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On-Farm Nutrient Depletion and Buildup in Vertisols under Soybean (*Glycine max*) based Cropping Systems in Semi Arid Central India

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ABSTRACT: Information on nutrient depletion and build up in production systems in India is not only scarce but also mostly generalized especially under dryland conditions where fertilizer input levels are sub-optimal. On-farm nutrient balance study was taken up in 2000-2001 and 2001-2002 at Lalatora watershed in Madhya Pradesh with soybean-chickpea and soybean-wheat cropping systems. Soils of this watershed were low in N and P but were high in available K. In general, nutrient input levels were very low and in some cases even nil thereby yield levels of these cropping systems were also found low. Distribution of rainfall was considered as an important factor influencing the response of crops to nutrients. Overall, the soybean-chickpea system removed more nutrients than soybean-wheat system. Among nutrients, N and K were depleted from soil while P was buildup under both the cropping systems. Results of the study suggest that attention is needed towards net depletion of N and K and utilization of build up P as a residual effect in subsequent crops.

Keywords: Cropping systems, depletion and buildup of nutrients, on-farm trials

Even with low productivity of 0.8 to 1.0 t ha^{-1}, continuous cropping without adequate restorative practices endangered the sustainability of agriculture largely due to mining of soils in tropical India. Characterizing nutrient supplying capacity of 21 locations of rainfed regions of India, Srinivasarao (2005) reported that soils of these regions were low in organic carbon and nitrogen and low to high in available P and K. Rainfed agriculture in the tropics is commonly referred to as one ton agriculture and is characterized as drought prone, low fertility, severely degraded and subsistence agriculture (Wani *et al.*, 2003). Wani *et al.* (2003) showed that long term average productivity of rainfed Vertisols over 30 years was 4.7 t ha^{-1} with improved management as compared to 1 t ha^{-1} with the farmers' practice. On the other hand, fertilizer application in rainfed agriculture is sub-optimal to nil because of low resources of poor farmers. Recent analysis of more than one thousand farmers' fields spread from north to south India revealed that more than 95 per cent farmers' fields were deficient in organic C and total nitrogen content (Rego *et al.*, 2005) and 80-100 per cent fields were deficient in zinc, boron and sulphur contents also. However, cropping systems with improved varieties and better management practices often remove lager quantities of nutrients than those added, thus, resulting in net depletion of soil nutrients. Nutrient depletion leads to soil degradation. A quantitative knowledge on the depletion or build up of plant nutrients in soils helps to understand the state of soil degradation and is helpful in devising nutrient management strategies. ICRISAT-led consortium developed an integrated watershed management espousing integrated genetic and natural resource management approach. This strategy involved farmers' participatory research and development approach under which number of on-farm nutrient management trials was conducted. This study involved monitoring of major nutrients depletion/buildup on farmers' fields with soybean based systems on Vertisols in India.

Materials and Methods

Crop yields of soybean-chickpea and soybean-wheat cropping systems were monitored in 6 farmers' fields in 2000-2001 and 8 farmers' fields in 2001-2002 in Lalatora watershed in Vidisha district of Madhya Pradesh. Initially, 31 farmers' fields were characterized for nutrient status (Table 1). Soils were medium to deep Vertisols, alkaline in reaction, non-saline and deficient in N and available P and sufficient in available K

(Jackson, 1973). Crops were grown with farmers' practice such as fertilizers and other inputs and grain and straw yields of the systems were recorded for two years. Total crop nutrient uptake of N, P and K were computed from plant nutrient contents and dry matter yields. For legume crops, it was assumed that 50 per cent N was derived from biological nitrogen fixation (Rego *et al.,* 2003). From the total uptake and nutrient input data, depletion or buildup of N, P and K in soil were computed.

Results and Discussion

Nutrient Input

In general, fertilizer application was lower than recommended levels in both the years. Nitrogen application during 2000-2001 varied from 9 to 14 kg ha^{-1} for soybean and from 7 to 46 kg ha^{-1} for chickpea with the mean total N addition for soybean-chickpea system being 27 kg ha^{-1}. In case of soybean, all the farmers applied N at 9 kg ha^{-1} while for wheat, it varied widely from 18 to 77 kg N ha^{-1} with the mean total addition for soybean-wheat system being 71 kg^{-1}. During 2001-2002, fertilizer N addition was lower than in the previous year. For soybean and chickpea, N added varied from 0 to 9 kg ha^{-1} with the mean total N applied for the system being 14 kg ha^{-1}. For soybean-wheat system, the mean total was 17 kg ha^{-1}. It indicates that N addition was more for soybean-wheat systems than for soybean–chickpea systems possibly due to awareness about biological nitrogen fixation in case of legume crops. Similarly, P application was higher in 2000-2001 than in 2001-2002, the mean total P applied for soybean-chickpea system being 31 kg ha^{-1} and 27 kg ha^{-1}, respectively. In case of soybean-wheat system, the mean total P application was 39 kg ha^{-1} and 33 kg ha^{-1} in 2000-01 and 2001-02 respectively. In both the years, K was not applied to all the crops due to high available K in soils.

Grain Yields

Despite high fertilizer application in 2000-01, crop yields were higher in 2001-02. However, soybean yields were higher in 2000-01 than in subsequent year while chickpea or wheat yields were higher in 2001-02. This could be attributed to amount of rainfall (around 1000 mm in the both the years) and its distribution. During first year, well distributed rainfall during rainy season and early withdrawal resulted in lower yields of post-rainy season crops. On the other hand, ill distribution during rainy season and late withdrawal of rainfall resulted in higher yield levels of post rainy crops in 2001-02. Therefore, good rainfall and its distribution are found crucial for achieving higher grain yield for unit fertilizer input under rainfed conditions (Venkateswarlu *et al.,* 2006).

Nutrient Uptake

Nitrogen uptake was highest followed by K and P uptake (Table 4). Soybean-chickpea system showed higher N uptake than soybean-wheat system in both the years. N uptake was almost similar in both the years in the case of soybean-wheat system. Phosphorus uptake was higher in 2001-02 than in 2000-01 due to higher grain and straw yields. Potassium uptake by soybean-chickpea system was 88 kg ha^{-1} and 124 kg ha^{-1} in 2000-01 and 2001-02, respectively while it was 89 kg ha^{-1} and 62 kg ha^{-1} in soybean-wheat system in 2000-01 and 2001-02, respectively.

Nutrient Depletion and Buildup

Among nutrients, there was depletion of N and K while build up of P was observed in both the cropping systems. Among nutrients, depletion of K in soil was more drastic than N. Nitrogen depletion was higher in 2001-02 than in 2000-01. Overall depletion of soil N was lower when nitrogen fertilizer was applied, while depletion was more in absence of N input. Net depletion of N was reported in absence of fertilizer N in a Vertisol under sorghum-chickpea system (Talanur and Badanur, 2003). Phosphorus buildup was observed in all the crops. It could be due to higher P input and low levels of P use efficiency leading to larger build up of added P in soil. More accumulation of P occurred in the soybean-wheat system than soybean-chickpea system due to larger P application to that system. As there was no K input, total crop K requirements were fully met from soil K reserves. In absence of added K, crops depend on nonexchangeable K reserves in soils for their K requirements. Srinivasarao *et al.* (1999) reported that long term cropping in absence of external K input, depleted nonexchangeable K reserves in soil substantially and there were considerable reductions in the release rates from soil reserve K fraction in medium black soils. During the two years in 2000-01 and 2001-02, 133 kg ha^{-1} and 130 kg ha^{-1} of N

Table 1. Nutrient status of surface soils (0-15 cm) of farmers' fields in Lalatora watershed, Madhya Pradesh (mean of 31 fields).

Parameter	Minimum	Maximum	Mean ± SD	Percent deficient
pH	7.61	8.31	-	-
EC	0.16	0.33	0.24±0.04	-
Organic carbon (%)	0.46	0.92	0.64±0.12	10
Total N (mg kg^{-1})	490	922	684±120	100
Available P (mg kg^{-1})	0.50	14.1	2.71±2.57	90
Available K (mg kg^{-1})	97	285	212±37	0

Table 2. Grain and stover yields of two different cropping systems on Vertisol in farmers fields (Mean±SE)

Yield	Soybean(6)*	Chickpea(6)*	Soybean(8)*	Wheat(8)*
Year 2000-01				
Grain	1475±66	1764±140	1569±88	2533±210
Stover	1395±63	1527±132	1484±83	2870±219
Year 2001-02				
Grain	1294±138	2750±182	1253±133	3942±145
Stover	1651±164	2102±108	1523±134	5527±373

* No. of farmers fields.

Table 3. Nutrient input (kg ha^{-1}) to two different cropping systems on Vertisols in farmers' fields

Nutrient	Soybean	Chickpea	Total system(6)	Soybean (8)	Wheat (8)	Total system(8)
Year 2000-01						
N	9-14(10)**	7-46(17)	27	9 (9)	18-77(62)	71
P	10-30(23)	0-10(8)	31	24 (24)	10-20(15)	39
K	0	0	0	0	0	0
Year 2001-02						
N	0-9 (8)	0-7(6)	14	7-14(10)	7-9(7)	17
P	0-24 (20)	0-8(7)	27	22-30(25)	8-10(8)	33
K	0	0	0	0	0	0

* No. of farmers; ** Mean.

Table 4. Nutrient uptake (kg ha^{-1}) by two cropping systems on Vertisols in farmers' fields

Nutrient	Soybean	Chickpea	Total system(6)	Soybean (8)	Wheat (8)	Total system(8)
Year 2000-01(6)*						
N	83-113(102)**	39-79(61)	163 #	81-140(105)	34-70(53)	158
P	5-9(7)	4-6(5)	12	6-11(8)	6-9(7)	15
K	35-53(45)	34-50(43)	88	40-69(52)	22-50(37)	89
Year 2001-02(8)*						
N	58-116(92)	62-109(94)	186	45-119(85)	53-98(69)	154
P	3-10(7)	6-11(9)	16	3-9(7)	7-14(11)	18
K	30-73(53)	59-82(70)	123	25-61(48)	43-90 (62)	110

* No. of farmers; ** Mean; # 50% N uptake was taken from BNF in legume crops.

Table 5. Depletion and build up of nutrients (kg ha^{-1}) under two cropping systems on Vertisols in farmers fields.

Nutrient	Soybean	Chickpea	Total system	Soybean	Wheat	Total system
Year 2000-01(6)*						
N	-32 to -47(-41)**	-30 to +22(-13)	-54***	-31 to –61(-43)	-16 to +31(+9)	-34
P	+1 to +22(+16)	-4 to +6(+3	+19	+13 to +18(+16)	+4 to +14(+8)	+24
K	-35 to -53(-45)	-34 to –50(-43)	-88	-40 to –69(-52)	-22 to –50(-37)	-89
Year 2001-02(8)*						
N	-23 to -49(-38)	-24 to -47(-41)	-79	-13 to –52(-33)	-46 to –91(-61)	-94
P	-3 to +19(+13)	-6 to +1(-2)	+11	+15 to +21(+18)	-6 to +1(-2)	+16
K	-41 to -73(-53)	-59 to –82(-70)	-124	-25 to –61(-48)	-43 to –90(-62)	-111

* No. of farmers fields; ** Mean; *** Mean of the system.

respectively was taken up from the soil by soybean-chickpea system. More depletion of N with only legume i.e. soybean-chickpea system is largely due to low levels of fertilizer N application, low BNF in farmers' fields due to inappropriate soil, water and nutrient management options and no return of residues to the soils. Similarly, P was buildup by 30 kg ha^{-1} and 39 kg ha^{-1} in soybean-chickpea and soybean-wheat system respectively. In case of K, depletion was 212 kg ha^{-1} and 200 kg ha^{-1} in soybean-chickpea and soybean-wheat systems, respectively. Tiwari *et al.* (2002) reported build up of N and P under long-term soybean-wheat system on a Vertisol at Jabalpur with recommended doses of NPK, while there was a net K depletion. In farmers' fields under sorghum and groundnut-based dryland cropping systems in semi arid tropical India, Rego *et al.* (2003) reported net negative balances of N and K whereas there was a buildup of P. Rego *et al.* (2005) stated that these rainfed soils have been under cultivation without much external input of nutrients for longer period, resulting in mining and depletion of scanty stocks of nutrients. They further stated that farmers avoid external input because of the risk of crop failure due to erratic rainfall in these regions.

Conclusions

This on-farm watershed study evaluating improved cultivars and management practices enabled to study nutrient balances in two commonly used soybean based production systems in Vertisol area of Central India. Responses to nutrient inputs were higher in the year with well distributed rainfall. Among nutrients, potassium depletion was higher followed by nitrogen while there was build up of P in soil. These findings call for urgent action to train the farmers to make them aware about the need for balanced nutrition for sustaining yields. This study also suggests that attention may be needed towards utilization of built up P to harness its residual effect in subsequent crops. These on-farm participatory trials revealed that soybean-based systems more so soybean+chickpea sequential system depleted soil for N as well as K and also for other secondary and micronutrients as crop residues are also removed from the fields along with grains. There is an urgent need to enhance awareness amongst farmers to follow balanced and integrated nutrient management strategies. Efforts to improve BNF on farmers fields through alleviating water logging, soil nutrient deficiencies as well as inoculating efficient rhizobial strains along with organic matter amendments.

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