Maximizing Yield, Nutrient Use Efficiency, and Profit in Summer Black Gram

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Nutrient demand analysis helps to identify the most profitable response to fertilizer applied to a largely neglected but particularly important pulse crop production system in northcentral India.

Uttar Pradesh is the most agriculturally important state in India with respect to staple food production. Because the majority of the population is vegetarian, pulses represent the major source of protein and assume great importance for food, nutrition, and agriculture sustainability. Black gram is a prominent rainy and summer season pulse crop presently occupying 492,000 ha in Uttar Pradesh. Average productivity is low at 429 kg/ha. Among the various factors influencing black gram yield, balanced use of plant nutrients is most critical. Inadequate and unbalanced use of fertilizers has resulted in large-scale multi-nutrient deficiencies which are spreading in space and time.

Fertilizer use in both rainy and summer season pulse crops is altogether missing, leading to poor crop yields. Presently, fertilizer use in the state is confined to rice, wheat, and other important crops such as sugarcane, potato, and oilseeds. In view of the fact that per capita per day availability of pulses in India is currently on the decline, it is important to evaluate the effect of adequate and balanced fertilization on maximizing yield and farmer profits with black gram.

A field experiment was conducted at the Fertilizer Research Station of Chandra Sekhar Azad University of Agriculture and Technology in Pura, Uttar Pradesh, during the summer season (March to June) of 2005. The site is located within the central plain zone of Uttar Pradesh, which has the largest area under pulse crops in India. The site had a sandy loam soil, pH 8.0, and 0.4% organic carbon. Available N (alkaline permanganate method) and P (Olsen) were low, and available K (ammonium acetate extractable) was medium. Fourteen treatments were formulated and tested based on need to improve the state recommendation (SR) for N, P, and K with and without secondary and micronutrients (**Table 1**). The experiment was laid out in a randomized block design with four replications. Urea, DAP, and KCl were used as N, P, and K fertilizer sources. All fertilizers were applied basally. Black gram variety "Type 9" was sown on March 25 and harvested at full maturity on June 23. The recommended package of agronomic practices was adopted including practical management of weeds and timely irrigation to avoid moisture stress.

A maximum seed yield of 1,254 kg/ha was obtained under T_9 (complete). Yield under T_9 was 123% above the control (**Table 1**). Treatments supplying less N (T_8) or no Zn (T_{11}) provided yields that were statistically equivalent to T_9. Stover yield followed a similar trend and varied between 1,068 kg/ha in the control to 2,006 kg/ha under T_9. Net returns for the most profitable treatments followed yield trends. Thus, a highest net return of Rs.9,480/ha was recorded for T_9, followed by T_8 at Rs.8,864 and T_{11} at Rs.8,795. Grain yield obtained under the control was 562 kg/ha, still above the state average, while the SR and STR produced 972 and 894 kg/ha, respectively. The lowest return above the control was obtained by omitting both P and K. Yield responded linearly to successive increases in K application rate. Yields at 0, 20, 40, and 60 kg K_2O/ha were 70, 80, 98, and 103% above the zero K control (T_3). Paired comparisons of treatments with and without B, Zn, and S demonstrated 7%, 4%, and 13% increases, respectively.

Crop response to balanced application of fertilizer was evident in plant nutrient uptake data (**Table 2**). Successive increases in K application rate enhanced N uptake by 2 to 20%, P uptake

Table 1. Effect of treatments on yield, seed response, and net return (Rs./ha) in black gram.

Treatments, kg/ha	Yield, kg/ha Seed	Yield, kg/ha Stover	Seed response over control, %	Net return[2] over control, Rs./ha
T_1 $N_0P_0K_0$ (Control)	562	1,068	-	-
T_2 $N_{15}P_0K_0S_{20}Zn_{15}B_5$	713	1,419	27	2,069
T_3 $N_{15}P_{40}K_0S_{20}Zn_{15}B_5$	955	1,776	70	5,384
T_4 $N_{15}P_{40}K_{20}S_{20}Zn_{15}B_5$	1,012	1,768	80	6,165
T_5 $N_{15}P_0K_{40}S_{20}Zn_{15}B_5$	894	1,520	59	4,548
T_6 $N_{15}P_{40}K_{40}S_{20}Zn_{15}B_5$	1114	1,938	98	7,562
T_7 $N_{15}P_{40}K_{60}S_{20}Zn_{15}B_5$	1142	1,900	103	7,946
T_8 $N_{15}P_{60}K_{60}S_{20}Zn_{15}B_5$	1,209	1,990	115	8,864
T_9 $N_{22}P_{60}K_{60}S_{20}Zn_{15}B_5$ (Complete)	1,254	2,006	123	9,480
T_{10} $N_{22}P_{60}K_{60}S_{20}Zn_{15}B_0$	1,170	1,925	108	8,330
T_{11} $N_{22}P_{60}K_{60}S_{20}Zn_0B_5$	1,204	1,980	114	8,795
T_{12} $N_{22}P_{60}K_{60}S_0Zn_{15}B_5$	1,106	1,880	97	7,453
T_{13} $N_{15}P_{40}K_0S_{20}$ (SR)	972	1,790	73	5,617
T_{14} $N_{15}P_{15}K_{15}S_{20}$ (STR)	894	1,600	59	4,548
C.D.[1] 5%	80	119		

[1]Critical difference; [2]1US$ = 40.45 India rupees

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; DAP = diammonium phosphate; KCl = potassium chloride; S = sulfur; B = boron; Zn = zinc.

by 5 to 22%, and K uptake by 8 to 33% compared to the control (**Table 2**). Consistent improvements in macronutrient uptake were also observed in treatments providing P, S, B, Zn, and additional N. As was observed with yield, maximum uptake for N, P, and K was achieved under the complete treatment.

Plant partitioning of nutrients between the seed and stover provides insight into the range of macronutrient removal that can be expected from black gram. Similar quantities of N and K are being exported in the form of harvested grain. On average, seed N represented 59% of total N uptake. Seed accumulation of N ranged from 18.0 to 44.6 kg/ha, whereas stover N varied from 13.7 to 30.1 kg/ha. Nitrogen concentrations in seed ranged between 3.20% (control) to 3.56% (complete), and stover N varied from 1.28% (control) to 1.50% (complete). Seed accumulation of K represented 72% of total uptake and ranged from 15.8 to 46.0 kg/ha. Stover K varied from 6.0 to 18.5 kg/ha. Seed K concentration varied from 2.82% (control) to 3.67% (complete), and stover K varied from 0.56% (control) to 0.92% (complete). Plant P was nearly equally distributed between the seed and stover as uptake ranged between 1.6 to 5.0 kg/ha within the seed and 1.6 to 4.2 kg/ha within the stover. Seed P content varied from 0.28% (control) to 0.40% (complete), whereas stover P varied from 0.15 (control) to 0.21% (complete).

The protein-rich nature of pulse crops means that these crops remove more nutrients per unit of harvested grain than cereals. Despite this, the gap between this demand and the amount of nutrients supplied to pulses is wide. Fertilizer, organic, or bio-fertilizer input is practically negligible. Evidence from this research indicates that pulse crops are quite responsive to the application of nutrients, and this is contrary to the common belief among farmers that pulses can be sustained with minimal nutrient input. Thus far, the emphasis for fertilizer use in pulses has been mainly focused on P, or N and P. In the present era of multi-nutrient deficiencies, application of K along with N and P and inclusion of secondary and micronutrients such as S, Zn, and B assumes great importance. Ample production and recycling of pulse biomass, for example after picking the pods of black gram, would also help increase soil fertility by adding biologically fixed N and improving the availability of indigenous soil nutrients.

As both area and production have been stagnating over the years, the per capita availability of pulses has declined from 61 g/day in 1950 to 30 g/day in 2000, reflecting large and uninterrupted growth in population. Affordability for this protein rich commodity has also declined due to market forces. India continues to be a net importer of pulses to meet its rising demand. India's pulse demand is estimated to reach 30 M t by 2012 – 17 to 18 M t more than current production.

Summary

Almost all types of pulse crops are grown throughout the year over three seasons in northcentral India: rainy/kharif (June to September), winter/rabi (October to March), and summer/zaid (March to June). This research achieved greater than 120% more grain productivity compared to the average summer season crop yield, plus a vast improvement in crop biomass production. On average, the additional cost of fertilizers over common practice would be Rs.1,730/ha. If such balanced fertilization were practiced in a phased manner, starting with one-quarter on the planted area in Uttar Pradesh, a net profit of Rs.9,480/ha would translate into a Rs.1.25 billion (US$30 million) cash infusion.

A strong educational effort is required by all agencies involved in improving crop productivity in India. Ensured availability of inputs through the supply chain will secure success. Government will power and policy would be most important for real adoption of adequate and balanced fertilization within the extensive pulse-growing areas. BC

Table 2. Effect of nutrient application rate on plant uptake in black gram.

	N		P		K		N+P+K	
K rate	Uptake, kg/ha	% increase	Uptake, kg/ha	% increase	Uptake, kg/ha	% increase	Uptake, kg/ha	% increase
K_0	55.7	–	5.9	–	41.1	–	102.7	–
K_{20}	57.1	2.5	6.2	5.1	44.3	7.8	107.6	4.8
K_{40}	65.8	18.1	6.8	15.2	51.8	26.0	124.4	21.1
K_{60}	66.6	19.6	7.2	22.0	54.7	33.1	128.5	25.3
P rate								
P_0	51.6	–	5.0	–	39.5	–	96.1	–
P_{40}	65.8	27.5	6.8	36.0	51.8	31.1	124.4	29.4
B rate								
B_0	69.1	–	8.0	–	57.5	–	134.6	–
B_5	74.7	8.1	9.2	15.0	64.5	12.2	148.4	10.2
Zn rate								
Zn_0	77.8	–	7.8	–	59.5	–	139.1	–
Zn_{15}	74.7	4.0	9.2	18.0	64.5	8.4	148.4	6.7
S rate								
S_0	65.7	–	7.7	–	54.5	–	127.9	–
S_{20}	74.7	13.7	9.2	19.5	64.5	18.4	148.4	16.0
N rate								
N_{15}	70.4	–	8.1	–	61.3	–	139.8	–
N_{22}	74.7	6.1	9.2	14.0	64.5	5.2	148.4	6.2

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