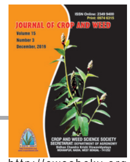
Journal of Crop and Weed, 18(3): 44-50 (2022)

ISSN- O : 2349 9400 ; P : 0974 6315



http://cwssbckv.org
www.cropandweed.com

Quality and suitability of fertilised *rabi* legume crops for green manuring

[*]A. CHENDRA BABU NAIDU, [1]G. S. MADHU BINDU, [2]M. MALLA REDDY AND [3]M. UMA DEVI

Department of Agronomy, College of Agriculture, Rajendranagar
[1]Examination Centre, PJTSAU, [2]Department of Agronomy, College of Agriculture, PJTSAU, Rajendranagar,
[3]Regional Agricultural Research Station, PJTSAU, Jagtial, Telangana.

Received : 04.06.2022 ; Revised : 28.09.2022 ; Accepted : 09.10.2022

DOI : https://doi.org/10.22271/09746315.2022.v18.i3.1615

ABSTRACT

A field study conducted at College of Agriculture, Rajendranagar to study the quality and suitability of selected green manure crops for rabi under fertilised conditions indicated that the leaf water content was maximum in dhaincha and lowest in horse gram at 30 DAS and at the time of incorporation during rabi. The N, P and K contents were maximum in sunhemp, horse gram, and cowpea, respectively. The cell wall constituents viz., lignin, cellulose, and hemicellulose were maximum in cowpea and minimum in pillipesara. The C:N ratio of the green manure crops was comparable and lower with horse gram and pillipesara while it was high and at par with cowpea and sunhemp. Fertilisation to green manure crops had significantly moderated the leaf water content with higher nitrogen, lignin, cellulose, hemicellulose contents and hence C:N ratios. From the results, sunhemp, cowpea and dhaincha with higher quality were considered suitable for rabi under fertilised conditions.

***Keywords*:** Green manuring, legumes, quality, *rabi*, suitability, C:N ratio.

Green manuring is a practice of turning undecomposed green plant tissue into the soil. The benefits of green manuring are multifold. It increases soil organic matter, available nitrogen and reduces nitrogen losses through leaching and soil erosion. It concentrates nutrients near the soil surface in the available form (Sultani *et al*., 2007). The green manuring and soil fertility transformation are considered synonymous with each other but the success of green manuring is largely dependent upon the quality and quantity of biomass produced and later crops to be grown to exploit upon the elevated soil environment much for the benefit of the crops. Both legumes and non-legumes are used as green manures. However, legumes are superior to green manure crops as they fix atmospheric nitrogen and add it to the soil nitrogen pool (Carlsson and Huss-Danell, 2003 and Mayer *et al*., 2003). Estimates suggest that a 40-50 day old green manure crop can supply up to 80-100 kg N ha^{-1} (Sharma *et al*., 2013). Dhanicha, sun hemp, mung bean and guar grown during *kharif* season as green manure crops have been reported to contribute 8-21 tonnes of green matter and 42-95 kg of N ha^{-1}. Similarly, khesari, cowpea, and berseem raised during *rabi* season can contribute 12-29 tons of green matter and 67-68 kg of N ha^{-1} (Mishra and Nayak, 2004). The rate of decomposition and the quantity of N contributed by the green manure crops depend upon the stage of incorporation of the green manure crops, the chemical characteristics of their biomass (Radicetti *et al*., 2017), and C:N ratios (Trinsoutrot *et al*., 2000).

Since green manure crops are rarely fertilised, their value is strongly dependant on their ability to use available nutrients. However, Ibrahim *et al*. (2020) and Carvalho *et al*. (2013) observed that most green manure crops respond well to fertilisation in terms of growth and quality. Also, the application of fertilisers like phosphorus to legume green manure crops may increase the production of nodules and the activity of rhizobium bacteria thus, increasing the amount of atmospheric N fixed in the soil. Therefore, to maintain a competitive agricultural system, the green manure practice must be managed together with chemical fertilisers (Valadares *et al*., 2016). Thus, it can be inferred from the above that supplementing green manure crops with the recommended dose of fertilisers may improve their quality thus enhancing biomass production and subsequent nitrogen addition. The carbon accumulation and the chemical characteristics of the green manure crops also may vary with the season during which they are raised. Hence it is determined to study the quality and suitability of selective green manure crops under fertilised and unfertilised conditions during *rabi*.

MATERIALS AND METHODS

The field trial was conducted during *rabi*, 2020-21 at college farm, College of Agriculture, Rajendra Nagar, Hyderabad. The experiment was laid out in a strip plot design and replicated thrice on a clay loam soil evaluating seven legume green manure crops *viz*., green gram, black gram, horse gram, cowpea, sunhemp, dhaincha and pillipesara under fertilised and unfertilised

Email: cchandrababualuru@gmail.com

How to cite : Chendrababunaidu, A., MadhuBindu, G. S., Malla Reddy, M. and Uma Devi, M. 2022. Quality and suitability of fertilized *rabi* legume crops for green manuring. *J. Crop and Weed*, **18** (3): 44-50.

conditions. The soil of the experimental site was alkaline in reaction with high organic matter and low soil available nitrogen and high soil available phosphorous and potassium. All the crops were sown in the first week of December. The climate of the experimental region is semi-arid (dry). The mean weekly maximum temperature during the experiment ranged from 27.1^{0}C to 38.1^{0}C while the mean weekly minimum temperature ranged from 11.1^{0}C to 22.6^{0}C. The mean weekly relative humidity during the experiment at 0730 hrs and 1400 hrs fluctuated between 72.9 to 95.7 per cent and 22.0 to 53.6 per cent, respectively. A total rainfall of 2.3 mm was received during the experiment which did not account to a single rainy day. The mean sunshine hours extended from 5.9 to 14.8 hours day^{-1}. The evaporative demand of the atmosphere as reflected by pan evaporimeter (USWB Class A pan) during the crop growth varied from 2.7 to 7.0 mm day^{-1}. The wind speed stretched from 2.5 kmph to 5.3 kmph. Recommended dose of fertilisers and seed rate for respective green manure crops are mentioned in Table 1.

Table 1: Seed rate (kg ha^{-1}) and RDF for the green manure crops

Green manure crops	$N - P_2O_5 - K_2O$ (kg ha^{-1})	Seed rate (kg ha^{-1})
Greengram	20-40-0	30
Black Gram	25-50-0	20
Horsegram	25-40-20	25
Cowpea	25-40-20	25
Sunhemp	12.5–40-0	50
Dhaincha	0–30-0	50
Pillipesara	30-60-0	20

The green manuring of the legume crops under the study were done at 50 per cent flowering of the respective crops. The quality of the legume green manures as influenced by fertilisation during *rabi* was studied in terms of leaf water content, plant nutrient (N, P, K) contents, cell wall constituents (cellulose, hemicellulose and lignin) and the C:N ratio. The leaf water content was determined using Barrs and Weatherly's method (1962). Plant samples were analysed for nitrogen, phosphorous and potassium contents by Microkjeldhal (AOAC, 1970), Vanado-molybdo-phosphoric yellow colour (Jackson, 1973), flame photometer (Jackson, 1967) and spectrophotometer (Wolf, 1971) methods, respectively. The C:N ratios in the present study were derived for the plant residues before incorporation. To arrive the C:N ratio, the total carbon and nitrogen contents of the green manure crops before incorporation was estimated by taking respective samples. Determination of lignin in the plant samples was done by the estimation of acid detergent lignin from the acid detergent fibre (ADF). Estimation of cellulose (expressed in %) in the crop residues was estimated using anthrone assay method where a neutral detergent solution was prepared initially. The hemicellulose content (expressed as %) in the residues was calculated as:

Hemicellulose = Neutral detergent fibre (NDF) – Acid detergent fibre (ADF)

Hemi-cellulose was obtained by subtracting ADF from NDF, since:

NDF = Cellulose + Hemicellulose + Lignin + Silica

ADF = Cellulose + Lignin + Silica

Hemicellulose % = NDF % - ADF %

Cellulose % = ADF – Residue after extraction with 72 per cent H_2SO_4

Lignin % = Residue after extraction with 72 per cent H_2SO_4 – Ash

The experimental data was analaysed following the procedure for strip plot design outlined by Panse and Sukhatme (!967). The significance was tested by 'F' test at 5 per cent level of probability (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Leaf water content

The data on leaf water content indicated that the green manure crops notably differed in their leaf water contents and also due to fertilisation. Their interaction was also found significant. Among the green manure crops, the leaf water content was maximum in dhaincha (90.6 %) followed by sunhemp (79.9 %) and green gram (75.7 %). The lowest content of leaf water on the other side was noted in horse gram (64.8%). The leaf water content at 30 DAS ranged from 64.8 to 90.6 per cent representing that all the green manure crops except horse gram maintained favourable water status in the leaves. Further, the leaf size and leaf area seem to have a role in retaining more moisture in leaves as noted from higher leaf moisture contents of dhaincha and sunhemp. Smaller leaf size and lesser leaf surface area exposed for transpiration might have resulted in their higher leaf water content values in these crops. Expanded canopies due to active vegetative growth during 50% flowering have accommodated high water content values over those at 30 DAS. Among the green manure crops, dhaincha remained the best crop with high leaf water content (94.7 %). On the other side, horse gram has maintained lower leaf water content at 50% flowering stage (71.0 %). The leaf water content at the 50 % flowering stage ranged from 71.0 to 94.7 per cent among the green manure crops.

Fertilisation to green manure crops was also found to have a favourable effect on leaf water content at 30

Table 2: Leaf water content at 30 DAS and 50 % flowering as influenced by the interaction of green manure crops with fertilisation

Green manure crops	Leaf water content (%)					
	30 DAS			50% flowering stage		
	Fertilised	Unfertilised	Mean	Fertilised	Unfertilised	Mean
M_1: Green gram	82.9	68.4	**75.7**	81.5	73.9	**77.7**
M_2: Black gram	83.6	64.4	**74.0**	80.1	75.7	**77.9**
M_3: Horse gram	62.9	66.7	**64.8**	70.2	71.9	**71.0**
M_4: Cowpea	76.4	69.9	**73.1**	77.9	77.5	**77.7**
M_5: Sunhemp	78.8	81.0	**79.9**	96.8	70.1	**83.5**
M_6: Dhaincha	92.7	88.4	**90.6**	98.8	90.6	**94.7**
M_7: Pillipesara	75.9	66.9	**71.4**	79.0	71.3	**75.1**
Mean	**79.0**	**72.2**		**83.5**	**75.9**	
	SEm(±)	**LSD (0.05)**		**SEm(±)**	**LSD (0.05)**	
Vertical strip (Green manure crops): A	**1.57**	**4.71**		**1.23**	**3.71**	
Horizontal strip (Fertilisation): B	**1.04**	**3.12**		**1.34**	**4.04**	
Interaction (A X B) at same vertical strip	**3.21**	**10.7**		**3.65**	**10.9**	
Interaction (A X B) at different horizontal strips	**8.72**	**28.8**		**9.17**	**32.1**	

Table 3: Nutrient content of green manure crops as influenced by fertilisation at 50% flowering stage

Treatment	Nutrient content (%) at 50% flowering stage		
	Nitrogen	Phosphorous	Potassium
Vertical strip (Green manure crops): A			
M_1: Green gram	1.55	0.36	1.02
M_2: Black gram	1.51	0.38	0.91
M_3: Horse gram	1.62	0.60	1.25
M_4: Cowpea	1.79	0.30	1.41
M_5: Sunhemp	3.00	0.47	1.28
M_6: Dhaincha	2.21	0.57	1.26
M_7: Pillipesara	2.00	0.39	1.04
SEm(±)	**0.02**	**0.02**	**0.03**
LSD(0.05)	**0.08**	**0.05**	**0.09**
Horizontal factor (Fertilisation): B			
S_1-Fertilised	2.06	0.46	1.32
S_2-Unfertilised	1.87	0.43	1.22
SEm(±)	**0.03**	**0.004**	**0.04**
LSD(0.05)	**0.11**	**NS**	**NS**
Interaction (A X B) at same vertical strip			
SEm(±)	**0.04**	**0.01**	**0.06**
LSD(0.05)	**0.12**	**NS**	**NS**
Interaction (A X B) at different horizontal strips			
SEm(±)	**0.13**	**0.03**	**0.19**
LSD(0.05)	**0.56**	**NS**	**NS**

Table 4: Nitrogen content at 50% flowering stage as influenced by the interaction of green manure crops with fertilisation

Green manure crops	Nitrogen content (%) at 50% flowering stage		
	Fertilised	Unfertilised	Mean
M_1: Green gram	1.54	1.57	**1.55**
M_2: Black gram	1.50	1.52	**1.51**
M_3: Horse gram	1.50	1.75	**1.62**
M_4: Cowpea	1.58	2.00	**1.79**
M_5: Sunhemp	3.47	2.53	**3.00**
M_6: Dhaincha	2.68	1.74	**2.21**
M_7: Pillipesara	2.16	1.84	**2.00**
Mean	**2.06**	**1.85**	
	SEm(±)	**LSD(0.05)**	
Interaction (A X B) at same vertical strip	**0.04**	**0.12**	
Interaction (A X B) at different horizontal strips	**0.13**	**0.56**	

Table 5: Lignin, Cellulose, Hemicellulose contents and C:N ratio of green manure crops as influenced by fertilisation at the time of incorporation of green manure crops

Treatment	Lignin content (%)	Cellulose content (%)	Hemicellulose content (%)	C:N ratio
Vertical strip (Green manure crops): A				
M_1: Green gram	1.38	7.30	5.50	19.0
M_2: Black gram	1.63	8.20	6.47	18.3
M_3: Horse gram	1.92	10.5	7.94	17.2
M_4: Cowpea	2.55	14.9	10.7	20.2
M_5: Sunhemp	2.32	13.1	10.1	20.8
M_6: Dhaincha	1.91	12.5	9.23	18.7
M_7: Pillipesara	1.02	5.60	4.05	16.9
SEm(±)	**0.04**	**0.19**	**0.17**	**0.51**
LSD(0.05)	**0.09**	**0.58**	**0.52**	**1.10**
Horizontal factor (Fertilisation): B				
S_1-Fertilised	2.02	12.1	8.81	19.9
S_2-Unfertilised	1.61	8.47	6.62	17.5
SEm(±)	**0.03**	**0.21**	**0.16**	**0.42**
LSD(0.05)	**0.08**	**0.60**	**0.48**	**1.36**
Interaction (A X B) at same vertical strip				
SEm(±)	**0.08**	**1.05**	**0.24**	**1.12**
LSD(0.05)	**NS**	**3.69**	**0.74**	**NS**
Interaction (A X B) at different horizontal strips				
SEm(±)	**0.23**	**0.83**	**0.61**	**3.11**
LSD(0.05)	**NS**	**3.58**	**2.62**	**NS**

DAS (79.6 %) and 50% flowering stage (83.5 %). Leaf development as noted from higher leaf area values due to ample availability of nutrients might have resulted in higher leaf water content in fertilised crops. An increase in leaf area with the application of N fertiliser was noted by Campbell *et al*. (1977). The advantage of leaf orientation and leaf size in maintaining higher leaf water contents was envisioned in dhaincha initially (30 DAS) under fertilised conditions (92.7 %) and later (at 50% flowering) under both fertilised (98.8 %) and unfertilised (90.6 %) conditions. At this stage, fertilised sunhemp also excelled equivalent to dhaincha-fertilised or unfertilised in registering higher leaf water content (96.8 %) among the other green manure-fertilised/unfertilised combinations.

An overview of the leaf water content data at 30 DAS and 50% flowering stage indicated that even though the leaves reached full development at 50% flowering stage, the amount of water occurring in them did not vary to a large extent than at 30 DAS. From this, it can be understood that at the earlier sampling period (30 DAS) the leaves took up more water, even though they were smaller than later in the season. The results are in agreement with those of Ackley (1954). Further, fertiliser application though had a pronounced influence on the leaf water contents during the initial growth but as the crop growth progressed the differences between fertilised and unfertilised treatments in actively growing green manure crops during *rabi* were nullified for leaf water content.

Plant nutrient contents

The contents of major plant nutrients N, P, and K were measured at 50% flowering stage of the green manure crops under fertilised and unfertilised conditions. The nitrogen content in the green manure crops varied significantly and it ranged from 1.51-3.00 per cent. Evidently, the nitrogen content was maximum (3.00%) in sunhemp compared to the other crops. More number of nodules, increased nodule efficiency due to the availability of more carbon source might have simulated the bacteria to fix atmospheric nitrogen in higher quantities and supplementing it to plants assimilation resulting in higher nitrogen content in the green manure crops under fertilised conditions and especially in fertilised sunhemp. The nitrogen contents on the other hand, were comparably lower in the green gram (1.55%) and black gram (1.51%). Further, all the green manure crops registered high N contents under fertilised conditions (2.06 %) than under unfertilised conditions (1.87 %). The interaction of green manure crops to nutrient addition was also found significant with respect to N content. Among all the green manure crops - fertilised or unfertilised combinations, fertilised sunhemp was found to be superior with higher N content (3.47 %).

A contrasting trend like N and P contents were noticed with regard to K content in green manure crops at 50% flowering stage. The highest K content was observed with cowpea (1.41%) followed by sunhemp (1.28%), dhaincha (1.26%), and horse gram (1.26%). The lowest K content on the other side was noted with black gram (0.91%). The K contents among the green manure crops ranged from 0.91 to 1.41 per cent. Similar to the results obtained with P content, the K contents in green manure crops were not affected by fertilisation and hence their interaction. K is an element that is not associated with any structural component of the plant tissue. However, this element plays an important role in the translocation of photosynthates from the source to the developing sink. Hence variations among the green manure crops were more prominent at 50% flowering in stocking K contents accounting for the developing sinks. Further, the availability of K from the soil in sufficient amounts may have nullified the effect of fertilisation in green manure crops.

Lignin, cellulose and hemicellulose contents

The cell wall constituents of the green manure crops studied in terms of lignin, cellulose and hemicellulose displayed significant effects due to fertilisation and their interactions except for lignin content at the time of incorporation. The studied cell wall constituents *viz*., lignin, cellulose, and hemicellulose were the maximum in cowpea with values 2.55, 14.9, and 10.7%, respectively. This was followed by sunhemp with lignin, cellulose, and hemicellulose contents of 2.32, 13.1, and 10.1%, respectively. The biochemical composition basically is of the same components, but the proportions can vary between species, plants of the same species, organs of the same plant, and crop conditions (Valadares *et al.,* 2016). The low lignin content and high cellulose and hemicellulose contents of green manure crops indicate their easily degradable nature upon incorporation and decomposition. Though the differences between the green manure crops for lignin, cellulose, and hemicellulose contents is unknown it can be related to canopy expanse and formation of more branches contributing to more lignin, hemicellulose, and cellulose content in cowpea than the other green manure crops. The lignin content among the green manure crops ranged from 1.02 to 2.55 per cent, the hemicellulose content from 5.6 to 14.9 per cent, and cellulose from 4.05 to 10.7 per cent.

Fertilisation to green manure crops was found to have a positive effect on the cell wall constituents. The lignin, hemicellulose, and cellulose contents in fertilised green manure crops were higher with 2.02, 12.1, and 8.81 per cent, respectively than the unfertilised green manure crops. High dry matter production and canopy expanse due to fertilisation possibly might have increased the primary cell wall contents (cellulose and hemicellulose). The lowest lignin content accumulated than the primary cell wall contents in either fertilised or unfertilised green manure crops may be implied as to the initiation of the secondary cell wall in response to the cease in vegetative growth and entry into the reproductive stage by the green manure crops. This also indicates that 50% flowering is the right stage to incorporate green manure crops into the soil with low lignin content and higher cellulose and hemicellulose contents aiding quick decomposition and release of nutrients upon incorporation.

Fertilisation interacted significantly with green manure crops only in respect of cellulose and hemicellulose. Among fertilised and unfertilised green manure crops, the cellulose content was the maximum in fertilised cowpea (17.3%), sunhemp (15.6%), and dhaincha (14.4%). However, the hemicellulose content was found to be significantly high in fertilised cowpea (12.2%) and sunhemp (11.6%) alone. The comparable growth of sunhemp in respect to canopy expanse and dry matter production might have resulted in equivalent concentrations of cellulose and hemicellulose to that of cowpea under fertilised conditions. On the other hand, lignin content remained unaffected by fertilisation in all the green manure crops.

C:N ratio of the green manures

The C:N ratio of the green manure crops at the time of incorporation varied significantly from 16.9 to 20.8. The C:N ratio was comparable and lower with horse gram (17.2) and pillipesara (16.9). On the other side, the C:N ratio was high and at par with cowpea (20.2), and sunhemp (20.8). Higher cell wall constituents despite higher N concentrations had widened the C:N ratios in cowpea and sunhemp at the time of incorporation. On the other hand, N concentrations of > 2 per cent with less lignified plant material were displayed in lower C:N ratios of the horse gram and pillipesara. Fertilisation to the green manure crops also had a significant role in narrowing the C: N (19.9) through the build-up of N concentration in the plant tissues due to increased assimilation.

CONCLUSION

Of the different green manure crops, sunhemp and cowpea are dependable for green manuring during *rabi* with higher quality in terms of leaf water, nutrient, lignin, cellulose, hemicellulose contents and C:N ratio. With the above quality, these crops may cater to both short and intermediate needs of the *rabi* crops in which they are green manured.

REFERENCES

Ackley, W.B. 1954. Seasonal and diurnal changes in the water contents and water deficits of Bartlett pear leaves. *Plant Physiol.,* **29**(5): 445.

AOAC (Association of Official Analytical Chemists). 1970. Official tentative method of analysis. Association of Official Analytical Chemists, Washington DC, Twelfth Edition.

Barrs, H.D. and Weatherly, P.E. 1962. A re-examination of the relative turgidity techniques for estimating water deficits in leaves. *Australian J. Biol. Sci*., **15**: 413-428.

Campbell, C.A., Nicholaichuk, W., Davidson, H.R. and Cameron, D.R. 1977. Effects of fertiliser N and soil moisture on growth, N content, and moisture use by spring wheat. *Canadian J. Soil Sci.,* **57**(3): 289-310.

Carlsson, G. and Huss-Danell, K. 2003. Nitrogen fixation in perennial forage legumes in the field. *Plant Soil*, **253**: 353-372.

Carvalho. C.M.D., Nascimento, J. D., Faustino, M.N.D.S., Meneses, J.A.G. and Silva J.V.D., 2013. Initial growth of the black cowpea under different environmental conditions and nitrogen fertilisation**.** *Brazilian J. Appl. Technol. Agric. Sci.,* **6** (3)*:* 47-52.

Ibrahim, A.K., Ibrahim, S.A., Voncir, N. and Hassan, A.M. 2020. Effect of some leguminous green manure crops and nitrogen levels on soil chemical properties of maize (*Zea mays* L.) grown soil. *IAR J. Agric. Res. Life Sci.,* **1**(1): 17-25.

Jackson, M. L. 1967. Soil Chemical Analysis. Prentice Hall Publication Pvt. Ltd, New Delhi.

Jackson, M.L. 1973. Soil Chemical Analysis. CBS Publishers and Distributors, Delhi.

Mayer, J., Buegger, F., Jensen, E.S., Schloter, M. and Heb, J. 2003. Residual nitrogen contribution from grain legumes to succeeding wheat and rape and related microbial process. *Plant Soil,* **255**(2): 541-554.

Mishra, B.B. and Nayak, K.C. 2004. Organic farming for sustainable agriculture. *Orissa Review*, **10**: 42-45.

Panse. V.G. and Sukhatme, P.V. 1967. Statistical methods of agricultural workers. 2nd Endorsement. ICAR Publication, New Delhi, India: 381.

Radicetti, E., Campiglia, E., Marucci, A. and Mancinelli, R. 2017. How winter cover crops and tillage intensities affect nitrogen availability in eggplant. *Nutrient Cycling in Agroecosystems.* **108**: 177-194.

Sharma, G.D., Thakur, R., Raj, S., Kauraw, D.L. and Kulhare, P.S. 2013. Impact of integrated nutrient management on yield, nutrient uptake, protein content of wheat and soil fertility in a typic haplustert. *Bioscan*, **8**(4): 1159-1164.

Snedecor, G.W. and Cochran, W.G. 1967. Statistical methods. Oxford and IBH Publishing Company 17, Parklane, Calcutta.

Sultani, M.I., Gill, M.A., Anwar, M.M. and Athar, M. 2007. Evaluation of soil physical properties as influenced by various green manuring legumes and phosphorus fertilisation under rainfed conditions. *Int. J. Environ. Sci. Technol.,* **4**(1): 109-118.

Trinsoutrot, I., Recous, S., Bentz, B., Lineres, M., Cheneby, D. and Nicolardot, B. 2000. Biochemical quality of crop residues and carbon and nitrogen mineralization kinetics under nonlimiting nitrogen conditions. *Soil Sci. Soc. Amer. J.,* **64**: 918-926.

Valadares, R.V., Avila-Silva, L.D., Teixeira, R.D.S., Sousa, R. N.D. and Vergütz, L. 2016. Green manures and crop residues as source of nutrients in tropical environment. In Marcelo L. Larramendy and Sonia Soloneski (eds). *Organic Fertilisers from basic concepts to applied outcomes,* Intech open.51-84.

Wolf, B. 1971. The determination of boron in soil extracts, plant materials, composts, manures, water and nutrient solutions. *Commu. Soil Sci. Plant Anal.,* **2**(5): 363-374.