Public–private partnership towards rural development: a study of *Artemisia annua* in Uttar Pradesh

Public–private partnership (PPP) model is now being adopted by many government organizations and research and development institutions. In today's economic scenario, the PPP model has been providing strength to the economy and also creating new employment opportunities for economic development. In India, the PPP model has not been popular so far in the area of agriculture and farming. These opportunities are being exploited for the benefits of farmers by the CSIR-Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow in the form of a PPP model for contractual cultivation of medicinal and aromatic plants with assured buy-back from the industry at a preferred price. This model has been well adopted by the farmers growing specified crops in partnership with the industry under the technical guidance of the Institute. *Artemisia annua*, an anti-malarial drug plant, is also cultivated under the PPP model in different parts of the country.

The first natural drug introduced for malaria control was quinine obtained from the cinchona plant of South America. Later on, several synthetic analogues of quinine were introduced into the market. A continued search for such plant-based drugs led to the identification of newer sources. Later, the Chinese drug qinghaosu (artemisinin) obtained from the herb 'QingHao' (*Artemisia*) came to limelight. This drug was originally used in ancient Chinese medicine for the treatment of febrile illness. The Chinese scientists discovered the anti-malarial property of QingHao in 1971. The crystallized active component named qinghosu was isolated, characterized and defined as possessing anti-malarial properties. No serious adverse effect of artemisinin and its derivatives in humans has yet been reported. In India, *A. annua* was introduced by CSIR-CIMAP in 1986, from the Royal Botanical Gardens, Kew, England. Agro-technologies for its cultivation in tropical to subtropical climate have been developed. Dried leaves of the plants are used for extraction of artemisinin. Leaves are the principal source for the synthesis and accumulation of artemisinin[1]. The Institute has also released high-yielding varieties of *A. annua* like Jeevan Raksha and CIM-Arogya. *A. annua* is an annual shrub indigenous to China and commercially cultivated in China, Vietnam, Tanzania and India. This crop can be well cultivated in both temperate and tropical climatic regions of India. The agro and process technologies have been transferred to many industries of Indian origin. *A. annua* is now cultivated in different states like Uttar Pradesh (UP), Bihar, Madhya Pradesh (MP), Uttarakhand and Gujarat with contractual cultivation (on buy-back guarantee basis) by the industry (Table 1). This crop is now becoming popular among a large number of farmers as a profitable venture through the efforts of CSIR-CIMAP. The plant is now economically grown for enhancement of rural livelihood and creating job opportunities. It also fits well in the existing cropping pattern adopted by the farmers[2]. The present correspondence is a case study on *A. annua* crop in UP, with regard to PPP for rural development.

The study was conducted during 2012–13 in four districts of UP, namely Barabanki, Sitapur, Lakhimpur and Raebareli. This is because in these districts contractual cultivation of *A. annua* is done by the farmers with a buy-back agreement with M/s Ipca Laboratories, Ratlam, MP, with technical guidance from CSIR-CIMAP. In the surveyed districts 80 farmers were identified based on the information available with the Institute and the industry. Those selected were mostly small and medium farmers according to their land holdings. These farmers were trained by the Institute in the cultivation of *A. annua* through organizing of awareness camps and demonstrations in their fields. Scientists from CSIR-CIMAP regularly visited the field for solving problems in cultivation and for educating farmers about primary processing of medicinal and aromatic plants, especially *A. annua*. Primary data were collected through personal interviews using a well-thought-out questionnaire.

Table 1. Estimated area and production of *Artemisia annua* in the country

	2008–09		2009–10		2010–11		2011–12		2012–13	
State	A	P	A	P	A	P	A	P	A	P
Uttarakhand	–	–	20	5	60	28	100	60	80	50
Uttar Pradesh	–	–	35	11	240	103	1200	769	1500	900
Gujarat	150	110	150	108	350	183	900	695	1000	850
Madhya Pradesh	60	35	5	1	25	13	40	20	50	22
Others	15	5	15	5	25	23	40	28	40	28
Total	225	150	225	130	700	350	2280	1572	2670	1850

A, Area (acres); P, Production (tonnes).
Source: Primary data collected from the field and industry.

Table 2. Socio-economic and resource structures of *A. annua* farmers in the study area

Particulars	Value
Average size of landholding (ha)	1.97
Average family size (no.)	7.89
Literacy level (%)	95.60
Occupation (%)	
Dairy, services and others (%)	27.20
Agriculture	72.80
Cropping pattern (%)	
Agricultural crops (paddy, wheat, potato, mustard, etc.)	55.32
Medicinal and aromatic crops (*A. annua*, etc.)	44.68
Average farm assets of farm building and irrigation structures (Rs)	226,573
Average farm assets (farm machinery/equipment and distillation unit) (Rs)	275,982

To study the economics of *A. annua*, a simple cost accounting method was followed. The price used in the analysis was that offered to the farmers by the industry under contractual cultivation for that crop harvesting period 2012–13. The Cob–Douglas production function was well-fitted to evaluate resource-use efficiency in the production of *A. annua* crop cultivated by the selected farmers[3,4]

$$Y = aX_1^{b1} \cdot X_2^{b2} \cdot X_3^{b3} \cdot X_4^{b4} \cdot X_5^{b5} \cdot X_6^{b6}, \quad (1)$$

where Y is the yield value of *A. annua* (Rs/ha), X_1 the human labour value (Rs/ha), X_2 the machine and tractor hours value (Rs/ha), X_3 the raising of nursery/seed value (Rs/ha), X_4 the manure and fertilizer value (Rs/ha), X_5 the irrigation value (Rs/ha) and X_6 indicates the transport charges (Rs/ha).

Family size is one of the important factors influencing adoption of cultivation of *A. annua*. Family size was found to be large in the case of selected farmers, average size of the family was 7.89 (Table 2). It was also observed that majority of *A. annua* growers were literate, which indicates that education creates awareness among the farmers for adoption of a new crop and technology. The average size of operational holdings with the selected farmers was found to be less than 2 ha. Farmers of the study area have cultivated traditional crops, i.e. paddy, wheat and sugarcane in 55.32% of their total cultivable land holdings. Antimalarial crop *A. annua* and other crops are being cultivated in rest of the cultivable land. This shows the interest among farmers for adoption of new crops. The role of investment pattern being significant in productivity of a crop, per farm investment on fixed assets like farm building, irrigation structures, tractor/equipment and distillation units were estimated (Table 2).

Table 3 gives the cost structure of *A. annua* cultivation. From the table it can be seen that cultivation of *A. annua* requires more labour input. It was observed during the study that small and medium farmers showed more interest for cultivation of this crop. Total variable cost was found to be Rs 21,844/ha. The input–utilization pattern in cultivation of the crop showed that two-thirds of the cost go for human labour engaged in transplanting, inter-culture, irrigation, harvesting, threshing and packaging (49.42%). Irrigation cost was 11.60%, while FYM and fertilizers accounted for 11.27%. The remaining cost was shared by the other inputs like seed and nursery, machine/tractor, etc.

Table 4 gives the economics for cultivation of *A. annua*. The data reveal that the total return is Rs 87,603/ha. The net return over variable cost is observed to be Rs 65,759/ha. The benefit–cost ratio is 4.01. *A. annua* generally grows wildly in China. However, a comparative study from Tanzania shows that as a labour-intensive crop, particularly at the planting and harvesting stages, *A. annua* is in many respects ideally suited to small land holders for cultivation. However, the viability of the enterprise depends on the costs and returns of *Artemisia* cultivation (net return US$ 600/ha for small holders and US$ 805/ha for commercial growers) and on its profitability in comparison to alternative cash crops[5]. Therefore, it could be concluded that cultivation of this crop is a profitable venture, compared to other existing crops. Farmers in the *Artemisia*-growing areas should be encouraged to diversify their existing cropping pattern towards medicinal/industrial crops to enhance their farm income.

Table 5 gives the estimated resource-use efficiency in *A. annua* cultivation. The R^2 value is 0.907, which indicates that 91% of the variations in *A. annua*

Table 3. Cost structure of *A. annua* cultivation (Rs/ha) during 2012–13

Particulars	Amount (Rs)	Percentage
Human labour (transplanting, inter-culture, irrigation, harvesting, threshing, etc.)	10,795	49.42
Machine/tractor	2,035	9.32
Raising of nursery and seed	2,054	9.40
FYM and fertilizers	2,461	11.27
Irrigation	2,535	11.60
Transport charges	1,536	7.03
Interest on working capital @4% for six months	428	1.96
Total variable cost	21,844	100.00

Table 4. Economics of production of *A. annua*: 2012–13

Particulars	Amount (Rs)
Yield of leaf main product (q/ha)	24.61
Price (Rs/q)	3,300
Return from main crop (Rs/ha)	81,213
Yield of by-product (wood) (q/ha)	31.95
Price (Rs/q)	200
Return from by-product (Rs/ha)	6,390
Gross return (Rs/ha)	87,603
Total variable cost (Rs/ha)	21,844
Net return over variable cost (Rs/ha)	65,759
Benefit–cost ratio	4.01

Table 5. Estimated production function for *A. annua* cultivation

Variables	Regression coefficient	Standard error
Regression constant (*a*)	0.126	0.880
Human labour value (Rs/ha)	0.321*	0.157
Machine and tractor value (Rs/ha)	0.087^{NS}	0.080
Raising of nursery/seed value (Rs/ha)	0.235*	0.109
Manure and fertilizer value (Rs/ha)	0.255*	0.059
Irrigation value (Rs/ha)	0.205^{NS}	0.137
Transport charges (Rs/ha)	0.345*	0.099
R^2	0.907*	–
N	60	–

*Significant at 5% level, NS, Non-significant.

yield are influenced by the explanatory variables included in the model. It is evident from the data that human labour, seed and nursery raising, manure and fertilizer, and transport charges show positive and significant impact on crop production. Hence, increase in inputs such as human labour, seed, nursery, manure, fertilizer and transport would influence the crop yield.

A. annua crop has been introduced by CSIR-CIMAP in India under contractual cultivation and buy-back arrangement with pharma industries to avoid marketing problems for the farmers. In the study areas in UP contractual cultivation is being done by the M/s Ipca Laboratories, Ratlam from 2009 onwards; the whole produce is purchased by the company directly from the farmers at a price mutually agreed to by both of them before planting the crop. Farmers are cultivating this crop on the basis of contractual cultivation guided by CSIR-CIMAP. However, the major constraints faced by farmers in producing the crop include shortage of labour in harvesting and threshing season, absence of input subsidies and poor access to loan from banks, shortage of electricity, lack of regulated market, lack of storage and drying facilities.

The present study shows that cultivation of *A. annua* provides high returns to farmers in a short span of about four months. The contractual cultivation under PPP model strengthens the farmers to adopt new technologies and crops. It is concluded from the study, that cultivation of industrial/medicinal crops under contractual cultivation will give a boost for expansion of new crops by providing assured returns to the farmers and avoiding the marketing problems and price-lowering during peak harvest season.

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An approach to improve shallow surface investigation using joint analysis of Rayleigh and Love waves

Rayleigh and Love waves travel along the surface and are commonly characterized by relatively low velocity, low frequency and high amplitude[1]. Longer wavelengths penetrate greater depths and exhibit greater phase velocities, and are more sensitive to the elastic properties of the deeper layers[2]. On the contrary, shorter wavelengths are more sensitive to the physical properties of shallow surface layers. The particle motion for the fundamental mode of Rayleigh waves in a homogeneous medium is elliptical in a counter-clockwise (retrograde) direction along the free surface[3]. With depth, the particle motion turns out to be prograde and is elliptical when reaching appropriate depth. The dispersive properties of Rayleigh wave for near-surface characterization have been well-established[3–9]. Love wave is generated from the total internal and multiple reflections of horizontally polarized shear wave (SH)[10]. The dispersion properties of Love wave are independent of *P*-wave velocity[11], thus, it gives a clear inverted *S*-wave velocity model.

Joint analysis of Rayleigh and Love waves dispersion is accomplished to improve the vertical shear wave velocity (V_S) profiles. If the energy of all modes is not considered accurately, it leads to ambiguous or erroneous subsurface velocity models. Non-uniqueness is a well-known issue that affects most of geophysical techniques[12,13]. However, the non-uniqueness of the solution[14,15] can be resolved by performing the inversion using prior geological information of the area. Therefore, joint analysis of dispersive properties for both the Rayleigh and Love waves could be used as a highly valuable tool in the improvement of subsurface investigation[16].

In the present study the data have been acquired over upper ground, Indian School of Mines, Dhanbad using the 24-channel Stratavizor NZ seismograph with 4.5 Hz vertical and horizontal geophones for understanding the potential usefulness of joint analysis of Rayleigh and Love wave dispersion to improve vertical shear wave velocity distribution in

Table 1. Summary of field data acquisition

Recorded component	Source	Type of geophone	Orientation of geophone
Vertical component of Rayleigh wave (*P*)	Vertical	Vertical (4.5 Hz)	Vertically inserted
Love wave (SH)	Horizontal	Horizontal	Perpendicular to the array