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Effect of Nitrogen and Sulphur on Growth and Yield Attributes of Potato (*Solanum tuberosum* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Author MS designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors MB and AG managed the literature searches, analyses of the study performed and final proof submission and author HS managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

This investigation was carried out to study the effect of four levels of nitrogen (0,90,180,270) and three levels of sulphur (0,25,50) application on growth and yield attributes of potation a split plot design with three replication, at lovely professional university, Phagwara, Punjab, India. The treatments ware replicated thrice in split plot design. The study revealed that application of N 180 $kgha^{-1}$ + S 50 $kgha^{-1}$ significantly enhanced morphological and quality attributes such as plant emergence, number of shoots, periodic plant height, dry matter accumulation, leaf area index, percent reducing sugar and tuber dry matter, there by proving the role of sulphur and nitrogen in high tuber yield in potato 'Kufri-chipsona-3'. Among all treatments,highest total and processable yield was exhibited by treatment T_9 i.e N 180 $kgha^{-1}$+S 50 kg/ha^{-1} expressing the role of S in N uptake and use efficiency. Benefit cost (B: C) ratio was 2.25 which also indicates maximum profitability obtained with this combination.

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Keywords: Potato; sulphur; nitrogen; yield; growth; quality; benefit cost ratio.

1. INTRODUCTION

Potato (*Solanum tuberosum*) is a third largest food crop of the world in terms of fresh produce after rice and wheat. India is the third largest producer of potatoes in world after China and Russia with a total production of 45.3 million tonnes from an area of 1992.2 thousand hectares -13). In Punjab, potato is cultivated on an area of 85.21 thousand hectares (5 per cent of total Indian area) with total production of 2.13 million tonnes which contributes 5.07 per cent in the total production of the country [1]. In Punjab, primarily potato belt is confined to Doaba region i.e. Hoshiarpur, Jalandhar, Kapurthala and Nawanshehar districts. It is also grown in Amritsar, Ludhiana, Moga and Patiala districts.

Nitrogen is one of the most essential nutrients required by plant globally. It is an integral component of many compounds such as chlorophyll, nucleotides, alkaloids, enzymes, hormones and vitamins, etc. which are essential for plant growth processes [2]. Nitrogen is valuable nutrient for plants and plays an important role in tuber size development but overdose of nitrogen lowers the tuber dry matter [3]. Proper level of nitrogen has a positive impact on quality and yield of potatoes. Appropriate use of nitrogen expanded the leaf area index and increases photo assimilates [4]. Excessive application of nitrogen decrease starch content and also spoil the taste while cooking. Industry requires 40-80 mm size of potatoes, high in dry matter and low reducing sugar for quality processing. Sulphur is one of sixteen essential nutrient elements and fourth major nutrient after NPK, required by plants for proper growth and yield as it is known to take part in many reactions in all living cells [5]. Sulphur deficient plants have poor utilization of nitrogen, phosphorus and potash at all age [6].

Intensive cropping and use of high-grade fertilizers have caused the depletion of sulphur in soils. Decrease in tuber dry matter yield particularly cystine and leucine were observed with sulphur deficiency [7]. Sulphur has a direct effect on soil as it may reduce pH which improves the availability of microelements such as Fe, Zn, Mn and Cu as well as crop yield and its related characteristics [8]. The need of application of sulphur along with its beneficial effects on yield and quality has been reported by earlier workers[9]. Sulphur also has influence on potato flower by involvement in the volatile S^- compound [10]. Therefore the present study was envisaged to determine the effect of nitrogen and sulphur on the yield and quality of potato ‘Kufri chipsona-3’ in split plot design, and to determine best treatment in terms of benefit-cost ratio.

2. MATERIALS AND METHODS

2.1 Experimental Site and Location

Field experiment was carried out during 2013-2014 at the Agriculture Research Field, Lovely Professional University(31°15’ N 75°41 E) Phagwara, (Punjab) under irrigated conditions. The experiment was conducted in Split plot Design having 12 treatments with three replications. The experiment was laid out on Sandy loam soil. The planting of crop was done on October 11, 2013. Seed tubers were planted by dibbling on ridges at the spacing of 60 X 20 cm. Chemical analysis of the soil showed a neutral pH (7.1), 0.46% organiccarbon,156 kg nitrogen 28.9 kgha^{-1}phosphorus, and 356 kgha^{-1} exchangeable potassium. Recommended dose of N, P and K (180:60:120 kg N, P_2O_5 and K_2O ha-^{1}) were applied. Full dose of P and K were applied along with 50 per cent of N at the time of planting. The remaining 50 per cent N was applied at time of earthling up.

2.2 Analysis of Variables

2.2.1 Growth characteristics

The emergence of potato seedlings from each plot was recorded on alternative day, starting from the day when sprouting start emerging above ground, and days taken to complete 50% and 100% emergence were counted for each treatment. The number of shoots emerged from the tubers were counted in a one row length from each plot and the plants data was recorded on five selected plants. Height of five randomly selected and tagged plants from each plot were measured at 30, 60 and 90 DAS (Days after sowing) as shown in (Fig. 1.1, 1.2 and 1.3). Dry matter was recorded from the randomly selected plants and then mean values were worked out. Fresh detached leaves were taken to measure leaf area index at 60 DAS with the leaf area meter.

$$\text{Leaf Area Index} = \frac{\text{Leaf Area (cm}^2)}{\text{Ground Area (cm}^2)}$$

2.2.2 Yield attributes

The number of tubers per plant ware calculated from same five randomly selected plants meant for plant height and number of stems per hill in each plot. Total tuber yield was calculated separately from each net plot for computation of yield in Kg ha^{-1}. Tuber diameter between 40 mm to 80 mm is considered as processable tuber. These are sorted out after harvest with help of Vernier Caliper. Then there average weight is calculated as per different treatments.

The tubers below 40 mm and above 80 mm are considered as non processable.

Non processable yield = Total yield – Processable yield.

Table 1. Different grades of potato

Serial number	Diameter	Grade
1	Above 80 mm	Large
2	Between 80 mm-40 mm	Medium
3	Below 40 mm	Small

2.2.3 Quality characters

Tuber dry matter accumulation was analysed after interval of 60 DAS, and 90 DAS and was determined by oven drying 50 g finely chopped and mixed tuber piecesat 65℃ till constant weight.The reducing sugars were estimated by Nelson-Somogi method [11]. The reducing sugars when heated with alkaline copper tartrate reduce the copper from the cupric to cuprous state and thus cuprous oxide isformed when cuprous oxide is treated witharsenomolybdic acid, the reduction of molybdic acid to molybdenum blue take place. The blue colour developed is compared with a st of standards in colorimeter at 620 nm. Digging of potatoes was done manually on January 23, 2014.

2.2.4 Economics

The gross monetary returns in rupees per hectare wereworked out on the basis of potato yield. The prevailing market price of potato in the phagwara district of Punjab, India was considered.

2.2.4.1 Gross returns ($ ha^{-1})

The gross returns were calculated by considering the prices of potato at the time of harvest.

Gross returns = Yield according to grades X Market price according to grade.

2.2.4.2 Net returns ($ ha^{-1})

The net return was calculated by deducting the cost of cultivation from the gross returns.

Net returns ($.) = Gross income -Total cost of cultivation.

The benefit cost ratio was calculated as follows;

$$\text{B: C ratio} = \frac{\text{Gross returns (\$ ha}^{-1})}{\text{Cost of cultivation (\$ ha}^{-1})}$$

2.3 Data Analysis

Statistical analysis of the data recorded was done as per split plot design (Cochran and Cox, 1963).

3. RESULTS AND DISCUSSION

3.1 Growth Analysis

A good and uniform emergence is required for the successful raising of any crop, which ultimately determines the crop yield. The data in Table 1 reveals that different treatments have insignificant effect on emergence. It means that there was almost similar level of plant population in all the treatment. This may be due to the fact that growing seedlings get their food from the tuber. [12] also reported that N application had insignificant effect on plant emergence under their conditions. Number of shoots per plant or per unit area is an index of growth and adaptability of the plant to the soil and climatic conditionand has a direct bearing on development of potato yield.The data revealed that treatment T_9 (Nitrogen 180 kg N and Sulphur 50 kg ha^{-1}) gave significantly maximum number of shoots. Number of shoots in T_3, T_6 T_7 T_{12} was statiscally at par to each other but significantly lower than T_{11}. T_{10} is significantly superior over T_4, T_5 and T_8. This might be due to the fact that fertilization application encouraged more number of independent stems. The results are in consonance with those of [13]. Who reported that the highest number of stems per hill (4.43) obtained when the highest rate of nitrogen (254 kg ha^{-1}) was applied. There was a periodic increase in plant height and it differs significantly among all the treatments. After 40 days maximum plant height (40.7) was recorded in treatment T_9, which was statically at par with T_{12}. T_6 was also at par with T_8 and T_{10} whereas, T_1 (33) recorded minimum plant height. Minimum plant height (50) was recorded in the control. After 80 days T_9 gave significantly higher plant height (65.5) which was superior to all the treatments. The probable reason for increasing plant height might be due to more uptake of N during growth period resulting in increase in cell size, elongation and enhancement of cell division which ultimately increase the plant growth. [14] found that the application of 100% N of recommended dose significantly increased the plant height with their genetic material under their conditions. The results are further supported by [15] who stated that application of N up to 240 kg ha^{-1} significantly increase the plant height. After 40 days dry matter accumulation (1.24) was recorded significantly higher in treatment T_9, followed by T_{12} which was statiscally at par with T_{11} and T_{10}. Treatment T_1 (0.68) recorded minimum dry matter accumulation. After 60 days highest dry matter accumulation (6.60) was recorded in treatment T_9, which is at par with T_{12}. Minimum dry matter accumulation (4.34) was recorded in control plot treatment. After 80 days T_3 gave significantly highest dry matter accumulation (8.02). Treatment T_1 gave lowest dry matter (6.05). The results are further supported by [16] who stated that application of N up to 200 kg/ha significantly increase the dry matter content with their genetic material under their conditions.The data of leaf area index was recorded in cm 2 at 60 days after sowing. The data is presented in Table 2 After 60 days highest leaf area index (5.12) was recorded in treatment T_9, which was at par with T_{12}. Whereas, minimum dry matter accumulation (1.17) occurred in control plot treatment. Researcher reported that application of N fertilizer give significantly higher leaf area index with their genetic material under their conditions. Dry matter accumulation is good growth index to express the photosynthetic efficiency of the plant. The dry matter accumulation was measured at 40, 60 and 80 DAS and the mean was worked out from five plants, which were selectedat randomly in each treatment. It was observed that after 60 days, maximum tuber dry matter was observed in T_9 (41.72 g $plant^{-1}$) and differ significantly from all other treatments. The minimum tuber dry matter was recorded in T_1 (17.85). Maximum dry matter accumulation in tubers after 90 days was observed in T_9 (80.15 g $plant^{-1}$) followed by T_{12}, T_{11} and T_8 whereas, T_5 and T_6 were at par to each other but significantly higher than T_2 and T_1. As above given discussion show that there is an increasing trend in dry matter accumulation up to 90 days. Due to high LAI, the crop under this treatment might be able to intercept relatively higher solar energy resulting in increased dry matter production in all the plant parts. [17] and [18] reported that application of N fertilizer and sulphur can significantly influence the dry matter accumulation of potato tubers with their genetic material under their conditions.

3.2 Yield Studies

The data on number of tuber at harvest was recorded. The number of tubers produced ware

Table 2. Effect of Nitrogen and sulphur on morphological characters of potato

Treatment	Days taken to 50% emergence	Days taken to 100 % emergence	No. of shoots 80 das	Dry matter (gram $plant^{-1}$)			Leaf area index	Plant height (cm)		
				40 days	60 days	80 days		40 days	60 days	80 days
No + S0	5.75^{a}	9.85^{a}	2.7^{c}	7.73^{f}	68.56^{g}	100.60^{i}	1.17^{e}	33.00^{h}	50.00^{a}	58.70^{f}
No + S25	5.58^{a}	9.58^{a}	2.7^{c}	9.26^{e}	69.53^{f}	102.73^{g}	1.45^{e}	34.70^{g}	50.30^{a}	58.90^{f}
No + S50	4.50^{a}	8.58^{a}	3.2^{b}	9.86^{e}	70.63^{e}	104.70^{e}	2.34^{d}	36.50^{ef}	52.60^{a}	59.80^{e}
N90 + S0	5.18^{a}	9.25^{a}	3.0^{b}	11.20^{d}	70.33^{e}	100.40^{i}	3.71^{c}	36.80^{e}	52.60^{a}	58.40^{f}
N90 + S25	4.90^{a}	9.0^{a}	3.0^{b}	11.70^{d}	71.46^{d}	101.70^{h}	3.81^{c}	36.00^{f}	53.60^{a}	60.20^{e}
N90 + S50	4.58^{a}	8.90^{a}	3.2^{b}	12.00^{d}	72.60^{c}	103.73^{f}	3.95^{c}	38.40^{cd}	55.80^{a}	61.80^{d}
N180 +S0	5.50^{a}	9.33^{a}	3.2^{b}	12.43^{cd}	71.46^{d}	100.76^{i}	4.04^{bc}	38.00^{d}	52.00^{a}	60.40^{e}
N180 + S25	5.0^{a}	8.90^{a}	3.0^{b}	12.70^{cd}	73.06^{c}	106.40^{d}	4.15^{bc}	38.50^{cd}	56.20^{a}	63.50^{c}
N180 + S50	4.93^{a}	8.83^{a}	4.4^{a}	12.96^{c}	74.10^{b}	110.53^{a}	5.12^{a}	40.70^{a}	59.80^{a}	65.50^{a}
N270 + S0	4.85^{a}	8.60^{a}	3.4^{b}	13.56^{bc}	71.50^{d}	103.70^{f}	4.06^{bc}	38.50^{cd}	56.90^{a}	63.50^{c}
N270 + S25	5.25^{a}	9.10^{a}	4.0^{a}	14.06^{b}	74.70^{b}	107.53^{c}	4.45^{b}	38.9^{c}	58.4^{a}	65.1^{a}
N270 + S50	5.02^{a}	8.70^{a}	3.3^{b}	15.00^{a}	75.63^{a}	109.14^{b}	5.04^{a}	39.8^{b}	59.2^{a}	64.4^{b}
C.D 5% main	NS	NS	0.55	0.86	0.65	0.78	0.46	0.5	NS	0.67
Sub	NS	NS	0.64	0.38	0.4	0.47	0.5	0.36	NS	0.28
Main X Sub	NS	NS	NS	NS	0.8	0.95	NS	NS	NS	0.56

counted from five randomly selected plants and the mean was worked out. Data in Table 3 reveals that higher yield of small sized tubers was recorded with T_9 (51.92) which was significantly higher than all other treatments. T_8, T_{10}, T_{11} and T_{12} were observed at par but significantly higher than T_3, T_2 and T_1. T_3 and T_4 were also found at par but significantly higher than T_6. [19] also found significant difference among different genotypes for grade wise tuber yield with their germplasm. The data on the effect of different fertilizer treatments on total tuber yield of potato are therefore, presented in Table 3 and are depicted in Fig. 1.4. Highest total yield was recorded in T_9, which was at par with T_8, T_{12} and T_{11}, whereas minimum total yield was reported in control plot treatment. These results are in line with [20] who reported that increase in tuber yield with increasing sulphur levels may be attributed to its role in better partitioning of the photosynthates in the shoot and tubers. Similarly, [21] have also reported significant effect on grade wise tuber yield and increase in bulking rate with sulphur application with their genetic material under their conditions. The increase in yield with the application of recommended doses of NPK by fertilizers and FYM (Farm yard manure) could be attributed to corresponding increase in leaf area, which is responsible for synthesizing photosynthates and increase in number and weight of tubers as reported by [22]. Processing industry requires 40-80 mm size of potatoes. Those size in between this range are consider fit for purpose of processing. Results in Table 3 revealed that T_9 have highest processable yield whereas, T_8 and T_{12} were statically at par to each other. All the treatments were found significantly higher than T_1 (control).

3.3 Quality Parameters

Dry matter accumulation by tubers is an important growth characteristic in potato which ultimately affects yield of the crop. Data on dry matter accumulation by tubers were recorded at 60 and 90 DAS. Maximum dry matter accumulation in tubers after 90 days was observed in T_9 (80.15 gplant^{-1}) followed by T_{12}, T_{11} and T_8 whereas, T_5 and T_6 were at par to each other but significantly higher than T_2 and T_1. The data clearly reveal that application of nutrients at different doses of nitrogen and sulphur significantly influenced the dry weight. As above given discussion show that there were an increasing trend in dry matter accumulation up to 90 days. Due to high LAI (Leaf Area Index), the crop under this treatment might be able to intercept relatively higher solar energy resulting in increased dry matter production in all the plant parts. Per cent reducing sugar was found maximum and significantly higher in T_9 treatment as compared to all other treatments. Reducing sugar content in treatment T_9 (0.37) was statistically at par to treatment T_8. Data Table 3 further revealed that treatment T_4 (0.31) along with T_3 (0.33) and T_1 (0.33) had the minimum reducing sugar. These results were in consonance to the findings of [23] with their genetic material. Raghav et al. [24] observed that there was significant effect on net income by using organic and inorganic manures with their genetic material under consideration.

Table 3. Effect of nitrogen and sulphur on yield and quality attributes of potato

Treatment	No. of tubers per plant	Percent reducing sugar	Processable yield (qha^{-1})	Grade wise yield			Non-processable yield(q ha^{-1})	Dry matter (gram plant^{-1})	
				Large	Medium	Small		60 days	80 days
No + S0	5.3^{a}	0.31^{d}	96.46^{h}	50.67^{c}	68.45^{f}	45.04^{b}	67.70^{e}	17.85^{e}	40.16^{e}
No + S25	6.6^{a}	0.32^{c}	107.80^{f}	55.90^{b}	85.78^{e}	42.22^{b}	75.10^{d}	18.19^{e}	41.11^{e}
No + S50	6.7^{a}	0.31^{d}	112.10^{e}	51.22^{c}	98.23^{d}	44.95^{b}	82.30^{c}	19.12^{e}	42.07^{e}
N90 + S0	5.6^{a}	0.31^{d}	104.86^{g}	58.33^{ab}	71.53^{f}	$44.81^{\mathbf{b}}$	69.56^{e}	28.02^{d}	67.28^{d}
N90 + S25	6.0^{a}	$0.33^{b c}$	135.06^{d}	44.64^{d}	117.3^{c}	41.84^{b}	68.76^{e}	32.93^{c}	70.09^{c}
N90 + S50	6.3^{a}	$0.33^{b c}$	142.60^{c}	45.22^{d}	129.34^{a}b	40.58^{b}	$72.73^{d e}$	36.44^{b}	70.41^{c}
N180 + S0	5.6^{a}	0.32^{c}	108.66^{f}	54.97^{b}	124.87^{b}	45.04^{b}	116.06^{a}	35.15^{bc}	71.26^{c}
N180 + S25	6.6^{a}	0.34^{b}	151.53^{b}	57.68^{ab}	128.58^{ab}	50.56^{a}	85.00^{c}	37.33^{b}	76.88^{b}
N180 + S50	7.6^{a}	0.37^{a}	160.60^{a}	61.02^{a}	133.06^{a}	51.92^{a}	85.40^{c}	41.72^{a}	80.15^{a}
N270 + S0	6.6^{a}	0.31^{d}	110.73^{ef}	53.04^{bc}	125.45^{b}	50.55^{a}	118.63^{a}	34.08^{c}	71.85^{c}
N270 + S25	7.0^{a}	$0.33^{b c}$	140.80^{c}	55.01^{b}	126.32^{b}	52.23^{a}	92.73^{b}	36.63^{b}	72.4^{c}
N270 + S50	6.6^{a}	0.32^{c}	149.56^{b}	57.7^{ab}	129.58^{ab}	50.62^{a}	88.36^{b}	41.15^{a}	76.12^{b}
C.D 5% Main	NS	0.0116	3.085	3.72	4.63	4.94	4.96	1.96	2.64
Sub	0.70	0.0104	1.487	1.24	2.26	1.46	2.26	0.71	1.12
Main X Sub	NS	0.0207	2.974	2.65	2.34	2.93	4.52	1.43	2.25

Significance at 5% of level of significance

Table 4. Economic analysis (in $ ha^{-1}) of nitrogen and sulphur for potato crop

Treatment	Land rent ($ ha^{-1})	Seed bed preparation ($ ha^{-1})	Labour ($ ha^{-1})	Harvesting labour	Seed ($ha^{-1})	Manure and fertilizer ($ ha^{-1})	Total input cost ($ ha^{-1})	Total income ($ ha^{-1})	Net income ($ ha^{-1})	B:C ratio
T_1	390.71	62.51	35.95	128.93	250.05	0.00	868.15	1394.15	525.99	1.60
T_2	390.71	62.51	35.95	128.93	250.05	51.25	919.40	1581.77	662.37	1.72
T_3	390.71	62.51	35.95	128.93	250.05	71.57	939.72	1677.49	737.77	1.78
T_4	390.71	62.51	35.95	128.93	250.05	34.35	902.52	1487.25	584.74	1.64
T_5	390.71	62.51	35.95	128.93	250.05	54.68	59,048.8	1777.88	855.04	1.92
T_6	390.71	62.51	35.95	128.93	250.05	75.00	922.83	1886.90	943.75	2.00
T_7	390.71	62.51	35.95	128.93	250.05	37.80	905.95	1960.16	1054.21	2.16
T_8	390.71	62.51	35.95	128.93	250.05	58.11	926.26	2057.06	1130.80	2.22
T_9	390.71	62.51	35.95	128.93	250.05	78.43	946.58	2137.34	1190.76	2.25
T_{10}	390.71	62.51	35.95	128.93	250.05	41.23	909.38	1987.76	1078.37	2.18
T_{11}	390.71	62.51	35.95	128.93	250.05	61.54	929.70	2024.66	1094.97	2.17
T_{12}	390.71	62.51	35.95	128.93	250.05	81.86	950.01	2067.03	1117.02	2.17

1. Selling cost ofone kg of potato, Small size = 0.07 $/kg, Medium size = 0.09 $ kg^{-1}, Large size = 0.09 $ kg^{-1},
2. COST of fertilizers nitrogen = 0.04 $ kg^{-1}, Phosphorus = 0.17 $ Kg^{-1}, Potash = 0.17 $ kg^{-1} Sulphur = 52 $ Kg^{-1}

Fig. 1.1. Crop growth at 30 days

Fig. 1.2. Crop growth at 60 days

Fig. 1.3. Plant height at 60 days

Fig. 1.4. Variation in tubers

3.4 Economic Analysis

Economic analysis of using different levels of nitrogen and sulphur for potato crop was determined by total input cost, total income and net income in $/ha in Phagwara district, Punjab, India. From data Table 4 total cost was determined by adding all six classes (Land rent, seed bed preparation, and labour, harvesting labour, seed, manure and fertilizer). Total income was calculated by multiplying total yield with marketable price of potato crop. Net income was also found out by reducing total cost from total income. Data in Table 4 revealed that treatment T_9 gave the maximum income followed by T_8, T_{12}, T_{11}, T_{10}, T_7 and T_6. The benefit cost ratio was found maximum in treatment T_9 followed by T_8, T_{10}, T_{12}, T_{11}, T_7 and T_6 whereas control (T_1) recorded minimum benefit cost ratio. Data showed that all treatments gave benefit cost ratio above 1, but application of 180 $kgha^{-1}$ of N and 50 kg/ha^{-1} of S recorded highest net income and benefit cost ratio. [24] observed that there was significantly effect on net income by using of organic and inorganic manures with their genetic material under their conditions.

4. CONCLUSIONS

Analysis of variance revealed significant difference for total and processable yield and other component traits. T_9 encompassing of N180+S50 exhibited highest number of shoots, plant height, dry matter accumulation, leaf area index, number of tubers per plant, grade wise yield, total yield, processable yield, non processable yield, percent reducing sugar, tuber dry matter. Treatment T_8 (N180 + S25) revealed the same trend in yield and its component traits but lesser than T_9 (N180+S50). There was an enhancement of morphological and quality attributes such as plant emergence, number of shoots, periodic plant height, dry matter accumulation, leaf area index, and percent reducing sugar and tuber dry matter proved the role of S in N use efficiency. In term of economics, crop grown under treatment T_9 (N180 +S50) gave higher total income and net income as compared with other treatments. Benefit cost ratio was significantly higher in T_9 than other treatments expressing importance of nitrogen and sulphur in enhancing yield and economic returns.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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