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Dry matter production and nutrient removal in wet seeded rice–cotton cropping sequence under integrated nutrient management practices

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ABSTRACT

A field investigation was carried out, to study the effect of integrated nutrient management practices on dry matter production, nutrient uptake and yield of wet seeded rice and cotton under sequential cropping system, during summer seasons of 2001 and 2002. The study was undertaken at the Central Farm, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Killikulam. Eleven treatments were imposed in wet seeded rice viz., pre sowing of Sesbania aculeata @ 50 kg seeds ha^{-1}, in situ incorporation at 45 days after sowing+100 % recommended dose of fertilizer (RDF) (150:50:50 Kg NPKha^{-1}), pre sowing of Sesbania aculeata @ 75 kg seeds ha^{-1}, in situ incorporation at 45 DAS+75 % RDF (112.5: 37.5:37.5 Kg NPK ha^{-1}), intercropping of Sesbania aculeata @ 25 kg seeds ha^{-1} and incorporation at 40 DAS + 100 % RDF, intercropping of Sesbania aculeata @ 37.5 kg seeds ha^{-1} and incorporation at 40 DAS +75 % RDF, GLM (Glyricidia maculata) @ 6.25 t ha^{-1} +100 % RDF, GLM (Glyricidia maculata) @ 9.75 t ha^{-1} + 75 % RDF, FYM @ 12.5 t ha^{-1} + 100 % RDF, FYM @ 18.75 t ha^{-1} + 75 % RDF, 100 % RDF alone (150:50:50 Kg NPK ha^{-1}), 75 % RDF alone (112.5: 37.5:37.5 Kg NPK ha^{-1}) and control. Four nutrient management practices were adopted viz., 100 % RDF (60:30:30 kg NPK ha^{-1}), 75 % RDF (45:22.5:22.5 kg NPK ha^{-1}), 50 % RDF (30:15:15 kg NPK ha^{-1}) and control in succeeding cotton crop. Application of FYM @ 12.5 t ha^{-1} + 150:50:50 kg NPK ha^{-1}recorded significantly higher dry matter production (10.90 t ha^{-1}) and nutrient uptake (154.2:24.8:171.6 kg NPK ha^{-1}) at harvest stage, grain yield (5538 kg ha^{-1}) and straw yield (8693 kg ha^{-1}) than inorganic fertilizer alone and control and it was on par with pre sowing of Sesbania aculeata @ 50 kg seeds ha^{-1}, in situ incorporation at 45 DAS +100 % RDF (150:50:50 kg NPK ha^{-1}). In succeeding cotton also, application of FYM @ 12.5 t ha^{-1} + 150: 50: 50 kg NPK ha^{-1} to rice exerted more residual effect and significantly improved the dry matter production (3.93 t ha^{-1}) and nutrient removal (85.6:15.4:105.6 kg NPK ha^{-1}) at harvest stage, seed cotton yield (1.29 t ha^{-1}) and stalk yield (2.78 t ha^{-1}). Direct application of inorganic fertilizer to residual crop/ succeeding cotton at 100 % RDF (60:30:30 kg NPK ha^{-1}) also significantly enhanced the dry matter production (4.18 t ha^{-1}) and nutrient removal (101.0:17.6:114.5 kg NPK ha^{-1}) at harvest stage, seed cotton yield (1.40 t ha^{-1}) and stalk yield (2.87 t ha^{-1}) than application of 75 % RDF (45:22.5:22.5kg NPK ha^{-1}) and 50 % RDF (30:15:15 kg NPK ha^{-1}).

Key words: *rice, cropping sequence, wheat, INM*

Rice accounts for significant contribution to the total food grain production in India. As the rice production area either stabilizes or declines there is a wide gap between projected demand and current levels of production (Vijayakumar *et al.,* 2005). But rice, continues to hold the key component for sustainable food production in India. The demand for rice is projected at 128 MT by the year 2012 and will require yield level of 3.0 t ha^{-1} that is significantly greater than present average yield of 1.93 t ha^{-1} (Wanjari *et al.,* 2006). In productivity in India is 4.62 t ha^{-1} against world average productivity of 6.21 t ha^{-1}, however, the national economy continued to receive great support from the cotton industry by way of export of cotton fibre, yarn and textiles (Anonymous, 2006). Amongst the cotton growing countries, India stands first rank in area under cultivation (8.6 m ha), which is almost 25 % of the global cotton area, but production is only 9 % of the global production. This compares poorly with China and United States and their contribution to total cotton production is around 22 and 19 %, respectively (Mayee *et al.,* 2004). This low level of productivity is due to degraded land, low fertile soil, pest and diseases, low input use, faulty cropping system and a low adoption of improved technologies by the farmers. Thus the yield gap in India is in the range of 35 to 75 %. This yield gap indicates that the present production levels need to be increased without disturbing the delicate environment (Wanjari *et al.,* 2006). Adopting suitable cropping system, selecting high input responsive varieties with proper crop management strategies such as holistic approaches in nutrient, water, weed, pest diseases management are the possible way to achieve this target (Yadav *et al.,* 2002).

The scope to bring more area under arable cultivation is very negligible, because of booming industries and manufacturing sector create curtain in availability of land and labour and boost the degradation of water and other natural resources. Degradation of natural resources and competition for arable land limit the horizontal expansion of cultivable land (Samui *et al.*, 2004). Hence only alternate to increase the production is through vertical expansion by intensive agriculture on time and space dimension. Such intensification needs intensive research in fertilizer management for diversified crops under cropping system (Tang Huajun and Eric Van Ranst, 2005). Normally crops grown in definite crop sequence require differential rate of fertilizer and the releases and availability of major nutrients (NPK) are influenced by the preceding crops grown in sequential cropping (Jaiswal and Singh, 2001).

Rice during wet season and cotton during summer in the normal sequential cropping system is extensively adopted in Southern Tamil Nadu and Cauvery Deltaic region. Options of raising a short duration second crop of cotton after harvest of rice is feasible wherever supplemental irrigation facility available during summer season. (Jayaselwyn Inbaraj, 1995). Both these crops (rice-cotton) are exhaustive of soil fertility and had resulted in decline of soil organic matter and deteriorating soil health. For sustainability on the system as well as over all soil health, organic sources plays an important role (Mahavishnan *et al.,* 2005). Incorporation of farmyard manure and green manuring in combination with inorganic fertilizers improves the productivity of component crops in cropping sequence, ameliorates and sustain soil health and also economize fertilizer need (Mundra *et al.,* 2003; Sumanthy *et al.,* 1999). For this an understanding of the conjunctive use of organic manures with industrial fertilizers, which enhances nutrient use efficiency by better uptake of nutrients and produce higher economic yield of crops in the sequence is critical. Hence, to explore this, a field investigation was conducted in the sandy loam soils of South Tamil Nadu, where in the effect of integrated nutrient management practices in wet seeded rice and its residual effect on succeeding cotton were not evaluated.

MATERIALS AND METHODS

A field experiment was conducted during summer season of 2001 and 2002 at the wetlands of Central farm, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Killikulam, Tamil Nadu. The soil of the experimental field were moderately deep and sandy clay in texture, with slightly alkaline in reaction (pH 7.6) and the electrical conductivity of the soil was 0.45dSm^{-1}. The soil was medium status in organic carbon content (0.52 %) and the fertility status of available nitrogen was low (172 kg ha^{-1}), available phosphorus was high (24 kg ha^{-1}) and available potassium was medium (176 kg ha^{-1}). The experiment was executed in split - plot design with three replications. Integrated nutrient management practices to direct wet seeded rice and nutrient management practices to succeeding cotton were taken in the main plot and subplots, respectively.

Eleven treatments comprised of eight integrated nutrient management (INM) practices and two levels of inorganic NPK fertilizer, 100 and 75 % recommended dose of fertilizer (RDF) and absolute control were imposed in wet seeded rice. The treatments were:T_1-pre sowing of *Sesbania aculeata* @ 50 kg seeds ha^{-1}, *in situ* incorporation at 45 days after sowing (DAS) + 100 % RDF (150:50:50 Kg NPK ha^{-1}), T_2 - pre sowing of *Sesbania aculeata* @ 75 kg seeds ha^{-1}, *in situ* incorporation at 45 DAS + 75 % RDF(112.5:37.5:37.5 Kg NPK ha^{-1}), T_3 -intercropping of *Sesbania aculeata* @ 25 kg seeds ha^{-1} and incorporation at 40 DAS + 100 % RDF, T_4 - intercropping of *Sesbania aculeata* @ 37.5 kg seeds ha^{-1} and incorporation at40 DAS + 75 % RDF, T_5 – *Glyricidia* leaf manure (GLM) @ 6.25 t ha^{-1} + 100 %

RDF, T_6 - GLM (*Glyricidia*) @ 9.75t ha^{-1} + 75 % RDF, T_7 - FYM @ 12.5 t ha^{-1} + 100 % RDF, T_8 - FYM @ 18.75 t ha^{-1} + 75 % RDF, T_9 -100 % RDF alone, T_{10} - 75 % RDF alone and T_{11} - control (no manure) was adopted. The inorganic nitrogen, phosphorus and potassium fertilizer were applied in the form of urea (46 % N), single super phosphate (16 % P_2O_5) and muriate of potash (60 % K_2O), respectively. The entire dose of P was applied as basal and N and K were applied in three splits *viz*.50 %, 25 % and 25 % of recommended level of fertilizer at 20, 40 and 60 DAS respectively. The required amount of FYM, GLM was applied and trampled seven days before drum seeding of rice and for presowing *Sesbania* incorporation the required quantity of seeds were sown 52 days before rice sowing and was trampled seven days before drum seeding. In intercropping of *Sesbania* incorporation treatment, the *Sesbania* seeds were sown along with drum seeding and *in situ* incorporated at 40 DAS using cono weeder. The rice variety used for trial was ADT 43. The pre-conditioned seeds were sown in the puddled and levelled field using the drum seeder developed by TNAU with row spacing of 22.5 cm except green manure intercrop treatment. For green manure intercrop treatment, a drum seeder with 25 cm row spacing was used. Adequate care was taken to protect the crop from weeds, insect pest and disease. Irrespective of treatment, harvesting was done at 105 days after sowing. At harvest, grain and straw yields were recorded after sun drying.

For succeeding cotton, to accommodate four nutrient management practices every gross plot of preceding rice was split into required number of subplots as per treatment schedule. The treated seeds of cotton variety MCU - 5 was sown after the harvest of rice without any field preparation and seeds were hand dibbled at 60 x 30 cm spacing. The fertilizer dose of 100 % RDF (S_1 - 60:30:30 kg NPK ha^{-1}), 75 % RDF (S_2 - 45:22.5:22.5 kg NPK ha^{-1}), 50 % RDF (S_3- 30:15:15 kg NPK ha^{-1}) and absolute control (S_4- 00:00:00 kg NPK ha^{-1}) was adopted and required quantity of inorganic fertilizer applied in the form of urea (46 % N), single super phosphate (16 %P_2O_5) and muriate of potash (60 % K_2O). Fifty per cent of N and entire dose of P and K were applied on 25 DAS and covered by earthing up and remaining half dose N was top dressed at 45 DAS. Adequate and need based prophylactic measures was taken against weeds, insect pest and disease. Seed cotton from net plot area was picked early in the morning, shade dried, weighed at each picking and yields of all picking were added and expressed in t ha^{-1}. With reference to plant sampling, five hills of rice plants and five plants of cotton were uprooted at randomly in row from boarder rows beyond net plot area. The roots were separated and above ground portions were washed with clean water and shade dried for one day and then oven dried at 65 ± 5°C. The dry plant samples were processed for determination of NPK content at different growth stages. For both the crops in sequence (rice - cotton), nutrient uptake by the crop was computed from the data on dry matter production and corresponding nutrient content.

RESULTS AND DISCUSSION

Dry matter production of wet seeded rice under different integrated nutrient management practices revealed that, conjunctive use of organic manure with inorganic fertilizer at different levels significantly enhanced dry matter accumulation in rice than inorganic fertilizer application alone (Table 1). Among the INM practices, application of FYM @ 12.5 t ha^{-1} +100 % RDF registered higher dry matter production of 2.52, 6.30, 8.36 and 1.09 t ha^{-1} at tillering, panicle initiation, flowering and harvest stage, respectively. This was significantly higher by 33, 16, 13 and 10 per cent than 100 % RDF and 35, 33, 25 and 14 per cent than 75 % RDF at tillering, panicle initiation, flowering and harvest stage respectively. But comparable dry matter production (DMP) was noticed with other integrated nutrient management (INM) practices *viz*., pre sowing of *Sesbania aculeata* @ 50 kg seeds ha^{-1}, *in situ* incorporation at 45 DAS+100 % RDF , intercropping of *Sesbania aculeata* @ 25 kg seeds ha^{-1} and incorporation at 40 DAS + 100 % RDF , GLM @ 6.25 t ha^{-1}+100 % RDF . The lowest dry matter production of 1.06, 2.77, 5.16 and 6.90 t ha^{-1} was recorded in absolute control at tillering, panicle initiation, flowering and harvest stage respectively. These results are in line with those reports of Vanathi and Mohammed Amanullah (2007) they reported that the increase in dry matter production of rice to such higher levels under INM practices may be attributed to uninterrupted supply of available nutrient from the soil by cumulative nutrient supply from inorganic fertilizer and organic manure through mineralization and decomposition process. It

Table 1. Effect of integrated nutrient management practices on dry matter production and yield of wet seeded rice

Treatments	Dry matter production at different growth stages (t ha^{-1})				Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
	Tillering	Panicle initiation	Flowering	Harvest		
T_1	2.47	6.22	8.21	10.76	5.44	8.61
T_2	2.29	5.76	7.59	10.21	4.96	7.68
T_3	2.41	6.16	8.16	10.69	5.39	8.56
T_4	2.22	5.64	7.54	10.07	4.86	7.52
T_5	2.36	5.96	7.90	10.48	5.29	8.38
T_6	2.17	5.50	7.54	10.07	4.72	7.45
T_7	2.52	6.30	8.36	10.90	5.53	8.69
T_8	2.33	5.81	7.74	10.28	5.05	7.83
T_9	1.90	5.44	7.43	9.86	4.38	7.37
T_{10}	1.86	4.75	6.71	9.59	4.04	7.14
T_{11}	1.06	2.77	5.16	6.90	3.17	6.05
CD (P =0.05)	0.11	0.28	0.39	0.52	0.25	0.40

RDF – Recommended dose of fertilizer (150:50:50 Kg NPK ha^{-1}), GLM - *Glyricidia* leaf manure, DAS – Day after sowing
T_1- *Sesbania aculeata* @ 50 kg seeds ha^{-1}, incorporation at 45 DAS + 100 % RDF, T_2 - *Sesbania aculeata* @ 75 kg seeds ha^{-1}, incorporation at 45 DAS+75% RDF, T_3 - *Sesbania aculeata* @ 25 kg seeds ha^{-1} incorporation at 40 DAS+100 % RDF, T_4 - *Sesbania aculeata* @ 37.5 kg seeds ha^{-1} incorporation at40 DAS+75 % RDF, T_5 –*Glyricidia* leaf manure @ 6.25 t ha^{-1} + 100 % RDF, T_6 - GLM @ 9.75t ha^{-1} + 75 % RDF, T_7 - FYM @ 12.5 t ha^{-1} + 100 % RDF, T_8 - FYM @ 18.75 t ha^{-1} + 75 % RDF, T_9 -100 % RDF alone, T_{10} - 75 % RDF alone , T_{11} - control (no manure)

implying a stimulatory effect of organic manures application in conjunction with chemical fertilizer on dry matter production capacity of rice and conversely absolute control recorded the lower dry matter production.

Wet seeded rice grain yield and straw yield varied from 3.17 to 5.53 t ha^{-1} and from 6.05 to 8.69 t ha^{-1}, respectively by different integrated nutrient management practices (Table 1). The highest yield of grain (5.53 t ha^{-1}) and straw (8.69 t ha^{-1}) were recorded in the treatment receiving FYM @12.5 t ha^{-1}+100 % RDF, which was significantly higher than absolute control, 75 % RDF and 100 per cent RDF. However, grain and straw yield from the treatment *viz.*, pre sowing of *Sesbania aculeata* @ 50 kg seeds ha^{-1}, *in situ* incorporation at 45 DAS + 100 % RDF (T_1), intercropping of *Sesbania aculeata* @ 25 kg seeds ha^{-1} and incorporation at 40 DAS + 100 % RDF (T_3) and GLM @ 6.25 t ha^{-1} + 100 % RDF (T_5) recorded on par yield with application of FYM @12.5 t ha^{-1} + 100 % RDF (T_7). Better biological yield in wet seeded rice by conjunctive application of organic sources and inorganic fertilizer might be the result of maximum utilization of nutrients and other natural resources on account of higher availability of major nutrients, besides some micro nutrients in soil (Kabat *et al.*, 2006). Because, transformation and transport of nutrient from different sources of organic manure influences the nutrient availability to the crop plants as well as the potential for higher production (Singh *et al.,* 1997). Judicious use of organic and inorganic fertilizer enabled rice plant to assimilate sufficient photosynthates resulting in increased dry matter production and these together produced more productive tillers, panicle and number of filled grains leading to higher grain yield (Mondal *et al.*, 2003). Similarly, better vegetative growth *viz.*, plant height, dry matter production, total tillers, leaf number, and final plant stand resulted in higher straw yield under integrated nutrient management practices.

Integrated application of FYM @12.5 t ha^{-1} + 100 % RDF recorded 47.6, 97.8, 135.3 and 154.2 kg N uptake ha^{-1} at tillering, panicle initiation, flowering and harvest stage, respectively (Table 2). This was significantly higher than application of inorganic fertilizer alone at 100 and 75 % RDF and absolute control. However, INM practices through pre sowing of *Sesbania aculeata* @ 50 kg seeds ha^{-1}, *in situ* incorporation at 45 DAS+100 % RDF, intercropping of *Sesbania aculeata* @ 25 kg seeds ha^{-1} and

Table 2. Effect of integrated nutrient management practices on nutrient uptake of wet seeded rice

Treatments	N uptake (kg ha^{-1})				P uptake (kg ha^{-1})				K uptake (kg ha^{-1})			
	Tillering	Panicle initiation	Flowering	Harvest	Tillering	Panicle initiation	Flowering	Harvest	Tillering	Panicle initiation	Flowering	Harvest
T_1	47.3	97.0	134.2	153.0	5.8	12.1	17.0	24.4	47.0	95.9	148.3	170.2
T_2	44.2	89.9	124.4	143.0	5.1	11.1	15.9	22.4	44.7	88.8	138.6	154.4
T_3	46.5	97.0	134.2	151.7	5.7	12.0	17.0	24.4	46.7	95.1	147.1	168.7
T_4	43.5	89.1	123.3	142.9	5.1	11.0	15.9	22.4	44.3	88.0	137.4	153.3
T_5	46.1	93.1	128.7	148.0	5.6	11.8	16.9	24.2	45.9	93.5	143.5	167.3
T_6	43.9	88.3	122.2	141.7	5.1	10.8	15.8	22.2	43.9	87.1	137.2	153.0
T_7	47.6	97.8	135.3	154.2	5.8	12.2	17.3	24.8	47.4	95.9	149.5	171.6
T_8	44.6	90.7	125.5	144.2	5.2	11.2	16.2	22.6	45.1	89.6	138.69	155.9
T_9	42.7	87.6	121.1	140.5	5.0	10.7	15.2	22.1	42.7	86.5	132.5	151.6
T_{10}	37.0	77.3	106.9	129.2	4.4	9.7	13.8	20.7	38.0	74.7	114.3	135.9
T_{11}	27.2	56.0	77.5	90.3	3.8	8.4	11.6	17.8	28.6	55.8	87.5	98.7
CD(P = 0.05)	2.22	4.56	6.23	7.30	0.27	0.57	0.82	1.18	2.25	4.49	6.96	7.94

T_1- *Sesbania aculeata* @ 50 kg seeds ha^{-1}, incorporation at 45 DAS + 100 % RDF, T_2 - *Sesbania aculeata* @ 75 kg seeds ha^{-1},incorporation at 45 DAS+75% RDF, T_3 - *Sesbania aculeata* @ 25 kg seeds ha^{-1},incorporation at 40 DAS+100 % RDF, T_4 - *Sesbania aculeata* @ 37.5 kg seeds ha^{-1} incorporation at40 DAS+75 % RDF, T_5 –*Glyricidia* leaf manure @ 6.25 t ha^{-1} + 100 % RDF, T_6 - GLM @ 9.75t ha^{-1} + 75 % RDF T_7 - FYM @ 12.5 t ha^{-1} + 100 % RDF, T_8 - FYM @ 18.75 t ha^{-1} + 75 % RDF T_9 -100 % RDF alone, T_{10} - 75 % RDF alone , T_{11} - control (no manure) incorporation at 40 DAS + 100 % RDF and GLM @ 6.25 t ha^{-1} + 100 % RDF recorded on par N uptake with integrated application of FYM @12.5 t ha^{-1} + 100 % RDF (T_7). This results put up the usefulness of different sources of organic manure in rice cultivation and N uptake of rice as estimated by many authors (Kabat *et al.,* 2006; Singh *et al.,* 2006). They stated that uptake of nitrogen by rice increased significantly with conjunctive use of organic manures with synthetic fertilizers as organic manures restore humus status of the soil ecosystem to holds its fertility and productivity. Integrated use of urea and organic manures is helpful in maintaining higher concentration of soil NH_4^{+-} N for longer period and realizing higher N uptake of rice.

Phosphors uptake of wet seeded rice also influenced by different integrated nutrient management practices and it varied from 3.8 to 5.8 kg ha^{-1}, 8.4 to 12.2 kg ha^{-1}, 11.6 to 17.3 kg ha^{-1} and 17.8 to 24.8 kg ha^{-1} at tillering, panicle initiation, flowering and harvest stage, respectively. Among the INM practices, integrated application of FYM @12.5 t ha^{-1}+100 % RDF recorded higher P uptake of 5.8, 12.2, 17.3 and 24.8 kg ha^{-1} at tillering, panicle initiation, flowering and harvest stage, respectively and was significantly higher than inorganic fertilizer application either at 100 % RDF or 75 %RDF and at par with pre sowing of *Sesbania aculeata* @ 50 kg seeds ha^{-1}, *in situ* incorporation at 45 DAS + 100 % RDF intercropping of *Sesbania aculeata* @ 25 kg seeds ha^{-1} and incorporation at 40 DAS + 100 % RDF and GLM @ 6.25 t ha^{-1} + 100 % RDF. Enhanced P uptake with judicious application of organic manures and inorganic fertilizers might be due to a combination of factors that enhance P availability in soils. This includes production of organic acids through decomposition of organic matter and subsequent releases of phosphate ions, formation of phospho-humic complexes and isomorphic replacement of phosphate ions by humate ions. Such effects on soil P and plant uptake were reported by many workers previously by conjunctive use of organic sources of manure and inorganic fertilizers (Subbiah *et al.,* 2000).

Similarly higher K uptake of 47.4, 95.9, 149.5 and 171.6 kg ha^{-1} by wet seeded rice also observed in treatment receiving FYM @12.5 t ha^{-1}+100 % RDF at tillering, panicle initiation, flowering and harvest stage respectively. This was significantly higher than inorganic fertilizer application at either 100 % RDF or 75 % RDF and control. Due to priming effect of organic manure / green manure on the decomposition related release of organic acids that solubilize native K (Bagavathi Ammal and Durairaj Muthiah, 1995). In addition, higher magnitude of increases in K uptake by conjunctive use of organic manures and inorganic fertilizers showed that, organic manures presumably play key role in enhancing the use efficiency of applied fertilizer as well as inherent nutrient availability in the soil (Singh *et al.,* 2001).

Integrated application of organic manure and inorganic fertilizer to preceding rice and application of chemical fertilizer to succeeding cotton significantly influenced DMP of cotton (Table 3). Among the INM adopted to preceding rice, application of FYM @ 12.5 t ha^{-1}+100 % RDF significantly registered higher DMP of 0.217, 1.27, 3.74 and 3.93 kg ha^{-1} at squaring, flowering, boll formation and harvest stage, respectively than inorganic fertilizer at 100% RDF or 75% RDF. But this was at par with pre sowing of *Sesbania aculeata* @ 50 kg seeds ha^{-1}, *in situ* incorporation at 45 DAS + 100 % RDF, intercropping of *Sesbania aculeata* @ 25 kg seeds ha^{-1} and incorporation at 40 DAS+100 % RDFat all the stages. The increase in DMP due to INM practices ascribed to increased growth and growth attributes of succeeding cotton, number of monopodial branches, chlorophyll formation, which ultimately improved photosynthesis area and their products. These results are in conformity with the findings of earlier study made by Mahavishnan *et al.* (2005). Favourable effects of conjunctive application of organic manures (FYM/green manure /GLM) and inorganic fertilizer could be attributed to better soil health, better residual nutrient availability, better nutrient uptake and there by better cotton growth and development.

Among the levels of inorganic fertilizer application to succeeding cotton, 100 % of RDF (S_1- 60:30:30 kg NPK ha^{-1}) recorded the dry matter production (DMP) of 2.2, 1.34, 3.96 and 4.18 t ha^{-1} at squaring, flowering, boll formation and harvest stage respectively this was significantly higher than application of 75 % RDF (S_2) and 50 % RDF (S_3). Higher plant height, physiological growth attributes and monopodial branches plant^{-1} with higher levels of inorganic fertilizer might have contributed to higher DMP. These results are in conformity with the finding

Table 3. Influence of residual effect of INM practices and direct effect of inorganic fertilizer on dry matter production and yield of succeeding cotton crop

Treatments	Dry matter production (t ha^{-1})				Seed cotton yield (t ha^{-1})	Stalk yield (t ha^{-1})
	Squaring	Flowering	Boll formation	Harvest		
Residual effect of INM practices						
T_1	0.21	1.27	3.71	3.91	1.28	2.77
T_2	0.19	1.14	3.34	3.54	1.12	2.53
T_3	0.21	1.26	3.70	3.90	1.28	2.75
T_4	0.19	1.13	3.32	3.52	1.12	2.51
T_5	0.18	1.25	3.67	3.87	1.27	2.74
T_6	0.19	1.12	3.29	3.51	1.11	2.50
T_7	0.21	1.27	3.74	3.93	1.29	2.78
T_8	0.19	1.15	3.36	3.56	1.13	2.53
T_9	0.19	1.11	3.23	3.41	1.10	2.48
T_{10}	0.17	1.02	2.94	3.10	1.07	2.44
T_{11}	0.14	0.84	2.35	2.50	0.77	1.89
CD(P = 0.05)	0.03	0.18	0.55	0.58	0.19	0.41
Direct effect of inorganic fertilizer on nutrient uptake of succeeding cotton crop						
S_1	0.22	1.34	3.96	4.18	1.40	2.87
S_2	0.21	1.27	3.67	3.90	1.29	2.78
S_3	0.20	1.19	3.48	3.70	1.21	2.68
S_4	0.13	0.78	2.21	2.32	0.66	1.82
CD(P = 0.05)	0.03	0.17	0.49	0.52	0.17	0.37

T_1- *Sesbania aculeata* @ 50 kg seeds ha^{-1}, incorporation at 45 DAS + 100 % RDF, T_2 - *Sesbania aculeata* @ 75 kg seeds ha^{-1} orporation at 45 DAS+75% RDF, T_3 - *Sesbania aculeata* @ 25 kg seeds ha^{-1} incorporation at 40 DAS+100 % RDF, T_4 - *Sesbania aculeata* @ 37.5 kg seeds ha^{-1} incorporation at40 DAS+75 % RDF, T_5 –*Glyricidia* leaf manure @ 6.25 t ha^{-1} + 100 % RDF, T_6 - GLM @ 9.75t ha^{-1} + 75 % RDF, T_7 - FYM @ 12.5 t ha^{-1} + 100 % RDF, T_8 - FYM @ 18.75 t ha^{-1} + 75 % RDF T_9 -100 % RDF alone, T_{10} - 75 % RDF alone , T_{11} - control (no manure)

S_1 - 100 % RDF (60:30:30 kg NPK ha^{-1}), S2 - 75 % RDF (45:22.5:22.5 kg NPK ha^{-1}), S_3 - 50 % RDF (30:15:15 kg NPK ha^{-1}), S_4 - control (00:00:00 kg NPK ha^{-1})

of earlier studies (Krishnan and Christopher Lourduraj, 1997). The lower DMP of succeeding cotton were recorded in control, because of lower availability of nutrients attributed to weak plant growth and lower number of branches $plant^{-1}$ and consequently lower yield attributes.

Significant variation in seed cotton yield and stalk yield was observed due to integrated application of organic manure and inorganic fertilizer to preceding rice in rice-cotton sequential cropping system (Table 3). A perusal data revealed that, the residual effect of INM practices to rice was manifested very clearly in succeeding seed cotton yield and stalk yield. Application of FYM @ 12.5 t ha^{-1}+100 % RDF, registered seed cotton yield of 1.29 t ha^{-1} and stalk yield of 2.78 t ha^{-1} this was significantly higher than 100 % RDF, 75 % RDF and control. However, this was at par with pre sowing of *Sesbania aculeata* @ 50 kg seeds ha^{-1}, *in situ* incorporation at 45 DAS+100 % RDF, intercropping of *Sesbania aculeata* @ 25 kg seeds ha^{-1} and incorporation at 40 DAS+100 % RDF. Whenever, shallow rooted crop (rice) rotated with deep rooted crop (cotton), it will help to minimizing the downward movement of nutrients in the soil profile and maximize the nutrient availability and thus improve the nutrient uptake. The highest seed cotton yield and stalk yield of cotton may be probably due to higher availability of residual nutrients, because conjunctive use of organic manures and synthetic fertilizers at higher levels precluded availability of major nutrients up to the harvest stage and enhanced the their uptake leading to

Table 4. Residual effect of INM practices and direct effect of fertilizer on nutrient uptake of succeeding cotton crop

Treatments	N uptake (kg ha^{-1})				P uptake (kg ha^{-1})				K uptake (kg ha^{-1})			
	Squaring	Flowering	Boll formation	Harvest	Squaring	Flowering	Boll formation	Harvest	Squaring	Flowering	Boll formation	Harvest
Residual effect of INM practices												
T_1	4.4	47.3	89.2	92.4	0.7	6.4	9.2	15.9	7.4	46.4	98.3	104.7
T_2	4.1	43.4	81.9	85.1	0.6	5.8	8.7	15.3	7.1	43.8	93.4	98.2
T_3	4.4	46.8	88.8	90.9	0.7	6.3	9.1	15.8	7.3	46.0	97.9	103.8
T_4	4..0	43.1	81.3	84.5	0.6	5.8	8.6	15.1	7.0	43.2	92.5	97.5
T_5	4.3	46.7	87.8	89.9	0.7	6.3	9.1	15.7	7.3	45.8	97.2	103.1
T_6	3.9	42.9	80.4	83.4	0.6	5.7	8.5	15.0	7.0	42.9	91.9	96.9
T_7	4.4	47.6	89.9	93.1	0.7	6.4	9.3	16.2	7.4	46.7	99.6	105.6
T_8	4.1	43.6	82.2	85.6	0.7	5.9	8.8	15.4	7.1	43.9	94.4	99.1
T_9	3.9	41.7	78.6	80.9	0.6	5.6	7.8	14.1	6.3	41.0	87.4	91.3
T_{10}	3.7	40.3	77.7	78.6	0.6	5.4	7.6	13.6	6.1	39.3	83.5	86.2
T_{11}	2.8	32.7	56.9	61.9	0.5	4.3	5.7	10.3	4.9	31.3	64.1	66.7
CD(P=0.05)	0.07	0.71	1.35	1.08	0.011	0.10	0.14	0.24	0.10	0.70	1.51	1.60
Direct effect of inorganic fertilizer												
S_1	4.8	50.4	96.9	101.0	0.8	6.8	9.9	17.6	6.8	50.3	107.7	114.5
S_2	4.4	47.6	89.9	92.6	0.7	6.4	9.4	16.2	6.4	47.0	100.4	105.9
S_3	4.1	45.2	85.5	88.9	0.7	6.2	8.9	15.5	6.1	44.8	96.0	100.5
S_4	2.9	29.2	53.0	54.5	0.5	4.0	5.4	9.8	4.0	28.9	59.7	61.9
CD(P=0.05)	0.06	0.64	1.35	1.03	0.011	0.10	0.12	0.22	0.09	0.63	1.34	1.42

T_1- *Sesbania aculeata* @ 50 kg seeds ha^{-1}, incorporation at 45 DAS + 100 % RDF, T_2 - *Sesbania aculeata* @ 75 kg seeds ha^{-1},incorporation at 45 DAS+75% RDF
T_3 - *Sesbania aculeata* @ 25 kg seeds ha^{-1}.incorporation at 40 DAS+100 % RDF, T_4 - *Sesbania aculeata* @ 37.5 kg seeds ha^{-1} incorporation at40 DAS+75 % RDF
T_5 –*Glyricidia* leaf manure @ 6.25 t ha^{-1} + 100 % RDF, T_6 - GLM @ 9.75t ha^{-1} + 75 % RDF T_7 - FYM @ 12.5 t ha^{-1} + 100 % RDF, T_8 - FYM @ 18.75 t ha^{-1} + 75 % RDF
T_9 -100 % RDF alone, T_{10} - 75 % RDF alone , T_{11} - control (no manure)

higher DMP and higher biological yields (Ramachandra *et al.,* 2007; Mahavishnan *et al.,* 2006).

The direct effect of inorganic fertilizer application to succeeding cotton was more pronounced in seed cotton yield and stalk yield. Among the levels of inorganic fertilizer application, 100% RDF (S_1- 60:30:30 kg NPK ha^{-1}) recorded higher seed cotton yield and stalk yield of 1.40 and 1.82 t ha^{-1}, respectively. This was significantly higher than application of 75 % RDF (S_2), 50 % RDF (S_3) and control (S_4), respectively. The lower levels of biological yield were recorded in control, which recorded the stalk yield of 665 kg ha^{-1} and stalk yield of 1827 kg ha^{-1}. The results are in conformity with the research findings reported by Blaise and Singh (2004) and Tomar *et al.* (2000). The increase in biological yield by application of higher levels of fertilizer application might be owing to increased nutrient availability throughout cropping period and very particularly at critical stages, it leads to higher plant height, leaf area index, monopodial branch and dry matter production that could be ascribed to higher yield attributes and photosynthetic activity. This might have resulted in better translocation and partitioning of assimilates towards biological yield attributes.

Nutrient (N, P and K) uptake of succeeding cotton was also enhanced by adopting different INM practices to first crop (rice) and application of inorganic fertilizer to second crop (cotton) in rice-cotton cropping sequence. With reference to residual effect of INM practices, control plots recorded lower nutrient uptake of 61.9:10.3:66.7 kg NPK ha^{-1} at harvest, this was significantly lower than 100% RDF and 75% RDF, which recorded nutrient uptake of 80.9:14.1:91.3 kg NPK ha^{-1} and 78.6:13.6:86.2 kg NPK ha^{-1}, respectively. Among the INM practices, application of FYM @ 12.5 t ha^{-1}+100 % RDF, pre sowing of *Sesbania aculeata* @ 50 kg seeds ha^{-1}, *in situ* incorporation at 45 DAS+100 % RDF recorded on par residual effect on nutrient removal of succeeding cotton and accounted 93.1:16.2:104.7 kg NPK ha^{-1} and 92.4:15.9:104.7 kg NPK ha^{-1} respectively. Both these treatments were superior by significantly than inorganic fertilizer application alone and control. The marked improvement in nutrient uptake by residual effect of INM practices was also reported by many earlier studies (Mahavishnan *et al.,* 2005; Vaiyapuri *et al.,* 1998). Increases in nutrient uptake by residual effect of conjunctive application of FYM and synthetic fertilizer may be ascribed to similar increased in growth attributes such as plant height, number of branches plant^{-1}, crop growth rate, leaf area index etc., with concomitant increase in dry matter production and nutrient content (Jayaselwyn Inbaraj, 1995). Besides, primary nutrients (N, P and K) supply, organic manures also supply some secondary nutrients, micronutrients and growth promoting substances, which might have helped in better crop growth and thereby higher biological yield.

Uptake of nutrients (NPK) by succeeding cotton was also influenced by direct application of different levels of inorganic fertilizer. Among the levels, 100% RDF (S_1) registered significantly higher nutrient uptake than 75% RDF (S_2), 50%RDF (S_3) and absolute control (S_4) at all the stages. At harvest stage it recorded 101.0:17.6:114.5 kg NPK ha^{-1} followed by application of 75 % RDF (92.6:16.2:105.9 kg NPK ha^{-1}) and the lowest nutrient uptake was recorded in absolute control (54.5:9.8:61.9 kg NPK ha^{-1}). This result is in corroboration with the reports of Katkar *et al.* (2002) and Singh *et al.* (1999). This improvement in nutrient uptake with increased supply of nutrients might be due to profuse plant growth, growth attributes and nutrient content leading to increase in DMP which in turn had positive effect on nutrient uptake than control. Optimum plant population with adequate supply of nutrients provided better crop ecology for better crop growth and development and higher biological yield and consequently greater removal of nutrients from the soil. From this experiment it was concluded that, integrated application of organic manures (FYM @ 12.5 t ha^{-1}/ *Sesbania aculeata* @ 50 kg seeds ha^{-1}, *in situ* incorporation at 45 DAS) + inorganic fertilizer (100 % RDF-150: 50:50kg NPK ha^{-1}) to wet seeded rice and application of 100 % RDF (60:30:30 kg NPK ha^{-1}) to succeeding cotton under irrigated condition in rice - cotton cropping sequence recorded higher dry matter production, biological yield, optimum nutrient removal on sustainable basis. Hence, this nutrient management method is ecologically viable method for good soil health, maintaining required levels of soil fertility and productivity.

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