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Yield and physical and microbial properties of soil under different fruit based diversified cropping models in arid region of Rajasthan

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Abstract: *The average plant height, plant girth and plant yield of aonla varied considerably in different cropping model systems. Highest yield of aonla recorded in aonla-khejri followed aonla-ber . Maximum value of OC, EC, pH, available nitrogen (kg/ha), available potassuim (kg/ha) were under Aonla-Khejri-Cluster bean-Ajowain cropping model followed by Aonla-Ber-Cluster bean-Fennel. The higher values in aonla involving ber and khejri could be due to synergistic crop interaction. Maximum water holding capacity at 0.33 and 6% bar was observed under Aonla+Ber (2.28 and 1.10%) followed by Aonla+Khejri (2.07 and 1.03%), Aonla+Bael (2.44 and 0.99%), Aonla+Karonda (1.76 and 0.61%) and Aonla+Morianga (1.84 and 0.56%). Similarly, maximum mean of available water was found in Aonla+Ber (7.43%) followed by Aonla+Khejri (6.6%), Aonla+Bael (4.14%), Aonla+Karonda (4.05%) and Aonla+Morianga during month of October, 2015. Higher bacterial, fungal and actinimycetes population (271 cfux10^6, 221 cfux10^3 and 116 cfux10^3) were observed in Aonla+Khejri followed by Aonla+Ber (205 cfux10^6, 164 cfux10^3 and 105 cfux10^3), Aonla+Bael , Aonla+Karonda and Aonla+Morianga. Physical and microbial properties of soil improved more under cropping model aonla-khejri (Model-III) and Aonla-Ber (Model-I) as compared to other models.*

INTRODUCTION

The crop production in the hot arid regions are constrained by low and erratic rainfall (100 - 420 mm/year), high evapo-transpiration (1500 - 2000 mm/year) and adverse soil physical and fertility conditions. Arid region soils are low in organic matter, macronutrient and micronutrient (Shyampura *et al.*, 2002, Rathore, 2009, Yadav and Meena, 2009, Yadav, 2011, Chattopadhyay *et al*, 1997, Singh, 2006, Singh, 2008). The low organic matter has been attributed to high temperature, low rainfall, scanty vegetation and single grained texture of soil.

Land, which is the most precious heritage and the physical base of biomass production of life supporting systems, is finite (Yadav *et al.*, 2006). Sustainable utilization of land is a must keeping in view the rapidly depleting such natural resources. Introduction of horticulture production system, particularly fruit tree based, into the already existing cropping systems in regions of adverse climatic conditions, such as those prevailing under arid environment, could be seen essentially as a strategy to reduce the risk in net returns of crops due to yield uncertainty. Fruit crops are efficient enough in providing higher economic return even under stress conditions than other annual crops. The approach aims at improving productivity by effective utilization of air space, which is not utilized in single tier system. The multitier system aims at sustainable management of natural resources like soil, water, space and environment (Saran *et al.*, 2015). In addition, inclusion of fruit trees in a cropping system encourages soil health and reduces erosion. Fruit based cropping system is recommended from the point of view of increasing and sustaining the soil fertility, where the soil is deprived of nutrients due to monoculture. The fruit based system contributes products as well as services, some of which have

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economic potential as cash crops (Rymbai *et al.*, 2014). Also, because of the many crop components and combinations possible, the fruit based system is highly adaptable and applicable to a wide area and range of physical and social conditions, worldwide (Sharma *et al.*, 2015).

With this point of view, work has been proposed on evaluation of physical and microbial properties of soil under fruit based diversified cropping models integrating complementary crop components as groundstorey agricultural/ cucurbitaceous vegetable/ spice and fodder crops with a view to develop a cropping system, which have potential advantages in production, stability of output, resilience to perturbation and ecological sustainability.

MATERIALS AND METHODS

After completion of nine year cycles of different cropping models *viz.*, *Aonla-Ber*-Cluster bean-Fennel (M-1), *Aonla-Bael*-Cluster bean-Coriander (M-2), *Aonla-Khejri*-Cluster bean-Ajowain (M-3), *Aonla*-Drumstick-Cluster bean-Dill (M-4), *Aonla-Khejri*-Grass (*L. sindicus*) (M-5) were assessed at ICAR-CIAH, Bikaner which are presently in the ninth year of plantation. Aonla was chosen as the base crop while *Ber, Bael, Khejri,* Drumstick and *Khejri* as component crops.

After completion of three cycles, beginning from seventh year of plantation, composite surface soil samples (0-30 cm) were taken from each plot, air-dried and passed through 2 mm sieve. Soil pH was determined in soil water suspension (1:2). Organic carbon was determined as per Walkley and Black method (1934). Available N was determined by the method proposed by Subhaiah and Asija (1956). Available P and K were determined by the method proposed by Olsen *et al.* (1954) and neutral ammonium acetate method by Pratt (1965), respectively. DTPA extractable Zn, Fe, Mn and Cu contents in the soils were determined by atomic absorption spectrophotometer (Lindsay and Norvell, 1978). Microbial population was estimated as per Lee *et al.* (2004). Water holding capacity was estimated as per the method suggested by Doran *et al.* (1994).

RESULTS AND DISCUSSION

All different cropping models of fruit based significantly varied in yield and fertility. The average yield of *aonla* varied considerably in different cropping model systems with highest being recorded in *aonla-khejri* (9.5 t/ha), *aonla-ber* (9.0 t/ha) followed by *aonla-bael* 8(8.9 t/ha) and *aonla*-karonda (8.4 t/ha), while the lowest was recorded in *aonla*-moringa (7.8 t/ha). The higher yield in *aonla* involving *ber* and *khejri* could be due to synergistic crop interaction. The average yield of *bael* was recorded to be 3.1 t/ha, while a single fruit weighed around 1.36 kg with maximum and minimum fruit weights recorded to be 2.7 kg and 0.7 kg, respectively. The average yield of *karonda* was recorded up to 7 t/ha planted in between *aonla* plants. Likewise, the yield of *ber* cv. Seb was recorded to be 12 t/ha in model M-1. Sharma *et al.* (2015) reported that multiple cropping system significantly improved growth attributes of pomegranate compared to monoculture cropping practice. Similarly, the improved growth of *aonla* under multiple cropping systems is likely to manifest itself in realization of higher yield as observed in this study.

Enhancing the long-term sustainability in productivity of crops and cropping systems is directly related to maintenance of an adequate level of soil organic matter. The benefits of maintaining desired levels of OC in low input agro-ecosystem are many like retention and storage of nutrient, increase in buffering capacity of soil, improvement in moisture retention and increased cation exchange capacity. Other benefits are activation of inherent microorganisms in rhizosphere (Manna *et al., 2003*). These aforementioned attributes consequently leads towards improved soil health and; thereby, bring sustainability in production system. Fruit trees contribute increase in organic carbon content in the soil due to decomposition of fallen leaves from them.

In this study, the initial value of soil OC (%), EC, pH, N, K (kg/ha), Zn, Cu, Fe, Mn were 0.02%, 1.00, 7.81, 105.30(kg/ha), 267.56 (kg/ha), 0.41ppm, 0.25 ppm, 5.75 ppm and 6.00 ppm, respectively. The maximum percent increase in organic carbon (OC), electrical conductivity (EC) and pH was under *Aonla-Khejri*-Cluster bean-*Ajowain* cropping model (1250, 200 and 105%, respectively) followed by *Aonla-Ber*-Cluster bean-Fennel (Table 1). The inclusion of legumes and cover crops linearly increase organic matter (OM) in soils (Kong *et al.*, 2005). Beer *et al.* (1990) noted OM in the 0–45 cm layer increased over 10 years by 42 and 16 Mgha^{-1} in the cacao–*Erythrina poeppigiana* and in the cacao–*Cordia alliadora*, respectively. Similarly, the maximum percent increase of nitrogen, potassuim and micronutrients (Zn, Cu, Fe and Mn) was under *Aonla-Khejri*-Cluster bean-*Ajowain* cropping model (which was 200, 150 and 1246, 236, 212 &215%, respectively) followed by *Aonla-Ber*-Cluster bean-Fennel (190, 134 & 978, 180, 209, 213%, respectively) (Table 1). Recently, Saran *et al.* (2015) noted that inclusion of mango and litchi in turmeric plantation was found to cast positive impact on the base crop.

Soil management practices that increase the soil water holding capacity (*via* improving the OM content in soil) and improve the ability of roots to extract more water from the soil profile, or decrease leaching losses could all potentially have positive impacts on water use efficiency (WUE), assuming these changes result in a concurrent increase in crop growth and yield (Hatfield *et al.,* 2001). In case of annual crops, 74% of roots do not go beyond 50 cm soil depth, whereas in case of perennial crops, top 50 cm almost devoid of feeder roots (Awasthi and Saroj, 2004). The spatially differential root distribution of different component crops in the system helps in higher nutrient and WUE of the multitier system as a whole as a result of presence of feeder roots of the component crops at different depths (Saran and Kumar, 2010). In the present investigation, Maximum water holding capacity at 0.33 and 6% bar was observed under *Aonla+Ber* (2.28 and 1.10%) followed by *Aonla+Khejri* (2.07 and 1.03%), *Aonla+Bael* (2.44 and 0.99%), *Aonla+Karonda* (1.76 and 0.61%) and *Aonla+Morianga* (1.84 and 0.56%) (Fig. 1 & 2). Maximum mean of available water (10 to 100 cm depth) was found in *Aonla+Ber* (7.43%) followed by *Aonla+Khejri* (6.6%), *Aonla+Bael* (4.14%) and *Aonla+Karonda* (4.05%) during month of October, 2015, while minimum mean of available water (10 to 100 cm depth) was found in *Aonla+Morianga* during month of October, 2015 (fig. 4&5). Evanlyo *et al.* (2008) reported that water holding capacity of any soil is directly influenced by its organic carbon contents, which is also evident in our study wherein, *Aonla+Khejri* and *Aonla+Ber* showed maximum accumulation of soil organic carbon as well as water holding capacity. These results are in conformity with those obtained by Sharma *et al.* (2015).

Plant species diversity in ecosystem encourages accumulation of organic material in soil, which in turn increases the general level of microbial activity in soil (Ratnadass *et al*., 2012). In this respect, rotating a variety of crops provides ecological niches for microorganisms and encourages microbial diversity. Microbial count in the rhizosphere soil of crops in different treatment combination clearly

Table 1

Per cent increase in soil properties and micronutrent contents in different fruit based cropping system.

Cropping systems	*Per cent increase in soil properties and micronutrent contents over intial value*								
	OC (%)	*EC*	*pH*	*N (kg/ha)*	*K (kg/ha)*	*Zn*	*Cu*	*Fe*	*Mn*
Aonla	400	142	93	138	108	239	124	150	146
Aonla+Ber	1150	161	106	190	134	978	180	209	213
Aonla+Bael	1200	194	106	146	108	532	128	129	167
Aonla+Khejri	1250	200	105	200	150	1246	236	212	215
Aonla+Moringa	450	147	105	161	124	266	140	151	178
Aonla+Karonda	650	174	105	146	122	446	156	177	162
Minimum	0.02	1.00	7.25	105.30	267.56	0.41	0.25	5.75	6.00
Maximum	0.25	2.00	8.27	210.30	401.26	5.11	0.59	12.21	12.91
Average	0.15	1.60	8.03	162.64	324.09	2.23	0.38	9.27	10.12

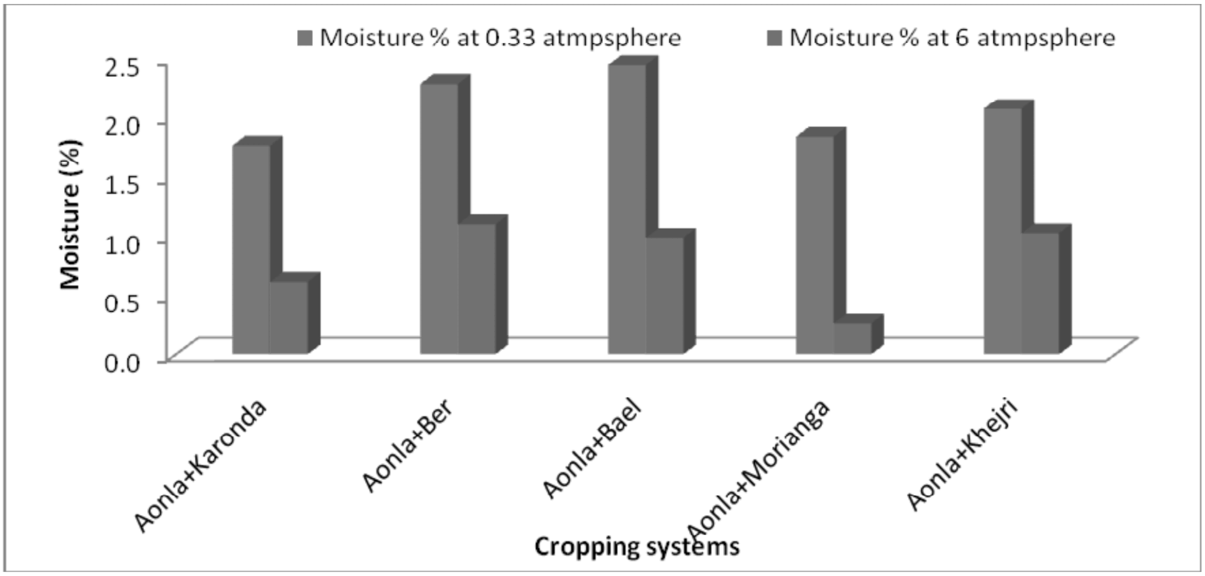

Figure 1: Effect of *aonla* based cropping model systems on available moisture (%) at 0.33 and 6 bar in soil.

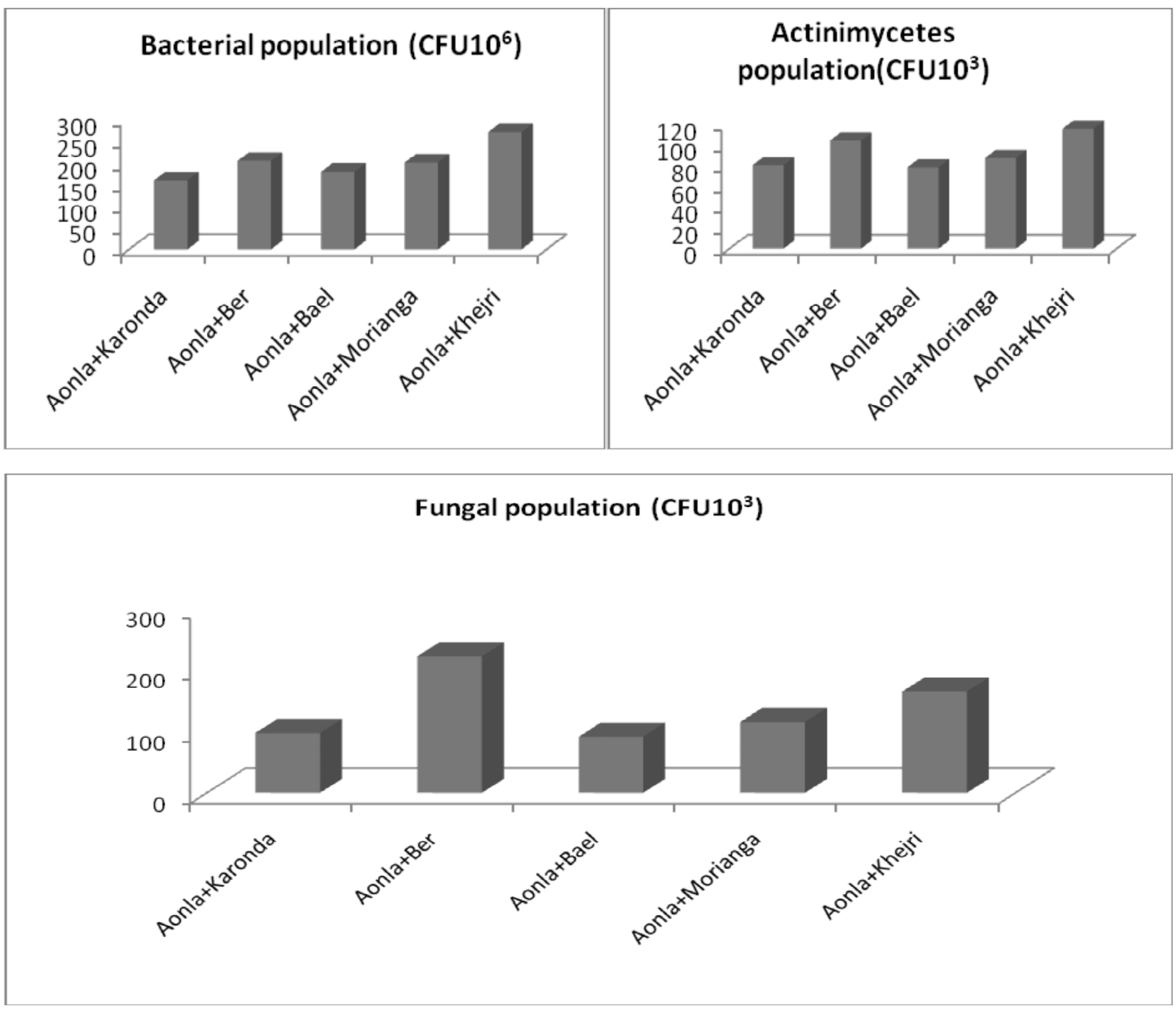

Figure 2: Effect of *aonla* based cropping model systems on microbial population in the soil.

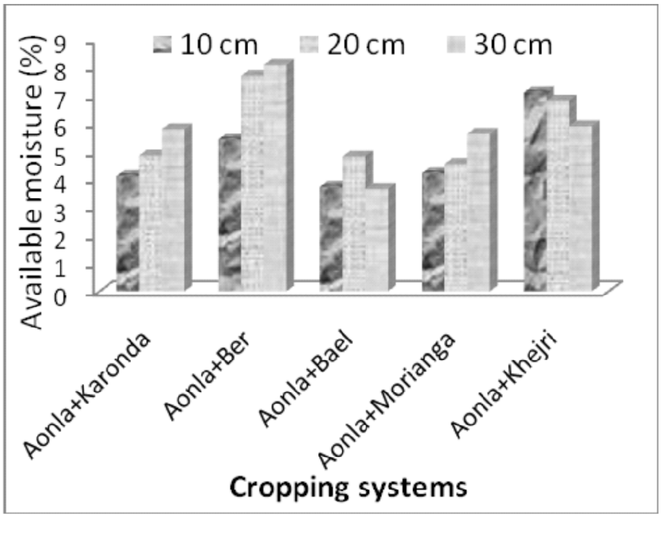

Figure 4: Effect of aonla based cropping model systems on available moisture % at different depth in month of October, 2015

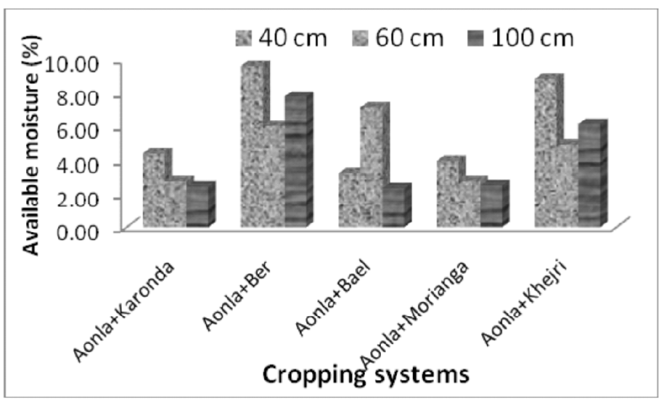

Figure 5: Effect of aonla based cropping model systems on available moisture % at different depth in month of October, 2015

indicates higher bacterial, fungal and actinimycetes population (271 cfux10^6, 221 cfux10^3 and 116 cfux10^3) in *Aonla+Khejri* followed by *Aonla+Ber* (205 cfux10^6, 164 cfux10^3 and 105 cfux10^3), *Aonla+Bael* , *Aonla+Karonda* and *Aonla+Morianga* (Fig. 3). The rhizodeposition of nutrients by plant roots supports increased microbial growth (Kumar *et al.*, 2013). Plant species and seasonal changes affect the indigenous bacterial soil communities and function of fungal communities (Mougel *et al.*, 2006; Kumar *et al.*, 2013). Hossain *et al.* (2010) also reported that litters from different grassland species influence the microbial population in the soil.

It can be concluded that fruit based diversified cropping has resulted in the increase in the essential relevant elements in soil, which in turn might have improved plant growth attributes, physical, chemical and biological attributes of the rhizospheric soil as compared to monoculture cropping practice.

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