Journal of Applied Biology & Biotechnology Vol. 11(5), pp. 152-156, Sep-Oct, 2023
Available online at http://www.jabonline.in
DOI: 10.7324/JABB.2023.113474

Performance of mung bean as influenced by different levels of fertilizers and cropping systems in the semi-arid region of India

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ARTICLE INFO

Article history:
Received on: March 12, 2023
Accepted on: July 05, 2023
Available online: August 10, 2023

Key words:
Cropping system,
Mung bean,
Nanofertilizers,
Fertilization,
Yield attributes.

ABSTRACT

Mung bean being a leguminous crop is helpful in improving the soil properties. Since it is a pulse crop, it is deprived of proper fertilization. Hence, the study was aimed to determine the best fertilizer combination and cropping system for mung bean production. The experiment comprised eight treatments and three replications arranged in a split-plot design. The results revealed that yield components, namely, number of pods/plant, number of seeds/pod, 1000 seed weight, stover yield, seed yield, and biological yield in sole mung bean were significantly higher when mung bean is grown as an intercrop. While in the case of different fertilizer levels, the treatment with the combination of nanofertilizers and NPK fertilizers produced higher yield attributes than all other treatments. In contrast, the control (no fertilizer) produced lower yield characters. The study concludes that the combination of 50% recommended dose fertilizer + 50% nano NPK fertilizers + sole mung bean produced the highest yield and can be used for higher mung bean production.

1. INTRODUCTION

Mung bean (*Vigna radiate* L.) is a major pulse crop in India that belongs to the Leguminosae family and contains significant amounts of proteins, minerals, nutrients, and essential amino acids. It has high economic and commercial values. Mung bean, also known as moong or green gram, is one of India's main pulse crop for agricultural exports. It is a rich source of protein, fiber, and iron and is oftenly cultivated as a *Kharif* crop, similar to a summer crop. The crop can be grown on a variety of soil types and gives excellent results when planted on well-drained loamy to sandy-loam soils [1,2]. In India, especially in the north-western region, rice-wheat cropping is one of the most common aspects of agriculture. However, the continuous implementation of this cropping system has resulted in significant challenges such as the decline in the soil nutrient reserves, deteriorated soil health, water depletion, an escalating production cost, a scarcity of labor, an increase in greenhouse gas emissions due to crop residue burning, climate vulnerabilities, and herbicide resistance in weeds [3,4]. Thus, to overcome these challenges, it is necessary to adopt maize-mung bean cropping system which has low water and nutrient demand compared to rice-wheat cropping system. As a leguminous crop, mung bean will benefit farmer's economies and enhance soil fertility, eventually substituting rice and wheat for farmers around the world [5].

Chemical fertilizers are now vital to existing agricultural production methods, yet they have also been correlated to environmental and ecological issues. The loss of nutrients from agricultural fields through leaching and gaseous emissions is the main factors contributing to environmental pollution and climate change. Sustainable crop production can be achieved if new nutrient sources are explored and existing sources are altered [6-8]. Research in nanotechnology may provide long-term solutions to significant problems faced by modern-day intensive agriculture. Nanofertilizer is a nutrient fertilizer that comprises nanostructured formulations for efficient uptake by plants due to the slower release of nutrients. However, in conventional bulk fertilizers, the plant uptake efficiency is low; hence, larger quantities are required. In NPK-based fertilizers, nutrient uptake efficiency is reduced mainly due to the drastic changes in chemical forms that plants cannot absorb, leading to runoff, leaching, and atmospheric losses. Thus, it is necessary to produce fertilizers that can be taken up more readily by plants while posing no threat to soil and the environment [9-11]. Furthermore, large surface areas of leaves allow nanoparticles to interact more effectively with target sites, besides other benefits. Nanofertilizers are better than fertilizers, because they provide nutrients for the plant and restore the soil to its natural state without damaging the soil [12,13]. Furthermore, nanofertilizers allow crop production systems to be more sustainable without compromising yields [6,14]. Although many studies have been conducted to increase mung bean crop yield, just a few uses of NPK nanofertilizers in India, particularly in the Punjab area, are reported in the literature. Therefore, the present study was undertaken to evaluate the response of mung bean to eco-friendly granular as well as foliar NPK nanofertilizers under semi-arid conditions of Punjab.

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2. MATERIALS AND METHODS

The study for this research was performed on the research farm of Lovely Professional University, Punjab, at an elevation of 249 m above mean sea level. The experimental location was situated at 31.2560° N latitude and 75.7051° E longitude. The soil of the experimental site was clay loam in texture, slightly alkaline in reaction (7.9), low in organic carbon (0.30%), medium in nitrogen (252 kg/ha), phosphorous (15 kg/ha), and potassium (15 kg/ha) availability. The treatment consisted of two cropping systems, namely, $M_{1:}$ Mung bean (Sole cropping) and M_2: Mung bean + Maize (Intercropping), and four levels of fertilizers, namely, S_1: Control, $S_{2:}$ 100% Recommended dose of fertilizers (RDF), $S_{3:}$ 100% Nano NPK fertilizers, and $S_{4:}$ 50% RDF + 50% Nano NPK fertilizers. The experiment was laid out in a split-plot design and replicated 3 times. The cropping systems were assigned to the main plots, while the fertilizer treatments were assigned to the subplot. The recommended fertilizer doses were applied @ 5 kg/acre N, 16 kg/acre P_20_5, and 0 kg/acre K in mung bean, while in maize 50 kg/acre N, 25 kg/acre P_20_5, and 12 kg/acre K, respectively. As chemical sources of fertilizer, urea, diammonium phosphate, and muriate of potash were used, and Nano NPK (19:19:19) in granular form was used as nanofertilizer treatment and applied as foliar application @ 2 g/L. The data collected were number (No.) of pods/plant, No. of seeds/pod, 1000 seed weight, stover, seed, and biological yield. Data were subjected to an analysis of variance using the star (statistical tool for agriculture) software. Duncan's multiple test range was used to separate the statistically significant means ($P \leq 0.05$).

3. RESULTS AND DISCUSSION

This study was aimed to quantify the degree of variance in various measures caused by treatment variables. The data have been statistically incorporated at appropriate places in table. It is, further, illustrated with graphs wherever necessary in the text. The main effects have been described first and the interaction effect if significant is narrated further.

3.1. Yield Parameters

3.1.1. No. of pods/plant, No. of seeds/pod, and 1000 seed weight (g)

The results revealed that the application of different levels of fertilizers had a significant ($P \leq 0.05$) impact on the yield parameters [Table 1, Figures 1 and 2]. Statistically, a higher No. of pods/plant, No. of seeds/pod, and 1000 seed weight were recorded in the sole mung bean compared to the intercrop mung bean. The possible reason could be due to the less competition and efficient utilization of growth resources, which led to better plant growth and development and, hence, increased the pods/plant, seeds/pod, and 1000 seed weight. Similar findings were also reported by Yousaf and Rahman, Khan *et al*. [15,16], who noted a significant increase in yield characteristics of sole mung bean in comparison when mung bean is intercropped with cereals. The relative decrease in the pods/plant, grains/pod, and 1000 seed weight in intercrop mung bean was due to the increase in competition between mung bean and maize for essential growth resources. A similar trend was observed by Legwaila *et al*., Morgado and Willey, and Khan and Khaliq [17-19], who observed cereal crops as a stronger competitors to legumes when grown in intercropping environments.

The maximum mean value of all the yield parameters was recorded in 50% RDF and 50% nano NPK fertilizers which proved to be significantly superior to all other treatments except in the pods/plant which was statically at par with 100% RDF and 100% nano NPK fertilizers, while the control consistently recorded the lowest mean values [Table 1]. This may be due to the more rapid supply of primary mineral nutrients by nanofertilizers through foliar spray through plant openings (stomata or wounds and scratches) in the leaves, which increased the delivery of nutrients for the metabolism of plants. This encourages vegetative and reproductive growth and aids in improving the yield characteristics of mung bean, namely, pods/plant, seeds/pod, and 1000 seed weight. The outcome is in accordance with the findings of [20-22], who reported an increase in growth and yield attributes due to enhanced efficiency of nanofertilizers nutrients through foliar spraying in cereals and pulses, respectively.

There was no significant interaction between the cropping system and levels of fertilizer in pods/plant, but it was significant in the case of the seeds/pod and 1000 seed weight. The maximum mean value was recorded in sole mung bean in conjunction with 50% RDF and 50% nano NPK fertilizers, while the minimum was found in intercrop mung bean in combination with the control [Tables 2 and 3].

3.1.2. Stover, seed, and biological yield (t/ha)

There was significant effect of the cropping system on all the yield components recorded, where the sole mung bean had significantly higher

Table 1: Effect of different levels of fertilizers on the yield parameters of sole and intercrop mung bean.

Treatments	No. of pods/plant	No. of seed/pod	1000 seed weight (g)	Stover yield (t/ha)	Seed yield (t/ha)	Biological yield (t/ha)
A - Main Plot						
M_1	35.10[a]	11.55[a]	36.84[a]	1.55[a]	1.32[a]	2.88[a]
M_2	26.64[b]	10.51[b]	31.02[b]	1.38[b]	1.01[b]	2.39[b]
SEM (±)	0.810	0.025	0.149	0.006	0.010	0.016
CD ($P \leq 0.05$)	5.330	0.166	0.979	0.038	0.068	0.107
B - Sub Plot						
S1	20.42[b]	8.34[d]	19.07[d]	0.997[d]	0.725[d]	1.72[d]
S2	35.18[a]	11.75[b]	39.76[b]	1.652[b]	1.325[b]	2.97[b]
S3	32.13[a]	11.12[c]	35.08[c]	1.282[c]	0.983[c]	2.26[c]
S4	35.73[a]	12.91[a]	41.88[a]	1.945[a]	1.642[a]	3.58[a]
SEM (±)	1.190	0.087	0.468	0.021	0.019	0.040
CD ($P \leq 0.05$)	3.720	0.272	1.458	0.066	0.060	0.125
Interaction (A×B)	NS	*	*	*	*	*

[a,b,c] and [d] are statically different at 0.05%, *: significant

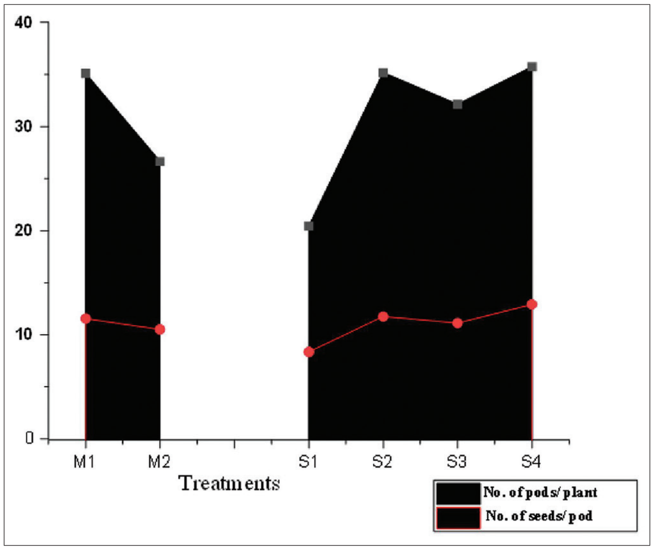

Figure 1: Effect of different levels of fertilizers on the No. of pods/plant and No. of seeds/pod of sole and intercrop mung bean.

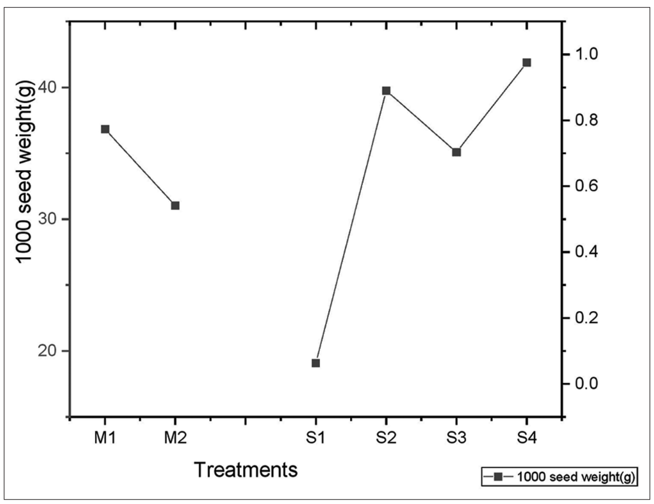

Figure 2: Effect of different levels of fertilizers on the 1000 seed weight of sole and intercrop mung bean.

stover, seed, and biological yield in comparison to intercrop mung bean [Table 1 and Figure 3]. This could be attributed to the fact that cereals are a stronger competitor and utilize plant resources better than legumes, coupled with mutual shading effect brought on by high plant densities in the cereal companion crops. These findings are also supported by Sarunaite *et al*., Jiao *et al*., and Jeyakumaran and Seran [23-25], who noticed cereals as a better competitor than legumes when intercropped.

The use of 50% RDF and 50% Nano NPK fertilizers consistently produced the highest stover, seed, and biological yield while the control consistently recorded the lowest values. The possible reason for these variations may be due to the capability of mung bean to utilize the vital nutrients provided by the RDF at the early growth stage combined with the nutrients supplied by the NPK nanofertilizers through foliar spray at the later stages. This accelerates the uptake of nutrients and water, enhancing photosynthesis, and leading to a higher production of dry matter, translating into the final yield. This supports the findings of [26], who reported a synergistic effect between conventional fertilizers and nanofertilizers for higher nutrient uptake in the cells of the plant.

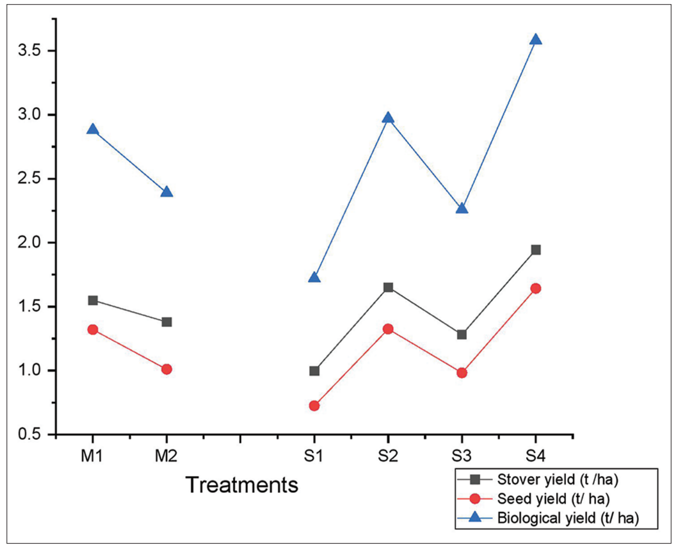

Figure 3: Effect of different levels of fertilizers on the yield of sole and intercrop mung bean. Data is in the form of Mean±SEM, *: Significance at $P\leq0.05$, NS: Non-Significant at $P\leq0.05$, CD: Critical difference, means followed by different letters (a, b, c and d) are statically different at 0.05%, M_1: Mung bean (sole cropping), M_2: Maize+Mung bean (intercropping), S_1: Control, S_2: 100% RDF, S_3: 100% nano NPK fertilizers, and S_4: 50% RDF+50% nano NPK fertilizers.

Table 2: Interaction between cropping system and different levels of fertilizer on the No. of seeds/pod.

Treatments	No. of seeds/pod			
	S_1	S_2	S_3	S_4
M_1	8.815	12.025	11.770	13.625
M_2	7.870	11.483	10.486	12.208
SEM (±)		0.110		
CD ($P\leq0.05$)		0.362		

Table 3: Interaction between cropping system and different levels of fertilizer on the 1000 seed weight.

Treatments	1000 seed weight (g)			
	S_1	S_2	S_3	S_4
M_1	21.895	44.113	38.604	42.757
M_2	16.260	35.420	31.413	41.008
SEM (±)		0.592		
CD ($P\leq0.05$)		1.975		

This led to increased photosynthesis, accumulation of higher levels of photosynthates, and transportation of nutrients to the economically important parts of the plant that correlate to a final seed yield. In addition, the findings were also in agreement with those of [27-29], who found that combining 50% NPK chemical fertilizers with 50% nano NPK fertilizers increased all sorghum characteristics in both seasons.

The interaction effects between the cropping system and levels of fertilizer were significant in all the parameters mentioned above. The sole mung bean was found to have the highest mean value when mixed with 50% RDF and 50% nano NPK fertilizers, whereas the intercrop mung bean was found to have the lowest mean value when combined with control [Tables 4-6].

Table 4: Interaction between cropping system and different levels of fertilizer on the stover yield.

Treatments	Stover yield (t/ha)			
	S_1	S_2	S_3	S_4
M_1	1.120	1.674	1.348	2.087
M_2	0.875	1.630	1.216	1.803
SEM (±)		0.026		
CD ($P \leq 0.05$)		0.087		

Table 5: Interaction between the cropping system and different levels of fertilizer on the seed yield.

Treatments	Seed yield (t/ha)			
	S_1	S_2	S_3	S_4
M_1	0.864	1.434	1.111	1.884
M_2	0.585	1.216	0.855	1.400
SEM (±)		0.026		
CD ($P \leq 0.05$)		0.095		

Table 6: Interaction between cropping system and different levels of fertilizer on the biological yield.

Treatments	Biological yield (t/ha)			
	S_1	S_2	S_3	S_4
M_1	1.984	3.109	2.459	3.970
M_2	1.460	2.846	2.071	3.203
SEM (±)		0.052		
CD ($P \leq 0.05$)		0.179		

4. CONCLUSION

The present research shows that foliar spray of nano NPK fertilizers affects mung bean growth, leading to favorable changes in yield attributes, and yield. Thus, the experiment concluded that the combination of 50% RDF + 50% nano NPK fertilizers + sole mung bean was found to be the best fertilizer combination and cropping system for increasing mung bean yield and can be followed for higher mung bean production. Nonetheless, further field research is needed for more clear results.

5. AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

6. FUNDING

There is no funding to report.

7. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

8. ETHICAL APPROVALS

The study does not involve experiments on animal or human subjects.

9. DATA AVAILABILITY

All data generated and analyzed are included within this research article.

10. PUBLISHER'S NOTE

This journal remains neutral with regard to jurisdictional claims in published institutional affiliation.

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How to cite this article:
Yomso J, Menon S, Sale MN, Yumnam J. Performance of mung bean as influenced by different levels of fertilizers and cropping systems in the semi-arid region of India. J App Biol Biotech. 2023;11(5):152-156.
DOI: 10.7324/JABB.2023.113474