Brown manuring as a tool of weed management and contributor to nitrogen nutrition of direct wet seeded rice

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ABSTRACT

Field experiments were conducted for two kharif seasons of 2012 and 2013 at Hyderabad to study the impacts of brown manuring (BM) with Sesbania aculeate and nitrogen fertilization of direct wet seeded rice (DWSR) performance. BM crop putting up 1.21 t ha^{-1} dry biomass (3.09 t ha^{-1} fresh biomass) in 30 days has accumulated 35.7, 3.9 and 17.2 kg ha^{-1} nitrogen (N), phosphorous (P) and potassium (K), respectively. BM has reduced the weed biomass production (g m-2) in DWSR by 40.5% and thus reduced their N-P-K uptake (kg ha^{-1}) by 2.22-0.23-2.03 over no BM treatment (5.15-0.51-4.56 kg ha^{-1} N-P-K). Though BM has improved rice grain yields of DWSR significantly (0.15 t ha^{-1}), the increases in net income were non-significant (921 Rs. ha^{-1}) over no BM. Nitrogen fertilization of DWSR @ 120 kg ha^{-1} was found promising from both yield and economics point of view. The yield and economic benefits of BM to DWSR can be derived when no N was applied (0.38 t ha^{-1} and Rs. 3286). The BM crop on average contributed 9.93 kg N ha^{-1} and this contribution was highest (14.9 kg ha^{-1}) when DWSR received no N.

Key words: *Brown manuring, Sesbania aculeata, direct wet seeded rice, nitrogen*

Rice (*Oryza sativa* L.) is grown as transplanted crop in puddle soils under assured irrigation during both *kharif* and *rabi* seasons with highest and stable productivity all over the world including India. This labour intensive production system has become less and less profitable sometimes even loss making proposition owing to decreased labour availability and increased labour wages. To make the rice cultivation profitable, researchers and farmers together have evolved the concept of direct seeding of rice (DSR) in puddle (direct wet seeding) and unpuddle soil (dry seeding i.e. aerobic rice). Simultaneously germinating weeds along with the rice crop in DSR (Chauhan and Johnson 2010) that are more diverse as compared to transplanted rice crop (Fukai 2002) puts intense biotic pressure on rice crop productivity. It is often said that the success of DSR depends on the efficiency of weed management. Brown manuring (BM) *i.e.,* co-culture of green manure crops like *Sesbania aculeata* (Wills.) Poir.) with rice and its kill at a month later through spray of 2,4-D herbicide has been explored as an ecological weed management (Maity and Mukherjee 2008) tool in DWSR. The BM crops being legumes have the inherent ability to fix atmospheric nitrogen (N) that may provide the scope for supplementing the N (Gopal *et al.* 2010) and other fertilizers nutrients in the rice cultivation. Thus, the herbicide and fertilizer input into the rice ecosystem can be reduced by resorting to the concept of BM. The fertilizer subsidy burden of the country especially of N can be offset to some extent with BM. In this context, the present field investigation was carried out to assess the contribution of BM to weed management and N nutrition of DWSR.

MATERIALS AND METHODS

Field investigations were made for two years (2012 and 2013) during *kharif* (June- November) seasons at research farm of Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana. The site is located at 19^0 N latitude and 74^0E longitude at an altitude of 700 m above mean sea level. The experimental fields with clayey loam soil (vertisol; Typic Pellustert) with a 7.8 pH (both the years) having 6.8 and 6.5 g kg^{-1} organic carbon, 265.4 and 256.3 kg ha^{-1} available nitrogen (rated as low), 18 and 17.6 kg ha^{-1} available phosphorus (rated as medium) 380.5 and 377 kg ha^{-1} of available potassium (rated as medium) during July, 2012 and 2013, respectively. Treatments formed by combination of two brown manure *i.e.*, with and without *S. aculeata* BM as main plots and four levels of nitrogen (0, 60, 90 and 120 kg ha^{-1}) as sub-plots were tested in four times replicated split plot design. A sub plot size of 20 m^2 size was used in the study. The experimental field was prepared by puddling thrice with power tiller followed by its precise levelling for quick drainage of water (both irrigation and rain water). Such a levelled field was partitioned into beds of 5.4 m width with the two adjacent beds getting separated by a 0.6 m furrow. These furrows facilitated quick draining of rain water during the initial 10 days after seeding and thus aided in better seed germination and thus successful crop establishment. Rice variety 'BPT5204' (Samba Mahsuri) seeds were soaked in water for a day followed by their incubation in gunny bag with frequent watering till start of germination (that took 30 hours time) were uniformly broadcast in a well prepared puddle soil bed using a seed rate of 40 kg ha^{-1} on 15th July in both the years. In BM plots, *S. aculeata* seeds @ 18 kg ha^{-1} that were soaked in water for 48 hours followed by their placement in gunny bags for promoting germination for 48 hours with frequent watering were broadcast immediately after rice seeding on the seed bed. On 10^{th} day of seeding, the germinated plants were thinned / readjusted (gap filling) to maintain a rice and BM crop plant population of 80 and 50 plants m^{-2}, respectively. During the first week of time after seeding, saturation moisture is maintained through giving light irrigations and removing excess water through furrows on every alternate day. The water level is gradually raised with increase in height of seedlings thereafter and 3 cm water level is maintained from 20^{th} day onwards. The field is dewatered to a thin layer of water during herbicide as well as fertilizer application. BM crop was knocked down by uniformly spraying 0.60 kg of 2,4-D ester dissolved in 300 litres of water ha^{-1} on 30th day of seeding (DAS). Plot wise weed count {grasses, sedges and broadleaved weeds (BLW)} was recorded from 1 m^2 quadrate prior to the herbicide spray in both BM (to kill the BM crop and broad leaved weeds) and non-BM plots (to kill broad leaved weeds). BM crop and the weeds from this quadrate in which weed count was recorded were uprooted, washed in water, oven dried and total dry weight was recorded seperately. Rice crop received uniformly 26.4 kg P through single super phosphate and 36 kg K ha^{-1} as muriate of potash that were applied in the last puddling. Nitrogen as per treatment through prilled urea was top dressed in 3 equal splits on 5, 35 and 55 DAS. Two manual weedings were done in DWSR on 34 and 54 DAS by taking due care not to up root the stems of BM crop. Despite of the care, the movement of labour for manual weeding has resulted in trampling and incorporation of some of the stems of BM crop into the soil (~10% of plants). Plant height and dry matter accumulation of DWSR crop was recorded periodically at monthly intervals. Yield attributes from ten randomly selected plants and yield data from net plot were recorded post harvest. The BM crop, weeds (grass, sedge and BLW, group wise were analysed and total was reported) and rice crop (grain and straw) were analysed for nutrient concentration (NPK) as per procedures of Singh *et al.* (2005) and the uptake was estimated as a product of concentration and yield. The contribution of BM crop to N nutrition of DWSR was arrived at by estimating the differences in uptake of N by rice crop and weeds in BM and no BM plot and sum of the differences of crop and weed uptake are arrived at and reported as N economy. The analysis of variance was done in split plot design. The significance of treatment differences was compared by critical difference at 5% level of significance (P=0.05) and statistical interpretation of treatments was done as per Gomez and Gomez (1988). In the calculation of economics, minimum support price of rice grain (Rs. 12,500 ton^{-1}) and market price of straw (Rs.1,500 ton^{-1}) were used. A nitrogen fertilizer price of Rs. 11.55 kg^{-1} was used. Dhaincha establishment (seed: 500 and labour for sowing Rs. 300) and its brown manuring cost (herbicide: 300 + labour for spraying: 300) was also included.

RESULTS AND DISCUSSION

Brown manure crop growth, biomass and nutrient accumulation

The data on plant height, biomass production and nutrient accumulation (Table 1) of BM crop Sesbania at 30 DAS was given on pooled basis as the data was statistically similar during both the years. The data indicated significant impacts of N fertilization of DWSR on BM crop plant height, total (leaf) biomass production and N, P and K nutrient accumulation in the biomass. The plant height, total (fresh and dry) biomass and leaf biomass production of BM crop though increased with each increase of N dose over control numerically, the increase could reach level of significance only with application of 90 kg N ha^{-1}. All the N fertilizer treatments irrespective of its level have resulted in statistically similar values of above parameters of BM crop. However, the biomass production (both fresh and dry) of BM crop receiving 120 kg N ha^{-1} was significantly higher than 60 kg N ha^{-1}. Further, no N applied plot has recorded at par plant height and biomass production (fresh, dry and leaf) values as that of 60 kg N ha^{-1}. The BM crop on average has attained a height of 30.2 cm in 30 DAS and put a fresh biomass of 3.09 t ha^{-1}. The BM crop on an average has 39.2% dry matter content (1.21 t ha^{-1}) in its fresh biomass. Leaf fraction accounted for 33.2% (0.40 t ha^{-1}) of BM crop dry matter production. The increase in plant height with N fertilization was ascribed to the fact that N being a constituent of phosphonucleotide might have favoured increase in cell division that has manifested in increased plant height. The increase in biomass production of BM crop with N fertilization was ascribed to the increase in plant height. The increase in plant height and biomass production with N fertilization of the current study corroborates the findings of Himanshu Singh and Gangaiah (2012). Application of 120 kg N ha^{-1} being at par with other two lower levels of fertilization (60 and 90 kg ha^{-1}) has accumulated significantly higher N, P and K in biomass of BM crop than the unfertilized control treatment. BM crop on an average has accumulated 35.7-3.91-17.2 kg N-P-K ha^{-1} in 30 days. Of the total nutrient accumulation in BM crop, leaf fraction on an average accounted for 33.0-37.1-40.7% of N-P-K (11.8-1.45-7.0 kg N-P-K ha^{-1}). The leaf nutrient accumulation in BM crop after its kill by herbicide is the major contributor to nutrition of current rice crop. To some extent decomposing roots and stems (minor fraction) may also contribute to rice crop nutrition in currents season. External application of N as fertilizer urea in a soil analysed low for available N might have favoured better supply of N for BM crop. Combined application of NPK has synergistically improved the uptake of P and K over no N applied control (PK applied) treatment. The higher biomass production coupled with more or less similar concentration of N, P and K nutrients in BM crop with N fertilization of DWSR has resulted in higher NPK accumulation in BM crop.

Table 1. Growth and nutrient accumulation of brown manure crop as affected by nitrogen fertilization of DWSR (pooled data of two years)

N dose (kg ha^{-1})	Plant height (cm) on 30 DAS	Total biomass production (kg ha^{-1})		Leaf biomass production (kg ha^{-1})	Nutrient accumulation (kg ha^{-1})		
		Fresh	Dry		N	P	K
0	26,5	2831.2	1140.0	366.0	32.4	3.65	16.0
60	30.4	3008.0	1190.5	401.5	35.2	3.87	16.9
90	31.3	3174.7	1230.5	413.0	36.8	3.99	17.6
120	32.5	3336.9	1278.5	424.0	38.5	4.15	18.3
Mean	**30.2**	**3087.7**	**1209.9**	**401.1**	**35.73**	**3.91**	**17.2**
SEm±	1.35	59	21.0	14.0	1.53	0.130	0.68
CD (P= 0.05)	4.32	188.2	67.0	44.7	4.89	0.415	2.17

Effects of brown manuring and nitrogen fertilization on weeds

The DWSR crop has a more diverse weed flora (18 weeds) and the diversity did not vary due to brown manuring and N fertilization. The DWSR crop irrespective of the treatments tested was invaded by seven grasses: (*Echinochloa colona* (L.) Link.; *Echinochloa crusgalli* (L.) Beauv. *Ischaemum rugosum Salisb*.; *Digitaria sanguinalis* L. (Scop.); *Dinebra retroflexa* (Vahl) Panzer; *Dactyloctenium aegyptium* (L.) Willd, *Leptochloa chinensis* (L.) Nees.); four sedges : *Cyperus rotundus* (L); *C. iria* (L); *Fimbristylis miliaceae* (L.) Vahl. and *Scirpus juncoides* and seven broad leaved weeds: *Ammania baccifera*, *Alternanthera sessilis* (L.) DC.; *Caesulia axillaris* Roxb; *Eclipta alba* (L.) Hassk.; *Ludwigia parviflora* Roxb.; *Marselia quadrifolia* (L.) and *Sphenoclea zeylanica* (Gaertn.).

Table 2. Effect of brown manuring and nitrogen fertilization on weed count, weed biomass and weed nutrient uptake in DWSR (pooled data)

Treatment	Weed count (m^2)				Weed biomass (g m^{-2})	Nutrient uptake by weeds (kg ha^{-1})		
	Grasses	Sedges	BLW	Total		N	P	K
Brown manure (BM)								
BM	33.00	6.80	3.05	42.85	15.35	2.93	0.28	2.53
No BM	38.85	11.15	4.90	54.90	28.31	5.15	0.51	4.56
SEm±	1.76	0.531	0.223	1.565	0.693	0.20	0.039	0.250
CD (P=0.05)	NS	2.390	1.004	7.043	3.119	0.90	0.176	1.125
Nitrogen dose (kg ha^{-1})								
0	35.65	9.10	3.85	48.50	18.19	3.50	0.32	2.91
60	35.75	9.25	4.00	48.80	21.38	3.91	0.39	3.46
90	36.50	9.15	3.95	48.30	23.29	4.24	0.43	3.84
120	35.85	9.40	4.15	48.70	24.48	4.50	0.45	4.00
SEm±	2.38	0.582	0.29	2.07	0.892	0.27	0.052	0.338
CD (P=0.05)	NS	NS	NS	NS	2.64	0.80	NS	1.001
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

The weed count, weed biomass and weed nutrient uptake data on pooled basis (Table 2) at 30 DAS has revealed significant impacts of Sesbania BM. The impact of N fertilization was found to be significant only on biomass and nutrient uptake of weeds. Pooled data reveals that weed count of grasses, sedges and BLW was reduced by 5.35, 3.85 and 1.85 BM as compared to no BM. The lower weed count in BM plots was ascribed to the fact that the additional population of Sesbania BM crop over and above that of the DWSR crop by way of restricting physical space (both above and below ground) has reduced the group wise weed count. This decrease in group wise weed count in BM plots has translated into 20.1% reduction in total weed count (42.85) over no BM treatment (54.90). The stiff competition of weeds with BM crop and DWSR crop for resources (especially for light and N nutrient as water is not a limitation in the study) together with reduced weed count has resulted in reduction of weed biomass by 45.7% in BM plot as compared to no BM plot (28.31 g m^{-2}). A decrease in weed count and biomass of DWSR due to BM of the current study was in accordance with the findings of Singh *et al.* (2007) and Chongtham *et al.* (2015). The lower biomass of weeds under BM has resulted in 2.22-0.23-2.03 kg ha^{-1} lesser uptake of N-P-K nutrients than in no BM DWSR crop (5.15-0.51-4.56 kg ha^{-1}).

The N fertilization data revealed its significant impacts on the weed biomass production and their nutrient (N and K) uptake. Nitrogen fertilization @ 60 kg ha^{-1} has resulted in significantly higher weed biomass production than no N applied plots. Though the weed biomass produced increased with further increase in N dose, the increase over 60 kg N was significant when 120 kg N was applied. Stiff competition of DWSR crop plants with the weeds for N, the limiting resource of the current study in no N fertilized control plot has resulted in significantly lower weed biomass production. In N fertilized plots, with increasing dose, the competition for N between weeds and crop decreased and thus recorded higher weed biomass production. Nutrient (N and K) uptake by weeds though increased with increasing dose of N to DWSR crop, the increase in uptake could become significant over no N applied treatment with 120 kg N application only. On an average, weeds removed 4.04- 0.40-3.55 kg N-P-K ha^{-1} at 30 DAS of DWSR crop. The increase in weed biomass production and N uptake of weeds with increased N fertilizations of the current study is in close agreement with the findings of Mahajan and Timsina (2011).

Rice crop performance

The data on growth, yield attributes and yield of DWSR crop as influenced brown manuring and nitrogen fertilization was presented in Table 3. The data indicates significant influence of BM on dry matter accumulation (DMA) at harvest and grain yield of rice while the influence of N fertilization was marked on all growth, yield attributes and yield. BM has improved the DMA and grain yield of rice by 38 g m^{-2} and 0.15 t ha^{-1} over no BM. The increase in DMA of rice under BM was ascribed to the cumulative effect of higher values of plant height at harvest, tiller number (panicles) and grain yield. Similarly the grain yield increases of rice with BM were ascribed to higher values of panicles m^{-2} (15.5) as compared to no BM treatment. Nutrient uptake (N and K) of DWSR was significantly influenced

Table 3. Performance of DWSR as affected by brown manuring and nitrogen fertilization (pooled data)

Treatment	Plant height (cm) at		Dry matter accumulation (g m^{-2})		Panicles m^{-2}	Number of grains panicle^{-1}	Test weight (g)	Grain yield (t ha^{-1})
	30 DAS	harvest	30 DAS	At harvest				
Brown manure (BM)								
BM	23.8	131.3	234.3	1247.0	540.3	78.7	24.2	4.81
No BM	25.1	127.6	246.0	1209.0	524.8	76.6	24.1	4.66
SEm±	0.72	3.19	5.02	6.00	13.03	1.70	0.10	0.022
CD (P=0.05%)	NS	NS	NS	27.00	NS	NS	NS	0.098
Nitrogen dose (kg ha^{-1})								
0	20.4	107.3	205.9	944.0	410.5	57.0	23.8	3.64
60	25.1	125.3	231.8	1231.0	528.5	80.9	24.2	4.75
90	25.8	134.9	254.1	1323.0	582.5	85.5	24.3	5.10
120	26.5	140.3	268.9	1414.0	608.5	87.0	24.4	5.47
SEm±	1.23	4.30	6.81	8.10	17.50	2.30	0.14	0.037
CD (P=0.05%)	3.64	12.77	20.19	24.10	51.80	6.79	NS	0.109

by brown manuring. BM has improved the uptake of N and K by 7.6 and 10.8 kg ha^{-1} over no BM plots (Table 4). The higher yield of rice under BM has contributed to higher nutrient uptake. The reductions in nutrient depletion by weeds coupled with enhanced supply of nutrients through decomposing biomass of BM crop have also added up to the sources of supply of nutrients to the crop. Rice crop under reduced weed stress (Table 2) and additional supply of N, P and K nutrients (Table 1) by gradually decomposing BM crop to rice as evident from higher uptake has resulted in higher yield attributes formation and thus higher grain yield formation. A similar increase in yield of DWSR due to BM were reported by Ravisankar *et al.* (2007) and Maity and Mukherjee (2008). An increase in nutrient uptake of rice due to BM of the current study was supported by the findings of Venkata Laksmi and Veeraraghavaiah (2015) in transplanted rice fed with Glyricidia green leaf manure.

Plant height and DMA of rice crop increased significantly with each increase of N dose up to 120 kg ha^{-1} though the increase was at decreasing rate. However, the increase in plant height at 30 DAS was not significant due to increase in N dose beyond 60 kg ha^{-1}. The increase in plant height coupled with increase in tiller number at different stages (as indicated by number of panicles) has resulted in increase in DMA at harvest (g m^{-2}) by 281, 97 and 0.91 with 60, 90 and 120 kg N fertilization over its preceding dose. The number of panicles m^{-2} and grains panicle^{-1} of rice increased significantly with increasing dose of N up to 90 and 60 kg ha^{-1} only. However, the increase in grain yield was significant with each increase of N dose from 0 to 120 kg ha^{-1}. The higher value of yield attributes at 120 kg N ha^{-1} has together have improved the grain yield to the highest level. Application of 60, 90 and 120 kg N ha^{-1} has increased the grain yield (t ha^{-1}) of DWSR by 1.11, 0.35 and 0.37 over their preceding level of 0, 60 and 90 kg N ha^{-1}, respectively. A similar increase in yield of DWSR due to N fertilization has been also reported by Yadav *et al.* (2014). The nutrient uptake of DWSR increased significantly with increase in N level (Table 4) at a decreasing rate. Though the increase in N and K uptake was significant with each successive increase of N dose from 0 to 120 kg, the increases in P uptake were significant up to 60 kg N ha^{-1} only. The increase in nutrient uptake of rice was primarily due to increase in DMA and grain yield as the nutrient concentration in straw and grain remained more or less constant in N fertilized treatments.

Interaction effect of N dose and BM (Fig. 1) on DMA and grain yield reveals that BM has improved DMA and grain yield of rice significantly (38 g m^{-2} and 0.16 t ha^{-1}) over no BM treatment when no N was applied. The significant influences of BM continued on rice grain yield as N dose increased to 60 kg N ha^{-1} and thereafter disappeared with increase in N dose to 90 and 120 kg ha^{-1}.

Nitrogen contribution and economics

As Sesbania is a legume crop, the contribution of this BM crop to N nutrition of DWSR is only estimated here (Table 4). Brown manuring in DWSR has accounted for a nitrogen contribution (increased crop uptake and reduced weed uptake) of 9.93 kg ha^{-1}. Its contribution was highest when no N was applied (14.9 kg ha^{-1}) and decreased as N dose increased to the lowest of 6.75 kg ha^{-1} at 120 kg N application.

Table 4. Effect of brown manuring and nitrogen fertilization on nitrogen uptake and economics of DWSR.

Treatment	Total (grain+straw) nutrient uptake (kgha^{-1})			Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	N contribution of BM (kgha^{-1})*
	N	P	K			
Brown manure (BM)						
BM	102.6	9.64	132.4	46760	24869	9.93
No BM	95.0	8.93	121.6	45457	23948	-
SEm±	1.30	0.402	1.50	-	300	
CD (P= 0.05)	5.90	NS	6.75	-	NS	
Nitrogen dose (kg ha^{-1})						
0	78.1	7.30	100.0	42145	12000	14.90
60	99.2	9.23	128.0	46277	24439	10.28
90	105.8	10.00	136.2	47525	28358	7.87
120	111.9	10.63	143.9	48487	32838	6.65
SEm±	1.81	0.542	2.03	-	405	
CD (P= 0.05)	5.38	1.61	6.02	-	1203	

*Worked as differences in crop and weed uptake of BM and no BM plots at different levels of N

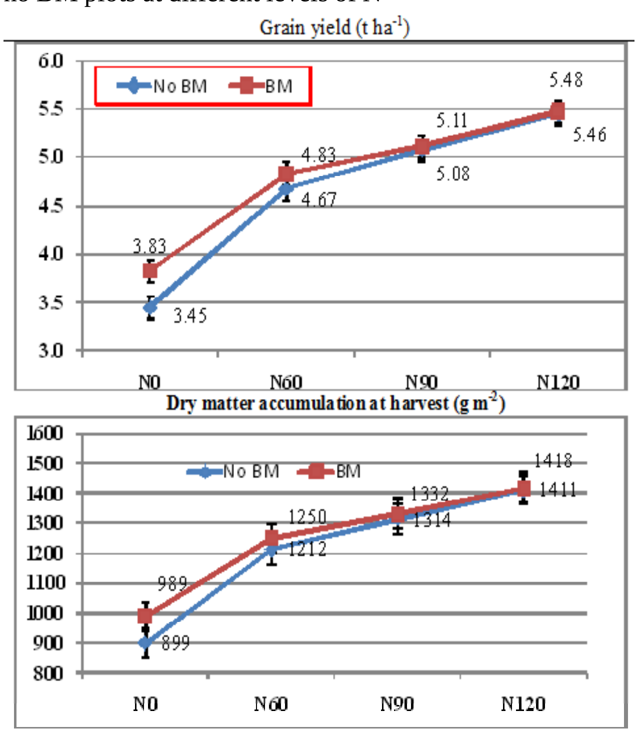

Fig. 1. Interaction effect of brown manuring and nitrogen fertilization on grain yield (t ha^{-1}) and Dry matter

The translation of nutritional and weed suppression benefits of BM that were manifested in increased yields of DWSR into monetary terms reveals that the net income increases (Rs. 921 ha^{-1}) were statistically insignificant. This was owing to the fact that BM involved an additiofnal cost of Rs. 1303 ha^{-1} that have eaten away the gross profits obtained. Nitrogen fertilization at 60, 90 and 120 kg ha^{-1} has improved the net income by Rs. 12,439, 3,519 and 4,480 over their respective preceding doses of 0, 60 and 90 kg N. Interaction effect of N dose and BM on net income of DWSR reveal that the BM has markedly increased net income (Rs. 3286 ha^{-1}) over no BM treatment (Rs. 10382 ha^{-1}) when no N was applied. With application of N, the net income differences between BM and no BM narrowed to Rs. 102 ha^{-1} at 60 kg N dose and gone on negative side becoming a loss making proposition at 90 and 120 kg N ha^{-1} application (Rs. -640 and Rs.-15 ha^{-1}). Thus BM is promising in DWSR when no N was applied.

From the study it is inferred that Sesbania aculeata brown manuring in direct wet seeded rice in puddle soil with its low biomass accumulation in 30 days period (1.2 t ha^{-1}) and only leaf fraction getting decomposed in the current cropping season has the weed suppressing ability and potential to contribute to NPK nutrition when no N was applied. Establishment of mechanisms to account for the imputed values of ecological gains from organic nutrient and weed management systems by BM crop may make it economically viable. There is need to assess the decomposition pattern of biomass of BM in rice and also in the succeeding crops especially those of BM crop stems and roots.

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