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# Demographic factors and perception in rhizobium inoculant adoption among smallholder soybeans (*Glycine max* L. Merryl) farmers of South Kivu Province of Democratic Republic of Congo

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**The use of rhizobium inoculants fertilizer in soybean production has been practiced for over a century all over the world, but in Africa, the technology is relatively new. Rhizobium inoculants have been disseminated in Eastern Democratic Republic of Congo (DRC) by Nitrogen 2 Africa (N2AFRICA) project of CIAT and later IITA since 2010. However, demographic factors and perception in rhizobium adoption remain unknown. We assessed the demographic factors and perception in rhizobium inoculant adoption among 193 smallholder soybeans farmers of South Kivu Province of DRC. The information was collected in September 2018 and included farms and farmers socio-economic characteristics and farmer's adoption and perception of rhizobium inoculants. We used Probit model to assess the factors that are likely to influence the adoption and measured the perception using 5-point Likert-type scale. Results indicated that the adoption of rhizobium inoculants was very low in South Kivu (21%) and was highly influenced (P<0.01) by gender of the household head, farmer's location, education type of household head, the knowledge of nodules roles and the household income. The perception of inoculant by farmers also highly influenced its adoption. Furthermore, farmers strongly perceive rhizobium as an affordable nitrogen source for enhancing soybeans productivity but less available in the market. More effort is needed in farmers' education about BNF to improve adoption of inoculants.**

**Key words:** Adoption, perception, smallholder's farmers, Biofix, Soybeans, N2 Africa, rhizobium inoculants.

## INTRODUCTION

The Democratic Republic of Congo is among the biggest countries in Africa and offers great potential for increased

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agricultural productivity (Lecoutere et al., 2009). Currently, its productivity is among the lowest in Africa and in the world (FAO, 2018) due to declining soil fertility (Pypers et al., 2011), and aggravated by lack of specific information on soil management and sustainability at farm level (Bashagaluke et al., 2015). Most crops; cereals and legumes, are cultivated without application of fertilizers and hence low yields (Lambrecht et al., 2016).

Soybean (*Glycine max* (L.) Merrill) is one of the most important legume crops (Hartman et al., 2011) cultivated in South Kivu province of Democratic Republic of Congo for its diverse uses (Bisimwa et al., 2012). This crop has been promoted since 1985 by humanitarian organization and United Nations agencies such as FAO, to address the issues of malnutrition induced human diseases following the political strife of 1985 (Kismul et al., 2015). Its cultivation has increased as a result of its utilization in public schools and hospitals to prevent and cure the wasting effects of malnutrition (Bisimwa et al., 2012; Kismul et al., 2015), in household (Pypers et al., 2011; de Jager et al., 2019) and in livestock especially in poultry production and aquaculture (Khojely et al., 2018).
Despite its importance, the potential productivity of this crop is challenged by poor soil fertility and low accessibility to mineral fertilizers by poor-resources farmers (Khojely et al., 2018; Pypers et al., 2011); hence reported yield is very low (0.51 t/ha) (FAO, 2018) compared to potential yield of 3t/ha (Salvagiotti et al., 2008). The use of organic fertilizers to alleviate this problem is constrained by their very limited availability leading to a very low utilisation per unit area (Lambrecht et al., 2016). The mineral fertilizers are also very expensive to farmers. Odame (1997) estimated that a farmer must sell about 10 kg of maize or 5 kg of common bean to buy 1 kg of N or P in the form of mineral fertilizers.

Fortunately, soybean is able to fix its own nitrogen from atmosphere in symbiosis with rhizobia bacteria by the process called Biological Nitrogen Fixation (BNF) (Collino et al., 2015; Giller et al., 2011; Hungria et al., 2005; Dakora and Keya, 1997). By BNF process, soybean crop can fix up to 80% of its nitrogen needs and thus alleviate the need of applying mineral fertilizers that are neither available nor affordable by smallholder's farmers (Chianu et al., 2011). Many soils contain *Rhizobia,* but often in small populations and they are less effective and mostly non-compatible to soybeans (Abaidoo et al., 2007). This requires inoculation with a highly effective and competitive Rhizobia strain in high quality formulations. Two approaches were used by international organization to address the problem of low yields of soybean in Africa. First, breeding for development of soybean cultivars that can nodulate freely with native rhizobia population (Mpepereki et al., 2000; Tefera, 2011). Second, introduction of inoculants containing highly effective rhizobia strains (van Heerwaarden et al., 2018).

Therefore, rhizobium inoculants fertilizers were introduced among smallholder's farmers of South Kivu by the N2 Africa project of International Institute of Tropical Agriculture(IITA) and partners' organizations, first in 2010 (Chianu et al., 2011; van Heerwaarden et al., 2018). The introduced commercial formula was the BIOFIX®. This inoculant is produced in Kenya and was initiated as part of the Microbial Resources Centre Network (MIRCEN) that was established by the University of Nairobi (Mutuma et al., 2014; Chianu et al., 2011). This product is licensed and marketed by MEA Limited, which started its production in 2010 (Ampadu-Boakye et al., 2017). Yield increase was observed in soybean inoculated by this inoculant in many countries (Waswa et al., 2014; Ulzen et al., 2016; Van Heerwaarden et al., 2018; Thilakarathna et al., 2019).

BIOFIX® for soybean contains the *Bradyrhizobium japonicum* strain USDA 110, a widely used industry standard concentrated at >$10^9$ Rhizobia $g^{-1}$ in an organic carrier material (Ulzen et al., 2016). This is one of the main legume inoculants commercially available in East Africa and is steadily being promoted among farmer groups of many countries assisted by many organizations such as N2 Africa (Chianu et al., 2011; Karanja et al., 1998; Wafulah, 2013; Farrow et al., 2016). Whereas Woomer et al. (1997) and Odame (1997) identified low farmers' awareness and inoculants unavailability as an important constraint to its adoption, the inoculant adoption and profitability assessed in other countries (Getachew, 2016; Mutuma et al., 2014; Nekesah, 2017; Ulzen et al., 2016); there is no information on demographic factors in rhizobium inoculant adoption among smallholder soybeans farmers in South Kivu Province of D.R Congo. Furthermore, previous conducted studies did not assess the perception of smallholder's farmers of the inoculants products since the adoption largely depends on perceptions (Negatu and Parikh, 1999; Ojiako et al., 2007). Therefore, the objective of this study is to assess the demographic factors and perceptions that are likely to influence the adoption of rhizobium inoculants among soybean smallholder's farmers of South Kivu Province of Democratic Republic of Congo.

## METHODOLOGY

### Study area

This study was conducted in South Kivu Province of Democratic Republic of Congo, targeting three villages namely Lurhala, Kalehe and Kamanyola where N2 Africa project of IITA has disseminated BNF technologies including rhizobium inoculants (Chianu et al., 2011). South Kivu Province is located in the Eastern part of Democratic Republic of Congo between 1° 36' and 5° South latitude and 26° 47' and 29° 20' East longitude (Pypers et al., 2011). The province of South Kivu has an area of 69,130 $Km^2$ and its population is currently estimated at 3,500,000 peoples with an average density of 50.6 inhabitants per $km^2$ (DSRP, 2011).

The area is recognized as a high humid forest zone depicted by high vegetation diversity (Potapov et al., 2012); highlands and soils are mostly infertile Dystric or Humic Nitisols or Humic Ferralsols (van Engelen et al., 2006). This region has a tropical climate with an average annual rainfall of 1500 mm and average temperature of 18°C (Nash and Endfield, 2002). The main activity in the region is agriculture with most cultivated crops including banana, cassava, beans and traditional livestock comprising cattle, sheep, goats, chicken and pigs (Maass et al., 2012).

### Sampling and data collection

The survey was conducted in two stages; a pre-survey (conducted from 23rd to 25th June 2018) was done in consultation with N2 Africa country coordinator and field specialist to determine the villages where inoculant product was promoted. From this stage, three villages were purposively selected namely Lurhala, Kalehe and Kamanyola and the sampling frame determined. At the second stage, two lists of soybeans farmers; (i) participating and (ii) not participating in the N2 Africa project were drawn in each village with the help of the farmer's group contact person and N2 Africa project field technician. Lastly, a random equal number of farmers were drawn from the two lists to participate in the survey conducted from 1st to 30th September 2018. From this process 200 farmers were selected but only 193 respondents were considered as they met the requirements of the survey. The true sample size was determined as guided by Murongo et al. (2018).

Data were collected through personal interviews, using pretested questionnaires. Information collected for demographic factors in inoculants adoption included farmers' characteristics (gender, education, household size and management, etc.), farm characteristics (farm size, number of cultivated land, etc.), institutional factors (group membership, credit access etc.) and capital endowment. Concerning perception of inoculants product, farmers were asked about their perception on the importance of soybean, the effectiveness of rhizobium inoculant in improving soybeans productivity, its availability, its accessibility and affordability. The market prices were used to estimate the cost of farm inputs and value of outputs in order to compute the gross margin.

### Analytical framework

Technology adoption can be modeled using a utility maximization problem (Sidibé, 2005). A farmer will only adopt a new technology, for example an improved crop variety or fertilizer, when the utility he derives from this technology ($U_n$) is greater than the utility of a traditional technology he had been using ($U_t$) (Mercer, 2004). The utility derivable from the new technology is considered as a vector of several factors ranging from farm observed characteristics (e.g., farm size) to perceived technology characteristics ($X_i$) through institutional factors (e.g., distance to the market, membership to farmers' organizations), farmer characteristics (e.g., gender of the farmer, age) and a disturbance term with mean zero (Sattler and Nagel, 2010). Perceived technology characteristics, or perceived varietal attributes under crop technology adoption, are also function of subjective and/or objective characteristics of the technology itself, but also farm and farmer-specific characteristics (Mariano et al., 2012). Thus, a given farmer, in the adoption process, will always consider the benefits and losses (both economic and social) of the new technology and eventually chooses the technology (*T*) that promises higher utility compared to the traditional technology.

Suppose an individual household's utility of adopting a new technology, depending on a vector of social, economic and physical factors (*X*), denoted by $U_n(X)$, and the utility of remaining with the traditional technology denoted by $U_t(X)$, then the utility models associated with adoption of the old and new technologies can be apprehended through a linear relationship:

$$U_n(X) = \theta_n' X + E_n \quad (1)$$

$$U_t(X) = \theta_t' X + E_t \quad (2)$$

Where $\theta_n' X$, $\theta_t' X$ and $E_n$, $E_t$ are response coefficients and disturbances associated with adoption of the new and old technologies respectively.

Under the adoption framework, the state of mind of the farmer is not observable but can only be seen through outcome of a decision-making process and this allows the classification of farmers into two groups: adopters and non-adopters. The adoption process can thus be modelled using a latent variable (Horrace and Oaxaca, 2006) denoted by ($y^*$). In our case, it measures the difference between the utility derived from the new technology and that of the old technology $[U_n(X) - U_t(X)]$. This variable can take both positive and negative values depending on whether the utility of the new technology outweigh that of the old technology and vice versa. So, in the real world, the outcome variable ($Y$)will take the value of 1 if the farmer adopted or is willing to adopt the new technology and 0 otherwise. Mathematically, the probability that a given farmer will adopt the new technology considering the explanatory factors can be expressed as follows:

$$\begin{aligned} P(Y=1) &= P(U_n > U_t) \\ &= P(\theta_n' X + E_n > \theta_t' X + E_t) \\ &= P[X(\theta_n - \theta_t) > E_t - E_n] \\ &= P[X\theta > E] \\ &= F(X\theta) \end{aligned} \quad (3)$$

Where $P$ is the probability function, $\theta = (\theta_n - \theta_t)$, a vector of unknown parameters to be estimated and which can be interpreted as net influence of explanatory variables on technology adoption; $E = (E_t - E_n)$ a random disturbance term; and $F(XB)$ the cumulative distribution function of $F$ evaluated at $XB$.

The parameters of such model can be estimated using maximum likelihood technique due to the non-linearity nature of the model (probabilistic model). Several empirical models can be used to map the relationship between the dependent variable and the independent variables. These include the Linear Probability Model (LPM) (Horrace and Oaxaca, 2006), logit and probit models (Briz and Ward, 2009). One of the major flaws of the LPM model comes from its estimation technique. It uses ordinary least squares (OLS) to estimate parameters of a binary-outcome variable. The predicted probability for such model may also go beyond 1 or below 0, violating basic principles of probability (Horrace and Oaxaca, 2006). This has made the model less used in studying technology adoption in empirical studies. Therefore, Logit and Probit are suitable for the current situation because they analyze better dichotomous outcome (Woodridge, 2002) but the choice between them has always been subject to several controversies. Cakmakyapan and Goktas (2013), for example, conducted a series of simulation in order to determine in which situation each model would be the most appropriate. Considering three cases from the variance and covariance matrix, namely "high", "low" and "no", they found that though both models were similar and could be used interchangeably. According to Zamasiya et al. (2014), the logit model seemed more appropriate in larger sample sizes (500, 1000) as compared to the probit model. In the current study, Probit model was used to identify determinants of adoption of rhizobium inoculants among soybean farmers. Farmers' perception towards rhizobium inoculants was measured using 5-point Likert-type scale (Preston and Colman, 2000; Bagheri, 2010;

Li, 2013). XL Stat software version16 was used for descriptive statistics and the statistical package R, version 4.1 for regression analysis. The Principal Component Analysis (PCA) was used to isolate factors and only significant variables toward adoption and perception were included in the regression analysis. Hosmer-Lemeshow test was performed to measure model goodness-of-fit (Fagerland and Hosmer, 2012).

## RESULTS AND DISCUSSION

### General characteristics of soybean farmers

The mean age of soybean farmers of South Kivu was 46 years (Table 1) with most of farmers being within productive age (more than 46 years old). This result shows a low involvement of the youths in soybean production, consequently, there is need to encourage youth involvement. This may be due to the fact that soybean is a crop cultivated for both nutrition security and cash income generation of the household; which is an elders' concern, on one hand. On the other hand, this can be explained by the fact that youths are not interested in performing various agriculture related activities. This result is consistent with Zamasiya et al. (2014) and Ojiako et al. (2007) who found that most soybean farmers are within productive age (43-50years).

Of the interviewed farmers, 68.7% were men while 31.2% were women. Men are mostly represented in the soybean culture in the study area, because this crop is becoming a cash crop in South Kivu due to the increasing market opportunity; men are mostly interested in such crops. These findings are in discordance with Mutuma et al. (2014) who found that in Kenya women are more involved in soybeans culture than men. This discordance is noted probably because the market opportunity for soybean in Kenya is not that considerable compared to D.R.Congo, where soybean crop is used like medicinal food to cure malnutrition diseases (Bisimwa et al., 2012).

The education type among soybeans farmers was mostly formal education (Table 1) with mean of 5 years spent in school (data not presented). The low education status is explained by the less access to education in rural area due to poverty. A study conducted by Mariano et al. (2012) also reported a low education status of farmers in Philippine and the same study demonstrated the negative influence of this low education on adoption of modern rice technologies. Most of the interviewed farmers had a mean of 26 years of experience in growing soybean (data not presented). The most practised religion was Catholicism (72.9%) followed by Protestantism (23.9%). The main source of income in the study area was the sale of agricultural products (88.4%) followed by small trade (6.8%). The household income was controlled mostly by both conjoint (45%) followed by the husband alone (23%) and was in the range of 50-100 US dollars (29%). Only few households (28%) received a mean credit of 128 USD and many households (68.7%) were members of farmer's group (data not presented).

The mean number of fields allocated to soybean was 2 fields per household with mean area under soybean crop of 0.46 ha (data not presented). This farm size is above 0.1ha, which is the approximate farm size usually allocated to legumes in Sab-Saharan Africa (Chianu et al., 2011) showing the importance of soybeans in this part of Africa.

### Comparative characteristics of soybean inoculants users and non-users

The number of soybean inoculants users was 41 against 152 of non-users (Table 2) showing an adoption rate of 21%. The users of soybean inoculants had more access to credit than non-users ($P<0.01$), they were more involved in groups and had stayed longer in groups than non-users ($P<0.01$). In addition, many of them were beneficiary of development or humanitarian projects ($P<0.01$). On the other hand, users of soybean inoculants had more awareness on roots nodules roles ($P<0.01$) and were in contact with organization promoting inoculants ($P<0.01$). These results were expected and showed that inoculants users have more access to information, and this increases their chance to adopt new technologies.

This corroborates findings of past studies (Getachew, 2016; Mutuma et al., 2014; Nekesah, 2017) who stated that projects that promote use of new agricultural technologies are important in facilitating their adoption. Katungi and Akankwasa (2010) also found that farmers who participate more in community-based organizations are likely to engage in social learning about the technology hence raising their likelihood to adopt the technologies. These finding imply that structuration of farmers in groups is important for better understanding and utilization of new technologies.

### Factors influencing inoculants adoption

The location, gender, education, knowledge of root nodules, household income and perception of rhizobium inoculant were significant in explaining adoption of rhizobium inoculants in the study areas (Table 3). Farmers located in Lurhala were more likely to adopt Rhizobium inoculants than those located in Kamanyola. This was expected and may be due to the fact that soil conditions vary among these villages. Lurhala, for instance, is characterized by highlands and less fertile soils compared to Kamanyola, which is a plain with moderate fertility soils (Pypers et al., 2011). The observed higher adoption in Lurhala may be because farmers in the area are in need of an affordable source of fertilizer to increase soybeans yield because of lower soil fertility status. This finding corroborates Mutuma et al. (2014)'s findings to the effect that farmers in Bondo were more likely to use inoculants than Mumias and Bungoma because of low soil fertility status.

**Table 1.** General characteristics of soybean farmers.

| Factor | Category | Frequency | Percent |
|---|---|---|---|
| Mean age | <18 | 1 | 0.5 |
| | 18-25 | 24 | 7.2 |
| | 26-35 | 36 | 18.7 |
| | 36-45 | 27 | 27.6 |
| | >46 | 89 | 45.8 |
| Gender of the farmer | Male | 126 | 68.7 |
| | Female | 67 | 31.2 |
| Type of Education | Formal | 139 | 72.4 |
| | Non formal | 14 | 7.3 |
| | Any | 39 | 19.8 |
| | Other | 1 | 0.5 |
| Religion | Catholicism | 140 | 72.9 |
| | Jehova Witness | 2 | 1 |
| | Protestantism | 46 | 24 |
| | Adventist | 4 | 1.6 |
| | Traditional | 1 | 0.5 |
| Household management | Husband is the head | 42 | 22.1 |
| | Wife is the head | 45 | 23.7 |
| | Conjoints | 87 | 45.8 |
| | Another person | 16 | 8.5 |
| Montly income interval | <30$ | 27 | 17.3 |
| | 30-50$ | 41 | 26.3 |
| | 50 -100$ | 46 | 29.5 |
| | 100 -200$ | 33 | 21.2 |
| | 200 -300 | 8 | 5.1 |
| | >500 | 1 | 0.6 |
| Source of income | Sale of agricultural products | 169 | 88.5 |
| | | 2 | 1 |
| | Small trade | 13 | 6.8 |
| | Employees | 2 | 1 |
| | Other | 5 | 2.6 |

Gender of the household head had unexpectedly a negative effect on the adoption of rhizobium inoculants fertilizer meaning that when a household is men headed, he is not likely to adopt the rhizobium inoculant. The higher adoption of women may be due to the fact that women have higher accessibility to products compared to men; they can even get price reduction when purchasing. This observation is in contradiction of the finding of Nekesah (2017) who found that male farmers are more likely to adopt inoculants fertilizers because they can leverage on their equity capital with which to purchase external farm inputs than women. Our study findings were in discordance perhaps because at the beginning of the project, inoculants were distributed for free by organization promoting it and thereafter they remained cheap and very accessible to farmers (Ampadu-Boakye et al., 2017). Women are usually more considered for donation compared to male. However, these findings are in agreement with Zamasiya et al. (2014) who found that a female-headed household is likely to adopt new technologies related to legumes because legumes are usually considered as female crop.

The type of education, also, unexpectedly negatively affects the use of inoculants meaning that farmers with

**Table 2.** Characteristics of soybean inoculants users versus non-users.

| Variable | Overall sample | Users | Non-users | Mean/proportion difference |
|---|---|---|---|---|
| Age | 46 | 46 | 46 | -0.28 |
| Gender | | 0.425 | 0.51 | 0.093 |
| Education level | 5.86 | 5.57 | 5.97 | 0.40 |
| Experience in agriculture | 26.48 | 25.75 | 26.74 | 0.995 |
| Household head | 7.81 | 8.4 | 7.6 | -0.8 |
| Household workers | 3.16 | 3.38 | 3.07 | -0.31 |
| Credit access | 0.3 | 0.5 | 0.22 | -0.27*** |
| Credit amount | 11478.4 | 17640 | 6549.12 | -11090.88 |
| Group membership | 0.73 | 1 | 0.63 | -0.36*** |
| Duration in farmer's group | 7.09 | 9.87 | 5.67 | -4.21*** |
| Project beneficiary | 0.52 | 0.87 | 0.39 | -0.48*** |
| Number of cultivated land | 2.72 | 2.97 | 2.60 | -0.36 |
| Knowledge of root nodules | 0.50 | 0.75 | 0.401 | -0.35*** |
| Contact with inoculant promotors | 0.47 | 0.81 | 0.30 | -0.51*** |
| Total number of farmers (N) | 193 | 41 | 152 | |

*** p<0.01, ** p<0.05, * p<0.1.

informal education were more likely to adopt inoculants fertilizers compared to those with formal education. This may be due to the fact that farmers who went through informal education undertook technical studies including short trainings in agricultural techniques organized by extension workers in rural areas. These findings are consistent with numerous authors (Šūmane et al., 2018; Mignouna et al., 2011; Namara et al., 2013). These authors stated that informal knowledge and learning is a valuable resource that can reorient modern agriculture towards more sustainable and resilient paths of development because this type of learning addresses the knowledge and learning needs of farmers. The awareness of roots nodules positively affected the adoption of inoculants. This was expected because being aware of the existence of root nodules in leguminous plants, knowing their role in nitrogen fixation and perceiving that the nodules are beneficially enhanced by inoculant use increase the decision of using inoculants. This was also observed by Mutuma et al. (2014) and Nekesah (2017).

Household income positively and significantly (P<0.01) affected the adoption of soybean inoculants. This is because when farmers are getting more income from farm crop, they take a risk and responsibility about a new technology. Duressa (2015) also reported that farm income has significant and positive effect on adoption of technologies. Households with relatively higher level of income are more likely to purchase or exchange improved technologies.

Furthermore, farmers' perceptions of rhizobium inoculants also played a key role in adoption of the latter. Perceiving that inoculant's price is affordable by farmers negatively affected its adoption meaning that cost is not the most important factor for adoption of inoculant. This might be due to the fact that when a technology is perceived to be affordable, its efficacy is questionable. These results are consistent with Sattler and Nagel (2010) in the study factors affecting farmers' acceptance of conservation measures in Germany; costs were not the most important factor for adopting conservation measures. Other factors, like effectiveness, associated risks, or time and effort necessary to implement a certain measure were more important.

However, perceiving that rhizobium inoculant is effective and available at sale points was more important for its adoption in our study area. This is due to the fact that the inoculation technology has been subject to intense promotion among farmers under Integrated Soil Fertility Management (ISFM) as one of soil fertility replenishment technologies that are suitable for different types of resource-poor farm households (Sanginga and Woomer, 2009). These findings agree with Farrow et al. (2016) who reviewed the literature on factors affecting inoculants adoptions. He mentioned that the most commonly mentioned factors affecting the adoption of inoculants as one of legume technologies were the biophysical relevance of the technology (such as suitability for the agro-ecological zone), followed by the effectiveness and availability of the technology.

Diagnostic tests through Wald statistic showed that the model is globally significant, justifying the use of the selected covariates to predict the response variable. As for the reported pseudo R2, its value of 0.56 indicated that the retained variables (the location, gender, education, knowledge of root nodules, household income and perception of rhizobium inoculants etc.) are useful in predicting adoption of rhizobium inoculants (Table 3). To measure goodness-of-fit, other statistical tests such as the Hosmer-Lemeshow test was performed. Results

**Table 3.** Factors affecting adoption of rhizobium inoculants.

| Variable | Adoption coefficients | Probability | Marginal effects | Probability |
|---|---|---|---|---|
| Gender | -1.049 (0.423)** | 0.013 | -0.167(0.0654)** | 0.011 |
| Age | -0.0268(0.0177) | 0.129 | -0.00425(0.00278) | 0.126 |
| Type of education | -0.841(0.431)* | 0.051 | -0.134(0.0679)** | 0.049 |
| litteracy | 1.224(0.812) | 0.131 | 0.194(0.129) | 0.132 |
| Farming experience | -0.00137(0.0161) | 0.932 | -0.000218(0.00255) | 0.932 |
| Religion | -0.125(0.419) | 0.764 | -0.0198(0.0659) | 0.764 |
| Household size | 0.0791(0.0518) | 0.127 | 0.0126(0.00813) | 0.123 |
| Credit access | 0.262(0.407) | 0.521 | 0.0415(0.0653) | 0.525 |
| Membership to farmer organization | 0.519(0.411) | 0.207 | 0.0824(0.0643) | 0.200 |
| Knowledge of roots nodules | 3.011(0.529)*** | 0.000 | 0.478(0.0653)*** | 0.000 |
| Contact with extension services | 0.627(0.414) | 0.130 | 0.0995(0.0643) | 0.122 |
| **Income variable** | | | | |
| 30$-50$ | 1.119(0.554)** | 0.043 | 0.170(0.0830)** | 0.041 |
| 50$ -100$ | 1.341(0.548)** | 0.014 | 0.207(0.0783)*** | 0.008 |
| 100$-200$ | 0.947(0.575)* | 0.099 | 0.142(0.0844)* | 0.092 |
| 200$-300$ | 0.310(0.971) | 0.750 | 0.0433(0.138) | 0.754 |
| **Location variable** | | | | |
| Kamanyola | -0.902(1.169) | 0.441(0.000) | -0.125(0.134) | 0.353 |
| Lurhala | 1.722(0.396)*** | | 0.279(0.0564)*** | 0.000 |
| **Perception variable** | | | | |
| Affordable price | -1.604***(0.459) | 0.000 | -0.255***(0.0680) | 0.000 |
| Inoculants accessibilité | -0.519(0.633) | 0.412 | -0.0824(0.100) | 0.411 |
| Inoculants effictiveness | 1.307***(0.483) | 0.007 | 0.207***(0.0720) | 0.004 |
| Availability at sale points | 0.901*(0.474) | 0.057 | 0.143*(0.0738) | 0.053 |
| Inoculant not important for soy | 0.461(0.430) | 0.283 | 0.0732(0.0686) | 0.286 |
| Soybean importance | -0.0152(0.426) | 0.972 | -0.00242(0.0677) | 0.972 |
| Constant | -2.276(1.093)** | 0.037 | | |
| Wald $chi^2$(24) | 81.39 | | | |
| Prob>$Chi^2$ | 0.0000 | | | |
| Pseudo $R^2$ | 0.5678 | | | |
| Observations | 140 | | 140 | |
| Robust standard errors in parentheses | | | | |

*** p<0.01, ** p<0.05, * p<0.1.

$(\chi^2 = 4.94, P-value = 0.7635)$ showing that the used Probit model fitted well the data. As for multicollinearity test, Variance Inflation Factors (VIF) reported figures less than 5 for most of the variables; this implies low level of multicollinearity among variables. Robust standard error was used to control the problem of heteroskedasticity and possible sample selection-bias in the data. And at last, a link test was performed for model specification and possible omitted-variables problem. The result of the test indicated that the model was well specified and is not suffering from any omitted-variable problem.

## Farmers' perception of rhizobium inoculants adoption

Inoculants users strongly agreed (65%) that soybean is an important crop, strongly agreed that inoculant improves soybean's yield (50%) and agreed that rhizobium inoculant is available at sale points. Inoculants users were not sure (21% agreed, 21% moderately agreed and 21% disagreed) on the importance of rhizobium inoculants for soybeans production (Figure 1). However, inoculants users strongly agreed that inoculants price is affordable with the majority of farmers' users of inoculants stating that the sales points of inoculants are inaccessible.

Concerning inoculants non-users; they also strongly agreed that soybean is an important crop, moderately agreed that inoculation can promote soybeans production, moderately agreed or disagreed (37, 37% respectively) on inoculants availability (Figure 2). In addition, they agreed that inoculants are not important for soybean's

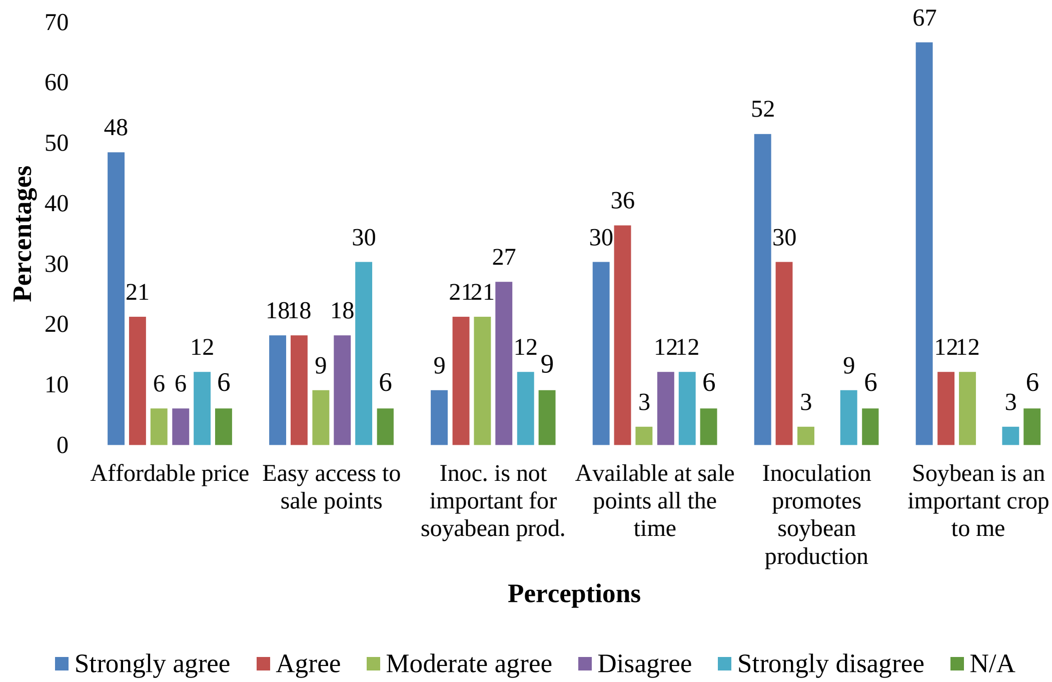


**Figure 1.** Perception of inoculant by users.

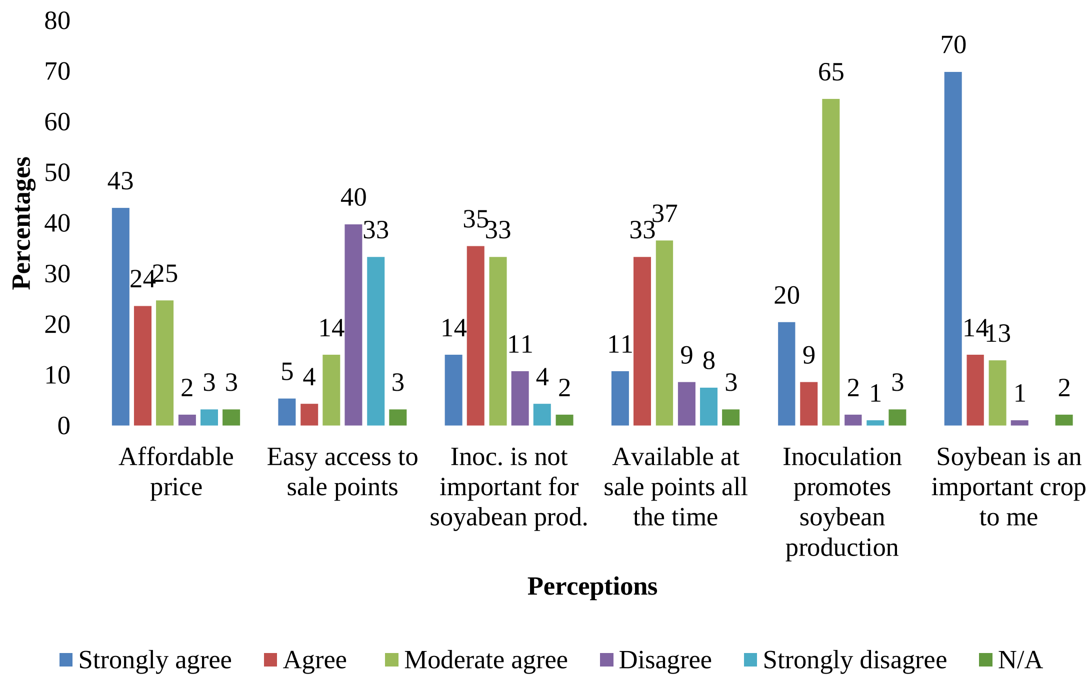


**Figure 2.** Perception of inoculant by non-users.

production and disagreed on inoculants' easy access. However, most of them strongly agreed that inoculants' price is affordable.

Inoculants users and non-user farmers strongly agreed that soybean is an important crop. This is explained by the fact that soybean in South Kivu is being used in households for malnutrition fighting and for cash income generation due to the presence of markets. This is in agreements with many authors. For example Khojely et al. (2018), Hartman et al. (2011) and Murithi et al. (2016) who stated that soybean is becoming an important and popular crop in Sub-Saharan Africa. Soybean plays a role in food and nutrition security (Owino et al., 2011; Bahwere et al., 2016; Rossi et al., 2005), in cash income generation (Bangsund et al., 1999), in animal nutrition (Huang et al., 2014; Yuan et al., 2016) and in soil fertility improvement (Sanginga, 2003; Miransari et al., 2013). This suggests that effort should be done to promote the productivity of this crop.

Inoculants users strongly agreed that inoculation promotes soybean production whereas the non-users only agreed moderately. This may be explained by the higher contact of inoculants users with organizations promoting inoculants and their long duration in farmers groups. This facilitates their easy access to information and evaluation of new technologies. The less agreement of non-users is explained by their less education on inoculation. In addition the response of soybeans to inoculation varies and depends on many factors. The importance of them include the number and quality of indigenous rhizobia, water stress (Serraj et al., 1999; De Vries et al., 1989; Sinclair et al., 1987; Ryan and Spencer, 2001), high temperature (Michiels et al.,1994), soil acidity (Giller, 2001) and salinity (Delgado et al., 1994) and nutrient deficiencies (Cassman et al., 1981). Marufu et al. (1995) observed that farmers' education on inoculation is a major driving force for the adoption of inoculants. Organizations promoting inoculants and extension services should determine the need to inoculate a certain area before the implementation of demonstration trials for good perception and high adoption of the product.

Concerning the inoculants availability at sale points, inoculants users agreed that this product is available in the market while in non-users group, the same number of farmers either agreed moderately or disagreed. This shows a moderate availability of inoculants, which may be owing to the fact that this product was produced under a project by, limited number of technicians who could produce only limited quantity of inoculants (Ampadu-Boakye et al., 2017). A study on farmers' inoculants adoption conducted in Zimbabwe demonstrated also a less availability of inoculants (Bala, 2008). These findings are in agreement with other studies that demonstrated a very low access to inoculants as major constraint to its adoption (Odame, 1997; Woomer et al., 1997; Kipkoech et al., 2007).

However, the two groups strongly agreed that the price of inoculants is affordable. This is in agreement with other studies (Mutuma et al., 2014; Nekesah et al., 2017). Chianu et al. (2011) argued that a 100 g-packet of inoculant is sufficient to inoculate 15 g of seeds and enough to plant 1 acre costs of only 1.2 US dollars while inorganic nitrogen fertilizer in form of Calcium Ammonium Nitrate needed for the same size of plot costs 34 US dollars. This shows that rhizobium inoculant is cheaper compared to inorganic N fertilizer 28 times and should be promoted among smallholders 'farmers.

## Conclusion

Demographic factors that affect the adoption of rhizobium inoculants in South Kivu Province of Democratic Republic of Congo include farmers' location, gender of household head, type of education, awareness of nodules roles on legumes and household income. However, farmers perceive rhizobium inoculant as an affordable source of Nitrogen for soybean but less accessible. Much effort is needed in extension services strengthening to ensure advanced farmers 'education about inoculation and rhizobium inoculant promotion. Local private firms and agro dealers involvement is important for more availability and accessibility of the product.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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