International Journal of Environment and Climate Change

Volume 13, Issue 9, Page 1414-1423, 2023; Article no.IJECC.102935
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

System Productivity and Balance of Soil Phosphorus in Rice - Zero till Maize (*Zea mays* L.) Cropping System as Influenced by Levels of Phosphorus

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i92371

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/102935

Original Research Article

Received: 24/05/2023
Accepted: 11/07/2023
Published: 19/07/2023

ABSTRACT

Aims: To study the phosphorus requirement of Rice - zero till maize (*Zea mays* L.) cropping system on system productivity and soil available Phosphorus balance.
Study Design: Randomized block design (two factors).
Methodology: The field experiment was conducted for two consecutive years at the College of Agriculture, Rajendranagar, Hyderabad. Levels of P_2O_5 (kg ha^{-1}) applied to rice (5 levels) and maize (3 levels) respectively were (P_{0-30}, P_{0-45}, P_{0-60}, P_{10-30}, P_{10-45}, P_{10-60}, P_{20-30}, P_{20-45}, P_{20-60}, P_{30-30}, P_{30-45}, P_{30-60}, P_{40-30}, P_{40-45} and P_{40-60}).

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Results: In terms of system productivity (maize grain equivalent yield kg ha^{-1} $annum^{-1}$) of rice–maize cropping system, the P_{40-60} and P_{30-60} treatments were found better than other Phosphorus management strategies.
The balance sheet of available Phosphorus in soil at the end of fourth season revealed that input-output balance was positive with P_{40-60} and P_{30-60} by specifying the application of 30 kg P_2O_5 ha^{-1} and/or 40 kg P_2O_5 ha^{-1} to rice and 60 kg P_2O_5 ha^{-1} to maize in rice-zero till maize cropping system.

Keywords: Balance; phosphorus; productivity; rice-zero till maize.

1. INTRODUCTION

Rice-maize is the predominant cropping system occupying in an area of 3.5 m ha in Asia after the Rice-rice and rice-wheat cropping system [1]. According to the study, rice-maize cropping system is swiftly intensifying in south Asia including India due to its potential from *rabi* maize, and its abridged water requirement compared rice-rice system and its multiple uses in poultry and fish feed industries.

In command areas *rabi* maize sowings are being delayed when farmers resort for conventional land preparation resulting in lower yields, thereby ‘late planting’ has become a major constraint. The yield reductions owed to late planting can be circumvented by sowing maize under zero tillage after harvesting of rice crop. Zero tillage would aid in reducing the potential for soil erosion and loss of soil organic matter [2], besides lessening the fuel consumption, labour requirement and turnaround time thus conserving soil and water.

Among the various inputs, Phosphorus is one of the most limiting nutrients in agricultural cropping systems [3-5]. Scheduling fertilizer to cropping systems rather than single crop basis help its rationalized application and economizing expenses [6,7,8]. If fertilizers are not added as per the requirements for high yield of maize there is a possibility of nutrient mining. Accurate nutrient drawn (Phosphorus) factors could be consequent for each soil and crop growing environments whereby yield could be optimized without considerable mining of nutrients from the soil [9]. Therefore, management practices relying on intensive cropping sequences require detailed information on nutrient changes in the soil to better manage additional fertility requirements of the subsequent crop.

Soil physical and chemical properties and associated management for alternating wetting and drying environments of Rice-Wheat system that could be well applied to Rice-Maize system as well [10-14]. It is reported that Rice-Maize system is quite different from Rice-Wheat or Rice-Rice system in nutrient extraction, which would be much greater due to higher yield of maize.

In rice and other ID crops in rice-based cropping systems, alternate wetting and drying during *rabi* season reduces native Phosphorus availability to ID crops like maize and increases crop response to applied Phosphorus. Furthermore, it has been advocated for the application of phosphatic fertilizers to *rabi* season crops and growing *kharif* season crops on residual fertility in most of the soils, wheat being a winter crop, responds more to phosphorus application than wet season rice [15]. Efficient utilization of fertilizer Phosphorus, residual and cumulative effects of Phosphorus should be considered while formulating fertilizer use recommendations in different cropping sequences [16].

Although several technologies have been developed for rice-wheat rotation, the same may not be suitable for rice-zero tillage maize situations especially on Phosphorus requirements. Keeping these things in mind the present study was organized to investigate the direct residual and cumulative effect of phosphatic fertilizer application on yield of crops and phosphorus balance in rice-zero till maize cropping system.

2. MATERIALS AND METHODS

The study was conducted in the College farm located at College of Agriculture, Rajendranagar, Hyderabad, Telangana, India (17º 19' North latitude, 78º 27' East longitude and 542.6 m above mean sea level). The soil at the experimental site was a well drained sandy clay loam [17] with 61.56 g sand, 15.58 g silt and 22.6 g clay per 100 g soil in the surface horizon. Initial soil properties of composite samples taken from 0 to 15 cm soil depth were with 0.63% Organic carbon [18], 8.33 pH [19], 0.46 dSm^{-1} electrical conductivity [19], 197.50 kg ha^{-1} available Nitrogen [20], 16.96 kg ha^{-1} available

Phosphorus [21] and 163.5 kg ha^{-1} available Potassium [22]. Experiment was conducted with rice and zero tillage maize respectively, during *kharif* and *rabi* seasons.

The experiment was laid out in randomized block design (two factors) with three replications at five Phosphorus levels to rice viz; F_1: No Phosphorus, F_2: 10 kg P_2O_5 ha^{-1}, F_3: 20 kg P_2O_5 ha^{-1}, F_4: 30 kg P_2O_5 ha^{-1} and F_5: 40 kg P_2O_5 ha^{-1} and three phosphorus levels to maize viz; P_1: 30 kg P_2O_5 ha^{-1}, P_2: 45 kg P_2O_5 ha^{-1} and P_3: 60 kg P_2O_5 ha^{-1}. The levels of P_2O_5 (kg ha^{-1}) applied to rice and zero tillage maize respectively in different treatments were ((T_1: P_{0-30}, T_2:P_{0-45}, T_3: P_{0-60}, T_4: P_{10-30}, T_5: P_{10-45}, T_6: P_{10-60}, T_7: P_{20-30}, T_8: P_{20-45}, T_9: P_{20-60}, T_{10}: P_{30-30}, T_{11}: P_{30-45}, T_{12}: P_{30-60}, T_{13}: P_{40-30}, T_{14}: P_{40-45} and T_{15}: P_{40-60}).

After completion of puddling rice seedlings of MTU 1010 variety were transplanted in the plots during *kharif* season of first year by adopting a spacing of 20 cm x 10 cm at shallow depth of 2-3 cm. Likewise, the rice seedlings during *kharif* season of the succeeding year were also planted in the same plots without disturbing the layout of previous year. The entire quantity of phosphorus according to treatments through single super phosphate and entire recommended potassium as Muriate of Potash were incorporated basally into the soil before last puddling. Recommended rate of Nitrogen was applied in equal splits at transplanting; maximum tillering and at panicle initiation stage of rice. All other recommended agronomic practices were followed uniformly for all the experimental plots of rice.

The Maize hybrid (Super 900 M) seeds were dibbled under no-till condition by adopting a spacing of 60 cm between rows and 20 cm between plants within a row during *rabi* season during consecutive years in the same plots without disturbing the layout of previous *kharif* season rice. The entire quantity of P_2O_5 according to treatments through single super phosphate and the entire recommended dose of Potassium as Muriate of Potash were applied in bands at 5 cm away and 5 cm below the seed at the time of sowing. The recommended dose of Nitrogen was applied as Urea in three equal split doses at basal and top dressing at knee high and tasselling stage of the maize crop. Paraquat @ 1.5 kg a.i.ha^{-1} was applied to the entire field after harvesting of rice crop to control the existing weeds and to prevent the re-growth of rice stubble. One day after sowing of maize seeds, pre emergence herbicide (Atrazine) was applied at recommended rate to the entire field. No irrigation was given after sowing of the crop as there was sufficient residual soil moisture. Subsequent need based irrigations and all other agronomic practices were followed uniformly for all the experimental plots.

The grain and straw yield of rice and grain and stover yield of maize were quantified separately from samples collected in a 16.64 m^2 area in rice and 10.56 m^2 area in maize and converted to kg ha^{-1}. Grain yields were adjusted to moisture content of 0.14 kg moisture kg^{-1} grain. Samples collected at harvest were shade dried followed by oven drying at 60°C to attain a constant weight. Samples of grain and straw of rice and grain and stover maize were finely ground and used for Phosphorus analysis by adopting standard procedures. The finely ground samples were digested with tri-acid mixture (Nitric acid, Sulphuric acid and Perchloric acid in 9: 4:1 ratio) and was used for Phosphorus estimation by Vanado-Molybdo Phosphoric acid method [10]. Phosphorus uptake by grain and stover was obtained by multiplying the P concentration with their respective grain and stover yield of maize and with seed and straw yield of rice to obtain uptake by rice grain and straw, respectively.

After the harvest of crops at the end of each season, treatment wise soil samples collected from 0–30 cm depth were air dried and analysed for available Phosphorus status following standard procedures [17]. Available Phosphorus of the soil samples were extracted with Olsen's extractant (0.5 M $NaHCO_3$). Phosphorus in the extractant was estimated colorimetrically by Ascorbic acid method [21] and was expressed as kg of Phosphorus ha^{-1} after adjusting for bulk density.

2.1 Phosphorus Balance

Input-Output Balance: Assuming that Phosphorus input from rain fall and irrigation water was small and equivalent to phosphorus leaching loss [23] and taking into account that straw and stalks of plants were removed after their cut at ground level and estimated the phosphorus input-output balance of each crop and cropping sequence for two years.

Input-output balance (kg P ha^{-1})= Fertilizer P input (kg P ha^{-1}) -Total P uptake (kg P ha^{-1})

Expected Balance: Phosphorus expected balance for crop sequence at the end of the second year was worked out as:

X = ((A + B) - C)

Where,

X is the expected balance of Phosphorus (kg) at the end of second year,
A is the Initial status of available phosphorus,
B is the addition of phosphorus through inorganic source to the crop sequence and
C is the quantity of Phosphorus (kg) removed by crop sequence.

2.2 Maize Equivalent Yield (kg ha^{-1} year^{-1})

Seed yield obtained from different treatments were converted into maize equivalents on the basis of local market prices with the help of the following formula

$$\text{Maize equivalent (Kg ha}^{-1}\text{ year}^{-1}) = \frac{\text{Seed yield of rice (kg ha}^{-1}) \text{ X price of rice (Rs. kg}^{-1})}{\text{Maize seed price (Rs. kg}^{-1}) + \text{Maize yield (kg ha}^{-1})}$$

2.3 Analysis of Variance (ANOVA)

Analysis of variance was carried out for each character separately as per standard statistical procedure for two factors randomized block design as suggested by the Panse and Sukhatme [24]. Wherever the treatment differences were found significant critical differences were worked out at five % probability level (P=0.05) and treatment differences that were non-significant were denoted by 'NS'.

3. RESULTS AND DISCUSSION

3.1 System Productivity

The System Productivity computed as maize grain equivalent yield of rice-maize cropping system, as influenced by different levels of Phosphorus in rice-maize sequence are presented (Table 1). Highest system productivity of 11161 and 10614 kg ha^{-1} yr^{-1} was recorded in rice-maize system with the application of recommended dose of Phosphorus to both crops (Rice-40 kg P_2O_5 ha^{-1}; Maize-60 kg P_2O_5 ha^{-1}) during first year and second year over all other treatment combinations except $P_{30\text{-}60}$ treatment. These results support the findings of many researchers [25,6,26].

Table 1. Effect of phosphorus levels on system productivity (maize equivalent yield) of rice-maize cropping system

Treatments	System productivity (kg ha^{-1} yr^{-1})	
	First year	Second Year
Phosphorus levels to rice and maize		
$P_{0\text{-}30}$	8942	8258
$P_{0\text{-}45}$	9506	9298
$P_{0\text{-}60}$	9897	9963
$P_{10\text{-}30}$	9525	8764
$P_{10\text{-}45}$	10005	9470
$P_{10\text{-}60}$	10355	10125
$P_{20\text{-}30}$	10003	9294
$P_{20\text{-}45}$	10463	9791
$P_{20\text{-}60}$	10783	10297
$P_{30\text{-}30}$	10422	9880
$P_{30\text{-}45}$	10618	10183
$P_{30\text{-}60}$	10945	10460
$P_{40\text{-}30}$	10692	9967
$P_{40\text{-}45}$	10861	10222
$P_{40\text{-}60}$	11161	10614
SE(m) ±	100	108
C.D.(P = 0.05)	291	314
Kharif		
F_1:No Phosphorus	9448	9173
F_2: 10 kg P_2O_5 ha^{-1}	9962	9453
F_3: 20 kg P_2O_5 ha^{-1}	10416	9794
F_4: 30 kg P_2O_5 ha^{-1}	10662	10174
F_5: 40 kg P_2O_5 ha^{-1}	10905	10268
SE(m) ±	58	63
C.D.(P = 0.05)	167	181

Treatments	System productivity (kg ha^{-1} yr^{-1})	
	First year	**Second Year**
Rabi		
P_1: 30 kg P_2O_5 ha^{-1}	9917	9233
P_2: 45 kg P_2O_5 ha^{-1}	10291	9793
P_3: 60 kg P_2O_5 ha^{-1}	10628	10292
S.Em.±	45	48
C.D.(P = 0.05)	130	140

3.2 Post-Harvest Available Phosphorus Status after Rice

3.2.1 Direct effect

Post-harvest soil available Phosphorus status after rice harvest as influenced by different levels of phosphorus application is presented (Table 2). Application of 40 kg P_2O_5 ha^{-1} to rice left behind greater amount of P in soil, which was followed by 30 kg P_2O_5 ha^{-1}, 20 kg P_2O_5 ha^{-1} and 10 kg P_2O_5 ha^{-1} and no phosphorus. The trend was similar in second year at the end of the rice crop in rice-maize sequence. The differences in soil P between any two Phosphorus levels were significant [25,6].

Table 2. Direct, residual and cumulative effect of phosphorus levels in rice-maize cropping system on phosphorus (kg ha^{-1}) after harvest of rice

Treatments	First year	Second year
Direct (*Kharif*)		
F_1:No Phosphorus	16.00	15.95
F_2: 10 kg P_2O_5 ha^{-1}	16.34	17.06
F_3: 20 kg P_2O_5 ha^{-1}	16.57	17.34
F_4: 30 kg P_2O_5 ha^{-1}	16.81	17.53
F_5: 40 kg P_2O_5 ha^{-1}	17.04	17.72
SE(m) ±	0.07	0.05
C.D.(P = 0.05)	0.19	0.13
Residual (*Rabi*)		
P_1: 30 kg P_2O_5 ha^{-1}	-	16.57
P_2: 45 kg P_2O_5 ha^{-1}	-	17.25
P_3: 60 kg P_2O_5 ha^{-1}	-	17.55
S.Em.±	-	0.04
C.D.(P = 0.05)	-	0.10
Phosphorus levels to rice and maize		
P_{0-30}	-	15.67
P_{0-45}	-	15.81
P_{0-60}	-	16.37
P_{10-30}	-	16.53
P_{10-45}	-	17.20
P_{10-60}	-	17.45
P_{20-30}	-	16.72
P_{20-45}	-	17.55
P_{20-60}	-	17.75
P_{30-30}	-	16.89
P_{30-45}	-	17.77
P_{30-60}	-	17.92
P_{40-30}	-	17.02
P_{40-45}	-	17.90
P_{40-60}	-	18.25
SE(m) ±	-	0.08
C.D.(P = 0.05)	-	0.23

Table 3. Direct, residual and cumulative effect of phosphorus levels in rice-maize cropping system on available phosphorus (kg ha^{-1}) after harvest of maize

Treatments	First year	Second Year
Direct (*Rabi*)		
P_1: 30 kg P_2O_5 ha^{-1}	16.57	15.70
P_2: 45 kg P_2O_5 ha^{-1}	17.25	15.99
P_3: 60 kg P_2O_5 ha^{-1}	17.57	16.51
S.Em.±	0.04	0.03
C.D.(P = 0.05)	0.14	0.10
Residual (*Kharif*)		
F_1:No Phosphorus	15.95	15.47
F_2: 10 kg P_2O_5 ha^{-1}	17.06	15.68
F_3: 20 kg P_2O_5 ha^{-1}	17.34	16.03
F_4: 30 kg P_2O_5 ha^{-1}	17.56	16.38
F_5: 40 kg P_2O_5 ha^{-1}	17.72	16.78
SE(m) ±	0.05	0.04
C.D.(P = 0.05)	0.16	0.13
Phosphorus levels to rice and maize		
P_{0-30}	15.67	15.16
P_{0-45}	15.81	15.31
P_{0-60}	16.37	15.95
P_{10-30}	16.53	15.43
P_{10-45}	17.20	15.59
P_{10-60}	17.45	16.02
P_{20-30}	16.72	15.62
P_{20-45}	17.55	16.11
P_{20-60}	17.75	16.35
P_{30-30}	16.89	15.84
P_{30-45}	17.77	16.28
P_{30-60}	18.03	17.02
P_{40-30}	17.02	16.44
P_{40-45}	17.90	16.68
P_{40-60}	18.25	17.23
SE(m) ±	0.12	0.08
C.D.(P = 0.05)	0.34	0.22

Table 4. Phosphorus balance sheet of rice- maize cropping system as influenced by levels of phosphorus

Treatments (kg P_2O_5 ha^{-1} during *kharif* (rice) and *rabi* (maize) seasons)	Added phosphorus (kg P ha^{-1})					Phosphorus uptake (kg P ha^{-1})					Available P (kg ha^{-1}) at the end of 4th season	Phosphorus balance (kg P ha^{-1})	
	Season				Total P	After each season				Total		Expected balance	Input-out put balance
	1st Rice	2nd Maize	3rd Rice	4th Maize		1st Rice	2nd Maize	3rd Rice	4th Maize				
P_{0-30}	0	13.2	0	13.2	26.4	15.71	13.40	14.89	10.88	54.88	15.16	-11.52	-28.48
P_{0-45}	0	19.8	0	19.8	39.6	15.60	15.80	17.30	13.56	62.26	15.31	-5.70	-22.66
P_{0-60}	0	26.4	0	26.4	52.8	15.70	16.85	18.38	15.33	66.26	15.95	3.50	-13.46
P_{10-30}	4.4	13.2	4.4	13.2	35.2	17.99	14.90	15.57	12.13	60.59	15.43	-8.43	-25.39
P_{10-45}	4.4	19.8	4.4	19.8	48.4	18.07	16.30	17.84	13.87	66.08	15.59	-0.72	-17.68
P_{10-60}	4.4	26.4	4.4	26.4	61.6	18.09	17.69	19.04	16.28	71.10	16.02	7.46	-9.50
P_{20-30}	8.8	13.2	8.8	13.2	44.0	20.05	15.21	17.77	13.01	66.04	15.62	-5.08	-22.04
P_{20-45}	8.8	19.8	8.8	19.8	57.2	20.05	16.92	19.29	14.43	70.69	16.11	3.47	-13.49
P_{20-60}	8.8	26.4	8.8	26.4	70.4	20.04	17.82	20.06	16.71	74.63	16.35	12.73	-4.23
P_{30-30}	13.2	13.2	13.2	13.2	52.8	20.77	16.59	18.10	15.01	70.47	15.84	-0.71	-17.67
P_{30-45}	13.2	19.8	13.2	19.8	66.0	20.77	17.46	19.76	16.10	74.09	16.28	8.87	-8.09
P_{30-60}	13.2	26.4	13.2	26.4	79.2	20.78	18.67	20.32	18.36	78.13	17.02	18.03	1.07
P_{40-30}	17.6	13.2	17.6	13.2	61.6	21.58	18.10	18.33	15.43	73.44	16.44	5.12	-11.84
P_{40-45}	17.6	19.8	17.6	19.8	74.8	21.47	18.48	19.96	16.28	76.19	16.68	15.57	-1.39
P_{40-60}	17.6	26.4	17.6	26.4	88.0	21.55	19.59	20.36	19.83	81.33	17.23	23.63	6.67
SE(m) ±	-	-	-	-	-		0.21	0.19	0.23	-	0.08	-	-
C.D.(P = 0.05)	-	-	-	-	-		0.62	0.55	0.67	-	0.22	-	-

3.2.2 Residual effect

The residual effect of previous year applied Phosphorus on soil available Phosphous in second year after harvest of rice increased significantly with increased Phosphorus levels to maize [27,7,8].

3.2.3 Cumulative effect

In the second year, the interaction between the Phosphorus levels applied to rice and maize showed that cumulative application of 40 kg P_2O_5 ha^{-1} in rice-maize sequence through P_{40-60} treatment left behind higher amount of Phosphorus in soil after second year rice over rest of the treatment combinations, however it was found at par with P_{30-60} treatment [16,3,28].

3.3 Post-Harvest Available Phosphorus Status after Maize

3.3.1 Direct effect

Post-harvest soil available nutrient status after maize harvest as influenced by different levels of phosphorus application is presented (Table 3). The direct effect of phosphorus application to maize both years showed that the soil was left significantly with more amount of available phosphorus when the soil was applied at higher rate of phosphorus @60 kg P_2O_5 ha^{-1} as compared to its lower rates of application [29,7,8].

3.3.2 Residual effect

The residual effect on soil phosphorus status during both years also showed significantly more amount of soil phosphorus due to its increased level of application [16,30,28,31].

3.4 Phosphorus Balance

The phosphorus balance in rice-maize sequence as influenced by different levels of Phosphorus to rice and maize in rice-maize cropping system is presented (Table 4). Initially the soil had 16.96 kg available Phosphorus ha^{-1}. Rice and maize removed increasingly higher quantities of Phosphorus from the soil with increase in the rate of its application up to 40 kg P_2O_5 ha^{-1} to rice and 60 kg P_2O_5 ha^{-1} to maize (P_{40-60}). The uptake of Phosphorus by maize crop was much less than the rice crop [28,31].

The total uptake of Phosphorus by four crops was 54.88 kg ha^{-1} at the end of the two crop cycles when no P was applied to rice and 30 kg P_2O_5 ha^{-1} to maize (P_{0-30}). The total uptake increased to 66.26 kg ha^{-1} when no Phosphorus was applied to rice and 60 kg P_2O_5 ha^{-1} to maize (P_{0-60}). The total uptake increased to 73.44 kg ha^{-1} with increased level of Phosphorus to rice (40 kg P_2O_5 ha^{-1}) and 30 kg P_2O_5 ha^{-1} to maize (P_{40-30}). The uptake increased further to a highest of 81.33 kg ha^{-1} by application of recommended dose of phosphorus to both rice and maize (P_{40-60}).

The available Phosphorus at the end of fourth season was 15.16 kg Phosphorus ha^{-1} with no Phosphorus to rice and 30 kg P_2O_5 ha^{-1} to maize (P_{0-30}) in rice-zero till maize cropping system against the initial value of 16.96 kg ha^{-1}. Further when expected balance was computed it should a negative balance of 11.52 kg ha^{-1}. The input-output balance was also found negative with a higher value of 28.48 kg P ha^{-1} with this treatment over other treatment combinations. Conversely, there was a slight improvement in the available Phosphorus (kg ha^{-1}) at the end of the fourth season (17.23) with application of 40 kg P_2O_5 ha^{-1} to rice and 60 kg P_2O_5 ha^{-1} to maize through P_{40-60} treatment. However, when input-output balance was considered in addition to P_{40-60} treatment (6.67 kg ha^{-1}), P_{30-60} treatment also showed a positive balance of 1.07 kg P ha^{-1}. These results are in conformity with the findings of different researchers [16,26, 32,33].

4. CONCLUSION

1. Higher system productivity realized due to the application of 30 kg P_2O_5 ha^{-1} to rice and 60 kg P_2O_5 ha^{-1} to maize in rice-zero till maize crop sequence with a saving of 10 kg P_2O_5 ha^{-1} $annum^{-1}$.
2. The soil Phosphorus was sustained to its initial level at the end of two crop cycles due to the application of 30 or 40 kg P_2O_5 ha^{-1} to rice and 60 kg P_2O_5 ha^{-1} to maize in rice-zero till maize crop sequence.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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