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Agronomic performance, nutrient cycling and microbial biomass in soil as affected by pomegranate based multiple crop sequencing

Som Dev Sharma[a], Pramod Kumar[b,*], Satish Kumar Bhardwaj[c], Ashu Chandel[d]

[a] Dr YSP UHF-COHF, Department of Horticulture, Neri, Hamirpur, Himachal Pradesh, India
[b] Dr YSP UHF-Regional Horticultural Research & Training Station, Dhaulakuan, Sirmour, Himachal Pradesh, India
[c] Dr YSP UHF-Department of Environmental Sciences, Nauni, Solan, 173 230 Himachal Pradesh, India
[d] Dr YSP UHF-Department of Basic Sciences, Nauni, Solan, 173 230 Himachal Pradesh, India

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ABSTRACT

The research has been focused for the systematic examination and assessment of cropping behavior, soil productivity and the promotion of soil biodiversity in pomegranate based multiple crop sequencing. The study also sought to monitor the agronomic performance, nutrient availability and microbial communities' in the rhizosphere. The potential of five crop sequencing systems comprised 'Pomegranate–Urd–Garlic' (P–U–G), 'Pomegranate–Urd–Pea' (P–U–P), 'Pomegranate–Turmeric' (P–T), 'Pomegranate–Broccoli' (P–B) and 'Pomegranate monoculture' (Pmono) under rainfed ecosystem has been demonstrated. After intercrop sequencing cycles, the essential relevant elements significantly improved growth attributes, physical, chemical and biological attributes of the rhizosphere soil compared to monoculture cropping practice. Maximum moisture content at field capacity (M_cF_c, 24.9%), water holding capacity (WHC, 33.3%) and soil organic carbon (OC, 7.16 g kg^{-1}) was recorded in P–U–P intercrop sequencing. This superior sequencing also recorded the available macronutrient contents (N, P, K), exchangeable Ca and Mg of soil which were increased by 8.15%, 36.9%, 8.6%, 31.5% and 22%, respectively over Pmono. Diethylenetriaminepentaacetic acid (DTPA)—extractable micronutrient cations (Fe, Cu, Zn, Mn) improved by 15.6%, 23.2%, 28.7% and 16.5%, respectively. Microbial biomass carbon (MB_C), microbial biomass nitrogen (MB_N), and the plate count (colony-forming units, CFUs) of *Bacillus*species, *Pseudomonas*species, total soil fungi, *Azotobacter chroococcum*and actinobacteria exhibited significant variability. MB_C and MB_N ranged from 172.3 to 255.9 mg kg^{-1} and 12.1 to 17.2 mg kg^{-1}, respectively. Microbial biomass of *Pseudomonas* species (116.5%), *Bacillus*species (80.5%), total soil fungi (204.4%), *A. chroococcum*(219.6%) and actinobacteria (205.6%) improved significantly over Pmono. Correlation analysis of different attributes representing the chemical and biological properties of soil also resulted in a significant association at $P < 0.05$ attribute pairs. Principal component analysis (PCA) of soil quality attributes was also worked out to evaluate the differences induced among intercrop sequencing systems. The results inferred that PC4 accounted for 100% of the total variance in all intercrop sequencing. Therefore, no correlation was observed between the soil properties, and the first, second and third PC (PC1, PC2, and PC3). It is expedient from the studies that the intercrop sequence systems have effects on soil fertility indicators and has the implications for agricultural productivity.

1. Introduction

Cropping systems set agricultural activities into a functional unit to harness the solar energy by preserving land productivity, environmental quality and maintains the desirable level of biological diversity and ecological stability. The intensified land-use system of agriculture will certainly put greater pressures on the available natural resources of our crop. The continuous increase of the world population and in particular to India has triggered the demand for food tremendously. Integrated farm sequencing explains a more integrated approach to farming as compared to existing monoculture approaches that has revolutionized conventional farming of horticulture, agro-industry and allied activities (Chan, 2006). Small and marginal farmers representing more than 86% of Indian farm families with holding size below 1.2 ha which live in the risk prone diverse production conditions. The possi-

* Corresponding author.
E-mail address: psharma09@yahoo.com (P. Kumar).

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ble way of increasing the productivity would be through multiple cropping systems like intercropping which is one of the options to feed more mouths. Intercropping is one of the important cropping system in both temperate and tropical Indian conditions that has become popular among the small scale farmers as it offers the possibility of yield advantage for both component crops or one of them as compared to mono-cropping through improved yield and stability of yield (Bhatti et al., 2006). The sequential crop system of farming has a large influence on soil properties including texture, nutrient cycling, and soil organic matter content (Haynes and Francis, 1990). The maintenance of the soil microbial biomass and their microbial activity in rhizosphere is fundamental for sustainable agricultural management (Insam, 2001). Though the history of multiple cropping is old, the concept has received very little attention from agricultural scientists, and what limited interest exists recently. Intercropping offers farmers the opportunity to exploit nature's principle of diversity on their farms. Moreover, the intercropping system greatly contributes to crop production by its effective utilization of resources, as compared to the monoculture cropping system and recently this system is attracting increasing interesting in low-input crop production systems and is being extensively investigated (Inal et al., 2007). Interspecific root interactions affect nutrient mobilization in the rhizosphere and efficiently contribute to nutrient acquisition by intercropping (Wasaki et al., 2003). Integrated farming is practiced since time immemorial for sustainable agriculture.

Pomegranate (*Punica granatum*L., Punicaceae) is an economically important fruit crop, native to Central Asia, is gaining popularity in sub-temperate and sub-tropical regions of India. The tree naturally tends to develop multiple trunks and has a bushy appearance, requires a long, hot and dry season in order to produce good yield of high-quality fruit and is highly adaptive to different agro-climatic and edaphic conditions. It is nearly of 6 months crop and provides enough time for crop residue turnover, thus maintaining the soil health and productivity in terms of availability and accessibility of nutrients, microbial biomass and microbial activity in the rhizosphere soil. Studies on the pomegranate based intercropping system with special reference to soil fertility, nutrient acquisition, and plant growth measurements are very scanty. Keeping in view, the present investigation was focused and planned to study the changes in soil physical–chemical and biological indicators, vegetative growth characteristics and biochemical processing under pomegranate based crop sequencing under mid hill rainfed conditions. Over-exploitation of natural resources and excessive use of chemicals such as fertilizer etc. have steadily declined agricultural productivity (Masto et al., 2007), which directly soil fertility and health with time is a primary indicator of whether agriculture is sustainable (Karlen et al., 1997). Farmers of the state have been growing cereals and pulses in the orchards as intercrops but there are no multi-storey cropping models available to farmers where unutilized space can be utilized for fruit crops in accordance to the height and canopy orientation of tree in the orchards. Little effort however, has been made in the field of research and development to identify suitable fruit based farming system under mid hill and socio- economic conditions. A multi-enterprise farming system model needs to be developed to increase productivity, the farm income level and year-round employment generation relevant to small and marginal farmers. Therefore, the development and popularization of location specific integrated fruit orchard based farming system in rainfed regions is essentially needed. Cropping system and/or intercrop sequencing has an immense effect on physical and chemical soil properties and thereby on crop productivity (Rahman and Ranamukhaarachchi, 2003). Soil fertility often changes in response to land use and cropping systems and land management practices (Jahiruddin and Satter, 2010). Intensive cropping promotes high levels of nutrient extraction from soils without natural replenishment. Nutrient management practices in the three different cropping systems have been earlier described in detail (Liebman et al., 2008; Davis et al., 2012). The intensification and diversification of cropping systems influenced soil physical, chemical and microbiological characteristics (Grant et al., 2002). The advancements have been adopted to enhance the cropping system performance through improvements in soil condition, the research is needed to better understand the crop sequence on the broad spectrum of physical, chemical, and biological soil properties (Liebig et al., 2004). The effects of modern agriculture on soil microbial communities are very complex; yet understanding them is important for the effective and sustainable management of agri-horticultural ecosystems (Buckley and Schmidt, 2001) and although it is generally accepted that these practices have the potential to increase microbial biomass and activity (Feng et al., 2003), the specific impacts that these practices have on microbial community composition are largely unknown. It is therefore, we designed and focused with the objective to identify the characteristics responsible for change in nutrient dynamics and biological potential of the soil, which may eventually be considered as determinants of soil health and productivity to better understand the potentials on cropping behavior and integrating crop at the farm scale. This paper presents the performance of five pomegranate based multiple crop sequencing systems in relation to cropping behavior and nutrient dynamics to assess the sustainability in rainfed ecosystem in the north-west Himalaya of India.

2. Materials and methods

2.1. Geographical location and general description of the experimental site

The study was conducted for two consecutive years between 2012 and 2013 on test crop pomegranate in farm sequencing system at the 'Integrated Horticulture Model Farm' of the Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India. The experimental orchard is located at an altitude of 1100 m above mean sea level, lies in the coordinates between 30°50′30″ North latitude and 77°88′30″ East longitude, representing the mid hill zone of the State. The climate of the experimental area is typically sub-temperate (north-west Himalaya). Seasonal meteorological data of the model farm including air temperature (minimum and maximum), rainfall, relative humidity and soil temperature (5 cm and 10 cm depth) during the study years are presented in Fig. 1. Heavy rainfall occurs in the monsoon season and is scarce in other times. The southwest monsoon in the region usually sets in the month of June and withdraws in the end of the month of September, contributing to about 75% of annual rainfall. July and August are the wettest months. The remaining 25% rainfall is received during the non-monsoon period in the wake of western disturbances and thunderstorms.

The site was under continuous fallow before the establishment of the experimental platform. Pomegranate orchard in model farm was established in January, 2011. The trees (2 years old) were placed at distance of 3 m × 4 m apart and were irrigated at field capacity level through drip fertigation system with 8 l discharges per emitter h^{-1}. There were four emitters per plant. After every winter season pruning was done for which weak and dead limbs and basal suckers were removed to train the trees with proper shape. The orchard was receiving the current applications for nutrition and other horticultural package of practices.

The experimental soil is texturally classified as sandy loam (sand: 36.2%, silt: 27.8%, clay: 29.0%) with 6.86 pH (1:2 soil water suspension), 0.18 d Sm^{-1} electrical conductivity (EC) and 4.00 g kg^{-1} of soil organic carbon (OC). Water

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