

## Research

# Farmers' motivational factors for medicinal plant production in the southwestern region of Bangladesh

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## Abstract

Medicinal plants (MPs) generate cash income and save millions of people in Bangladesh. The aim of this study is to identify farmers' motivational factors to cultivate MPs. This study is based on primary data collected from 196 sample households from two MP-growing districts of Bangladesh. Three MPs, namely, *Aloe vera*, *Bombax ceiba*, and *Withania somnifera*, were considered for this study. Principal component analysis (PCA), the z test, the Wilcoxon signed-rank test and factor analysis (FA) were used in this study. The results showed that household size and male-headed household status are driving socioeconomic factors. Ownership of water pumps, number of rooms in the house, access to contract marketing, and off-farm income are significant economic factors encouraging households to cultivate MPs. Farming experience, scientific knowledge, access to high land and access to loamy land are significant biophysical factors motivating farmers to cultivate MPs. More technical support and institutionalized contract marketing systems should be continued and established for the sustainability of MP cultivation.

**Keywords** Impulse factors · Sales contract · Inspiration · MP cultivation · Bangladesh

## 1 Introduction

Medicinal plant (MP) cultivation is a lucrative agribusiness and provides opportunities for diversified agriculture in Bangladesh. MPs have been the main source of therapeutic vegetation and have been depleted from forests that now grown on crop fields to meet increasing demand from pharmaceuticals, cosmetics and other industries [1, 2]. The driving factors to shift in MP cultivation are simple production systems, higher productivity and high returns, and low cost of production, which can be produced in small landholdings and cultivated throughout the year [3, 4].

In Bangladesh, 722 MP species are recorded, of which 255 plants are regularly used in preparing medicine for health-care purposes [5–8]. Approximately 60000 marginal and small farmers, including females (approximately 48000), are involved in the cultivation of MPs [9]. Almost 80% of the country's inhabitants rely on MPs for their primary healthcare [8], Chowdhury et al. [10–12]. The total number of plant-based medicine manufacturers in Bangladesh is 587, of which 271 are Unani, 205 are Ayurvedic and 111 are herbal, with 7935, 4742 and 741 registered medicines, respectively [13]. The annual consumption of MPs is approximately 20000 tons, and Bangladesh is a market of approximately Taka 300 crore annually [9, 14]. In 2021–22, Bangladesh exported US\$ 0.39 million in MP and MP products [15].

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As a field crop, there is an enormous demand and business potential for MPs in Bangladesh. Farmers are commercially grown *Aloe vera*, *Bombax ceiba*, *Withania somnifera*, *Asparagus racemosus*, *Scoparia dulcis*, and *Rauwolfia serpentina* in their fields [3, 16]. Looking at commercial prospects, farmers are widely cultivating *A. vera*, *B. ceiba*, and *W. somnifera* with a total area of 245 hectares (ha) [17]. Farmers cultivated these three MPs, due to higher profitability, lubricative return, unsuitability of soil for other crops cultivation [18], use of fallow lands, getting easy money, earn money all over the year, availability of selling facilities, less technology and less technical support required for cultivation. These are perennial plants, and stems, leaves and roots contain many biological features [19–24].

Commercial production of MPs requires a combination of production and marketing skills of farmers. Numerous factors have affected farmers' engagement in MP production. Some studies suggest that a higher return from farming helps in crop selection and cultivation decisions [25, 26] and that sociodemographic features can affect farmers' information acquisition [27], technology adoption [28], and risk perception [29]. There is a vast literature on MP studies, including profitability options for MP cultivation [24, 25], constraints [30], value chain analysis [3, 7, 31–37], resource conservation and utilization [38–44] and sustainability of MP cultivation [45–49]. Although extensive research has been conducted regarding MP cultivation practices, the value chain and marketing, the literature regarding motivational factors for MP production is limited. To the best of authors' knowledge, studies about farmers' behavioural intension [50], cultivation of MPs as a means of diversification [51], social practices of cultivation of MPs [52], and factors influencing sustainability of MPs [53] are close related studies found in the literature. The innovativeness of this study is to investigate the motivational factors behind shifting land from traditional crops cultivation to MPs cultivation. Thus, this study addresses the following research question: what are the key factors affecting farmers' participation in MP production, and how do these factors differ among farmer categories? The present study attempts to identify the motivational factors of MP (*A. vera*, *B. ceiba* and *W. somnifera*) cultivation. Furthermore, this study identifies the factors contributing to the business sustainability of MP production to illustrate some essential pathways to promote sustainable MP production and intensification options. The findings of the study will be helpful for farmers, researchers and policy makers to make production decisions, future research work and policy development, respectively, regarding the MP subsector of Bangladesh.

## 2 Materials and methods

### 2.1 Study area

The commercial cultivation of MPs is found in the Rajshahi, Chittagong and Hill tracts areas of Bangladesh (Fig. 1). In the Rajshahi region, Natore and Bogura are two famous districts where farmers cultivate MPs commercially in their crop fields. In addition, traditional marketing and contract marketing systems have also operated in these areas. Specifically, Bogura Sadar and Natore Sadar upazilas have well-known identities for MP production and transactions. Therefore, the present study considers these two upazilas (Fig. 1).

### 2.2 Species selection

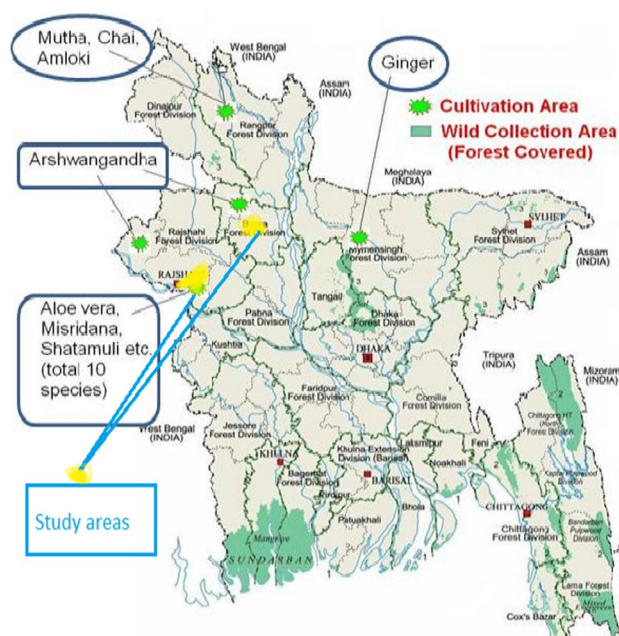
Three important MPs, namely, *A. vera*, *B. ceiba*, and *W. somnifera*, were selected based on their agribusiness prospects and commercial cultivation practices. *A. vera* is a perennial plant that can be harvested every 6–8 weeks after planting. *B. ceiba* is known as a 'silent doctor' for its medicinal benefits and can be harvested after 8–10 months. *W. somnifera* is a hardy plant and can be harvested for roots by digging 150 to 180 days after sowing. These three plants are cultivated in the study areas with acreage coverage of 38%, 27%, and 16%, respectively BBS [54].

### 2.3 Sampling technique and sample size

The study used a multistage purposive sampling technique for selecting study locations. First, the Natore and Bogura districts are selected based on commercial production and marketing intensity. Eleven lowest-level administrative units locally known as 'unions' under Bogura Sadar upazila and 4 unions under Natore Sadar upazila are famous for MP production [18, 29]. Therefore, in the second stage, these 2 upazilas are selected. From these two upazilas, a list of MP farmers is collected, and a simple random sampling technique is applied for selecting farmers.

Natore Sadar and Bogura Sadar upazilas have 56097 and 33587 farm households, respectively BBS [55]. In these two Upazilas, approximately 5000 farm households are engaged in MP production, 30% (approximately 1500

**Fig. 1** Studied Upazilas located in Bangladesh



farmers) of which are commercial cultivators [56, 57]. Approximately 65% of them (approximately 960) cultivated selected MPs (*A. vera*, *B. ceiba* and *W. somnifera*) commercially. Therefore, in total, 196 households were interviewed through a face-to-face interview technique by using the formula applied by Kothari [58]. ( $n = \frac{Z^2 * \sigma^2 * N}{(N-1)e^2 + Z^2 * \sigma^2}$ , where  $n$  = sample size,  $N$  = population (960),  $\sigma$  = estimated variance in population;  $e$  = desired precision,  $Z$  = standard normal variation,  $e$  = marginal error. For this study, the marginal error was considered at 10%, the confidence level at 95% and the variance in the population at 75%. Considering these values, a survey sample ( $n$ ) is 176 or more is acceptable for statistical justification.)

The area coverage of *A. vera*, *B. ceiba* and *W. somnifera* was 63%, 16% and 21%, respectively [59]. The respondents were 123 for *A. vera* (77 from Natore and 46 from Bogura), 31 for *B. ceiba* root (19 from Natore and 12 from Bogura) and 42 for *W. somnifera* (26 from Natore and 16 from Bogura) by using the probability proportional to size (PPS) sampling method [60]. Data analysis was carried out by using Stata 14.0, R, @riskAmp-free version, and Solver plug-ins for Microsoft Excel 2019.

## 2.4 Analytical techniques

Factors affecting farmers' participation in MP production practices are identified by principal component analysis (PCA). The formula is:

$$Y_i = a_{i1}X_1 + a_{i2}X_2 + \dots + a_{ip}X_p - \dots - (1), \quad i = 1, \dots, p \quad (1)$$

The coefficients  $a_{ij}$  are called the loadings for the  $i^{\text{th}}$  principal component ( $y_i$ ). The study identified social, economic, and biophysical motivations of farmers for participating in MP production. We know that PCA should be applied using continuous variables. However, in the case of sociodemographic, economic and biophysical variables, the involvement of mixed variables (quantitative in continuous and qualitative in nominal) is observed. PCA requires numerical variables, and multiple correspondence analysis (MCA) uses categorical variables; therefore, according to Chavent et al. [61], PCA of mixed data was applied for this study.

Before running the model, the data were rescaled as the conditions of PCA. In this study, continuous variables are measured at different scales/units, and nominal variables are dichotomous; therefore, quantitative variables are transformed to z scores, and qualitative variables are transformed to dummies of 1/0. Moreover, the study estimates the variance inflation factor to detect the presence of multicollinearity among the variables.

### 3 Results and discussion

#### 3.1 Farmers' motivational factors for MP cultivation

Several factors affect farmers' choice of MP cultivation. Broad sociodemographic, economic and biophysical factors affect farmers for selected MPs as enterprises.

##### 3.1.1 Sociodemographic motivational factors

Table 1 shows that the average family size of the surveyed farmers is  $5.14 \pm 2.09$ , which is higher than the national average (4.3) [62]. Households with large families may imply available labor to help in different farm activities, such as purchase inputs, applying input in the crop field, transport of input and output and use of technology on the farm. The number of school-going children per family is  $1.33 \pm 1.15$ , and the number of working members in the households of MP production is  $2.25 \pm 1.53$ . It is also shown that approximately 80% of the households are male headed, which is lower than the national average (85.8%) [62], indicating that more male adults would be associated with a higher likelihood of participation in MP production (Table 1). The marital status of the MP farmers indicates that approximately 91.6% of the respondents are married, and approximately 81.1% of farmers are familiar with crop farming. This indicates that married farmers as well as those whose main occupation is farming would be associated with a higher likelihood of participating in MP production.

Before proceeding to PCA, the value of the variance inflation factor (VIF) indicates the presence of no multicollinearity in the data as VIFs <10 [63].

Dummy takes the value 1 for positive response and 0 for others; '%' indicated the value in percentage of N=196

The communalities, ranging from 0.34 to 0.83 (Table 2), consistently surpass a moderate threshold, indicating satisfactory shared variance among the variables. Additionally, the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) attains a value of 0.52, exceeding the acceptable threshold of 0.5. This affirms the appropriateness of employing Principal Component Analysis (PCA) for these data (Table 2). The high significance of Bartlett's test ( $p < 0.0001$ ) further strengthens the justification for conducting PCA, underscoring the presence of meaningful relationships among the variables in the dataset.

The first principal component (PC1) had the highest eigenvalue of 2.0 and accounted for 18.18% of the total variability of the data set. PC2 has an eigenvalue of 1.578 and accounts for 14.35% of the variance. PC3 has an eigenvalue of 1.52 and accounts for 13.77% of the variance. The last six PCs (i.e., PC6–PC11) yielded progressively smaller eigenvalues and did not explain significant variability in the data set (31.58%). Therefore, according to the Kaiser rule (the Kaiser rule is to drop all components with eigenvalues under 1.0 [64]), only the first five PCs explaining approximately 68.42% of the total variability are considered.

Table 3 presents the results of each variable's loading with eigenvectors on the five components extracted. The first principal component is positively correlated (the cutoff points of correlation coefficient values are arbitrary and inconsistent [65], Overholser and Sowinski [66]. A coefficient of <0.1 indicates a negligible and >0.9 a very strong

**Table 1** Definition of socio-demographic variables for PCA

| Variables    | Definition and measurement | Mean (Stdev)/%                          | Extraction    |
|--------------|----------------------------|-----------------------------------------|---------------|
| Quantitative | age                        | Age of household head in year           | 40.47 (12.92) |
|              | edu                        | Education in year of schooling          | 5.33 (4.24)   |
|              | hhsz                       | Household size                          | 5.14 (2.09)   |
|              | M:F                        | Male female ratio                       | 1.26 (0.81)   |
|              | schol                      | Number of schools going children        | 1.33 (1.15)   |
|              | wmemb                      | Number of working members               | 2.25 (1.53)   |
|              | deci                       | Decision taking in household            | 1.25 (0.70)   |
| Qualitative  | gend                       | Gender of household head (dummy)        | 79.59%        |
|              | occu1                      | Main occupation is crop farming (dummy) | 77.04%        |
|              | occu2                      | Medicinal crop farming (dummy)          | 9.18%         |
|              | mari                       | Marital Status (dummy)                  | 90.82%        |

**Table 2** Eigenvalues and percentages of inertia for socio-demographic variables

| Component                             | Initial eigenvalues         |             |              | Extraction sums of squared loadings |             |              |
|---------------------------------------|-----------------------------|-------------|--------------|-------------------------------------|-------------|--------------|
|                                       | Eigenvalue                  | Inertia (%) | Cumulative % | Eigenvalue                          | Inertia (%) | Cumulative % |
| F1                                    | 2.00                        | 18.18       | 18.18        | 2.00                                | 18.183      | 18.183       |
| F2                                    | 1.58                        | 14.35       | 32.53        | 1.578                               | 14.346      | 32.529       |
| F3                                    | 1.52                        | 13.78       | 46.31        | 1.515                               | 13.775      | 46.305       |
| F4                                    | 1.42                        | 12.79       | 59.09        | 1.407                               | 12.794      | 59.099       |
| F5                                    | 1.03                        | 9.32        | 68.42        | 1.026                               | 9.324       | 68.423       |
| F6                                    | 0.98                        | 8.93        | 77.35        |                                     |             |              |
| F7                                    | 0.88                        | 8.01        | 85.36        |                                     |             |              |
| F8                                    | 0.56                        | 5.08        | 90.44        |                                     |             |              |
| F9                                    | 0.48                        | 4.38        | 94.82        |                                     |             |              |
| F10                                   | 0.32                        | 2.92        | 97.74        |                                     |             |              |
| F11                                   | 0.25                        | 2.26        | 100          |                                     |             |              |
| Kaiser-Meyer-Olkin Measure            |                             |             |              | 0.520                               |             |              |
| Bartlett's sphericity test statistics | Chi-square (Observed value) |             |              | 390.860                             |             |              |
|                                       | Chi-square (Critical value) |             |              | 73.310                              |             |              |
|                                       | p-value                     |             |              | < 0.0001                            |             |              |
|                                       | Alpha                       |             |              | 0.05                                |             |              |

Extraction method: Principal component analysis.

**Table 3** Principal coordinates and squared cosines of socio-demographic variables

| Variables | Principal coordinates |        |        |        |        | Squared cosines (cos <sup>2</sup> ) |              |              |              |              |
|-----------|-----------------------|--------|--------|--------|--------|-------------------------------------|--------------|--------------|--------------|--------------|
|           | F1                    | F2     | F3     | F4     | F5     | F1                                  | F2           | F3           | F4           | F5           |
| Age       | 0.513*                | 0.003  | 0.329  | −0.588 | −0.073 | 0.264                               | 0.000        | 0.108        | <b>0.346</b> | 0.005        |
| Edu       | −0.179                | −0.201 | −0.422 | 0.610* | −0.116 | 0.032                               | 0.041        | 0.178        | <b>0.372</b> | 0.013        |
| Hhsize    | 0.691*                | −0.041 | 0.270  | 0.539* | 0.056  | <b>0.477</b>                        | 0.002        | 0.073        | 0.291        | 0.003        |
| M:F       | −0.082                | 0.001  | 0.144  | −0.060 | 0.935* | 0.007                               | 0.000        | 0.021        | 0.004        | <b>0.874</b> |
| Schol     | 0.480                 | 0.057  | 0.426  | 0.493* | 0.094  | 0.231                               | 0.003        | 0.181        | <b>0.243</b> | 0.009        |
| Wmemb     | 0.482*                | 0.284  | 0.047  | 0.127  | −0.136 | <b>0.232</b>                        | 0.081        | 0.002        | 0.016        | 0.018        |
| Deci      | −0.328                | 0.736* | 0.187  | 0.112  | −0.177 | 0.108                               | <b>0.541</b> | 0.035        | 0.013        | 0.031        |
| Gend-0    | −0.619                | 1.499  | 0.644  | 0.126  | 0.075  | 0.098                               | <b>0.576</b> | 0.106        | 0.004        | 0.001        |
| Gend-1    | 0.159                 | −0.384 | −0.165 | −0.032 | −0.019 | 0.098                               | <b>0.576</b> | 0.106        | 0.004        | 0.001        |
| Occu1-0   | −0.995                | −0.518 | 1.139  | 0.227  | −0.161 | 0.295                               | 0.080        | <b>0.387</b> | 0.015        | 0.008        |
| Occu1-1   | 0.296                 | 0.154  | −0.339 | −0.068 | 0.048  | 0.295                               | 0.080        | <b>0.387</b> | 0.015        | 0.008        |
| Occu2-0   | 0.133                 | 0.152  | −0.180 | −0.042 | 0.034  | 0.175                               | 0.227        | <b>0.321</b> | 0.017        | 0.012        |
| Occu2-1   | −1.315                | −1.500 | 1.781* | 0.412  | −0.340 | 0.175                               | 0.227        | <b>0.321</b> | 0.017        | 0.012        |
| Mari-0    | −0.902                | 0.515  | −1.010 | 0.931  | 0.703  | 0.082                               | 0.027        | <b>0.103</b> | 0.088        | 0.050        |
| Mari-1    | 0.091                 | −0.052 | 0.102  | −0.094 | −0.071 | 0.082                               | 0.027        | <b>0.103</b> | 0.088        | 0.050        |

\* Significantly correlated (for this study, positive correlation values above 0.5 and negative values farthest from 0 are set to significant); Values in bold correspond for each variable to the factor for which the squared cosine is the largest.

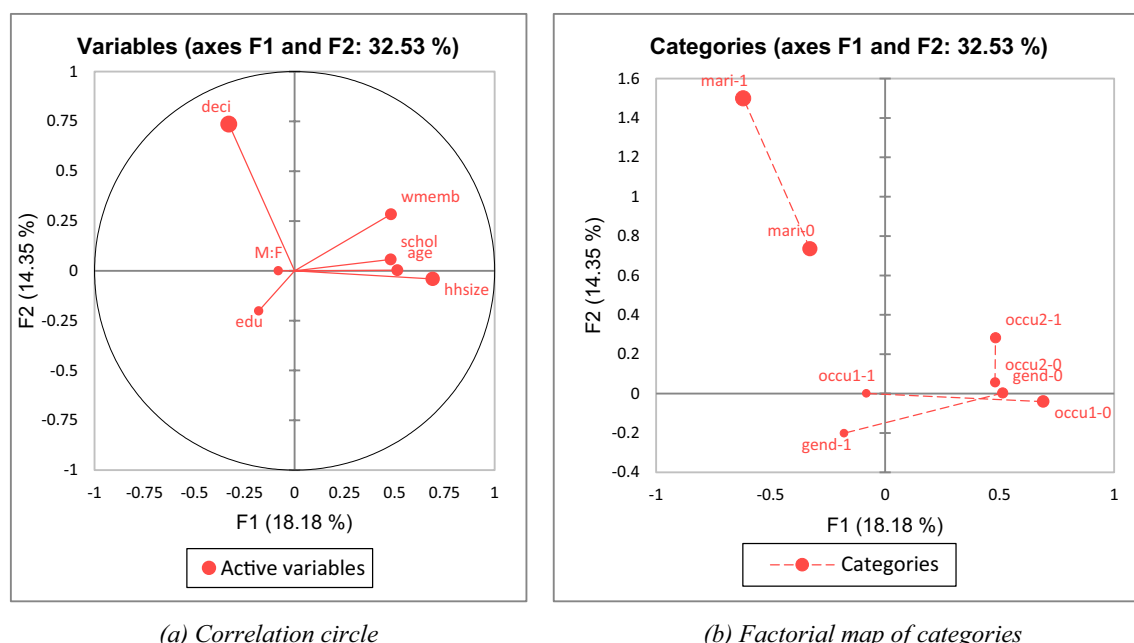
relationship, values in-between are disputable. A correlation coefficient of 0.65 may be interpreted as a “good” or “moderate” correlation. It is also difficult to reach a conclusion of value 0.39 that represents a “weak” association, whereas 0.40 is a “moderate” association [67]. With four of the quantitative and three qualitative variables. Out of the variables, component 1 seemed to significantly increase with increasing age, household size and number of working members in the household. The strongest variable in this component is household size. The second component significantly increases with decision making in the households, while component 3 shows a positive correlation with the variable of occupation in MP farming (occu2). Component 4 is primarily increasing with education, household

size, and number of schools going children. The increasing trend in component 5 is orchestrated by the male–female ratio in the household.

The factor score is used to classify social motivations by plotting in two dimensions with PC1 (=F1) in the horizontal axis (x) and PC2 (=F2) in the vertical axis (y), commonly known as Biplot (the Biplot was developed by Gabriel [68] that generalize the simple two-variables scatterplot), as shown in Fig. 2. The positive value direction of PC1 showed household size, age of household head, number of working members in household and main occupation is medicinal crop farming, while the negative value direction exhibited education, male–female ratio, decision taking, marital status, gender of household head and main occupation is crop farming. For PC2, its upward positive value shows decision making in MP production, and the variables are age of household head, number of schools going children, number of working members in household and male–female ratio. PC2 also shows downward negative values for education, household size and gender of the household head.

The values of the squared cosines ( $\cos^2$ ) (a variable factor loading indicates the correlation between it and a given principal component (PC). By squaring factor loading, squared loading is found that also known as squared cosine or  $\cos^2$  which provides a measure of the proportion of variance in a variable that is captured by a PC. The sum of its squared loading of each variable across all PCs equals to 1. The squared loading between a quantitative variable and a factorial axis is equal to the squared correlation between the variable and the axis. In addition, the squared loading between a qualitative variable and a factorial axis is equal to the correlation ratio between the variable and the axis.), are shown in Table 3. A high  $\cos^2$  indicates a good presentation of the variable on the PC where the variable is positioned close to the circumference of the correlation circle, while a low  $\cos^2$  indicates that the variable is not well represented and the variable is close to the center of the circle. Component 1 contributes highly to household size and the number of working members in the household, while component 2 contributes most to the decision making and gender of the household head (Table 3).

The findings from principal component analyses indicated that household size with more working members and male-headed communities practicing farming activities will have the highest possibilities to motivate households in MP cultivation. Farmers with a large number of family members are most likely to have a good number of working members, and a productive age structure is supported and influences households in MP farming practices in the community. This finding is consistent with Kideghesho and Msuya's [69] study. They examined the influence of gender and socioeconomic factors on the domestication of MPs in the West Usambara Mountains of northern Tanzania. They reported that the domestication of MPs is higher in households with large families than in those with small ones. This is likely because family size has implications for the household labor force, and thus, large families have more labor, which could contribute



**Fig. 2** **a, b** Correlation circle (quantitative variables) and factorial map of categories of socio-demographic variables

positively to domestication of all wild plants, including MPs. Luoga et al. [70] indicated similar results. Dixie et al. [71], Babu et al. [72], Rashid [73], and Asigbaase et al. [74] found similar results.

### 3.1.2 Economic motivational factors

The overall annual average net farm income is about BDT.  $307.3 \pm 252.6$  thousand (Table 4). Approximately 94% of the farmers earned income from off-farm sources, which may encourage technology adoption. Approximately 12.8% of farmers have received incentives from different organizations, and 26% have received training on MP production practices. Livestock is an economic variable that is highly correlated with the adoption of agricultural technologies [75], Groher et al. [76]. On average, 69% of MP farmers have livestock and poultry, and 13% have fisheries/ponds. Households' dwellings are building, *semipacca* or tin, and they have an average of three rooms ( $2.659 \pm 2.014$ ) in their dwelling. For *B. ceiba* and *W. somnifera*, the farmers require storage facilities, and they often store them in bags and place them in their rooms. More rooms available to a household might indicate a wealthier family and thus a higher probability of adopting MP production technology. Approximately 89.8% of farmers have access to contract marketing of their produce (Table 4).

The communalities are all above mediocre, ranging from 0.359 to 0.791. The KMO is 0.569 (higher than 0.5), and Bartlett's measure is found to be highly significant ( $p < 0.0001$ ). Both tests suggested the appropriateness of PCA.

The first PC had the highest eigenvalue of 2.05 and accounted for 13.68% of the total variability of the data set (Table 5). The second PC had an eigenvalue of 1.71 and accounted for 11.4% of the variance in the data. Following the next three PCs, the eigenvalues are found at 1.43, 1.24 and 1.15, which account for 9.5%, 8.3% and 7.7% of the variance in the data, respectively. The remaining ten PCs (i.e., PC6–PC15) yielded progressively smaller eigenvalues and did not explain significant variability in the data set. Therefore, according to the Keiser rule, only the first five PCs explaining approximately 50.67% of the total variability are selected.

PC1 is not significant for any of the variables (Table 6). Three variables, ownership of fisheries/ponds, ownership of water pump and ownership of motorbike, have significant and positive relations with PC2. Positive and significant relations are found in PC3 with access to training, ownership of water pump and ownership of tractor. PC4 is positively and significantly associated with access to incentives, ownership of fisheries/ponds and ownership of motorbikes. PC5 shows a positive and significant correlation with ownership of water pumps and ownership of tractors.

The highly positive value direction of PC1 showed farm size, access to contract marketing and access to incentives, while the negative value direction exhibited the number of rooms in house, annual income and off-farm income. For PC2, its upward positive value shows farm size, annual income, number of rooms in house, access to contract marketing, access to incentives, ownership of livestock & poultry and ownership of motorbike, while the downward negative value

**Table 4** Definition of economic variables for PCA

| Variables    |        | Definition and measurement               | Mean (SD)/%     | Extraction |
|--------------|--------|------------------------------------------|-----------------|------------|
| Quantitative | Fsize  | Farm size in ha                          | 0.44 (0.57)     | 0.57       |
|              | Inc    | Annual income in thousand Taka           | 307.30 (252.60) | 0.57       |
|              | Room   | Number of rooms in house                 | 2.54 (1.89)     | 0.56       |
| Qualitative  | Offinc | Off-farm income (dummy)                  | 0.949           | 0.684      |
|              | Contm  | Access to contract marketing (dummy)     | 0.898           | 0.602      |
|              | Incen  | Access to incentives (dummy)             | 0.128           | 0.359      |
|              | Train  | Access to training (dummy)               | 0.260           | 0.623      |
|              | Lives  | Ownership of livestock & poultry (dummy) | 0.694           | 0.425      |
|              | Fishe  | Ownership of fisheries/ponds (dummy)     | 0.133           | 0.533      |
|              | Build  | Access to building (dummy)               | 0.434           | 0.484      |
|              | Wpmp   | Ownership of water pump (dummy)          | 0.092           | 0.719      |
|              | Tract  | Ownership of tractor (dummy)             | 0.010           | 0.791      |
|              | Motor  | Ownership of motorbike (dummy)           | 0.179           | 0.633      |
|              | Tv     | Ownership of television (dummy)          | 0.531           | 0.558      |
|              | Mobi   | Ownership of mobile (dummy)              | 0.888           | 0.497      |

Dummy takes the value 1 for positive response and 0 for others; '%' indicated the value in percentage of N=196.

**Table 5** Eigenvalues and percentages of inertia for economic variables

| Component                             | Initial eigenvalues         |             |              | Extraction sums of squared loadings |             |              |
|---------------------------------------|-----------------------------|-------------|--------------|-------------------------------------|-------------|--------------|
|                                       | Eigenvalue                  | Inertia (%) | Cumulative % | Eigenvalue                          | Inertia (%) | Cumulative % |
| F1                                    | 2.05                        | 13.68       | 13.68        | 2.05                                | 13.68       | 13.68        |
| F2                                    | 1.71                        | 11.40       | 25.08        | 1.71                                | 11.40       | 25.08        |
| F3                                    | 1.43                        | 9.56        | 34.64        | 1.43                                | 9.56        | 34.64        |
| F4                                    | 1.25                        | 8.30        | 42.95        | 1.25                                | 8.30        | 42.95        |
| F5                                    | 1.19                        | 7.72        | 50.67        | 1.16                                | 7.72        | 50.67        |
| F6                                    | 1.07                        | 7.12        | 57.79        |                                     |             |              |
| F7                                    | 0.98                        | 6.51        | 64.29        |                                     |             |              |
| F8                                    | 0.94                        | 6.26        | 70.55        |                                     |             |              |
| F9                                    | 0.84                        | 5.61        | 76.16        |                                     |             |              |
| F10                                   | 0.79                        | 5.25        | 81.41        |                                     |             |              |
| F11                                   | 0.68                        | 4.51        | 85.92        |                                     |             |              |
| F12                                   | 0.64                        | 4.27        | 90.19        |                                     |             |              |
| F13                                   | 0.59                        | 3.95        | 94.14        |                                     |             |              |
| F14                                   | 0.45                        | 2.99        | 97.14        |                                     |             |              |
| F15                                   | 0.43                        | 2.87        | 100          |                                     |             |              |
| Kaiser-Meyer-Olkin Measure            |                             |             |              | 0.569                               |             |              |
| Bartlett's sphericity test statistics | Chi-square (Observed value) |             |              | 550.938                             |             |              |
|                                       | Chi-square (Critical value) |             |              | 164.216                             |             |              |
|                                       | p-value                     |             |              | < 0.0001                            |             |              |
|                                       | Alpha                       |             |              | 0.05                                |             |              |

Extraction method: Principal component analysis.

direction exhibits ownership of water pump and ownership of motorbike. These results are also shown in Fig. 3, which shows that PCs and important variables motivated farmers in MP production.

The cosines in Table 6 show that PC1 contributes highly to annual income, number of rooms in house, access to building, and ownership of motorbike, while PC2 contributes most to off-farm income, access to contract marketing and ownership of fisheries/ponds. The cosines of the remaining factors are found under the remaining components (F3 to F5). Farm size has higher cosines under PC3.

The economic motivational factors showed that the ownership of water pumps, number of rooms in house, access to contract marketing, and off-farm income have relatively potential to encourage households to cultivate MPs. Water pump ownership is the driving factor in MP production. MP cultivation requires timely irrigation for MP plant growth, yield and quality, which is supported by the study of [77]. Increased access to irrigation can increase farm productivity and important nutritional improvements, which further enhance food availability and dietary diversification [78, 79]. Off-farm income and ownership of fisheries/ponds also have the potential to motivate MP production. Off-farm income helps farmers purchase production inputs by overcoming credit constraints, which is supported by Nguyen et al. [80] and Balana and Oyeyemi [81], Dixie et al. [71], Babu et al. [72], Rashid [73], and Asigbaase et al. [74].

### 3.1.3 Biophysical motivational factors

The influences of biophysical factors on participating farmers in MP production are shown in Table 7. The conditions of the farmlands under biophysical factors include land type, land size, soil type and soil depth. The majority of farmers (93.9%) cultivated MPs in high land, and 83.2% of the farmers cultivated MPs in loamy soil. Saber et al. [82] suggested that loamy soil played an important role in MP growth, essential yield, and the chemical composition of essential oil. The average plot size was  $26.69 \pm 20.18$  decimals, while the average soil depth was 5.352 inches in the farmer plots where they cultivated MPs. This finding implies that the cultivated land areas are generally small in size and could be a limiting factor to the level of output. The findings revealed that farmers have less than 15 years of farming experience (average 13.95 years), while only 79% of farmers have scientific knowledge about MP farming operations. This implies that farmers with more farming experience have more farming knowledge and are likely to participate in MP production.

**Table 6** Principal coordinates and squared cosines ( $\cos^2$ ) of economic variables

| Variables | Principal coordinates |        |        |        |        | Squared cosines ( $\cos^2$ ) |              |              |              |              |
|-----------|-----------------------|--------|--------|--------|--------|------------------------------|--------------|--------------|--------------|--------------|
|           | F1                    | F2     | F3     | F4     | F5     | F1                           | F2           | F3           | F4           | F5           |
| Fsize     | 0.056                 | 0.089  | −0.238 | −0.230 | −0.099 | 0.003                        | 0.008        | <b>0.057</b> | 0.053        | 0.010        |
| Inc       | −0.701                | 0.147  | −0.174 | 0.027  | 0.292  | <b>0.491</b>                 | 0.022        | 0.030        | 0.001        | 0.085        |
| Room      | −0.534                | 0.330  | −0.211 | −0.310 | 0.076  | <b>0.285</b>                 | 0.109        | 0.045        | 0.096        | 0.006        |
| Offinc-0  | 1.972                 | 2.981  | 0.510  | −0.159 | −0.012 | 0.209                        | <b>0.478</b> | 0.014        | 0.001        | 0.000        |
| Offinc-1  | −0.106                | −0.160 | −0.027 | 0.009  | 0.001  | 0.209                        | <b>0.478</b> | 0.014        | 0.001        | 0.000        |
| Contm-0   | 0.672                 | 1.919  | 1.001  | −0.707 | 0.360  | 0.051                        | <b>0.419</b> | 0.114        | 0.057        | 0.015        |
| Contm-1   | −0.076                | −0.218 | −0.114 | 0.080  | −0.041 | 0.051                        | <b>0.419</b> | 0.114        | 0.057        | 0.015        |
| Incen-0   | 0.080                 | 0.008  | 0.205  | −0.085 | 0.054  | 0.044                        | 0.000        | <b>0.288</b> | 0.050        | 0.020        |
| Incen-1   | −0.550                | −0.056 | −1.403 | 0.584* | −0.367 | 0.044                        | 0.000        | <b>0.288</b> | 0.050        | 0.020        |
| Train-0   | 0.076                 | 0.173  | −0.362 | −0.152 | 0.091  | 0.017                        | 0.085        | <b>0.373</b> | 0.066        | 0.024        |
| Train-1   | −0.217                | −0.493 | 1.030* | 0.433  | −0.259 | 0.017                        | 0.085        | <b>0.373</b> | 0.066        | 0.024        |
| Lives-0   | 0.052                 | −0.009 | −0.115 | 0.914  | 0.416  | 0.001                        | 0.000        | 0.006        | <b>0.369</b> | 0.076        |
| Lives-1   | −0.023                | 0.004  | 0.051  | −0.403 | −0.183 | 0.001                        | 0.000        | 0.006        | <b>0.369</b> | 0.076        |
| Fishe-0   | 0.129                 | −0.144 | −0.011 | −0.125 | 0.123  | 0.108                        | <b>0.137</b> | 0.001        | 0.103        | 0.098        |
| Fishe-1   | −0.841                | 0.945* | 0.069  | 0.820* | −0.802 | 0.108                        | <b>0.137</b> | 0.001        | 0.103        | 0.098        |
| Build-0   | 0.291                 | −0.004 | −0.254 | 0.239  | 0.288  | <b>0.110</b>                 | 0.000        | 0.084        | 0.074        | 0.108        |
| Build-1   | −0.380                | 0.006  | 0.332  | −0.312 | −0.376 | <b>0.110</b>                 | 0.000        | 0.084        | 0.074        | 0.108        |
| Wpmp-0    | 0.135                 | −0.057 | −0.056 | 0.035  | −0.210 | 0.181                        | 0.032        | 0.031        | 0.012        | <b>0.437</b> |
| Wpmp-1    | −1.337                | 0.564* | 0.554* | −0.344 | 2.080* | 0.181                        | 0.032        | 0.031        | 0.012        | <b>0.437</b> |
| Tract-0   | 0.008                 | 0.012  | −0.039 | −0.033 | −0.034 | 0.006                        | 0.013        | <b>0.145</b> | 0.104        | 0.112        |
| Tract-1   | −0.787                | −1.118 | 3.752* | 3.177* | 3.290* | 0.006                        | 0.013        | <b>0.145</b> | 0.104        | 0.112        |
| Motor-0   | 0.211                 | −0.173 | 0.063  | −0.150 | 0.135  | <b>0.204</b>                 | 0.138        | 0.018        | 0.104        | 0.084        |
| Motor-1   | −0.969                | 0.797* | −0.291 | 0.691* | −0.622 | <b>0.204</b>                 | 0.138        | 0.018        | 0.104        | 0.084        |
| Tv-0      | 0.478                 | −0.139 | −0.505 | −0.025 | 0.307  | 0.202                        | 0.017        | <b>0.225</b> | 0.001        | 0.083        |
| Tv-1      | −0.423                | 0.123  | 0.446  | 0.022  | −0.271 | 0.202                        | 0.017        | <b>0.225</b> | 0.001        | 0.083        |
| Mobi-0    | 1.045                 | 1.414  | −0.158 | 1.108  | 0.003  | 0.138                        | <b>0.253</b> | 0.003        | 0.155        | 0.000        |
| Mobi-1    | −0.132                | −0.179 | 0.020  | −0.140 | 0.000  | 0.138                        | <b>0.253</b> | 0.003        | 0.155        | 0.000        |

\*\* Significantly correlated (positive correlation values above 0.5 and negative values farthest from 0 are set to significant); Values in bold correspond for each variable to the factor for which the squared cosine is the largest.

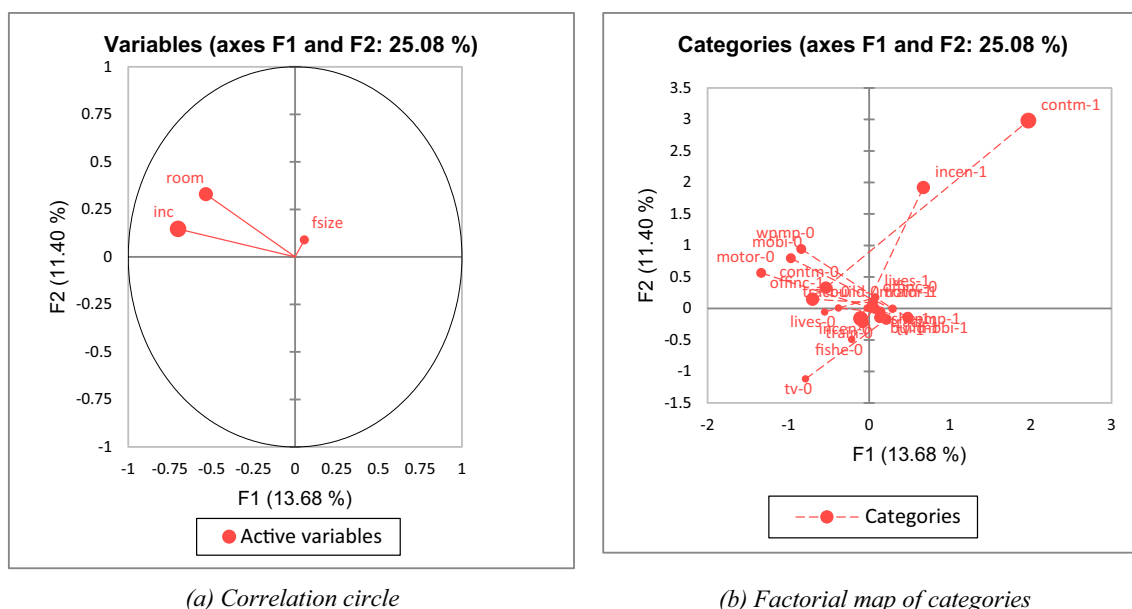
The PCA shows that the communalities are all above mediocre, ranging from 0.324 to 0.889 (Table 8). The KMO value is found to be 0.54, and Bartlett's measure is found to be highly significant ( $p < 0.0001$ ), indicating the appropriateness of PCA.

PC1 had the highest eigenvalue of 1.685 and accounted for 18.73% of the total variability of the data set, followed by PC2 and PC3. PC4 and PC5 have eigenvalues of 1.08 and 0.90, which account for 12.04% and 10.01% of the variances in the data, respectively (Table 8). According to the Keiser rule, only the first five PCs explaining approximately 68.74% of the total variability are selected for the factor analysis.

Table 9 presents the results of each variable's loading with eigenvectors on the five components extracted. PC1 seems to increase with increasing farming experience, access to fallow land, access to soil depth and risk-taking attitude. In PC1, access to soil depth emerges as the strongest variable, indicating its significant role in farmers' decision-making. This underscores the importance of understanding and utilizing soil resources in the cultivation of medicinal plants.

PC2 demonstrates an increase associated with multiple factors, including access to fallow land, plot size, soil depth, risk-taking attitudes, and scientific knowledge. The Biplot in Fig. 4 visually supports these relationships, emphasizing the multifaceted nature of motivations contributing to farmers' participation in MP production. This suggests that a combination of factors, ranging from land availability to risk attitudes and scientific knowledge, plays a collective role in shaping farmers' decisions.

Furthermore, PC3 highlights a positive and significant correlation with access to fallow land. The importance of fallow land in this context implies its role as a potential resource for farmers in their pursuit of medicinal plant cultivation.



**Fig. 3** Correlation circle (quantitative variables) and factorial map of categories of economic variables

**Table 7** Definition of biophysical variables for PCA

| Variables    |        | Definition and measurement                 | Mean (Stdev)/% | Extraction |
|--------------|--------|--------------------------------------------|----------------|------------|
| Quantitative | Exp    | Farming experience in year                 | 13.95 (9.75)   | 0.468      |
|              | Faland | Access to fallow land in hectare           | 2.42 (13.52)   | 0.435      |
|              | Plotz  | Access to plot size in decimal             | 26.69 (20.19)  | 0.889      |
|              | Soild  | Access to soil depth in inches             | 5.35 (3.01)    | 0.607      |
|              | Risk   | Risk taking attitude, likert scale         | 1.35 (2.36)    | 0.324      |
| Qualitative  | Aloe   | Access to <i>A. vera</i> crop (dummy)      | 0.628          | –          |
|              | Shimul | Access to <i>B. ceiba</i> crop (dummy)     | 0.163          | –          |
|              | Ashwa  | Access to <i>W. somnifera</i> crop (dummy) | 0.209          | –          |
|              | Know   | Scientific knowledge (dummy)               | 0.791          | 0.609      |
|              | Highl  | Access to high land (dummy)                | 0.939          | 0.427      |
|              | Loaml  | Access to loamy land (dummy)               | 0.832          | 0.556      |
|              | Soseed | Access to quality seeds (dummy)            | 0.974          | 0.555      |

Dummy takes the value 1 for positive response and 0 for others; '%' indicated the value in percentage of N=196.

This aligns with the notion that specific land-use practices, such as fallow periods, can positively influence agricultural outcomes.

In the case of PC4, plot size emerges as a crucial factor motivating farmers to decide on MP production. This emphasizes the significance of land size in influencing the decision-making process, possibly indicating that farmers with larger plots are more inclined to venture into medicinal plant cultivation. The cosine values PC1 contribute highly to access to soil depth, scientific knowledge and access to loamy land, while PC2 contributes most to farming experience.

The important biophysical motivational factors are farming experience, scientific knowledge, access to high land and access to loamy land, which encourage farmers to participate in MP production. Farming with more scientific knowledge and access to loamy land communities will have the highest potential to participate in MP production. For example, *A. vera* grows well in all kinds of soils, but well-drained soil rich in organic matter is preferable [83] because of its sensitivity to stagnant water conditions [84]. Chowdhury et al. [85] summarized similar results. Other studies [86–90] have also reported a positive correlation between soil type and plant growth. These studies indicated that soil ensures physical support for the growth, yield and quality of a plant species, and their suitability is a prerequisite for higher yield and better quality crops.

**Table 8** Eigenvalues and percentages of inertia for biophysical variables

| Component                             | Initial eigenvalues         |             |              | Extraction sums of squared loadings |             |              |
|---------------------------------------|-----------------------------|-------------|--------------|-------------------------------------|-------------|--------------|
|                                       | Eigenvalue                  | Inertia (%) | Cumulative % | Eigenvalue                          | Inertia (%) | Cumulative % |
| F1                                    | 1.69                        | 18.73       | 18.73        | 1.685                               | 18.73       | 18.73        |
| F2                                    | 1.36                        | 15.10       | 33.83        | 1.359                               | 15.1        | 33.83        |
| F3                                    | 1.16                        | 12.87       | 46.7         | 1.158                               | 12.87       | 46.70        |
| F4                                    | 1.08                        | 12.04       | 58.73        | 1.083                               | 12.04       | 58.73        |
| F5                                    | 0.90                        | 10.01       | 68.74        | 0.901                               | 10.01       | 68.74        |
| F6                                    | 0.85                        | 9.39        | 78.14        |                                     |             |              |
| F7                                    | 0.75                        | 8.36        | 86.50        |                                     |             |              |
| F8                                    | 0.66                        | 7.31        | 93.81        |                                     |             |              |
| F9                                    | 0.56                        | 6.18        | 100          |                                     |             |              |
| Kaiser-Meyer-Olkin Measure            |                             |             |              | 0.540                               |             |              |
| Bartlett's sphericity test statistics | Chi-square (Observed value) |             |              | 96.464                              |             |              |
|                                       | Chi-square (Critical value) |             |              | 50.998                              |             |              |
|                                       | p-value                     |             |              | < 0.0001                            |             |              |
|                                       | Alpha                       |             |              | 0.05                                |             |              |

Extraction method: Principal component analysis.

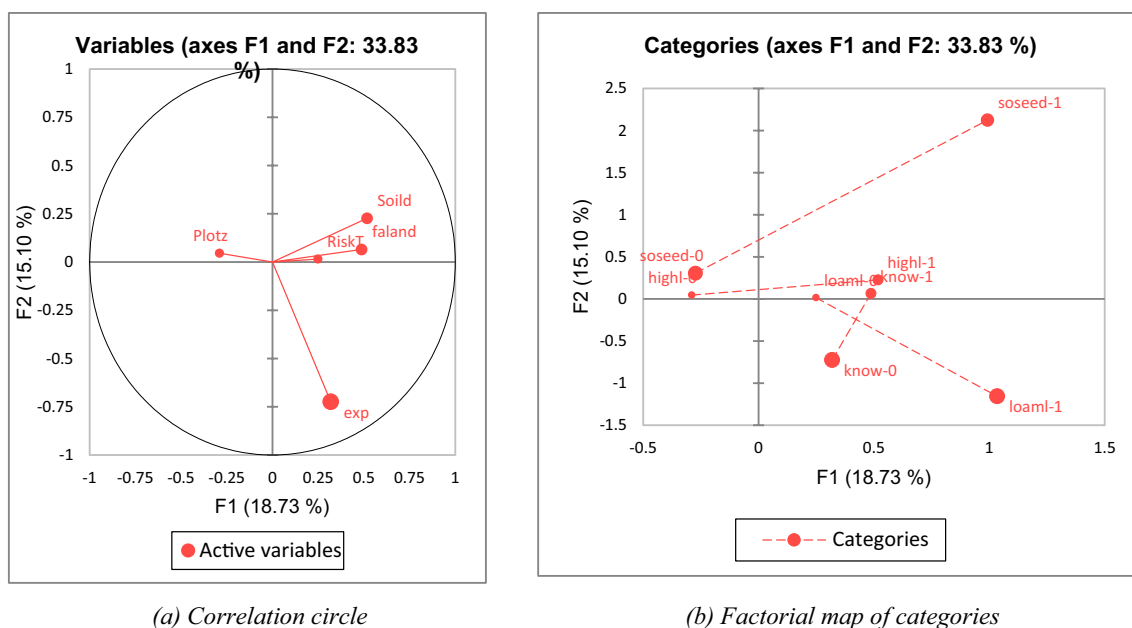
**Table 9** Principal coordinates squared cosines ( $\cos^2$ ) of biophysical variables

| Variables | Principal coordinates |        |        |        |        | Squared cosines ( $\cos^2$ ) |              |              |              |              |
|-----------|-----------------------|--------|--------|--------|--------|------------------------------|--------------|--------------|--------------|--------------|
|           | F1                    | F2     | F3     | F4     | F5     | F1                           | F2           | F3           | F4           | F5           |
| exp       | 0.319                 | −0.724 | −0.085 | 0.074  | 0.302  | 0.102                        | <b>0.525</b> | 0.007        | 0.006        | 0.091        |
| faland    | 0.487                 | 0.065  | 0.532* | −0.268 | −0.309 | 0.237                        | 0.004        | <b>0.283</b> | 0.072        | 0.095        |
| Plotz     | −0.290                | 0.046  | 0.373  | 0.614* | 0.126  | 0.084                        | 0.002        | 0.139        | <b>0.377</b> | 0.016        |
| Soild     | 0.517*                | 0.227  | 0.453  | −0.212 | 0.213  | <b>0.268</b>                 | 0.051        | 0.206        | 0.045        | 0.046        |
| RiskT     | 0.248                 | 0.015  | 0.301  | 0.698* | −0.214 | 0.062                        | 0.000        | 0.091        | <b>0.487</b> | 0.046        |
| know-0    | 1.034                 | −1.157 | −0.019 | 0.140  | 0.302  | <b>0.283</b>                 | 0.354        | 0.000        | 0.005        | 0.024        |
| know-1    | −0.274                | 0.306  | 0.005  | −0.037 | −0.080 | <b>0.283</b>                 | 0.354        | 0.000        | 0.005        | 0.024        |
| highl-0   | 0.992                 | 2.124  | −0.511 | 0.481  | 2.710  | 0.064                        | 0.294        | 0.017        | 0.015        | <b>0.479</b> |
| highl-1   | −0.065                | −0.138 | 0.033  | −0.031 | −0.177 | 0.064                        | 0.294        | 0.017        | 0.015        | <b>0.479</b> |
| loaml-0   | 1.410                 | 0.733  | −0.471 | 0.125  | −0.375 | <b>0.402</b>                 | 0.109        | 0.045        | 0.003        | 0.028        |
| loaml-1   | −0.285                | −0.148 | 0.095  | −0.025 | 0.076  | <b>0.402</b>                 | 0.109        | 0.045        | 0.003        | 0.028        |
| soseed-0  | 2.648                 | 0.876  | −3.763 | 1.674  | −1.697 | 0.184                        | 0.020        | <b>0.371</b> | 0.073        | 0.075        |
| soseed-1  | −0.069                | −0.023 | 0.099  | −0.044 | 0.044  | 0.184                        | 0.020        | <b>0.371</b> | 0.073        | 0.075        |

\*\* Significantly correlated (positive correlation values above 0.5 and negative values farthest from 0 are set to significant); Values in bold correspond for each variable to the factor for which the squared cosine is the largest.

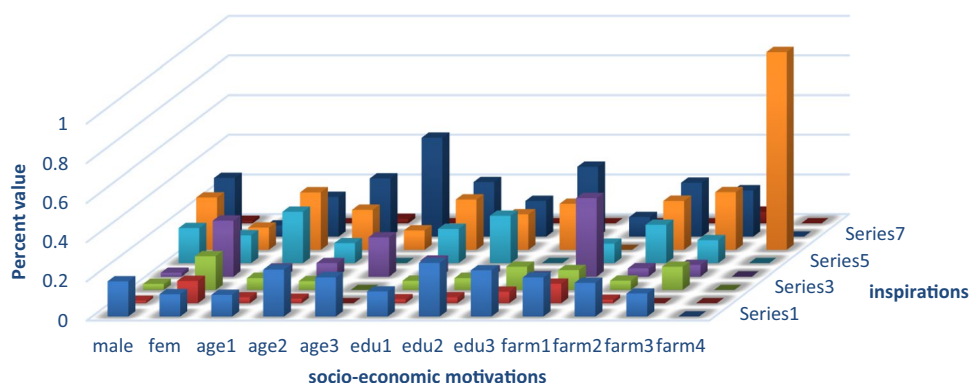
### 3.2 Inspiration for MP production

Figure 5 shows that male farmers are most likely to be motivated by the profit trends of MP production, followed by family members and neighbors, while female farmers are likely to be motivated by NGOs and agriculture extension workers. Age 1 group (up to 40 years) farmers are most likely to be motivated by family members, followed by farmer groups and seeing the profit trends of MP production. The results also reveal that farmers tend to be motivated by profit trends that increase with increasing age and education. Educated farmers with some college education (edu2) are most likely to be motivated by farmer groups. Farm size is also versatile to motivation dynamics. Small (farm2), medium (farm3) and large (farm4) farms are most likely to be motivated by family members and to see the profit trends from MP production, while landless farmers (farm1) are motivated through NGO workers.



**Fig. 4** Correlation circle (quantitative variables) and factorial map of categories of biophysical variables

**Fig. 5** 3D view of the contingency table of inspirations to motivations



Identifying and exploring the relationships between motivational factors and socioeconomic considerations that influence farmers' decisions to participate in medicinal plant (MP) production, the study utilizes Correspondence Analysis (CA). The extracted inertias offer estimates of the contribution of each variable to the components, shedding light on the factors responsible for farmers' rational decisions in engaging with MP production.

It is found that a new set of 7 orthogonal variables (PCs) are generated by PCA, while total inertia is found at 0.222. PC1 has the highest inertia, accounting for 44.97% of the total variability of the data set. The inertia of PC2 is equal to 38.67% of the total inertia, followed by 38.67%, 7.81%, 4.78%, 2.25%, 1.08% and 0.43% of the remaining components (PC3–PC7), respectively. The first two components explained approximately 83.639% of the significant variability in the data set (Table 10). Therefore, according to the Keiser rule, only the first two PCs are selected. Bartlett's measure is found to be highly significant, as the value  $p < 0.0001$ , which rejects the null hypothesis  $H_0$  and accepts the alternative hypothesis  $H_a$  with highly significant; therefore, it is concluded that the analysis (PCA) is appropriate.

PC1 is significantly influenced by the female headed household and landless farm, but inspiration comes from the company agent and group of farmers. The second component increases positively with a female headed household and age3 (65 and above) and negatively with a large farm (farm4) under rows, while under columns, the company agent and NGO are cases that increase positively (Table 11).

The biplot in Fig. 6a, b shows that the contribution by F1 was 44.97%, followed by F2 at 38.67%, while the total contribution was 83.64%. The biplot (rows) in Fig. 6a shows the positive direction of the group of farmers, while the negative value direction exhibits a neighbor. PC2 has an upward positive response for NGOs and a downward negative response

**Table 10** Eigenvalues and percentages of inertia for inspirations

| Statistics                 | F1                          | F2    | F3    | F4    | F5       | F6    | F7    |
|----------------------------|-----------------------------|-------|-------|-------|----------|-------|-------|
| Eigenvalue                 | 0.100                       | 0.086 | 0.017 | 0.011 | 0.005    | 0.002 | 0.001 |
| Inertia (%)                | 44.97                       | 38.67 | 7.81  | 4.79  | 2.25     | 1.08  | 0.432 |
| Cumulative %               | 44.97                       | 83.64 | 91.45 | 96.24 | 98.49    | 99.57 | 100   |
| Total inertia              |                             |       |       |       | 0.222    |       |       |
| Bartlett's sphericity test | Chi-square (Observed value) |       |       |       | 231.160  |       |       |
|                            | Chi-square (Critical value) |       |       |       | 98.481   |       |       |
|                            | p-value                     |       |       |       | < 0.0001 |       |       |
|                            | alpha                       |       |       |       | 0.05     |       |       |

Extraction method: Principal component analysis.

**Table 11** Principal coordinates of inspirations to motivations for MPs production

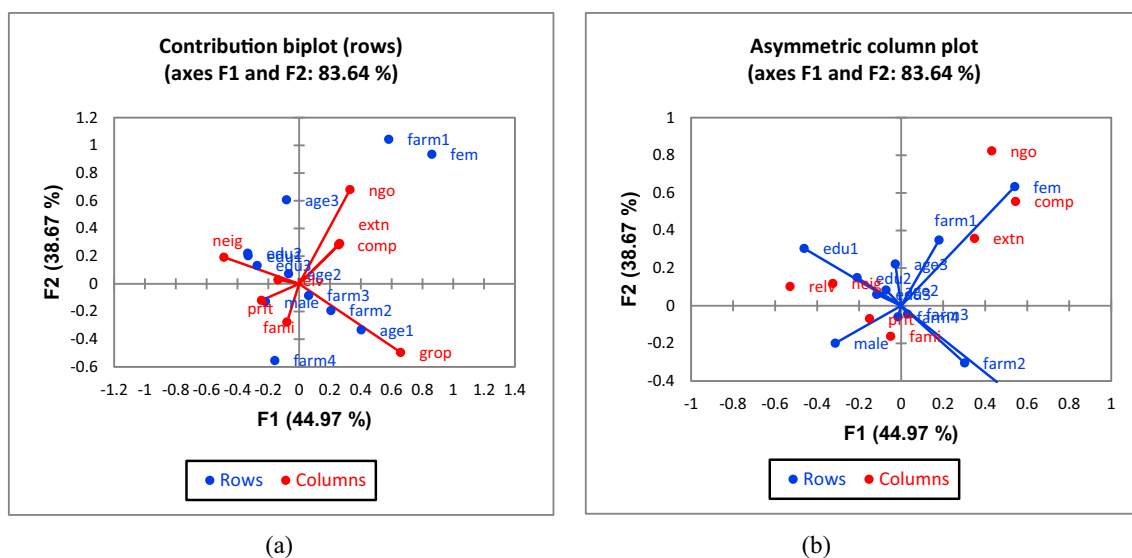
| Variables & Statistics |       | Principal coordinates (PCs) |              |              |              | Squared cosines (cos <sup>2</sup> ) |              |         |           |
|------------------------|-------|-----------------------------|--------------|--------------|--------------|-------------------------------------|--------------|---------|-----------|
|                        |       | F1                          | F2           |              |              | F1                                  | F2           |         |           |
| Socio-economic factors | Male  | − 0.218                     | − 0.128      |              |              | <b>0.732</b>                        | 0.252        |         |           |
|                        | Fem   | 0.861**                     | 0.936**      |              |              | 0.451                               | <b>0.533</b> |         |           |
|                        | Age1  | 0.403                       | − 0.332      |              |              | <b>0.577</b>                        | 0.392        |         |           |
|                        | Age2  | − 0.068                     | 0.073        |              |              | 0.116                               | 0.135        |         |           |
|                        | Age3  | − 0.082                     | 0.607**      |              |              | 0.006                               | 0.315        |         |           |
|                        | Edu1  | − 0.330                     | 0.202        |              |              | <b>0.699</b>                        | 0.262        |         |           |
|                        | Edu2  | − 0.334                     | 0.221        |              |              | <b>0.488</b>                        | 0.214        |         |           |
|                        | Edu3  | − 0.273                     | 0.132        |              |              | 0.231                               | 0.054        |         |           |
|                        | Farm1 | 0.582**                     | 1.044        |              |              | 0.215                               | <b>0.692</b> |         |           |
|                        | Farm2 | 0.207                       | − 0.193      |              |              | <b>0.486</b>                        | 0.422        |         |           |
|                        | Farm3 | 0.061                       | − 0.084      |              |              | 0.011                               | 0.021        |         |           |
|                        | Farm4 | − 0.158                     | − 0.553**    |              |              | 0.008                               | 0.102        |         |           |
| Inspirations           |       | neig                        | comp         | extn         | ngo          | grop                                | fami         | prft    | relv      |
| PCs                    | F1    | − 0.325                     | 0.545**      | 0.349        | 0.431        | 0.605**                             | − 0.050      | − 0.151 | − 0.529** |
|                        | F2    | 0.119                       | 0.554**      | 0.358        | 0.823**      | − 0.422                             | − 0.162      | − 0.068 | 0.103     |
| Cos <sup>2</sup>       | F1    | <b>0.798</b>                | 0.395        | 0.337        | 0.200        | <b>0.665</b>                        | 0.053        | 0.405   | 0.201     |
|                        | F2    | 0.107                       | <b>0.409</b> | <b>0.355</b> | <b>0.731</b> | 0.324                               | <b>0.561</b> | 0.083   | 0.008     |

\*\* Significantly correlated (positive correlation values above 0.5 and negative values farthest from 0 are set to significant); Values in bold correspond for each variable to the factor for which the squared cosine is the largest; Extraction method: Principal component analysis.

for farmers. The biplot (rows) result for classification is presented in four quadrants (Q): Q1 is the group of farmers; Q2 is the NGO, agriculture extension officer and company agent; Q3 is the neighbor; and Q4 is profit trends and family members. Figure 6b shows the asymmetric biplot (column plot), where the positive value direction of PC1 shows age 1 (below 40), while the negative value direction exhibits edu1 (up to the 8th standard). For PC2, its upward positive value shows a female headed household, and the downward negative value shows a small farm (farm2). The result for classification is presented in four quadrants (Q): Q1 is age below 40 and small farm; Q2 is female headed household and landless farm; Q3 is education up to 8th standard; Q4 is male headed household (Fig. 6b).

The cosines for rows variables showed that component 1 contributes highly to male-headed households, age below 40, education up to the 8th standard, education up to some college education and small farms, while component 2 contributes most to female-headed households and landless farms. Regarding column variables, the cosines in Table 11 show that component 1 contributes highly to neighbors and groups of farmers, while Component 2 contributes most to company agents, agriculture extension officers, NGOs and family members.

It can be asserted that, within the spectrum of motivations for company agents, NGOs, groups of farmers, and relatives, there is a discernible inclination towards encouraging farmers with specific socio-economic factors. Notably, female-headed households, individuals aged 65 or above, landless farms, and large farms exhibit a relatively higher potential



**Fig. 6** **a** Biplot regarding rows. **b** Biplot regarding columns

to participate in medicinal plant (MP) production. In the study area, the company agent inspired farmers to participate in MP production mainly to fulfill their company's demand for raw materials, specifically MP crop produces. NGOs work with MP farmers mainly to develop this sector by implementing extension activities such as training. Company agent and NGO workers assist farmers in production practices; thus, farmers can produce in standard quality. These two factors are identified as highly potential motivational factors to participate in MP production. This is likely because access to extension services has been found to be a key driver in technology adoption and exposing farmers to information based upon innovation-diffusion theory. Extension agents usually target specific farmers who are recognized as peers (farmers with whom a particular farmer interacts), exerting a direct or indirect influence on the whole population of farmers in their respective areas [26].

## 4 Conclusion and policy recommendations

MP production in Bangladesh contributes to diversifying agriculture, generates employment and ensures cash income through traditional and contract marketing systems. The results showed that socioeconomic factors such as household size with more working members and male-headed communities practicing farming activities will have the highest possibilities in MP cultivation. Economic factors such as ownership of water pumps, number of rooms in houses, access to contract marketing, and off-farm income have the potential to encourage households to cultivate MPs. The biophysical motivational factors are farming experience, scientific knowledge, access to high land and access to loamy land, which encourage farmers to participate in MP production. Farming with more scientific knowledge and access to loamy land communities will have the highest potential to participate in MP production. Among the inspirations to motivate company agents, NGOs, groups of farmers and relatives play vital roles. Therefore, it can be said that male headed household, access to contract marketing, and farming experience are motivated factors to the farmers to cultivate more MPs in the study areas. The policy therefore suggests that technical support especially extension support, vocational education for scientific knowledge dissemination and farmers groups should be encouraged through different government line departments and NGOs to encourage farmers more in MP production and participate in contract marketing systems.

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**Author contributions** MIH conceptualized, designed, analysed and prepared the draft manuscript. MAS collected primary data, analysed data and materialized first draft of the manuscript. MFB outlined and checked the consistency. MEAB checked grammar, consistency and further improved the article. All authors reviewed the manuscript.

**Data availability** The data that support the findings of this study are available from the corresponding author.

## Declarations

**Ethics approval and consent to participate** It should be mentioned in here that there was no chance to apply for Research Ethics Board (REB) permission because there was no institutional ethical board to approve social science study. Because of this academic constraint, the study was exempt from needing ethics approval.

**Informed consent** All study participants gave the authors their informed consent before their data was used in a scholarly publication. This research did not involve any minors.

**Competing interests** The authors declare no competing interests.

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