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Validations of fertilizer recommendations based on soil tests for yield targets of mulberry under farmers' field conditions in Chhotanagpur plateau of Jharkhand

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ABSTRACT

Soil test crop response correlations studies conducted with mulberry on sandy loam yellow-reddish coarse textured soil under rainfed condition at Regional Sericultural Research Station, Ranchi, Jharkhand provided correlations of high predictability between biomass yield of mulberry, soil available nutrients and fertilizers applied. Based on yield target, fertilizer adjustment equations for situation and site-specific fertilizer recommendations for mulberry have already been evolved. The reproducibility of these recommendations has been verified by undertaking follow-up trials under farmers' field conditions. The results showed that fertilizer application based on yield target gave higher yields over the farmers' practice. The target yield approach was also found superior in respect of net benefit, B/C and response ratios to the fertilizer application based on soil tests.

Key words: Fertilizer recommendations, soil test crop response, yield, validation

Fertilizer constitutes one of the costliest inputs in the present day sericulture. Greater economy in fertilizer use can be made, if fertilizers are applied on the basis of soil test. This practice ensures balanced fertilization, higher yield and more profitability. The fertility gradient field experimental technique of Bray (1949) and Ramamoorthy *et al.* (1967) for evolving soil test based fertilizer recommendations to crops is unique in the sense that response of crop to applied nutrients is studied on representative soils, where, variations in soil fertility had earlier been created by applying different amounts of fertilizer nutrient to the preceding crop. The approach circumvents the effects of soil heterogeneity, management practices and climatic conditions on the response behaviour of crops through native and fertilizer nutrients. Besides balanced nutrition of growing crop, the approach gives due consideration to soil fertility and strikes a real balance between the nutrients already available in the soil and those required by the crops to achieve a predetermined yield target. This helps to maintain soil fertility. The present studies were, therefore, undertaken with a view to test evolved soil test based fertilizer recommendations for mulberry for their adaptability under farmers' field conditions.

MATERIALS AND METHODS

Five frontline farm demonstrations on mulberry were conducted during 2004-2005 in three districts of Jharkhand to demonstrate the balanced use of fertilizer based on targeted yield concept. The treatments comprised of

(i) Farmers' practice

(ii) Fertilizer application based on soil test: According to this approach fertilizer recommendations are made by classifying the soil into low, medium and high categories for a given nutrient. General recommendations are made for medium category and the fertilizer dose is increased (low category soils) or decreased (high category soils) by 25%.

(iii) Fertilizer application based on soil test to attain a yield target of 7.00 t ha^{-1} $year^{-1}$.

The available status of soil nutrients (Table 2) was used to compute fertilizer doses for each target of mulberry through adjustment equations using basic data that had earlier been generated from fertility gradient field experiments for mulberry. The detailed procedure has been described by Bose *et al.* (2006).

RESULTS AND DISCUSSION

Verification of target yield equations under farmers' field conditions

The applicability of the target yield equations developed for mulberry was tested by conducting five follow-up trials in Lohardaga, Gumla and Khunti districts of Jharkhand. The results showed that against the mulberry yield target of 7.00 t ha^{-1} $year^{-1}$, the yield at five locations varied from 7.26 to 7.67 t ha^{-1} $year^{-1}$, with a mean of 7.55 t ha^{-1} $year^{-1}$ (Table 3). The variations in yield obtained from the targeted ones ranged from 3.71 to 9.57%. The farmers' practice of fertilizer application was the least efficient in producing leaf yield. The leaf yield obtained by applying fertilizer on the basis of soil tests averaged 8.30 t ha^{-1} $year^{-1}$. Economics of fertilizer application based on targeted concept gave net benefit varying from ₹4881.00 to ₹6083.00 ha^{-1} $year^{-1}$ (Table 1). The corresponding values for fertilizer application based

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on soil tests for mulberry were ₹ 4266.00 to ₹5054.00 ha^{-1} $year^{-1}$. The benefit : cost and response ratios of fertilizer application based on targeted yield concept varied from 8.37 to 10.47 and 23.32 to 27.82 whereas the corresponding values for fertilizer application based on soil tests were 1.66 to 1.96 and 12.48 to 13.92, respectively. These results are in conformity with the results of Reddy and Ahmad (1999) and Milap *et al.* (2006) who observed higher benefit-cost ratio through targeted yield approach in comparison to farmers' practice and general recommended dose of fertilizer in groundnut grown on rice fallows in Andhra Pradesh and mustard and rapeseed in Punjab, respectively. The superiority of targeted yield approach over the dose recommended by the soil test could be ascribed to the fact that every fertilizer recommendation of target is based on the actual soil test values and it avoids the sub- or super-optimal use of fertilizer under low, medium and high soil fertility conditions.

Table 1: Economics of demonstrations at farmers' fields

Treatment	N:P: K (kg ha^{-1} $year^{-1}$)	Leaf yield (kg ha^{-1} $year^{-1}$)	Additional leaf yield (kg ha^{-1} $year^{-1}$)	Value of additional leaf yield (₹ ha^{-1})	Cost of fertilizer (₹ ha^{-1})	Net benefit (₹ ha^{-1})	B:C ratio	Response ratio (kg kg^{-1})
Serenghatu, Lohardaga								
Farmers' practices	40 : 15 : 15	4718	---	---	---	---	---	---
As per soil test	187 : 50 : 37	8245	3527	7054	2576	4478	1.74	12.87
7.00 t ha^{-1} $year^{-1}$ target	52 : 28 : 29	7640	2922	5844	536	5308	9.90	26.81
Citri Ambatoli, Lohardaga								
Farmers' practices	40 : 15 : 15	4900	---	---	---	---	---	---
As per soil test	187 : 50 : 37	8321	3421	6842	2576	4266	1.66	12.48
7.00 t ha^{-1} $year^{-1}$ target	56 :33 :15	7670	2770	5540	591	4949	8.37	26.63
Ekkaguri, Lohardaga								
Farmers' practices	40 : 15 : 15	4450	---	---	---	---	---	---
As per soil test	187 : 50 : 37	8112	3662	7324	2576	4748	1.84	13.36
7.00 t ha^{-1} $year^{-1}$ target	65 : 26 :10	7260	2810	5620	490	5130	10.47	27.82
Bharno, Gumla								
Farmers' practices	40 : 15 : 15	4612	---	---	---	---	---	---
As per soil test	187 : 50 : 37	8427	3815	7630	2576	5054	1.96	13.92
7.00 t ha^{-1} $year^{-1}$ target	64 : 30 : 29	7610	3398	6796	713	6083	8.53	27.62
Sundari, Khunti								
Farmers' practices	40 : 15 : 15	4851	---	---	---	---	---	---
As per soil test	187 : 50 : 37	8400	3549	7098	2576	4522	1.75	12.95
7.00 t ha^{-1} $year^{-1}$ target	60 : 25 : 32	7580	2729	5458	577	4881	8.45	23.32

Rate : N 10.90, P_2O_5 23.13 and K_2O 7.47 Rs kg^{-1}. Mulberry leaf ₹ 2.00 kg^{-1}

Table 2: Location and fertility status of experimental sites

Location	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Serenghatu, Lohardaga	209	30	280
Citri Ambatoli, Lohardaga	201	27	341
Ekkaguri, Lohardaga	175	31	361
Bharno, Gumla	182	29	280
Sundari, Khunti	190	32	268

Table 3: Fertilizer applied and yield obtained in different experimental sites

Site	Target (t ha^{-1} $year^{-1}$)	Fertilizer applied (kg ha^{-1} $year^{-1}$)			Yield obtained (t ha^{-1} $year^{-1}$)	Deviation (± %)
		N	P_2O_5	K_2O		
Serenghatu	7.0	52	28	29	7.64	+9.14
Citri Ambatoli	7.0	56	33	15	7.67	+9.57
Ekkaguri	7.0	65	26	10	7.26	+3.71
Bharno	7.0	64	30	29	7.61	+8.71
Sundari	7.0	60	25	32	7.58	+8.28

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Eeffect of arsenate on phosphorus accumulation in rice under simulated condition

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ABSTRACT

During the study of arsenic (As) accumulation in plant parts, a pot experiment in simulated As condition with different doses of arsenate (As^V) viz., 20, 30, 50 ppm and control with four popular rice varieties viz. Triguna, IR 36, PNR 519 and IET 4786 was conducted. It was observed that availability of phosphorus (P) concentration in soil was increased after irrigation with As^V. Phosphorus accumulation increased in root and husk with increase of As^V in all the cultivars. P accumulated in increased level in shoot of all cultivars up to 30 ppm of As^V except in IET 4786 where it increased up to 50 ppm. P accumulation was also increased in seeds of Triguna and IR 36 with the increase of As^V up to 50 ppm but it had shown reducing effect on P accumulation above 20 ppm in IET 4786 and above 30 ppm in PNR 519.

Key words: Arsenate, arsenic, phosphorus, rice cultivars

Inorganic arsenic (As_i) is a class I carcinogen (Anon, 2004). This is widespread chronic As_i poisoning in regions of Asia, South America and elsewhere, due to the consumption of drinking water with geogenically elevated As_i, with the situation at its worst in the densely populated floodplains and deltas of south and southeast Asia (Brammer and Ravenscroft, 2009; Nordstrom, 2002). Now alongwith drinking water, plant-based food is also an important source of As_i contamination.

Consequently rice is a major crop being cultivated in the areas where severe As contamination exists including Bangladesh, India, Taiwan and China (Williams *et al.*, 2005). Rice has been reported to accumulate up to 1.8 mg kg^{-1} As in grains and up to 92 mg kg^{-1} in straw (Abedin *et al.*, 2002). The total As (mg kg^{-1} dw) concentration in rice varies from 0.005 to 0.710 in different varieties and it also differs from one geographical region to other e.g. <0.01-2.05 for Bangladesh, 0.31-0.76 for China, 0.03-0.44 for India and 0.11-0.66 for USA (Zavala and Duxbury, 2008). Arsenic contamination of rice is therefore a newly uncovered disaster on a massive scale. The physical and chemical techniques available for remediation of As has not shown promise to deal with this huge problem (Mondal *et al.*, 2006).

Development of arsenic tolerant rice (Safe grain Arsenic levels for population) through breeding and molecular approaches is an urgent necessity for improving the safe crop productivity in developing countries, particularly in India (Tripathi *et al.*, 2007; Adhikari *et al.*, 2009.).

MATERIALS AND METHODS

A pot experiment in simulated As condition was conducted in the net house of Rice Research Station, Chinsurah, West Bengal during *boro* 2007-08. Four popular HYVs of rice *viz.* Triguna, IR 36, PNR 519 and IET 4786 (Satabdi) were selected for the experiment. Grains were allowed to germinate after surface sterilization (by 0.1% $HgCl_2$ for 1 min). Transplanting was done with the seedlings of three week. Three seedlings (1 seedlings /hill) of each cultivar were planted at three different places of one pot (14" earthen pot) and the pots were placed into a net house under natural light and humid conditions. Pots were watered daily with deionized water to maintain water logging condition. During tillering, the plants were irrigated with different arsenic concentrations (0, 20, 30 and 50 ppm) and for this Na_2HAsO_4 were used. Two more irrigations of arsenic were given at pre-flowering and post-flowering stages.

Plants were uprooted carefully and washed thoroughly and brought to the laboratory for analysis. In the laboratory plants were separated into root, shoot, husk and grains. After separation, roots were washed with Milli-Q water. Washed rice roots (1g) were treated with dithionate citrate bicarbonate (DCB) solution (Taylor and Crowder, 1983) to know the level of mineral nutrients adsorbed on the plaque and their relation with As sequestration. pH and EC of soil were measured by ion meter (Orion, USA), while water holding capacity was measured by hydrometry.

P level in rice plant parts and soil including DCB solution , was determined by colorimetric method (Jackson, 1973). As was quantified with the help of inductively coupled plasma mass spectrometer (ICP-MS, Agilent 7500ce) coupled with high performance liquid chromatography (HPLC) and procedure of analysis was performed by following the protocol of Abedin *et al.*, 2002a).

All the experiment was conducted following a randomized block design. Two ways analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) was performed to determine the significant difference between treatments and genotypes.

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RESULTS AND DISCUSSION

The level of P in Fe-plaque increased by increasing the As^V supply in soil, upto 30 ppm, but at higher As^V dose (50 ppm) a slight reduction in P was observed in IR 36 and IET 4786 (Fig. 1A). Table 1 showed physico-chemical properties and P and As composition in control pot soil and after supply of different As concentrations. Fe-plaque is commonly formed on the rice roots due to release of oxygen and oxidants into rhizosphere (Liu *et al.*, 2006) and thus differential ability of rice genotypes in terms of oxygen evolution from roots leads to variable Fe-plaque-forming ability and subsequently, variable tendency to accumulate metals and metalloids (Dwivedi *et al.*, 2010). But accumulation of P in the root of IET 4786 (Shatabdi) was exceptionally high at 50 ppm arsenic concentration in compare to the root of other cultivars at the same level. High concentration As and low concentration of P in rice roots indicate that As can competitively inhibit P uptake by roots (Zhang and Duan, 2008) owing to the fact that As is a phosphate analogue and thus both compete for the same transporters (Meharg and Macnair, 1992). The maximum P accumulation (mg kg^{-1}) in shoot was found in variety Triguna (388.01) followed by IET 4786 (316.58) and PNR-519 (307.79) and least in IR-36 (305.68). The P content in the shoot increases with the increasing As upto 30 ppm, but increasing trend of P accumulation was observed upto 50 ppm in IET 4786 (Fig. 1C). Zhang and Duan (2008) also reported that shoot P concentration of various tested genotypes decreased due to increased concentration of As. The content of P in husk increased upto 50 ppm in all the varieties and maximum increase was found in Triguna followed by IR-36, PNR-519 and IET-4786 (Fig. 1D). Maximum P accumulation (mg kg^{-1}) in seed was found in IET 4786 (37.86) under control conditions and was increased upto 20 ppm; there after it was in decreasing trend. P accumulation was maximum (80.65 mg kg^{-1}) in the seed of PNR 519 at 30 ppm As^V. Increasing trend of P accumulation (mg kg^{-1}) in seed was found in Triguna and IR 36 upto 50 ppm As^V supply. In case of IET 4786, P accumulation was in decreasing rate above 20 ppm As^V while it was slightly declined above 30 ppm As^V in case of PNR 519 (Fig. 1E). It was clearly observed from the result that P accumulated at higher amount in root and shoot but at lower amount in husk and seed of all the four cultivars. Increasing or decreasing rate of P accumulation is not in similar order in all the cultivars. In IET 4786, P accumulation was much higher in root and shoots but very low in seed as compare to other cultivars. Thus accumulation of P at different parts of rice plant not only depend on the genotypic differences of the cultivars but also the genetic architecture of the individual cultivar may have some partitioning effect in uptake and transport of P in different parts of the plant along with the supply of irrigation water with As^V. Zhang and Duan (2008) found significant difference in As uptake and translocation between rice genotype. Rai *et al.* (2011) reported that IET-4786 is very sensitive to arsenic stress due to reduction of both sulphate assimilation pathway and antioxidant defence enzymes in As-detoxification. However Triguna and IR-36 showed considerable detoxification mechanism due to up-regulation of several of these genes during arsenic stress.

Table 1: Physico-chemical properties and P and As composition in control pot soil and after supply of different As concentrations

Parameters	Control	As (20 ppm)	As (30 ppm)	As (50 ppm)
pH	7.60 ± 0.32	7.40 ± 0.76	7.30 ± 0.54	7.00 ± 0.44
Electrical conductivity (EC)	176.70 ± 5.66	275.30 ± 8.21	283.00 ± 8.88	332.30 ± 9.21
Total organic carbon (%)	2.21 ± 0.05	2.46 ± 0.04	2.23 ± 0.04	2.30 ± 0.02
Water holding capacity (%)	71.98 ± 3.50	74.79 ± 4. 90	75.62 ± 4.10	76.54 ± 5.10
Bulk density (g cm^{-3})	1.26 ± 0.04	1.20 ± 0.04	1.21 ± 0.03	1.18 ± 0.05
Particle density (g cm^{-3})	1.68 ± 0.01	1.72 ± 0.03	1.81 ± 0.02	1.79 ± 0.04
Available P	447.42 ± 11.30	725.69 ± 17.00	605.56 ± 27.20	525.47± 16.70
Fe	76146 ± 336.30	75436 ± 300.90	76429 ±26	73214 ± 299.50
As	5.43 ± 0.23	24.0 ±1.67	26.27 ±1.210	31.17 ±2.81

All the values are mean of triplicates ±S.D. ANOVA significant at $p \leq 0.01$.