

Original Research Article

Effect of weed management practices and bio-fertilizers with and without FYM on weed flora, growth and yield of blackgram (*Vigna mungo L*)

ABSTRACT

A field experiment was conducted in farmer's field at Narasipuram block, Coimbatore, Tamil Nadu during summer season, 2021-22, to study the influence of weed management practices and bio-fertilizers with and without FYM on weed flora, growth and yield of blackgram. The experiment was laid out in split plot design with three replications. Treatments consisted of four weed management practices as main plots, viz., M₁- PE Pendimethalin 30 % EC 1 kg ha⁻¹ sprayed at 3 DAS, M₂ - EPOE imazethapyr 10 % SL 50 g ha⁻¹, M₃ - Quizalofop-p-ethyl 5% EC 50 g ha⁻¹ applied at 10 DAS and M₄ - two hand weeding (15 and 30 DAS) and for different treatments of bio-fertilizers with and without FYM viz., S₁ - Rhizobium + Phosphobacteria, S₂ - Rhizobium + Phosphobacteria + AM fungi, S₃ - S₁ + FYM, S₄ - S₂ + FYM and S₅ - control. The results revealed that interaction effect of pendimethalin 1 kg ha⁻¹ (M₄) and *Rhizobium* + Phosphobacteria + AM fungi with FYM (S₄) recorded maximum growth and yield parameters viz., plant height, dry matter production, number of pods plant⁻¹, seeds pods⁻¹, pod length and 100 grain weight. Moreover, produce higher grain and haulm yield compared over rest of treatments.

Comment [a1]: Explain the abbreviation

Formatted: Not Highlight

Key words : Blackgram, herbicide, bio-fertilizers, FYM, weed control efficiency

1. INTRODUCTION

In pulse, blackgram is one of the short duration crops and a lack of ability to compete with different weed [2] and highly shy with weeds [3]. Hence, weed competition was higher during early growth stages as well as critical period usually between 15 – 45 days after sowing [1]. Therefore, weed control practices have to be carried out at initial stage that ensured proper crop growth. Weeds caused severe yield loss varied from 41.6 to 64.1 percent depends on its nature, intensity and period of growth [4, 5]. Two hand weeding was most effective compared to other weed control methods, but due to labour scarcity, higher labour charges and time consuming, it was not adopted by farmer. So, the best alternative practices to control weeds were either use of pre-emergence or early post emergence herbicides. But, pre-emergence herbicides mostly efficient in short period and thereafter, late emerging weeds were competing for spacing, nutrients and sunlight. So, use of early post emergence herbicides offers ways to manage late emerging weeds. Pendimethalin is a herbicide of di-nitroaniline class, used as a pre- emergence purpose. Application of pre-emergence herbicides after first shower were effective against weeds if weeds were not germinated. Whereas Imazethapyr belongs to imidazoline class and had selective chemical compound to inhibits metabolism of grasses and broad-leaf weeds. Quizalofop-p-ethyl was selective herbicide, to control an annual and perennial weed which belonging to chemical family aryloxyphenoxy group, that inhibited fatty acid synthesis in weeds, while applied as early post emergence herbicide. Bio-fertilizers (*AM* fungi, *Rhizobium*, Phosphobacteria) were living organisms, cost effective, eco-friendly and alternative for chemically synthesized fertilizers, which substituted inorganic fertilizers by fixing atmospheric nitrogen and mobilize inorganic phosphorous followed by solubilization, led to more availability of nutrients to plants and better yield performance [6]. Earlier works [7] revealed that blackgram seeds were treated with phosphorous solubilizing bacteria and *AM* fungi might had substituted for 50 % phosphatic fertilizer under silt loam soil in blackgram.

Comment [a2]: Check on grammar

To increase the productivity of blackgram, timely weed management with proper care is necessary. With this context, a research work was carried out to study the influence of weed management practices and bio-fertilizers combined application of organics on weed flora and yield of blackgram under field conditions.

2. MATERIALS AND METHODS

The field experiment was conducted at farmer's field in Narasipuram block at Coimbatore during summer season, 2021- 22 under irrigated condition. The soil of experimental field was clay loam in texture. Analysed results of initial soil sample were furnished below in (Table 1). The field experiment was laid out in split plot design with nine treatments. Among this main plot consisted of four treatments and five treatments for subplots in combinations with three replications. The main plots consisted three herbicides as M₁- Pendimethalin 30% EC 1 kg ha⁻¹ on 3DAS, M₂ – Imazethapyr 10% SL 50 g ha⁻¹ on 10 DAS and M₃- Quizalofop-p-ethyl 5% EC 50 g ha⁻¹ on 10 DAS and M₄ – Two hand weeding at 15 and 30 DAS. In subplots, S₁- *Rhizobium* + Phosphobacteria, S₂ – *Rhizobium* + Phosphobacteria + AM fungi, S₃ – S₁ + FYM, S₄ – S₂ + FYM, S₅- Control. The biofertilizers and FYM were applied at recommended dose, as given in Crop Production Guide (2020).

Table 1: Initial soil analysis

S. No	Parameters	value
Mechanical properties		
1	Bulk density (Mg m ⁻²)	1.28
2	Particle density (Mg m ⁻²)	2.08
3	Total porosity (%)	38.46
Chemical properties		
4	pH – (1:2.5 ratio soil : water)	6.53
5	EC (dSm ⁻¹ 25°C)	0.13
6	Organic carbon (%) - Walkley and Black method	0.72
7	Available N (kg ha ⁻¹) - KMnO ₄ -Oxidizable method	238
8	Available P (kg ha ⁻¹) - Bray's no - 1 method	65
9	Available K (kg ha ⁻¹) - 1 N Neutral NH ₄ OAc method	218
10	Available S (mg kg ⁻¹) - 1% CaCl ₂ Turbidimetric method	7.9

Blackgram variety 'Vamban 9' was sown in line method at seed rate of 20 kg ha⁻¹ during summer season, 2021 - 22 with plant spacing of 30 x 10 cm. Before sowing, seeds were treated with biofertilizer @ 600 g ha⁻¹ followed by soil application of 2 kg ha⁻¹ mixed together with 25 kg of soil. Basal nutrient requirement of (per hectare) 25 kg N, 45 kg P₂O₅, 25 kg K₂O and 10 kg S (CPG, 2020) supplemented by addition of Urea, Single Super Phosphate (SSP) and Muriate of Potash (MOP). Life irrigation was given on 3rd day after sowing followed by PE and EPOE herbicides were sprayed on 3 and 10 DAS by using knapsack power sprayer with 500 L ha⁻¹ of water. Crop was irrigated for four to five times till harvest by visual observations of crop and field conditions. The weed species were counted in trial plots by using quadrat (0.25 m²) at four random sites in each plot at 20 and 40 DAS, which expressed in terms of number m⁻². Then, weeds were grouped into grasses, sedges and broad leaf weeds based on morphology in nature. Weed dry weight was recorded at 20 and 40 days after sowing, expressed as g m⁻². Weeds were pulled out from trial plots, where quadrat was used to record weed population. Weeds were kept in open condition for drying, followed by oven dried until it attains constant weight. An unweeded plot was maintained outside the experimental layout plan, for the purpose of calculate weed control efficiency and to know the predominant weed flora. Weed control efficiency (%) was worked out, [8],

$$\text{WCE (\%)} = \frac{(\text{Weeds dry weight in control plot} - \text{Weeds dry weight in treatment plots})}{\text{Weeds dry weight in control plot}} \times 100$$

All data were statistically analysed through subjecting with Analysis of Variance (ANOVA) as reported by Panse and Sukhatme (1967). The pooled data of weeds were transformed to square root method (x+0.5) and probability of significant difference made at P ≤ 0.05.

3. PLANT OBSERVATIONS

Biometric observations viz., plant height was carried out at 25, 50 DAS and at harvest. While, dry matter production was recorded after attained constant weight in hot air oven at 65°C on 25 and 50 DAS. Then, yield parameters like pods plant⁻¹, seeds pod⁻¹, pod length, 100 grain weight, grain and haulm yield of blackgram were also recorded.

Comment [a3]: Indicate the lab used to test the soil samples

Comment [a4]: The treatment combinations are more than nine. Check

Comment [a5]: What does this mean? Soil followed by soil? Please clarify

Comment [a6]: Why two herbicides when they are supposed to be three? Where is M₃?

Formatted: Highlight

Formatted: Highlight

4. RESULTS AND DISCUSSION

Application of PE pendimethalin and EPOE Imazethapyr, Quizalofop-p-ethyl had not shown any adverse effect in terms of germination, yellowing of leaves and leaf injury or change in morphology of leaves in blackgram. But, harmful effects of these herbicide against weeds were discussed on following order.

Comment [a7]: At what stage was this applied? It is not indicated in the methodology!

4.1. Effect on weed floral growth

The weed species identified in experimental field were arranged in the order of broad leaf weeds > grasses > sedges depending upon weed density during crop period. Major weeds species were found in field trials were *Trianthema portulacastrum* (Horse pursulane), *Digera arvensis* (False amaranth), *Portulaca oleracea* (Purslane), *Amaranthus viridis* (Slender amaranth), *Parthenium hysterophorus* (Congress weed), *Cleome viscosa* (Tick weed) as broad leaf weeds, then grasses like as *Echinochola colona* (Jungle rice), *Echinochola crusgalli* (cockspur) and finally *Cyperus rotundas* (purple nut sedge) as sedges.

4.2. Effect on weed density

Total weed density was influenced by various weed control practices. At 20 and 40 DAS, hand weeding twice at 15 and 30 DAS recorded lowest weed population of 9.00 and 22.0 no m⁻², respectively, which was superior over remain chemical weed control methods (Table 2). These results were confirmed by Rajib, 2014 [9]. Among the different herbicides used, pendimethalin 30% EC 1 kg ha⁻¹ secured last position on decreasing order of weed population of 18.9 and 45.0 no m⁻² on 20 and 40 DAS, respectively. This might have happened due to the suppression of weeds at critical growth period and exposure of toxic effects of herbicide. Further, Imazethapyr 10 % SL 50 g ha⁻¹ recorded weed density of 22.3 and 59.6 no m⁻² followed by treatment of quizalofop-p-ethyl 50 g ha⁻¹.

Comment [a8]: How was 1kg measured out from an Emulsifiable concentrate (EC) which is a liquid? Should report volume, not weight.

The effect of bio-fertilizers with and without farmyard manure was found to be significant on weed density recorded at 20 and 40 DAS.

Table 2: Weed density (no m⁻²) as influenced by herbicides, organics and bio-fertilizers in blackgram.

Herbicides	Organics and bio - fertilizers											
	20 DAS						40 DAS					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M ₁	4.58 (21.0)	4.54 (20.7)	3.87 (15.0)	3.55 (12.7)	5.00 (25.0)	4.31 (18.9)	7.11 (50.6)	6.96 (48.4)	6.06 (36.8)	5.27 (28.0)	7.83 (61.3)	6.64 (45.0)
M ₂	5.06 (25.7)	4.27 (18.8)	4.04 (16.5)	4.50 (20.3)	5.48 (30.1)	4.67 (22.3)	8.37 (70.2)	7.55 (57.0)	7.01 (50.3)	6.80 (46.8)	8.57 (73.8)	7.66 (59.6)
M ₃	5.32 (28.4)	4.93 (24.6)	4.35 (19.0)	4.40 (19.4)	5.81 (33.0)	4.96 (25.0)	9.03 (81.8)	8.53 (73.3)	7.32 (53.9)	7.02 (49.4)	9.40 (88.3)	8.26 (69.4)
M ₄	2.70 (7.33)	3.02 (9.17)	2.61 (6.83)	2.76 (7.67)	3.74 (14.0)	2.97 (9.00)	4.72 (22.5)	4.23 (18.0)	4.09 (16.7)	4.32 (19.0)	5.86 (34.3)	4.64 (22.0)
Mean	4.41 (20.6)	4.19 (18.4)	3.73 (14.4)	3.89 (15.0)	5.01 (25.7)	4.23 (18.8)	7.31 (56.3)	6.82 (49.2)	6.12 (39.4)	5.86 (35.8)	7.91 (64.4)	6.80 (49.0)
	SEd			CD (P=0.05)			SEd			CD (P=0.05)		
Main plot	0.12			0.30			0.20			0.48		
Sub plot	0.16			0.32			0.24			0.48		
M×S	029			NS			0.46			NS		
S × M	0.30			NS			0.47			NS		
Note:	Main plot M ₁ : PE Pendimethalin 30% EC 1 kg ha ⁻¹ on 3 DAS M ₂ : EPOE Imazethapyr 10% SL 50g ha ⁻¹ on 10 DAS M ₃ : EPOE Quizalofop- p- ethyl 5% EC 50g ha ⁻¹ on 10 DAS M ₄ : Hand weeding on 15 and 30 DAS						Sub plot S ₁ : <i>Rhizobium</i> and Phosphobacteria inoculation S ₂ : <i>Rhizobium</i> , Phosphobacteria and AM fungi S ₃ : S ₁ + FYM S ₄ : S ₂ + FYM S ₅ : Control					

Comment [a9]: Explain to the readers the Critical Difference (CD) in relation to your treatments

Comment [a10]: Explain the observations in the text

4.3. Effect on weed dry weight

During all growth stages, weed management practices showed significant effect on total weed dry weight. At 20 and 40 DAS, minimum weed dry weight of 1.39 and 3.83 gm⁻² was noticed on hand weeding twice treatment. Among the herbicide weed management practices, PE pendimethalin 30 % EC 1 kg ha⁻¹ recorded least weed dry weight

accumulation of 2.95 and 8.03 g m⁻² on 20 and 40 DAS, respectively. Which induced harmful effect on indeterminate weeds at early growth period, followed by imazethapyr 10% SL 50 g ha⁻¹ achieved lower weed dry weight of 3.51 and 9.67 g m⁻², respectively (Table 3). PE pendimethalin 30% EC 1 kg ha⁻¹ reduced weed germination that was predominant factor for reduction of weed dry weight accumulation [10] and inhibiting weeds development at early stages [11]. Higher weed dry weight accumulation of 3.88 and 10.8 g m⁻² and weed density of 25 and 69.4 no m⁻² were attributed in quizalofop-p-ethyl 5% EC 50 g ha⁻¹ on 20 and 40 DAS due to uninterrupted weed growth was observed compared to other weed management practices.

The effect of bio-fertilizers with and without farmyard manure was found to be significant on weed dry matter recorded at 20 and 40 DAS.

Table 3 : Weed dry weight (g m⁻²) as influenced by herbicides, organics and bio-fertilizers in blackgram.

Herbicides	Organics and bio - fertilizers											
	20 DAS						40 DAS					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M ₁	3.99	3.27	2.13	1.80	3.55	2.95	9.05	8.26	6.94	6.12	9.78	8.03
M ₂	4.07	3.09	2.77	3.31	4.28	3.51	11.1	8.65	9.19	7.85	11.6	9.67
M ₃	4.46	3.96	3.13	3.04	4.79	3.88	12.7	11.2	8.73	7.85	13.7	10.8
M ₄	1.04	1.30	1.18	1.43	1.99	1.39	3.58	3.88	3.40	3.36	4.92	3.83
Mean	3.39	2.91	2.30	2.40	3.65	2.93	9.11	8.00	7.06	6.30	9.98	8.09
	SEd			CD (P=0.05)			SEd			CD (P=0.05)		
Main plot	0.21			0.51			0.35			0.87		
Sub plot	0.23			0.47			0.48			0.97		
M×S	0.46			NS			0.92			NS		
S × M	0.46			NS			0.95			NS		

4.4. Effect of weed control efficiency

The highest weed control efficiency (74.8 %) was registered in hand weeding twice on 15 and 30 DAS [12] (Figure: 1), which was significantly recorded lower weed counts and reduced dry weight until entire crop period, compared over herbicidal practices. However, pendimethalin 1 kg ha⁻¹ recorded minimum weed biomass of 8.03 g m⁻² on 40 DAS, resulted of satisfactory weed control efficiency about 69.7 % was achieved than remaining treatments. Similar, results were confirmed by Sharma *et al*, 2016 [13].

Among the treatments of bio-fertilizers with and without FYM application, the treatment received *Rhizobium* + Phosphobacteria +AM fungi + FYM had shown one step ahead performance of crop growth under stress conditions. It might be eventuated due to better water status induced by AM fungi via stimulating drought inducible genes in standing crop [14], high suppressive of weeds and also improved uptake of macronutrients and micro nutrients, [15].

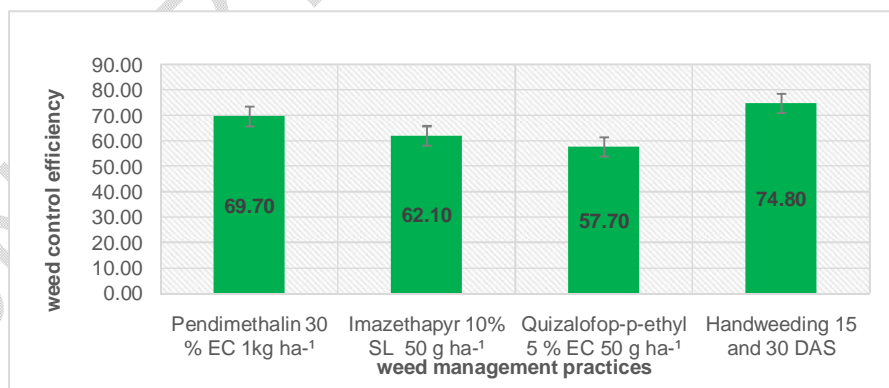


Figure 1. Effect of weed management practices on weed control efficiency in blackgram.

4.5. Growth attributes

The effect of different weed management practices on growth parameters i.e., plant height and dry matter production were observed. From the concluded data on 25, 50 DAS and at harvest, pendimethalin 1 kg ha⁻¹ was recorded

Comment [a11]: Check on grammar

maximum plant height of 14.2, 33.5 and 48.3 cm and plant dry matter of 51.5 and 122 g m⁻², respectively (Table 5, 6) which was on par with hand weeding twice on all stages of plant growth and dry matter production at 50 DAS, followed by rest of treatments. The results were confirmed by finding of Khairnar *et al*, 2014 [16,17].

Table 5: Plant height (cm) as influenced by herbicides, organics and bio-fertilizers in blackgram.

Herbicides	Organics and bio - fertilizers																	
	25 DAS						50 DAS						At harvest					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M ₁	13.1	13.9	14.6	15.6	13.9	14.2	30.9	33.4	36.2	38.0	29.1	33.5	45.6	48.9	49.7	56.3	40.9	48.3
M ₂	12.7	12.9	13.3	14.0	12.1	13.0	28.8	31.4	31.2	34.0	26.9	30.5	40.2	42.8	47.9	48.8	36.4	43.2
M ₃	12.4	13.1	13.1	13.7	12.5	12.9	29.7	30.8	31.1	33.0	27.3	30.4	40.9	44.4	43.4	44.2	35.9	41.8
M ₄	12.8	13.8	14.3	14.8	12.4	13.6	31.4	32.6	32.6	35.1	27.9	31.9	43.8	47.8	50.4	55.2	40.3	47.5
Mean	12.7	13.4	13.6	14.5	12.7	13.5	30.2	32.1	32.8	35.0	27.8	31.6	42.6	46.0	47.9	51.5	38.4	45.2
	SEd		CD (P=0.05)				SEd		CD (P=0.05)				SEd		CD (P=0.05)			
Main plot	0.26		0.64				0.59		1.45				0.85		2.07			
Sub plot	0.32		0.66				0.74		1.51				1.34		2.73			
M×S	0.64		NS				1.45		NS				2.68		NS			
S × M	0.63		NS				1.48		NS				2.55		NS			

Among the bio-fertilizers with and without FYM, the treatment received *Rhizobium* + Phosphobacteria + AM fungi + FYM was recorded maximum plant height of 14.5, 35 and 51.5 cm on 25, 50 DAS and at harvest, respectively. Higher dry matter production of 52.7 and 139 g m⁻² was recorded on 25 and 50 DAS, respectively. Rest of treatments recorded superior performance over the control.

Table 6: Plant dry matter production (g m⁻²) as influenced by herbicides, organics and bio-fertilizers in blackgram.

Herbicides	Organics and bio - fertilizers											
	25 DAS						50 DAS					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M ₁	47.2	53.2	52.1	62.9	42.1	51.5	124	116	145	148	76.8	122
M ₂	40.0	42.7	46.8	47.3	31.4	41.7	92.1	120	114	135	67.9	106
M ₃	35.3	41.0	40.3	44.5	29.5	38.1	98.4	103	115	128	66	102
M ₄	41.2	47.7	52.7	56.0	33.2	46.3	100	131	123	145	72	114
Mean	41.1	46.1	48.0	52.7	34.0	44.4	104	117	124	139	70.6	111
	SEd		CD (P=0.05)				SEd		CD (P=0.05)			
Main plot	0.75		1.83				3.32		8.14			
Sub plot	1.23		2.51				3.32		6.75			
M×S	2.33		NS				6.80		14.51			
S × M	2.46		NS				6.63		13.51			

4.6. Yield attributes

The yield parameters have shown significant difference among various weed management practices. pendimethalin 1 kg ha⁻¹ has recorded maximum number of productive pods plant⁻¹, pod length and 100 grain weight of 21.4 no, 5.01 cm and 4.53 g, respectively, (Table 7, 8) which were being statistically on par with hand weeding twice, followed by remaining treatments. Similar results reported by researcher [17] that was application of pendimethalin 1 kg ha⁻¹ along with one hand weeding imposed similar performance on pods plant⁻¹, seeds pod⁻¹, grain yield and haulm yield (kg ha⁻¹) as compared with hand weeding on 15 and 30 DAS.

Table 7: Number of productive pods plant⁻¹ (no) and seeds pod⁻¹ (no) as influenced by herbicides, organics and bio-fertilizers in blackgram

Herbicides	Organics and bio - fertilizers	
	No. of productive pods plant ⁻¹ (no)	Seeds pod ⁻¹ (no)

	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M ₁	20.4	22.4	25.0	24.3	14.9	21.4	5.53	5.74	5.52	6.64	4.16	5.52
M ₂	15.2	16.7	21.0	25.3	12.0	18.0	4.67	4.91	5.42	5.91	4.08	5.00
M ₃	16.6	18.8	17.9	19.1	11.1	16.7	4.51	5.25	5.28	5.38	4.14	4.91
M ₄	19.5	21.2	21.9	23.5	14.5	20.1	4.73	5.72	5.93	6.04	4.02	5.29
Mean	17.9	19.8	21.4	23.1	13.1	19.1	4.86	5.40	5.54	5.99	4.10	5.18
	SEd		CD (P=0.05)				SEd		CD (P=0.05)			
Main plot	0.59		1.44				0.20		NS			
Sub plot	0.68		1.38				0.20		0.40			
M×S	1.35		2.76				0.40		NS			
S × M	1.35		2.85				0.39		NS			

The treatment engaged with *Rhizobium* + Phosphobacteria +AM fungi + FYM achieved maximum number of productive pods plant⁻¹, pod length and 100 grain weight of 23.1 no, 5.16 cm and 4.73 g, respectively, followed by the treatment received Rhizobium + Phosphobacteria + FYM. Subsequently, control expressed inferior performance on yield attributes compared to rest of the treatments [18]. More flowering and grain development while combined form of organics and bio-fertilizers application. Thereafter, phosphorous, macro and micro nutrients had undergone mineralization process during decomposition of farmyard manure as well as availability of adsorbed phosphorous increased through solubilization process induced by organic acid synthesized from organic matter decomposition [19]. Phosphorous solubilizing bio-fertilizer facilitated to mineralization, solubilization and translocation of organic and inorganic phosphorous led to improved availability and uptake of phosphorous by plants [20].

Comment [a12]: Is this your observation or the observation of author 18?

Table 8: Pod length (cm) and 100 grain weight (g) as influenced by herbicides, organics and bio-fertilizers in blackgram.

Herbicides	Organics and bio - fertilizers											
	Pod length (cm)						100 grain weight (g)					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M ₁	4.99	5.11	5.19	5.35	4.39	5.01	4.06	4.33	4.84	5.36	4.03	4.53
M ₂	4.30	4.28	4.37	5.04	4.27	4.45	3.81	4.17	3.79	4.26	3.59	3.92
M ₃	4.09	4.30	4.62	4.67	4.13	4.36	3.73	4.35	4.30	4.51	3.51	4.08
M ₄	4.26	4.98	5.12	5.60	4.17	4.83	4.43	4.53	4.78	4.80	3.65	4.44
Mean	4.41	4.67	4.82	5.16	4.24	4.66	4.01	4.35	4.43	4.73	3.69	4.24
	SEd		CD (P=0.05)				SEd		CD (P=0.05)			
Main plot	0.12		0.30				0.12		0.30			
Sub plot	0.11		0.23				0.15		0.30			
M×S	0.24		0.51				0.29		NS			
S × M	0.23		0.47				0.29		NS			

4.7. Grain and haulm yield

Yield data were recorded for different weed control treatments (Table 9). The higher grain (873 kg ha⁻¹) and haulm yield (1322 kg ha⁻¹) were recorded in pendimethalin @ 1 kg ha⁻¹ applied treatment, which was statistically on par with hand weeding twice [21, 22], followed by imazethapyr 50 g ha⁻¹ and Quizalofop-p-ethyl 50 g ha⁻¹, respectively. Finally, quizalofop-p-ethyl 5 % EC recorded least performance on weed suppression during critical stages led to obtained lower grain yield of 731 kg ha⁻¹ and haulm yield of 1031 kg ha⁻¹, respectively. More grain and haulm yield reported in blackgram, when pendimethalin applied as pre-emergence on 3 DAS by findings of earlier researchers [23] Further, proper plant growth establishment occurred by effective suppression of weeds at early growth period led to greater number of pods plant⁻¹ and grain yield.

Among the bio-fertilizers with and without FYM, the treatment engaged with *Rhizobium* + Phosphobacteria +AM fungi + FYM expressed significant performance of higher grain yield (888 kg ha⁻¹) and haulm yield (1346 kg ha⁻¹). It might have registered by crop dominance and suffocation of weed at critical growth period [24], followed by treatment of *Rhizobium* + Phosphobacteria + FYM (857 kg ha⁻¹ and 1279 kg ha⁻¹). Remaining treatment shown superior effect over the control. *Rhizobium* induced root nodules development through symbiosis with blackgram resulted in maximum plant height, no. of pods plant⁻¹, grain and haulm yield in blackgram. It might be happened by positive plant- microbes interaction led to enhanced microbial activity and colonization in rhizosphere region. Consequently, nutrient assimilation from deeper layer of soil resulting in more nutrient absorption, increased growth and yield attributes. Earlier researcher

[25] found that the treatment received FYM at 4 tonnes per hectare respond properly with blackgram, results of obtained higher yield.

Table 9: Grain and haulm yield (kg ha⁻¹) as influenced by herbicides, organics and bio-fertilizers in blackgram.

Herbicides	Organics and bio - fertilizers											
	Grain yield (kg ha ⁻¹)						Haulm yield (kg ha ⁻¹)					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M ₁	892	914	952	979	628	873	1310	1380	1426	1524	971	1322
M ₂	775	812	813	849	614	773	1138	1213	1240	1312	930	1166
M ₃	718	774	760	794	609	731	991	1081	1055	1108	922	1031
M ₄	857	872	902	932	636	840	1215	1308	1391	1441	1035	1278
Mean	811	843	857	888	622	804	1163	1245	1279	1346	965	1200
	SEd			CD (P=0.05)			SEd			CD (P=0.05)		
Main plot	18.8			46.1			30.0			73.4		
Sub plot	15.2			30.9			26.8			54.6		
M×S	33.0			71.7			56.6			121.7		
S × M	30.0			61.8			53.6			109.2		

Interaction between herbicide and bio-fertilizers with and without FYM shown significant differences in respect of grain and haulm yield from the data given in (Table 9) it was observed that the combination of M₁S₄ (Pendimethalin 1 kg ha⁻¹ and Rhizobium + Phosphobacteria +AM fungi + FYM) recorded maximum grain (979 kg ha⁻¹) and haulm yield (1524 kg ha⁻¹). Existing studies [26] revealed the combination effect of phosphatic fertilizers, farm yard manure and phosphorous solubilizing bio-fertilizers recorded higher grain and haulm yield due to imposing of synergistic effect among inorganic phosphatic fertilizers, phosphorous solubilizing fertilizer and FYM.

5. CONCLUSION

The results of experiment revealed that application of pendimethalin 1 kg ha⁻¹ was best alternatives to hand weeding twice, which noticed higher yield attributes and yield in blackgram. Moreover, Rhizobium + Phosphobacteria + AM fungi + FYM produced better grain and haulm yield in summer blackgram. It concluded that combined effect of pendimethalin application on 3 DAS with bio-fertilizer and FYM achieved distinct performance on grain (979 kg ha⁻¹) and haulm yield (1524 kg ha⁻¹). Further, research was needed with special focus to fine tuning the dose and time of application of herbicides along with cost-effective management practices, to enhance the productivity of blackgram.

Comment [a13]: The formulation is a liquid. How did you measure kg?

REFERENCE

1. Vivek, N. S., Rana, R. S., & Tomar, S. S. Effect of Weed Interference on Weeds and Productivity of Black gram (*Phaseolus mungo*). *Indian Journal of Weed Science*. 2008, **40(1-2)**: 65-67
2. Choudhary, V. K., Suresh, K. P., & Bhagawati, R. Integrated weed management in black gram (*Vigna mungo* L.) under mid hills of Arunachal Pradesh. *Indian Journal of Weed Science*. 2012, **57**: 382-385
3. Randhawa, J. S., Deol, J. S., Sardana, V., & Singh, J. Crop-weed competition studies in summer blackgram (*Phaseolus mungo*). *Indian Journal of Weed Science*. 2002, **34(3 - 4)**: 299-300
4. Chand R., Singh N. P., & Singh, V. K. Effect of weed control treatments on weeds and grain yield of late sown urd bean (*Vigna mungo* L.) during Kharif season. *Indian Journal of Weed Science*. 2004, **36**: 127-128
5. Singh., & Guriqbal. "Weed management in summer and kharif season blackgram [*Vigna mungo* (L.) Hepper]." 2011: 77-80.
6. Ahemad, M., & Kibret, M. Mechanisms and applications of plant growth promoting rhizobacteria: current perspective. *Journal of King saud University-science*. 2014, **26(1)**: 1-20.
7. Singh, J., Bhatt, R., Dhillon, B. S., Al-Huqail, A. A., Alfagham, A., Siddiqui, M. H., & Kumar, R. Integrated use of phosphorus, farmyard manure and biofertilizer improves the yield and phosphorus uptake of black gram in silt loam soil. *Plos one*. 2022, **17(4)**: e0266753.
8. Mani VS, Pandita ML, Gautam KC and Das B. Weed killing chemicals in potato cultivation. Proceedings of the National Academy of Sciences of the United States of America (PANS). 1973, **23**: 17-18
9. Rajib Das., Patra, B. C., Mandal, K., & Animesh Pathak. Integrated weed management in Blackgram (*Vigna mungo*, L) and its effect on soil microflora under sandy loam soil of West Bengal. *The Bioscan*. 2014, **9(4)**: 1593-1596.
10. Jagadesh, M., & Raju, M. Efficacy of sequential application of pre-and early post-emergence herbicides for management of weeds in blackgram. *Indian Journal of Weed Science*. 2021, **53(2)**: 158-163.

11. Shashidhar, K. S., Jeberson, S., Premaradhya, M., Singh, N., & Bhuvanewari, S. Weed management effect in blackgram under acidic soils of Manipur. *Indian Journal of Weed Science*. 2020, **52(2)**: 147-152.
12. Nirala, H., Sonit, A., & Rathore, A. L. Post-emergence herbicides for weed control in blackgram. *Indian Journal of Weed Science*. 2016, **48(1)**: 76-78.
13. Sharma N K, Mundra S L & Kalita S, Effect of weed control on growth and productivity of soybean. *Indian J Weed Sci* 2016,**48**: 90–92.
14. Porcel, R., Aroca, R., & Ruiz-Lozano, J. M. Salinity stress alleviation using arbuscular mycorrhizal fungi. A review. *Agronomy for Sustainable Development*, 2012, **32(1)**: 181-200.
15. Chhabra, M. L., & Jalali, B. L. Impact of pesticides-mycorrhiza interaction on growth and development of wheat. *Journal of Biopesticides*, 2013, **6**: 129–132.
16. Khairnar C B, Goud V V & Sethi H N Pre- and post-emergence herbicides for weed management in mungbean. *Indian J Weed Sci*, 2014, **46**: 392–95.
17. Peer F A, Hassan B, Lone B A, Qayoom S, Ahmad L, Khanday B A, Singh P & Singh G. Effect of weed control methods on yield and yield attributes of soybean. *African J Agric Res* 2013, 8: 6135-41.
18. Vigneshvarraj, A., Elayaraja, D., Arivukkarasu, K., & Jawahar, S. Influence of integrated nutrient management on nodulation, yield, quality and economics of greengram in coastal saline sandy soil.
19. Mitran, T., & Mani, P. K. Effect of organic amendments on rice yield trend, phosphorus use efficiency, uptake, and apparent balance in soil under long-term rice-wheat rotation. *Journal of Plant Nutrition*. 2017, **40(9)**: 1312-1322.
20. Gupta, G., Panwar, J., & Jha, P. N. Natural occurrence of *Pseudomonas aeruginosa*, a dominant cultivable diazotrophic endophytic bacterium colonizing *Pennisetum glaucum* (L.) R. Br. *Applied Soil Ecology*. 2013, **64**: 252-261.
21. Jitendra, J., Amaregouda, A., Chetti, M. B., Hiremath, S. M., Nawalgatti, C. M., & Gali, S. K. Effect of herbicides on weed growth, yield and yield components of soybean (*Glycine max* L.). *Karnataka Journal of Agricultural Sciences*, 2013, **26(2)**: 314-315.
22. 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*, 2021, **67(3)**: 410-425.
23. Goud V V & Patil A N. Increase in growth and yield of pigeonpea with weed management. *Indian J Weed Sci*, 2014, **46**: 264–66.
24. Balyan, J. K., Choudhary, R. S., Kumpawat, B. S., & Choudhary, R. Weed management in blackgram under rainfed conditions. *Indian Journal of Weed Science*, 2016, **48(2)**: 173-177.
25. Jha, D. P., Sharma, S. K., & Amarawat, T. Effect of organic and inorganic sources of nutrients on yield and economics of blackgram (*Vigna mungo* L.) grown during kharif. *Agricultural Science Digest-A Research Journal*, 2015, **35(3)**: 224-228.
26. Patel, B. N., Patel, K. H., Singh, N., & Shrivastava, A. Effect of phosphorus, FYM and bio-fertilizer on growth, yield attribute, yield and quality of summer greengram (*Vigna radiata* L.). *Journal of pharmacognosy and phytochemistry*, 2019, **8(5)**: 1108-1112.