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Diversifying cropping systems with aromatic crops for better productivity and profitability in subtropical north Indian plains

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ABSTRACT

Diversifying agroecosystems with incorporation of suitable crops could deliver great results pertaining productivity, profitability and sustainability. In the study, we have exclusively focused on the improvement of agricultural income through integration of aromatic crops in the crop rotations. Data set of the research findings would help in providing information about aromatic and agricultural crops, their cultivation cost, economical indices, and profit earned by the farmers in access to diversified cropping systems. Maximum gross returns (357×10^3 INR or 5.56×10^3 USD), net returns (250×10^3 INR or 3.90×10^3 USD), per day return (2.6×10^3 INR or 41 USD), benefit cost ratio (10.52), and marginal benefit cost ratio (8.04) was found in T_8 – (basil-pea-menthol mint) cropping system. Diversified cropping system with basil, pea and menthol mint is suitable combination of annual cropping sequence. This would aid sustaining higher yields and monetary returns to farmers.

1. Introduction

Conservation agriculture (CA) covers multifunctional aspects including diversification of crop rotations with economically viable crops for improving the agricultural sustainability, profitability and mitigation of climate change through carbon sequestration (Powlson et al., 2016). The maximum gain of CA can be realized only if cropping systems are taken into consideration (Bhattacharyya et al., 2015). Diversification refers to modifying the agroecosystem by revising cropping patterns/rotations/sequences/cycles aiming at reducing summer fallow or intervening period, increasing the cropping intensity as well as diversity and delivering benefits to farmers through the production of economically important crops (Birthal et al., 2015; Weinberger and Lumpkin, 2007; Barghouti et al., 2004; Joshi et al., 2004; Ali and Abedullah, 2002). Agricultural profits are key source of income to rural population (Ma and Maystadt, 2017) and diversification plays a pivotal role in sustaining agriculture and agriculture based livelihood (Bigsten and Tengstam, 2011; Jayne et al., 2010). Hence, it becomes imperative to introduce diversified, socially acceptable, economically justifiable, climate change adaptable and sustainable cropping systems. Concept of diversification should primarily cover social and economic contexts by regulating price risk and addition of non-food crops in the conventional cropping system. Additionally it also enhances the soil health and crop productivity by extensive efficiency utilization of accessible resources. Polakova et al. (2016) have recommended strategy for diversifying the rural economy by aiding the farmers in finding new commercial ways of utilizing the existing resources of conventional agriculture.

Cropping intensity can be described as the annual time period when crops are grown in a sequence (Caviglia and Andrade, 2010). High cropping intensity reduces agricultural pressure on the land resource as well as restores diversity (Dore et al., 2011). Diversified and intensive cropping systems in synchronization with other CA practices (Gupta and Seth, 2007) can reduce or entirely eliminate the regularity of summer fallow or intervening period in the conventional cropping systems (Peterson et al., 1998). Potential productivity and monetary profits are the guiding principles of the farmers for adopting a diversified and intensified cropping system while non-adoption of appropriate cropping system and excessive use of water restricts its availability. Crop diversification is effective in influencing poverty (Birthal et al., 2015) where adoption of high value aromatic crops can be a novel concept to diversify and intensify (Jayne et al., 2010) the existing cropping systems. The demand of these income generating aromatic crops is increasing globally (Barataa et al., 2016; Birthal et al., 2015) and more than fifty percent of which are harvested from the wild (Traffic International, 2015). Several reports have also highlighted the global importance of aromatic plants due to huge volume of trade at national and international levels (I.C.M.A.P., 2003; Kuipers, 1997). Aromatic crops are economically important for the farmers as they

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provide additional monetary profits like higher net returns per unit area, low incidence of pests and diseases, improvement of degraded and marginal soils, longer shelf life of end products and foreign exchange earning potential (Rao et al., 2004, 2000; G.O.I., 2000). The economically value added product (essential oil) of aromatic crops is a necessity as its demand is increasing in the world market. Aromatic crop like basil is generally grown during the rainy season (July to October) in subtropical north Indian plains (Padalia et al., 2017; Pandey et al., 2016; Singh et al., 2010a) as a commercial alternative to conventional rice crop. Rice cultivation necessitates exhaustive resources like water, fertilizers, weed and pest management (Bhatt et al., 2016). Some regions of the subtropical north Indian plains are rain-fed and cultivation of rice is uneconomical due to its low productivity and high input cost (Bhatt et al., 2016). Moreover, due to planetary problems like global warming and climate change, there is a reduction in the rainfall period and productivity of rice in India. Basil can also be cultivated as an alternative crop in water stressed and degraded soils (Khalid, 2006; Gupta et al., 1998; Narayana, 1998). Basil apart from being a profitable and environmentally adaptable alternate to rice in the rainy season delivers agricultural sustainability.

There is a need to evaluate the alliance of cropping systems diversification and intensification through integration of aromatic crops for better crop yields, soil quality and farmer's economic returns. Thus, the present study aims to evaluate the economic profitability of the diversified traditional cropping systems with the integration of aromatic crops.

2. Materials and methods

2.1. Details of experimental site

The experimental site was the research farm of CSIR–Central Institute of Medicinal and Aromatic Plants (CIMAP) (26.5 ^{0}N, 80.5 ^{0}E), Lucknow, Uttar Pradesh, India which is classified as a subtropical zone. The climate of the site is characterised with hot summers, fairly cool winters and with an average annual precipitation of 1000 mm, ranging from the month of July to September. The soil of experimental field was categorized as loamy sand having pH 8.1 with organic C of 3.3 g kg^{-1} soil and N, P, K as 47, 42, and 156 mg kg^{-1} soil, respectively.

2.2. Experimental details

A field experiment laid out in a randomized block design with three replications was conducted for four consecutive years (2012–13, 2013–14, 2014–15, and 2015–16). A field plot of each bed size of 3 m × 4 m (12 m^2) was used for the proposed annual cropping systems and comprised a total of 8 treatments; details of which are given in Table 1.

Table 1
Annual cropping systems of the experiment.

Treatments/Cropping Systems	Rainy season crop	Winter season crops	Summer season crops
T_1–B-W-C	Basil	Wheat	Cowpea
T_2–B-W-M	Basil	Wheat	Menthol mint
T_3–B-P-C	Basil	Potato	Cowpea
T_4–B-P-M	Basil	Potato	Menthol mint
T_5–B-L-C	Basil	Lentil	Cowpea
T_6–B-L-M	Basil	Lentil	Menthol mint
T_7–B-Pe-C	Basil	Pea	Cowpea
T_8–B-Pe-M	Basil	Pea	Menthol mint

*B – *Ocimum basilicum* (Basil); W – *Triticum aestivum* (Wheat); P – *Solanum tuberosum* (Potato); L – *Lens culinaris* (Lentil/Masur); Pe – *Pisum sativum* (Pea); C – *Vigna unguiculata* (Cowpea); M – *Mentha arvensis* (Menthol mint).

2.3. Crop management

Details of agricultural and aromatic crops included in the proposed annual cropping systems are depicted in Table 2. Seeds of agricultural crops were procured from certified retailers, while the seeds and suckers of *Ocimum basilicum* L. cv. CIM-Saumya and *Mentha arvensis* L. cv. Kosi, respectively were procured from the gene bank of CSIR-CIMAP, Lucknow. During the cropping periods, standard agronomic procedures were performed for the cultivation of all the crops. Basil seeds and menthol mint suckers were sown on raised and flat beds, respectively. One month old seedlings of both the aromatic plants were used for transplanting in the experimental field, approximately one lakh transplants per hectare of menthol mint and sixty seven thousand transplants per hectare of basil (Aush Gyanya, CSIR-CIMAP, 2016). The fertilizers nitrogen (N), phosphorus (P) and potassium (K) were applied in the ratio of 80:60:60 (N:P:K) and the sources of N, P and K were urea, diammonium phosphate and muriate of potash, respectively. Urea (N) was applied in 3 splits, whereas, DAP (P) and MoP (K) were applied as the basal dose in each crop before sowing/planting. In the permanent beds and conservation tillage plot, manual weeding was done at regular time intervals. Each bed of the experimental plot having specific crop was irrigated as per the scheduled time and requirement. Crops were harvested at their specific harvesting time mentioned in Table 2. The agricultural crops residue and distillation waste of the aromatic crops were integrated back into the respective crop beds.

2.4. Data collection

Biological yields of the agricultural crops were taken separately. Fresh herb of aromatic crops was taken for the estimation of essential oil content. Total fresh biomass and grain yields were estimated on the basis of harvest taken from 12 m^2 beds. Essential oil yield was calculated on the basis of essential oil percentage and fresh biomass production.

2.5. Essential oil distillation

Both the aromatic crops (basil and menthol mint) were harvested at the time mentioned in Table 2. Fresh above ground biomass (200 g per bed) was used for the extraction of essential oil through hydro-distillation in a Clevenger's hydro-distillation apparatus for 3–4 h (Clevenger, 1928).

2.6. Analysis of crops economics

We evaluated the agronomical productivity and economical profitability of various combinations of crops proposed in each cropping system. Cost of cultivation included several variables which are mentioned in Table 3. Cost of key inputs and outputs were based on the standard market prices of relevant years. Total variable cost of each cropping system for four consecutive years is given in Table 5.

2.7. Economical indices

Economical indices aids in providing good comparison of different cropping systems in terms of monetary profits. The following economical indices were calculated for better understanding of results to assess the economic justifiability:

2.7.1. Gross returns (GR)

Gross returns are the monetary returns of the grain/essential oil produced from the crops included in the cropping systems which were calculated on the basis of standard market prices. The formula of gross returns is expressed in the Eq. (1).

$$GR = Grain\ or\ Essential\ oil\ yield \times Respective\ market\ prices \quad (1)$$