Indian Journal of Agricultural Sciences **82** (12): 1044–50, December 2012

Multi-tier cropping system to enhance resource utilization, profitablity and sustainablity of *Bt* cotton *(Gossypium hirsutum)* production system

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Received: 24 June 2011; Revised accepted: 20 July 2012

ABSTRACT

Intercropping of short duration vegetables with cotton, forming a multi-tier system may transform the cost intensive cotton production system to a more remunerative and sustainable one. Thus, to study the appropriate combination of vegetables as an intercrop(s) for multi-tier in cotton, an on station field trial was conducted during fall seasons (August to February) of 2005-06 and 2006-07 under irrigated condition at Central Institute for Cotton Research, Regional Station, Coimbatore. The treatment combinations comprised eight *Bt* cotton based multi-tier intercropping systems in additive series along with a sole Bt cotton tried in a randomised block design with three replications. Results revealed that crop growth attributes, yield traits and yield of cotton were not significantly influenced by different multi-tier cropping systems. Seed cotton yield in different intercropping systems ranged from 2.55 to 2.91 Mg/ha, whereas sole cotton yield was 2.62 Mg/ha. None of the cotton quality parameters showed any significant differences under multi-tier cropping system. Yet, highest gross return (₹ 150278/ha) , net return (₹ 99232/ha), per day profitablity (₹ 662/day) and seed cotton equivalent yield (7.37 tonnes/ha) were with multi-tier system of cotton + radish + cluster bean+ beet root (T2). This also showed highest relative production efficiency (RPE, 182%), relative economic efficiency (REE, 309 %) and land equivalent ratio (LER, 3.6) amongst the intercropping systems evaluated. Diversity index (DI), measuring the diversity, was also highest (3.8) with the above system (T2) indicating self-sustaining nature of the system.

Key words: Diversity index, Gross return, Light interception, Multi-tier systems, Net return, Seed cotton yield

Monocropping is exception, while mixture (of species) is the rule of nature. In multi-tier systems, the possibility of more efficient use of resources like sunlight, nutrients and water is leading to increased biological diversity and higher production stability. In addition, the root systems of the component crops are also located at distinct zones so as to explore the soil for moisture and nutrients. Intercrops were observed to serve as an insurance against the menace of pest and disease, vagaries of weather, market fluctuation and help to increase the net profit to growers (Raghu Rami Reddy and Shaik Mohammad 2009). Reviewing cropping system in South Asia, it was observed that intercropping is a well established practice covering over 12 m ha (Woodhead *et al*. 1994).

India is the second largest producer of vegetables in the world, although the productivity levels of vegetables have increased manifolds, it won't be sufficient to feed ever increasing population as a result of increased demands. This will complicate the issue of price rise further leading to increased costs of vegetables (Anon 2009). Since cotton is a crop of relatively longer duration, its slow initial growth offers a vast scope for cultivation of suitable intercrops (Gadade *et al*. 2006) including short duration vegetables.An ideal cotton based multi-tier vegetable intercropping should aim to produce higher economic return and yields per unit area, offer greater stability in production, meet the domestic needs of the farmer. The crops with diverse features (growth habit, root depth and duration) such as coriander, radish, beet root, cluster bean, vegetable cowpea, and dolichos were useful in making multi-tier system with Bt (*Bacillus thuriengensis* L.) cotton to enhance resource utilization, profitablity and sustainability of *Bt* cotton *(Gossypium hirsutum)* production system.

MATERIALS AND METHODS

A field trial was conducted during fall season (August to February) of 2005–06 and 2006–07 at Central Institute for

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Cotton Research, Regional Station, Coimbatore. The experimental soil was clay loam in texture, low in available N (220 kg/ha), medium in available P (15.2 kg P_2O_5/ha) and high in available K (843.2 kg K_2O/ha) with a pH of 8.5. The experiment was laid out in a randomized block design with three replications. The treatment combinations comprised eight *Bt* cotton based multi-tier vegetables intercropping systems and sole cotton (control for comparison) under irrigated condition. The intercropping system are as under: Cotton + radish + v. cowpea + beet root (T1), cotton + radish + cluster bean + beet root (T2), cotton + radish + dolichos + beet root (T3), cotton + coriander + v. cowpea + cluster bean (T4), cotton + coriander + dolichos + cluster bean (T5), cotton + beet root + v. cowpea + cluster bean (T6), cotton + cluster bean + v. cowpea+ dolichos (T7) and cotton + radish + beet root + coriander (T8). Cotton (*Gossypium hirsutum* L.) hybrid RCH 20 *Bt*, coriander (*Coriandrum sativum* L.) cultivar Surabhi, radish (*Raphanus sativus* L.) cultivar Pusa Chetki, beet root (*Beta vulgaris* L.*)* cultivar DDR, cluster bean (C*yamopsis teragonolaba* L.) cultivar Pusa Navbahar, dolichos (*Lablab purpureus var.typicus*) cultivar 'Flora' and vegetable cowpea (*Vigna unguiculata* L. Walp) cultivar CO2 were included in the trial. Recommended nutrient level of cotton, (90:45:45 kg N:P_2O_5:K_2O per hectare) was applied uniformly in all the treatments. In addition to that recommended NPK level (kg per hectare) for intercrops (viz. coriander (3.3:6.6:0), radish (3:12.5:6), beet root (15:40:25), cluster bean (9.3:18.5:9.3), dolichos (12.5:25:0) and vegetable cowpea (9.3:18.5:0) was also applied. The doses of fertiliser level to intercrops were arrived by adjusting the plant population of selected intercrop kept in a system with per hectare recommended nutrient level of the crop. The total N to the system was applied at two equal splits, first at the time of planting and second at 40 DAS (days after sowing), while entire P and K were applied as basal at the time of planting.

The field was ploughed once with tractor drawn mould board plough and then harrowed twice. Bt Hybrid RCH 20 was planted at 120 cm × 45 cm where two ridges at 60 cm apart were formed, and various intercrops (three crops) were planted on four sides of the two ridges in sequence (Fig 1). Radish, coriander and others vegetables (beet root, cluster bean, vegetable cowpea and dolichos) were planted at intra-row spacing of 10, 15 and 20 cm respectively. Crop received a total rainfall of 722.0 and 446.4 mm during 2005–06 and 2006–07 where effective rainfall were only 398.8 and 253.6 mm respectively (measured by the FAO method suggested by Brouwer and Heirloom 1986). In addition to effective rainfall, water need of the crop was supplemented by irrigation. No additional irrigation was provided for the intercropping systems (similar to sole cotton crop). Cotton hybrid seeds treated with imidacloprid were taken up for planting. Endosulfan (2 l/ha) was used to contain the menace of leaf eating caterpillar in radish at 21 and 23 DAS, neem oil (5%) had been sprayed to reduce the menace of aphids in

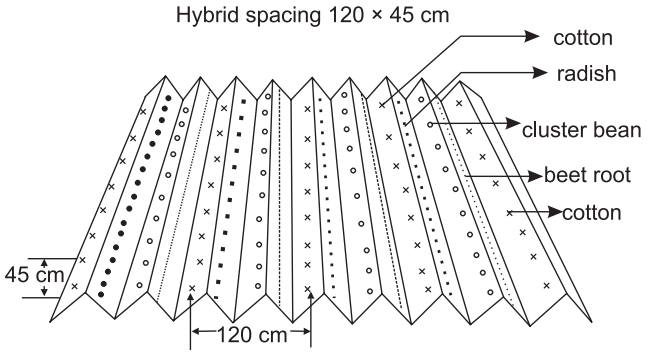

Fig 1 Method of planting in multi-tier cropping system in *Bt* cotton

vegetable cowpea and dolichos at 33 and 67 DAS, and metasystox (500 ml/ha) + endosulfan (2 l/ha) combination had been used for cotton for control of sucking pest and boll-worms at 80 and 100 DAS respectively for the year of 2005-06 and 2006-07. Growth characters, yield attributes, and yield of main crop (seed cotton) and intercrops were recorded during the course of investigation. Cotton equivalent yields were worked out by equating prices of component crops' yield as suggested by De *et al.* (1976).

Gross return, net return and benefit: cost analysis was also derived on the basis of prevailing market price of inputs and outputs.

Relative production efficiency (RPE) was calculated using the following formulae as under:

RPE = (EYD-EYE)*100/EYE, Where EYD is the equivalent yield under improved/diversified system, while EYE is the existing system yield. Relative Economic Efficiency (REE) is a comparative measure of economic gains over the existing system. It is expressed in percentage (REE = (DNR-ENR)*100 ENR^{-1}), where DNR is the net return obtained under improved/diversified system, while ENR is net return in the existing system. Pooled analysis was made from two years data to have a reliable assessment on multi-tier intercropping.

RESULTS AND DISCUSSION

Cotton

Seed cotton yield and quality parameters

The modification/changes of management practices might have specific impact on cotton growth and yield, which needs assessment. Analysis of pooled data on growth characters and seed cotton yield (Table 4) showed that could not be significantly influenced by multi-tier cropping systems. As a result seed cotton yield for different systems ranged from 2.55 to 2.91 Mg/ha and sole cotton yield of 2.62 Mg/ha was recorded. Since vegetable intercrops, viz. coriander within 30- 45 DAS, radish at 45 DAS, vegetable cowpea, cluster beans, beet root and dolichos within 75 DAS were harvested, none of the above crops competed with the main crop of

cotton during the growth and development. As a result, almost statistically similar growth characters and seed cotton yield was recorded in base crop cotton under different multi–tier/sole crop systems.

Pooled analysis also revealed that none of the above cotton quality parameters were influenced by intercropping system, since resilience genetic nature of the above parameters was not altered by these agronomic manipulation. Fibre quality being mostly genetically inherited, the response was not distinct (Bhuva *et al.* 1995). Similarly, Mohammad *et al.* (2001) noticed that fibre qualities indices such as ginning percentage (GOT), fibre length, fibre fineness, maturity co-efficient and fibre strength were not altered by intercropping.

Intercrops

Yield (Mg/ha) of vegetable intercrops (Table 1) varied amongst system for radish (4.86 to 6.66), vegetable cowpea (2.66 to 3.29), beet root (2.57 to 6.24), cluster bean (3.84 to 4.69), coriander (3.54 to 3.72) and dolichos (0.12 to 0.22). Pure crop yield (Mg/ha) of vegetables, radish, vegetable cowpea, beet root, cluster bean, coriander, and dolichos were 21.48, 4.79, 17.12, 7.59, 15.14 and 0.68 respectively. As a result, net return (×'000 ₹/ha) calculated from intercrops varied in radish (16.93 to 24.15), vegetable cowpea (10.63 to 15.26), beet root (12.23 to 34.04), cluster bean (17.81 to

Table 1 Growth characters, yield and economics of cotton and intercrops involved in multi-tier system

Multi-tier systems	Plant height at 45 DAS (cm)	Plant height at 70 DAS (cm)	Root length (cm) at 45 DAS	Root volume (cc) at 45 DAS	LA (cm^2) at 45 DAS	LA (cm^2) at 70 DAS	Yield (kg/ha)	Gross return (₹/ha)	CC (₹/ha)	Net return (₹/ha)	B/C ratio	SCEY (kg/ha)
T1.Cotton	35.3	72.6	21.6	10.3	1 463	18 954	2 735	55 915	28 876	27 039	1.9	27.4
Radish	27.6		28.6	330.2	1 575		4 858	21 863	4 935	16 927	4.4	10.7
V. cowpea	50.6	50.5	22.3	20.6	5 205	5 063	3 291	23 034	7 778	15 256	3	11.3
Beet root	30.3	48.3	15.6	70.3	1 342	5 250	4 666	29 162	4 572	24 590	6.4	14.3
T2.Cotton	45.1	77.7	19	10.6	1 421	17 856	2 545	51 980	28 680	23 301	1.8	25.5
Radish	20.3		23.6	160	1 147		6 660	29 969	5 823	24 146	5.1	14.7
Cluster bean	53.3	67.4	13.6	10.3	2 161	3 791	4 536	32 888	11 489	21 399	2.9	16.1
Beet root	35.3	50.1	17.6	75.3	809	4 578	5 671	35 442	5 055	30 386	7	17.4
T3.Cotton	52.1	71.6	24.6	14.3	1 651	18 246	2 685	54 825	28 902	25 924	1.9	26.9
Radish	25.3		36	300	1 058		5 857	26 355	5 158	21 197	5.1	12.9
Dolichos	42.3	65.7	22.6	10.3	5 170	4 573	162	2 100	4 166	-2 066	-0.5	1
Beet root	45.3	53.1	13.6	85.3	1 490	7 904	6 240	39 001	4 966	34 035	7.9	19.1
T4.Cotton	44.6	72.1	19.5	10.3	1 546	19 602	2 785	56 870	29 161	27 709	2	27.9
Coriander	26.3		15.3	16.5	3 296		3 628	23 580	3 684	19 896	6.4	11.6
V.cowpea	43.6	50.9	21	30.3	4 695	6 847	3 037	21 260	7 682	13 578	2.8	10.4
Cluster bean	26.3	77.9	20.3	10.3	2 695	2 670	4 165	30 198	10 655	19 543	2.8	14.8
T5.Cotton	36.3	73.9	19.6	13.5	1 377	19 658	2 830	57 695	29 647	28 048	1.9	28.3
Coriander	23.3		21.3	23.2	2 530		3 772	24 521	3 923	20 599	6.3	12
Dolichos	44.3	78.9	27.6	15.3	4 044	3 032	215	2 796	4 300	-1 504	-0.7	1.4
Cluster bean	38.6	75	19	10.3	1 364	1 958	4 580	33 203	11 462	21 741	2.9	16.3
T6.Cotton	40.3	77.2	25.3	10.6	1 475	20 102	2 910	59 390	29 413	29 977	2	29.1
Beet root	27.3	48.1	21	10.3	646	6 218	2 571	16 071	3 843	12 228	4.2	7.9
V. cowpea	44.3	50.7	18.3	15.6	5 048	3 417	2 662	18 637	8 010	10 627	2.3	9.1
Cluster bean	51.6	69.6	20.6	12.3	1 498	2 901	4 692	34 016	10 525	23 491	3.2	16.7
T7.Cotton	46.6	76.4	16.6	10.6	1 586	20 246	2 880	58 710	29 595	29 116	2	28.8
Cluster bean	54.3	78.2	21	10	2 265	4 535	3 844	27 869	10 058	17 811	2.8	13.7
V. cowpea	42.6	49.4	19.6	16.3	4 366	6 967	2 844	19 908	7 398	12 510	2.7	9.8
Dolichos	56.3	61.3	30.3	20	5 229	3 736	116	1 512	4 119	-2 607	-0.4	0.7
T8.Cotton	39.3	74.6	20.3	12.6	1 443	18 012	2 585	52 950	28 353	24 598	1.9	26
Radish	24.3		30.3	385	1 241		5 091	22 908	4 820	18 088	4.8	11.2
Beet root	26.6	44.8	13.3	50.3	1 214	4 908	5 347	33 421	4 857	28 564	6.9	16.4
Coriander	18.6		12.6	20	2 629		3 536	22 987	3 901	19 085	5.9	11.3
T9. Cotton	47.6	81.6	18.3	15.6	2 889	21 302	2 615	53 320	29 038	24 282	1.8	26.1

Price: Cotton (₹ 20.4/kg), radish (₹ 4.5/kg), v.cowpea (₹ 7.0/kg), beet root (₹ 6.25/kg), cluster bean (₹ 7.25/kg), coriander (₹ 6.5/kg) and dolichos (₹ 13/kg) (prevailing prices of experimental periods)

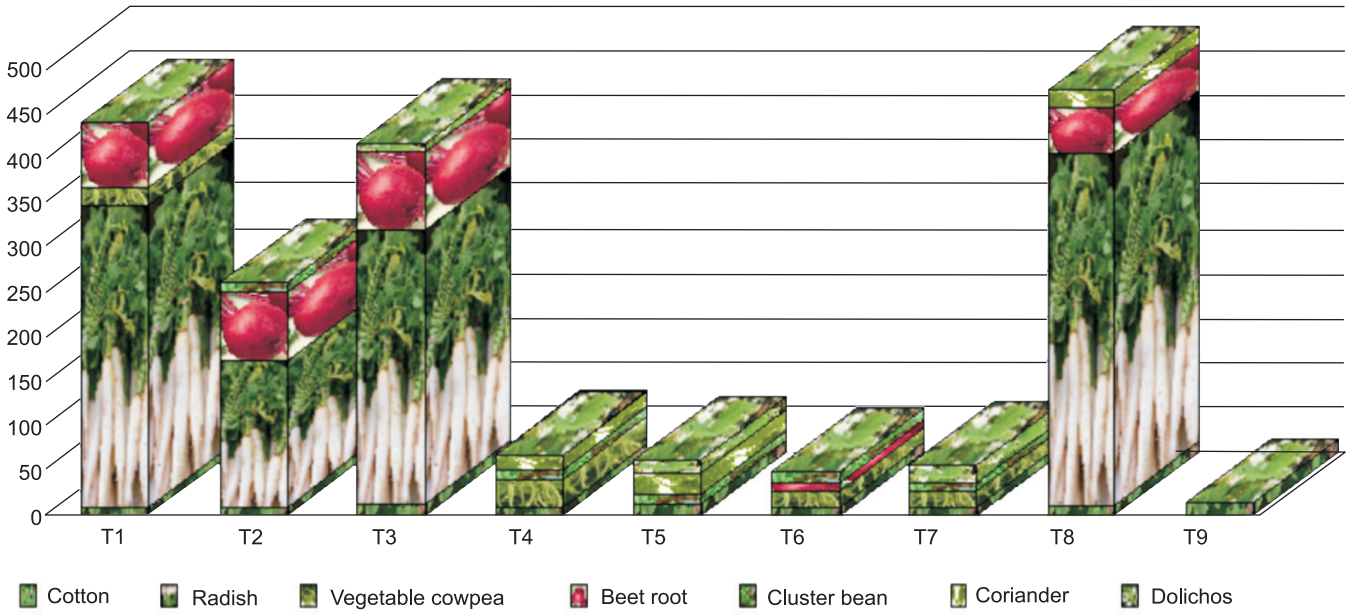

Fig 2 Root volume (cc) of multi-tier systems

23.49), coriander (19.09 to 20.60) and dolichos (–1.50 to –2.61). Since dolichos introduced as component in multi-tier system had higher vegetative growth but poor conversion of vegetative into economic produce led to net loss. While in others, the beneficial effects of intercrops were apparent. Thus, the advantage of multi-tier system was also reflected from the fact that failure of one intercrop was well compensated by other intercrops in the system by buffering effect.

Multi-tier (intercropping) system

The advantages of this are physically reflected from the differential growth characters. For example, mean plant height, root length and root volume (Fig 2) observed amongst the systems at 45 DAS were 24.4, 29.6 cm and 293.8 cc with radish, 45.3, 20.3 cm and 20.7 cc with vegetable cowpea, 33.6, 16.4 cm and 55.3 cc with beet root, 42.7, 20.2 cm and 10.7 cc with cluster bean, 46.4, 25.2 cm and 14.1 cc with dolichos, 22.7, 16.4 cm and 19.9 cc with coriander and 43.5, 20.1 cm and 12.4 cc with base crop cotton. These variations resulted in formation of a multi-tier (Table 1). LAI of the different system was also worked out at 45 DAS by including leaf area of base crop (cotton) and multi-tier forming intercrops (vegetables). It revealed that LAI was significantly influenced by the multi-tier systems as highest of LAI of 2.5 was with cotton + cluster bean + v.cowpea + dolichos (T_7) which in fact was five times than that in sole cotton (0.5). Pooled mean data on per cent photosynthetic active radiation (PAR) interception showed that highest value of 83.7 was measured with the system (T7) with the maximum LAI (2.5). Higher LAI recorded in different multi-tier systems also favoured higher interception of light.

Production efficiency

Multi-tier systems significantly enhanced relative production efficiency (RPE) (102.8 to 182.2%), relative economic efficiency (REE) (134.0 to 308.7), land equivalent ratio (LER) (1.8 to 2.5) and, diversity index (DI) (2.5 to 3.8). Amongst the multi-tier intercropping systems evaluated, cotton + radish + cluster bean + beet root (T_2) was having the highest RPE, REE and LER of 182.2%, 308.7% and 2.2 respectively (Table 2). Thus, the increased system efficiency was due to additional yield and return realised from intercrops. Raghu Rami Reddy and Shaik Mohammad (2009) reported that LERs were more than unity by intercropping in cotton.

Input use efficiency

Water

Being a costly and scarce resource, irrigation water and its availability for agriculture is expected to go down further due to increased domestic and industrial demands. Water-use efficiency (WUE, kg/ha/cm) and water productivity (WP, ₹/m^3) were influenced significantly by multi-tier cropping systems. The improvement in above parameters under multi-tier system ranged from 202.3 to 281.8 and 203.8 to 283.3 per cent higher over control. As a result, highest water use efficiency of 108.2 kg/ha/cm and water productivity of ₹ 22.1/m^3 of water used were calculated with cotton + radish + cluster bean + beet root (T2, Table 2). Sole cotton system produced only 38.4 kg by using of one hectare centimetre of water while gross return of ₹ 7.8/hectare was realized for m^3 of water (1 000 litres). Thus, most efficient cropping pattern is one, which is capable of giving maximum return per unit

Table 2 Biometric, effect on weeds, input use efficiency, production and economic efficiency of multi-tier systems

Multi-tier systems	LAI at 45 DAS	Weed dry weight (kg/ha)	WSE (%)	LI (%)	WUE (kg/ ha-cm)	WPY (₹/M3)	RPE (%)	REE (%)	Total fertiliser (kg/ha)
T1. Cotton + radish + v. cowpea+ beet root	1.8	439.2	42.8	67	93.6	19.1	144.1	245.2	309.3
T2. Cotton + radish + cluster bean+ beet root	1	552.1	28.1	68.7	108.2	22.1	182.2	308.7	318.6
T3. Cotton + radish + dolichos + beet root	1.7	635.1	17.3	68	88	18	129.7	225.7	319
T4. Cotton + coriander + v.cowpea + cluster bean	2.3	461.5	39.9	78.1	94.9	19.4	147.7	232.4	258.1
T5. Cotton + coriander + dolichos+ cluster bean	1.7	617.4	19.6	63.3	85.1	17.4	122	183.7	267.8
T6. Cotton + beetroot + v. cowpea+ cluster bean	1.6	393.9	48.7	69.8	92.2	18.8	140.6	214.3	324.9
T7. Cotton + cluster bean + v. cowpea + dolichos	2.5	284.1	63	83.7	77.7	15.9	102.8	134	282.4
T8. Cotton + radish + beetroot + coriander	1.2	508.3	33.8	63.7	95.2	19.4	148.4	272	294.7
T9. Sole cotton (120 cm × 45 cm)	0.5	767.9		34	38.4	7.8	0.1	0	180
SEd	0.1	103.5			6.7	1.4	8.4	20.8	
CD 5%	0.2	210.6			13.7	2.8	17.1	42.3	

LAI, Leaf area index; WSE, weed smothering efficiency; LI, light interception; WUE, water-use efficiency; RPE, relative production efficiency; REE, relative economic efficiency

quantity of water on a long term sustainable basis (Jain 2008).

Light

Unlike rainfall and nutrients, use of solar energy is limited to be captured and stored for latter use in the way that other natural resources are managed, as light is instantaneously available and needs to be instantaneously intercepted and used. In the current investigation, the highest percentage of light interception was observed at 45 DAS with multi-tier system of cotton intercropped with cluster bean, vegetable cowpea and dolichos (T_7, 83.7 %) (Table 2). High foliage producing capacity of vegetable cowpea, dolichos and coriander resulted in high light interception in the above systems. Since the least light interception (34.0) was observed with sole cotton, the efficiency was not much higher in sole cotton mainly because of slow ground coverage by cotton foliage.

Labour

Labour requirement of the multi-tier cropping ranged from 367 to 507 man days in comparison to sole cotton with 284 man days. Labour intensiveness associated with multi-tier systems was analysed and it was observed that labour use efficiency in term of gross return per labour was higher with systems. Amongst intercropping systems, the highest labour use efficiency of ₹ 310.5/labour (of 8 hours) was arrived at with cotton + radish + beet root + coriander (T_8) and sole cotton system had value of ₹ 184/ labour (Table 4).

Weed smothering efficiency

Cotton (especially hybrids) is a widely spaced crop in India and it takes at least 90 days to cover the land area. The interspaces between cotton rows are occupied by weeds and compete with crop. Shading the top soil and competition for water and nutrients will certainly suppress weed germination and growth (Altieri and Liebman 1986). In the current investigation also, cotton intercropped with cluster bean, vegetable cowpea and dolichos (T_7) registered the highest weed smothering efficiency of 63.0% (Table 2). High foliage producing capacity of vegetable cowpea, dolichos and coriander resulted in high light interception and suppressed underground weed growth. Greengram as intercrop in cotton had weed smothering efficiency of 71.9 per cent (Sivakumar and Subbian (2010).

Nutrient available and uptake

Multi-tier intercropping systems are highly intensive in nature and their impact on productivity of the soil needs to be assessed. In the present study, nutrient available in post harvest soil of different systems were varied significantly except for soil available P. Distinctive feature of most members of the fabaceae (pulses sub-family) is the capability to fix atmospheric N_2 biologically by prime modulators. It helped to estimate significantly higher available N (198.2 kg/ha) in a multi-tier system involved with cotton with three

Table 3 Available major nutrients status of post harvest soil and nutrient uptake of multi-tier systems

Multi-tier systems	Available nutrients (kg/ha)			Nutrient uptake (kg/ha)		
	N	P_2O_5	K_2O	N	P	K
T1. cotton +radish + v. cowpea+ beet root	191.4	23	779.9	221.7	39.7	222.4
T2. cotton +radish +cluster bean+ beet root	174.5	17.9	690.5	192.5	36.4	206.1
T3. cotton +radish +dolichos + beet root	180.5	17.6	760.3	169.9	28.4	161.7
T4. cotton +coriander +v. cowpea+ cluster bean	185	18.9	763.5	204.5	40.7	213.6
T5. cotton +coriander +dolichos+ cluster bean	182.8	21.4	859.8	151.5	31.3	155.6
T6. cotton +beetroot + v. cowpea+ cluster bean	187.5	16.6	763.5	220.7	42.6	228.5
T7. cotton +cluster bean + v. cowpea+ dolichos	198.2	21.9	815.6	195.6	39.3	203.4
T8. cotton +radish +beet root+ coriander	177.5	18.6	692	166.8	27.6	157.9
T9. sole cotton	187.1	17.5	788.4	102	19.2	82.8
SEd	7.4	2	24	10.6	4.7	10.7
CD (5%)	15	NS	49	21.6	9.6	21.7

Table 4 Economics and efficiency of land, labour time and diversity as influenced by multi-tier systems

Multi-tier systems	Seed Cotton yield (Mg/ha)	Gross Return (₹/ha)	Net return (₹/ha)	B/C ratio	SCEY (kg/ha)	Per day profitablity (₹/day)	Labour (man days/ ha)	LER	ATER	DI
T1. cotton +radish + v. cowpea+ beet root	2.74	129 973	83 812	2.8	63.7	559	405	2.2	1.6	3.4
T2. cotton +radish + cluster bean+ beet root	2.55	150 278	99 232	2.9	73.7	662	484	2.2	1.5	3.8
T3. cotton +radish + dolichos+ beet root	2.69	122 281	79 090	2.8	59.9	527	379	1.9	1.4	2.9
T4. cotton +coriander + v.cowpea+ cluster bean	2.79	131 908	80 726	2.6	64.7	538	471	2.5	1.7	3.4
T5. cotton +coriander + dolichos+ cluster bean	2.83	118 215	68 884	2.4	57.9	459	447	2.3	1.6	2.8
T6. cotton +beetroot + v. cowpea+ cluster bean	2.91	128 114	76 322	2.5	62.8	509	507	2.4	1.8	3.1
T7. cotton +cluster bean + v. cowpea+ dolichos	2.88	107 999	56 830	2.1	52.9	379	469	2.4	1.7	2.5
T8. cotton +radish + beetroot +coriander	2.59	132 266	90 334	3.2	64.8	602	367	1.8	1.3	3.5
T9. sole cotton (120 cm×45 cm)	2.62	53 320	24 282	1.8	26.1	162	284	1.0	1.0	1.0
SEd	0.2	7 630	7 200	0.1	3.5	48		0.2	0.2	0.2
CD 5%	NS	15 518	14 640	0.2	7.2	98		0.4	0.3	0.5

SCEY, Seed cotton equivalent yield; LER, land equivalent ratio; ATER, area time equivalent ratio; DI, diversity index

legumes (cluster bean, vegetable cowpea and dolichos, T_7, Table 3). Thus, growing of legumes, as an intercrop was beneficial to soil health and soil fertility (Sankaranarayanan *et al.* 2010). Significantly least soil available N (174.5 kg/ha) and K (690 kg/ha) were estimated with high productive system consisting of multi-tier one, viz. cotton + radish + cluster bean + beet root (T_2) which might be due to more uptake of nutrients, might have reduced soil availability.

NPK uptake of multi-tier system in the present trial ranged from 151.5 to 221.7, 27.6 to 42.6 and 155.6 to 228.5 kg per hectare for N, P and K respectively. Results revealed that cotton intercropped with beet root, v. cowpea and cluster bean (T_6) had significantly higher uptake of 220.7, 42.6 and 228.5 kg/ha in terms of N, P & K respectively whereas sole cotton removed only 102, 19.2 and 82.8 kg of the above nutrients respectively. Thus, the ability of intercropping system to make more efficient use than sole crops was evident both for soluble and non-soluble nutrients. Because of different root growth pattern of component species, intercropping explores the entire soil mass for nutrient uptake. Similarly, maximum N, P and K uptake were under intercropping system (Harisudan 2004 and Rao *et al*. 2009)

Economics

The multi-tier system significantly increased gross return, net return, BCR, per day profitability and seed cotton equivalent yield. This enhanced the gross return in the range of 202.5 to 281.8%, net return by 234 to 409%, BCR by 117 to 172%, and per day profitability by 234 to 409% and seed cotton equivalent yield by 202.6 to 282.3% in comparison to sole cotton. Total productivity of intercropping systems was significantly superior to yield equivalent of cotton (Raghu Rami Reddy and Shaik Mohammad (2009)).Sole crop of cotton with short duration vegetables significantly enhanced and net monetary returns (Venkataraman 2008). Highest gross return (₹ 150 278/ha) , net return (₹ 99 232/ha), per day profitablity (₹ 662/day) and seed cotton equivalent yield (7.31 Mg/ha) were obtained with multi-tier system of cotton + radish + cluster bean + beet root (T_2, Table 4). The system (T_2) was more efficient as it enhanced gross return, net return, BCR, per day profitablity and seed cotton equivalent yield @ 281.8, 408.7, 161.7 408.6 and 282.3% respectively in comparison to those in sole cotton. Intensification of crop on time and space dimension in the system (T_2) by selecting short duration, non-competitive crops and method of planting adopted could not suppress growth of the base crop and produce statistically as much as equal seed cotton yield (2.55 Mg/ha) as that of sole crop in addition to supplementing it by vegetable yield. These included production of 6.66 Mg/ha of radish, 4.54 Mg/ha of cluster bean and 5.67 Mg/ha of beet root, which favoured for higher economic return. Sole cotton registered the lower values of gross return (₹ 24 282/ha), BCR (1.8) and per day profitability (162) and seed cotton yield (2.61 Mg/ha). On the similar lines, cropping system did not influence seed cotton yield but additional yield of intercrops make system more remunerative over the sole cotton (Seema Sepat and Ahlawat 2010). Intercropping practice stabilizes the productivity, besides enhancing the total returns (Singh *et al*. 2009 and Singh and Ahlawat 2011).

The study suggested that higher yield and profit could be realized with the introduction of multi-tier cropping (cotton + radish + cluster bean + beet root) in a unique tier-arrangement in *Bt* cotton hybrids under irrigated condition.

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