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Microbial consortia and herbicide regimes on nodulation efficiency and yield attributes in Mungbean (*Vigna radiata*)

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Abstract

Weed infestation and optimum nutrient management are two critical constraints limiting mungbean (*Vigna radiata* L. Wilczek) productivity in the *rabi* season in the Krishna region of Andhra Pradesh, India. A field experiment was conducted during the *rabi* 2024-25 at Regional Agricultural Research Station (RARS), Lam, Guntur, using a factorial randomized block design (FRBD) with 3 replications, to evaluate the combined effects of herbicide-based weed management regimes and microbial consortia based nutrient management treatments on weed control efficiency, nodulation parameters, yield attributes, and benefit cost (B:C) ratio in mungbean. Results demonstrated that post-emergence application of Fomesafen @ 220 g ha⁻¹ + Fluzifop-p-butyl @ 220 g ha⁻¹ at 15-20 days after sowing (DAS) reported the highest weed control efficiency (93.1% at 30 DAS) and hand weeding twice at 20 and 40 DAS recorded the highest nodule count (27.8 plant⁻¹) and nodule dry weight (2.4 mg plant⁻¹). Soil application of 75% N-P-K-Zn combined with N-P-K-Zn microbial consortia @ 2 kg ha⁻¹ along with fortified farmyard manure (FYM) delivered the highest grain yield (883 kg ha⁻¹) and best B:C ratio (0.64). The significant interaction of weed management treatments and microbial consortia confirmed that an integrated approach improves system productivity without adversely affecting the root zone microbiome.

Keywords: *Vigna radiata*, mungbean, microbial consortia, weed control, herbicide, nodulation, N-P-K-Zn biofertilizer, *Rabi* crop, Andhra Pradesh

Introduction

Mungbean (*Vigna radiata* L.) is most important short duration pulse crops grown across South and Southeast Asia, valued for its high protein content, rapid growth cycle, and higher capacity for biological nitrogen fixation (BNF) through symbiosis with soil rhizobia. In India, it is cultivated across diverse agroclimatic zones in both *kharif* and *rabi* seasons in Krishna Delta of Andhra Pradesh representing a key production zone during the post-monsoon period. Mungbean productivity remains far below its genetic potential, due to biotic pressures, weed infestation and suboptimal nutrient management practices.

Weed infestation is one of the economically damaging threats to mungbean production. Crop weed competition for resources such as soil moisture, solar radiation, and mineral nutrients, and their rapid propagation with prolific seed production makes eradication difficult once established in crop fields. Studies in the tropical and subtropical regions have shown that weed infestation can reduce the mungbean grain yield by up to 40% compared to weed free conditions, with losses ranging from 0.589 to 0.989 t ha⁻¹ under uncontrolled weed pressure (Mirjha *et al.*, 2001) [8]. Weeds also serve as alternative host plants for insect pests and disease causing pathogens, further compounding crop health risks (Revathi *et al.*, 2012) [15]. The problem is even elevated during the *rabi* season when intermittent rainfall, combined with a chronic shortage of agricultural farm workers and higher labour costs, renders traditional hand weeding both logistically impractical and economically unviable (Venkata Rao *et al.*, 2017) [21].

In response to these constraints, farmers across the Krishna Delta and adjoining areas have increasingly adopted chemical herbicides as the primary tool for weed management. Herbicides supports the speed, cost efficiency, and broad spectrum control; however, their indiscriminate use can adversely affect the rhizosphere microbiome and critically, the symbiotic nodulation

apparatus that legumes rely upon for biological nitrogen acquisition. Post-emergence herbicides belonging to the imidazolinone and aryloxyphenoxypropionate families, including imazethapyr, have been shown to exert inhibitory effects on mungbean nodulation when applied at inappropriate rate/growth stages (Singh and Singh, 2020) ^[17]. The challenge for mungbean agronomy needs focus in identifying herbicide regimes that deliver effective weed suppression while preserving the functional integrity of the root zone microbiome.

Simultaneously, nutrient management strategies of mungbean have evolved significantly with the advancement of biofertilizer and microbial consortia technologies. Multi strain microbial consortia incorporating nitrogen fixing bacteria, phosphate solubilizing bacteria (PSB), and potassium mobilizing microorganisms have demonstrated synergistic benefits over single strain inoculants in terms of nodulation, nutrient uptake, and grain yield in leguminous crops (Bansal, 2009; Joshi *et al.*, 2022) ^[1, 5]. Combined inoculation with Rhizobium and plant growth promoting rhizobacteria (PGPR) has been shown to increase nodule number by up to 44.5% and nodule dry weight by 23.9% over uninoculated controls in mungbean, along with measurable improvements in soil fertility indicators including available nitrogen, phosphorus, and potassium at harvest (Neha *et al.*, 2019) ^[12]. When integrated with reduced chemical fertilizer doses, such consortia present a sustainable pathway to maintain productivity while mitigating the environmental and economic costs of synthetic nutrient inputs. (Meena *et al.*, 2015; Yousefi *et al.*, 2025) ^[7, 22].

Research on NPK consortia with zinc-solubilizing bacteria (ZSB) has further confirmed that multi-functional microbial inoculants can maximise effective nodulation, nodule dry weight, grain yield, and protein content in mungbean (Navsare *et al.*, 2018) ^[11]. A study using NPK Consortia with ZSB was recorded maximum effective nodules plant⁻¹ (41.5), nodule dry weight (96.3 mg plant⁻¹), and grain yield (1,106 kg ha⁻¹) in mungbean, underscoring the potential of multi-nutrient consortia to substantially uplift crop productivity. However, the interactive effects of herbicide-based weed management with microbial consortia-based nutrient management remain insufficiently investigated, particularly under the specific agroclimatic and soil conditions of the Krishna Delta.

This study majorly focuses evaluating three herbicide regimes and two formulations of N-P-K-Zn microbial consortia against conventional practices in *rabi* mungbean to identifying the most productive, economically viable, and ecologically sound combination of weed management and nutrient management practices for the region.

Materials and Methods

The field experiment was conducted during the *rabi* season 2024-25 at the Regional Agricultural Research Station (RARS), ANGRAU, Lam, Guntur, Andhra Pradesh, India. The experimental farm is geographically situated at 25°18' N latitude and 83°36' E longitude, at an altitude of 128.93 m above mean sea level (MSL). The site experiences a semi-arid tropical climate with moderate temperatures during the *rabi* season (October- February), characterized in Krishna Delta agroclimatic zone. Experimental site soils are deep, medium black cotton soils (Vertisols) with moderate water holding capacity and a neutral to slightly alkaline pH.

The experiment was conducted as a three replicate, factorial randomized block design (FRBD), considering weed management practices as first factor in which four treatments

W2- Hand weeding twice 20 and 40 days after sowing (DAS), W3- Fomesafen @ 220 g ha⁻¹ + Fluzifop-p-butyl @ 220 g ha⁻¹ at 15-20 DAS, and W4 - Propaquizafop 2.50% + imazethapyr 3.75% ME @ 125 g ha⁻¹ at 15-20 DAS tested against W1-weedy check and nutrient management with microbial consortia for the second factor was considered as M2- 75% N-P-K-Zn +Seed inoculation with N-P-K-Zn microbial consortia @50 g kg⁻¹, M3- 75% N-P-K-Zn +Soil application N-P-K-Zn microbial consortia @ 2 kg ha⁻¹ along with fortified FYM were tested against M1- 100% N P K Zn in various treatment combinations denoted as combination of two factors (W and M) to evaluate weed parameters viz., weed count (number m⁻²) and weed dry weight (g m⁻²) at 30 DAS and 45 DAS from fixed quadrats in each plot. Weed control efficiency (WCE%) was calculated relative to the weedy check (W1). Nodulation parameters viz., Number of nodules per plant and nodule dry weight (mg plant⁻¹) recorded at 50% flowering stage by carefully uprooting representative plants from each plot, washing roots, and counting and oven-drying nodules. Growth (plant height, branches plant⁻¹) and yield attributes viz., pods plant⁻¹, pod length, seeds pod⁻¹, test weight, grain yield (kg ha⁻¹) and stover yield (kg ha⁻¹) at physiological maturity. Economic parameters viz., net returns (NR, Rs. ha⁻¹) and benefit-to-cost ratio (B:C ratio) were calculated based on prevailing input and output prices and Soil nutrient status *i.e* key soil nutrient parameters (N P K) were recorded at harvest to assess the effect of treatments on post-crop health.

Plot wise data collected was tested for normality preliminarily. A two-factor analysis of variance (ANOVA) was performed on square root transformed data to verify statistical significance. Treatment means was compared by critical difference (CD) method at P<0.05 significance level. Graphical representations including weed control efficiency charts and soil nutrient status heat maps were developed using the R statistical software environment.

Results and Discussion

3.1 Weed Count and Weed Dry Biomass

Weed infestation quantified by weed count (number m⁻²) and weed dry biomass (g m⁻²) at 30 and 45 DAS, was significantly influenced by weed management (Table 1). The weedy check (W1) recorded the highest weed counts of 38.2 and 68.0 weeds m⁻² at 30 and 45 DAS, respectively, with corresponding weed dry weights of 8.7 and 59.2 g m⁻², indicating the intense competitive pressure exerted by weeds in the absence of management. These findings are in confirmation with the literature reporting the severity of weed competition in mungbean in the absence of control measures (Singh and Singh, 2020) ^[18].

Among the weed management treatments, W3 (Fomesafen @ 220 g ha⁻¹ + Fluzifop-p-butyl @ 220 g ha⁻¹ applied at 15-20 DAS) reported the lowest weed count and weed dry biomass with WCE of 93.1% and 89.5% at 30 and 45 DAS, respectively. W4 (Propaquizafop + Imazethapyr ME @ 125 g ha⁻¹) followed performing better than hand weeding (W2) in terms of herbicidal efficiency against the dominant weed flora. The relative superiority of W3 over W4 and W2 in weed suppression indicating that appropriate herbicides with complementary modes of action can outperform single-active formulations and even manual weeding in controlling mixed-species of weed communities in mungbean fields. Literature on chemical weed management in greengram similarly highlighted the potential of combining broadleaf and grass herbicides for achieving broad-spectrum weed control (Singh and Singh, 2020) ^[17].

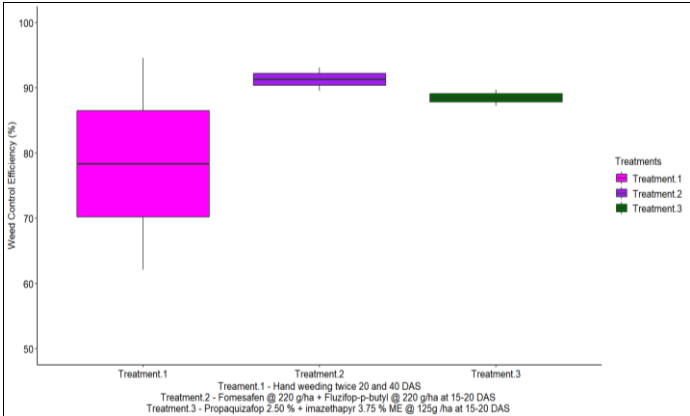
Table 1: Weed growth in mungbean as influenced by different weed and nutrient management practices during *rabi*, 2024-25

Treatments	Weed count* (No/m2)		Weed dry wt.* (g/m2)		WCE (%)	
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
FACTOR A: 1) Weedy check	6.2 (38.2)	8.3 (68.0)	3.1 (8.7)	7.7 (59.2)	-	-
2)Hand weeding twice 20 and 40 DAS	4.6(20.4)	5.4 (29.3)	2.1 (3.3)	2.1 (3.2)	62.1	94.6
3)Fomesafen @ 220 g/ha + Fluzifop-p-butyl @ 220 g/ha at 15-20 DAS	1.8 (20.4)	4.4 (19.1)	1.2 (0.56)	2.7 (6.2)	93.1	89.5
4)Propaquizafop 2.50% + imazethapyr 3.75% ME @ 125g /ha at 15-20 DAS	3.0 (9.7)	5.8 (33.3)	1.4 (0.9)	2.9 (7.6)	89.7	87.2
Sem±	0.366	0.243	0.103	0.151		
CD	1.1	0.7	0.3	0.4		
FACTOR B: 1)100%N P KZn	3.8 (16.3)	6.2 (39.3)	2.0 (3.4)	3.8 (19.1)	-	-
2)75% NPKZn +Seed inoculation with NPKZn microbial consortia @50g/kg	4.3 (20.6)	5.9 (36.3)	2.1 (3.8)	3.7 (16.0)	-	-
3)75% NPKZn +Soil application NPKZn microbial consortia @2kg/ha along with fortified FYM	3.6 (16.6)	5.9 (36.6)	1.8 (2.8)	4 (22.2)	-	-
Sem±	0.317	0.211	0.089	0.131		
CD(0.05)	NS	NS	NS	NS		
CV(%)	28.2	12.2	15.9	11.8		

Note: * Indicates the values transformed with sqrt+1 and values in parenthesis are original

In terms of monetary returns, the chemical weed management treatment W3 proved to be a more economically advantageous practice than hand weeding twice at 20 and 40 DAS (W2), due to the reduced labor requirements and the higher costs associated with hiring agricultural workers in the context of declining farm labor availability during the *rabi* season (Venkata Rao *et al.*, 2017) ^[21]. Microbial consortia treatments are not reported statistically significant differences in weed count or weed dry weight, as microbial consortia are primarily intended to influence the soil-plant-nutrient interface rather than directly suppressing weed growth. However, a numerically lower weed count and weed dry biomass were observed under M3 (soil application of microbial consortia with fortified FYM).

weight under W3 suggesting mild phytotoxic or allelopathic effect of the Fomesafen + Fluzifop-p-butyl combination on root morphology or rhizobia infection processes, even though grain yield under W3 was not significantly lower than W4. Previous literature reported that imazethapyr at higher doses or early application timings, can negatively impact symbiotic parameters such as nodule number and nodule dry weight in mungbean (Singh and Singh, 2020) ^[18] Whereas the herbicide formulations used in the present study, applied at the recommended doses in the 15-20 DAS window, limited these adverse effects to a tolerable extent while maintaining effective weed management. (Choudhary *et al.*, 2024) ^[2]. Nodulation response to the applied microbial consortia treatments was higher, though not statistically significant, under M2 and M3 relative to M1 these results indicated that while the microbial consortia did not drastically alter the absolute nodulation outcome within this experimental context, the inoculant application did not negatively impact rhizobia colonization. Research results of various legume species confirmed that N-P-K and PGPR consortia can synergistically enhance nodulation through mechanisms such as production of plant growth hormones (IAA, GA3), phosphate solubilization, and improved root architecture, which together increase the number of potential infection sites for rhizobia entry (Neha *et al.*, 2019; Mogal *et al.*, 2019; Yousefi *et al.*, 2025) ^[12, 9, 22]. The marginal benefit observed under M3 indicating the combined effect of fortified FYM improving soil organic matter and microbial activity in the rhizosphere these results are in confirmation with Javaid and Bajwa (2011) ^[4].



* Treatments were compared against the weedy check

Fig 1: Weed control efficiency of different combinations of herbicide treatments

3.2 Nodulation: Number and Dry Weight of Nodules

Nodule count plant⁻¹ and nodule dry weight recorded at 50% flowering were significantly influenced by the weed management practices. Hand weeding at 20 and 40 DAS (W2) recorded the greater number of nodules plant⁻¹ (27.8) and nodule dry weight (2.4 mg), significantly superior over all herbicide treatments and the weedy check. The inhibitory effect of weed competition on nodulation was evident from the lowest values of 21.9 nodules plant⁻¹ and 1.7 mg dry weight in the weedy check, supporting earlier findings that weed pressure significantly influences the legume nodulation capacity. In the herbicide treatments, W4 performed better than W3 in nodulation parameters, recording 25.8 nodules plant⁻¹ and 2.1 mg nodule dry weight compared to 22.7 nodules plant⁻¹ and 1.3 mg dry weight under W3. The relatively lower nodule dry

3.3 Grain Yield and Stover Yield

Grain yield was significantly affected by both weed management and nutrient management practices, and significant interaction between the two factors was recorded. Among the weed management treatments, hand weeding twice (W2) recorded the highest grain yield of 873 kg ha⁻¹, followed closely by W3 (820 kg ha⁻¹) and W4 (817 kg ha⁻¹), all significantly superior to the weedy check W1 (657 kg ha⁻¹). The yield penalty of ~24.7% under the weedy check relative to the best weed management treatment (W2) indicating the importance of timely and effective weed management in *rabi* mungbean. The yield difference between W3 and W4 suggests that both herbicide regimes are broadly equivalent in yield protection, despite differing in their modes of action and impacts on nodulation. (Mirjha *et al.*, 2001; Raman and Krishnamoorthy, 2005) ^[8, 14]. Stover yield was also followed the pattern of grain yield across weed management treatments, with W4 recording the highest

(1,526 kg ha⁻¹) followed by W3 (1,515 kg ha⁻¹) and W2 (1,422 kg ha⁻¹), all treatments are significantly above the weedy check (1,258 kg ha⁻¹).

In the microbial consortia treatments, M3 recorded the highest grain yield of 883 kg ha⁻¹, significantly superior to M1 (684 kg ha⁻¹) and M2 (809 kg ha⁻¹). The yield advantage of 29% with M3 over M1 indicating that substituting 25% of chemical fertilizer inputs with microbial consortia combined with fortified organic matter can not only compensate for the reduced chemical input but also improve overall system productivity. The interaction effect between weed management and nutrient management confirmed the synergistic benefits of integrating effective chemical weed control with bioinoculant application.

3.4 Net Returns and Benefit to Cost Ratio

Among the weed management, W3 (Fomesafen + Fluzifop-p-butyl) recorded the highest net returns (Rs. 25,272 ha⁻¹) and B:C ratio (0.55), followed by W4 (Rs. 24,512 ha⁻¹; B:C 0.53) and W2 (Rs. 24,124 ha⁻¹; B:C 0.47), compared to the weedy check (Rs. 6,307 ha⁻¹; B:C 0.15). The economic advantage of W3 over W2 reflects not only comparable grain yields but also substantially lower per-hectare input costs for herbicide application relative to twice manual weeding, which involves considerable labour expenditure (Kumar *et al.* 2016) [6].

Among the nutrient management treatments, M3 reported the highest net returns (Rs. 29,867 ha⁻¹) and B:C ratio (0.64), compared to M2 (Rs. 24,692 ha⁻¹; B:C 0.54) and M1 (Rs. 16,465 ha⁻¹; B:C 0.38). The reduced chemical fertilizer input by 25% in combination with the grain yield increase due to microbial consortia, resulted to improved economic outcome under M3. Similar findings have been reported in soybean (*Glycine max*) with pre-emergence herbicide combined with appropriate inoculant management, preserved root nodulation and nitrogen fixation and improved the economic returns (Ribeiro *et al.*, 2021) [16].

3.5 Soil Nutrient Status at Harvest

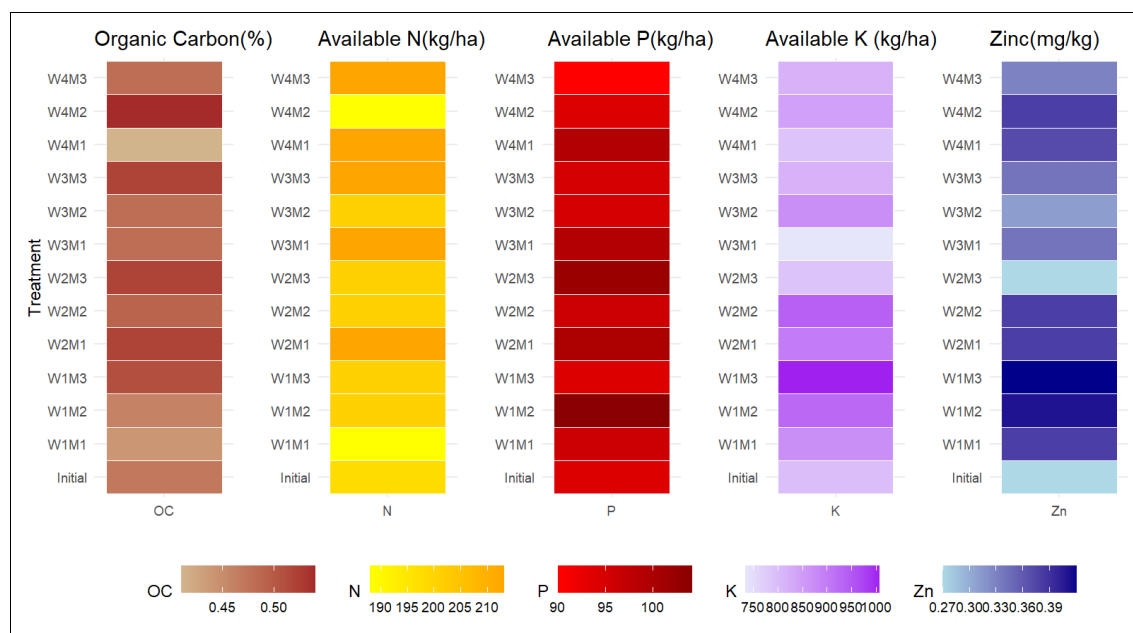
At harvest soil nutrient analysis (Table.3) differential effects of the treatment combinations on residual soil nutrient pools.

Treatment M3 has relatively improved post-harvest nutrient status, suggesting that bioinoculant application combined with fortified FYM contributed to a more active soil nutrient cycling process during the crop season. The preservation and enhancement of soil nutrient status under M3 have important implications for succeeding crops in the rotation, as the residual benefits of microbial consortia on soil microbial biomass carbon, enzyme activity, and nutrient availability have been documented to persist into subsequent crop seasons, particularly for available nitrogen, phosphorus, and potassium.

Integration of herbicide-based weed management with microbial consortia application did not result in any adverse long-term changes in soil health parameters compared to M1, indicating that the herbicide regimes evaluated in this study, when applied at recommended doses and timings, are compatible with rhizosphere microbiome preservation. This outcome echoes the finding by Ribeiro *et al.* (2021) [16] in soybean, where sustained herbicide management combined with inoculant application-maintained root nodulation efficiency and symbiotic nitrogen fixation comparable to non-herbicide controls.

Table 3: Available Soil nutrient status in the experimental site after harvest of the crop

Treatment combinations	Status	OC (%)	Available Nutrients (kg ha ⁻¹)			
			N	P	K	Zn (mg kg ⁻¹)
	Initial	0.47	198	94	796	0.27
W1M1	Final	0.44	188	96	870	0.38
W1M2		0.46	201	104	925	0.41
W1M3		0.51	201	94	1006	0.42
W2M1		0.52	213	100	898	0.38
W2M2		0.49	201	96	938	0.38
W2M3		0.52	201	102	789	0.27
W3M1		0.48	213	99	734	0.34
W3M2		0.48	201	95	870	0.31
W3M3		0.52	213	95	816	0.34
W4M1		0.41	213	99	789	0.37
W4M2		0.54	188	94	843	0.38
W4M3		0.48	213	90	816	0.33



* Each color represents lighter to darker based on the test values in the treatment combination

Fig 2: Soil nutrient status at harvest in various treatment combinations

Table 2: Growth and yield of mungbean influenced by weed and nutrient management practices

Treatments	Plant height (cm)	Nodule count	Nodule dry wt. (mg)	Branches /plant	Pods /plant	Pod length (cm)	Seeds /pod	100 grain wt. (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	NR (Rs./ha)	B:C
FACTOR A: 1) Weedy check	49	21.9	1.7	1.6	21.8	7.1	11.2	3.53	657	1258	6307	0.15
2) Hand weeding twice 20 and 40 DAS	47.6	27.8	2.4	1.8	26.9	7.3	11.6	3.65	873	1422	24124	0.47
3) Fomesafen @ 220 g/ha + Fluzifop-p-butyl @ 220 g/ha at 15-20 DAS	48.3	22.7	1.3	1.9	22.9	7.0	11.5	3.64	820	1515	25272	0.55
4) Propanil + imazethapyr 3.75% ME @ 125g/ha at 15-20 DAS	45.6	25.8	2.1	1.8	22.7	7.0	11.6	3.63	817	1526	24512	0.53
Sem±	0.960	1.02	0.215	0.054	0.700	0.163	0.090	0.030	28.1	44		
CD	NS	3	0.6	0.2	2.0	NS	0.2	0.09	82	130		
FACTOR B: 1) 100% N P K Zn	48.7	23.2	1.8	1.7	22.5	7.2	11.4	3.47	684	1341	16465	0.38
2) 75% NPK Zn + Seed inoculation with NPK Zn microbial consortia @ 50g/kg	47.8	24.7	2.0	1.8	23.2	7.1	11.5	3.61	809	1422	24692	0.54
3) 75% NPK Zn + Soil application NPK Zn microbial consortia @ 2kg/ha along with fortified FYM	46.3	25.8	1.9	1.9	25.0	7.0	11.6	3.76	883	1527	29867	0.64
Sem±	0.830	0.880	0.186	0.047	0.610	0.141	0.070	0.026	24.3	38		
CD	NS	NS	NS	0.1	1.8	NS	0.2	0.08	71	112		
CV	6.0	12.5	34.2	9.0	8.9	6.9	2.3	2.50	10.7	9.3		
Interaction					SIG							

Summary

Chemical weed management with post-emergence herbicides, specifically Fomesafen @ 220 g/ha + Fluzifop-butyl 220 g/ha applied at 15-20 DAS (W3) is superior to conventional hand weeding (W2) in terms of weed control efficiency, higher net monetary returns, and greater practical field applicability given prevailing labor availability constraints. Although, hand weeding remains the benchmark for maximizing nodulation parameters, its economic limitation renders the herbicide application as a great recommendation for large-scale cultivation. Furthermore, The substitution of 25% of RDF with soil application of an N-P-K-Zn microbial consortia along with fortified FYM (M3) not only maintained but significantly enhanced grain yield (883 kg ha⁻¹) and economic returns (B:C ratio 0.64) compared to the conventional 100% chemical fertilizer treatment (M1).

The significant interaction between weed management and microbial consortia treatments indicates that the productivity gains from each approach are complementary and mutually reinforcing. Effective herbicide-based weed management reduces crop weed competition that facilitates optimal root development and rhizobial colonization. Concurrently, microbial consortia application enhances the soil nutrient cycling and biological nitrogen fixation, collectively leading to enhanced system productivity.

Finally, the absence of adverse effects of the tested herbicide on post-harvest soil nutrient status or overall microbiome functionality, particularly in combination with microbial consortia treatment, indicates the compatibility of the recommended herbicide formulations with bioinoculant based sustainable agriculture practices.

References

- Bansal R. Synergistic effect of Rhizobium, PSB and PGPR on nodulation and grain yield of mungbean. *Journal of Food Legumes*. 2009;22(1):37-39.
- Choudhary B, Chaturvedi V, Dhaker DL, Parkesh S, Sonu S. Effect of different post-emergence herbicides on the growth and yield of mungbean (*Vigna radiata* L.). *International Journal of Research in Agronomy*. 2024;7(9S):1651-1656.
- Herridge DF, Robertson MJ, Cocks B, Peoples MB, Holland JF. Low nodulation and nitrogen fixation of mungbean reduce biomass and grain yields. *Australian Journal of Experimental Agriculture*. 2005;45(5):269-277.
- Javaid A, Bajwa R. Field evaluation of effective microorganisms (EM) application for growth, nodulation, and nutrition of mungbean. *Turkish Journal of Agriculture and Forestry*. 2011;35(4):377-386.
- Joshi N, Chandra R, Pareek N. Effect of consortia and mono inoculants of Rhizobium sp. and PGPR on productivity of urdbean (*Vigna mungo* L.), soil health and profitability. *Journal of the Indian Society of Soil Science*. 2022;70(4):389-399.
- Kumar N, Hazra KK, Nadarajan N. Efficacy of post-emergence application of imazethapyr in summer mungbean (*Vigna radiata* L.). *Legume Research*. 2016;39(1):117-121.
- Meena R, Dhakal Y, Bohra JS, Singh SP, Singh M. Influence of bioinorganic combinations on yield, quality and economics of mungbean. *American Journal of Experimental Agriculture*. 2015;5(2):123-130.
- Mirjha PR, Prasad SK, Singh M, Paikra RH, Patel S. Effect of weed control measures on weeds, nodulation, growth and yield of mungbean (*Vigna radiata*). *Indian Journal of Agronomy*. 2001;46(3):483-489.
- Mogal C, Jha S, Kumar R, Parekh V, Chauhan DA. Quantification of plant hormones and synergistic effect of PGPR on yield attributing characters of mungbean (*Vigna radiata* (L.) Wilczek). *International Journal of Chemical Studies*. 2019;7(5):2736-2741.
- Nath CP, Kumar N, Hazra KK, Praharaj CS. Bio-efficacy of different post-emergence herbicides in mungbean. *Weed Research*. 2022;62(6):405-414. doi:10.1111/wre.12555.
- Navsare RI, Mane SS, Mahorkar KD. Effect of potassium and zinc solubilizing microorganism on nutrient uptake and microbial population of mungbean. *International Journal of Current Microbiology and Applied Sciences*. 2018;7(2):715-720.
- Neha, Chandra R, Pareek N, Raverkar KP. Effect of Rhizobium and PGPR inoculation in mungbean on productivity and soil properties in mungbean-wheat sequence. *Journal of the Indian Society of Soil Science*. 2019;67(4):397-406.
- Pataczek L, Armas JCB, Petsch T, Hilger T, Ahmad M. Single-strain inoculation of *Bacillus subtilis* and *Rhizobium phaseoli* affects nitrogen acquisition of an improved mungbean cultivar. *Journal of Soil Science and Plant Nutrition*. 2024;24:6027-6038.
- Raman R, Krishnamoorthy R. Nodulation and yield of mungbean (*Vigna radiata* (L.)) influenced by integrated weed management practices. *Legume Research*. 2005;28(2):115-119.

15. Revathi M, Prabhakaran NK, Chinnusamy C, Meena S. Influence of establishment methods and weed management practices on nutrient removal by weeds and uptake by rice in puddled lowland. *Madras Agricultural Journal*. 2012;99(7-9):496-499.
16. Ribeiro VHV, Maia LGS, Arneson NJ, Oliveira MC, Read HW, Ané JM, *et al*. Influence of pre-emergence herbicides on soybean development, root nodulation, and symbiotic nitrogen fixation. *Crop Protection*. 2021. doi:10.1016/j.cropro.2021.105735.
17. Singh R, Singh G. Influence of herbicides on symbiotic parameters, growth, yield and nutrient uptake in mungbean (*Vigna radiata* (L.) Wilczek). *Archives of Agronomy and Soil Science*. 2020;67(5):657-669.
18. Singh R, Singh G. Weed management in greengram: A review. *Indian Journal of Weed Science*. 2020;52(1):1-15.
19. Singh VK, Singh A, Verma S, Kumar M, Kumar V. Effect of various microbial inoculums on the growth, quality and nutrient uptake of mung bean (*Vigna radiata* L.). *Environment and Ecology*. 2023;41(3A):1580-1586.
20. Tariq M, Hameed S, Yasmeen T, Ali A. Non-rhizobial bacteria for improved nodulation and grain yield of mung bean (*Vigna radiata* (L.) Wilczek). *African Journal of Biotechnology*. 2012;11(4):829-835.
21. Venkata Rao P, Subbarami Reddy A, Sateesh Babu J, Ramana MV. Integrated weed management practices for improved productivity and economics in mungbean (*Vigna radiata* L.). *Journal of Research, ANGRAU*. 2017;45(1):32-38.
22. Yousefi A, Nabati J, Mirzaeetalarposhti R, Malakshahi Kurdestani A. Optimizing mungbean productivity and root morphology with biofertilizers for sustainable farming. *Scientific Reports*. 2025;15. doi:10.1038/s41598-025-28815-8.