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Optimization of yield, quality and nutrient uptake of chilli (*Capsicum annuum* L) through intercropping and integrated nutrient management practices

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Abstract
A study was carried out to assess the effect of intercrops and integrated nutrient management on yield, quality and nutrient uptake of chilli during 2015-16 at College of Horticulture, Venkataramannagudem. Impact of four intercrops *i.e* onion (M_1), coriander (M_2), fenugreek (M_3) and marigold (M_4) combined with five INM treatments *viz.*, 100% RDN through urea (S_0), 25% RDN through FYM + 75% RDN through urea (S_1), 25% RDN through vermicompost + 75% RDN through urea (S_2), 25% RDN through poultry manure + 75% RDN through urea (S_3) and 25% RDN through neem cake + 75% RDN through urea (S_4) on performance of the chilli was studied.. It was found that intercrops and INM treatments showed significant influence on yield, quality and nutrient uptake of chilli. Chilli intercropped with fenugreek (M_3) treatment recorded maximum values for yield, quality and nutrient uptake in chilli, whereas, chilli with marigold (M_4) treatment recorded the minimum values for all the parameters. INM treatments found superior over 100% RDN through inorganic fertilisers. Application of 25% RDN through neem cake + 75% RDN through urea (S_4) treatment recorded the highest values for all the parameters. Among the interactions, the chilli, intercropped with fenugreek and applied with 75% RDN through urea + 25% RDN through neem cake (M_3S_4) was found superior among all the treatments.

Keywords: Chilli, intercropping, INM treatments, yield, quality and nutrient uptake

Introduction
Chilli is a major commercial spice crop in the world. It is largely grown for its fruits in India. It is an essential ingredient in Indian cuisine. In curries, chilli is used as a paste, powder, broken split or whole form. In Indian pickles, chilli powder is added for thickening and for bright colour. Capsanthin, a pigment in chilli used for natural colouration to Jams, Jellies and squashes, since it is a natural pigment and no harmful or side effects on human health. There is lot of demand for chilli oleoresin in the world market. At present, India is the largest producer of chillies in the world followed by China, Pakistan and Mexico.

In India, Andhra Pradesh is the leading state in Chilli production followed by Karnataka, West Bengal and Odisha. At present, Andhra Pradesh accounts for 40 per cent of the total production of chillies in India. It is followed by Karnataka with 13-14 per cent, Maharashtra and Orissa with 8-9 per cent each and Rajasthan, Tamil Nadu and West Bengal with 5-6 per cent each. (http://www.ikisan.com).

Chilli crop in A.P is normally grown as mono crop following all modern agricultural practices. Judicious use of chemicals in chilli not only deteriorated soil health but turned it highly vulnerable to large extent of pest and diseases. Several sucking pests like mites and thrips cause significant yield loss. Further chilli market is very uncertain and fluctuating market prices cause severe economic loss to the farmers. Intercropping with suitable, synergistic crop improves the fertility and protects the top soil and gives additional income.

The integrated management of crops through suitable cropping system and organic nutrient sources has manifold advantages in improving the productivity, soil fertility and economic potential per unit area (Singh, 2014). The soil fertility is improved by addition of both organic manures and inorganic fertilizers and intercropping with legumes through integrated nutrient management system. The INM acknowledges the need for both organic and mineral inputs to sustain soil health and crop production due to positive interactions and complementarities between them. The INM (Integrated Nutrient Management) is economically cheap, technically sound, practically feasible and capable of maintaining the sustainability in crop production.

The traditional organic manures and vermicompost release the nutrients slowly, hence the effect is exhibited not only on the instant crop but also it remains for prolonged period and thus has great significance (Singh *et al.* 2016).

In view of these, the present investigation was taken up to find out suitable intercropping system and INM practices for chilli.

Material and Methods

The experiment was carried out at College of Horticulture, Venkataramannagudem, West Godavari District, Andhra Pradesh during late kharif 2015-16. Chilli variety LCA 655 was selected for the experiment, which is a pre released and dual purpose variety developed at Horticultural Research Station, Lam, Guntur. Chilli is planted at a spacing of 60 cm X 30 cm and intercrops were planted in between chilli rows. Onion seedlings were transplanted in two rows with spacing of 15×10 cm, coriander and fenugreek seeds are sown in three lines, and marigold seedlings were transplanted in one row at spacing of 20 × 20 cm in between two rows of chilli. Recommended dose of fertilizers for chilli is 300:60:120 Kg NPK ha^{-1} in Andhra Pradesh. 25% of RDN in the form of organic manures *viz.,* FYM, vermicompost, poultry manures and neem cake and 75% of RDN was applied in the form of urea in INM plots. Phosphorous in the form of SSP and potassium as Muriate of Potash were applied uniformly to all the plots as per the recommendation. Quantity of organic manure equivalent to 25% recommended N was calculated based on the nutrient analysis of manures done at Soil Science laboratory at College of Horticulture, VR Gudem. Recommended package of practices were followed during the cropping period. Data on vegetative growth parameters were collected at regular intervals. Five pickings were taken up for recording dry chilli yield. Quality parameters like capsanthin, capsaicin, oleoresin were estimated in dry chilli powder as per the standard procedures outlined by Roserbrook *et al.*, and NPK uptake values were estimated in plant samples as per the procedures given by Jackson (1973) [5], Black (1965) [1] and Williams and Twine (1960) [12] respectively and the results were discussed hereunder.

Results and Discussion

Effect of Intercrops and INM practices on dry chilli yield, quality and nutrient uptake

It was observed that, intercrops and INM treatments had shown significant influence on growth and dry yield of chilli.

Among the intercrops, chilli + fenugreek combination (M_3) recorded the maximum pooled values for dry chilli yield per plant (6.76 kg) and dry chilli yield per ha (52.1 q). However, the dry chilli yield per plant and yield per ha were on par with the yields obtained in chilli + onion (M_1), chilli + coriander treatments (M_2) respectively. The lowest values for all the above parameters were recorded in chilli plots planted with marigold intercrop (Table 1).

The study on quality parameters revealed that the parameters like number of discoloured fruits, capsanthin and capsaicin content of the chilli fruits were not significantly affected due to intercropping. However, the parameters like discoloured fruit weight, ascorbic acid and oleoresin content were significantly influenced by intercrops. Similarly nutrient uptake was also influenced by intercrops. Among the intercrops, chilli intercropped with onion (M_1) recorded significantly the lowest discoloured fruit weight (36.25 kg) and was found on par with chilli intercropped with fenugreek (M_3). The highest discoloured fruit weight was found in chilli intercropped with coriander (M_2) treatment (44.29 kg).

The highest oleoresin content (11.91%), highest N uptake (52.59 kg/ha) and K uptake (34.31 kg/ha) were recorded in chilli + fenugreek treatment (M_3). However, the maximum ascorbic acid content was recorded in green chilli + marigold (M_4) treatment. Similar results were obtained by Durgannavar *et al.* (2013) [3] in chilli + cotton cropping system with coriander as intercrop and Yamuna *et al.* (2017) [13] who observed that intercropping increased total N, P and K uptake enhancing grain and stover haulm yield of maize and intercrops when compared to sole cropping.

After perusal of the pooled data on dry yield, it was clear that all the INM treatments exhibited superiority over 100% RDN through urea (S_0). Maximum dry chilli yields per plot (6.75 kg), and dry chilli yield per ha (52 q) were recorded with chilli applied with 25% RDN through neem cake + 75% RDN through urea (S_4), whereas, the lowest values for all the parameters were recorded in chilli applied with 100% RDN through urea (S_0) (Table 1).

The study on quality parameters revealed that parameters like ascorbic acid, oleoresin, capsanthin and capsaicin content of the chilli fruit were significantly influenced by integrated nutrient management practices. Maximum values for ascorbic acid (125.25 mg), capsanthin (24073 EOA) were recorded in chilli applied with 25% RDN through neem cake + 75% RDN through urea (S_4), oleoresin (11.79%), capsaicin (0.298%) were observed in chilli applied with 25% RDN through FYM + 75% RDN through urea (S_1), whereas, the lowest values for ascorbic acid content (102.57 mg), oleoresin (10.22%) and capsaicin (0.210%) were recorded with the application of 100% RDN through urea (S_0) treatment.

Combination of organic manures and inorganic fertilizers, showed an advantage over the recommended practices in terms of dry chilli fruit quality. The highest capsaicin content was seen in INM treated plots compared to inorganic treatments alone, which is consistent with several other reports. Application of organic manures might have helped to improve physico-chemical properties of the soil, imparting favourable soil structure for root growth and soil enzymes (the latter continue to break down organic matter in the soil to release nutrients and make them available near the rhizosphere for absorption by plant roots, thereby improving fruit quality (Srinivasan *et al.,* 2014) [10]. The increase in content of capsaicin may be due to steady availability of nutrients by the combined application of organics and inorganics and hence, higher uptake of nutrients (Kondapa *et al.,* 2009) [6].

The highest N uptake (50.89 kg/ha) and the K uptake (34.74 kg/ha) were recorded with chilli applied with 25% RDN through neem cake + 75% RDN through urea (S_4). On the other hand, application of 25% RDN through FYM + 75% RDN from urea (S_1) recorded the lowest discoloured fruit weight (30.16 kg), which was found on par with application of 25% RDN through neem cake + 75% RDN through urea (S_4) (32.75 kg). Significantly the highest discoloured fruit weight was found with 100% RDN through urea (S_0) (53.51kg).

In the present study, the organics (FYM, vermicompost, neem cake, poultry manure etc.,) influenced the uptake of nutrients by the crop considerably. Tavaprakash and Velayudhan (2007) [11] also reported the same that, INM practices influenced nutrient uptake except 100% RDN through urea. There is a positive correlation between nutrient uptake and

yield. Generally when the uptake of Nitrogen is more, the crop would have a tendency to absorb more P and K. The built up of higher photosynthetic rate might have lead to better nutrient uptake by the crop.

The study revealed that interaction effect of intercrops and INM has significant influence on dry chilli yield, ascorbic acid content, discoloured fruit weight and nutrient uptake whereas, it has shown no influence on quality parameters like oleoresin, capsanthin and capsaicin. The treatment combination of chilli + fenugreek and application of 25% RDN through neem cake + 75% RDN through urea (M_3S_4) recorded maximum dry chilli yield per ha (61.9 q), N uptake (57.17 kg /ha) and K uptake (39.82 kg/ha), whereas, the lowest values for all the above parameters were recorded with the treatment combination of marigold irrespective of INM treatments. The combined application of organic and inorganic fertilizers in equal proportion to supply the recommended level of nitrogen not only increase the yield of crops but also enhance the nutrients availability in soil and their uptake by crops Chideshwari *et al*. (1997) [2].

Among all the treatment combinations, sole chilli + 25% RDN applied through neem cake + 75% RDN through urea (M_0S_4) recorded significantly the highest ascorbic acid content (131.72 mg/100g) in pooled data followed by chilli intercropped with onion + application of 25% RDN through neem cake + 75% RDN through urea (M_1S_4) (126.58 mg/100g) and chilli intercropped with coriander + application of 25% RDN through neem cake + 75% RDN through urea (M_2S_4) (126.00 mg/100g). Significantly the highest discoloured fruit weight (62.40 kg) was recorded with chilli + coriander and application of 25% RDN through poultry manure + 75% RDN through urea (M_2S_3). The lowest discoloured fruit weight was recorded with chilli + coriander and application of 25% RDN through FYM + 75% RDN through urea (M_2S_1) (25.52 kg). The increase in the quality attributes in INM plots compared to recommended dose of fertilizers could be due to enhanced growth promoting substances which accelerates the physiological process like synthesis of carbohydrates. Ascorbic acid content could be affected by soil condition, plant nutrition, cultivation practices, light intensity, maturity and treatment with growth regulators and insecticide (Gould, 1974) [4]. Mary and Balakrishnan (1990) [7] reported that high N uptake enhanced the enzyme activities for amino acid synthesis and increased ascorbic acid content in fruits.

Table 1: Effect of intercropping, integrated nutrient management practices and their interaction on yield, quality and nutrient uptake of chilli

Treatment Main plot	Dry chilli yield per plot *(kg)	Dry chilli yield per ha (qt)	Ascorbic acid** (mg/100g)	No. of discoloured fruits (%)	Discoloured fruits (kg/ha)	Oleoresin (%)	Oleoresin (kg/ha)	Capsanthin (EOA units)	Capsaicin (%)	N uptake (Kg/ha)	P uptake (Kg/ha)	K uptake (Kg/ha)
M_0	6.35	49.00	116.79	7.47	42.08	11.18	494.50	21252	0.246	49.80	8.24	31.76
M_1	6.42	49.50	110.41	7.30	36.25	11.31	506.62	22025	0.249	51.40	8.00	33.57
M_2	6.68	51.50	115.41	8.18	44.29	11.64	544.48	22782	0.251	52.37	7.81	33.29
M_3	6.76	52.10	98.96	7.64	40.30	11.91	558.91	21907	0.234	52.59	8.13	34.31
M_4	3.27	25.20	116.91	8.47	38.76	10.19	233.44	22653	0.240	38.27	7.49	28.38
S.Em.±	0.184	0.142	1.570	0.321	1.307	0.089	12.992	739.102	0.004	0.696	0.300	0.709
CD (P = 0.05)	0.609	0.470	5.201	NS	4.327	0.294	43.026	NS	NS	2.306	NS	2.349
Sub plot												
S_0	4.79	36.90	102.57	9.95	53.51	10.22	348.35	21128	0.210	45.00	7.97	27.73
S_1	6.29	48.50	105.89	7.06	30.16	11.77	517.37	21894	0.298	50.63	8.05	31.57
S_2	6.02	46.40	110.68	7.95	36.10	11.34	479.26	22204	0.237	48.48	7.52	33.40
S_3	5.65	43.50	114.08	7.87	49.16	11.11	448.07	21320	0.220	49.42	8.34	33.87
S_4	6.75	52.00	125.25	6.22	32.75	11.79	544.91	24073	0.255	50.89	7.78	34.74
S.Em.±	0.156	0.120	1.843	0.303	1.000	0.131	12.084	391.014	0.007	0.695	0.340	0.639
CD (P = 0.05)	0.449	0.345	5.287	0.869	2.869	0.375	34.666	1121.727	0.021	1.993	NS	1.832

M0: Sole chilli S0: 100% RDN through urea
M1: Chilli + Onion S1: 25% RDN through FYM + 75% RDN through urea
M2: Chilli + Coriander S2: 25% RDN through vermicompost+ 75% RDN through urea
M3: Chilli + Fenugreek S3: 25% RDN through poultry manure + 75% RDN through urea
M4: Chilli + Marigold S4: 25% RDN through neem cake + 75% RDN through urea
*Dry chilli yield is taken from five pickings.
** Ascorbic acid was estimated for green chilli. All other parameters were estimated for dry chilli.

Table 1.1: Effect of intercropping, integrated nutrient management practices and their interaction on chilli yield, quality and nutrient uptake of chilli

(MXS)	Dry chilli yield per plot (kg)*	Dry chilli yield per ha (qt)	Ascorbic acid (mg/100g)	No. of discoloured fruits (%)	Discoloured fruits (kg/ha)	Oleoresin (%)	Oleoresin (kg/ha)	Capsanthin (EOA units)	Capsaicin (%)	N uptake (Kg/ha)	P uptake (Kg/ha)	K uptake (Kg/ha)
M_0S_0	5.24	40.40	120.68	10.47	60.94	9.90	360.54	19642	0.212	44.57	8.21	29.20
M_0S_1	6.59	50.80	117.83	6.40	30.50	11.49	523.54	21553	0.310	54.65	8.13	32.39
M_0S_2	6.33	48.70	93.22	7.33	34.87	11.48	503.73	22468	0.244	54.02	7.41	34.32
M_0S_3	6.11	47.10	120.52	6.93	55.55	11.60	492.28	21655	0.218	50.81	8.98	32.83
M_0S_4	7.50	57.70	131.72	6.20	28.53	11.39	592.38	20943	0.245	54.52	8.45	36.45
M_1S_0	5.11	39.40	113.17	8.80	52.80	10.12	358.44	20740	0.219	38.25	9.08	24.13
M_1S_1	6.82	52.60	87.03	6.73	25.87	11.51	545.50	21553	0.296	52.96	9.05	30.97
M_1S_2	6.53	50.30	119.70	7.47	33.64	11.49	519.74	22468	0.212	49.42	7.74	34.84

M_1S_3	6.24	48.10	105.58	7.20	41.90	11.47	496.93	20445	0.259	52.96	7.25	31.33
M_1S_4	7.40	57.10	126.58	6.28	27.01	11.93	612.50	24919	0.260	53.83	6.87	35.00
M_2S_0	5.50	42.40	99.87	10.87	51.47	10.55	403.04	20618	0.203	56.27	7.47	37.78
M_2S_1	7.29	56.20	115.50	6.85	25.52	12.07	610.90	22143	0.310	50.98	7.25	34.70
M_2S_2	7.18	55.30	113.17	7.39	35.89	11.73	586.07	25010	0.246	52.53	7.69	31.02
M_2S_3	6.18	47.70	122.50	8.31	62.40	11.22	523.19	21960	0.201	52.89	9.38	36.76
M_2S_4	7.23	55.80	126.00	7.47	46.17	12.63	599.19	24176	0.296	54.59	7.23	33.00
M_3S_0	5.77	44.40	94.85	9.88	45.98	11.14	468.89	21848	0.201	44.82	7.99	28.82
M_3S_1	6.85	52.80	84.35	7.53	35.33	13.12	620.64	21960	0.257	53.90	7.82	38.85
M_3S_2	6.84	52.70	96.83	8.23	45.24	11.82	559.88	20537	0.268	50.77	7.78	30.05
M_3S_3	6.40	49.40	99.28	8.13	44.16	11.24	498.94	20384	0.200	50.84	8.70	32.39
M_3S_4	7.93	61.10	119.47	4.44	30.80	12.24	646.21	24807	0.243	57.17	8.36	39.82
M_4S_0	2.31	17.80	124.83	9.73	56.34	9.40	150.83	22794	0.218	46.50	7.10	25.50
M_4S_1	3.88	29.90	108.15	7.80	33.59	10.64	286.24	22265	0.316	39.09	7.99	29.96
M_4S_2	3.22	24.80	106.55	9.31	30.86	10.16	226.87	20537	0.215	35.67	6.95	30.39
M_4S_3	3.29	25.40	122.50	8.79	41.77	9.99	228.98	22153	0.221	34.17	7.39	27.54
M_4S_4	3.67	28.30	122.50	6.73	31.22	10.76	274.27	25518	0.234	35.88	7.99	28.49
Main with Sub												
S.Em.±	0.411	0.317	4.904	0.719	2.922	0.199	29.051	2375.957	0.010	1.557	0.671	1.586
CD (P = 0.05)	NS	NS	16.234	NS	6.711	NS	NS	NS	NS	4.596	NS	4.245
Sub with Main												
S.Em.±	0.363	0.279	5.401	0.686	2.389	0.276	27.435	1694.927	0.015	1.554	0.743	1.461
CD (P = 0.05)	NS	NS	15.889	NS	7.170	NS	NS	NS	NS	4.598	NS	4.343

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