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Hari Mohan Meena
PhD Research Scholar, Department of Soil Science and Agricultural Chemistry, UAS, GKVK, Bengaluru, Karnataka, India

HC Prakasha
Head & Professor, Department of Soil Science and Agricultural Chemistry, UAS, GKVK, Bengaluru, Karnataka, India

Correspondence
Hari Mohan Meena
PhD Research Scholar, Department of Soil Science and Agricultural Chemistry, UAS, GKVK, Bengaluru, Karnataka, India

Residual effect of soil test value based fertilizer application and amendments on cowpea productivity in acidic soil

Hari Mohan Meena and HC Prakasha

Abstract
A study on the residual effect of soil test value based fertilizer application and amendments on cowpea productivity in an acid soil was carried out in randomized complete block design with eight treatments. The results revealed that residual effect of soil test value based fertilizer application along with biochar or lime significantly increased the growth and yield parameters like plant height, number of branches plant^{-1}, number of pods plant^{-1}, pod length, number of seeds pod^{-1} and 100-seeds weight (g) at harvest of cowpea over package of practice and farmer's practice. Significantly increased the seed and haulm yield of cowpea with residual effect residual effect of soil test value based fertilizer application along with biochar and lime as compared to farmer's practice. Balanced use of fertilizer led to a significant increase in the productivity of cowpea.

Keywords: Residual effect; soil test value based fertilizer; amendments; productivity of cowpea

Introduction

Pulses are second most important group of crops after cereals. Among the pulse crops, cowpea is an important food grain legume and grown in most of the regions of India which showed very encouraging results and promises to have a far reaching significant in achieving a breakthrough in the pulse production. The grain is a good source of human protein, while the haulms are valuable source of livestock protein. It is also a source of income for many smallholder farmers in India and contributes to the sustainability of cropping systems and soil fertility improvement in marginal lands through provision of ground cover and plant residue, nitrogen fixation and suppressing weed. In India, it is cultivated in 654 lakh ha with an annual production of 599 lakh tonnes leading to average productivity of 916 kg ha^{-1} (Anonymous, 2018) [2]. Fertilizers have played a vital role in increasing agricultural production and productivity in India but continuous and imbalanced use of chemical fertilizers has led to the reduction in production and deterioration of soil health. Over dependence on high analysis fertilizers has encouraged the process of soil degradation and is badly influencing production potential and soil health. As a result, most of the productive soils are becoming unproductive. Imbalanced fertilization is one of the important factors limiting crop yields. Problem is more severe in acid soils which are under continuous cropping system (Prasad *et al*., 2010) [12].

Soil acidity is one of the most yield limiting factors for crop production. In India, 30 per cent of the cultivated land is considered acidic, where efficient fertilizer management is a problem. Out of 49 million ha of acid soils, 26 million ha have soil pH below 5.6 and 23 million ha have a pH between 5.6 and 6.5. Out of 19.2 m ha of geographical area in Karnataka, nearly 9.6 m ha (50 % of the total area) of area is acidic in nature. Soil acidity is quantified on the basis of H^+ and Al^{3+} ions concentrations in the soil exchangeable complex that causes acidity which limits plant growth and yield, and uptake of many essential nutrients (Chintala *et al*. 2012a) [3].

Ameliorating acid soils and creating favorable conditions for better uptake of plant nutrients, application of biochar and lime are important management practices. Liming of acid soils increases the availability of several plant nutrients, increases the base saturation, and inactivates Fe, Al and Mn in soil solution, thus minimizing P fixation by Fe and Al. Agricultural lime is the most widely accepted methods of ameliorating acid soils, the character which govern the effectiveness of agricultural lime are fineness and content of calcium in the liming material.

Recently, biochar has emerged use as a soil amendment to improve and maintain the soil acidity and to enhance soil carbon sequestration because it is a fine grained carbon rich material and highly porous substance that produced from the thermal conversion (pyrolysis) of biomass in a low or no oxygen environment (Lehmann *et al*., 2006) [6]. Application of biochar to acidic soil increased its sorption capacity for nutrients (Sohi *et al*., 2010) [14] and reduced the exchangeable acidity (Van Zwieten *et al*., 2009) [18], and also enable to adsorb or retain nutrients and water and provide a habitat for beneficial microorganisms to flourish (Lehmann *et al*., 2006 and Warnock *et al*., 2007) [6, 19]. Organic matter is a source of carbon and nutrients to plants and soil microorganisms, which serves as a catalyst that enhances plant uptake of nutrients and water.

In a cropping system, response of the component crop is influenced by the proceeding crop and inputs applied to them (Patidar and Mali, 2002) [10]. Biochar added to acidic soil leaves susbtantial amount of residual nutrients to succeeding crop beside, it supplying nutrients to the current crop. Some studies have been reported that biochar and lime have significant residual effects on the soil and succeeding crop. This experiment was aimed to determine the residual effect of soil test value based fertilizer application and amendments on growth and yield of cowpea (*Vigna unguiculata* L.) in acidic soil.

Material and methods

In order to assess the residual effect of soil test value based fertilizer application and amendments on growth and yield of succeeding cowpea crop, an experiment was conducted at farm of Zonal Agriculture Research Station, Mandya. The experiment was carried out during *summer* 2017 in the same field representing same treatments without disturbing the plots. The experimental site is situated at 12°57'03" N latitude and 76°82'05" E longitude at an altitude of about 705 m above mean sea level. The soil of the experimental site was sandy clay loam in texture.

At the initiation of the experiment, the pH of the soil of the experimental field was 5.20. The contents of organic carbon, available nitrogen, available phosphorus and available potassium were 4.50 g kg^{-1}, 262 kg ha^{-1}, 12.50 kg ha^{-1} and 272 kg ha^{-1}, respectively. Residual effect of the treatments imposed for rice was studied on succeeding cowpea crop. The eight treatments were as follows: T_1: Farmer's practice, T_2: RDF + FYM + $ZnSO_4$, T_3: T_2 + lime, T_4: T_2 + biochar, T_5: T_2 + mangla setright, T_6: Soil test value based fertilizer application (STV) + FYM + $ZnSO_4$, T_7: T_6 + lime and T_8: T_6 + biochar. In this experiment, there were three replications. The experiment was conducted in Randomized Complete Block Design (RCBD). The plot size was 10.8 m^2 (3.6m × 3m). As per UAS package of practice the recommended dose of NPK fertilizer for rice in acidic soil was applied @ 100, 50 and 50 kg N, P_2O_5 and K_2O ha^{-1}, respectively, Farm Yard Manure (FYM) and $ZnSO_4$ were applied at the rate 10 tones ha^{-1} and 20 kg ha^{-1}, respectively. In farmers' practice treatment (T_1), 150, 40 and 35 kg N, P_2O_5 and K_2O ha^{-1}, respectively were applied. The initial value of available nitrogen and phosphorus in experimental soil was low therefore nitrogen and phosphatic fertilizer in the treatments T_6, T_7 and T_8 were applied based on soil test value which accounts to 25 per cent more than recommended dose of fertilizer. FYM @ 10 t ha^{-1}and $ZnSO_4$ @ 20 kg ha^{-1} were applied in common for all the treatments except treatment T_1 (Farmers' practice). Lime was applied at 4.10 t ha^{-1} on the basis of lime requirement as outlined by Schoemaker methods. Biochar was applied at the rate of 2.50 tones ha^{-1} based on the carbon equivalent to the FYM carbon. A mangla setright dose of 150 kg acre^{-1} was directly applied on the basis of pH of soil. All the amendments were applied to the respective experimental plots one month before planting and mixed by ploughing. The chemical characteristics of the amendments are given in table 1.

Table 1: Physical and chemical characteristics of Biochar, Mangala setright and FYM

Parameters	Biochar	Mangala setright	FYM
pH (1:100)	10.12	4.54	7.14
EC (dS m^{-1}) (1:100)	2.92	1.66	1.22
Bulk density (Mg m^{-3})	0.48	ND	0.29
Total carbon (%)	74.50	ND	17.8
Nitrogen (%)	0.24	0.04	0.67
Phosphorus (%)	0.13	0.01	0.20
Potassium (%)	1.38	0.08	0.63
Calcium (%)	2.32	15.00	0.78
Magnesium (%)	0.46	3.00	0.35
Sulphur (%)	0.08	5.00	0.28
Zinc (mg kg^{-1})	22.80	0.35	16.40
Iron (mg kg^{-1})	432.60	1.95	540.85
Copper (mg kg^{-1})	33.20	0.78	2.76
Manganese (mg kg^{-1})	514.27	1.15	44.70

The seeds of cowpea (C-152) were sown with a seed rate of 25 kg ha^{-1}. The seeds were sown immediately after the harvest of rice crop with minimum tillage operation by direct dibbling in between the rows of standing stubbles for utilizing residual moisture in the main crop. Irrigation was given at an interval of 7-10 days after sowing of cowpea to maintain adequate soil moisture in the root zone. Harvesting of cowpea was done by picking (two picking) of matured pods from each net plot. The pods of cowpea in net plot area were harvested and threshed to separate seeds and the weight of seeds per net plot area was recoded to compute the yield on area basis. Later the plants were uprooted and were left in the field for drying. The growth and yield parameters of residual cowpea were recorded at harvest from five randomly tagged plants from the net plot area of each treatment.

The data were analyzed as per the standard statistical procedure. The analysis of variance (ANOVA) for RBD was performed using an'F' test as per the procedure suggested by Gomez and Gomez (1984) [4].

Results and discussion

Residual effect of soil test value based fertilizer application and amendments on growth and yield attributes of cowpea crop

Plant height (cm)

Residual effect of biochar along with STV + FYM + $ZnSO_4$ (T_8) significantly increased plant height (67.55 cm) at harvest as compared to all treatments except the treatment T_4 (RDF + biochar + FYM + $ZnSO_4$) which was found on par (65.90 cm) (Table 2). Significantly maximum plant height (59.42 cm) at harvest was recorded in treatment which received STV + lime + FYM + ZnSO4 (T_7) as compared to RDF + FYM + $ZnSO_4$ (51.08 cm) and was found on par with treatment T_3 (57.28 cm), T_5 (57.02 cm) and T_6 (52.59 cm). The shortest plant height was recorded in farmer's practice (39.50 cm) which was statistically inferior in comparison to all treatments.

Number of branches plant^{-1}

The data further revealed that number of branches plant^{-1} of cowpea were found significantly highest value of 9.42 in treatment T_8 which received STV + biochar + FYM + $ZnSO_4$ over rest of the treatments except treatment T_4 (RDF + biochar + FYM + $ZnSO_4$) of 9.32 (Table 2). A significantly lowest value of 5.84 was recorded in the farmer's practice (T_1). Significantly higher Number of branches plant^{-1} of 8.22 was recorded in the treatment which received lime along with STV + FYM + $ZnSO_4$ (T_7) as compared to 7.58 in T_2 (RDF + FYM + $ZnSO_4$) and was found on par with 8.13 in T_3 (RDF + lime + FYM + $ZnSO_4$).

Number of pods plant^{-1}

The residual effect of T_8 (STV + biochar + FYM + $ZnSO_4$) recorded significantly maximum number of pods plant^{-1} (16.80) at harvest of cowpea in comparison to all the treatments except treatment T_4 (RDF + biochar + FYM + $ZnSO_4$) which was found on par (15.56) (Table 2). Significantly increased the number of pods plant^{-1} with values of 14.22 in the treatment which received STV + lime + FYM + $ZnSO_4$ (T_7) as compared to 10.58 in RDF + FYM + $ZnSO_4$ (T_2) and was found on par with 13.05 in RDF + lime + FYM + $ZnSO_4$ (T_3), 12.29 in RDF + mangala setright + FYM + $ZnSO_4$ (T_5) and 11.32 in STV + FYM + $ZnSO_4$ (T_6). The minimum number of pods plant^{-1} with values of 8.80 was found in farmer's practice (T_1) which was significantly inferior in comparison to all treatments.

Table 2: Residual effect of soil test value based fertilizer application and amendments on growth and yield attributes of cowpea in acidic soil

Treatments	Plant height (cm)	Number of branches per plant	Number of pods per plant	Pod length (cm)	Number of seeds per pod	100-seed Weight (g)
T_1 : Farmers' practice	39.50	5.84	8.80	8.94	6.17	10.80
T_2 : RDF + FYM + $ZnSO_4$	51.08	7.58	10.58	10.25	8.08	11.15
T_3 : T_2 + Lime	57.28	8.13	13.05	12.16	9.42	12.73
T_4 : T_2 + Biochar	65.90	9.32	15.56	14.70	11.90	13.86
T_5 : T_2 + Mangala Setright	57.02	8.05	12.29	11.62	9.02	12.29
T_6 : STV + FYM + $ZnSO_4$	52.59	7.72	11.32	10.99	8.92	11.72
T_7 : T_6 + Lime	59.42	8.22	14.22	13.02	10.09	13.35
T_8 : T_6 + Biochar	67.55	9.42	16.80	15.66	12.72	14.29
S.Em±	2.65	0.39	0.82	0.82	0.64	0.72
CD (p=0.05)	8.04	1.17	2.49	2.48	1.95	2.99

Note: STV – soil test value based fertilizer application

Pod length (cm)

Table 2 embodies the residual effect of T_8 (STV + biochar + FYM + $ZnSO_4$) recorded significantly maximum pod length (15.66 cm) in comparison to all the treatments except the treatment T_4 (RDF + biochar + FYM + $ZnSO_4$) which was found on par (14.70 cm). Residual effect of lime along with STV + FYM + $ZnSO_4$ (T_7) significantly increased the pod length of 13.02 cm over RDF + FYM + $ZnSO_4$ (T_2) of 10.25 cm. However, it was found on par with treatments T_3 (RDF + lime + FYM + $ZnSO_4$) of 12.16 cm and T_5 (RDF + mangala setright + FYM + $ZnSO_4$) of 11.62 cm. The shortest pod length of cowpea with value of 8.94 cm was noticed in the farmer's practice plot (T_1) which was statistically inferior as compared to rest of the treatments.

Number of seeds pod^{-1}

Among the STV treatments, the residual effect of T_8 (STV + biochar + FYM + $ZnSO_4$) recorded significantly maximum number of seeds pod^{-1} (12.72) followed by T_7 which received STV + lime + FYM + $ZnSO_4$ (10.09) as compared to T_2 which received RDF + FYM + $ZnSO_4$ (8.08) (Table 2). However, treatments T_8 (STV + biochar + FYM + $ZnSO_4$) and T_7 (STV + lime + FYM + $ZnSO_4$) were found on par with the treatments T_4 which received RDF + biochar + FYM + $ZnSO_4$ (11.90) and T_3 which received RDF + lime + FYM + $ZnSO_4$ (9.42), respectively. Significantly minimum number of seeds pod^{-1} (6.17) was recorded in the farmer's practice treatment as compared to all the treatments.

100-seeds weight (g)

Hundred grains weight value of 14.29 g was found significantly highest in T_8 (STV + biochar + FYM + $ZnSO_4$) followed by 13.35 g in T_7 (STV + lime + FYM + $ZnSO_4$) as compared to 11.15 g in T_2 (RDF + FYM + $ZnSO_4$). But these values were found on par with 13.86 g in T_4 (RDF + biochar + FYM + $ZnSO_4$) and 12.73 g in T_3 (RDF + lime + FYM + $ZnSO_4$). While low value of thousand grains weight (10.80 g) was observed in farmer's practice which was statistically inferior as compared to rest of the treatments.

Growth and yield parameters of cowpea differed significantly due to residual effect of soil test value based fertilizer application and amendments (biochar and lime). The higher plant height was recorded in treatment receiving soil test value based fertilizer application along with biochar followed by lime. The plant height increased with increase in the rate of N and P application based on soil test value + FYM + $ZnSO_4$ along with biochar and lime. The plant height increased might be due to the presence of relatively higher quantities of available N, P and K in the soil before sowing of cowpea seeds. Hence, the residual effect of the soil test value based fertilizer application + FYM + $ZnSO_4$ along with biochar and lime to the previous rice crop did have a favorable effect on plant height of succeeding cowpea crop.

Growth and yield parameters of cowpea significantly increase in biochar and lime treated plots as compared to untreated plots. This might be due to ameliorative measures of these amendments in alleviating the harmful effects of acidity, exchangeable Al and Fe, crop might also benefited by the improved physical properties such bulk density, porosity and maximum water holding capacity of soil leading to more vegetative growth in these treatments. These finding are in conformity with Pramanik *et al*. (2004) [11].

The increase in vegetative growth of cowpea with liming could be ascribed to better availability of nutrients due to moderation of soil reaction and might also be due to increased biological N fixation. The sufficient Ca^{2+} supply in the soil to mitigate N_2 fixation limitations of cowpea. The favorable influence of liming on growth of cowpea might be due to the indirect effect of increasing the nitrogen availability to the plants through increased nitrification by moderating the pH in acid soil. The study results are conformity with findings of and Rajashree and Pillai (2001) [13]. The increase in growth and yield parameters of cowpea in biochar and lime treated plots might be attributed to improvement of soil pH and other physic-chemical properties of soil that increases the plant availability of soil nutrients during crop growth period. Similar results were reported by Mathew and Thampatti (2007) [7]. The residual effect of biochar + FYM + $ZnSO_4$ with soil test value based fertilizer applied to preceding rice crop significantly increased the growth and yield attributes of the succeeding cowpea crop over without amendments plots, which might be due to the steady nutrient releasing capacity of biochar which had only 45 to 50 per cent impact on first crop but a good residual effect on the second crop.

The combined application of lime with FYM and chemical fertilizer significantly increased growth and yield parameters of cowpea over the farmer's practice, which might be due to the improvement in soil conditions and increased availability of nutrients through manure and lime application, and also to the addition of NPK which is important during initial root growth, nutrient uptake and therefore plant development (Abbas *et al*., 2011) [1].

Residual effect of soil test value based fertilizer application and amendments on the productivity of cowpea crop

The data on the residual effect of soil test value based fertilizer application and amendments applied to preceding rice crop on seed, haulm and biological yield of succeeding cowpea crop are present in table 3. The highest residual effect was registered by application of biochar along with STV + FYM + $ZnSO_4$ (T_8) obtained significantly higher seed yield of 689.05 kg ha^{-1} and was found on par with 648.90 kg ha^{-1} in T_4 (RDF + biochar + FYM + $ZnSO_4$) followed by 562.22 kg ha^{-1} in T_7 (STV + lime + FYM + $ZnSO_4$) as compared to 457.76 kg ha^{-1} in T_2 (RDF + FYM + $ZnSO_4$). Significantly lower seed yield of 352.47 kg ha^{-1} was recorded in farmer's practice as compared to all the treatments.

Table 3: Residual effect of soil test value based fertilizer application and amendments on grain and haulm yield of cowpea in acidic soil

Treatments	Seed Yield (kg ha^{-1})	Haulm Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})
T_1 : Farmers' practice	352.47	1279.50	1631.97
T_2 : RDF + FYM + $ZnSO_4$	457.76	1454.75	1912.51
T_3 : T_2 + Lime	538.72	1592.95	2131.67
T_4 : T_2 + Biochar	648.90	1739.23	2388.13
T_5 : T_2 + Mangala Setright	512.29	1532.35	2044.64
T_6 : STV + FYM + $ZnSO_4$	473.66	1485.26	1958.91
T_7 : T_6 + Lime	562.22	1633.09	2195.31
T_8 : T_6 + Biochar	689.05	1785.72	2474.77
S.Em±	50.08	33.53	54.55
CD (p=0.05)	151.90	101.69	165.47

Note: STV – soil test value based fertilizer application

Similarly, higher haulm yield of residual cowpea was recorded in T_8 which received STV + biochar + FYM + $ZnSO_4$ (1785.72 kg ha^{-1}) which was significantly superior in comparison to all the treatments except the treatment T_4 comprised of RDF + biochar + FYM + $ZnSO_4$ (1739.23 kg ha^{-1}). Significantly higher haulm yield of 1633.09 kg ha^{-1} was observed in T_7 (STV + lime + FYM + $ZnSO_4$) as compared to 1454.75 kg ha^{-1} in T_2 (RDF + FYM + $ZnSO_4$) and was found on par with 1592.95 kg ha^{-1} in T_3 (RDF + lime + FYM + $ZnSO_4$) and 1532.35 kg ha^{-1} in T_5 (RDF + mangala setright + FYM + $ZnSO_4$). The lower stalk yield of 1279.50 kg ha^{-1} was recorded in farmer's practice which was significantly inferior in comparison to all the treatments.

The data further indicated that the higher biological yield (2474.77 kg ha^{-1}) of cowpea was recorded in the treatment T_8 (STV + biochar + FYM + $ZnSO_4$) which was statistically superior to rest of the treatments except T_4 which received RDF + biochar + FYM + $ZnSO_4$ (2388.13 kg ha^{-1}). Residual effect of lime along with STV + FYM + $ZnSO_4$ (T_7) significantly increased the biological yield of 2195.31 kg ha^{-1} over RDF + FYM + $ZnSO_4$ (T_2) of 1912.51 kg ha^{-1}. The lower biological yield of 1631.97 kg ha^{-1} was found in farmer's practice (T_1) which was significantly inferior as compared to all treatments.

The highest residual effect was observed in the treatment which received biochar along with STV, FYM and $ZnSO_4$ (T_8) which obtained higher seed and haulm yield of cowpea might be due to increased soil pH, decreased soil acidity and exchangeable Al toxity which in turn better availability of nutrients like N, P, Ca and Mg to cowpea crop during *Summer* season when applied to preceding rice crop. The superiority of residual effect of integrated use of biochar, FYM and $ZnSO_4$ along with soil test value based fertilizer application might be due to efficient utilization of mineralized nutrients from biochar and FYM along with atmospheric N fixed by the cowpea crop itself would have increased the availability of N throughout the growth period and thereby increased the assimilation of photosynthates which in turn better source and sink relationship led to better performance of cowpea.

Residual effect of lime increased the seed and haulm yield of cowpea over no lime amended plots might be attributed to amelioration measures of acidic soil by lime application which improve soil pH and decrease exchangeable acidity and Al activity, which might have helped in better nutrient utilization by cowpea crop. Liming affects the solubility and availability of most of the plant nutrients, raises the level of exchangeable base status of calcium, neutralize the effect of Al^{3+} and H^+ (raising the soil pH), improves soil structure, and promotes root distribution (Nekesa *et al*., 2005) [9].

The higher seed and haulm yields of cowpea increased with application of lime than farmer's practice. The increase in yield might be due to the neutralization of exchangeable Al^{3+} ions and increase in available Ca^{2+}, which in turn resulted in excellent seed filling. The better uptake of nutrients facilitated by liming increased vegetative growth and resulted in increased dry matter production and ultimately seed yield of cowpea (Mathew and Thampatti, 2007) [7].

Significantly increased yield of cowpea with soil test value based fertilizer application might be attributed to better growth and enhanced photosynthesis in presence of required nutrients in adequate amount and also due to better translocation of photosynthates to sink because of balanced fertilization (Sudhakar *et al*., 2006) [15]. Application of biochar and lime increased the pH and decreased the active forms of Al and soil acidity, which might have led to favourable conditions for higher crop yield. Similar result was reported by Sumner *et al*. (1986) [16]. Calcium is a structural component of cell walls and is vital in the formation of new cells; hence the Ca supply through lime and biochar in the present study could have had a favorable effect on crop yield in lime and biochar treated plots. The results are in agreement with the findings of Troeh and Thompson (1993), Meng and Fu (1994) and Havlin *et al*. (2005) [17, 8, 5].

Conclusion

It is evident from the results that the residual effect of soil test value based fertilizer application along with amendments (Biochar/lime) significantly increased the productivity of cowpea. The integrated use of the chemical fertilizer along with amendments (biochar/lime) influenced the growth and yield parameters of cowpea significantly. The use of amendments along with soil test value based fertilizer application is absolutely essential to sustain the productivity of crop in acid soils and to maintain the soil health for the use of this natural resource by future generations.

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