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*Full Length Research Paper*

# Nutritional status in soil and plants of herbal crops under agroforestry system

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**The present study was conducted to find out the nutritional status in soil and plants of herbal crops under Sapota-Jatropha based three-tier agroforestry system at the Agronomy Farm (Block-E), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat) during rainy season 2011 and 2012. Three medicinal plants *viz*., Basil (*Ocimum sanctum* L.), Kalmegh ( *Andrographis paniculata* Well.) and Mint (*Mentha arvensis* L) were selected for the present study. The observations *viz*. organic carbon, N, P, K, Ca, Mg, Fe, Mn, Zn and Cu in soil were analyzed after harvesting. Intercropping of Basil, Kalmegh and Mint recorded higher nutrients namely, organic carbon, N, P, K, Ca, Mg, Fe, Mn, Zn and Cu in soil as well as in plant under Sapota – Jatropha cropping system as compared to sole crop. The trend was same in both the years as well as in pooled.**

**Key words:** Agroforestry, basil, herbal, intercropping, kalmegh, mint, nutrient.

## INTRODUCTION

Medicinal plants growing in forests require partial shade, moist soils rich in organic matter, high relative humidity and mild temperatures. Cultivation of such medicinal plants can be taken up in thinned forests, cleared forest patches, and as intercrops in orchards and new forest plantations (Venugopal et al., 2008).There are number of indigenous under storey herbs and shrubs that can be produced as a part of forest farming or in new forest plantation to improve economic return as well as soil health from the forests in India. Newly established forest plantations can be intercropped with medicinal plants similar to food crops until the trees cover the ground.

The participation of the local people with the right to share benefits of the plantations, especially ownership to crops, has helped government to establish plantations without conflict with the local people in many Asian countries. The same approach can be employed for the cultivation of medicinal plants in the new plantations. In the rehabilitation of degraded forest lands, participating, planning and implementation with local communities and economic benefits from an early stage onwards will ensure commitment of the people. The intensity of shade experienced by the under storey medicinal plants growing in forests and tree plantation affects their growth and chemical composition.

In recent year's attention has focused on the diversified

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medicinal plant production system for maximizing utilization of resources as compared to the monoculture cropping systems. This allows judicious use of the internal spaces of the trees and crops promoting diversification, enhancing per capita land productivity and cultivation of the crops in demand (Willey, 1979). Medicinal plants in the nature are now under great pressure due to their excessive collection and exploitation (Laloo et al., 2000). Continuous exploitation of several medicinal plant species and substantial loss of their habitats have resulted in the population decline of many high value medicinal plant species over the years (Kala and Sajwan, 2003). As such there is no sufficient work on agroforestry system of horticultural, silvicultural and medicinal crops in India with regards to soil health and leaf nutrition.

## MATERIALS AND METHODS

The experiment was conducted under rainfed conditions during *kharif* season (June to July) 2011and 2012 at Navsari Agricultural University, Navsari, Gujarat. The climate of the area is characterized by three well defined seasons namely monsoon, winter and summer. The seven year old plantation of Sapota (*Manilkara acharas* (Mill) Fosberg.) at 10.0 x 10.0 m spacing, inter cropped with five year old plantation of Jatropha (*Jatropha curcus* L.) at 2.5 x 2.5 m spacing were used for intercropping study. Three herbal medicinal plants *viz*. Basil (*Ocimum sanctum* L.) at 50 x 40 cm, Kalmegh (*Andrographis paniculata* Well.) at 50 x 40 cm and Mint (*Mentha arvensis* L) at 30 x 45 cm were selected for the present study.

The statistically, experiment was laid out in randomized block design with replicated four times with following treatments that is $T_1$ – *Manilkara achras* + *Jatropha curcas* + *Ocimum sanctum*, $T_2$ – *Manilkara achras* + *Jatropha curcas* + *Andrographis paniculata*, $T_3$ – *Manilkara achras* + *Jatropha curcas* + *Mentha arvensis* , $T_4$ – *Ocimum sanctum* sole, $T_5$ – *Andrographis paniculata* sole, $T_6$ – *Mentha arvensis* sole. Farm Yard manure was applied at 20t/ha to all the plots uniformly and was incorporated into the soil at the time of land preparation. Nitrogen, phosphorus and potash were applied at the rate of 40:15:15 Kg per hectare (for Basil), 40:20:40 kg per hectare (for Kalmegh), 120:50:60 kg per hectare (for Mint) respectively. All intercultural operations were done when it was necessary. Soil analysis techniques are:

### Nutrient analysis of soils

Experimental block's soil sample (0 to 30 cm) were collected before and after the experiment and used for determining the basic physico-chemical properties. The soil samples were dried in shade, processed and used for further analysis.

### Nutrient analysis of plants

Plant samples used for studying dry matter production were used for estimating nutrient content in whole plant. The samples were powdered and stored in plastic container and were used for further analysis.

### Statistical analysis

The collected data were analyzed statistically as per the appropriate procedure by using randomized block design in four replicates for each treatment as described by Panse and Sukhatme (1978) and the treatment means were compared by means of critical differences at 5% level of probability.

## RESULTS AND DISCUSSION

### Nutrient status in soil after the harvesting of the herbal crops

#### *Organic carbon status (g kg$^{-1}$) in soil*

The data regarding organic carbon status of the soil after the harvest of herbal crops during June to July, 2011, 2012 and in their pooled analysis are presented in Table 1. The result revealed that the status of organic carbon in soil at harvest was significant during both the years of experimentation and in their pooled data.

The data indicates that intercrop of basil ($T_1$, 7.10 g kg$^{-1}$) recorded significantly higher organic carbon status in. While in plots with kalmegh and mint recorded maximum organic carbon status in soil when grown under Sapota-Jatropha ($T_2$, 6.78 g kg$^{-1}$ and $T_3$, 6.94 g kg$^{-1}$, respectively) during 2011. During the year 2012, significantly higher organic carbon status in soil was observed in basil, kalmegh and mint when these were grown under Sapota-Jatropha ($T_1$, 7.25 g kg$^{-1}$, $T_2$, 6.91 g kg$^{-1}$ and $T_3$, 7.07 g kg$^{-1}$, respectively) compared to sole basil, kalmegh and mint ($T_4$, 6.37 g kg$^{-1}$, $T_5$ 6.15 g kg$^{-1}$ and $T_6$, 6.30 g kg$^{-1}$) respectively.

In pooled analysis the same trend of organic carbon in soil was observed as per the trend of second year results. The per cent increase in organic carbon in soil in the first year was recorded maximum in basil (11.99 %) followed by kalmegh (10.78 %) and mint (10.69 %). With regards to the second year and pooled data, it showed the similar trend to those of the results of first year. Content of organic carbon in soil was higher under intercrop of basil, kalmegh and mint under Sapota-Jatropha as compared to sole cropping of basil, kalmegh and mint. This may be due to more litterfall from trees and it may also be due to decomposition of litter. This is supported by Jaimini et al. (2006).

### Available nitrogen status (kg ha$^{-1}$) in soil

The mean data pertaining to variation in the available nitrogen status in the soil after the harvest of herbal crops are presented in Table 2. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The available nitrogen status in the soil was recorded higher when herbal crops are grown under Sapota-Jatropha as compared to sole cropping. It is evident from data that significant difference in the nitrogen status in soil was observed in all the herbal medicinal plants grown under Sapota-Jatropha and in sole crops. Significantly higher nitrogen in soil was

**Table 1.** Organic carbon and major nutrients available in soil at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry sy

| Treatment | Organic Carbon (g kg$^{-1}$) | | | Nitrogen (kg ha$^{-1}$) | | | Phosphorus (kg ha$^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Pooled | 2011 | 2012 | Pooled | 2011 | 2012 | Pooled | |
| $T_1$ - Basil Intercrop | 7.10 (11.99)* | 7.25 (13.81)* | 7.18 (13.07)* | 271.22 (22.91)* | 274.73 (22.41)* | 272.97 (22.66)* | 437.78 (16.08)* | 448.35 (15.58)* | 443.06 (15.83)* | 3 (2 |
| $T_2$ - Kalmegh Intercrop | 6.78 (10.78)* | 6.91 (12.36)* | 6.85 (11.56)* | 249.73 (13.79)* | 252.49 (13.62)* | 251.11 (13.71)* | 419.64 (17.65)* | 431.77 (17.48)* | 425.71 (17.57)* | 3 (1 |
| $T_3$ - Mint Intercrop | 6.94 (10.69)* | 7.07 (12.22)* | 7.00 (11.29)* | 261.08 (18.35)* | 264.59 (17.93)* | 262.83 (18.14)* | 425.00 (15.79)* | 439.50 (16.28)* | 432.25 (16.03)* | 3 (1 |
| $T_4$ - Basil Sole | 6.34 | 6.37 | 6.35 | 220.67 | 224.43 | 222.55 | 377.13 | 387.90 | 382.51 | 3 |
| $T_5$ - Kalmegh Sole | 6.12 | 6.15 | 6.14 | 219.46 | 222.22 | 220.84 | 356.67 | 367.54 | 362.10 | 3 |
| $T_6$ - Mint Sole | 6.27 | 6.30 | 6.29 | 220.60 | 224.36 | 222.48 | 367.05 | 377.98 | 372.52 | 3 |
| S. Em ± | 0.224 | 0.246 | 0.166 | 8.765 | 12.710 | 7.720 | 20.132 | 20.247 | 14.276 | 1 |
| CD at 5 % | 0.67 | 0.74 | 0.48 | 26.41 | 38.30 | 22.29 | 60.67 | 61.02 | 41.23 | |

*Figure in parenthesis indicates percentage increases over respective sole cropping.

**Table 2.** Secondary nutrients available in soil at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

| Treatment | Calcium (mg kg$^{-1}$) | | | | Magnesium ( |
|---|---|---|---|---|---|
| | 2011 | 2012 | Pooled | 2011 | 2012 |
| $T_1$ - Basil Intercrop | 6085.16 (0.03)* | 6090.16 (0.06)* | 6087.66 (0.04)* | 1815.50 (0.10)* | 1817.54 (0 |
| $T_2$ - Kalmegh Intercrop | 6082.17 (0.10)* | 6086.17 (0.09)* | 6084.17 (0.10)* | 1814.10 (0.12)* | 1815.11 (0 |
| $T_3$ - Mint Intercrop | 6084.18 (0.04)* | 6087.18 (0.01)* | 6085.68 (0.03)* | 1814.42 (0.07)* | 1816.43 (0 |
| $T_4$ - Basil Sole | 6083.22 | 6086.72 | 6084.97 | 1813.65 | 1814.6 |
| $T_5$ - Kalmegh Sole | 6076.12 | 6080.62 | 6078.37 | 1812.00 | 1813.0 |
| $T_6$ - Mint Sole | 6081.85 | 6086.35 | 6084.10 | 1813.10 | 1813.8 |
| S. Em ± | 341.240 | 402.493 | 263.839 | 98.046 | 121.11 |
| CD at 5 % | NS | NS | NS | NS | NS |

*Figure in parenthesis indicates percentage increases over respective sole cropping.

recorded when basil, kalmegh and mint grown under Sapota-Jatropha ($T_1$, 271.22 kg ha$^{-1}$, $T_2$, 249.73 kg ha$^{-1}$ and $T_3$, 261.08 kg ha$^{-1}$) followed by sole basil, kalmegh and mint ($T_4$, 220.67 kg ha$^{-1}$, $T_5$, 219.46 kg ha$^{-1}$ and $T_6$, 220.60 kg ha$^{-1}$) respectively.

In second year, significantly higher nitrogen in soil was recorded when basil grown under Sapota-Jatropha ($T$ 274.73 kg ha$^{-1}$) which was followed by sole basil ($T_4$, 224.43 kg ha$^{-1}$). Mint showed same trend that of as basil. While nitrogen was maximum in soil was noted when kalmegh grown under Sapota-Jatropha ($T_2$, 252.49 kg ha$^{-1}$) which was at par with sole kalmegh ($T_5$, 2 pooled analysis year result. Per the first year w (22.91%) follow (13.79%). Simila and pooled data

**Table 3.** Micro nutrients available in soil at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.

| Treatment | Iron (mg kg$^{-1}$) | | | Manganese (mg kg$^{-1}$) | | | Zinc (mg kg$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Pooled | 2011 | 2012 | Pooled | 2011 | 2012 | Pooled |
| $T_1$ - Basil Intercrop | 5.12 (0.79)* | 5.22 (2.15)* | 5.17 (1.37)* | 10.54 (1.05)* | 10.56 (1.05)* | 10.55 (1.05)* | 0.85 (1.19)* | 0.88 (4.76)* | 0.86 (2.38)* |
| $T_2$ - Kalmegh Intercrop | 5.06 (0.80)* | 5.08 (0.79)* | 5.07 (0.80)* | 10.34 (0.78)* | 10.36 (0.78)* | 10.35 (0.78)* | 0.79 (3.95)* | 0.81 (5.19)* | 0.80 (3.90)* |
| $T_3$ - Mint Intercrop | 5.08 (0.99)* | 5.10 (0.99)* | 5.09 (0.99) | 10.43 (0.68)* | 10.46 (0.77)* | 10.44 (0.68)* | 0.83 (0.00)* | 0.84 (0.00)* | 0.83 (0.00)* |
| $T_4$ - Basil Sole | 5.08 | 5.11 | 5.10 | 10.43 | 10.45 | 10.44 | 0.84 | 0.84 | 0.84 |
| $T_5$ - Kalmegh Sole | 5.02 | 5.04 | 5.03 | 10.26 | 10.28 | 10.27 | 0.76 | 0.77 | 0.77 |
| $T_6$ - Mint Sole | 5.03 | 5.05 | 5.04 | 10.36 | 10.38 | 10.37 | 0.83 | 0.84 | 0.83 |
| S. Em ± | 0.263 | 0.173 | 0.157 | 0.354 | 0.417 | 0.273 | 0.045 | 0.046 | 0.032 |
| CD at 5 % | NS | NS | NS | NS | NS | NS | NS | NS | NS |

*Figure in parenthesis indicates percentage increases over respective sole cropping.

### Available phosphorus status (kg ha$^{-1}$) in soil

The data regarding phosphorus status in soil of different herbal crops are presented in Table 1. The results were found significant during both the years (2011 and 2012) and in pooled analysis. From data, it can be seen that in first year of study, basil grown under Sapota-Jatropha ($T_1$, 38.84 kg ha$^{-1}$) noted significantly higher phosphorus in soil which was followed by sole basil ($T_4$, 31.50 kg ha$^{-1}$). Kalmegh and mint recorded maximum phosphorus in soil when this grown under Sapota-Jatropha ($T_2$, 35.56 kg ha$^{-1}$ and $T_3$, 36.70 kg ha$^{-1}$, respectively) cropping system. In second year, the significantly higher phosphorus recorded in soil when basil grown under Sapota-Jatropha ($T_1$, 40.09 kg ha$^{-1}$) which was followed by sole basil ($T_4$, 31.75 kg ha$^{-1}$). In the pooled analysis, the similar scenario of phosphorus in soil of all herbal crops (basil, kalmegh and mint) was observed.

### Available potassium status (kg ha$^{-1}$) in soil

The mean data pertaining to variation in the available potassium status in the soil after the harvest of herbal crops are presented in Table 1. The results were found significant during both the years (2011 and 2012) and in pooled analysis. Maximum potassium in soil was noted when basil grown under Sapota-Jatropha ($T_1$, 437.78 kg ha$^{-1}$) cropping system. Significantly higher potassium in soil was recorded when kalmegh and mint grown under Sapota-Jatropha ($T_2$, 419.64 kg ha$^{-1}$, $T_3$ 425.00 kg ha$^{-1}$) as compared to sole kalmegh and mint ($T_5$, 356.67 kg ha$^{-1}$ $T_6$, 367.05 kg ha$^{-1}$). The results of second year showed the same trend as that of first year results.

In pooled analysis, significantly higher potassium in soil was recorded when basil grown under Sapota-Jatropha ($T_1$, 443.06 kg ha$^{-1}$) was followed by sole basil ($T_4$, 382.51 kg ha$^{-1}$) kalmegh and mint. Content of major nutrients such as N, P, K in soil were higher under intercropping of basil, kalmegh and mint under Sapota-Jatropha as compared to sole cropping of basil, kalmegh and mint.This may be due to higher microbial activities coupled with recycling of nutrients through leaf litter and more favorable physical condition *viz*., soil moisture, temperature under trees than sole.

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### Micro nutrients

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**Table 4.** Organic carbon and major nutrients content in plant at harvest of herbal crops as influenced by Sapota- Jatropha three-tier agroforestry syste

| Treatment | Organic Carbon (g kg-1) | | | Nitrogen (kg ha-1) | | | Phosphorus (kg ha-1) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Pooled | 2011 | 2012 | Pooled | 2011 | 2012 | Pooled |
| T1 - Basil Intercrop | 43.80 | 44.33 | 44.06 | 1.458 | 1.459 | 1.458 | 0.141 | 0.143 | 0.142 |
| | (5.75)* | (5.80)* | (5.76)* | (0.97)* | (0.90)* | (0.90)* | (5.22)* | (4.38)* | (5.19)* |
| T2 - Kalmegh Intercrop | 42.65 | 42.90 | 42.78 | 1.126 | 1.128 | 1.127 | 0.123 | 0.126 | 0.125 |
| | (5.54)* | (5.41)* | (5.47)* | (0.54)* | (0.45)* | (0.54)* | (2.50)* | (2.44)* | (3.31)* |
| T3 - Mint Intercrop | 43.40 | 43.70 | 43.55 | 1.360 | 1.361 | 1.361 | 0.128 | 0.130 | 0.129 |
| | (5.44)* | (5.68)* | (5.55)* | (0.37)* | (0.22)* | (0.37)* | (4.07)* | (4.00)* | (4.03)* |
| T4 - Basil Sole | 41.42 | 41.90 | 41.66 | 1.444 | 1.446 | 1.445 | 0.134 | 0.137 | 0.135 |
| T5 - Kalmegh Sole | 40.41 | 40.70 | 40.56 | 1.120 | 1.123 | 1.121 | 0.120 | 0.123 | 0.121 |
| T - Mint Sole | 41.16 | 41.35 | 41.26 | 1.355 | 1.358 | 1.356 | 0.123 | 0.125 | 0.124 |
| S. Em ± | 1.352 | 1.803 | 1.127 | 0.040 | 0.049 | 0.032 | 0.005 | 0.005 | 0.003 |
| CD at 5 % | NS | NS | NS | 0.12 | 0.14 | 0.09 | 0.01 | 0.01 | 0.00 |

*Figure in parenthesis indicates percentage increases over respective sole cropping.

And copper status in soil of herbal crops under Sapota-Jatropha and sole crops of basil, kalmegh and mint are furnished in Table 2. The results were found non-significant during 2011, 2012 and in their pooled data. The presented data clearly revealed that content of micro nutrients such as Fe, Mn, Zn and Cu in soil under intercropping of basil, kalmegh and mint with Sapota-Jatropha as compared to sole cropping of basil, kalmegh and mint were found non-significant. Sapota-Jatropha as tree component have failed in altering the status of micronutrients through addition of leaf litter.

## Leaf nutrient content in herbal crops

### *Organic carbon content (%)*

The result reveals that organic carbon content after the harvest of herbal crops was non - significant during both the years of experimentation and in their pooled data. It is evident from results presented in Table 4 that organic carbon content was found non - significant in basil, kalmegh and mint under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint. It might be due to that organic carbon content being the basic building blocks are ought to be the same, however, in term of total biomass the organic carbon will differ greatly.

### *Nitrogen content (%)*

The maximum content of nitrogen was recorded in intercropping of all herbal crops grown under Sapota-Jatropha as compared to sole cropping (Table 4). In the first year data, the content of nitrogen by the basil, kalmegh and mint grown under Sapota-Jatropha treatment ($T_1$, 1.458, $T_2$, 1.126 and $T_3$, 1.360%) noted maximum. Further perusal of data reveals that herbal crops (basil, kalmegh and mint) in second year and pooled analysis showe that of first year.

### *Phosphorus co*

The data show study, higher c when basil, ka Sapota-Jatropha 0.128%) croppi second year ( showed the sam content of phos kalmegh and m results.

### *Potassium con*

The total conten harvest betwee

**Table 5.** Secondary nutrients content in plant at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.

| Treatment | Calcium (%) | | | | Ma |
|---|---|---|---|---|---|
| | 2011 | 2012 | Pooled | 2011 | |
| $T_1$ - Basil Intercrop | 1.745 (0.06)* | 1.748 (0.17)* | 1.746 (0.06)* | 0.469 (0.21)* | 0.4 |
| $T_2$ - Kalmegh intercrop | 1.456 (0.14)* | 1.458 (0.14)* | 1.457 (0.14)* | 0.438 (0.23)* | 0.4 |
| $T_3$ - Mint Intercrop | 1.687 (0.12)* | 1.690 (0.12)* | 1.688 (0.12)* | 0.446 (0.22)* | 0.4 |
| $T_4$ - Basil Sole | 1.744 | 1.745 | 1.745 | 0.468 | |
| $T_5$ - Kalmegh Sole | 1.454 | 1.456 | 1.455 | 0.437 | |
| $T_6$ - Mint Sole | 1.685 | 1.688 | 1.686 | 0.445 | |
| S. Em ± | 0.05 | 0.06 | 0.04 | 0.014 | |
| CD at 5 % | 0.16 | 0.19 | 0.12 | NS | |

*Figure in parenthesis indicates percentage increases over respective sole cropping.

in Table 4 during 2011, 2012 and their pooled data. All the herbal intercrops in their sole stand recorded non-significant results in their respective intercropping systems during the study. Looking to the data presented that higher content of major nutrients N, P, K were found under intercropping of basil, kalmegh and mint under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint. The content of all these nutrients increased with increased shade. Higher nutrient in intercropping which might be due to lesser weed competition there by higher absorption and utilization. Similar result was reported by Mohsin (2005) in mint and Rao et al. (2000) in nutrient removal in palmarosa and blackgram intercropping system.

### *Calcium content (%)*

The data on first year presented in Table 5 indicates that basil, kalmegh and mint when grown under Sapota-Jatropha ($T_1$, 1.745%, $T_2$, 1.456% and $T_3$, 1.687%, respectively) observed higher content of calcium. In second year and in pooled analysis, the similar scenario of total content of calcium in basil, kalmegh and mint herbal crops was observed as in the case of first year results. The content of secondary nutrients Ca was found significant and Mg was found non - significant under Sapota-Jatropha of basil, kalmegh and mint as compared to sole crop of basil, kalmegh and mint. The content of all these nutrients increased with increase in shade. Higher nutrient in intercropping which might be due to lesser weed competition there by higher absorption and utilization.

### *Magnesium content (%)*

The data regarding total content of magnesium at harvest between intercrops and sole crop are in Table 5. The statistical comparison showed that content of magnesium by herbal crops as affected by intercropping and sole cropping are found non-significant for both the years as well as in pooled analysis also.

### *Iron content (ppm)*

The total content of iron by crops recorded higher when herbal crops were grown under Sapota-

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### *Zinc content (p*

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**Table 6.** Micro nutrients content in herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.

| Treatment | Iron (ppm) | | | Manganese (ppm) | | | Zinc (ppm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Pooled | 2011 | 2012 | Pooled | 2011 | 2012 | Pooled |
| $T_1$ - Basil Intercrop | 134.76 (0.03)* | 136.22 (0.90)* | 135.47 (0.43)* | 55.65 (0.02)* | 56.15 (0.47)* | 55.90 (0.23)* | 27.35 (0.18)* | 27.60 (0.18)* | 27.48 (0.18)* |
| $T_2$ - Kalmegh Intercrop | 112.22 (0.04)* | 114.22 (0.48)* | 113.22 (0.26)* | 48.54 (0.02)* | 49.03 (0.49)* | 48.78 (0.23)* | 22.26 (0.04)* | 22.51 (0.04)* | 22.39 (0.04)* |
| $T_3$ - Mint Intercrop | 122.33 (0.07)* | 124.24 (0.94)* | 123.24 (0.43)* | 52.54 (0.06)* | 53.29 (0.06)* | 52.92 (0.06)* | 26.65 (0.04)* | 27.15 (0.97)* | 26.90 (0.49)* |
| $T_4$ - Basil Sole | 134.72 | 135.01 | 134.89 | 55.64 | 55.89 | 55.77 | 27.30 | 27.55 | 27.43 |
| $T_5$ - Kalmegh Sole | 112.18 | 113.68 | 112.93 | 48.53 | 48.79 | 48.67 | 22.25 | 22.50 | 22.38 |
| $T_6$ - Mint Sole | 122.24 | 123.08 | 122.71 | 52.51 | 53.26 | 52.89 | 26.64 | 26.89 | 26.77 |
| S. Em ± | 4.52 | 5.51 | 3.56 | 1.647 | 1.877 | 1.249 | 0.848 | 0.913 | 0.623 |
| CD at 5 % | 13.61 | 16.62 | 10.29 | 4.96 | 5.66 | 3.61 | 2.55 | 2.75 | 1.80 |

*Figure in parenthesis indicates percentage increases over respective sole cropping.

during first year study, when basil, kalmegh and mint were grown under Sapota- Jatropha ($T_1$, 27.35%, $T_2$, 22.26% and $T_3$, 26.65 %) had, higher content of zinc. In second year and in pooled analysis, the similar scenario of total content of zinc in basil, kalmegh and mint herbal crops were observed as in the case of first year result.

### *Copper content (ppm)*

The total content of copper by crops was recorded higher when herbal crops were grown under Sapota-Jatropha as compared to their respective sole cropping (Table 6). In the first year basil, kalmegh and mint when grown under Sapota-Jatropha treatment ($T_1$, 12.44%, $T_2$, 9.45% and $T_3$, 12.42%) noted maximum content of copper. Further perusal of data reveals that herbal crops (basil, kalmegh and mint) in second year and pooled analysis exhibited similar trends as that of the first year. Percent increase in content of copper in plant was recorded maximum in mint (9.72%) which was followed by kalmegh (0.21%) and basil (0.16%). In the the second year and pooled data, it showed the similar trend to those of the results of first year. Higher content of micro nutrient *viz.,* Fe, Mn, Zn, Cu were found under intercropping of basil, kalmegh and mint under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint. All these nutrients are increased with increase in shade probably due to their accumulation under shaded condition. It also may be due to a possible synergistic effect caused by relative shading and due to more contribution of organic matter to the soil by Sapota and Jatropha.

## Conclusion

The organic carbon, N, P, K, Ca, Mg and micronutrients in soil was noted significantly higher under Sapota-Jatropha as compared to sole crops of basil, kalmegh and mint. The trend was same in both the years of study as well as in pooled analysis. Similarly, higher organic carbon content, N, P, K, Ca, Mg and micronutrients in leaf

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