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To study the growth performance of tuber crops under three-tier agroforestry system

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Abstract
An experiment was conducted to find out performance of tuber 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. Statistically the experiment was laid out in randomized block design with six treatments and four replications. Three medicinal plants *viz*., Kalihari (*Gloriosa superba* L.), Kali musli (*Curculigo orchioides* Gaertn) and Safed musli (*Chlorophytum borivilianum* Ker.) were selected for the present study. The observations viz. plant height (cm), number of tubers per plant, length of tuber, girth of tuber, crown spread (E-W & N-S) (cm), fresh and dry weight per plant (g) and survival percent were recorded at the end of experiment after planting. Intercropping of kalihari, kali musli and safed musli recorded higher plant height, the sole crop of kalihari, kali musli and safed musli recorded maximum number of tubers per plant, length of tuber, girth of tuber and survival percent. The maximum fresh and dry weight per plant was recorded in sole crop as compared to intercrop. The trend was same in both the years as well as in pooled.

Keywords: agroforestry, tuber, intercropping, kalihari, kali musli and safed musli

Introduction
The forest of India is Pandora's Box having rich collection of medicinal plants. Forests are the primary sources of medicinal plants. To meet the requirements of expanding regional and international markets and healthcare needs of growing populations, increasing volumes of medicinal plants are harvested from forests and other natural sources. Loss of forest lands for agriculture and plantation, overgrazing, irregular exploitation of herbs in forest and other natural woodlands are contributing for extinction of many species and depletion of the supply of medicinal plants from forests. Over exploitation and consequent depletion of medicinal plants not only affects their supply and loss of genetic diversity within these species but seriously affects the livelihood of indigenous people living in forest fringe (Patra, 2012). 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) [12]. 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 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 medicinal plant production system for maximizing utilization of resources as compared to the monoculture cropping systems. The improved use of resources results in greater total intercrop yields as compared to sole crops of the same species grown on the same area (Oraon *et al.*, 2005) [5]. 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) [13]. Medicinal plants in the nature are now under great pressure due to their excessive collection and exploitation (Laloo *et al.*, 2000) [4]. 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) [2]. As such there is no sufficient work on agroforestry system of horticultural, silvicultural and medicinal crops in India. Therefore, the study conducted to develop the suitable agroforestry system for hort- silvicultural and medicinal crops.

Materials and methods

An experiment was conducted under rainfed conditions during *kharif* season 2011 and 2012 at Navsari Agricultural University, Navsari, Gujarat. The climate of the area is characterized by three well defined seasons *viz*., monsoon, winter and summer. The monsoon commences from the middle of June and ends by the second fortnight of September. The climate of this area is humid and the mean relative humidity remained above 68.27 per cent throughout the year. The weather condition was favored for growing rainy, winter and summer crops during study. The seven year old plantation of Sapota (*Manilkara acharas* (Mill) Fosberg.) at 10.0m x 10.0m spacing, inter cropped with five year old plantation of Jatropha (*Jatropha curcus* L.) at 2.5m x 2.5m spacing were used for intercropping study. Three tuber medicinal plants *viz*. Kalihari (*Gloriosa superb* L.) at 30cm x 60cm, Kalimusli (*Curculigo orchioides* Gaertn) at 30cm x 30cm and Safedmusli (*Chlorophytum borivilianum* Ker.) at 30cm x 30cm were selected for the present study. The statistically, experiment was laid out in randomized block design with replicated four times with following treatments i. e. T_1 – *Manilkara achras* Mill + *Jatropha curcas* L. + *Gloriosa superba* L., T_2 – *Manilkara achras* Mill + *Jatropha curcas* L. + *Curculigo orchioides* Gaertn, T_3 - *Manilkara achras* Mill + *Jatropha curcas* L.+ *Chlorophytum borivilianum Ker*., T_4 – *Gloriosa superba* L. sole, T_5 – *Curculigo orchioides* Gaertn sole, T_6 – *Chlorophytum borivilianum* Ker. Sole. Farm Yard manure was applied @ 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 50:50:70 Kg per hectare (for Kalihari), 25:15:10 kg per hectare (for Kalimusli), 60:65:20 kg per hectare (for Safedmusli) respectively. All intercultural operations were done when it was necessary. Fifteen plants were randomly selected from net plot area of each treatment per replication and were tagged. The selected plants were used for recording all the observations. The observations viz. plant height (cm), number of tubers per plant, length of tuber, girth of tuber, crown spread (E-W & N-S) (cm), survival percent and fresh and dry weight per plant (g) were recorded at the end of experiment after planting.

Results and discussion

Plant height (cm)

The mean data pertaining to variation in plant height of intercrops and sole tuber crops are presented in Table - 1. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The plant height was recorded maximum when tuber crops grown under Sapota-Jatropha as compared to sole cropping. In the first year it is evident from data presented in Table – 1 that significant differences in the plant height were observed in all the tuber medicinal plants grown under Sapota-Jatropha and in sole crops. The plant height of kalihari, kali musli and safed musli was recorded maximum (T_1, 45.53 cm, T_2, 19.05 cm and T_3, 27.46 cm) under Sapota-Jatropha and was on the same bar with respective sole crops (T_4, 44.95 cm, T_5, 17.26 cm and T_6, 25.53 cm). Further perusal of data reveals that tuber crops (Kalihari, Kali musli and Safed musli) in second year and pooled analysis showed the similar trends as that of first year result. In first year percent increase in plant height was recorded maximum in kali musli (10.37 %) which was followed by safed musli (7.56 %) and kalihari (1.29 %) over their respective sole crops. With regards to the second year and pooled data, it showed the similar trend to those of the results of first year. This might be due to their ability to retain more soil moisture and better microclimate. Secondly it might be due to less light intensity under intercropping as compared to open condition. These results are in conformity with the findings of Arya *et al.* (2011) [1], Kumar (2010) [3] in safed musli and Vanlalhluna and Sahoo (2010) [11] in ginger.

Number of tubers per plant

The data regarding number of tubers per plant of different tuber crops are presented in Table – 1. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The number of tubers per plant was noted maximum in sole cropping as compared to intercropping under Sapota-Jatropha. From Table – 1, it can be seen that in first year of study, sole kalihari treatments T_4 (2.65) noted maximum number of tubers per plant which was on same bar with kalihari grown under Sapota-Jatropha (T_1, 2.38). While in other tuber crops kali musli and safed musli recorded significantly higher number of tubers per plant (T_5, 4.30 and T_6, 7.40, respectively) in sole cropping followed by intercrop under Sapota-Jatropha (T_2, 3.45 and T_3, 6.55) respectively. It can be seen from Table – 1 that, during second year of investigation and pooled analysis the same trend as per the trend of first year was evident. In first year the percent reduction in number of tubers per plant was recorded minimum in kalihari (10.19 %) which was followed by safed musli (11.49 %) and kali musli (19.77 %). Similar trend was observed in second year and pooled result. The possible reason can be attributed to this phenomenon is that the available light, space, water or nutrients in a pure cropping system result in production of more number of tubers. As light passes through the tree canopy in plantations the plants through the phytochemical system may induce marked morphogenetic changes in plant and inhibit branching. Similar results were corroborated by Thakur and Dutt (2003) [10].

Length of tuber (cm)

The observations on the length of tuber of sole crop and tuber crops grown under Sapota-Jatropha are furnished in Table – 1. The statistical comparison showed that the length of tuber as affected by intercrops and sole are found significant for both the study years and in pooled analysis. It is revealed from the data given in Table – 1 that in first year of study, sole kalihari treatment (T_4, 13.38 cm) noted significantly maximum length of tuber which was followed by kalihari grown under Sapota-Jatropha (T_1, 12.10 cm). In the tuber crops kali musli and safed musli maximum length of tuber (T_5, 5.25 cm and T_6, 6.23 cm, respectively) was in sole cropping and with slightly lower values when grown under Sapota-Jatropha (T_2, 5.10 cm and T_3, 6.20 cm) respectively. During 2012 higher length of tuber was registered in the (T_4) sole kalihari crop (13.83 cm) which was on same bar with treatment T_1 (13.65 cm). The other tuber crops kali musli and safed musli showed similar trend as in kalihari. Similar trend was observed in pooled data. During 2011 percent reduction in length of tuber was (0.48 %) in safed musli which was followed by kali musli (2.86 %) and kalihari (9.57 %). Same trend was observed in second year and pooled data. This may be due to more light availability under open condition and absence of competition

from trees and more photosynthesis. Similar result was observed by Thakur and Dutt (2003) [10]. Maximum length of tuber in safed musli was found under Sapota-Jatropha intercrop compared to sole crop of safedmusli. Similar results were corroborated by Kumar *et al.* (2010) [3].

Girth of tuber (cm)

The data regarding variation in girth of tuber between intercrops and sole crop are tabulated in Table – 1. The statistical comparison showed that the girth of tuber as affected by intercrops and sole are found significant for both years (2011 and 2012) and in pooled analysis also. During 2011 maximum girth of tuber was noted in sole crop of kalihari (T_4, 5.93 cm) and kali musli (T_5, 2.18 cm) which was statistically at par with kalihari (T_1, 5.53 cm) and Kali musli (T_2, 1.90 cm) grown as an intercrop. Sole crop of safed musli reported significantly maximum girth of tuber (T_6, 4.93 cm) which was followed by safed musli when grown under Sapota-Jatropha (T_3, 4.20 cm). A perusal of data presented in Table – 1 revealed that, during second year (2012), girth of tuber was significantly maximum in sole kalihari and kali musli (T_4, 7.08 cm and T_5, 3.13 cm, respectively) which was followed by intercrop of kalihari and kali musli (T_1, 5.90 cm and T_2, 2.38 cm) respectively. Sole crop of safed musli reported maximum girth of tuber (T_6, 4.00 cm) which was on the same bar with safed musli when grown under Sapota-Jatropha (T_3, 3.88 cm). In pooled analysis, the maximum girth of tuber was recorded in sole tuber crops (kalihari, kali musli and safed musli) which were statistically at par with when these tuber crops were grown under Sapota-Jatropha. During 2011 percent reduction in girth of tuber was noted minimum in kalihari (6.75 %) which was followed by kali musli (12.84 %) and safed musli (14.81 %). Similar trend was observed in second year and pooled result also. This might be due to the fact that plants grown in open condition have better opportunities to reap the solar energy requirement for photosynthetic activity for the production of photosynthates and increased carbohydrate synthesis which is ultimately reflected as better growth and production of biomass.

Survival percent

The survival percent of plant under Sapota-Jatropha and sole crops showed in Table - 2 during 2011, 2012 and in their mean data. All the tuber intercrops in their sole stand was recorded significant results in their respective intercropping systems during 2011, 2012 and pooled data. It is evident from data presented in Table - 2 that significant differences in the survival percent were observed in all the tuber medicinal plants grown under Sapota-Jatropha and in sole crops. The survival percents of kalihari, kali musli and safed musli was higher (T_4, 52.30 %, T_5, 74.83 %, T_6, 72.20 %) under Sapota-Jatropha was same bar with sole crop (T_1, 51.43 %, T_2, 73.80 %, T_3, 71.35 %) respectively. Further perusal of data revealed that tuber crops of second year data and pooled data showed the similar trend of first year results. Percent reduction in survival percent (2011) was obtained minimum in safed musli (1.18 %) which was followed by kali musli (1.38 %) and kalihari (1.66 %). Similar trend of results were obtained in case of second year and pooled analysis. This may due to their capability in establishing root system. It may also due to the possibility of their beneficial compatibility, interaction and greater biological efficiency of crop grown in association.

Fresh weight of tuber per plant (g)

The data with respect to fresh weight of tuber per plant of different tuber crops are furnished in Table – 2. The results were found significant during 2011, 2012 and in pooled analysis. Maximum fresh weight of tuber per plant of all the tuber crops was observed in sole cropping as compared to grown under Sapota-Jatropha. During 2011 an appraisal of data presented in Table – 2 indicates that the fresh weight of tuber per plant was noted higher in sole crop of kalihari, kali musli and safed musli (T_4, 30.08 g, T_5, 6.58 g and T_6, 36.14 g) which was on same bar with kalihari, kali musli and safed musli when grown under Sapota-Jatropha (T_1, 28.58 g, T_2, 5.79 g and T_3, 34.09 g) respectively. In the second year, significantly maximum fresh weight of tuber per plant was found in the sole crop of kalihari in treatment T_4 (33.14 g) which was followed by kalihari when grown under Sapota-Jatropha (T_1, 29.75 g). The other tuber crops (kali musli and safed musli) in sole crop (T_5, 6.73 g and T_6, 38.88 g, respectively) observed maximum fresh weight of tuber per plant which was statistically at par with intercrop under Sapota-Jatropha (T_2, 6.00 g and T_3, 35.49 g) respectively. Pooled estimates showed similar trend as second year result. Percent reduction in fresh weight of tuber per plant (2011) was recorded minimum in kalihari (4.99 %) which was followed by safed musli (5.09 %) and kali musli (12.01 %). With regard to the second year and pooled data, it showed the similar trend to those of the result of first year. It might be due to the uninterrupted and adequate amount of incident sunlight besides, zero tree-crop competition. Similar result was found by Vanlalhluna and Sahoo (2010) [11], Venugopal *et al.* (2008) [12] and Parekh *et al.* (2005) [6].

Dry weight of tuber per plant (g)

The data concerning the dry weight of tuber per plant of different tuber crops are summarized in Table - 2. During both the years (2011 and 2012) of study and in pooled analysis results were found significant. In all the tuber crops maximum dry weight of tuber per plant was recorded in sole crop as compared to their respective intercropping under Sapota-Jatropha. The statistical analysis of the first year (2011) data showed maximum dry weight of tuber per plant in sole crop of kalihari, kali musli and safed musli (T_4, 15.00 g, T_5, 4.95 g and T_6, 9.65 g) which was on the same bar with the intercrop of kalihari, kali musli and safed musli under Sapota-Jatropha (T_1, 14.48 g, T_2, 4.10 g and T_3, 9.17 g) respectively. An analysis of second year and pooled data showed that the trend was just in the same line as that of the first year result. During 2011 percent reduction in dry weight of tuber per plant was found minimum in kalihari (3.47 %) which was followed by safed musli (4.97 %) and kali musli (17.17 %). Same result was recorded in second year and pooled data. It may be due to less competition for light, nutrient and moisture in open condition for synthesizing food material. Similar result was found by Vanlalhluna and Sahoo (2010) [11], Venugopal *et al.* (2008) [12], Shinde (2001) [8] and Singh *et al.* (1997) [9].

Conclusion

Intercropping of Kalihari, Kali musli and Safed musli under Sapota-Jatropha recorded higher plant height as compared to their sole cropping during both the years and pooled analysis. The sole crop of Kalihari, Kali musli and Safed musli was recorded maximum number of tubers per plant, length of tuber, girth of tuber and survival percent as compared to intercrop under Sapota-Jatropha in both the years and pooled analysis. Significantly maximum fresh and dry weight per plant was recorded in sole crop of Kalihari, Kali musli and

Safed musli as compared to intercrop under Sapota-Jatropha. The trend was same in both the years as well as in pooled analysis.

Table 1: Growth performance of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Plant height (cm)			Number of tubers per plant			Length of tuber (cm)			Girth of tuber (cm)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T_1 - Kalihari Intercrop	45.53 (1.29)*	43.40 (7.16)*	44.47 (4.07)*	2.38 (10.19)*	3.08 (4.64)*	2.73 (7.14)*	12.10 (9.57)*	13.65 (1.30)*	12.88 (5.36)*	5.53 (6.75)*	5.90 (16.67)*	5.71 (12.15)*
T_2 – Kali musli Intercrop	19.05 (10.37)*	15.06 (7.19)*	17.06 (8.94)*	3.45 (19.77)*	4.08 (18.07)*	3.77 (18.75)*	5.10 (2.86)*	4.55 (0.00)*	4.83 (1.43)*	1.90 (12.84)*	2.38 (23.96)*	2.14 (19.55)*
T_3 – Safed musli Intercrop	27.46 (7.56)*	30.99 (11.08)*	29.23 (9.43)*	6.55 (11.49)*	7.38 (9.23)*	6.97 (10.30)*	6.20 (0.48)*	7.18 (1.37)*	6.69 (0.89)*	4.20 (14.81)*	3.88 (3.00)*	4.04 (9.62)*
T_4 - Kalihari Sole	44.95	40.50	42.73	2.65	3.23	2.94	13.38	13.83	13.61	5.93	7.08	6.50
T_5 – Kali musli Sole	17.26	14.05	15.66	4.30	4.98	4.64	5.25	4.55	4.90	2.18	3.13	2.66
T_6 – Safed musli Sole	25.53	27.90	26.71	7.40	8.13	7.77	6.23	7.28	6.75	4.93	4.00	4.47
S. Em ±	0.905	1.188	1.707	0.145	0.191	0.120	0.385	0.490	0.312	0.151	0.207	0.393
CD at 5 %	2.73	3.58	6.21	0.44	0.58	0.35	1.16	1.48	0.90	0.46	0.62	1.43

Note: Figure in parenthesis indicates percentage increase over respective sole cropping

Table 2: Survival and fresh and dry weight of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Survival percent			Fresh weight of tuber per plant (g)			Dry weight of tuber per plant (g)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T_1 - Kalihari Intercrop	51.43 (1.66)*	52.13 (2.25)*	51.78 (1.95)*	28.58 (4.99)*	29.75 (10.23)*	29.16 (7.75)*	9.17 (4.97)*	9.25 (7.50)*	9.21 (6.31)*
T_2 – Kali musli Intercrop	73.80 (1.38)*	75.10 (1.55)*	74.45 (1.46)*	5.79 (12.01)*	6.00 (10.85)*	5.90 (11.41)*	4.10 (17.17)*	4.24 (15.20)*	4.17 (16.10)*
T_3 – Safed musli Intercrop	71.35 (1.18)*	72.33 (2.59)*	71.84 (1.90)*	34.30 (5.09)*	35.49 (7.53)*	34.89 (6.36)*	14.48 (3.47)*	14.78 (4.52)*	14.63 (4.00)*
T_4 - Kalihari Sole	52.30	53.33	52.81	30.08	33.14	31.61	15.00	15.48	15.24
T_5 – Kali musli Sole	74.83	76.28	75.55	6.58	6.73	6.66	4.95	5.00	4.97
T_6 – Safed musli Sole	72.20	74.25	73.23	36.14	38.38	37.26	9.65	10.00	9.83
S. Em ±	2.647	2.337	1.765	1.152	0.984	0.757	0.412	0.543	0.341
CD at 5 %	7.98	7.04	5.10	3.47	2.97	2.19	1.24	1.64	0.98

Note: Figure in parenthesis indicates percentage increase over respective sole cropping

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