Amongst the households, majority (72%) is participated in farmers' group and cooperatives, and 64 percent reported that improved seeds were available in the local stores.

Table 2: Descriptive Statistics of the Variables Included in Empirical Models

Variables	Description	Mean	Std. Dev.
<u>Dependent variable</u>			
IMV_adoption	= 1 if respondent plants IMVs	0.682	0.466
<u>Independent variables</u>			
Age	Age of household head in years	44.56	10.81
Male_dummy	=1 if the head is male	0.709	0.456
Education	Years of formal education of the household head	7.906	3.368
HHsize	Number of household members	5.793	2.012
Farm_size	Cultivated area by household in current year (ha)	0.655	0.278
Area_IMVs	Percentage of land area allocated for IMVs	65.97	17.89
Livestock_asset	=1 if household own livestock	0.579	0.494
Off-farm_work	=1 if participated in off-farm work	0.767	0.423
Partici_group	=1 if participated in information/farmers' group	0.723	0.448
Extn_service	=1 if extension service is available	0.591	0.492
Seed_access	=1 if seed is available at local store	0.644	0.479
Dist_mrkt	Distance to input/output market (km)	12.89	5.88
Yield_potential	=1 if the IMVs to yield more than the local one	0.827	0.379
Pests_resistance	=1 if the IMVs to be more resistant to pests/diseases than the local one	0.478	0.500
Palatability	=1 if the IMV is perceived to be more palatable than the local one	0.204	0.403
Region_dummy	=1 if the household resides in tropical plain region	0.500	0.500

Source: Author's survey, 2013.

Table 3 presents the results of statistical significance tests on equality of means for continuous variables and equality of proportions for binary variables for adopters and non-adopters. There appeared to be a significant difference in age and the years of schooling of the household heads among adopters and non-adopters, with the former being younger and more educated. Further,

farm size, livestock assets, participation in groups, access to seed, and extension service showed significant differences between these two groups while gender of household head, off-farm work participation and distance to market did not show significant differences between the adopters and non-adopters.

Table 3: Characteristics of Adopters and Non-adopters

Variables	Adopters	Non-adopters	Difference	t-Stat (χ^2 value)
Age of household head (years)	42.22	49.61	-7.38	6.83***
Gender of household head male (%)	70.77	71.21	-0.44	0.01
Years of schooling of household head	9.14	5.25	3.89	-12.99***
Household size (number)	5.97	5.40	0.57	-2.72***
Farm size (ha)	0.75	0.44	0.31	-12.70***
Livestock assets (dummy)	0.68	0.35	0.34	42.27***
Off-farm work participation (dummy)	0.75	0.81	-0.06	2.07
Participation in group (dummy)	0.88	0.38	0.51	114.9***
Access to seed (dummy)	0.79	0.33	0.47	85.56***
Distance to nearest market (km)	12.97	12.72	0.25	-0.39
Extension service received (dummy)	0.84	0.06	0.78	225.38***

Note: *** denotes statistical significance at 1% level of confidence.

3.2 Factors Affecting the Adoption Decisions

The results of the adoption model that determines the factors influencing the probability of adopting IMVs are presented in Table 4. The results indicates that age and education of the household head significantly influenced the probability of adopting IMVs, which is consistent with the findings in previous studies [19, 23, 25]. As expected, the probability of adopting IMVs is negatively influenced by age, which means that the older farmers are less likely to adopt improved seeds. This result is consistent with [36]. There may be the case that local maize, which has a flint grain texture, is more palatable, contains higher proportion of hard starch granules, easy to manage postharvest and high flour to grain extraction [37].

Therefore, older people, who are used to the traditional flour for their daily consumption, are more resistant to change to improved or hybrid seeds which have either dent or semi-flinty grain textures. Similar to previous findings by [23, 30, 38], the results suggests that the more educated the farmer is, the more likely he/she will adopt IMVs possibly because they can better process information more rapidly than otherwise.

Two important wealth related variables, farm size and livestock asset, positively and significantly affect the adoption of IMVs. The positive sign on farm size indicates that as farm size increases, the likelihood of adopting IMVs increases. This result is consistent with earlier findings [25, 27, 30].

Table 4: Probit Estimates of the Probability of Adoption Decisions

Variables	Parameter estimates	z	Average marginal effects
Age	-0.025 (0.015)	-1.66*	-0.002
Male_dummy	-0.281(0.317)	-0.88	-0.022
Education	0.148 (0.046)	3.22***	0.011
HHsize	0.021(0.095)	0.23	0.002
Farm_size	2.281 (0.786)	2.90***	0.175
Livestock_asset	0.669 (0.290)	2.30**	0.051
Off-farm_work	-0.325 (0.365)	-0.89	-0.025
Partici_group	0.691 (0.307)	2.25**	0.053
Extn_service	2.365 (0.365)	6.47***	0.181
Seed_access	0.553 (0.282)	1.96**	0.042
Dist_mrkt	-0.044 (0.031)	-1.40	-0.003
Yield_potential	1.307 (0.415)	3.15***	0.100
Pests_resistance	0.268 (0.279)	0.96	0.021
Palatability	0.338 (0.364)	0.93	0.026
Region_dummy	-1.094 (0.351)	-3.12***	-0.084
Constant	-2.803 (0.958)	-2.93***	
Log likelihood	-56.6217		
LR $\chi^2(15)$	406.61		
Prob> χ^2	0.0000		
Pseudo R ²	0.7822		
% correctly predicted	95.19%		

Note: ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively. The numbers in parenthesis are standard errors.

We found that the higher the participation of farmers in groups and local cooperatives, the more likely that households will adopt improved seeds. This supports the hypothesis that farmers' exposure to various information sources is able to analyze the risks, benefits and take advantage of new innovations. This result is consistent with [25, 39]. The availability of extension services significantly increased the adoption of IMVs among farm households, underlining the importance of extension in promoting adoption. This result is consistent with [19, 30, 39]. IMVs adoption is positively influenced by the availability of seed in local stores. This is expected as farming households residing in remote areas hardly get reliable sources of improved seeds, magnifying the importance of the availability of seed in local area. Our possible explanation is that availability of seeds in the

local stores eases the households to purchase and cultivate new improved varieties in their field [19, 23].

Yield potential had positive and significant impact on farmers' decisions to plant a given variety [23]. It is, therefore, not surprising that the probability of adopting an IMV will increase once a farmer perceives that the yield potential of the given variety is higher than that of the existing local ones. Households in hill region were more likely to adopt IMVs in contrast to their counterpart in tropical plain terai region, suggesting the suitability of climate for maize production in mid-hill region. In this analysis, we also estimated average marginal effects which are presented in column 4 of Table 4.

3.3 Intensity of Adoption

In this section, we present the results of the intensity of adoption of IMVs using the second step of Cragg's

double-hurdle model. We performed truncated regression, so, all the zero values (those who did not adopt IMVs) from the selection model (first hurdle) were truncated and only positive values (proportion of land allocated for IMVs) were included in the regression model. After the adoption, as shown in Table 5, most of the socio-economic related variables such as age and education were not significant. This implies that the age and education of household head no longer played significant role in determining how much area to be allocated for IMVs after the adoption.

Table 5: Estimates of the Intensity of Adoption

Variables	Coefficient	Z value
Age	0.179 (0.112)	1.61
Male_dummy	0.729 (2.274)	0.32
Education	0.073 (0.438)	0.17
HHsize	-0.203 (0.521)	-0.39
Farm_size	-7.282 (4.115)	-1.77*
Livestock assets	7.059 (2.119)	3.33***
Off-farm_work	0.784 (2.308)	0.34
Partici_group	5.515 (3.068)	1.80*
Extn_service	8.464 (2.683)	3.15***
Seed_access	6.765 (2.435)	2.78***
Dist_mrkt	-0.317 (0.185)	-1.72*
Yield_potential	27.846 (6.708)	4.15***
Pest_resistance	4.081 (2.034)	2.01**
Palatability	2.545 (2.246)	1.13
Region_dummy	-6.354 (2.438)	-2.61***
Constant	18.007 (10.68)	1.69*
Sigma (σ)	15.921 (0.672)	23.69***
Log likelihood	-1188.5023	
Wald $\chi^2(15)$	73.03	
Prob > χ^2	0.0000	
Number of observations	284	

Note: ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively. The numbers in parenthesis are standard errors.

Similar to findings of [23, 38], the significant and negative relationship between farm size and intensity of adoption suggests that any additional land increases was diverted to other crops. Participation in farmers groups and the access to extension services significantly affected the adoption intensity of IMVs among farm households, underlining the importance of extension services in farming operation. Similarly, access to seed was found to be positively associated with the intensity of IMVs adoption, suggesting that the higher the accessibility of improved maize seeds the larger the proportion of land is allocated to plant IMVs. The significant and negative sign of distance to market shows that the farm households are willing to adopt and expand the area cultivation of IMVs if their farm is located nearby input / output markets. This result is consistent with [23].

Two technology specific variables, grain yield potential and pest resistant, significantly influenced the intensity of adoption. If the farmers perceive that the new variety is superior to the local ones in terms of yield and pest/disease

resistant, they will increase their intensity of use by almost 28 percent and 4 percent respectively. This results are consistent with [23]. The negative and significant result of the regional dummy variable indicated that farmers living in hill region allocated more area for IMVs than their counterpart living in tropical plain region. This reflects the unobserved regional differences between two agro-climatic regions. Our results are robust and reliable enough to show the importance of improved maize seed technology adoption among farm households in rural areas. We believe that this study investigation has significant learning potential to international readership and addresses the challenges facing food security in developing countries.

IV. CONCLUSION

Farm households in developing countries face everyday decisions on how to optimize the production function by minimizing the constraint resources. Such decisions include choice of adopting improved and time saving technologies that enables farmers to increase farm production and profit. This paper addresses this issue by examining the key factors of adoption decision of IMVs and intensity of adoption by farm households in Central Nepal. Using cross-sectional data obtained from a household survey and employing Cragg's double-hurdle model, this study found heterogeneous factors influencing two different stages of IMVs adoption and use intensity.

There seem to be no significant gender differential between adopters and non-adopters of IMVs. However, there were significant differences in age and education of household head, household size, farm size, access to seed and extension services between the adopters and non-adopters. The study revealed that the factors influencing the probability of adoption were age and education of household head, access to improved seeds, livestock assets and availability of extension technicians. Further, the likelihood of adoption is significantly and positively associated with the participation in farmers' group and cooperatives. Interestingly, farmers' characteristics related variables such as age, education, gender no longer played significant role in determining how much area was allocated for IMVs after the adoption. In this stage, technology specific attributes such as yield potential and pest/disease resistant appeared to be significant. Distance to market has a negative and significant impact on the intensity of adoption by farm household. Regional location of farm household also influenced both the adoption decision and intensity of adoption.

At the policy level, as technology specific variables played a significant role, intervention program on varietal package is necessary which offers choice among appropriate pools of seed varieties with useful traits such as high yields, pest/disease resistant and suitable to local climatic condition. Increasing adoption of such varieties helps increase production, ensure food security and improve the general livelihoods of farm households. Access to information and extension services should also be strengthened by enhancing and institutionalizing the

role of information and communication offices in disseminating field trial results on IMVs and facilitating farmers' access to government programs and services.

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