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Soil Science

Cotton Productivity, Profitability and Changes in Soil Properties under Different Nutrient Management Practices

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Abstract

Cotton is an important fibre crop of global significance, which is, cultivated in tropical and sub-tropical regions of more than seventy countries the world over. A field experiment was conducted during *kharif,* 2013 to evaluate the nutrient requirement of *Bt* cotton *vis-a-vis* fertilizer practices in vogue. At different growth stages, except control, all other treatments recorded higher number of monopodial and sympodial branches than 100% RDF. Incremental doses of fertilizers increased number of bolls plant^{-1} but very high doses practiced by farmers did not help in increasing boll number. Kapas yield increased with increasing fertilizer dose from 100 to 150% but was on par with the yield realized in 100% NPK and soil test based fertilizer application. Quality parameters like seed index, lint index and ginning out turn were not influenced by the fertilizer treatments. Availability nitrogen was lowest in control and highest in farmers' practice. Availability phosphorus and potassium was lowest in control and highest in soil test based fertilizer application. Available sulphur content in soil was lowest in control and highest in 150% RDF + S @ 30 kg ha^{-1}. Micronutrient status in soil at flowering and harvest stages was not significantly influenced by the fertilizer treatments. Economic analysis also indicated that application of very high doses of fertilizers did not help in getting higher net returns or higher benefit cost ratio. It is logical to resortof soil test based fertilizer application or to adopt the present recommendation of 150:60:60 kg NPK ha^{-1} for profitable cultivation of *Bt* cotton in Warangal district of Telangana state.

Highlights:

- Adoption of soil test based fertilizer application or present recommendation of 150:60:60 kg NPK ha^{-1} stands valid for profitable cultivation of *Bt* cotton in Warangal district of Telangana State.

Keywords: *Bt* cotton, nutrient management, productivity, profitability, nutrient availability, economics

Cotton is an important fibre crop of global significance, which is, cultivated in tropical and sub-tropical regions of more than seventy countries the world over. The major producers of cotton are China, India, USA, Pakistan, Uzbekistan, Argentina, Australia, Greece, Brazil, Mexico and Turkey. These countries contribute about 85% to the global cotton production. India made its long-awaited entry into commercial agricultural biotechnology in March 2002 with the approval of *Bt*-cotton hybrids for commercial cultivation. India has the largest acreage (10.33 m. ha) under cotton at global level and has the productivity of 486 kg lint ha^{-1} and ranks second in production 295 lakh bales (5.02 m MT) after China during 2013-14. Introduction of *Bt* hybrids has promoted cotton cultivation to an extent of 15.37 lakh hectare during 2014-15 in the state of Telangana and Warangal is one of the major cotton growing district with 2.5 lakh hectares during 2014-15 (Advance estimates of Department of Agriculture, Govt of Telangana State).Cotton, particularly hybrid cotton being exhaustive, draw plenty of soil nutrients and thus under continuous cropping pattern nutrient management assumes importance. The yield potential of the crop can be exploited to the maximum only when the nutrient requirements are fully met. The optimal dose of nutrients builds up a favourable condition in increasing cotton productivity and improves the quality. On the other hand, excess application of fertilizer has its own limitation in promoting vegetative growth. Response of nutrients in cotton varies significantly among varieties and locations and therefore, region specific recommendation of nutrients are essential. Keeping these points in view, the present study was undertaken to investigate the response of *Bt* cotton to different fertilizer levels and finding the best management practice for higher productivity and profitability.

Material and Methods

The present study was carried out during *kharif,* 2013 at research farm of KVK, Malyal, Warangal district. Nine treatments viz., Control, Farmers practice, Recommended dose of fertilizers (RDF-150:60:60 kg NPK ha^{-1}), RDF + S @ 30 kg ha^{-1}, Soil test based fertilizer application for an yield target of 25q ha^{-1}, 125% RDF, 125% RDF + S @ 30 kg ha^{-1},150% RDF, 150% RDF + S @ 30 kg ha^{-1} were tested in randomised block design with 3 replications to evaluate the nutrient requirement of *Bt* cotton *vis-a-vis* fertilizer practices in vogue. The soil of the experimental site was sandy clay loam in texture with 67% sand, 13% silt and 20% clay content. The soil was neutral in reaction (7.04) with low electrical conductivity (0.17dSm^{-1}), medium in organic carbon content (0.57%), low in available N(156.8 kg ha^{-1}), low in available P(9.98 kg ha^{-1}) and medium in available K (190.4 kg ha^{-1}), deficient in available S (5.2 ppm), low in available Zn (0.22 ppm) and high in Cu, Mn and Fe (3.7, 30.8 and 16.3 ppm respectively).

All the treatments were imposed using straight fertilizers Viz., Urea, Single Super Phosphate, Muriate of Potash and Sulphur dust to supply NPK and Sulphur. Entire dose of phosphorus and sulphur were applied at the time of sowing as basal while nitrogen and potassium were applied in four splits at 20, 40, 60 and 80 days after sowing as recommended by the State Agricultural University (ANGRAU).

As specific STCR equations for *Bt* cotton in Warangal district were not available, soil test equations developed for *Alfisols* of Kadapa region of Andhra Pradesh by STCR approach were used for obtaining the fertilizer doses under Soil test based fertilizer application for an yield target of 25q ha^{-1} treatment:

$$F\ N = 8.15 \times T - 0.57\ SN;$$
$$F\ P_2O_5 = 2.95 \times T - 2.80\ SP;$$
$$F\ K_2O = 5.92 \times T - 0.66\ SK$$

To identify the farmers' nutrient management practices, a survey was carried out by collecting information from cotton cultivators in Warangal district during pre *kharif* season of 2013. Results revealed that farmers of this region apply very high doses fertilizers to cotton. The average fertilizer dose adapted in Warangal district was 333:97:142:17 kg NPKS ha^{-1} as against recommended dose of 150:60:60 and yield realized was ranging from 21-35 q ha^{-1} with an average 30 q ha^{-1}.

Available nutrients were estimated by using the standard extractants and procedures viz. nitrogen by 0.32% Alkaline $KMnO_4$ (Subbaiah and Asija, 1956), phosphorus by Olsens method with 0.5M $NaHCO_3$ (Olsen *et al.* 1954), potassium with 1 N Neutral Normal Ammonium Acetate method (Jackson, 1973) and sulphur by Turbidometric method with 0.15% $CaCl_2$ (Williams and Steinberg, 1959). The available micronutrients (Zn, Cu, Mn and Fe) were analysed in Atomic absorption spectrophotometer using DTPA extractant (Lindsay and Norvell, 1978).

Results and Discussion

Effect of fertilizer doses on monopodial and sympodial branches

The data on important yield attributing parameters is presented in Table 1. Production of branches in cotton was significantly influenced by fertilizer management. At different growth stages (80, 100 and 120 DAS) highest monopodial and sympodial branches per plant was recorded with farmer's practice and lowest with control. Increasing doses of fertilizers resulted in increased number of monopodial branches at all stages. In case of sympodial branches, at 80 DAS, except with control the differences among various fertilizer doses were non-significant. With advancement of stage i.e. at 100 DAS and 120 DAS the number of fruiting branches were high in treatments receiving higher fertilizers. Except control, all other treatments recorded higher number of sympodial branches than 100% RDF. The increase in sympodial branches $plant^{-1}$ might be due to the fact that

Table 1. Yield attributes of *Bt* cotton as influenced by different fertilizer practices

Treatments	Number of monopodial branches plant^{-1}			Number of sympodial branches plant^{-1}			Number of bolls plant^{-1}			Boll weight (g boll^{-1}) at 120 DAS
	80 DAS	100 DAS	120 DAS	80 DAS	100 DAS	120 DAS	80 DAS	100 DAS	120 DAS	
Control (No fertilizer)	1.03	1.22	1.45	10.65	13.48	17.49	7.9	10.17	15.6	3.50
Farmers practice (333-97-142-17 kg NPKS ha^{-1})	1.70	1.96	2.00	21.50	25.64	29.67	12.5	20.08	32.3	4.70
Recommended dose of fertilizers (RDF) (150-60-60 kg NPK ha^{-1})	1.38	1.68	1.75	16.87	20.54	22.87	13.1	22.10	33.6	4.76
RDF + S @ 30 kg ha^{-1} (150-60-60-30 kg NPKS ha^{-1})	1.42	1.73	1.84	17.50	22.07	23.80	13.5	22.60	34.6	4.81
Soil Test based fertilizer application (114-104-28 kg NPK ha^{-1})	1.40	1.70	1.80	18.56	22.54	24.05	13.8	23.60	35.1	4.87
125% RDF (188-75-75 kg NPK ha^{-1})	1.51	1.83	1.85	19.05	23.04	25.70	14.0	24.10	36.2	4.91
125% RDF + S @ 30 kg ha^{-1} (188-75-75 -30 kg NPKS ha^{-1})	1.55	1.87	1.89	19.70	23.51	27.00	14.5	25.10	37.2	4.95
150% RDF (225-90-90 kg NPK ha^{-1})	1.59	1.90	1.92	20.50	24.02	28.07	15.1	27.10	38.3	4.97
150% RDF + S @ 30 kg ha^{-1} (225-90-90 -30 kg NPKS ha^{-1})	1.65	1.92	1.96	21.00	24.60	29.00	15.5	28.01	40.1	5.07
SEm ±	0.12	0.13	0.09	1.63	2.86	2.30	1.0	2.4	2.6	0.13
CD (P=0.05)	0.35	0.40	0.26	4.93	6.12	6.96	3.0	7.2	7.8	0.39

Table 2. Productivity and Profitability of *Bt* cotton as influenced by different fertilizer practices

Treatments	Productivity				Profitability			
	Seed cotton yield (kg ha^{-1})	Seed Index (g)	lint index (g)	Ginning Out Turn (%)	Cost of Cultivation (₹ ha^{-1})	Gross Returns (₹ ha^{-1})	Net Returns (₹ ha^{-1})	Benefit Cost ratio
Control (No fertilizer)	1249	8.24	4.83	37.0	29350	46123	16863	1.57
Farmers practice (333-97-142-17 kg NPKS ha^{-1})	3582	8.30	4.88	36.5	41978	132542	90564	3.16
Recommended dose of fertilizers (RDF) (150-60-60 kg NPK ha^{-1})	3616	8.32	5.00	37.5	35618	135069	99451	3.79
RDF + S @ 30 kg ha^{-1} (150-60-60-30 kg NPKS ha^{-1})	3665	8.34	5.07	37.7	35794	135365	99571	3.78
Soil Test based fertilizer application (114-104-28 kg NPK ha^{-1})	3688	8.32	5.03	37.5	36130	136457	100327	3.78
125% RDF (188-75-75 kg NPK ha^{-1})	3717	8.37	5.09	37.8	37157	137545	100388	3.70
125% RDF + S @ 30 kg ha^{-1} (188-75-75 -30 kg NPKS ha^{-1})	3747	8.40	5.14	38.0	37333	138627	101294	3.71
150% RDF (225-90-90 kg NPK ha-1)	3837	8.42	5.10	37.5	38711	141967	103256	3.67
150% RDF + S @ 30 kg ha-1 (225-90-90 -30 kg NPKS ha-1)	3845	8.44	5.08	37.3	38887	142257	103370	3.66
SEm ±	202	0.05	0.41	2.0				
CD (P=0.05)	612	NS	NS	NS				

Table 3. Physico–chemical properties and organic carbon content of post harvest soil as influenced by different fertilizer practices

Treatments	pH	EC (dS m^{-1})	CEC (cmol (P^+) kg^{-1})	OC (%)
Control(No fertilizer)	7.1	0.16	23.0	0.60
Farmers practice (333:97:142:17 kg NPKS ha^{-1})	6.9	0.19	28.8	0.54
Recommended dose of fertilizers (RDF) (150:60:60 kg NPK ha^{-1})	7.0	0.17	27.2	0.57
RDF + S @ 30 kg ha^{-1} (150:60:60:30 kg NPKS ha^{-1})	7.0	0.17	28.0	0.57
STB fertilizer application (114:104:28 kg NPK ha^{-1})	7.0	0.17	26.9	0.57
125% RDF(188:75:75 kg NPK ha^{-1})	7.0	0.18	28.1	0.56
125% RDF + S @ 30 kg ha^{-1} (188:75:75:30 kg NPKS ha^{-1})	7.0	0.18	28.5	0.56
150% RDF (225:90:90 kg NPK ha^{-1})	6.9	0.19	29.8	0.55
150% RDF + S @ 30 kg ha^{-1} (225:90:90:30 kg NPKS ha^{-1})	6.9	0.19	30.5	0.55
SEm±	0.07	0.007	2.0	0.01
CD (P=0.05)	NS	NS	NS	NS

Table 4. Available nitrogen, phosphorus, potassium and sulphur status in soil at flowering and harvest of *Bt* cotton as influenced by different fertilizer practices

Treatments	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Sulphur (ppm)	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
Control (No fertilizer)	134.7	123.7	8.5	7.9	174.5	162.0	3.4	2.4
Farmers practice (333-97-142-17 kg NPKS ha^{-1})	187.5	170.8	37.3	32.5	267.5	235.3	13.6	10.7
Recommended dose of fertilizers (RDF) (150-60-60 kg NPK ha^{-1})	150.5	141.3	21.0	17.7	211.5	196.9	7.7	6.1
RDF + S @ 30 kg ha^{-1} (150-60-60-30 kg NPKS ha^{-1})	163.2	145.8	22.5	19.7	215.3	198.2	8.6	7.8
Soil Test based fertilizer application (114-104-28 kg NPK ha^{-1})	143.8	135.2	40.0	34.2	196.8	183.9	8.7	7.4
125% RDF (188-75-75 kg NPK ha^{-1})	156.1	145.2	25.5	19.6	225.2	209.0	8.1	6.5
125% RDF + S @ 30 kg ha^{-1} (188-75-75 -30 kg NPKS ha^{-1})	168.8	158.2	28.5	23.3	230.9	217.3	9.3	8.5
150% RDF (225-90-90 kg NPK ha^{-1})	165.3	150.3	32.0	27.2	239.7	223.7	8.6	7.1
150% RDF + S @ 30 kg ha^{-1} (225-90-90 -30 kg NPKS ha^{-1})	173.5	165.4	34.2	30.0	245.1	228.8	14.8	12.1
SEm $\pm$	6.4	7.8	1.3	1.7	8.2	11.6	0.7	0.5
CD (P=0.05)	19.3	23.5	4.0	5.1	24.8	35.0	2.1	1.6

Table 5. Available Micronutrient status of soil at flowering and harvesting stages of *Bt* cotton as influenced by different fertilizer practices

Treatments	Zn (μg g^{-1})		Cu (μg g^{-1})		Mn (μg g^{-1})		Fe (μg g^{-1})	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
Control (No fertilizer)	0.32	0.23	2.90	2.67	27.0	26.0	18.1	15.0
Farmers practice (333-97-142-17 kg NPKS ha^{-1})	0.34	0.19	3.01	2.89	28.3	27.8	18.3	17.1
Recommended dose of fertilizers (RDF) (150-60-60 kg NPK ha^{-1})	0.44	0.26	3.21	2.94	28.2	27.9	18.5	16.1
RDF + S @ 30 kg ha^{-1} (150-60-60-30 kg NPKS ha^{-1})	0.40	0.26	2.98	2.74	27.0	26.4	18.0	15.8
Soil Test based fertilizer application (114-104-28 kg NPK ha^{-1})	0.42	0.25	3.17	2.72	27.0	28.0	17.9	15.9
125% RDF (188-75-75 kg NPK ha^{-1})	0.43	0.23	3.11	2.81	27.5	27.2	18.6	17.9
125% RDF + S @ 30 kg ha^{-1} (188-75-75 -30 kg NPKS ha^{-1})	0.42	0.22	3.08	2.90	29.0	28.1	19.3	17.3
150% RDF (225-90-90 kg NPK ha^{-1})	0.46	0.21	2.92	2.78	28.3	28.0	18.3	15.7
150% RDF + S @ 30 kg ha^{-1} (225-90-90 -30 kg NPKS ha^{-1})	0.36	0.21	2.96	2.85	28.2	27.8	19.0	16.0
SEm $\pm$	0.05	0.01	0.25	0.06	0.70	0.43	0.63	1.89
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

nitrogen helped in cell division and cell elongation leading to increased number of lateral branches. Kumar *et al.* (2011) reported increase in monopodial branches plant^{-1} by 5.4 percent with the application of 125% of recommended dose of fertilizer when compared to 100% RDF (150:60:60 kg NPK ha^{-1}) and 1.4% increase in sympodials due to application of 125% recommended dose of fertilizer.

Effect of fertilizer doses on boll number and development

Boll number and boll weight are very important yield attributing characters that decide the yield. At all stages, control treatment recorded lowest number of bolls plant^{-1}. Incremental doses of fertilizers increased number of bolls plant^{-1} but very high doses of fertilizers as practiced by farmers did not help in increasing boll number. At all the stages, higher number of bolls were produced by the crop that received 150% RDF + S @ 30 kg ha^{-1} but it was on par with number of bolls in other fertilizer treatments. Boll weight at 120 DAS also followed similar trend as that of boll number. In confirmation to reports of Devraj *et al.* (2011) and Nehra *et al.* (2012) this trend reiterates the fact that excess application of fertilizers particularly nitrogen results in increased vegetative growth but does not help in promoting production of reproductive parts that contribute to yield.

Effect of fertilizer doses on seed cotton (kapas) yield: The yield potential of the crop can be exploited to the maximum only when the nutrient requirements are fully met. On the other hand, excess application of fertilizer has its own limitations. In the present study, kapas yield was significantly influenced by the fertilizer doses (Table 2). Lowest yield (1249 kg ha^{-1}) was recorded in unfertilized plots. Increasing fertilizer dose from 100 to 150% increased the kapas yield but it was on par with the yield realized in 100% NPK (3616 kg ha^{-1}) and soil test based fertilizer application treatments (3688 kg ha^{-1}). Further, in farmers' practice the yield (3582 kg ha^{-1}) was even less and on par with that of 100% NPK. This might be due to imbalance of nutrients caused by excessive application of fertilizers. Fertilizer response studies in *Bt* cotton hybrid carried out by Reddy *et al.* (2010) indicated that response to nitrogen was observed up to 150 kg ha^{-1} only, and with further increase in N level cotton yield was reduced and response to phosphorus and potassium was observed up 60 kg ha^{-1} each. Studies of Asewar *et al.* (2012) and Buttar *et al.* (2010) also confirm these results.

Though the experimental soil was deficient in sulphur, response was not observed to applied sulphur. Inclusion of 30 kg sulphur along with 100% RDF or other levels of fertilizers (125 and 150%) did not result in any additional yield increment in this study. A seed cotton yield of 3665, 3747 and 3845 kg ha^{-1} was realized with addition of 30 kg Sha^{-1} along with 100%, 125% and 150% recommended doses of NPK respectively. This might be due to the fact that sulphur received through SSP was sufficient to meet the requirement of crop. Thus use of straight fertilizers like SSP to supply phosphorus not only reduced the cost of production but also helped in meeting the sulphur demand of crop. At higher levels of phosphorus (125 and 150%) inclusion of sulphur resulted in very little increment in yields. This might be due to antagonistic effect of phosphorus and sulphur as both are present in available form in soil as anions (Marok and Dev, 1980). Further, kapas yield in soil test based fertilizer treatment (3688 kg ha^{-1}) was higher than the targeted yield of 25 q ha^{-1}. The reason was that, since no STCR equations were available for *Bt* cotton in Warangal region, equations developed for red soils of Kadapa region of Andhra Pradesh were used for this study. The result suggests the need for development and validation of new STCR equations for use in Warangal district, especially in the context of very high yield potential of recent *Bt* cotton hybrids as indicated by the yield in control (1249 kg ha^{-1}). These higher yields also indicate the nutrient mining ability of cotton hybrids to meet their nutrient requirements even under low nutrient supply.

In confirmation to the findings of Kumar *et al.* (2010) quality parameters viz. seed index, lint index and ginning out turn were not influenced by the fertilizer treatments. Seed index was highest (8.44 g) in 150% RDF +S@ 30 kg ha^{-1} treatment and was lowest in control (8.24 g). Lint index and ginning out turn were highest (5.14g and 38.0%) in 125% RDF +S @ 30 kg ha^{-1} treatment and lowest were recorded in control (4.83 g and 37.0%). This might be due to the fact that quality was more controlled by genetic make-up of the plant than nutrient supply and uptake by plant (Rao and Janawade, 2009).

Effect of different fertilizer doses on Economics of cotton cultivation

The details of cost of cultivation and returns along with benefit cost ratio under different fertilizer practices was presented in Table 2. A perusal of data revealed that highest gross returns (₹ 1,42,257 ha^{-1}) and net returns (₹ 1,03,370 ha^{-1}) were realized with 150% RDF + S @ 30kg ha^{-1} treatment, but benefit cost ratio was high with application of recommended doses of fertilizer (3.79) and soil test based fertilizer application (3.78). Application of sulphur @ 30 kg ha^{-1} along with RDF also resulted in same benefit cost ratio with very meager additional returns of ₹ 120 ha^{-1}. Farmers' practice of application of very high doses of fertilizers was involving an additional cost of nearly ₹ 6,500 when compared to application of recommended doses of fertilizer or application of fertilizers based on soil test. Farmers practice neither helped in getting higher net returns or higher benefit cost ratio Hence it is logical to resort to application of soil test based fertilizer application or to adopt the present recommendation of 150:60:60 kg NPK ha^{-1} for profitable cultivation of *Bt* cotton in Warangal district.

Effect of fertilizer doses on soil physico-chemical properties and nutrient availability

Soil physico-chemical properties like soil reaction, electrical conductivity, organic carbon content and cation exchange capacity at harvest did not show any significant change with reference to fertilizer treatments (Table 3).

Availability of nutrients at flowering and harvest stages recorded significant changes with reference to treatments (Table 4). Nitrogen availability was lowest in control (134.7 and 123.7 kg ha^{-1}) and was highest in farmers' practice (187.5 and 170.8 kg ha^{-1}) at flowering and harvest stages respectively and these were significantly different from nitrogen status in 100% RDF treatment. Gadhiya *et al.* (2009) also reported increased available N content in soil after harvest of *Bt* cotton crop with higher dose of N application. Phosphorus availability was lowest in control (8.5 and 7.9 kg ha^{-1}) and highest in soil test based fertilizer application treatment (40.0 and 34.2 kg ha^{-1}) at flowering and harvest respectively. At both the stages, farmers' practice treatment also recorded high (37.3 and 32.5 kg ha^{-1}) and on par available P as that of soil test based fertilizer treatment. In all other treatments, phosphorus status was low and treatmental variations were significant. Available potassium content in soil decreased from flowering to harvest. Availability of potassium at was lowest in control (174.5 and 162.0 kg ha^{-1}) and was highest in farmers' practice treatment (267.5 and 235.3 kg ha^{-1}) at flowering and harvest stages respectively. In soil test based fertilizer treatment also the available potassium was significantly low and was on par with control. Available potassium status was significantly higher in 150% RDF (with and without sulphur) over 100% RDF. Kalaichelvi (2008) reported that the application of higher levels of nutrients at the rate of 200:100:100 kg NPK ha^{-1} had obtained significantly higher nitrogen and phosphorus availability but no significant influence on potassium availability at a 60 DAS, 80 DAS and post harvest stage of the *Bt* cotton crop.

Addition of sulphur along with fertilizers resulted in higher sulphur status in soil. Available sulphur content in soil was lowest in control (3.4 and 2.4 mg kg^{-1}) and highest in 150% RDF +S @ 30 kg ha^{-1} treatment (14.8 and 12.1 mg kg^{-1}) at flowering and harvest stages respectively. Farmer's practice (13.6 and 10.7 mg kg^{-1}) also recorded high and on par available sulphur as that of 150% RDF +S @ 30 kg ha^{-1} treatment. In all other treatments, sulphur status was low and treatmental variations were non-significant.

Micronutrient status in soil at flowering and harvest stages was not significantly influenced by the fertilizer treatments (Table 5). Available zinc, copper, iron and manganese were high at flowering stage and decreased at harvest. At flowering, available zinc status was highest in 150% RDF (0.46 mg kg^{-1}) and lowest was recorded in control (0.32 mg kg^{-1}). At harvest 100% RDF treatment with and without sulphur recorded highest zinc status (0.26 mg kg^{-1}) and the lowest was recorded farmers' practice (0.19 mg kg^{-1}) indicating the imbalance arising due excessive use of fertilizers. Available copper, at flowering stage was highest in soil test based fertilizer application treatment (3.17 mg kg^{-1}) and lowest was recorded in control (2.90 mg kg^{-1}). At harvest, 125% RDF with sulphur recorded highest copper status (2.90 mg kg^{-1}) and the lowest was recorded farmers' practice (2.67 mg kg^{-1}). Available manganese, at flowering stage was highest in 125% RDF + S @ 30 kg ha^{-1} treatment (29.0 mg kg^{-1}) and lowest was recorded in control, 100% RDF + S @ 30 kg ha^{-1} and soil test based fertilizer application treatments (27.0 mg kg^{-1}). At harvest 125% RDF with sulphur recorded highest manganese status (28.1 mg kg^{-1}) and the lowest was recorded control (26.0 mg kg^{-1}). Highest available iron status at flowering was recorded in 125% RDF with sulphur (19.3 mg kg^{-1}) and the lowest in soil test based fertilizer application treatment (17.9 mg kg^{-1}) while at harvest higher available iron was recorded in 125% RDF (17.9 mg kg^{-1}) and lowest was recorded in control (15.0 mg kg^{-1}).

Conclusion

From the study it can be concluded that, adoption of higher fertilizer doses helped in higher plant growth and biological yield but optimum economic yield could achieved by resorting to soil test based fertilizer application or by restricting to the presently available recommendation of 150:60:60 kg NPK ha^{-1}. Application of very high fertilizer doses as in farmers practice is likely create nutrient imbalances in days to come.

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