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Changes in Soil CO_2 efflux rate at different growth stages in *baramasi*, regular and biennial bearing mango

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Abstract
A study on changes in soil CO_2 efflux (soil respiration) at different growth stages in *Baramasi*, regular and biennial bearing mango was carried out at Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India during 2012-13 and 2013-14. The results revealed that the maximum soil respiration rate and soil temperature were found significantly in the rooting zone of cultivar Alphonso whereas the minimum soil respiration rate and soil temperature were observed in the periphery of cultivar *Baramasi*. At pre flowering stage soil respiration and soil temperature were low as compared to flowering stage and post flowering stages in all the cultivars. The maximum soil RH was significantly found in the periphery of cultivar *Baramasi* whereas the minimum soil RH was recorded under cultivar Alphonso, the highest soil RH was recorded during pre flowering thereafter post flowering stage however the lowest soil RH was observed at flowering stage in all the cultivars. Changes in soil CO_2 efflux, soil temperature and soil relative humidity has been attributed to lower solar flux rates, which could affect photosynthesis rates and also root respiration and ultimately the overall growth and development of mango.

Keywords: mango, *Baramasi*, Soil CO_2 efflux, Soil temperature, Soil relative humidity.

Introduction
Mango (*Mangifera indica* L.) belonging to family Anacardiaceae that is the most important commercially grown fruit crop of the country. Because of wider variability, delicious taste and flavor, wider cultivated area and availability to everywhere in India mango is called the king of fruits. India has the richest collection of mango cultivars. Mango is found in almost all the states of India, mainly in tropical and subtropical climatic areas, that is excellent conditions for crop development, higher yield and fruit quality**.** In India, mango has been under cultivation since 4000 years and over 1000 varieties are said to exist in the country. The cultivated mango varieties in India, exhibit an unusual diversity of fruit forms, flavours and tastes (Mukherjee, 1951) [15]. Many mango cultivars are being popularly grown in different agro-ecological regions of India for several decades. Mango productivity depends on many factors such as genotypes, climatic factors, agro-techniques, soil conditions, pests and disease management etc. Soil CO_2 efflux (Soil respiration) is a complex process controlled by biotic and abiotic factors (Buchmann, 2000) [1]. It is the sum of an autotrophic component by roots and the associated rhizosphere and a heterotrophic component by soil microorganisms that decompose the organic materials from both above and below-ground litter (Epron *et al*., 1999) [6]. Tripathi and Tomar (2009) [30] suggested that the requirement of optimum soil temperature is different for various crop species. Germination of seeds, root and shoot growth, flowering-fruiting, water and nutrient uptake and metabolic systems of fruit crops are greatly influenced by soil temperature (Hogue and Neilsen 1986, Tagliavini *et al.* 1991, Engels and Marschner 1992, Marshner 1995, McMichael and Burke 1998, Toselli *et al.* 1999) [8, 28, 5, 14, 29]. About One-third of the global soil Carbon (C) storage is reported in the upper layer (upto 3m depth) of tropical soils (Jobbagy & Jackson, 2000) [9]. Increasing soil temperature may therefore lead to additional carbon dioxide (CO_2) release (Trumbore *et al*., 1996) [31]. Soil temperature or root zone temperature has direct or indirect influence on the production and productivity of fruit crops due to change in water and nutrient uptake process, metabolic activity and germination process. Production of fruit crops are affected by the influence in overall growth and development of fruit plants with the alteration in soil respiration, temperature and relative humidity. However, limited studies have been carried out on soil CO_2 efflux and soil

environment (temperature and relative humidity) of mango. Therefore, the present investigation was conducted to study the changes in soil CO_2 efflux, soil temperature and relative humidity at different growth stages in *baramasi*, regular and biennial bearing mango for their role in growth and development.

Materials and Methods

Plant materials and Experimental site

The present investigation was carried out during the year 2012-2013 and 2013-2014 on four cultivars of mango these cultivars comprise of *Baramasi* type, regular (Amrapali) and irregular (Langra and Alphonso) type. Five plants from each cultivar were selected as replication dor the study. The experiment was conducted in AICRP (Fruits) garden, Sabour, the permanent experimental site of the Bihar Agricultural College, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India.

Soil of the experimental plot

Soil of the orchard where experimental plants were grown is Indo-Gangetic alluvial in origin. The land was fairly levelled. The soil was fair in texture and medium in fertility level. Soil properties of experimental plot are given in table-1.

Table 1: Soil properties of experimental plot

Properties	Units	
Physical Properties		
Soil type	Silty loam	
Clay content	20-25 %	
Bulk density	1.45 g/cc	
Moisture holding capacity	50-60 %	
Chemical Properties	**0-15 cm**	**15-30 cm**
pH (1:2:5)	6.84	6.79
Conductivity	0.093	0.085
Organic Carbon (%)	0.48	0.45
Available N(kg/ha)	190.68	182.75
Available P(kg/ha)	26.15	24.33
Available K(kg/ha)	276.80	222.79
Zn (mg/kg)	2.60	2.30
Cu (mg/kg)	2.13	1.65
Fe (mg/kg)	45.86	44.76
Mn (mg/kg)	49.84	41.62

Observations

Soil CO_2 efflux (µmol $CO_2/m^{2/}s$) rate at pre flowering, during flowering and post flowering stages was measured by portable photosynthesis system (LI-COR LI- 6400 XT, Lincoln, NE, USA) by using soil CO_2 efflux chamber to determine soil CO_2 efflux (Sotta *et al*., 2006) [26] in the periphery of plant. Data was recorded by putting the soil CO_2 efflux chamber at 3 cm deep and 1 meter apart from the main trunk. This process was repeated five times throughout the periphery of each tree during the period from 0900 to 1200 h in the morning. Soil CO_2 efflux (µmol CO_2/m^2/sec) was calculated from the linear change in CO_2 concentration multiplied by the density of air and the ratio of chamber volume to soil surface area. Soil temperature was measured with a thermocouple probe connected with the portable photosynthesis system. Soil relative humidity was also observed the help of same instrument.

Statistical analysis and interpretation of data

The experimental data were subjected to statistical analysis in order to find out which of the treatments showed significant variation in different parameters/attributes studied under investigation. The technique of analysis of variance (ANOVA) for randomized block design (RBD) was adopted as suggested by Panse and Sukhatme (1985) [16].

Results

The result are depicted in Figure-1 indicated that soil respiration rate was comparatively higher at post flowering stage followed by during flowering stage whereas lower value was recorded at pre flowering stages in all the cultivars while the trend of cultivar's soil respiration rate was almost similar at both the experimental years 2012-2013 and 2013-2014. Significantly higher soil respiration rate at post flowering stage was observed in the periphery of cultivar Alphonso (6.53 and 6.89 µmol CO_2/m^2/sec respectively) followed by Amrapali (6.21 and 6.34 µmol CO_2/m^2/sec respectively) and Langra (5.89 and 5.83 µmol CO_2/m^2/sec respectively) whereas the minimum soil respiration rate was observed in the periphery of cultivar *Baramasi* (4.90 and 4.84 µmol CO_2/m^2/sec respectively) during in both the consecutive experimental years (2012-13 and 2103-14 respectively). Similar trend was also noticed during flowering stage where maximum soil respiration rate was recorded in the periphery of cultivar Alphonso (3.69 and 3.63 µmol CO_2/m^2/sec respectively) followed by Amrapali (3.60 and 3.51 µmol CO_2/m^2/sec respectively) and Langra (3.41 and 3.31 µmol CO_2/m^2/sec respectively) whereas the minimum soil respiration rate was observed µmol CO_2/m^2/sec cultivar *Baramasi* (2.83 and 2.73 µmol CO_2/m^2/sec respectively) during in both the consecutive experimental years (2012-13 and 2103-14 respectively). Likewise, same pattern was found at pre flowering stage, at which Alphonso (3.59 and 3.60 µmol CO_2/m^2/sec respectively) had the higher rate of soil respiration followed by Amrapali (3.49 and 3.34 µmol CO_2/m^2/sec respectively) and Langra (3.37 and 3.16µmol CO_2/m^2/sec respectively) however, *Baramasi* had the minimum rate (2.63 and 2.63µmol CO_2/m^2/sec respectively) during both the years of study (2012-2013 and 2013-2014 respectively).

The results presented in Figure-2 revealed that the value of soil temperature was increased regularly from pre flowering to post flowering stage in all the cultivars and this trend was almost similar in both the experimental years 2012-2013 and 2013-2014 in all cultivars. Soil temperature at pre flowering stage during 2012-2013 and 2013-2014 was recorded the highest in the periphery of Alphonso (21.91 and 21.78 °C respectively) followed by Amrapali (21.32 and 20.69 °C respectively) and Langra (21.17 and 20.61 °C respectively) whereas lowest in the periphery of *Baramasi* (20.75 and 19.33 °C) respectively. At flowering stage soil temperature level was noted maximum in the periphery of cultivar Alphonso (25.11 and 25.56 °C respective yeas) followed by Amrapali (23.50 and 23.18 °C respective years) and Langra (23.20 and 22.93 °C respective years) whereas *Baramasi* (22.68 and 22.52 °C respective years) had minimum temperature during 2012-2013 and 2013-2014 respectively. Similarly at post flowering stage the soil temperature level were increased up to 30.28 and 29.94 °C in the periphery of cultivar Alphonso, 29.07 and 28.93 °C in Amrapali and 28.85 and 28.45 °C in Langra, whereas 28.01 and 28.28 °C in the periphery of *Baramasi* during both the experimental years respectively.

The results given in Figure-3 indicated that the highest soil relative humidity (RH) was recorded during pre flowering thereafter post flowering stage however, the lowest at flowering stage under all the cultivars and this trend was almost similar during both the experimental years 2012-2013

and 2013-2014 in all cultivars. The maximum soil RH at pre flowering was recorded significantly in the periphery of cultivar *Baramasi* (97.36 and 96.28 % respective years) followed by Langra (93.44 and 95.66 % respective years) and Amrapali (92.78 and 95.60 % respective years) whereas the minimum soil RH was recorded in the periphery of cultivar Alphonso (79.00 and 81.77 % respective years) during both the consecutive experimental years respectively. Likewise, at post flowering stage RH was maximum in the periphery of cultivar *Baramasi* (88.93 and 90.87 %) whereas minimum under Alphonso (77.69 and 78.91 %) during 2012-13 and 2013-14 respectively. Similarly, cultivar *Baramasi* (85.64 and 87.03 %) had maximum soil RH whereas, minimum under Alphonso (75.69 and 77.67 %) at flowering stage during both experimental years (2012-2013 and 2013-2014) respectively.

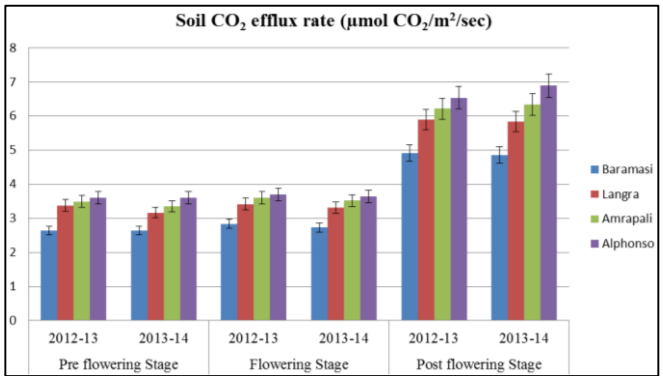

Fig 1

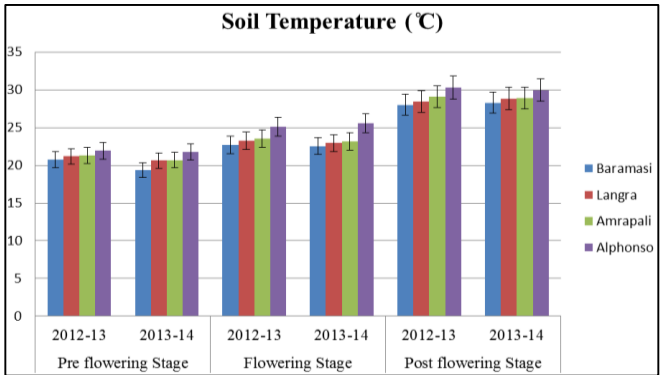

Fig 2

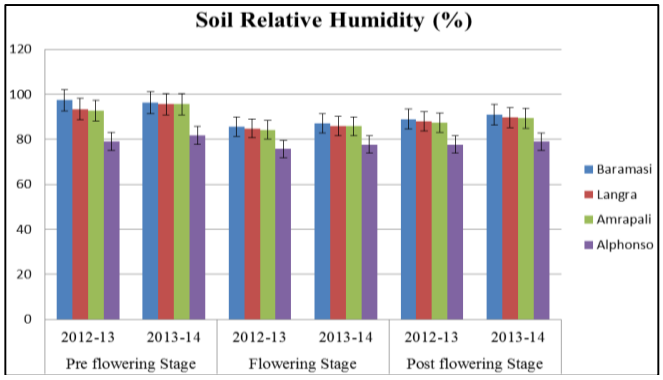

Fig 3

Discussion

Roots are important sink for metabolites. Flowering associated physiological changes in roots play important role in the development of mango (Singh, 2015) [25]. Root zone soil water deficits, reducing the partial pressure of intercellular CO_2 by reducing stomatal conductance, affecting photosynthesis in mango (Schaffer *et al*., 2009) [23]. Pezeshki and Santos (1998) [18] reported reduction in stomatal conductance is a result of internal water deficits caused by root volumes restrictions rather than a general shortage of soil moisture level. Limited oxygen levels as a result of restricted rooting volume and increased root density might also cause the inhibition of leaf gas exchange. Shi *et al*. (2006) [24] reported that plant phenology may play an important role in root respiration through its influence on root growth rhythms. Root growth is strongly correlated with leaf area index (LAI), which is not a simple temperature dependent factor, and thus phenology can modify the temperature dependence of soil CO_2 efflux. They further observed that soil CO_2 efflux exhibited a pronounced seasonal variation in different phenological stages of winter wheat development. Although, there is no report in the literature related with mango to support our results but De Jong and Schappert (1972) showed that soil respiration in wheat cropland was more than 830 g $m^{-2}d^{-1}$ after fallow in summer. Kowalenko and Ivarson (1978) observed that CO_2 efflux in fallow sand was six to seven times less than as computed by De Jong and Schappert (1972). Buyanovsky *et al*. (1986) measured seasonal variation of soil respiration at a rate from less than 40 g $m^{-2}d^{-1}$ in winter to 790 g $m^{-2}d^{-1}$ in summer during a 3-year period for winter wheat cropland in Columbia, Missouri. Sanchez *et al*. (2002, 2003) reported soil CO_2 effluxes of 312 and 318 g $m^{-2}d^{-1}$ in cereal and barley land in the central Spanish Plateau. Kirschbaum, (1995) reported that the potential increase in CO_2 release from the soil caused by future elevated temperature may have a positive feedback effect on the atmospheric CO_2 and global change. While Parker *et al*. (1983) reported that the activation energy for soil respiration decreased from 84.9 to 39.5 kJ mol^{-1} when a desert soil was wetted. Fang and Moncrieff (2001) found and exponential increase in respiration rate with respect to temperature (Raich and Schlesinger, 1992; Lloyd and Taylor, 1994) [20, 12] with a minimum efflux of 0.035 and 0.057 mg CO_2 $m^{-2}s^{-1}$ for forest soil and farmland soil at about 10^0C, respectively. They did not find any optimal temperature for soil respiration with soil temperature up to 32 ^{0}C. Soil moisture had relatively little effect on soil CO_2 efflux (Shi *et al*., 2006). Soil temperature and soil moisture are among the most important factors controlling the CO_2 efflux (Raich and Schlesinger, 1992 [20]; Raich and Potter, 1995 [19]; Davidson *et al*., 1998) [3]. Sotta *et al*. (2007) [27] observed that the low soil CO_2 efflux at the end of the wet season corresponded with high CO_2 concentrations in the topsoil, which suggests that low gas diffusivity may have contributed to the low soil CO_2 efflux. Similarly, Wofsy *et al*. (1988) [32] observed reduced soil CO_2 efflux from an Amazonian forest during the wet season has been attributed to lower solar flux rates, which could affect photosynthesis rates and indirectly also root respiration.

Conclusion

It can be concluded with the present findings that the soil CO_2 efflux, soil temperature and soil relative humidity significantly varied among the cultivars during every stages. Changes in soil CO_2 efflux, soil temperature and soil relative humidity has been attributed to lower solar flux rates, which could affect photosynthesis rates and also root respiration and ultimately the overall growth and development of mango. Further the information may be helpful in studying the relationship of soil respiration with the growth and development of mango.

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