The Andhra Agric. J 60(3):511-516, 2013

Performance of Andrographis (Kalmegh) in Tree Based Cropping Systems under Dryland Conditions

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ABSTRACT

The field experiment was conducted in the existing plantations at College of Agriculture, Rajendranagar, Hyderabad during *kharif* seasons of 2008 and 2009 in red sandy loam soils. The medicinal crop of andrographis was intercropped in the existing tree crops of amla and terminalia, respectively. The treatments consisted of three cropping systems as main plot treatments and six INM treatments as sub plot treatments. The treatments were laid out in split plot design and replicated thrice. The results revealed that growth parameters of andrographis *i.e.,* plant height, dry matter production and leaf area were found maximum in sole cropping of andrographis followed by intercropping in amla and terminalia. Days to 50% flowering and physiological maturity were delayed by 3-4 days under intercropping situation over sole cropping. Herbage yield (5396 and 5193 kg ha^{-1} in first and second year) of andrographis was significantly more with INM practice (20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1}).

Key words : Agri-horticulture, Andrographis, Intercropping.

With dwindling supplies from natural sources and increasing global demand, the Medicinal and Aromatic Plants (MAPs) are grown under forest cover because most of them are shade tolerant. *Andrographis paniculata* (Kalmegh) is such a medicinal plant which can be grown under shade, intercropped with tree species. It contains bitter principles – andrographolide, a bicyclic diterpenoid lactone and kalmeghin and are useful in liver disorders, malaria and blood purification. The fresh and dried leaves of Kalmegh and juice extracted from the herb are the official drugs of Indian Pharmacopoeia.

Application of chemical fertilizers may alter the desired chemical composition of medicinal plants and lead to accumulation of residue in the plant. Therefore, integrated nutrient management shall ensure sustainable productivity of medicinal plants and product quality. Keeping in view, the importance of agri-horticultural systems, studies on production potential of medicinal plants under integrated nutrient management practices in drylands was studied.

MATERIAL AND METHODS

The field experiment was carried out during *kharif* seasons of 2008 and 2009 at College of Agriculture, Rajendranagar, Hyderabad. The soil of the experimental site was red sandy loam in texture and belongs to soil order Alfisols. The experimental site of the plantation area (amla and terminalia) was characterized by semi arid climate with low organic carbon (0.42%), low available N (181 kg ha^{-1}), medium in available phosphorus (32 kg ha^{-1}) and available potassium (213 kg ha^{-1}).

The treatments comprised of three cropping systems (CS) [(i) Intercropping andrographis in amla based cropping system (C_1), (ii) Intercropping andrographis in terminalia based cropping system (C_2), (iii) Sole cropping of andrographis (C_3)] as main plots and six integrated nutrient management (INM) practices [(i) Control (M_1), (ii) 20 kg N ha^{-1} through urea (M_2), (iii) Vermicompost @ 2 t ha^{-1} (M_3), (iv) FYM @ 5 t ha^{-1} (M_4), (v) 20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1} (M_5) and (vi) 20 kg N ha^{-1} through urea + FYM @ 5t ha^{-1} (M_6)] as sub plot treatments. The treatments were laid out in split plot design replicated thrice.

The tree species namely amla (*Emblica officinalis*), variety – Narendra 7 and improved lines of local variety of terminalia (*Terminalia chebula*) were planted in the year 2004 at 3.6 x 3.6 m spacing. The tree planted area was divided into plots of 7.2 x 3.6 m consisting of two rows with 3 trees accommodating 12 rows of andrographis. The data was recorded on dry matter accumulation, leaf area and final herbage yield at different cuttings.

Table 1. Dry matter production (g m^{-2}) and leaf area $plant^{-1}$ (cm^2) of andrographis at first and second cut as influenced by different cropping systems and integrated nutrient management practices.

Treatment	Dry matter production (g m^{-2})				Leaf area $plant^{-1}$ (cm^2)			
	2008-09		2009-10		2008-09		2009-10	
	1st cut	2nd cut (final harvest)	1st cut	2nd cut (final harvest)	1st cut (105 DAS)	2nd cut (final harvest)	1st cut (105 DAS)	2nd cut (final harvest)
Cropping systems (CS)								
C_1-Andrographis intercropping in Amla	82.4	517.0	71.8	473.3	71.7	180.8	63.6	176.8
C_2 - Andrographis intercropping in Terminalia	68.7	472.1	61.2	449.8	64.7	173.2	57.2	167.3
C_3 - Sole cropping of Andrographis	94.2	559.0	82.8	531.5	73.2	187.4	69.4	183.0
SEm+	1.56	4.57	1.69	6.89	1.46	1.15	2.10	1.99
CD (P=0.05)	4.34	12.69	4.68	19.13	4.05	3.19	5.84	5.53
Integrated Nutrient Management (INM)								
M_1 - Control (no manuring)	62.9	488.4	57.7	453.9	60.2	158.6	47.2	157.8
M_2 - 20 kg N ha^{-1} through urea	69.5	497.1	59.1	464.6	65.4	168.0	53.0	164.6
M_3 - Vermicompost @ 2 t ha^{-1}	85.5	520.8	73.8	490.3	70.5	182.9	65.8	178.1
M_4 - FYM @ 5 t ha^{-1}	78.5	510.6	67.8	478.0	65.5	177.6	62.4	172.0
M_5 - 20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1}	98.9	544.4	89.7	518.5	80.7	201.6	78.7	194.4
M_6 - 20 kg N ha^{-1} through urea + FYM @ 5 t ha^{-1}	95.2	534.9	83.5	504.0	76.8	194.1	73.4	187.1
SEm±	4.52	6.28	4.36	4.88	2.38	3.06	2.49	3.38
CD (P=0.05)	9.22	12.83	8.91	9.97	4.85	6.24	5.09	6.91
(CS X INM) Interaction								
SEm±	7.82	10.89	7.56	8.46		5.29	4.31	5.86
CD (P=0.05)	NS	NS	NS	NS		NS	NS	NS

Leaf area $plant^{-1}$ (cm^2)	2008-09		1st cut (105 days)			
	M_1	M_2	M_3	M_4	M_5	M_6
CS X INM interaction						
C_1	58.0	61.5	74.9	69.2	85.4	80.9
C_2	50.9	58.0	68.3	62.4	75.9	72.8
C_3	71.8	76.7	68.2	64.9	80.8	76.6
CS X INM at Main						
SEm±	4.11					
CD (P=0.05)	8.40					
CS X INM at Sub						
SEm+	3.47					
CD (P=0.05)	7.42					

The andrographolide content of dried leaves and shoots was estimated at each harvest as per the procedure outlined by Srivastava *et al.* (1959) and expressed on dry weight basis in per cent. Andrographolide content was estimated at first cut (flower initiation) and harvest stage.

RESULTS AND DISCUSSION

Dry matter production

Maximum dry matter production was registered in sole cropping. The increase in dry matter due to C_3 (sole cropping of andrographis) over C_2 (intercropping andrographis in terminalia) in first year and second year at 105 DAS was 37.1 and 35.3 per cent, respectively.

There was profused regrowth of andrographis after first cutting and gave the highest dry matter yield at second cutting (final harvesting). The regrowth pattern in terms of dry matter production at different growth stages after first cut, indicated the significant superiority of sole cropping of andrographis over intercropped andrographis in C_1 (intercropping andrographis in amla) and C_2 (intercropping andrographis in terminalia). While comparing the two intercropping systems, the cropping system C_1 proved significantly superior to C_2 in terms of dry matter production. There was an increase of 18.4 and 18.2 per cent in dry matter due to C_3 over C_2 at final harvesting in first and second year, respectively (Table 1).

Dry matter production in sole cropping was maximum due to better availability of natural resources like light, water and nutrients compared to intercropped situation. Andrographis intercropped under amla gave higher dry matter production when compared to terminalia. But the decrease was to a lesser extent. Srinivas *et al.* (2008) reported similar results.

The highest dry matter yield of 98.9 and 89.7 g m^{-2} was recorded by M_5 (20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1}) during first cut of first year and second year, respectively. Similarly, M_5 was found with maximum dry matter of 544.4 and 518.5 g m^{-2} at the time of second cut *i.e.,* final harvesting in first and second year, respectively. INM treatment resulted in better plant growth and higher dry matter accumulation due to better availability of nutrients. Similar findings were reported by Saharan (2001).

Leaf area

Sole crop of andrographis recorded significantly higher leaf area per plant over the two intercropping situations *i.e.,* intercropping with amla and intercropping with terminalia at all the stages. Among the intercropping situations, C_1 (intercropping andrographis in amla) recorded significantly more leaf area per plant than C_2 at all the crop growth stages (Table 1).

The leaf area per plant was influenced by INM treatments *i.e.,* M_5 and M_6 when compared to individual manurial treatments of M_3 and M_4. Of the manurial treatments, M_5 (20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1}) recorded maximum per plant leaf area followed by M_6 as compared to the remaining manurial treatments. There was an increase of 34.0 and 66.9% in leaf area per plant due to M_5 over M_1 at first cut in first and second year, respectively. Similarly, M_5 in turn resulted in 27.1 and 23.2% increase in leaf area per plant over M_1 at second cut (final harvest) in first and second year, respectively. Increased plant height under M_5 treatment increased leaf area per plant due to enrichment of soil. Similar results were reported by Sanjutha *et al.* (2008).

Herbage yield

The sole cropping system of andrographis recorded the highest herbage yield at first cut (2515 and 2451 kg ha^{-1}) and second cut (2684 and 2592 kg ha^{-1}) in both the years of study and proved significantly superior to intercropping systems *i.e.,* C_1 and C_2 at second cutting but stood at par with C_1 at first cutting during first year. Sole cropping proved superior to both the intercropping systems at both the cuttings during second year. C_3 recorded an increased yield of 31.7 and 113.2 kg ha^{-1} at first and second cutting in first year over C_2, respectively. Similarly, in second year, C_3 resulted in herbage yield increase over C_2 to an extent of 18.3 and 55.7 kg ha^{-1} (Table 2).

Herbage yield of andrographis obtained from two cuts under sole cropping was higher over the other two cropping situations. This might be due to non intervention of the tree component in respect to availability of light, water and nutrients. Andrographis under amla recorded high herbage yield over terminalia due to maximum light interception resulting in better crop growth. These results are in confirmity with the findings of Kaushalendra Kumar Jha and Chandra Gupta (1991).

Among the two INM treatments, M_5 (20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1}) gave the highest and significantly more herbage yield over M_6 (20 kg N ha^{-1} through urea+ FYM @ 5 t ha^{-1}) at first and second cutting also in both the years. The yield advantage due to M_5 over M_1 and M_2 at first cutting was 366 and 277 kg ha^{-1} respectively

Table 2. Herbage yield (kg ha^{-1}) of andrographis on fresh weight basis and andrographolide (%) as influenced by different cropping systems and integrated nutrient management practices.

Treatment	Herbage yield (kg ha^{-1})				Andrographolide (%)			
	2008-09		2009-10		2008-09		2009-10	
	1st cut	2nd cut (final harvest)	1st cut	2nd cut (final harvest)	1st cut	2nd cut (final harvest)	1st cut	2nd cut (final harvest)
Cropping systems (CS)								
C_1-Andrographis intercropping in Amla	2485	2592	2416	2561	2.4	1.5	2.3	1.5
C_2 - Andrographis intercropping in Terminalia	2484	2571	2433	2536	2.2	1.4	2.1	1.3
C_3 - Sole cropping of Andrographis	2515	2684	2451	2592	2.5	1.8	2.3	1.7
SEm+	16.02	11.42	3.72	10.80	0.02	0.03	0.02	0.01
CD (P=0.05)	44.48	31.70	10.34	29.99	0.05	0.08	0.05	0.04
Integrated Nutrient Management (INM)								
M_1 - Control (no manuring)	2304	2502	2322	2464	2.2	1.4	2.1	1.3
M_2 - 20 kg N ha^{-1} through urea	2393	2562	2362	2522	2.2	1.4	2.1	1.4
M_3 - Vermicompost @ 2 t ha^{-1}	2515	2638	2457	2579	2.4	1.6	2.3	1.5
M_4 - FYM @ 5 t ha^{-1}	2492	2593	2422	2536	2.3	1.5	2.2	1.5
M_5 - 20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1}	2670	2726	2531	2662	2.5	1.8	2.4	1.7
M_6 - 20 kg N ha^{-1} through urea + FYM @ 5 t ha^{-1}	2594	2672	2505	2613	2.5	1.7	2.4	1.6
SEm±	14.59	12.09	12.59	11.12	0.03	0.03	0.03	0.02
CD (P=0.05)	29.80	24.68	25.71	22.71	0.05	0.05	0.05	0.04
(CS X INM) Interaction								
SEm±	25.28	20.94			0.05	0.05	0.05	0.05
CD (P=0.05)	NS	NS			NS	NS	NS	NS

Herbage yield (kg ha^{-1}) 2009-10	1st cut						2nd cut (Final Harvest)					
CS X INM interaction	M_1	M_2	M_3	M_4	M_5	M_6	M_1	M_2	M_3	M_4	M_5	M_6
C1	228	233	245	239	253	248	243	252	259	252	266	262
	7.8	3.2	7.2	4.8	0.4	9.8	3.0	4.9	0.1	7.1	2.1	6.7
C2	228	236	245	240	255	252	245	251	254	253	261	254
	9.7	8.2	7.1	5.6	4.8	1.2	4.1	4.7	9.9	4.0	2.8	9.1
C3	238	238	245	246	250	250	250	252	259	254	271	266
	8.4	4.1	7.7	5.3	6.4	4.8	4.9	5.1	7.3	7.3	1.4	2.9
CS X INM at Main												
SEm±			21.81						19.26			
CD (P=0.05)			44.53						39.34			
CS X INM at Sub												
SEm±			10.44						24.79			
CD (P=0.05)			21.58						55.61			

Table 3. Total gross and net monetary returns (Rs ha^{-1}) from the system (tree+crop) in andrographis as influenced by different integrated nutrient management practices and their combinations.

Treatment	2008-09			2009-10		
	Total Gross monetary returns (Rs ha^{-1})	Total Net monetary returns (Rs ha^{-1})	Profit per rupee investment	Total Gross monetary returns	Total Net monetary returns	Profit per rupee investment
Intercropping in amla						
M_1 - Control (no manuring)	70109	46609	1.98	66686	40836	1.58
M_2 - 20 kg N ha^{-1} through urea	74120	50220	2.10	68719	42444	1.62
M_3 - Vermicompost @ 2 t ha^{-1}	102669	74969	2.71	98087	68012	2.26
M_4 - FYM @ 5 t ha^{-1}	99703	71003	2.47	95733	64658	2.08
M_5 - 20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1}	108795	80695	2.87	101527	71027	2.33
M_6 - 20 kg N ha^{-1} through urea + FYM @ 5 t ha^{-1}	106988	77888	2.68	100384	68884	2.19
Mean	93731	66897	2.47	88523	59310	2.01
Intercropping in terminalia						
M_1 - Control (no manuring)	229863	206363	8.78	226766	200916	7.77
M_2 - 20 kg N ha^{-1} through urea	240596	216696	9.07	235382	209107	7.96
M_3 - Vermicompost @ 2 t ha^{-1}	371501	343801	12.41	365024	334949	11.14
M_4 - FYM @ 5 t ha^{-1}	369164	340464	11.86	362209	331134	10.66
M_5 - 20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1}	381075	352975	12.56	370965	340465	11.16
M_6 - 20 kg N ha^{-1} through urea + FYM @ 5 t ha^{-1}	377829	348729	11.98	367328	335828	10.66
Mean	328338	301505	11.11	321279	292066	9.89
Sole crop						
M_1 - Control (no manuring)	62187	42187	2.11	58720	36370	1.63
M_2 - 20 kg N ha^{-1} through urea	64157	43757	2.14	58911	36136	1.59
M_3 - Vermicompost @ 2 t ha^{-1}	67047	42847	1.77	60660	34085	1.28
M_4 - FYM @ 5 t ha^{-1}	66064	40864	1.62	60151	32576	1.18
M_5 - 20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1}	69556	44956	1.83	62614	35614	1.32
M_6 - 20 kg N ha^{-1} through urea + FYM @ 5 t ha^{-1}	68733	43133	1.68	62012	34012	1.21
Mean	66291	42957	**1.86**	60511	34799	1.37

and at second cutting it was 224 and 111 kg ha^{-1} during first year. Similarly, M_5 registered an yield advantage of 209 and 169 kg ha^{-1} over M_1 and M_2 at first cut, and 198 and 141 kg ha^{-1} during second cut in the second year, respectively.

The interaction effect between cropping systems and nutrient management practices revealed that under a given cropping system, the INM practices in particular M5 and M6, significantly increased the herbage yield at first cutting and second cutting. The INM practices behaved almost in similar pattern under the three cropping systems at first cutting but at second cutting, again the superiority of sole cropping under different INM practices was observed over C_1 and C_2. The results highlight the importance of INM practice irrespective of cropping systems.

Andrographolide content

Maximum andrographolide content was recorded by sole crop (2.47 and 2.34%) followed by intercropping system of C_1 (2.37 and 2.28%) and C_2 (2.19 and 2.12%) at first cutting in both the years (Table 2).

The effect of organic manurial application treatments *i.e.,* M_3 and M_4 was observed over control and also fertilizer N application alone treatment. Between M_3 (Vermicompost @ 2 t ha^{-1}) and M_4 (FYM @ 5 t ha^{-1}), M_3 was found significantly superior to M_4 in terms of andrographolide content increase in both the years. The efficiency of INM treatments *i.e.,* M_5 and M_6 in increasing the andrographolide content at first cutting and second cutting was noticed during both the years. Among the two INM treatments *i.e.,* M_5 and M_6, M_5 comprising of 20 kg N ha^{-1} through urea + Vermicompost @ 2 t ha^{-1} was the best treatment in registering the highest andrographolide content *i.e.,* 2.53 and 1.75 per cent at first and second cut, respectively in first year and 2.43 and 1.68 per cent at first and second cut, respectively in second year.

This could be attributed to immediate supply of nitrogen through urea application at initial crop growth and later by mineralization of nitrogen through organic manure resulting in a steady supply of nutrients during the later crop growth period (Kavitha and Swarajyalakshmi, 2002). These results are in accordance with the findings of Sanjutha *et al.* (2008).

Economics

The gross and net returns were the highest with terminalia + andrographis intercropping system. There was about three times more profit per rupee investment due to terminalia + andrographis over amla + andrographis cropping system. The monetary benefit due to different INM practices was not upto mark in case of terminalia + andrographis as compared with amla + andrographis system wherein the INM treatments resulted in the highest monetary benefit as compared to either control or rest of the treatments. Though in sole cropping, control (M_1) gave more profit per rupee investment, when andrographis was intercropped with amla and terminalia, M_5 treatment recorded maximum per rupee investment due to additional income from the fruit. So, the tree + crop system finally gave more profit per rupee investment in INM practices of M_5 treatment (Table 3).

These improved returns from the agri-horticultural systems were also reported by CRIDA (2001) and Sunanda Rani *et al.* (2006).

On the basis of total system based evaluation, cultivation of terminalia + andrographis intercropping system gave the highest monetary returns over amla + andrographis. The increase in profit per rupee investment could be attributed to adequate supply of nutrients with conjunctive use of organic and inorganic manures at balanced proportions coupled with better crop growth and higher yields. Similar results were reported by Bheemaiah *et al.* (1996).

It is concluded that terminalia based agri-horticultural system with andrographis as an intercrop proved to be economically viable and more profit oriented system because the main product of fruit trees is the market valued component.

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(Received on 12.03.2012 and revised on 26.04.2012)