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Residual and Cumulative Effects of Organic and Inorganic P on Economics of Soybean (*Glycine max* L.) - Onion (*Allium cepa* L.) Cropping Sequence in a High P Alfisol

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A B S T R A C T

A field experiment was conducted during kharif (soybean), 2012 and rabi (onion) 2012-13 in a sandy clay loam soils of college farm, College of Agriculture, Rajendranagar, Hyderabad to study the response of P levels (0, 30 and 60 kg P_2O_5 ha^{-1}) either alone or in combination with PSB @ 5 kg ha^{-1}, biochar @ 5 t ha^{-1}, humic acid @ 20 kg ha^{-1} and citric acid @ 10 mM concentration to study the direct, residual and cumulative effects of the treatments imposed on yield of soybean (direct) and onion (Residual and Cumulative), soybean equivalent yield (Residual and Cumulative) and benefit : cost ratio of soybean (direct) and onion (Residual and Cumulative). The mean seed yield of the soybean with biochar was 2077 kg ha^{-1} which was significantly higher against the control seed yield of 1329 kg ha^{-1}. Biochar resulted in a significant increase in mean onion yield to 22.1 t ha^{-1} against 15.8 t ha^{-1} when organics were not supplemented, the yield response being 39.9 per cent across inorganic P and mode of effect. Yield of soybean - onion cropping sequence was higher with biochar and humic acid when applied along with 30 kg P_2O_5 ha^{-1} with corresponding soybean equivalent yields of 7063 and 6740 kg ha^{-1}. For soybean-onion cropping sequence, residual effect of 30 kg P_2O_5 ha^{-1} + humic acid was economically better with higher B: C ratio of 2.0 followed by 30 kg P_2O_5 ha^{-1} + biochar in both residual and cumulative effects which showed 1.9.

Introduction

Phosphorus is a component of the complex nucleic acid structure of plants, which regulates protein synthesis. Phosphorus is, therefore, important in cell division and development of new tissue. Phosphorus is also associated with complex energy transformations in the plant. P requirement for soybean crop is more during pod and seed development where more than 60% of P ends up in the pods and seeds. Soybean is a P dependent crop, and application of proper P concentrations coordinated production, improved physiological characteristics, and enhanced nutrient uptake (Yan *et al.*, 1995). Onion is one of the most commercially valuable vegetables grown in India. It is considered as a rich source of carbohydrates, proteins and vitamin C besides minerals like phosphorus and calcium. P fertilizer recommendation for soybean and onion crops was same.

The use of fertilizer is one of the most important factors to increase crop yield in soya bean production. Phosphorus is an important element which application is necessary for growth, development and yield of soya beans (Kakar *et al.,* 2002). Reasonable yield and profit can be obtained from the production of soybean if farmers concern themselves with the various ways in which growth and yield of the crop can be enhanced. One of these ways is to consider the nutrient requirement of the crop. This is important because of the depletion of nutrients in the soil caused by continuous cropping. Basso and Rictchie (2005) suggested that for continuous use of land for crop production, organic and inorganic fertilizers must be incorporated into the soil as this will provide multiple benefits for improving the chemical and physical status of the soil as well as improve yield of soya bean.

Application of mineral fertilizer as soil fertility management under intensive continuous cropping is no longer feasible due to non-availability, high cost where available and the numerous side effects on the soil (Akindede and Okeleye, 2005). Farmers using mineral fertilizer for years usually notice signs of soil exhaustion shown by sick appearance of the plant, leaf discolorations, retarded growth and low yield. A combined use of both organic and inorganic fertilizer is beneficial.

Most of the P present in soils is in unavailable forms and added soluble forms of P are quickly fixed by many soils. The inoculation of phosphorus solubilizing microbes has been shown to increase the P availability, P uptake and crop yields. Biochar, a solid co product from the thermo chemical production of bioenergy, has been reported to increase nutrient availability in soils through increased cation retention and decreased phosphate adsorption (Lehmann *et al.*, 2006). In addition, biochar is highly recalcitrant to microbial decomposition and thus guarantees a long term benefit for soil fertility (Steiner *et al.*, 2007). Low molecular weight organic acids have been shown to decrease P adsorption and increase P availability through complexation of cations such as Ca, Al, and Fe (Geelhoed *et al.,* 1999).

Keeping in view the significance of optimization of phosphorus fertilizers by using organics in maintaining the soil health and improvement in the productivity of crops and less study on this cropping sequence, an investigation entitled "Residual and Cumulative Effects of Organic and Inorganic P on Economics of Soybean (*Glycine max* L.) -Onion (*Allium cepa* L.) Cropping Sequence in a High P Alfisol" was planned.

Materials and Methods

During *kharif* (soybean) 2012, the experiment was laid out in split plot design consisting 3 main levels of inorganic P (0, 30 and 60 kg P_2O_5 ha^{-1}) and 5 sub levels of organics (no organics, PSB, biochar, humic acid and citric acid). In r*abi* (onion) 2012-13, the experiment was laid out in split-split plot design, with 2 sub – sub levels (no application, application of best combination from *kharif* to study the residual and cumulative effects respectively). For this all the plots were divided into two equal halves. For one half, neither inorganic P nor organics were applied to know the residual effect on onion grown during *rabi* after harvest of soybean crop. In another half, the best combination from *kharif* was applied to study the cumulative effects. For all the treatments N and K were be applied uniformly at the rate of 30 kg N ha^{-1} and 40 kg K_2O ha^{-1} for soybean, 150 kg N ha^{-1} and 60 kg K_2O ha^{-1}

for onion in the form of urea and MOP respectively. Inorganic P will be applied in the form of DAP and N was adjusted with urea.

The experimental soil was sandy clay loam in texture, slightly alkaline (pH 7.64) in reaction, non-saline (0.195 dS m^{-1}) in nature and medium in organic carbon (0.57 %). The soil was low in available nitrogen (177 kg N ha^{-1}), high in available phosphorus (29.9 kg P ha^{-1}) and potassium (449 kg K ha^{-1}) (Table 1). Nutrient uptake (kg ha^{-1}) by soybean and onion were calculated using the values of per cent nutrient concentrations and dry matter production (kg ha^{-1}). Soybean equivalent yield of soybean – onion cropping sequence was calculated.

The benefit cost ratios were computed through partial budgeting technique by taking into consideration the additional cost incurred due to imposition of the treatments and the additional returns realized, expressed in monetary terms. The treatment without inorganic phosphorus and organic application was taken as control for the purpose of comparison.

The data on various parameters was statistically analysed following the method of analysis of variance for split and double split designs and the significance was tested by 'F' test (Snedecor and Cochran, 1967). Critical difference for comparing the treatment means and their interactions were calculated at 5 per cent level of probability.

Results and Discussion

Seed yield of soybean

The mean seed yield of the soybean with biochar was 2077 kg ha^{-1} which was significantly higher against the control seed yield of 1329 kg ha^{-1}, PSB seed yield of 1287 kg ha^{-1} and citric acid yield of 1463 kg ha^{-1} (Table 2). However, the seed yield put forth by biochar and humic acid were at a par with the per cent yield response being 56 and 55 per cent respectively, across the inorganic P application. The beneficial effects of biochar are determined primarily by some of its properties like high porosity, responsible for its high water retention capacity; high cation exchange capacity, which favours the retention of nutrients and intercept their losses and it has the ability to habitat most of the beneficial organisms, which can increase the release and uptake of nutrients by plants (Atkinson *et al.*, 2010 and Sohi *et al.*, 2010). Beneficial effects of humic substances were shown on plant growth, mineral nutrition, seed germination, seedling growth, root initiation, root growth shoot development and the uptake of macro and micro nutrients, in addition to the claim that 1kg of HA can substitute for 1 ton of manure (Tahir *et al.*, 2011).

When organics were applied alone, humic acid recorded significantly higher seed yield of 1906 kg ha^{-1} over the yields obtained with the control, PSB and citric acid treatments. However, it was on a par with the biochar. Integration of inorganic P at 30 kg P_2O_5 ha^{-1} with biochar showed significantly higher seed yield of 2453 kg ha^{-1}, which was 63.1 per cent higher when compared to inorganic P at 30 kg P_2O_5 ha^{-1} when applied alone. The beneficial effects of biochar are more pronounced when applied in combination with inorganic nutrients rather alone (Baronti *et al.*, 2010).

Bulb yield of onion

Among the organics, biochar application lead to a statistically significant positive effect on both biomass and yield. Biochar resulted in a significant increase in mean onion yield to 22.1 t ha^{-1} against 15.8 t ha^{-1} when organics were not supplemented, the yield response being 39.9 per cent across inorganic P and mode of effect. Biochar addition can increase crop production by improving the physical, chemical properties and soil fertility via effects on the microbial community Lehmann *et al.*, 2011. Among the mode of effect (residual/cumulative), cumulative effect was found to show significant influence resulting in a mean yield of 21 t ha^{-1} which was higher by 22.1 per cent as against 17.2 t ha^{-1} due to the residual effect. Cumulative application of 50% reduced level of inorganic P (30 kg P_2O_5 ha^{-1}) along with biochar to onion, the treatment found to fare well with soybean, showed significantly higher yield than the residual effect across organics and inorganic P (Table 3).

When inorganic P was not applied to soybean, biochar resulted in a significantly higher mean yield of 18.9 t ha^{-1} against 14.2 t ha^{-1}in the treatment that did not receive any organics resulting in a 33 per cent increase in the yield. However, biochar and humic acid were comparable in the yield and at a par. Application of 30 kg P_2O_5 ha^{-1} alone to the soybean across organics and mode of effects resulted in a mean onion bulb yield of 16.4 t ha^{-1} against 14.2 t ha^{-1} in the control, the per cent increase being 15.5 per cent. However, 30 and 60 kg P_2O_5 ha^{-1} levels were on par with each other. Similar response up to 30 kg P_2O_5 ha^{-1} level was observed when integration was exercised with the organics. At this level of inorganic P, the combination with biochar showed significantly higher yield of 23.1 t ha^{-1}. Chandrika and Reddy (2011) also reported similar yields of onion i.e., 31.18 and 23.60 t ha^{-1} respectively in 2004 and 2005 years (Agrifound light red).

Soybean equivalent yield of soybean – onion cropping sequence

When inorganic P was applied alone showed a sharp increase to 4783 kg ha^{-1} at 30 kg P_2O_5 ha^{-1} and later showed a marginal increase to 4920 kg ha^{-1} at 60 kg P_2O_5 ha^{-1} (Table 4). Humic acid when applied alone resulted in the highest soybean equivalent yield of 5629 kg ha^{-1} closely followed by biochar with 5496 kg ha^{-1}. While, at 30 kg P_2O_5 ha^{-1}, biochar put forth higher system yield of 7063 kg ha^{-1} against 6740 kg ha^{-1} with humic acid. Similar trend was observed at the highest level of inorganic P application with a marginal reduction in soybean equivalent yields of 7223 and 6661 kg ha^{-1} respectively. The soybean equivalent yield due to residual and cumulative effects was 5083 and 5848 kg ha^{-1} respectively.

Soybean B-C ratio

Highest B: C ratio was observed with 30 kg P_2O_5 ha^{-1} + humic acid (2.33) followed by 30 kg P_2O_5 ha^{-1} + biochar (2.14). It may be due to the low cost of cultivation *i.e.*, 57,067 Rs ha^{-1} for 30 kg P_2O_5 ha^{-1} + humic acid and a little difference in yield between 30 kg P_2O_5 ha^{-1} + humic acid and 30 kg P_2O_5 ha^{-1} + biochar. Similar results were obtained with Madhavi (2014) in sandy loam soils with high in P status using maize as a test crop and reported that the highest B: C ratio (3.84) was obtained in treatment receiving 75 percent NPK with biochar @ 7.5 t ha^{-1} followed by 75 percent NPK with biochar @ 7.5 t ha^{-1} and humic acid @ 30 kg ha^{-1} (3.77), while recommended NPK alone realized a B: C ratio of 3.66. Treatment receiving 75 percent NPK alone shows lowest (3.30) B: C ratio (Table 5).

Onion B-C ratio

Rabi Among all the treatments, superior B: C ratio recorded with 60 kg P_2O_5 ha^{-1} + biochar in residual effect (2.0) followed by 30 kg P_2O_5 ha^{-1} + biochar in cumulative effect (1.9). It may be due to the low cost of cultivation for residual effect *i.e.*, 1,12,933 Rs ha^{-1} than cumulative effect the value being 1,24,667 Rs ha^{-1} (Table 6).

Table.1 Salient soil characteristics of experimental site

S. No.	Name of the property	Value
I.	**Physical properties**	
a)	Textural fraction	
	1) Sand (%)	**72.04**
	2) Silt (%)	**7.4**
	3) Clay (%)	**20.56**
b)	Textural class	**Sandy clay loam**
II.	**Physico-chemical analysis**	
a)	Soil reaction (pH)	**7.64**
b)	Electrical conductivity (dSm^{-1})	**0.195**
III.	**Chemical properties**	
a)	Organic carbon (%)	**0.57**
b)	Available Nitrogen (kg ha^{-1})	**177**
c)	Available phosphorus (kg P ha^{-1})	**29.9**
d)	**Available potassium (kg K ha^{-1})**	**449**

Table.2 Effect of organics, inorganic P and their interaction on seed yields (kg ha^{-1}) of soybean

Main / **Sub**	**Seed yield**			
	Inorganic P levels (P_2O_5 kg ha^{-1})			
	0	30	60	Mean
No organics	938	1507	1541	**1329**
PSB	1311	1253	1295	**1287**
Biochar	1717	2453	2062	**2077**
Humic acid	1906	2283	1996	**2062**
Citric acid	1074	1796	1517	**1463**
Mean	**1389**	**1899**	**1683**	
	S.Em.±		**CD (*P*=0.05)**	
Main	25		98	
Sub	53		155	
Main at Sub	92		269	
Sub at Main	65		195	

Table.3 Residual and cumulative effects of organics, inorganic P and their interaction on onion yield (t ha^{-1})

Organics-Sub treatments	Inorganic P levels (kg P_2O_5 ha^{-1}) -Main treatments									Means		Mean for Organics
	0			30			60					
	Residual	Cumulative	Mean	Residual	Cumulative	Mean	Residual	Cumulative	Mean	Residual	Cumulative	
No organics	11.9	16.5	**14.2**	14.5	18.3	**16.4**	16.3	17.5	**16.9**	14.2	17.5	**15.8**
PSB	13.0	18.7	**15.8**	17.5	22.9	**20.3**	18.4	22.5	**20.4**	16.3	21.4	**18.8**
Biochar	16.3	21.5	**18.9**	21.2	24.9	**23.1**	22.6	25.8	**24.2**	20.0	24.1	**22.1**
Humic acid	16.1	21.1	**18.6**	21.3	23.3	**22.3**	21.0	23.3	**22.2**	19.5	22.6	**21.0**
Citric acid	13.6	17.8	**15.7**	16.5	20.6	**18.5**	18.0	20.6	**19.3**	16.0	19.6	**17.8**
Mean	**14.2**	**19.1**	**16.6**	**18.2**	**22.0**	**20.1**	**19.3**	**21.9**	**20.6**	**17.2**	**21.0**	**19.1**

	MT	ST	SST	MT at ST	MT at SST	ST at MT	ST at SST	SST at MT	SST at ST	SST at MT, ST	ST,SST at MT	MT at ST, SST
SEm±	0.3	0.2	0.1	0.4	0.3	0.4	0.3	0.2	0.3	0.5	0.3	0.1
CD (*P*=0.05)	1.1	0.6	0.4	1.2	1.2	1.1	0.8	0.6	0.8	NS	NS	NS

Table.4 Soybean equivalent yield of soybean – onion cropping sequence

S. No	Treatments	soybean equivalent yield (kg ha^{-1})
1	No inorganic P + No organics (Res)	3311
2	No inorganic P + No organics (Cum)	4239
3	No inorganic P + PSB (Res)	3906
4	No inorganic P + PSB (Cum)	5046
5	No inorganic P + Biochar (Res)	4970
6	No inorganic P + Biochar (Cum)	6021
7	No inorganic P +Humic acid (Res)	5126
8	No inorganic P +Humic acid (Cum)	6131
9	No inorganic P + Citric acid (Res)	3791
10	No inorganic P + Citric acid (Cum)	4629
11	30 kg P_2O_5 ha^{-1} +No organics (Res)	4397
12	30 kg P_2O_5 ha^{-1} +No organics (Cum)	5168
13	30 kg P_2O_5 ha^{-1} +PSB (Res)	4764
14	30 kg P_2O_5 ha^{-1} +PSB (Cum)	5842
15	30 kg P_2O_5 ha^{-1} +Biochar (Res)	6685
16	30 kg P_2O_5 ha^{-1} +Biochar (Cum)	7440
17	30 kg P_2O_5 ha^{-1} +Humic acid (Res)	6540
18	30 kg P_2O_5 ha^{-1} +Humic acid (Cum)	6939
19	30 kg P_2O_5 ha^{-1} +Citric acid (Res)	5100
20	30 kg P_2O_5 ha^{-1} +Citric acid (Cum)	5910
21	60 kg P_2O_5 ha^{-1} +No organics (Res)	4793
22	60 kg P_2O_5 ha^{-1} +No organics (Cum)	5047
23	60 kg P_2O_5 ha^{-1} +PSB (Res)	4975
24	60 kg P_2O_5 ha^{-1} +PSB (Cum)	5786
25	60 kg P_2O_5 ha^{-1} +Biochar (Res)	6580
26	60 kg P_2O_5 ha^{-1} +Biochar (Cum)	7223
27	60 kg P_2O_5 ha^{-1} +Humic acid (Res)	6199
28	60 kg P_2O_5 ha^{-1} +Humic acid (Cum)	6661
29	60 kg P_2O_5 ha^{-1} +Citric acid (Res)	5114
30	60 kg P_2O_5 ha^{-1} +Citric acid (Cum)	5639

Table.5 Benefit-Cost ratio for Soybean crop

S. No	Treatments	Yield (t ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
1	No inorganic P + No organics	0.9	13235	23458	10223	0.77
2	No inorganic P + PSB	1.3	13435	32777	19342	1.44
3	No inorganic P + Biochar	1.7	18235	42932	24697	1.35
4	No inorganic P +Humic acid	1.9	15835	47652	31817	2.01
5	No inorganic P + Citric acid	1.1	13811	26852	13041	0.94
6	30 kg P_2O_5 ha^{-1} +No organics	1.5	14542	37679	23137	1.59
7	30 kg P_2O_5 ha^{-1} +PSB	1.3	14742	31333	16591	1.13
8	30 kg P_2O_5 ha^{-1} +Biochar	2.5	19542	61332	41790	2.14
9	30 kg P_2O_5 ha^{-1} +Humic acid	2.3	17142	57067	39925	2.33
10	30 kg P_2O_5 ha^{-1} +Citric acid	1.8	15118	44908	29790	1.97
11	60 kg P_2O_5 ha^{-1} +No organics	1.5	15849	38533	22684	1.43
12	60 kg P_2O_5 ha^{-1} +PSB	1.3	16049	32382	16333	1.02
13	60 kg P_2O_5 ha^{-1} +Biochar	2.1	20849	51560	30711	1.47
14	60 kg P_2O_5 ha^{-1} +Humic acid	2.0	18449	49906	31457	1.71
15	60 kg P_2O_5 ha^{-1} +Citric acid	1.5	16425	37932	21507	1.31

Table.6 Benefit-Cost ratio for Onion crop

S. No	Treatments	Yield (t ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
1	No inorganic P + No organics (Res)	11.9	37967	59317	21350	0.6
2	No inorganic P + No organics (Cum)	16.5	40992	82533	41541	1.0
3	No inorganic P + PSB (Res)	13.0	37967	64867	26900	0.7
4	No inorganic P + PSB (Cum)	18.7	41192	93383	52191	1.3
5	No inorganic P + Biochar (Res)	16.3	37967	81317	43350	1.1
6	No inorganic P + Biochar (Cum)	21.5	45992	107600	61608	1.3
7	No inorganic P +Humic acid (Res)	16.1	37967	80500	42533	1.1
8	No inorganic P +Humic acid (Cum)	21.1	43592	105633	62041	1.4
9	No inorganic P + Citric acid (Res)	13.6	37967	67933	29966	0.8
10	No inorganic P + Citric acid (Cum)	17.8	41568	88883	47315	1.1
11	30 kg P_2O_5 ha^{-1} +No organics (Res)	14.5	37967	72250	34283	0.9
12	30 kg P_2O_5 ha^{-1} +No organics (Cum)	18.3	42304	91517	49213	1.2
13	30 kg P_2O_5 ha^{-1} +PSB (Res)	17.6	37967	87767	49800	1.3
14	30 kg P_2O_5 ha^{-1} +PSB (Cum)	22.9	42504	114733	72229	1.7
15	30 kg P_2O_5 ha^{-1} +Biochar (Res)	21.2	37967	105800	67833	1.8
16	30 kg P_2O_5 ha^{-1} +Biochar (Cum)	24.9	43704	124667	80963	1.9
17	30 kg P_2O_5 ha^{-1} +Humic acid (Res)	21.3	37967	106433	68466	1.8
18	30 kg P_2O_5 ha^{-1} +Humic acid (Cum)	23.3	44904	116400	71496	1.6
19	30 kg P_2O_5 ha^{-1} +Citric acid (Res)	16.5	37967	82600	44633	1.2
20	30 kg P_2O_5 ha^{-1} +Citric acid (Cum)	20.6	42880	102850	59970	1.4
21	60 kg P_2O_5 ha^{-1} +No organics (Res)	16.3	37967	81300	43333	1.1
22	60 kg P_2O_5 ha^{-1} +No organics (Cum)	17.5	43611	87650	44039	1.0
23	60 kg P_2O_5 ha^{-1} +PSB (Res)	18.4	37967	92000	54033	1.4
24	60 kg P_2O_5 ha^{-1} +PSB (Cum)	22.5	43811	112267	68456	1.6
25	60 kg P_2O_5 ha^{-1} +Biochar (Res)	22.6	37967	112933	74966	2.0
26	60 kg P_2O_5 ha^{-1} +Biochar (Cum)	25.8	48611	129017	80406	1.7
27	60 kg P_2O_5 ha^{-1} +Humic acid (Res)	21.0	37967	105067	67100	1.8
28	60 kg P_2O_5 ha^{-1} +Humic acid (Cum)	23.3	46211	116633	70422	1.5
29	60 kg P_2O_5 ha^{-1} +Citric acid (Res)	18.0	37967	89917	51950	1.4
30	60 kg P_2O_5 ha^{-1} +Citric acid (Cum)	20.6	44187	103050	58863	1.3

Table.7 Benefit cost ratio for Soybean-Onion cropping sequence

S. No	Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
1	No inorganic P + No organics (Res)	51202	82775	31573	0.6
2	No inorganic P + No organics (Cum)	54227	105992	51765	1.0
3	No inorganic P + PSB (Res)	51402	97644	46242	0.9
4	No inorganic P + PSB (Cum)	54627	126160	71533	1.3
5	No inorganic P + Biochar (Res)	56202	124249	68047	1.2
6	No inorganic P + Biochar (Cum)	64227	150532	86305	1.3
7	No inorganic P +Humic acid (Res)	53802	128152	74350	1.4
8	No inorganic P +Humic acid (Cum)	59427	153285	93858	1.6
9	No inorganic P + Citric acid (Res)	51778	94785	43007	0.8
10	No inorganic P + Citric acid (Cum)	55379	115735	60356	1.1
11	30 kg P_2O_5 ha^{-1} +No organics (Res)	52509	109929	57420	1.1
12	30 kg P_2O_5 ha^{-1} +No organics (Cum)	56846	129195	72349	1.3
13	30 kg P_2O_5 ha^{-1} +PSB (Res)	52709	119099	66390	1.3
14	30 kg P_2O_5 ha^{-1} +PSB (Cum)	57246	146066	88820	1.6
15	30 kg P_2O_5 ha^{-1} +Biochar (Res)	57509	167132	109623	1.9
16	30 kg P_2O_5 ha^{-1} +Biochar (Cum)	63246	185998	122752	1.9
17	30 kg P_2O_5 ha^{-1} +Humic acid (Res)	55109	163500	108391	2.0
18	30 kg P_2O_5 ha^{-1} +Humic acid (Cum)	62046	173467	111421	1.8
19	30 kg P_2O_5 ha^{-1} +Citric acid (Res)	53085	127508	74423	1.4
20	30 kg P_2O_5 ha^{-1} +Citric acid (Cum)	57998	147758	89760	1.5
21	60 kg P_2O_5 ha^{-1} +No organics (Res)	53816	119833	66017	1.2
22	60 kg P_2O_5 ha^{-1} +No organics (Cum)	59460	126183	66723	1.1
23	60 kg P_2O_5 ha^{-1} +PSB (Res)	54016	124382	70366	1.3
24	60 kg P_2O_5 ha^{-1} +PSB (Cum)	59860	144648	84788	1.4
25	60 kg P_2O_5 ha^{-1} +Biochar (Res)	58816	164494	105678	1.8
26	60 kg P_2O_5 ha^{-1} +Biochar (Cum)	69460	180577	111117	1.6
27	60 kg P_2O_5 ha^{-1} +Humic acid (Res)	56416	154973	98557	1.7
28	60 kg P_2O_5 ha^{-1} +Humic acid (Cum)	64660	166539	101879	1.6
29	60 kg P_2O_5 ha^{-1} +Citric acid (Res)	54392	127849	73457	1.4
30	60 kg P_2O_5 ha^{-1} +Citric acid (Cum)	60612	140982	80370	1.3

B-C ratio of soybean-onion cropping sequence

Higher B: C ratio observed with 30 kg P_2O_5 ha^{-1} + humic acid in residual effect (2.0) followed by 30 kg P_2O_5 ha^{-1} + biochar in residual and cumulative effects *i.e*., 1.9.

It may be due to low cost of cultivation (55,109 Rs ha^{-1}) and low net returns (1,08,391 Rs ha^{-1}) due to 30 kg P_2O_5 ha^{-1} + humic acid in residual effect (Table 7). Biochar and humic acid once applied to the field it prolongs its benefit for the next season.

Highest B - C ratio of soybean was obtained with 30 kg P_2O_5 ha^{-1} + humic acid (2.33), while, 60 kg P_2O_5 ha^{-1} + biochar was superior with a B:C ratio of 2.0 in putting forth the residual effect followed by 30 kg P_2O_5 ha^{-1} + biochar in cumulative effect (1.9).

For soybean-onion cropping sequence, higher B: C ratio was obtained with 30 kg P_2O_5 ha^{-1} + humic acid in residual effect (2.0) followed by 30 kg P_2O_5 ha^{-1} + biochar in residual and cumulative effects *i.e*., 1.9.

Even though, the net returns are lower (1,08,391 Rs ha^{-1}) in case of the treatment receiving 30 kg P_2O_5 ha^{-1} + humic acid in residual effect, the cost of cultivation also was less (Rs. 55,109 ha^{-1}) resulting in wider B-C ratio.

In soybean, Inorganic P at 30 and 60 kg P_2O_5 ha^{-1} across the organics significantly increased the mean seed yield of soybean to 1899 and 1683 kg ha^{-1} over 1389 kg ha^{-1} in the control which accounted for 36.7 and 21.2 per cent higher yield respectively in a high P soils. The mean seed yield of the soybean with biochar was 2077 kg ha^{-1} which was significantly higher than the control seed yield of 1329 kg ha^{-1}. In onion, Cumulative effect was found to show significant influence resulting in a mean yield of 21t ha^{-1} which was higher by 22.1 per cent than 17.2 t ha^{-1} due to the residual effect. Soybean equivalent yield of soybean - onion cropping sequence when inorganic P was applied alone showed a sharp increase to 4783 kg ha^{-1} at 30 kg P_2O_5 ha^{-1} and later showed a marginal increase to 4920 kg ha^{-1} at 60 kg P_2O_5 ha^{-1}. Humic acid when applied alone resulted in the highest soybean equivalent yield of 5629 kg ha^{-1} closely followed by biochar with 5496 kg ha^{-1}. While, at 30 kg P_2O_5 ha^{-1}, biochar put forth higher system yield of 7063 kg ha^{-1} against 6740 kg ha^{-1} with humic acid. Similar trend was observed at the highest level of inorganic P application with a marginal reduction in soybean equivalent yields of 7223 and 6661 kg ha^{-1} respectively. The soybean equivalent yield due to residual and cumulative effects were 5083 and 5848 kg ha^{-1} respectively.

For soybean-onion cropping sequence, residual effect 30 kg P_2O_5 ha^{-1} + humic acid were economically better with higher B: C ratio of 2.0 followed by 30 kg P_2O_5 ha^{-1} + biochar in both residual and cumulative effects which showed 1.9. By this, one can emphasize that biochar and humic acid applied for the preceding crop of the sequence will benefit the succeeding crop by the way of sustained residual effect.

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