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Varietal response to next generation on production and profitability of Mung Bean (*Vigna radiata* L.)

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Abstract
The field experiment was conducted at the research farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, over two consecutive summer seasons, i.e., 2021 and 2022. The study encompassed twelve distinct treatment combinations, incorporating two varieties (Pusa-1431 and Virat) and six nutrient management treatments (100% NPK, 75% NPK + 5 t ha-1 FYM, 75% NPK + 5 t ha-1 FYM + NPK Consortia, 75% NPK + 5 t ha-1 FYM + Nano-P Spray at 25 DAS, 75% NPK + NPK Consortia + Nano-P Spray at 25 DAS, and 75% NPK + 5 t ha-1 FYM + NPK Consortia + Nano-P Spray at 25 DAS). The experiment followed a factorial randomized block design with three replications.

The outcomes underscore the substantial superiority of the Pusa-1431 variety compared to the Virat variety in terms of yield attributes, including the number of pods per plant, pod length (cm), number of grains per pod, and test weight, ultimately impacting overall yield. Moreover, the study revealed that applying 75% NPK + 5 t ha-1 FYM + NPK Consortia + Nano-P Spray at 25 DAS led to noteworthy increases in the aforementioned yield attributes—number of pods per plant, pod length (cm), number of grains per pod, test weight, grain yield, straw yield, and biological yield—surpassing the outcomes of traditional farmer practices. The treatment closely followed in performance by 75% NPK + 5 t ha-1 FYM + Nano-P Spray at 25 DAS. Furthermore, the economic assessment indicated that both Pusa-1431 variety and the application of 75% NPK + 5 t ha-1 FYM + NPK Consortia + Nano-P Spray at 25 DAS yielded significantly higher net returns and a superior benefit-to-cost ratio when compared to other treatments.

Keywords: Treatment, combinations, incorporating

Introduction
Protein is an important ingredient of human food. Its shortage in human diet leads to manifold problems, viz poor growth and development particularly of growing child [1]. In India, the protein status of common man's diet is far less than the minimum recommendations (80 g day-1) of Indian Council of Medical Research (ICMR). It contains 24.7 % protein, 0.6% fat, 0.9% fiber and 3.7 ash with sufficient quantity of calcium, phosphorus and important vitamins. Pulses are drought tolerant and prevent soil erosion accounted to their deep root and good ground covers, and thus called as "Marvel of Nature" [2].

`Nitrogen, phosphorus and potassium play vital role in the growth and development of the plant [3]. They are an integral part of several biologically important macromolecules including amino acids, nucleotides, co-enzymes and growth hormones which directly regulate plant metabolism [4]. Farm yard manure, decomposed mixture of dung and urine of farm animals along with their litter and left over material from roughages or fodder fed to the cattle, supplies all major (N, P and K) and micro (Fe, Mn, Cu and Zn) nutrients necessary for plant growth. Besides, FYM improves physico-chemical properties of soil. However, its sole use can hardly meet the crop needs at desired rate and time [5]. Bio-fertilizers play an important role in increasing availability of nitrogen and phosphorus. Inoculation of seeds with Rhizobium culture is a low cost method of nitrogen fertilization in legume and has been found beneficial to enhance the soil quality by providing more biological fixation of atmospheric nitrogen which may be helpful in boosting up production [6].

Nano- fertilizers provide the major nutrients to the crop as per the requirement in a phased manner as they contains nutrients and growth promoters encapsulated in nano scale polymers. These nano particles are capable of holding bountiful of nutrient ions due to their high surface area and release it slowly and steadily commensurating with crop demand thus ensuring increased nutrient use efficiency [7].

Foliar nutrition recognized as an important method of fertilizer application since foliar nutrient usually penetrate the leaf cuticle or stomata and enter the cells facilitating easy and rapid utilization of nutrients leading no wastage and quick supply of food and thereby reduce the requirement of fertilizers [8].

Nanotechnology has demonstrated a significant capacity to enhance the vitality of soil, amplify crop growth, and augment agricultural yields. As outlined by Kim *et al*. (2018) [9] and Chhipa *et al*. (2016) [10], this technology involves employing materials, tools, and techniques at the nanoscale within the realm of agriculture. Notable examples encompass Nanopesticides, Nanosensors, and Nanofertilizers. Among these advancements, the emergence of nano fertilizers stands out as a captivating application of nanotechnology in agriculture.

These specialized fertilizers enable plants to assimilate essential minerals like nitrogen, phosphorus, and potassium in the form of nanoparticles, a departure from conventional fertilizers. A method known as foliar application, which involves delicately misting liquid nutrients onto leaves, has gained prominence as an approach to enhance the uptake of nutrients from the aerial parts of plants. [11] and [12] have explored and documented the effectiveness of this technique.

Methods and Materials

The field experiment was conducted at research farm, Chandra Shekhar Azad university of Agriculture and technology Kanpur Uttar Pradesh for two consecutive years during Summer seasons 2021 and 2022. The twelve treatment combinations consisting of two varieties (Pusa-1431 and Virat) and six nutrient management practices (100 %NPK, 75 % NPK + FYM @ 5 t ha^{-1}, 75% NPK + FYM @ 5 t ha^{-1} + NPK Consortia, 75% NPK + FYM @ 5 t ha^{-1} + Nano – P Spray at 25 DAS, 75% NPK + NPK Consortia + Nano – P Spray at 25 DAS and 75 % NPK+ FYM @ 5 t ha^{-1} + NPK Consortia + Nano – P Spray at 25 DAS) were tested in factorial randomized block design with three replications.. The treatments were randomly allotted to different plots using random number table of Fisher and Yates (1963) [13]. The seed yield of each net plot (inclusive of tagged plants) was recorded in kg $plot^{-1}$ after cleaning the threshed produce was converted as q ha^{-1}. Straw yield was obtained by subtracting the seed yield (q ha^{-1}) from biological yield (q ha^{-1}).

Results and Discussion

The data analysis in Table 1 reveals that the mungbean variety Pusa-1431 exhibited superior performance across various metrics, including the number of pods per plant, pod length (measured in centimeters), number of grains per pod, and test weight, as compared to the Virat variety. This superiority held true for both years of observation and when considering the combined analysis. Moreover, the application of a combined treatment involving 75% NPK, 5 tons per hectare of FYM, NPK Consortia, and Nano-P Spray at 25 days after sowing (DAS) significantly enhanced the mentioned metrics. This improvement was evident in both years and when data was pooled, outperforming the results obtained from the 100% NPK treatment.

The data from Table 2 indicates notable differences in grain yield among different mungbean varieties, both within the individual years of experimentation and when pooling data. Specifically, the Pusa-1431 variety exhibited a considerable advantage over the Virat variety, showcasing the highest grain yield of 11.0 quintals per hectare in the pooled data. This amounted to an increase of 11.8% compared to the grain yield of the Virat variety (9.7 quintals per hectare).

Furthermore, the application of optimal nutrient management practices significantly enhanced the mungbean grain yield when compared to the 100% NPK treatment across both years of experimentation and when data was pooled. Notably, the combined treatment involving 75% NPK, 5 tons per hectare FYM, NPK Consortia, and Nano-P Spray at 25 DAS yielded the highest grain yield of 12.4 quintals per hectare, surpassing the outcomes of other treatments. This result was comparable to the grain yield obtained from the treatment involving 75% NPK, 5 tons per hectare FYM, and Nano-P Spray at 25 DAS. Interestingly, when evaluating pooled data, the application of 75% NPK, 5 tons per hectare FYM, NPK Consortia, and Nano-P Spray at 25 DAS led to a substantial 33.06% increase in grain yield over the 100% NPK treatment. This treatment also outperformed other treatments in pooled analysis.

The superiority of straw and biological yields over the Virat variety was notable, particularly with the application of the treatment involving 75% NPK, 5 tons per hectare FYM, NPK Consortia, and Nano-P Spray at 25 DAS, which resulted in higher values for these parameters. This enhancement in crop growth and yield can be attributed to the combination of optimal nutrient levels and improved fertility, which create a conducive environment for the plant's physiological and biochemical development.

Among the various nutrients, nitrogen plays a vital role as a plant nutrient. It's essential for chlorophyll synthesis, a critical component of photosynthesis. Nitrogen deficiency affects chlorophyll production, hindering essential functions such as nutrient uptake and energy conversion. Additionally, nitrogen is integral to amino acids, forming the foundation of plant proteins [14 and 15]. Phosphorus serves as an energy source and also plays a crucial role in various metabolic processes. Phosphorus is vital for nucleic acid structure and enzymatic activity. Adequate phosphorus supply early in a plant's lifecycle influences reproductive development and root system growth [16]. Potassium, while not a structural element within the plant, is pivotal for various functions, including carbohydrate metabolism, enzyme activation, and water regulation [17]. It also contributes to nutrient uptake, protein synthesis, and translocation of assimilates. It has additional benefits like disease resistance improvement, quality enhancement, and reduction in crop lodging. For mungbean yield formation, the interaction between source (photosynthesis and assimilate availability) and sink components (storage organs) governs the process. The improvements in both these regulating processes, evident through increased biomass accumulation, nutrient levels, and yield components in the Pusa-1431 variety, result in a significant rise in grain yield. The mungbean's grain yield depends on essential factors like grains per unit area and grain weight (test weight), both of which benefit from increased pod numbers and test weight in the Pusa-1431 variety. Biological yield encompasses both grain and straw yield. Pusa-1431's higher grain yield likely contributes to its elevated biological yield. This variance in yield components and yield among varieties is consistent with earlier studies by researchers [18 and 19].

Data presented in Table 3 illustrates significant differences in the B:C (Benefit-Cost) ratio among mungbean varieties. Variety Pusa-1431 achieved the highest B:C ratio of 2.18 when considering pooled data, exceeding the Virat variety's ratio of 1.95 by 0.23. Moreover, the application of the treatment involving 75% NPK, 5 tons per hectare FYM, NPK Consortia, and Nano-P Spray at 25 DAS resulted in a B:C ratio of 2.35, significantly surpassing other treatments in both individual years and pooled analysis. This result was on par with the B:C ratio of the treatment involving 75% NPK, 5 tons per hectare FYM, and Nano-P Spray at 25 DAS (2.25), indicating a remarkable 25.53% improvement over traditional farming practices.

Table 1: Varietal response to next generation on Yield Attribuutes of Mung Bean (*Vigna radiata* L.)

S. No.	Treatment Combinations	No. of Pods plant^{-1}			Pod length (cm)			No. of Grains pod-1			1000 grains weight(g)		
		2021	2022	Pooled Data	2021	2022	Pooled Data	2021	2022	Pooled Data	2021	2022	Pooled Data
(A) Variety (2)													
1		12.7	12.9	12.7	6.2	6.5	6.3	6.1	6.3	6.2	32.0	32.6	32.3
2		13.7	14.0	13.8	8.1	8.3	8.2	7.0	7.2	7.1	33.2	33.8	33.5
	SE(m)	0.2	0.2	0.2	0.1	0.1	0.1	0.09	0.1	0.09	0.3	0.5	0.4
	CD	0.6	0.6	0.6	0.3	0.3	0.3	0.2	0.4	0.3	NS	NS	NS
(B) Nutrient Management (6)													
1		11.3	11.7	11.5	5.7	6.0	5.8	5.7	5.9	5.8	31.7	32.0	31.8
2		11.8	12.0	11.9	6.2	6.7	6.4	6.3	6.5	6.4	32.0	32.7	32.3
3		14.0	14.4	14.2	7.0	7.6	7.3	6.6	6.8	6.7	33.2	33.4	33.3
4		14.4	14.7	14.6	7.8	8.0	7.9	6.7	6.9	6.8	33.4	33.9	33.6
5		13.1	13.4	13.2	7.3	7.6	7.4	6.4	6.6	6.5	32.1	33.2	32.5
6		14.6	15.0	14.8	8.0	8.5	8.2	7.2	7.4	7.3	33.8	34.3	34.0
SE(m)		0.3	0.4	0.3	0.1	0.2	0.1	0.2	0.3	0.2	0.8	1.0	0.9
CD		1.0	1.0	1.0	0.5	0.7	0.6	0.5	0.7	0.6	NS	NS	NS

Table 2: Varietal response to next generation on Yield of Mung Bean (*Vigna radiata* L.)

S. No.	Treatment Combinations	Grain Yield (q ha^{-1})			Straw Yield (q ha^{-1})			Biological Yield (q ha^{-1})			Harvest Index		
		2021	2022	Pooled Data	2021	2022	Pooled Data	2021	2022	Pooled Data	2021	2022	Pooled Data
(A) **Variety (2)**													
1	IPM 205-7 (VIRAT)	9.3	10.1	9.7	28.6	30.3	29.5	38.7	40.5	39.6	24.2	24.9	24.6
2	PUSA: - 1431	10.5	11.5	11.0	32.8	34.4	33.6	43.2	46.6	44.9	24.4	25.0	24.7
	SE(m)	0.153	0.1	0.1	0.4	0.4	0.4	0.6	0.7	0.7	0.3	0.4	0.4
	CD	0.5	0.5	0.5	1.3	1.4	1.4	1.8	2.3	2.1	NS	NS	NS
(B) Nutrient Management (6)													
1	100 % NPK (20 N_2, 40 P_2O_5, 20 K_2O kg ha^{-1})	7.9	8.7	8.3	26.3	28.3	27.3	34.2	37.0	35.6	23.1	23.4	23.3
2	75 % NPK + FYM @ 5 t ha^{-1}	8.7	9.9	9.3	27.7	30.1	28.9	36.4	40.1	38.3	23.9	24.5	24.2
3	75% NPK + FYM @ 5 t ha^{-1} + NPK Consortia	10.3	11.3	10.8	31.7	33.4	32.6	42.7	45.1	43.9	24.6	25.3	25.0
4	75% NPK + FYM @ 5 t ha^{-1} + Nano – P Spray at 25 DAS	10.9	11.9	11.4	33.3	34.4	33.9	44.3	46.3	45.3	24.7	26.3	25.5
5	75% NPK + NPK Consortia + Nano – P Spray at 25 DAS	9.7	10.4	10.1	30.0	31.8	30.9	30.3	42.2	36.3	24.5	24.9	24.7
6	75 % NPK+ FYM @ 5 t ha^{-1} + NPK Consortia + Nano – P Spray at 25 DAS	11.9	12.9	12.4	35.0	36.3	35.7	47.7	49.1	48.4	25.3	26.1	25.7
	SE(m)	0.30	0.2	0.3	0.8	0.8	0.8	1.1	1.3	1.2	0.6	0.6	0.6
	CD	0.96	0.95	1.0	2.3	2.5	2.4	3.1	3.3	3.2	NS	NS	NS

Table 3: Varietal response to next generation on economics of Mung Bean (*Vigna radiata* L.)

S. No.	Treatment Combinations	Cost of Cultivation (Rs ha^{-1})			Gross Return (Rs ha^{-1})			Net Return (Rs ha^{-1})			Benefit: Cost ratio		
		2021	2022	Pooled Data	2021	2022	Pooled Data	2021	2022	Pooled Data	2021	2022	Pooled Data
(A) Variety (2)													
1	IPM 205-7 (VIRAT)	40,312.1	41,212.1	40,762.1	73,531.0	85,640.5	79,585.8	33,219.0	44,428.5	38,823.7	1.82	2.07	1.95
2	PUSA: - 1431	40,812.1	41,712.1	41,262.1	83,109.3	97,358.5	90,233.8	42,297.2	55,646.4	48,971.8	2.03	2.33	2.18
	SE(m)	591.7	604.7	598.2	1,204.1	1,402.8	1,303.4	620.6	804.6	712.4	0.03	0.03	0.03
	CD	N/A	NS	NS	3,554.4	4,140.7	3,847.4	1,831.8	2,375.0	2,103.0	0.09	0.10	0.09
(B) Nutrient Management (6)													
1	100 % NPK (20 N_2, 40 P_2O_5, 20 K_2O kg ha^{-1})	38,689.4	39,589.4	39,139.4	62,889.0	73,872.7	68,380.8	24,199.6	34,283.3	29,241.5	1.63	1.87	1.75
2	75 % NPK + FYM @ 5 t ha^{-1}	40,871.8	41,771.8	41,321.8	69,023.4	82,812.5	75,917.9	28,151.6	41,040.7	34,596.1	1.69	1.98	1.84
3	75% NPK + FYM @ 5 t ha^{-1} + NPK Consortia	40,971.8	41,871.8	41,421.8	81,408.0	95,406.8	88,407.4	40,436.2	53,535.0	46,985.6	1.99	2.28	2.13

4	75% NPK + FYM @ 5 t ha^{-1} + Nano – P Spray at 25 DAS	40,879.8	41,779.8	41,329.8	86,447.4	99,973.0	93,210.2	45,567.6	58,193.3	51,880.4	2.11	2.39	2.25
5	75% NPK + NPK Consortia + Nano – P Spray at 25 DAS	39,479.8	40,379.8	39,929.8	76,785.8	88,697.4	82,741.6	37,306.0	48,317.6	42,811.8	1.95	2.20	2.07
6	75 % NPK+ FYM @ 5 t ha^{-1} + NPK Consortia + Nano – P Spray at 25 DAS	42,479.8	43,379.8	42,929.8	93,367.3	1,08,234.5	1,00,800.9	50,887.5	64,854.8	57,871.1	2.20	2.50	2.35
	SE(m)	1024.8	1047.3	1036.0	2,085.6	2,429.7	2,257.6	1,074.9	1,393.6	1,234.0	0.05	0.06	0.05
	CD	NS	NS	NS	6,156.3	7,171.9	6,663.9	3,172.9	4,113.7	3,642.5	0.15	0.17	0.16

Conclusion

In conclusion, based on the two years of experimentation, it can be deduced that the mungbean variety Pusa-1431 demonstrated superior yield, net returns, and B:C ratio, thus making it the preferred choice. The Virat variety closely followed suit. The application of the treatment involving 75% NPK, 5 tons per hectare FYM, NPK Consortia, and Nano-P Spray at 25 DAS emerged as a promising integrated nutrient management approach. Similarly, the treatment involving 75% NPK, 5 tons per hectare FYM, and Nano-P Spray at 25 DAS also exhibited comparable efficacy."

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