Vegetative and reproductive growth of some selected vegetables with legumes under mono-cropping vs mix-cropping and determine the soil microbial activity.

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***Abstract*-** The study was carried out as pot experiments in the green house condition to evaluate the growth and yield performances of vegetables (tomato, curry chilli, okra) with legumes (cowpea, bush bean, Mung bean, soybean, ground nut, Snuhemp) under mono-cropping and mixcropping as well as compare the degree of soil microbial activity.

Six different crop combinations for one experiment; **Experiment one**; Sunhemp, Okra, Ground nut, Sunhemp and Okra, Sunhemp and Ground nut, Okra and Ground nut, **Experiment two**; Tomato, Cowpea, Bush bean, Cowpea and Tomato, Bush bean and Tomato, Cowpea and Bush bean, **Experiment three**; Soybean, Mung bean, Curry chilli, Soybean and Mung bean, Soybean and Curry chilli, Mung bean and Curry chilli were used. Two plants were maintained per pot. Complete Randomized Design (CRD) with three replicates was used. Statistical analysis was carried out using the Student Newman-Kuells Means Separation Test of SAS program (9.1.3).

Number of pods, number of leaves, shoot length, root length, number of pods, pod/seed weight (wet/dry) and wet/ dry weight of stem were measured. Soil microbial activity was measured according to the CO_2 evolution method. Okra grew better when mixcropped with ground nut or sunhemp (legumes) than a mono-crop. Significantly higher yield were recorded from okra when grown with ground nut (53%) and sunhemp (17.39%) as compared to mono-cropped plants. Significantly higher yield (112.37%) was recorded in sunhemp when growing with ground nut as comparing to mono-cropped sunhemp. Ground nut produced 128.61% more yield when intercropped with sunhemp as compared to mono cropped ground nut. When consider tomato, mixcropping with cowpea or bush bean (legumes) is more beneficial than mono-cropping. Significantly higher yield obtained from tomato (45% and 15%) when grow with bush bean comparing to cowpea respectively. Significantly yield was increased from 106% of cowpea when growing with tomato comparing to mono-cropping of cowpea. Bush bean, mixcropping with tomato is better than mono-cropping of bush bean obtained 35% yield increment. Higher yield were recorded from curry chilli when grown with soybean (87%) and Mung bean (171%) as compared to mono cropped plants. Mungbean produced 35% more yield when mixcropped with curry chili as compared to mono cropped Mungbean.

Mixcropping legumes with vegetables are more beneficial for legumes as well as vegetables. Significantly highest mean microbial activity (850 CO_2 mg/kg of soil, 780 CO_2 mg/kg of soil, 840 CO_2 mg/kg of soil) was observed from experiment 1, 2, 3 respectively. However the highest microbial activity does not mean the highest yield.

***Index Terms*-** Mixcrop, Mono-crop, legumes, Tomato, curry chili, okra

I. INTRODUCTION

Mixed cropping defined as the agricultural practice of cultivating two or more crops in the same space at the same time (Hugar and Palled, 2008). Mixcropping is a key factor for approach to sustainable food security in the developing world (Garrity *et al*, 2010). Vegetable crops are often intercropped with legume to enhance resource usage. Twenty seven present of the world's primary crop production, with grain legumes alone contributing 33% of the dietary protein nitrogen (N) needs of humans (Vance *et al*., 2000). Legumes have ability to develop root nodules and to fix N_2 in symbiosis with compatible rhizobia. It is beneficial to use non-leguminous crop cultivation.

Okra (*Hibiscus esculentus* Var Haritha; Malvaceae) is a vegetable with high nutrient, easy to cultivate and profitable. Curry chilli (*Capsicum* spp.; Solanaceae) is one of consumer preferable vegetable crop in Sri Lanka. Tomato (*Lycopersicon esculentum* Mill.; Solanaceae) is an important Solanaceous vegetable crop grown throughout the world for its versatile uses. It is one of the most important protective foods as it possesses appreciable quantities of vitamins, minerals and sometime rightly referred as poor man's orange. (Devi M *et al*, 2008). Ground nut (*Arachis hypogaea*; Fabaceae; Fabaceae) is an oil crop that fixes atmospheric nitrogen with the help of *Rhizobium* in the root nodules. Sunhemp (*Crotalaria juncea* L; Fabaceae) is a rapidly growing green manure crop in many tropical and sub tropical areas in the world as an organic nitrogen source. Cowpea (*Vigna unguiculata*), bush Bean (*Phaseolus vulgaris*), soybean (*Glycine max* L.) and mung bean (*Vigna radiata)* are highly consuming legumes in Sri Lanka. The main objective of the study was to determine whether mixcropping legumes with vegetables are more useful or not to increase the yield of the each crop.

II. MATERIALS AND METHODS

Experimental location: Study was conducted at Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya. Mapalana is located in the low country wet zone (WL_2) where the annual rainfall is > 1900 mm. The mean monthly temperature

is 27.5 ^{0}C and relative humidity is around 72%. Potting media was prepared using 2:1/2:1 ratio of top soil, sand and compost. Pots (1x1.5x1.5 ft^3) were filled with potting media and sterilized using Topsin fungicide (6g /10 L of water). After sterilization, pots were wet for seven days.

Seeds of all selected vegetables and legumes were obtained from Department of Agriculture. Six different crop combinations for each experiment;

Experiment 1: Sunhemp, Okra, Ground nut, Sunhemp with Okra, Sunhemp with Ground nut, Okra with Ground nut

Experiment 2: Tomato, Cowpea, Bush bean, Cowpea with Tomato, Bush bean with Tomato, Cowpea with Bush bean

Experiment 3: Soybean, Mung bean, Curry chilli, Soybean with Mung bean, Soybean with Curry chilli, Mung bean with Curry chilli was used.

After 21 days of nursery period healthy same size seedlings were kept in the pots and maintained three plants per pot. Thinned out weaker plant after 10-12 days and remained healthy two plants in each pot. All management practices were conducted according to recommendations of the Department of Agriculture from seed germination to harvesting.

Number of pods, number of leaves, shoot length, root length, number of pods, pod/seed weight (wet/dry) and wet/ dry weight of stem (Sunhemp) were measured. Soil microbial activity was measured according to the CO_2 evolution method. Complete Randomized Design (CRD) with three replicates was used. Statistical analysis was carried out using the Duncan's multiple range test of SAS program (9.1.3).

Determination of soil microbial activity: Soil microbial activity was measured according to the CO_2 evolution method. Ten grams (10 g) of Soil sample from the each treatment was taken in to a jam bottle and mixed with 3.5 ml distilled water. The controller set was filled with 3.5 ml of distilled water. Ignition tube was taken and filled with 3 ml of 2N NaOH and then placed on the jam bottle so that the emitted CO_2 from the soil will be absorbed in to the NaOH solution. Soil samples were kept in dark room for one week. Then contents in ignition tubes were washed in to 250ml conical flasks separately and mixed with 7.5 ml of 2N $BaCl_2$. Few drops of phenolphthalein were added and mixtures were titrated by 0.5N HCl. Burette reading was taken at the point of which burette color changes from pink to colorless.

III. RESULTS AND DISCUSSION

Experiment 1: Sunhemp (*Crotalaria juncea*), Okra (*Hibiscus esculentus*) and Ground nut (*Arachis hypogaea*) under monocropping Vs mixcropping

All observed parameters; number of pods, pod weight, shoots length, number of leaves, root length was higher in mixcropping with sunhemp or ground nut (legumes) comparing to mono cropping. Okra mixcropping with sunhemp or ground nut (legumes) is more beneficial than monocropping. Significantly higher yield obtained from okra (53%) when grow with ground nut. Number of pods per plant in okra was increased from 30% when grow with ground nut comparing to monocropping (Table 1a, 1b, 1c and Fig.1).

Table1a. Affect of Treatments (T2 Okra with Okra; T4 Okra with Sunhemp; T6 Okra with ground nut) for growth and yield performances Okra

Treatment	No of pods/plant	Pod weight/plant (g)	Shoot length (cm)	No of leaves/plant	Root Length (cm)
T2 Okra with Okra	6.67 b	133.26 b	57.33 b	8.67 a	54.33 a
T4 Okra with Sunhemp	7.83 b	141.82 b	65.00 b	9.67 a	39.33 b
T6 Okra with ground nut	8.67 a	203.93 a	74.33 a	10.33 a	57.00 a

Column values followed by the same letter are not significantly different as determined by Duncan's multiple range test (P=0.05).Values in same column with same letter denoted non- significant difference

Significantly yield was increased by 112.37% of sunhemp when growing with ground nut comparing to monocropping. But there was no significant different in wet and dry weight of stem. Wet weight of pods /plant, Dry weight of pods/plant and seed weight/plant was significantly increased 90.82%, 115%, 117.55% of sunhemp respectively when growing with ground nut compare to monocropping.

Table 1b. Affect of treatment (T1; sunhemp with sunhemp, T4; Sunhemp with Okra, T5; Sunhemp with Ground nut) for growth and yield performances Sunhemp.

Treatmets	No of pods/plant	No of leaves/ plant	Shoot length/ plant (cm)	Root length/ plant (cm)	Wet weight of stem (g)	Dry weight of stem (g)	Wet weight of pods/plant (g)	Dry weight of pods/plant (g)	Seed weight/plant (g)
T1 sunhemp with sunhemp	37.67 b	54.33 a	177.5 a	35.50 a	41.67 a	21.33 a	13.95 b	11.13 b	6.95 b
T4 ; Sunhemp with Okra	54.33 b	72.00 a	186.0 a	40.67 a	49.33 a	25.33 a	20.62 ab	18.09 ab	11.00 ab
T5 Sunhemp with Ground nut	80.00 a	71.33 a	200.0 a	43.00 a	59.33 a	33.33 a	26.62 a	23.94 a	15.12 a

Column values followed by the same letter are not significantly different as determined by Duncan's multiple range test (P=0.05).Values in same column with same letter denoted non- significant difference

Ground nut mixcropping with Sunhemp is better than monocropping of Ground nut, obtained 128.61 % yield increment.

Table 1c; Affect of treatment (T3; Ground nut with Ground nut, T5; Ground nut with Snuhemp, T6; Ground nut with Okra) for growth and yield performances Ground nut.

Treatment	Yield
T3- Ground nut with Ground nut	9.33 c
T5- Ground nut with Snuhemp	21.33 a
T6- Ground nut with Okra	15.00 b

Column values followed by the same letter are not significantly different as determined by Duncan's multiple range test (P=0.05).Values in same column with same letter denoted non- significant difference

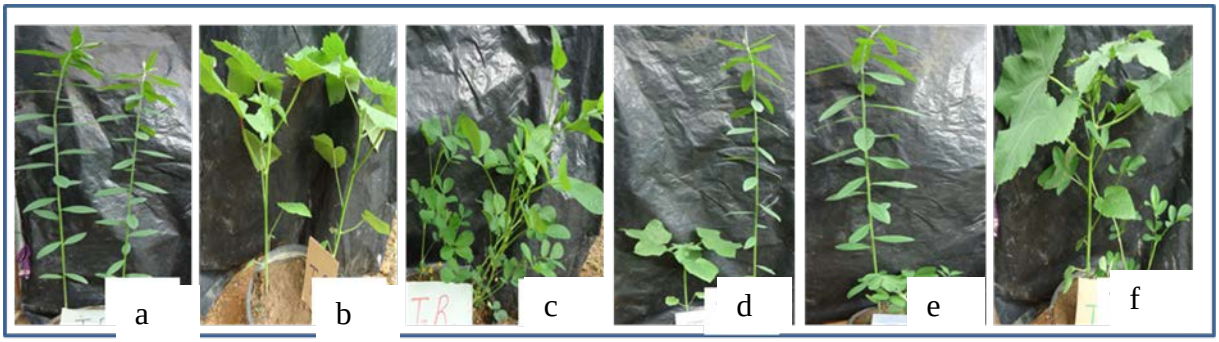

Fig 1. How plants are growing in the pots a. sunhemp with sunhemp b. okra with okra c. groundnut with groundnut d. okra with sunhemp e. sunhemp with groundnut f. okra with groundnut

Significantly highest mean microbial activity was observed in mixcropping sunhemp with okra. But the highest microbial activity does not mean the highest yield in Okra or sunhemp, may be other factors were also effect on yield (Table 1d).

Table 1d: Soil microbial activity

Treatment	Microbial activity (CO_2 mg/kg of soil)
T1 -Sunhemp with sunhemp	210 c
T2 -Okra with Okra	480 b
T3 -Ground nut with Ground nut	480 b
T4 -Sunhemp with Okra	850 a
T5 -Ground nut with Snuhemp	570 b
T6 -Ground nut with Okra	150 c

Experiment 2: Cowpea **(*Vigna unguiculata*)**, Bush Bean **(*Phaseolus vulgaris*) and** Tomato (***Lycopersicon esculentum*)** under monocropping Vs mixcropping

All observed parameters of tomato; number of flowers, number of pods, weight of fruit/pod, number of leaves and plant height were higher in mixcropping with cowpea or bush bean (legumes) compare to mono-cropping. Tomato, mixcropping with cowpea or bush bean (legumes) is more beneficial than mono-cropping. Significantly higher yield obtained from tomato (45% and 15%) when grow with bush bean comparing to cowpea respectively. Number of fruits per plant in tomato was increased by 50% when grow with bush bean comparing to monocropping. (Table 2a).

Table 2a. Affect of Treatments (T1.Tomato with Tomato; T4. Cowpea with Tomato; T5. Bean with Tomato) for growth and yield performances Tomato

Treatment	Number of flowers/plant	Number of fruits or /plant	Weight of fruit/ plant (g)	Number of Leaves/plant	Plant height (cm)
T1-Tomato with Tomato	36.00 c	27.33 c	924.00 b	39.0 b	94.0 c
T4-Cowpea with Tomato	41.33 b	33.33 b	1066.33 b	41.0 b	105.0 b
T5-Bean with Tomato	62.33 a	41.00 a	1340.33 a	59.0 a	152.0 a

Column values followed by the same letter are not significantly different as determined by Duncan's multiple range test (=0.05).Values in same column with same letter denoted non- significant difference

Significantly yield was increased from 106% of cowpea when growing with tomato comparing to mono-cropping but the number of root nodules were decreased by 80% (Figure 2a). Number of pods per plant in cowpea was increased from 100% when grow with tomato comparing to mono-cropping (Table 2b). But the highest number of root nodules (13/plant) of cowpea was observed when the plant is growing as mono-crop (Figure 2b).

Table 2b. Affect of Treatments (T2. cowpea with cowpea; T4. cowpea with Tomato; T6. Cowpea with bean) for growth and yield performances Cowpea

Treatment	Number of flowers/plant	Number of pods/plant	Weight of seed/ plant (g)	Number of Leaves/plant	Plant height (cm)	Number of root nodules/plant
T2- cowpea with cowpea	9.33 b	6.00 b	8.70 b	9.167 b	125.00 b	13.33 a
T4- cowpea with Tomato	22.33 a	12.33 a	18.66 a	16.00 a	158.33 a	2.667 b
T6 - Cowpea with bean	9.33 b	5.66 b	9.00 b	13.00 a	131.667 b	6.000 b

Column values followed by the same letter are not significantly different as determined by Duncan's multiple range test (P=0.05).Values in same column with same letter denoted non- significant difference

Figure 2a. Number of seed per plant in cowpea. a. Cowpea mono-cropping, b. mixcropping with tomato, c. mixcropping with bush bean

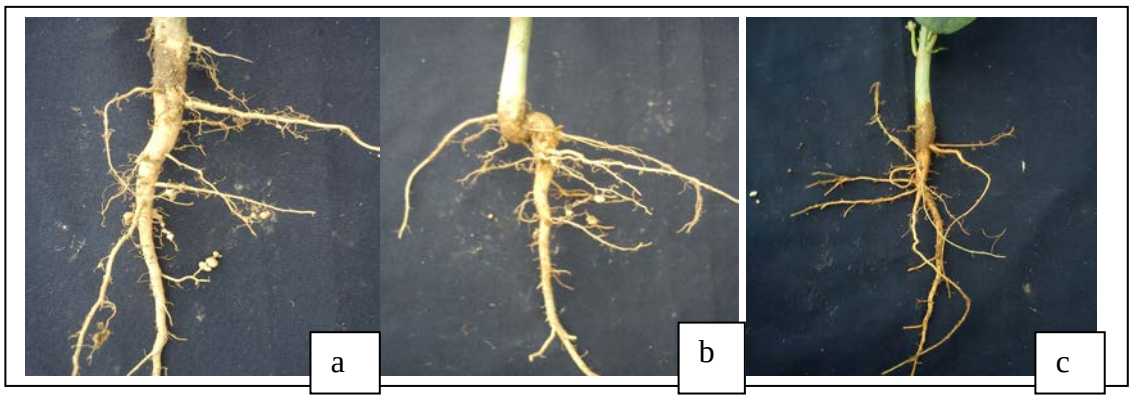

Figure 2b. Root nodules in cowpea. a. mixcropping with bean, b. mixcropping with tomato, c. Cowpea mono-cropping

Bush bean, mixcropping with tomato is better than mono-cropping obtained 35% yield increment. However the number of root nodules was decreased by 94%. The highest number of root nodules (5.7/plant) of bush bean was observed when the plant is growing as mono-crop. Number of pods per plant in bush bean was increased by 58% when grow with tomato comparing to mono-cropping (Table 2c and Figure 2c). When legumes grow as mono-crop or inter-crop with another legume is not significantly increase the yield. MIxcropping legumes (bean or cowpea) with tomato is more beneficial for legume as well as tomato.

Table2c. Affect of Treatments (T3. Bean with bean; T5. Bean with Tomato; T6. Cowpea with bean) for growth and yield performances Bush bean.

Treatment	Number of flowers/plant	Number of pods/plant	Weight of seeds/ plant (g)	Number of Leaves/plant	Plant height (cm)	Number of root nodules/plant
T3 B/B	14.83 c	12.66 b	65.33 b	19.167 ab	86.167 a	5.666 a
T5 T/B	26.00 a	20.00 a	88.33 a	23.667 a	72.00 b	0.333 b
T6 C/B	20.33 b	14.00 b	61.00 b	13.667 b	66.00 c	0.666 b

Column values followed by the same letter are not significantly different as determined by Duncan's multiple range test (P=0.05).Values in same column with same letter denoted non- significant difference.

Figure 2c. Root nodules in bush bean. a. Mono-cropping bush bean, b. Mix-cropping with cowpea, c. Mixcropping with tomato

Significantly highest mean microbial activity was observed in tomato, grown as mono-crop but the highest microbial activity does not mean the highest yield in tomato, may be other factors were also effect on yield (Table 2d).

Table 2d. Soil microbial activity

Treatment	Microbial activity (CO_2 mg/kg of soil)
T1- Tomato with tomato	840 a
T2- Cowpea with cowpea	180 b
T3- Bean with bean	240 b
T4- Cowpea with tomato	120 b
T5- Bean with tomato	120 b
T6- Cowpea with bean	120 b

Experiment 3: Soy bean (*Glycine max* L.), mung bean (*Vigna radiata*) and curry chilli (*Capsiccum annum var.grossum*) in mono-cropping and mix-cropping

All observed parameters of curry chilli; number of pod/plant, pod weight/plant (g), Wet weight of seeds (g) and Dry weight of seeds (g) were higher in mixcropping with Mungbean compare to mono-cropping. Higher yield were recorded from curry chilli when grown with soybean (87%) and Mung bean (171%) as compared to mono cropping (Table 3a).

Table 3a. Effect of Treatments (T_3-: Curry chilli with Curry chilli, T_5-: Curry chilli with Soy bean; T_6-: Curry chilli with Mung bean) for growth and yield performances of Curry chilli

Treatment	Plant height (cm)	Number of leaves/plant	Number of Pods /plant	Pod weight/plant (g)
T_3 C/C	54.00 c	39.00 c	8.00 b	94.20 b
T_5 C/S	55.00 b	65.00 b	5.00 c	64.90 c
T_6 C/M	74.00 a	80.00 a	10.00 a	176.00 a

Column values followed by the same letter are not significantly different as determined by Duncan's multiple range test (P=0.05).Values in same column with same letter denoted non- significant difference

Table 3b. Effect of Treatments (T_1-: Soy bean with Soy bean; T_4- Soy bean with Mung bean; T_5- Soy bean with Curry chilli) for growth and yield responses of Soybean.

Treatment	Plant height (cm)	Number of leaves/plant	Number of root nodes /plant	Number of Pods/plant	Pod weight /plant (g)	wet weight of seeds(g)	Dry weight of seeds(g)
T1 S/S	95.38 a	53.00 a	11.50 a	47.00 b	26.675 b	19.855 b	13.530 b
T4 S/M	65.00 a	64.50 a	15.00 a	53.00 b	29.655 b	22.020 b	16.420 b
T5 S/C	65.00 a	82.50 a	14.00 a	93.50 a	53.330 a	40.240 a	30.530 a

Column values followed by the same letter are not significantly different as determined by Duncan's multiple range test (P=0.05).Values in same column with same letter denoted non- significant difference

Higher yield were recorded from soybean when grown with curry chilli (23%) and Mung bean (130%) as compared to mono cropping (Table 3b and Figure 3a).

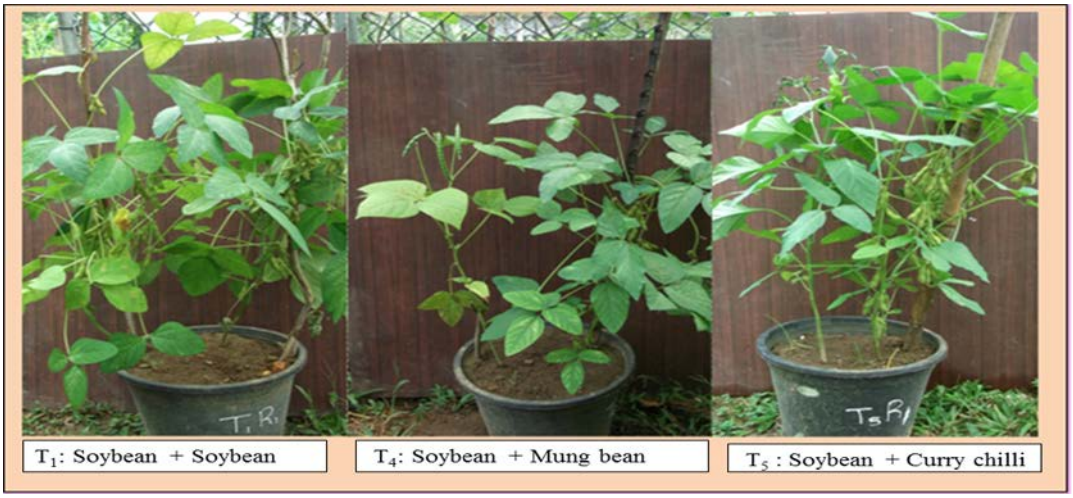

Figure 3a.Growth of plants at 70 days after planting. T_1 - monocroping of soy bean, T_2- MIxcropping with mung bean, T_3 – Mixcropping with curry chilli

Table 3c. Effect of Treatments (T_2-: Mung bean with Mung bean; T_4-: Mung bean with Soy bean; T_6-: Mung bean with Curry chilli) for growth and yield responses of mung bean.

Treatment	Plant height (cm)	Number of leaves/plant	Number of root nodes /plant	Number of Pods/plant	Pod weight /plant (g)	wet weight of seeds(g)	Dry weight of seeds (g)
T2 M/M	56.750 a	18.00a	0.500 b	11.50 ab	9.295 b	6.250 b	5.785 b
T4 M/S	54.000 a	16.00a	10.50 a	7.50 b	8.180 b	4.615 b	4.090 b
T6 M/C	57.500 a	12.50a	7.00 a	17.00 a	13.815 a	10.110 a	9.870 a

Column values followed by the same letter are not significantly different as determined by Duncan's multiple range test (P=0.05).Values in same column with same letter denoted non- significant difference

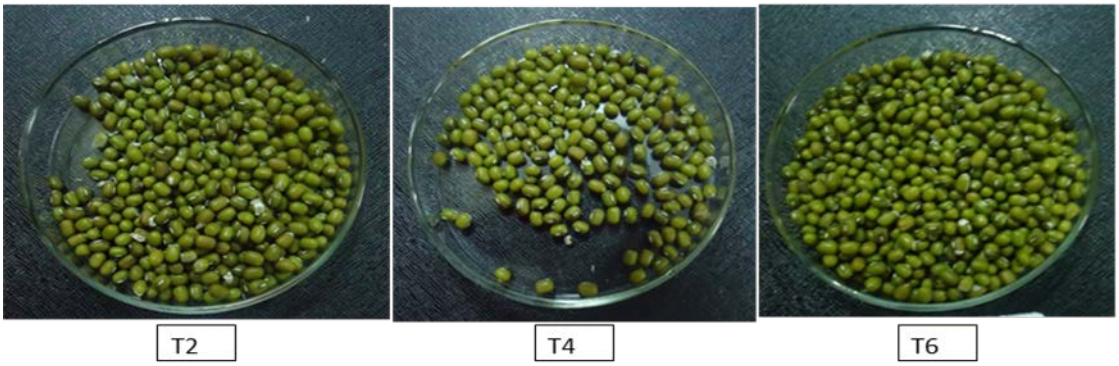

Figure 3b. Number of dry seeds per plant (T2- Mungbean with Mungbean, T4- Soybean with Mungbean, T6 Mung bean with Curry chilli)

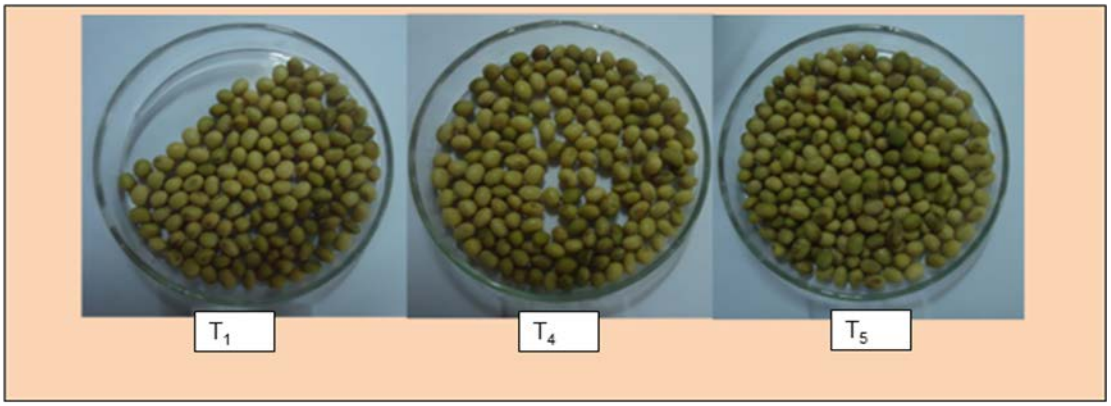

Figure 3c. Number of dry seeds per plant Mungbean produced 35% more yield when mixcropping with curry chilli as compared to Mungbean mono cropping (Table 3c, Figure 3b and 3c).

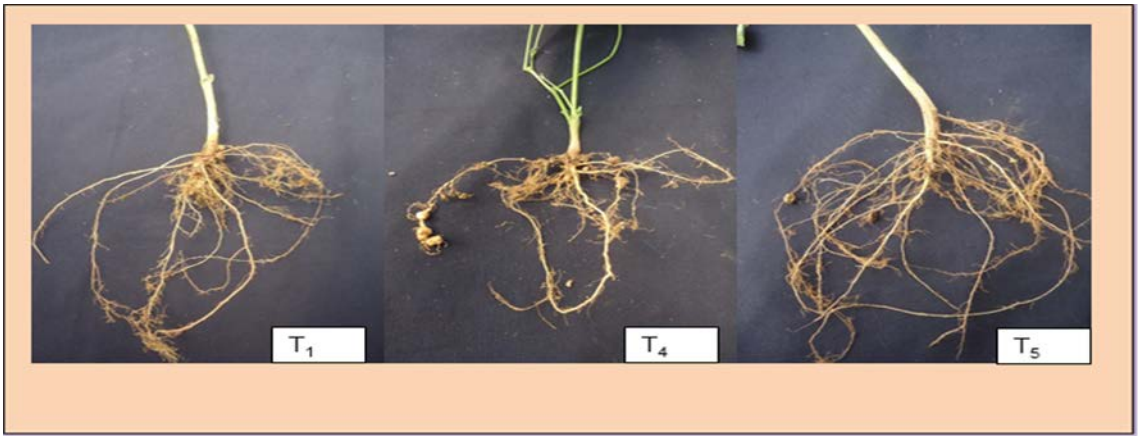

Figure 3d. T1- Soybean with Soybean, T4- Soybean with Mungbean, T5- Soybean with Curry chilli

Significantly highest mean microbial activity was observed in soybean intercropping with Mungbean. Due to both crops are legumes microbial activity may be increased (Table 3d and Figure 3d).

Intercropping cereals with food or green manure legumes is recommended for enhancing the supply of nitrogen to the cereal (Sangakkara *et al*, 2003). Introducing legumes in the productive system can bring benefits such as improvement of the physical characteristics of the soil, including aggregation and implementation of organic carbon, increased biomass, nutrient recycling, nitrogen supplied by biological fixing, soil moisture maintenance, decrease in maximum temperatures and heat amplitude, permanent protection against the main soil degrading agents and weed control (Diego *et al*, 2013**).**

Table 3d. Soil microbial activity of different treatments

Treatment	Microbial activity (weight of mineralized carbon in mg/kg of soil)
T1- Soy bean with Soy bean	420 b
T2- Mung bean with Mung bean	420 b
T3- Curry chilli with Curry chilli	300 b
T4- Soy bean with Mung bean	780 a
T5- Soy bean with Curry chilli	420 b
T6- Mung bean with Curry chilli	300 b

IV. Conclusions

When legumes grow as mono-crop or mix-crop with another legume did not significantly increase the yield. Mixcropping legumes (soy bean or mung bean, cowpea or bush bean, Sunhemp or Ground nut) with curry chilli or tomato or okra are more beneficial for legume as well as vegetable crop. Significantly highest mean microbial activities were observed in mixcropping with legumes as well as mono cropping. Therefore, the highest microbial activity does not mean the highest yield; other factors may be also affected on yield.

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