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Intercropping of aromatic crop *Pelargonium graveolens* with *Solanum tuberosum* for better productivity and soil health

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Abstract

Farmers in hilly regions experience low production potential and resource use efficiency due to low valued crops and poor soil health. Geranium (*Pelargonium graveolens*L.) is a vegetatively propagated initially slow growing, high value aromatic crop. Potato (*Solanum tuberosum*L.) is also vegetatively propagated high demand cash crop. A field experiment was carried out in temperate climate to investigate the influence of geranium intercropping at different row strips (1:1 and 1:2) and plant density (60×45,75×45 and 90×45cm) with potato intercrop on biomass ,oil yield, monetary advantage and soil quality parameters. The row spacing 60×45cm and row strip1:1 was found to be superior and produced 92 t ha^{-1}and 14 kg ha^{-1}biomass and oil yield, respectively. The row strip 1:2 intercrop earned a maximum $2107, followed by $ 1862 with row strip 1:1 at 60×45cm plant density. Significant variations were noticed in soil organic carbon (C_{org}), total N (N_t), available nutrients, soil microbial biomass (C_{mic}) and nitrogen (N_{mic}) content. Maximum improvement of C_{org} (41.0 %) and N_t(27.5%) with row strip 1:1 at 75 × 45cm plant density. While higher soil respiration rate, C_{mic}, N_{mic}, and $qCO_2$was found with 1:2 row strip at 60 × 45 plant density. The buildup of $C_{org}$and C_{mic} potato intercrop can promote long term sustainability on productivity and soil health.

Key words

Aromatic crop, Inter cropping, Soil organic carbon, Soil respiration

Introduction

Geranium (*Pelargonium graveolens* L., family Geraniaceae) is an important high value, aromatic shrub originated from South Africa as well as Reunion Medagascar, Egypt and Morocco. Geranium is grown in various parts of India, from the plains to high altitudes, and in spite of some differences in the major components of oils, the oils are accepted in domestic market in India. Significant data is available on geranium cultivation and its processing for essential oil from different parts of India (Jain *et al*., 2001). Essential oil obtained by distillation of aerial parts (fresh biomass) is extensively used in perfumery and cosmetic industries. Traditionally, it is also used to staunch bleeding, heal wounds, ulcers, skin diseases, diarrhoea, dysentery and colic. The oil has antimicrobial and insecticidal properties and substantial use in aromatherapy. The current international demand is more than 600 tons, mostly met by countries like China, Morocco, Egypt, Reunion Island and South Africa (Anonymous, 1996-1997). As against the annual consumption of 149 tons, India produces 5 tons of geranium oil annually and the rest is met largely through import (Shawl *et al.*2006).

In valley regions of western Himalaya (1200-1800 msl altitude), various pulses (e.g., "Masur" - *Ervum lens*; "Kulat" - *Dolichos biflorus*) are grown as intercrops during the two harvest seasons, *viz.* early winter after the rainy season (millet) and midsummer before the hot dry season (barley-wheat). Dry and wet rice, taro, pumpkins, beans, corn, ginger, chili, cucumbers, leafy vegetables, and tobacco are also grown during these seasons. Potato in India is not primarily a rural staple, but is approximately 28 % urban, a proportion which has remained fairly stable over the past decade, but urban Indians with higher incomes are providing much of the growing demand for potato (Chauhan, 2010).

Diversification of crops, the need to maintain current levels of cropped area under food and related crops. Thus research has to be directed towards incorporating medicinal and aromatic crops (MACs) in existing cropping systems such as intercrops, crop rotations, under crops etc. There is an excellent body of literature on the improvised cropping systems involving MACs (Prakasa Rao, 2009). These systems not only improve production systems but also economy, equity and opportunities for knowledge based rural enterprise. MACs based cropping systems in north and south India have shown that farmers gain significantly higher profits from their lands (Kumar and Patra 2000 and Rajeswara Rao *et al*., 2000). These systems have not only influenced the economics but also paved way for agro-based enterprises in the regions.

Optimum crop geometry is one of the important factors for higher production, by efficient utilization of underground resources and also harvesting as much as solar radiation and in turn better photosynthetic formation (Thavaprakasha *et al.,* 2005). Short duration vegetables grown in-between the aromatic crops is the recent advancement to fulfill the requirement of vegetables without any reduction of production area. Performance of radish (Reddy *et al.,* 2001), coriander (Chellaiah *et al.,* 2002), and other crops like vegetables, fodder, pulses and cereals (Verma *et al.,* 2009; Singh *et al.,* 2004; Rajeswara Rao, 2002) as intercrops under different cropping situations are well documented. In the present study, organic C and total N content, microbial biomass C and N, soil respiration, available nutrients and microbial metabolic quotient (qCO_2) were determined. The microbial metabolic quotient (qCO_2) has been used as bioindicator of environmental stress on microbial communities (Anderson and Domsch, 1978).

qCO_2 metabolic quotient = ($\mu g\ CO_2$ –C evolved 10 d^{-1} g^{-1} soil / μg soil MBC g^{-1} soil) 10 d x 1000 (Meyer *et al*.,1996).

Geranium and potato can be grown in *Rabi* season (winter season) in the Himalayan region of India. Potato takes 90-100 days and geranium 150-160 days to come to maturity for harvest. The compatibility of these two crops as companion crop in an intercropping system was not explored earlier. The present study was conducted to evaluate the feasibility of growing short duration vegetable (potato) crop during the initial log phase of aromatic crop geranium to affect the production potential, economic returns and soil health of intercropping systems.

Materials and Methods

Experimental design : A field experiment was conducted at the experimental farm of the Central Institute of Medicinal and Aromatic Plants, Research Centre, Purara, Bageshwar, Uttrakhand, India. The study area has a temperate climate. The study was laid out in a plot size 3 × 2m using randomized complete block design with nine treatments combination and four replications. The soil was a sandy loam with pH 6.3 (soil: water, 1:2.5), soil organic carbon 0.40%, available nitrogen145 kg ha^{-1}, available P 10.0 kg ha^{-1}, available K 130 kg ha^{-1}. Treatments were: sole geranium and intercrops spaced at 60, 75, and 90cm between rows and 45 cm between plants with two row strips combination 1:1 and 1:2. In between two rows of planted geranium, one or two rows of potato were sown / planted. The number of plants/plot of geranium was constant in all the treatments.

Terminal stem cuttings of uniform size (9-10 cm length, 3-4 nodes and 3-4 terminal leaves) of geranium cv. CIM-Pawan grown in polythene bags (10cm ×16 cm diameter filled with native soil) were kept under partial shade and regularly watered. Healthy, profusely rooted, 30-day-old rooted plants and potato tubers were planted in first week and last week of February, respectively in each cropping year. Crops were irrigated at 15 days intervals and kept weed free through frequent manual weeding. Sowing, planting, harvesting, crop geometry and fertilizer application are given in Table 1.

Harvesting and yield advantage calculations : Geranium was harvested in the first week of July and the aerial biomass was distilled in a field distillation unit operating on hydro-cum-steam distillation principle. The essential oil yield (kg ha^{-1}) was calculated

Table 1 : Crop culture summary for rose-scented geranium with potato intercrop

Treatments	Planting Month (s)	Harvesting Month (s)	Seed rate (t ha^{-1})/ plantlets (Nos. ha^{-1})			Crop geometry Geranium/	*Fertilizer inputs intercrops
			60x45cm	75x45cm	90x45cm		
Geranium alone	February (1st week)	July (160 days)	37037	29629	24691	1	80:60:60
Geranium intercrop	February (1st week)	July (160 days)	37037	29629	24691	-	-
Potato alone	February (2nd week)	May (98days)	0.12	0.96	0.79	1	100:60:60
Potato intercrop	February (2nd week)	May (98days)	0.12	0.96	0.79	1:1	120:80:80
Potato intercrop	February (2nd week)	May (98days)	0.16	0.13	1.05	1:2	120:80:80

*1/3 N, full P and K at planting; 1/3 N after 45 days of planting; 1/3 N after the intercrop harvest. ** 1st fort night of February;*** 2nd fort night of February by multiplying the crop yield by essential oil recovery from the distillation unit and the specific gravity of essential oil. Intercrop of potato was manually harvested in first week of May. The assessment of the benefit or overall advantage of intercrop were evaluated (Verma *et al.,* 2013).

Soil sampling and analysis : Composite surface (0-15cm) soil samples (i.e., 5 random core samples from each plot were thoroughly mixed together) were collected from each plot at the harvesting time. The composite samples were placed in plastic bags and transported to the laboratory, where field moist soils were sieved (2 mm mesh size), homogenized and stored at 5 ºC in an air tight container in the presence of sodalime. The physico-chemical properties of soil were analysed by the following methods: Soil organic carbon (C_{org}) by Walkley and Black, 1934; total Kjeldhal nitrogen (N_t) by Page *et al.* (1982); alkaline $KMnO_4$ extractable N (available N) by Subbiah and Asija (1956); available P using NH_4F (Bray and Kurtz 1945) and available K using NH_4 (Page *et al.,* 1982), respectively. Soil microbial carbon (C_{mic}) and nitrogen (N_{mic}) were determined using chloroform fumigation-incubation method (Jenkinson and Powlson, 1976). Incubation experiments were conducted in the laboratory at 28ºC. To determine basal respiration, 50g of un-fumigated soil was incubated in 1litre air tight sealed jars along with a small flask containing 10 ml of 1M NaOH. Evolved CO_2C trapped in NaOH was measured after 10 d by titrating it with 1MHCl. To determine NH_4^+N and NO_3^-N, pre-and post incubated samples were extracted with 2M KCl and the soil extract was analyzed (FIA Analyzer, FOSS make). Data were subjected to analysis of variance using SPSS programme (version 17), as applicable to randomized block designs.

Results and Discussion

Intercropping of geranium with potato in different row strips and plant density led to significant yield reductions compared to geranium sole. Geranium crop planted at 60cm spaced single row strips produced significantly higher biomass and oil yield (91.6 t $ha^{-1}$and 13.7 kg ha^{-1}) as compared to rest treatments (Fig.1B & C). This high yield was due to having a maximum plant population, suitable space for full light and nutrient absorption. Apparently minimum biomass and oil yield (63.6 t $ha^{-1}$and 9.1 kg ha^{-1}) was recorded at 90cm spaced with double row stripe (1:2). Potato double strips row (1:2) as intercrop in geranium was more competitive than single strips (1:1) in all plant density. Potato, though of short duration fast growing , trailed over growing of geranium plants thereby cutting of light to then and by quickly covering inter-and intra-row spaces (with its numerous branches and canopy which covered over the ground) restricted leaf and stem (the main yield attributing characters) production in geranium. As a result of competition for light, spaces and other resources, biomass and oil yield of geranium suffered heavy losses. As a consequence, the impact of initial growth suppression could be seen even at the time of intercrop harvest, though geranium plants recovered from the initial competitive shock and produced comparable yields. Potato double strips (1:2) intercrop with all plant density thus proved to be the most competitive and not compatible intercrop with geranium. Similar finding were reported with other intercrop crops also such as fodder crops like *Avena sativa* and *Trifolium alexandrinum* L. (Verma *et al*., 2009); vegetables crops like *Brassica oleracea,* capitata *var*; *Brassica oleracea var. botrytis; cauliflower, Brassica oleracea var. botrytis; green pea, Pisum sativum and Raphanus sativus* (Verma *et al*., 2011) and *Cymbopogon winterianus* (Rajeswara Rao, 2000). The finding of present experiment therefore supports the observations of other researchers. Potato

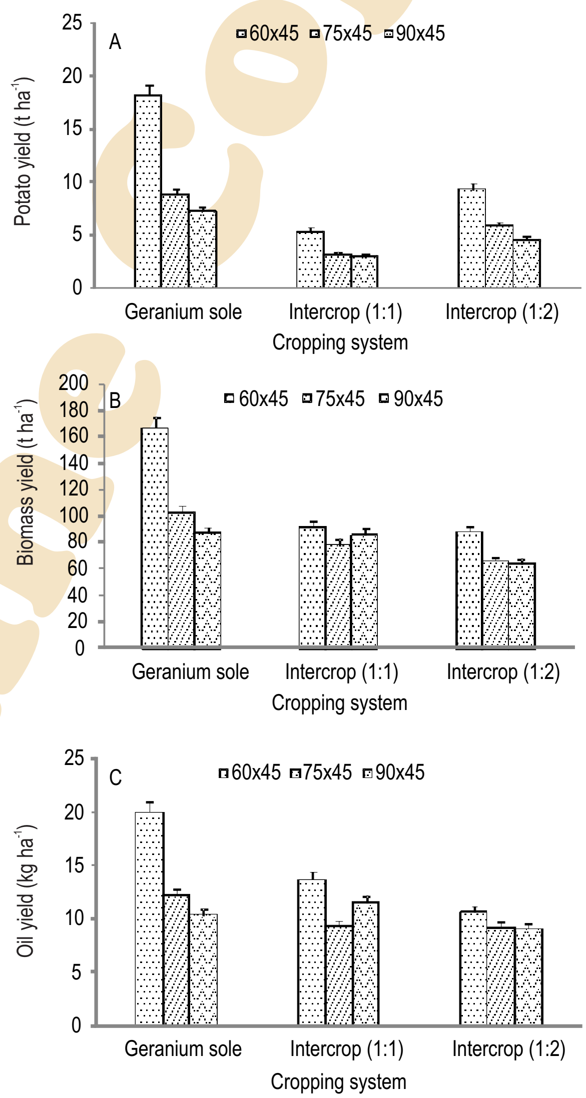

Fig. 1 : Yield attributes of geranium and potato intercrop (A: Potato yield; B: Biomass yield of geranium; C: Oil yield of geranium). Bar denote mean ±SE

plants grew much faster than geranium plants, shaded them and competed with them throughout the growth until the potato crop was harvested. Potato plant completed their crop cycles much earlier than the harvest of geranium providing plants enough time to recover from the competitive experience, grow and yielded nearly 2/3 to the geranium alone.The potato tuber yield was influenced by geranium in all plant density (Fig.1A). Potato tuber expressed highest yield (18.2 t ha^{-1}) at 60 × 45 cm plant spacing in pure stand. In intercropping, maximum yield was 9.35t ha^{-1} followed by 5.94t ha^{-1} at 60 × 45 cm and 75 × 45cm plant spacing, respectively with 1:2 row strips. The potato tuber yield decreased and varied in different row strips and plant density, due to plant population as compared to sole geranium.

The intercropping systems showed considerable differences at all plant density with respect to monetary return over sole geranium/potato (Fig.2). The percent monetary returns due to intercrops at 1:1 and 1:2 row strips were 9.4% and 23.5%; 15.4% and 48.1%, and 48.4% and 53.2 %, respectively at 60 × 45cm, 75× 45cm and 90 × 45cm plant density. Maximum returns were found at 1:2 row strip at all plant density. This indicated that inclusion of aromatic crop (geranium) with vegetables (potato) in intercropping systems enhanced monetary returns. Higher monetary returns under above cash crops sequence might be due to high production efficiency of high valued crops. Similar trends of high monetary advantages of other aromatic crops by inclusion of pulses, vegetables and cereals were reported (Tajuddin *et al.,* 1993; Verma *et al.*, 2011; Verma *et al.*, 2013)

The amount of soil organic carbon (C_{org}) was generally greater in intercrop as compared to sole geranium (Fig.3A). A significant increase in soil C_{org} was recorded in geranium intercrop sole 1:1(36.6%) and 1:2 (25.1%) row strip as compared with geranium. There was an increase of 21 to 25% in N_t to various row strip intercrops compared with geranium alone, and plant density also showed significant variation (Fig.3B). 6.4 % increase was recorded at 75 × 45cm and 90 × 45 cm as compared to 60 × 45cm spacing. Increase in N_t under intercrops might be due to additional dose of chemical N given for intercrop and also resultant biomass due to various intercrops. This indicate that with more N_t, availability of available N had increased, during the buildup of C_{org}, however, N_t probably is being continuously used for degradation of plant residue. Although any permanent changes in soil organic matter is a very slow process, the soluble and intermediates C pool is easily affected by cultivation, amendments, and weather conditions (Suman *et al*. 2006; Zaman and Chang 2004; Salinas-Garcia *et al*. 1997). Higher C_{org}, and N_t in potato 1:1 row strip was due to less competition of light moisture and nutrients than row strip1:2 intercrops. Soil C/N ratio ranged from 11.8 to 13.9 in geranium alone and 1:2 row strip

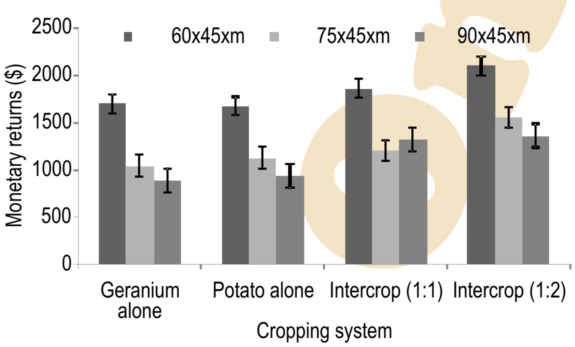

Fig. 2 : Monetary advantages due to intercrops. Bar denote SE**.** (Geranium oil rate @Rs 4000 per kg, Potato tuber @ Rs 600, 1$=47Rs)

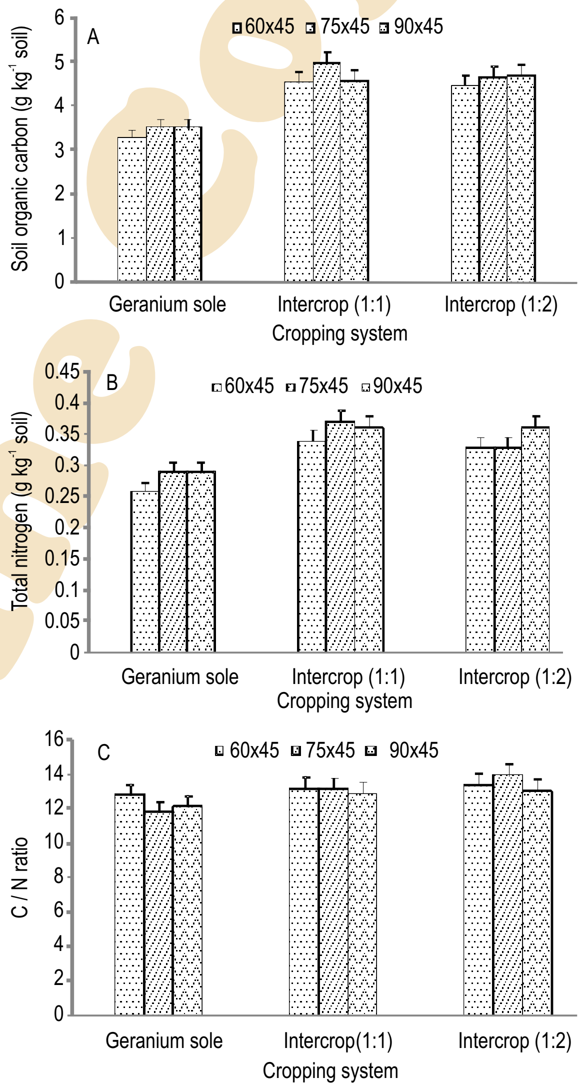

Fig. 3 : Soil organic carbon, total nitrogen and C/N ratio after geranium harvested soil (A: Soil organic carbon; B: Total nitrogen; C: C/N ratio). Bar denote mean ±SE

respectively, at 75x45 cm plant density. The pattern of accumulation of C_{org} and N_t in geranium intercrops at different plant densities is shown in Fig. 3. Intercropping having wider C/N ratio, a higher biomass input, or both resulted in a greater accumulation of C_{org} and lesser of N_t.

Availability of nutrients was significantly decreased due to intercrops compared with sole geranium, with maximum for row strip 1:2 at 60 x 45cm plant density followed by 75 x 45cm plant density (Fig.4A). Availability of P also decreased due to the intercrops (Fig.4B). Increased soluble organic matter which are mainly organic acids that increase the rate desorption of

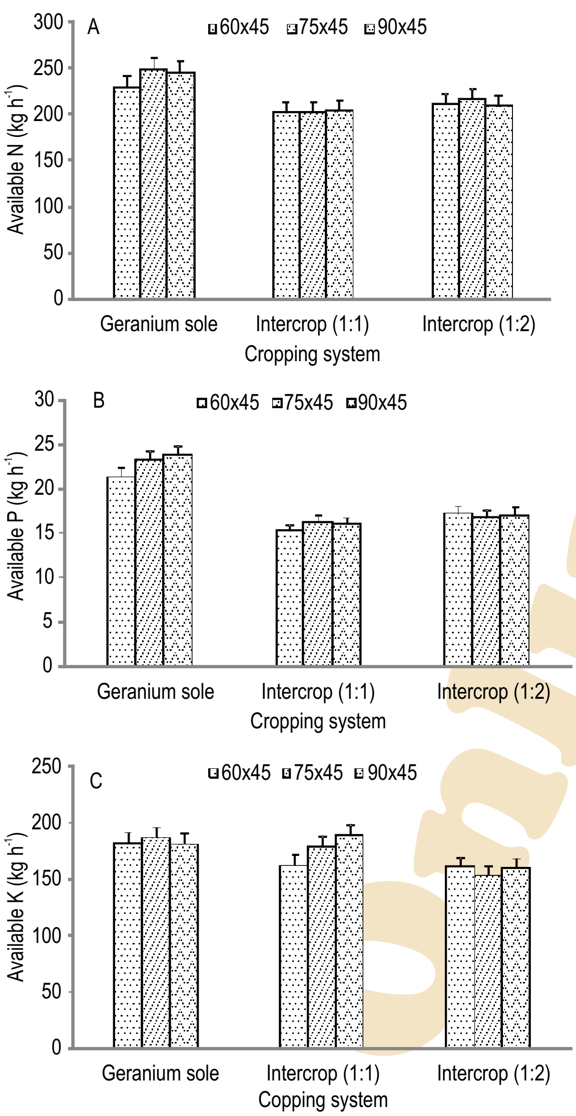

Fig. 4 : Available nutrients status after geranium harvested soil (A- Available N; B- Available P; C- Available K). Bar denote mean ±SE

phosphate and thus improves the available P content in the soil (Suman *et al*. 2006; Cong and Mercky 2005).There was also a significant change in the availability of K (Fig.4C). No fixed trend could be found for different treatment combinations.

Soil respiration rate increased due to intercrops and plant density of both row strips treatments, with a maximum in row strip 1:2 (76.2%), (85.3%) and (78.3%) at 60 x 45cm, 75 x 45cm and 90 x 45cm, respectively over geranium sole at different plant densities (Fig.5A). The greater amount of C_{mic} in row strip 1:2 and 60 x 45cm plant density, residue influenced respiration rate. Suman *et al*. (2006) and Raiesi (2004) showed increase in decomposition of initial C, present in cereals, pulses, vegetables and green manuring systems, due to incorporation of residue upto 35%. Soil microbial biomass C (C_{mic}) increased greater in 1:2 row strip (32.0%), (32.4%) and (36.4%) at 60 x 45cm, 75 x 45cm and 90 x 45cm, respectively over sole geranium at different plant densities (Fig.5B). Soil N_{mic} increased significantly when both row strips and different plant densities were intercropped (Fig. 5C). The wider plant density in both row strips showed less N_{mic} which might be due to less N_t and available nutrients in the soil of these treatments. The C/N ratio of the microbial biomass is also an indicator of relative proportion of fungi to bacteria (Fauci and Dick, 1994).

Intercropping treatments consistently had higher C_{org} and higher C_{mic}, which is consistent with reports that showed that higher C_{org} content stimulates microbial activity (Suman *et al.*2006; Zaman and Chang 2004). C_{mic} accounted for C_{org} content under different intercropping systems. These are in agreement with reports that revealed C_{mic} generally comprised of 1 to 4% organic C and C_{mic} and C_{org} percentage could be useful as a soil quality indicator to allow comparisons across soils with different organic matter contents (Suman *et al*., 2006). This might be calibrated as soil quality indicator that could predict whether soils are accumulating or losing C. None of intercrop treatments reduced C_{mic} and C_{org} and there was higher affinity for C_{mic} with C_{org} (Fig. 3). These results are in agreement with other studies (Suman *et al.,* 2006) and support the concept that C is usually a limiting factor for microorganisms in agricultural soils and that the effect of N on C_{mic} is indirect via altered C input. Moreover, the type of residues had a marked impact on C_{mic} and C_{org} as evidenced by the effects of different crop residues and plant litter on a range of above and underground properties and process (Nilsson *et al.,* 1999). Crop residues like lentil (*Lens culinaris* Medik), rajmash (*Phaseolus vulgaris* L.), cowpea (*Vigna aunguiculata* (L.) Walp.) and soybean (Glycin max (L.) Merr.) and other pulses support more microbial growth although they have less residue input to soils than cereals and other crops (Balota *et al.* , 2003).

The soil respiration/ soil microbial biomass carbon ratio is expressed as the metabolic quotient (qCO_2), also called specific respiration, which is the amount of CO_2 carbon produced per unit

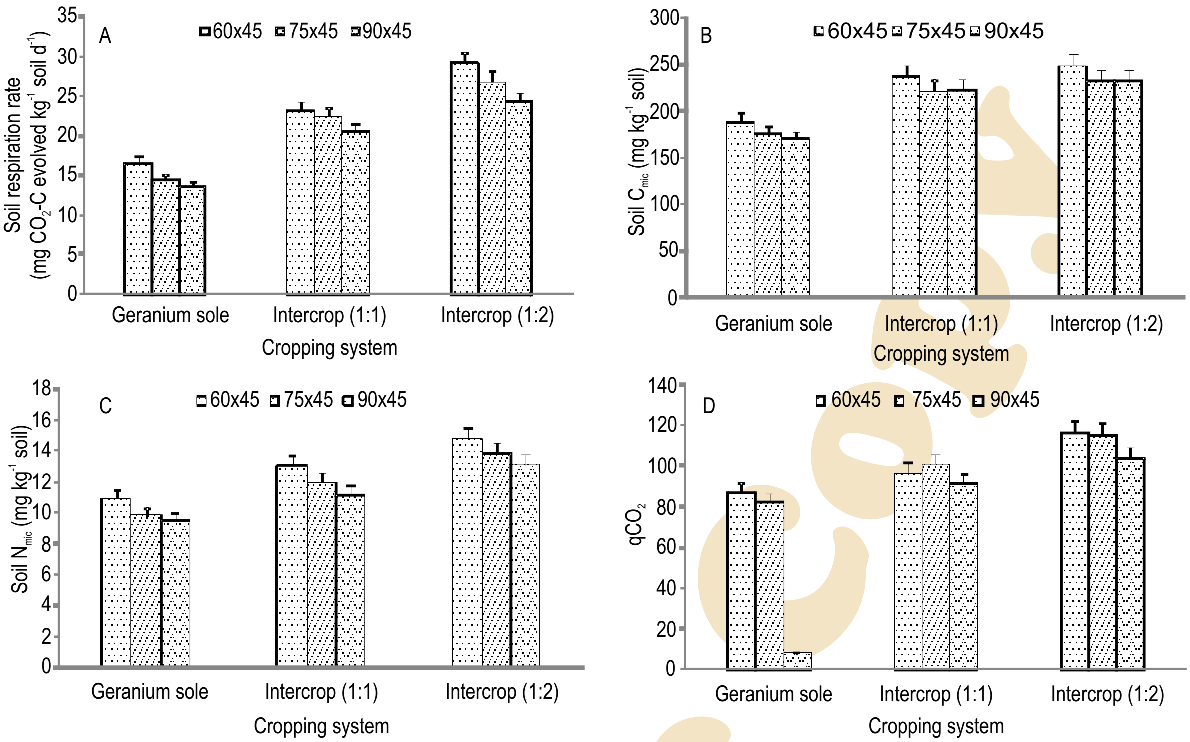

Fig. 5 : Soil respirations, microbial biomass carbon and nitrogen status after geranium harvested soil (A: Soil respiration; B: Soil biomass carbon; C: Soil biomass nitrogen; D: Soil microbial metabolic quotient. Bar denote mean ±SE

microbial biomass carbon ($CO_2C\text{-}h^{-1}C_{mic}^{-1}$). The qCO_2 is significantly affected by row strips but is not affected by plant density of geranium intercrops (Fig. 5D). Row strip 1:2 at 60 x 45cm showed maximum qCO_2(24.9%), followed by 75 x 45cm spacing (28.2%), gave an indication of either variable quality or quantity of the crop residues as compared with sole geranium. He *et al*. (2003) reported that qCO_2 lower under traditional management than the sustainable management where different types of organic substrates are added to soil.

In conclusion, as far as the aim of this paper is concerned, rose-scented geranium intercropped with potato will improve the economy, equity and opportunities for producers of hilly regions and also measure soil quality indicators in different plant densities. Soil quality of rhizospheric region of geranium is affected by intercrops. The incorporation of carbon substrate led to improved yield and buildup of C pool, $C_{mic,}$ and increases the available nutrient content and sustainability of soil health.

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